Fisheries Assessment Plenary

May 2022
Stock Assessments and Stock Status

Volume 3: Red Gurnard to Yellow-eyed Mullet

Fisheries New Zealand

Tini a Tangaroa

Te Kāwanatanga o Aotearoa
New Zealand Government

Fisheries New Zealand

Tini a Tangaroa

Fisheries Science and Information

Fisheries Assessment Plenary

May 2022

Stock Assessments and Stock Status
Volume 3: Red gurnard to Yellow-eyed mullet

Fisheries New Zealand

MAY 2022 PLENARY VOLUME CONTENTS

CONTENTS
Volume 3: Red gurnard to Yellow-eyed mullet

RED GURNARD (GUR)

(*Chelidonichthys kumu*)
Kumukumu

1. FISHERY SUMMARY

1.1 Commercial fisheries

Red gurnard are a major bycatch of inshore trawl fisheries in most areas of New Zealand, including fisheries for red cod in the southern regions and flatfish off the west coast of the South Island (WCSI) and in Tasman Bay. They are also directly targeted in some areas e.g., GUR 2. Some minor target fisheries for red gurnard are known in Pegasus Bay, off Mahia, and off the west coast South Island. Red gurnard is also a minor bycatch in the jack mackerel trawl fishery in the South Taranaki Bight. Up to 15% of the total red gurnard catch is taken by bottom longline and set net.

Red gurnard was introduced into the Quota Management System (QMS) in 1986. The 1986 TACCs were based on 1984 landings for Southland and 1983 landings for other regions. TACCs for GUR 2, GUR 8, and GUR 10 have remained unchanged since, and these fisheries remain TACC only fisheries. TACs and allowances have since been set for GUR 7, GUR 3, and GUR 1 (1997, 2000, and 2021, respectively), with GUR 3 and GUR 7 having numerous changes to TACC and allowances since their introduction to the QMS, discussed below. All current TACs, allowances, and TACCs are given in Table 1. Under the Adaptive Management Programme (AMP), which ended 30 September 2009, the TACCs for GUR 3 and 7 were increased to 600 t and 815 t, respectively, for the 1991–92 fishing year, and then the GUR 7 TACC was reduced to 678 t, in 1997–98. The TACC for GUR 3 was increased to 900 t for the 1996–97 fishing year under the AMP but was decreased to 800 t in 2002–03.

For the 2009–10 fishing season, the TACC in GUR 7 was increased to 715 t, including an allocation of 10 t for customary, 20 t for recreational use, and 14 t allocation for other sources of mortality. The GUR 7 TACC was further increased to 785 t in October 2012, 845 t in October 2015, 975 t in October 2017, 1073 t in October 2019, 1180 t in October 2020, and to 1298 in October 2021 along with increased allowances. For the 2009–10 fishing season, the TACC for GUR 3 was increased from 800 t to 900 t, with allocations of 3 t, 5 t, and 45 t for customary, recreational, and other sources of mortality, respectively. The GUR 3 TACC was further increased to 1100 t in October 2012, 1220 t in October 2015, 1320 t in October 2018, and to 1500 t in 2020 along with increases in recreational and other sources of mortality allowances (now 6 t and 105 t, respectively). In October 2021, when a new TAC was set, the TACC for GUR 1 was decreased from 2288 t to 800 t and allocations of 40 t for customary, 100 t for recreational, and 56 t for other sources of mortality were also set.

RED GURNARD (GUR)

Reported landings since 1931 are shown in Tables 2 and 3. Historical landings and TACC values for the five main GUR stocks are shown in Figure 1.

Table 1: Current TACs, TACCs, and allowances (t) for red gurnard by Fishstock as of October 2021.

Fishstock	TAC	TACC	Customary allowance	Recreational allowance	Other mortality
GUR 1	996	800	40	100	56
GUR 2		725			
GUR 3	1 614	1 500	3	6	105
GUR 7	1 422	1 298	17	42	65
GUR 8		543			
GUR 10		10			

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	GUR 1	GUR 2	GUR 3	GUR 7	GUR 8
1931–32	67	0	1	16	0
1932–33	42	0	0	13	0
1933–34	67	84	1	20	0
1934–35	50	179	0	2	0
1935–36	75	147	18	2	0
1936–37	114	215	37	25	1
1937–38	205	193	83	21	0
1938–39	109	118	151	31	2
1939–40	121	149	147	25	1
1940–41	124	222	215	38	1
1941–42	107	200	267	38	0
1942–43	124	332	287	58	0
1943–44	128	244	294	53	0
1944	238	292	291	60	0
1945	360	338	222	94	3
1946	426	387	290	119	4
1947	376	297	243	162	10
1948	385	243	267	226	9
1949	371	264	316	323	13
1950	306	186	486	332	13
1951	221	231	750	202	10
1952	394	378	658	211	5
1953	490	494	614	334	3
1954	496	462	660	382	7
1955	495	283	652	490	25
1956	434	312	782	435	29
1957	494	402	737	409	46
1958	430	394	745	400	51
1959	460	320	806	212	44
1960	489	417	1 008	421	27
1961	559	419	1 180	419	27
1962	505	592	1 244	322	14
1963	576	562	1 364	367	8
1964	977	814	1 708	397	16
1965	1 020	668	1 459	400	34
1966	1 157	754	1 178	436	27
1967	1 051	836	745	522	45
1968	1 137	583	510	368	52
1969	1 345	632	487	256	33
1970	1 493	823	841	381	53
1971	1 225	570	940	379	37
1972	770	347	662	333	15
1973	1 278	406	1 393	491	21
1974	881	299	1 083	586	41
1975	691	199	655	365	28
1976	1 055	217	960	545	52
1977	1 288	381	975	579	45
1978	1 571	519	1 106	487	26
1979	1 936	382	690	349	18
1980	1 845	438	672	253	34
1981	2 349	603	438	318	16
1982	2 084	454	379	368	34

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 3: Reported landings (t) of red gurnard by Fishstock from 1983–84 to the present and actual TACCs (t) from 1986–87 to the present. The QMS data are from 1986 to the present. [Continued on next page]

Fishstock QMA (s)	GUR 1 1 & 9		GUR 2 2		GUR 3 3, 4, 5 & 6		GUR 7 7	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	2 099	–	782	–	366	–	468	–
1984–85*	1 531	–	665	–	272	–	332	–
1985–86*	1 760	–	495	–	272	–	239	–
1986–87	1 021	2 010	592	610	210	480	421	610
1987–88	1 139	2 081	596	657	386	486	806	629
1988–89	1 039	2 198	536	698	528	489	479	669
1989–90	916	2 283	451	720	694	501	511	678
1990–91	1 123	2 284	490	723	661	524	442	678
1991–92	1 294	2 284	663	723	539	600	704	815
1992–93	1 629	2 284	618	725	484	601	761	815
1993–94	1 153	2 284	635	725	711	601	469	815
1994–95	1 054	2 287	559	725	685	601	455	815
1995–96	1 163	2 287	567	725	633	601	382	815
1996–97	1 055	2 287	503	725	641	900	378	815
1997–98	1 015	2 287	482	725	477	900	309	678
1998–99	927	2 287	469	725	395	900	323	678
1999–00	944	2 287	521	725	411	900	331	678
2000–01	1 294	2 287	623	725	569	900	571	678
2001–02	1 109	2 287	619	725	717	900	686	681
2002–03	1 256	2 287	552	725	888	800	793	681
2003–04	1 225	2 287	512	725	725	800	717	681
2004–05	1 354	2 287	708	725	854	800	688	681
2005–06	1 113	2 287	542	725	957	800	604	681
2006–07	1 180	2 287	575	725	1 004	800	714	681
2007–08	1 198	2 287	517	725	842	800	563	681
2008–09	1 060	2 287	621	725	939	800	595	681
2009–10	1 075	2 287	853	725	1 018	900	603	715
2010–11	1 046	2 288	587	725	929	900	545	715
2011–12	981	2 288	558	725	915	900	684	715
2012–13	1 103	2 288	603	725	1 168	1 100	763	785
2013–14	1 005	2 288	555	725	1 223	1 100	837	785
2014–15	1 020	2 288	695	725	1 150	1 100	852	785
2015–16	860	2 288	748	725	1 348	1 220	852	845
2016–17	856	2 288	669	725	1 279	1 220	905	845
2017–18	785	2 288	560	725	1 419	1 220	882	975
2018–19	710	2 288	587	725	1 467	1 320	998	975
2019–20	745	2 288	562	725	1 537	1 320	1 182	1 073
2020–21	847	2 288	412	725	1 646	1 500	1 153	1 180

Fishstock QMA (s)	GUR 8 8		GUR 10 10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	251	–	0	–	3 966	–
1984–85*	247	–	0	–	3 047	–
1985–86*	163	–	0	–	2 929	–
1986–87	159	510	0	10	2 403	4 230
1987–88	194	518	0	10	3 121	4 381
1988–89	167	532	0	10	2 749	4 596
1989–90	173	538	0	10	2 745	4 730
1990–91	150	543	0	10	2 866	4 762
1991–92	189	543	0	10	3 390	4 975
1992–93	208	543	0	10	3 700	4 978
1993–94	174	543	0	10	3 142	4 978
1994–95	217	543	0	10	2 969	4 982
1995–96	182	543	0	10	2 927	4 982
1996–97	219	543	0	10	2 796	5 281
1997–98	249	543	0	10	2 532	5 143
1998–99	170	543	0	10	2 284	5 143
1999–00	222	543	0	10	2 429	5 143
2000–01	291	543	0	10	3 348	5 143
2001–02	302	543	0	10	3 429	5 143
2002–03	342	543	0	10	3 831	4 993
2003–04	329	543	0	10	3 508	4 993
2004–05	370	543	0	10	3 974	4 993
2005–06	373	543	0	10	3 589	4 993
2006–07	349	543	0	10	3 822	4 993
2007–08	223	543	0	10	3 344	4 993
2008–09	274	543	0	10	3 489	4 993
2009–10	239	543	0	10	3 789	5 181
2010–11	182	543	0	10	3 289	5 181
2011–12	213	543	0	10	3 351	5 181
2012–13	170	543	0	10	3 807	5 451
2013–14	151	543	0	10	3 769	5 451
2014–15	193	543	0	10	3 910	5 451
2015–16	145	543	0	10	3 953	5 631
2016–17	145	543	0	10	3 854	5 631
2017–18	209	543	0	10	3 855	5 761
2018–19	267	543	0	10	4 029	5 861
2019–20	386	543	0	10	4 412	5 959

RED GURNARD (GUR)

Table 3 [continued]

Fishstock	GUR 8		GUR 10			
QMA (s)	8		10			Total
	Landings	TACC	Landings	TACC	Landings	TACC
2020–21	249	543	0	10	4 306	6 246

*FSU data.

Annual landings of GUR 1 were relatively stable from 1986–87 to 2014–15, generally ranging between 920 t and 1300 t; substantially lower than the 2288 t TACC. Since then, catches have declined slightly, with 745 t landed in 2019–20. About 60% of the GUR 1 total is taken from FMA 1, as a bycatch of a number of fisheries including inshore trawl fisheries for snapper, John dory, and tarakihi. The remaining 40% is taken from FMA 9, mainly as a bycatch of the snapper and trevally inshore trawl fisheries.

GUR 2 landings have fluctuated within the range of 451–853 t since 1991–92, typically well below the TACC. In addition to the target fishery, red gurnard are taken as a bycatch of the tarakihi, trevally, and snapper inshore trawl fisheries. A decreasing trend in effort in GUR 2 is evident from 2009–10 to 2020–21 and GUR 2 landings in 2020–21 were the lowest since 1989–90.

GUR 3 landings regularly exceeded the TACC between 1988–89 and 1995–96 and this stock has been consistently over-caught since 2004–05. Landings increased steadily from 2010–11 to 2020–21 with multiple small increases in the TACC during that period.
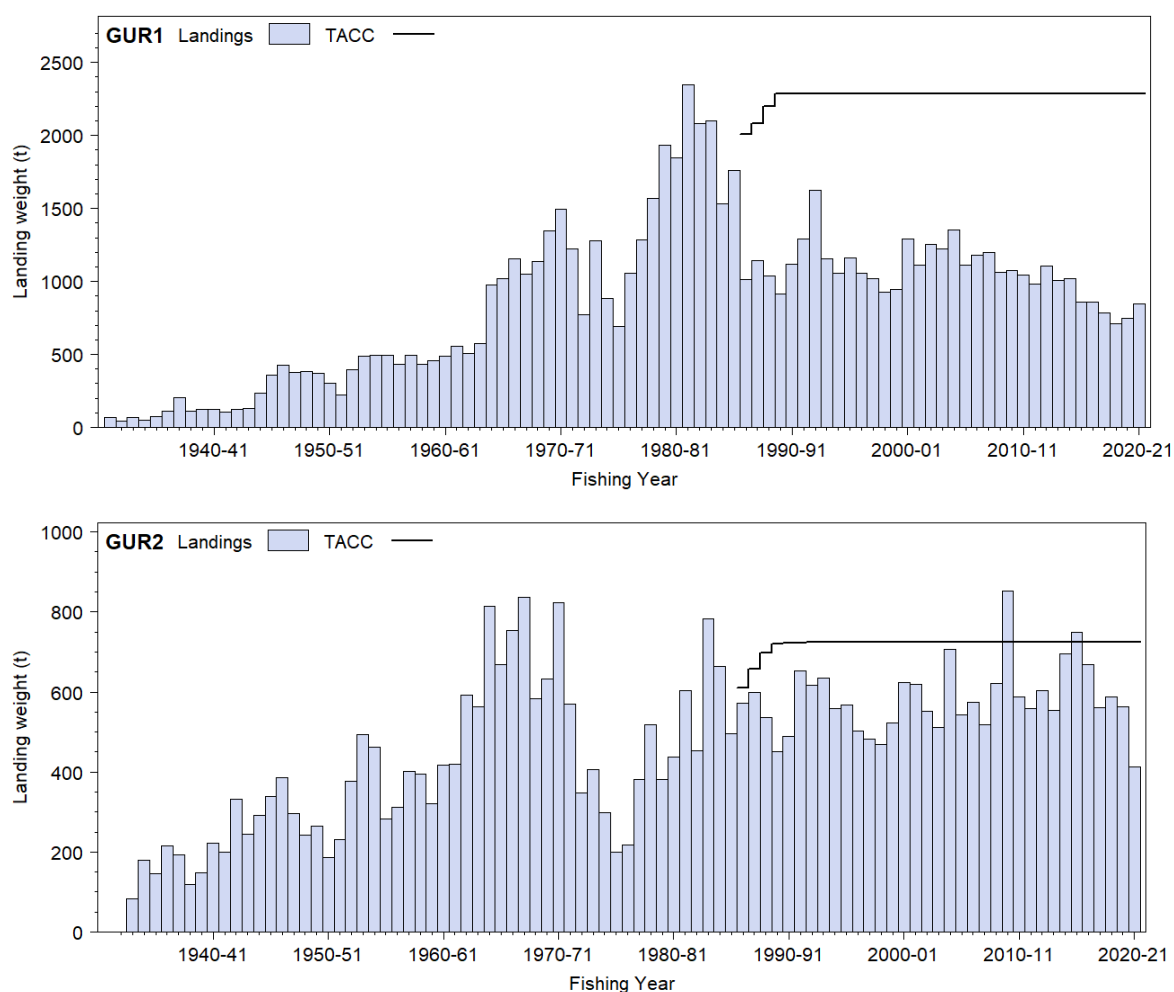
Figure 1: Reported commercial landings and TACCs for the five main GUR stocks. From top to bottom: GUR 1 (Auckland East) and GUR 2 (Central East). [Continued on next page]
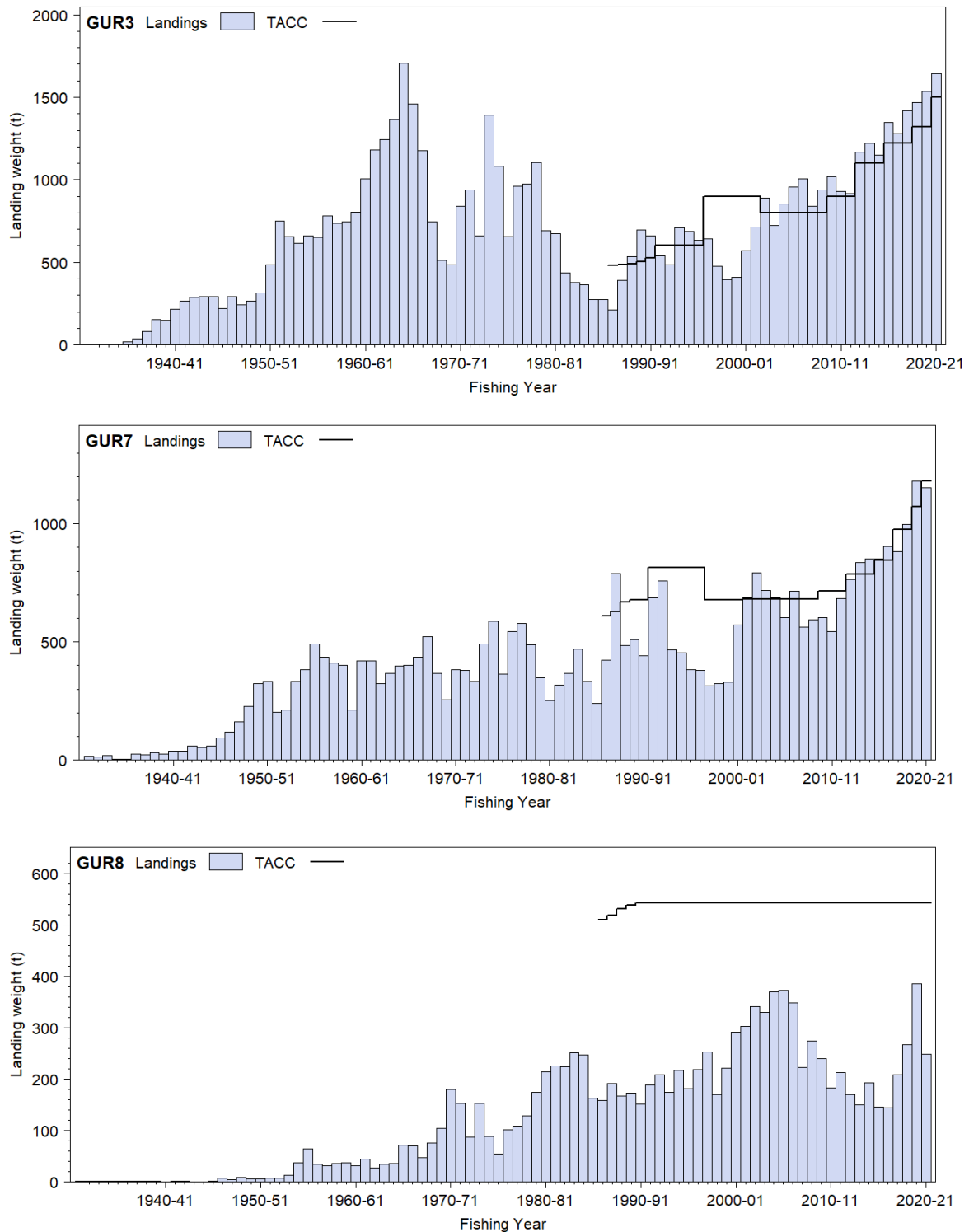
Figure 1 [Continued]: Reported commercial landings and TACCs for the five main GUR stocks. From top to bottom: GUR 3 (South East Coast), GUR 7 (Challenger), and GUR 8 (Central Egmont).

GUR 7 landings declined steadily from 761 t in 1992–93, to 309 t in 1997–98, but then increased to 793 t by 2002–03. Landings then generally declined to 2010–11. Landings increased steadily from 2010–11 to 2020–21 with multiple small increases in the TACC during that period.

Landings in GUR 8 have remained well below the TACC since 1986–87, averaging 225 t.

1.2 Recreational fisheries

Red gurnard is, by virtue of its wide distribution in harbours and shallow coastal waters, an important recreational species. It is often taken by fishers targeting snapper and tarakihi, particularly around the

RED GURNARD (GUR)

North Island. The allowances within the TAC for each Fishstock are shown in Table 1, but have currently only been set for GUR 3 and GUR 7.

1.2.1 Management controls

The main methods used to manage recreational harvests of red gurnard are minimum legal size limits (MLS), method restrictions, and daily bag limits. Fishers can take up to 20 GUR as part of their combined daily bag limit and the MLS is 25 cm.

1.2.2 Estimates of recreational harvest

Recreational catch estimates are given in Table 4. There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and offsite methods where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest for red gurnard were calculated using an offsite approach: the offsite regional telephone and diary survey approach. Estimates for 1996 came from a national telephone and diary survey (Bradford 1998). Another national telephone and diary survey was carried out in 2000 (Boyd & Reilly 2004) and a rolling replacement of diarists in 2001 (Boyd et al 2004) allowed estimates for a further year (population scaling ratios and mean weights were not re-estimated in 2001).

Table 4: **Recreational harvest estimates for red gurnard stocks. The telephone/diary surveys and earlier aerial-access surveys ran from December to November but are denoted by the January calendar year. The surveys since 2010 have run through the October to September fishing year but are denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey harvest estimates, Hartill & Davey 2015, and Davey et al 2019). [Continued on next page]**

Stock	Year	Method	Number of fish	Total weight (t)	CV
GUR 1	1996	Telephone/diary	262 000	108	0.07
	2000	Telephone/diary	465000	223	0.16
FMA 1 only	2005	Aerial–access	–	127	0.14
FMA 1 only	2012	Aerial–access	–	24	0.09
FMA 1 only	2012	Panel survey	120 500	49	0.16
	2012	Panel survey	241 957	103	0.15
FMA 1 only	2018	Aerial–access	–	31	0.11
FMA 1 only	2018	Panel survey	85 000	36	0.14
	2018	Panel survey	168 798	86	0.15
GUR 2	1996	Telephone/diary	38 000	16	0.18
	2000	Telephone/diary	209 000	127	0.37
	2012	Panel survey	66 661	38	0.20
	2018	Panel survey	71 702	39	0.28
GUR 3	1996	Telephone/diary	1 000	–	–
	2000	Telephone/diary	11 000	5	0.70
	2012	Panel survey	4 605	2	0.62
	2018	Panel survey	3 486	2	0.39
GUR 7	1996	Telephone/diary	26 000	12	0.15
	2000	Telephone/diary	36 000	11	0.23
	2012	Panel survey	23 653	12	0.24
	2018	Panel survey	60 759	38	0.18
GUR 8	1996	Telephone/diary	67 000	28	0.15
	2000	Telephone/diary	99 000	40	0.36
	2012	Panel survey	93 656	47	0.23
	2018	Panel survey	55 314	31	0.19

The harvest estimates provided by these telephone diary surveys are no longer considered reliable for various reasons. With the early telephone/diary method, fishers were recruited to fill in diaries by way of a telephone survey that also estimates the proportion of the population that is eligible (likely to fish). A 'soft refusal' bias in the eligibility proportion arises if interviewees who do not wish to co-operate falsely state that they never fish. The proportion of eligible fishers in the population (and, hence, the harvest) is thereby under-estimated. Pilot studies for the 2000 telephone/diary survey suggested that this effect could occur when recreational fishing was established as the subject of the interview at the

outset. Another equally serious cause of bias in telephone/diary surveys was that diarists who did not immediately record their day's catch after a trip sometimes overstated their catch or the number of trips made. There is some indirect evidence that this may have occurred in all the telephone/diary surveys (Wright et al 2004).

The recreational harvest estimates provided by the 2000 and 2001 telephone diary surveys are thought to be implausibly high for many species, which led to the development of an alternative maximum count aerial-access onsite method that provides a more direct means of estimating recreational harvests for suitable fisheries. The maximum count aerial-access approach combines data collected concurrently from two sources: a creel survey of recreational fishers returning to a subsample of ramps throughout the day; and an aerial survey count of vessels observed to be fishing at the approximate time of peak fishing effort on the same day. The ratio of the aerial count in a particular area to the number of interviewed parties who claimed to have fished in that area at the time of the overflight was used to scale up harvests observed at surveyed ramps, to estimate harvest taken by all fishers returning to all ramps. The methodology is further described by Hartill et al (2007).

This aerial-access method was first employed and optimised to estimate snapper harvests in the Hauraki Gulf in 2003–04. It was then extended to survey the wider SNA 1 fishery in 2004–05 and to provide estimates for other species, including red gurnard (FMA 1 only for GUR). In response to the cost and scale challenges associated with onsite methods, in particular the difficulties in sampling other than trailer boat fisheries, offsite approaches to estimating recreational fisheries harvest have been revisited. This led to the development and implementation of a national panel survey for the 2011–12 fishing year (Wynne-Jones et al 2014) and repeated for the 2017–18 fishing year (Wynne-Jones et al 2019). The panel survey used face-to-face interviews of a random sample of New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information in standardised phone interviews.

1.3 Customary non-commercial fisheries

Red gurnard is an important species for customary non-commercial fishing interests, by virtue of its wide distribution in shallow coastal waters. However, no quantitative estimates of customary non-commercial catch are currently available.

1.4 Illegal catch

No quantitative information is available.

1.5 Other sources of mortality

No quantitative information is available.

2. BIOLOGY

Gurnard growth rate varies with location, and females grow faster and are usually larger at age than males. Maximum age (A_{MAX}) is about 16 years and maximum size is 55+ cm. Red gurnard reach sexual maturity at an age of 2–3 years and a fork length (FL) of about 23 cm, after which the growth rate slows. An analysis of the age and growth of red gurnard in FMA 7 revealed that young fish 1–4 years old tend to be most common in Tasman Bay and Golden Bay. Three to six year old fish are found on the inshore areas off the west coast South Island and the older fish are predominantly found further offshore (Lyon & Horn 2011).

Biological parameters relevant to the stock assessment are shown in Table 5.

M was estimated using the equation $M = \log_e 100/\text{maximum age}$, where maximum age is the age to which 1% of the population survives in an unexploited stock. Samples from the east coast South Island (ECSI) suggested an A_{MAX} of about 16 years for males and 13 years for females, giving estimates for M of 0.29 and 0.35, respectively. Samples from the west coast South Island (WCSI) indicate an A_{MAX} of about 15 years for both sexes, giving an estimate of 0.31 for M. These samples were not from virgin populations, so M may be overestimated.

Table 5: Estimates of biological parameters for red gurnard.

Fishstock						Estimate	Source
1. Natural mortality (*M*)							
				Female		Males	
GUR 1W & 1E				0.30		0.35	Stevenson (2000)
GUR 3				0.29		0.35	Sutton (1997)
GUR 7				0.31		0.31	Sutton (1997)

2. Weight = *a*(length)^b (Weight in g, length in cm fork length)								
						Both Sexes		
				a		*b*		
GUR 1				0.00998		2.99		Elder (1976)
GUR 1W & 1 E				0.026		2.775		Stevenson (2000)
GUR 2				0.0053		3.19		Stevenson (2000)

	Females			Males			Source
3. von Bertalanffy growth parameters							
	L_∞	*k*	t_0	L_∞	*k*	t_0	
GUR 1	36.4	0.641	0.189	28.8	0.569	-0.552	Elder (1976)
GUR 1W	45.3	0.25	-0.88	36.5	0.45	-0.30	Stevenson (2000)
GUR 1E	44.5	0.28	-0.76	35.2	0.49	-0.24	Stevenson (2000)
GUR 3	48.2	0.44	0.1	42.2	0.49	-0.26	Sutton (1997)
GUR 7	45.7	0.40	-0.36	40.3	0.37	-0.96	Sutton (1997)

Red gurnard have a long spawning period which extends through spring and summer with a peak in early summer. In the Hauraki Gulf, ripe adults can be found throughout the year. Spawning grounds appear to be widespread, although perhaps localised over the inner and central shelf. Egg and larval development takes place in surface waters, and there is a period of at least eight days before feeding starts. Small juveniles (under 15 cm FL) are often caught in shallow harbours, but rarely in commercial trawls.

3.   STOCKS AND AREAS

There are no data that would alter the current stock boundaries. No information is available on stock separation of red gurnard. For GUR 3 the Working Group noted that spatial information from the CPUE analyses indicated that separate stocks or sub-stocks may exist between the east and south coasts of the South Island.

4.   STOCK ASSESSMENT

4.1   Biomass estimates
Relative abundance indices have been obtained from trawl surveys of the Bay of Plenty, west coast North Island, and Hauraki Gulf within the GUR 1 fish stock (Table 6, Figure 2); west coast South Island and Tasman Bay/Golden Bay combined (GUR 7); and east coast South Island (GUR 3) (Table 7).

East coast South Island (ECSI) inshore trawl survey
The ECSI winter surveys from 1991 to 1996 in 30–400 m were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range, but these were discontinued after the fifth in the annual time series because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007 and this time included additional 10–30 m strata in an attempt to index elephantfish and red gurnard which were officially included in the list of target species in 2012. Only six surveys (2007, 2012, 2014, 2016, 2018, and 2021) provide full coverage of the 10–30 m depth range.

In the 1990s, red gurnard biomass averaged 422 t in the core strata, increasing more than three-fold to 1453 t in 2007. From 2007 to 2014 biomass had an upward trend followed by a substantial decline in 2016 when biomass more than halved (Table 7, Figure 3). The biomass increased again in 2018 to 2043 t, the second highest estimate in the time series, and remained high, at 2068 t in 2021. Biomass for the four core plus shallow strata followed the same general trend as that for the core strata. The proportion of pre-recruit biomass in the core strata varied greatly among surveys, from 2 to 20%, and in 2021 it was 10%. In some years the proportion of pre-recruit biomass in the core plus shallow strata was greater than that of the core strata, indicating that younger fish were more common in shallow water. The proportion of juvenile

biomass (based on the length-at-50% maturity) within the core strata was close to zero for all surveys including 2021 when it was 0.4% (Beentjes et al in prep).

Table 6: Estimates of red gurnard recruited biomass (t) from *Kaharoa* trawl surveys within GUR 1. Red gurnard is assumed to recruit at 30 cm TL. For the west coast North Island trawl survey, core strata are north of New Plymouth.

| Survey area	Year	Trip code	Biomass (t)	CV(%)
Bay of Plenty	1983	KAH8303	229	31
	1985	KAH8506	27	17
	1990	KAH9004	234	11
	1992	KAH9202	166	10
	1996	KAH9601	185	16
	1999	KAH9902	180	17
	2020	KAH2001	130	14
	2021	KAH2101	85	10
Hauraki Gulf	1984	KAH8421	208	21
	1985	KAH8517	33	57
	1986	KAH8613	124	32
	1988	KAH8810	329	25
	1989	KAH8917	58	39
	1990	KAH9016	64	17
	1992	KAH9212	169	7
	1993	KAH9311	85	18
	1994	KAH9411	98	21
	1997	KAH9720	107	22
	2000	KAH0012	15	52
	2019	KAH1907	120	34
	2020	KAH2006	96	12
West coast North Island	1989	KAH8918	758	13
	1991	KAH9111	1435	18
	1994	KAH9410	1662	28
	1996	KAH9615	1090	11
	1999	KAH9915	610	13
	2018	KAH1806	551	14
	2019	KAH1906	758	13
	2020	KAH2005	824	13
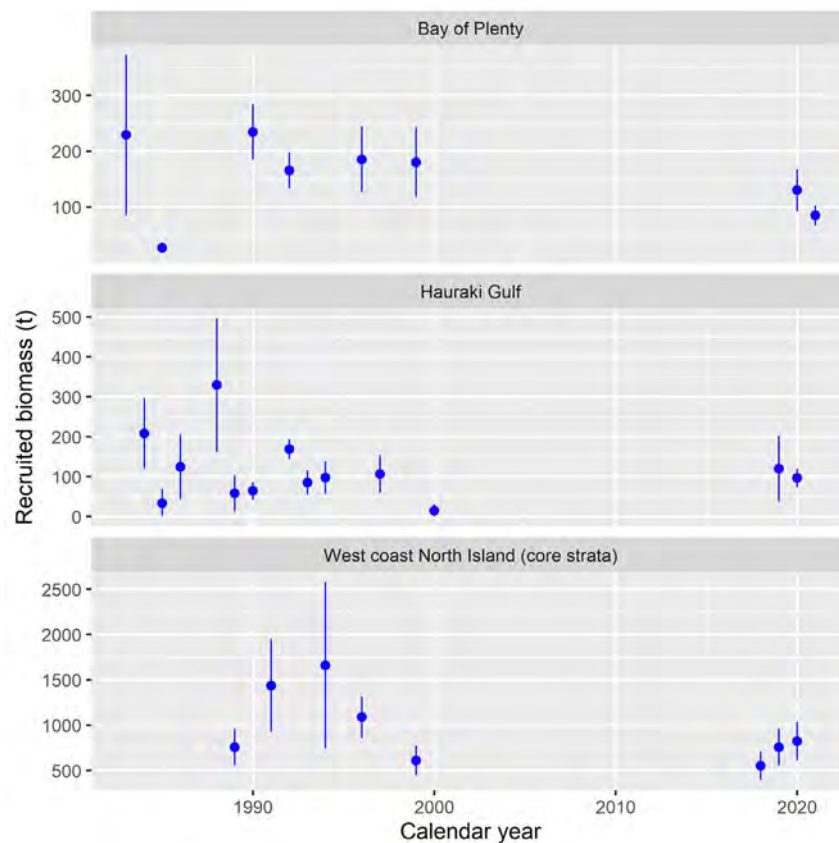
Figure 2: Estimates of recruited (length ≥ 30 cm) red gurnard biomass (t) from *Kaharoa* trawl surveys within GUR 1. Error bars are ± two standard deviations.

1241

RED GURNARD (GUR)

Table 7: Relative biomass indices (t) and coefficients of variation (CV) for red gurnard around the North Island and South Island*. Biomass estimates for ECSI in 1991 were adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16, and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (30 cm). Biomass estimates from current surveys with extreme catchability are denoted with a #.

Region	Fishstock	Year	Trip number	Total biomass estimate	CV (%)	Total biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
WCSI	GUR 7	1992	KAH9204	572	15	–	–	–	–	–	–	–	–	454.0	15.4
		1994	KAH9404	559	15	–	–	–	–	–	–	–	–	478.3	16.0
		1995	KAH9504	584	19	–	–	–	–	–	–	–	–	501.6	21.7
		1997	KAH9704	471	13	–	–	–	–	–	–	–	–	309.8	14.5
		2000	KAH0004	625	15	–	–	–	–	–	–	–	–	444.0	14.9
		2003	KAH0304	#270	20	–	–	–	–	–	–	–	–	253.7	20.9
		2005	KAH0503	442	17	–	–	–	–	–	–	–	–	374.7	16.2
		2007	KAH0704	553	17	–	–	–	–	–	–	–	–	431.6	17.9
		2009	KAH0904	651	18	–	–	–	–	–	–	–	–	400.4	19.1
		2011	KAH1104	1 070	17	–	–	–	–	–	–	–	–	798.6	18.6
		2013	KAH1305	754	12	–	–	–	–	–	–	–	–	546.5	13.4
		2015	KAH1503	1 774	16	–	–	–	–	–	–	–	–	1 335.2	18.6
		2017	KAH1703	1 708	12	–	–	–	–	–	–	–	–	1 352.0	12.0
		2019	KAH1902	1 642	16	–	–	–	–	–	–	–	–	1 079.0	16.0
		2021	KAH2103	2 022	18	–	–	–	–	–	–	–	–	1 663	18
North Island east coast	GUR 2	1993	KAH9304	439	44	–	–	–	–	–	–	–	–	–	–
		1994	KAH9402	871	16	–	–	–	–	–	–	–	–	–	–
		1995	KAH9502	178	26	–	–	–	–	–	–	–	–	–	–
		1996	KAH9602	708	29	–	–	–	–	–	–	–	–	–	–
ECSI (winter)	GUR 3			30–400 m		10–400 m		30–400 m		10–400 m		30–400 m		10–400 m	
		1991	KAH9105	763	33	–	–	NA	NA	–	–	NA	NA	–	–
		1992	KAH9205	142	30	–	–	21	58	–	–	121	30	–	–
		1993	KAH9306	576	31	–	–	26	45	–	–	551	31	–	–
		1994	KAH9406	123	34	–	–	2	42	–	–	121	34	–	–
		1996	KAH9606	505	27	–	–	8	44	–	–	496	26	–	–
		2007	KAH0705	1 453	35	2 048	27	298	40	494	32	1 155	35	1 554	27
		2008	KAH0806	1 309	34	–	–	100	59	–	–	1 210	33	–	–
		2009	KAH0905	1 725	30	–	–	62	34	–	–	1 663	30	–	–
		2012	KAH1207	1 680	28	3 515	17	193	40	742	31	1 487	27	2 773	16
		2014	KAH1402	2 063	25	3 215	17	409	45	585	32	1 654	23	2 630	16
		2016	KAH1605	941	30	2 420	15	63	41	306	19	877	30	2 114	15
		2018	KAH1803	2043	19	3 831	17	308	24	610	21	1735	20	3 221	18
		2021	KAH2104	2068	32	3 724	19	215	50	422	28	1854	14	3 302	18
ECSI (summer)	GUR 3	1996–97	KAH9618	765	13	–	–	–	–	–	–	–	–	–	–
		1997–98	KAH9704	317	16	–	–	–	–	–	–	–	–	–	–
		1998–99	KAH9809	493	13	–	–	–	–	–	–	–	–	–	–
		1999–00	KAH9917	202	20	–	–	–	–	–	–	–	–	–	–
		2000–01	KAH0014	146	34	–	–	–	–	–	–	–	–	–	–

*Assuming areal availability, vertical availability, and vulnerability equal 1.0. Biomass is only estimated outside 10 m. Note: because trawl survey biomass estimates are indices, comparisons between different seasons (e.g., summer and winter ECSI) are not strictly valid.
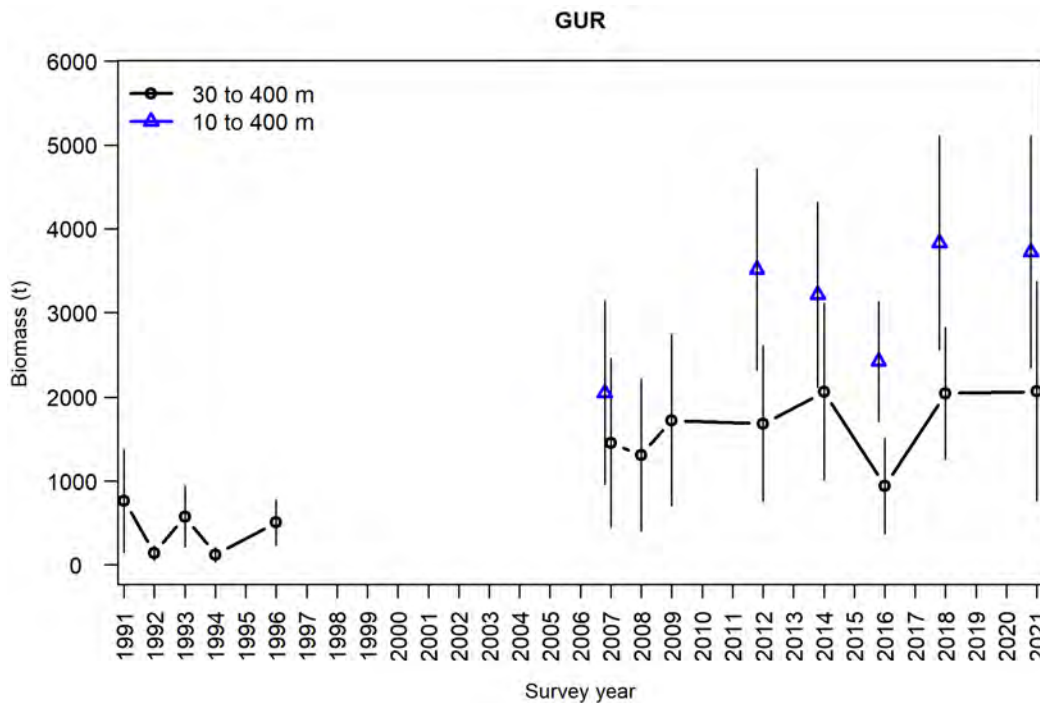
Figure 3: Red gurnard total biomass for all ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m) in 2007, 2012, 2014, 2016, 2018, and 2021. Error bars are ± two standard deviations.

The additional red gurnard biomass captured in the 10–30 m depth range accounted for 29%, 52%, 36%, 61%, 47%, and 44% of the biomass in the core plus shallow strata (10–400 m) for 2007, 2012, 2014, 2016, 2018, and 2021, respectively, indicating the importance of shallow strata for red gurnard biomass. These observations indicate that the core strata survey (30–400 m) may not be shallow enough to provide an index for sub-mature gurnard.

The addition of the 10–30 m depth range had no significant effect on the length frequency distributions in some years (2007, 2014, and 2018), but in 2012 and 2016 there were abundant 1+ cohorts in 10–30 m that were poorly represented in the core strata. In 2021, a 0+ cohort (13–18 cm) is apparent that was only sampled in the 10–30 m depth range (Beentjes et al in prep). Based on the six surveys that included the 10–30 m strata, there are generally more pre-recruit fish in the shallow strata, suggesting that the core plus shallow strata (10 to 400 m) survey is probably indexing red gurnard abundance, including juveniles. The distribution of red gurnard hot spots varies, but overall this species is consistently well represented over the entire survey area from 10 m to 100 m, but is most abundant in the shallow 10–30 m strata. They are almost absent deeper than 100 m.

West coast South Island (WCSI) inshore trawl survey
Relative biomass estimates were consistent from 1992 to 2000 but had declined by the 2003 survey (Figure 4). Biomass increased after 2003 and, since 2015, has been at record highs, with 2021 being the highest estimate in the time series (2022 t) (Table 7, Figure 4). A large proportion of the biomass had always occurred in the Tasman Bay and Golden Bay region, but markedly more was from the west coast South Island in most years since 2011.

The trend in pre-recruit biomass for the entire survey area has largely followed that of the recruited (> 30 cm) fish; however, in 2019 recruited biomass dropped compared with 2017 and pre-recruited biomass increased, and in 2021 recruited biomass increased and pre-recruited biomass decreased (Figure 5).

Scaled length frequencies are similar between surveys. Larger numbers of smaller fish are found in Tasman Bay and Golden Bay which is thought to be a nursery area, and larger numbers of large fish are found off the west coast. This was more pronounced in 2021 than it was in 2019. However, a wide size range occurs in both areas (see figure 5i from MacGibbon et al 2022). Almost all trawl stations in strata less than 100 m capture red gurnard. Catches in 100–200 m strata decline markedly and no stations in strata deeper than 200 m catch red gurnard.

RED GURNARD (GUR)
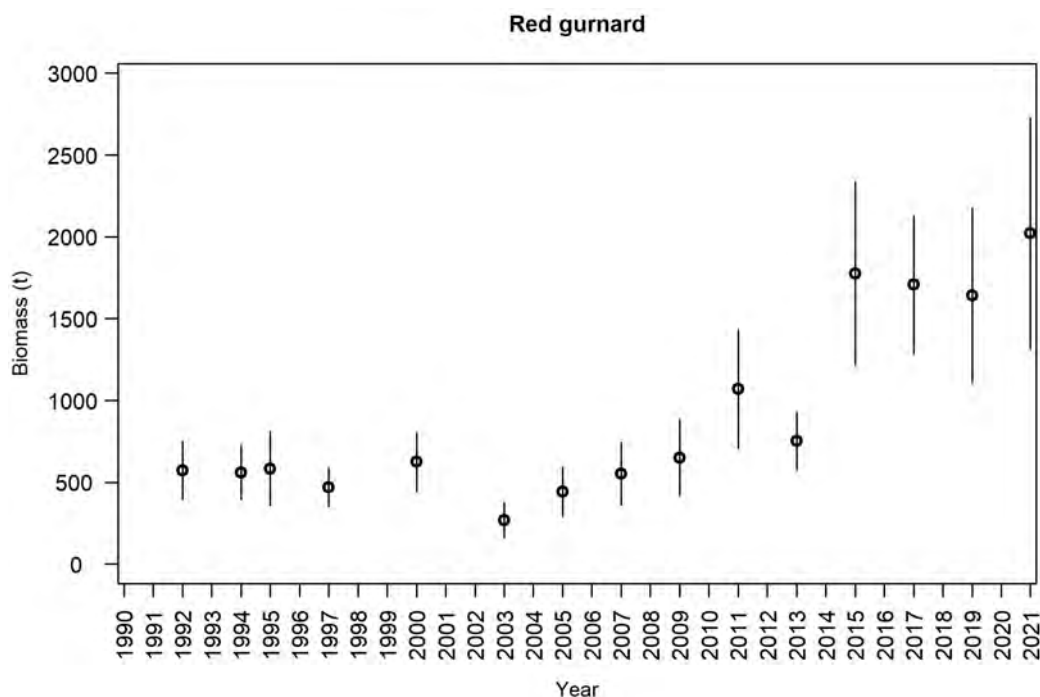
Figure 4: Red gurnard biomass trends from the west coast South Island inshore trawl survey time series. Error bars are ± two standard deviations.
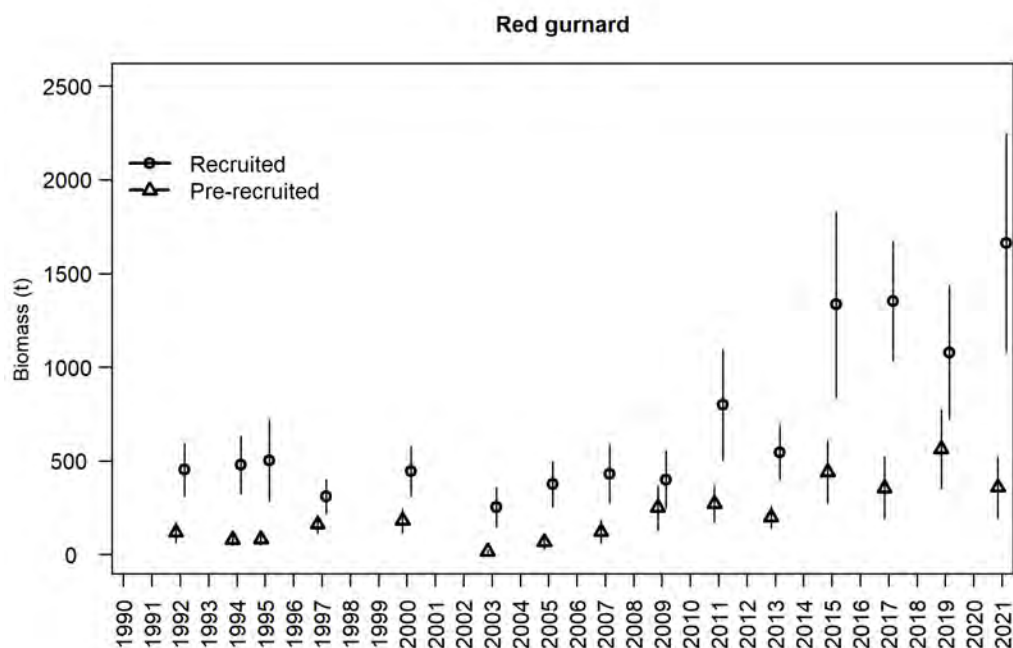
Figure 5: Red gurnard pre-recruit (< 30 cm) and recruited biomass trends from the west coast South Island inshore trawl survey time series. Error bars are ± two standard deviations.

4.2   CPUE Analyses

GUR 1

In 2022, McKenzie (in prep) updated CPUE analyses for GUR 1W (west coast, Figure 6), GUR 1E (east Northland and Hauraki Gulf, Figure 7), and GUR 1BP (Bay of Plenty, Figure 8).

The analyses were based on catch and effort data for individual tows reported on TCEPR, TCER, and ERS forms because adequate time series are available in the northern inshore trawl fisheries from 1995–96. Based on catch and effort data from single bottom trawls targeting gurnard, snapper, trevally, tarakihi, barracouta, or John dory, two GLM models were produced for each subarea: one based on the magnitude of positive catch (lognormal distribution), and the other a binomial model of the probability

of capture (based on the proportion of tows capturing GUR). The two models were then combined to produce a single series for each sub-area, and the Working Group accepted the combined models as indices of abundance. The data used to generate the GLM models were restricted to core fleets of vessels having had at least three trips in each of three years.
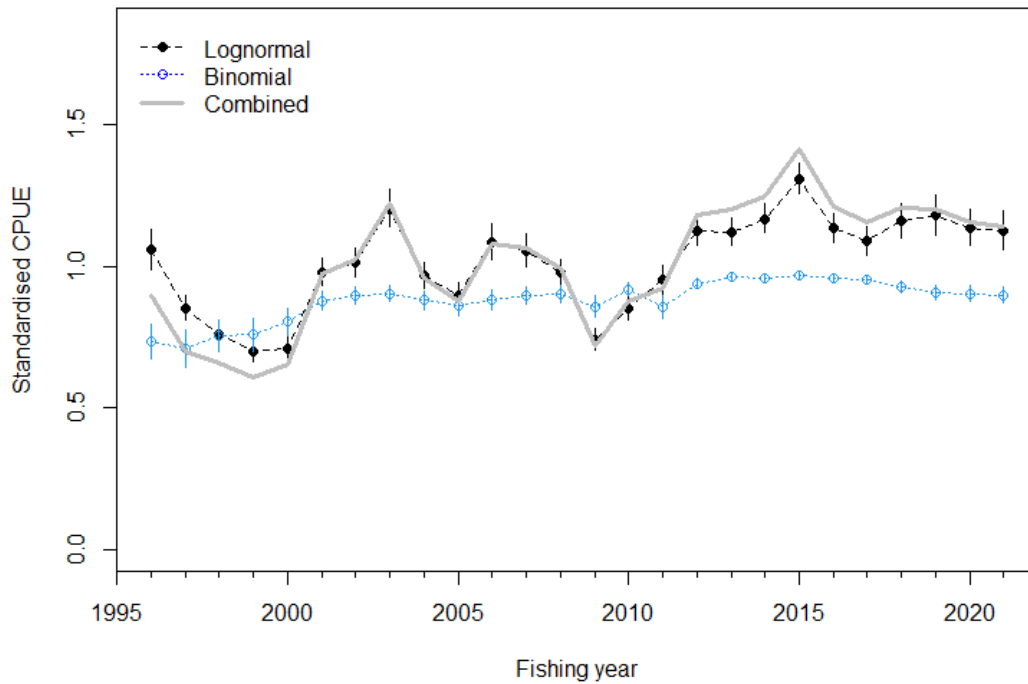
Figure 6: Standardised probability of catch (binomial model), positive CPUE indices (lognormal model), and combined model for GUR 1W using bottom trawl tow data from TCEPR/ TCER/ERS forms (McKenzie in prep). Error bars are 95% confidence intervals.
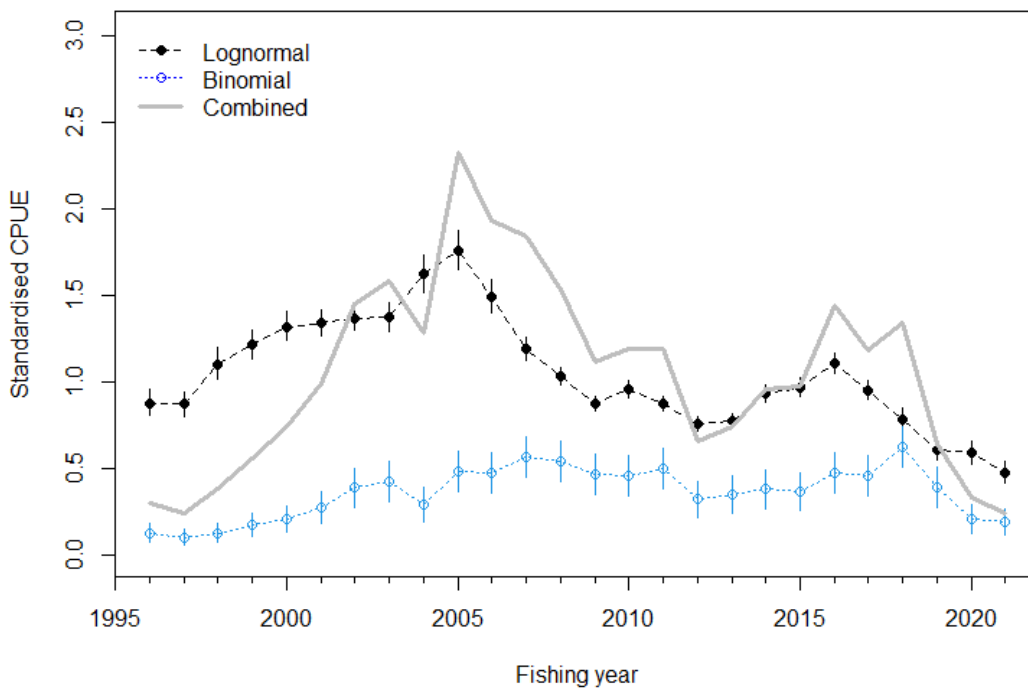
Figure 7: Standardised probability of catch (binomial model), positive catch CPUE indices (lognormal model), and combined model for GUR 1E using bottom trawl tow data from TCEPR/ TCER/ERS forms (McKenzie in prep). Error bars are 95% confidence intervals.

RED GURNARD (GUR)
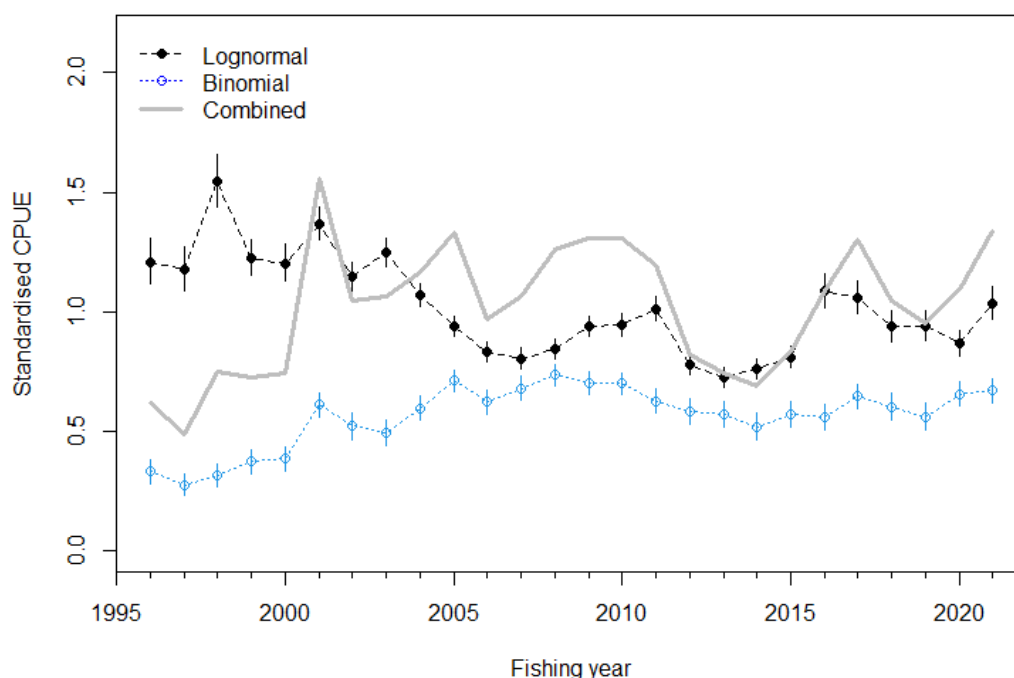
Figure 8: Standardised probability of catch (binomial model), positive catch CPUE indices (gamma model), and combined model for GUR 1BP using bottom trawl tow data from TCEPR/ TCER forms (Kendrick & Bentley in prep a). Error bars are 95% confidence intervals.

All three series show strong cyclical fluctuations with a recovery from low levels between 1996 and 1999 to a peak in the early 2000s, followed by a subsequent decline to low levels again between 2009 and 2013, then an increase to levels near, over above the long-term average between 2015 and 2017. In subsequent years the levels have declined (GUR 1W, GUR 1E), or declined then increased again (GUR 1BP). Despite overall similarities, the series differ somewhat with respect to the magnitude of the fluctuations and the specific years for the nadir and the peak.

Establishing B_{MSY} compatible reference points for GUR 1

In 2013, the Working Group accepted mean standardised bottom trawl CPUE for the period 1995–96 to 2011–12 as B_{MSY}-compatible proxies for each of the GUR 1 sub-stocks. All three series were based on combined positive catch and probability of capture models derived from event scale fishing events (i.e., tow). GUR abundance tends to fluctuate in cycles, according to recruitment, and the period was chosen because it included at least one cycle of abundance and high catch. The Working Group accepted the default Harvest Strategy Standard definitions that the Soft Limit and Hard Limit would be one half and one quarter the target for each sub-stock, respectively.

Future Research Considerations

- Integrate the results of the re-instated west coast North Island (WCNI) trawl survey and CPUE series into the stock assessment.
- Integrate the results of the re-instated Hauraki Gulf trawl survey and CPUE series into the stock assessment.
- Integrate the results of the re-instated Bay of Plenty trawl survey and CPUE series into the stock assessment.
- Age otoliths from recent surveys for the stock assessments.

GUR 2

GUR 2 is monitored using standardised CPUE from the bottom trawl fishery targeting gurnard, snapper, or trevally.

In 2017, Schofield et al (2018a) updated CPUE analyses for GUR 2. Landings were allocated to daily aggregated effort using methods described by Langley (2014) to improve the consistency of the data collected from the different statutory reporting forms (CELR and TCER). A core fleet of vessels that had completed at least five trips per year in at least seven years was modelled using a Weibull distribution. A shorter time series based on TCEPR and TCER (available since 2007–08) data, analysed at tow by tow resolution, closely resembled the mixed-form series for the years in common.

The NINSWG noted that almost of the records in the aggregated data had catches of gurnard and that a binomial index was flat. As a result, the positive catch index was retained as the key monitoring series.

The indices were updated in 2018 and 2019, and in 2020 a new fisheries characterisation was also carried out. This indicated that the fishery had been stable in the intervening period, and the accepted indices were updated with the addition of data from the ERS – Trawl reporting regime which was introduced for deepwater vessels from 2017–18, and for all other fisheries during 2019. The indices were further updated in 2022, with data to 30 September 2021.

In the longer CPUE series using aggregated data (i.e., PseudoCELR series) there are indications of cyclical variations in abundance with a 4- to 5-year period (Figure 9). There was an overall decreasing trend in CPUE from 1990 to 2007, after which CPUE stabilised and then increased to 2016, before decreasing to 2017. CPUE then increased to 2020, but dropped in 2021. As before, the series using tow level data showed a similar pattern to the longer, daily aggregated, index for years after 2007–08 (Figure 9).

In 2022, a further tow level series was added, including tarakihi as a target species. Tarakihi-target effort has been excluded from previous GUR 2 CPUE standardisations due to the deeper distribution of tarakihi effort. However, depth is included as a covariate in the event level data and the positive catch component of a mixed-target CPUE series, with tarakihi target effort included, and this index shows a similar pattern to both the existing series (Figure 8). However, gurnard are not caught universally in tarakihi-target trawling and a combined (binomial and positive catch) CPUE series is required if tarakihi effort is included.
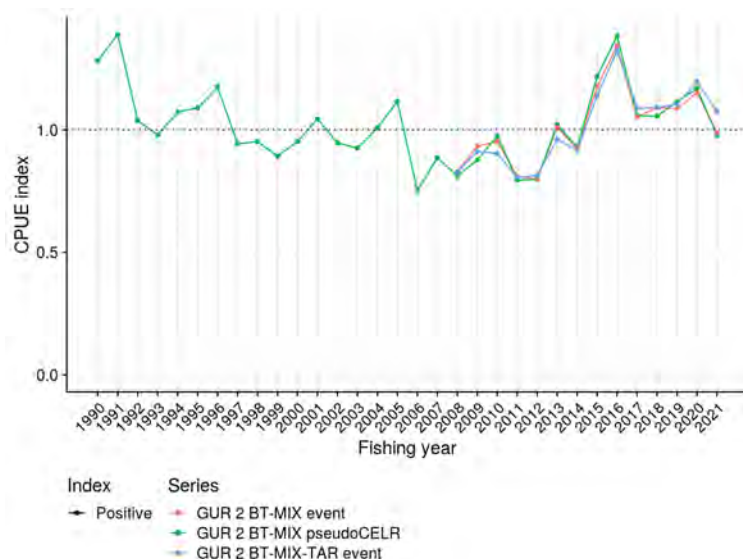
Figure 9: Comparison of standardised catch per unit effort (CPUE) indices for GUR 2 from bottom trawling targeting gurnard, snapper, and trevally (BT-MIX pseudoCELR; Weibull) combined over all form types, and more recently from data based on TCEPR/ TCER/ER (tow) format data only (BT-MIX event; gamma). The positive catch series using tow format data and including tarakihi as a target species is also illustrated (BT-MIX-TAR event; Weibull). The series are scaled relative to the geometric mean of the years they have in common.

RED GURNARD (GUR)

Chapman-Robson estimates of total mortality (Z) for GUR 2, based on the age composition of bottom trawl landings in 2009–10, were 0.518 (SE = 0.0159, CV=3.1%) and 0.632 (0.0196, 3.1), depending on whether the age at full recruitment was at 2 or 3 years (Parker & Fu 2012). Assuming an instantaneous rate of natural mortality of 0.307, fishing mortality was estimated to be 0.189 or 0.303.

Although it was not possible to produce reliable estimates of spawner biomass per recruit based targets of F (due to unreliable estimates of growth rate and size at maturity), estimates of F from this study were either lower or approximately equal to the estimate of natural mortality (depending on the age at full recruitment assumed). Assuming that the fishery is sampling the age structure of the population, and given that catches and standardised CPUE have been reasonably constant over the last decade, these results suggest that GUR 2 was not over-exploited in 2010, and that the stock is likely to be at or above B_{MSY}.

Establishing B_{MSY} compatible reference points
In 2014, the NINSWG adopted mean CPUE from the (BT(MIX)) model for the period 1990–91 to 2009–10 as a B_{MSY}-compatible proxy for GUR 2. In 2020 the reference period was extended from 1991 to 2018, on the grounds that the new period included two peaks in abundance. The Working Group adopted the default Harvest Strategy Standard definitions for the Soft Limit and Hard Limit of one half and one quarter the target, respectively.

Future research considerations
- Include tarakihi target effort in future tow-level indices for GUR 2 and consider the inclusion of tarakihi target effort in CPUE analyses for other gurnard stocks.

GUR 3
Prior to 2022, GUR 3 was monitored based on trends in standardised CPUE indices from the main trawl fisheries: the flatfish target fishery and a mixed trawl fishery (targeting red cod, giant stargazer, barracouta, tarakihi, and red gurnard). These indices were derived from data from the main inshore statistical areas of GUR 3 (018, 020, 022, 024, 026, 025, and 030).

In 2022, the CPUE analyses were revised and restricted to Pegasus Bay (Statistical Area 020) and Canterbury Bight (022) to enable a more direct comparison with the ECSI trawl survey biomass indices. The CPUE analyses were also partitioned by depth (proxied by target species) to be comparable with the depth partition of the trawl survey indices. The BT-MIX CPUE series was derived from trawls targeting red cod, tarakihi, and barracouta and is comparable to the longer time series of trawl surveys encompassing the 30–400 m depth range, while the BT-FLA CPUE indices are comparable with the shallower area (10–30 m) sampled by the more recent trawl surveys.

The catch and effort data from the two fisheries were aggregated ('rolled up') to a standard vessel-day format for the period 1989–90 to 2020–21. A core fleet was defined for each data set and CPUE indices were derived using a delta-lognormal modelling approach, including the explanatory variables fishing year, vessel, month, target species, statistical area, and fishing duration to model the probability of red gurnard catch (binomial model) and the magnitude of positive catches (lognormal model).

The two sets of CPUE indices increased considerably over the time series, although the scale of the increase was substantially higher for the BT-FLA (8-fold) compared with the BT-MIX CPUE indices (3 fold). The BT-MIX indices were the preferred set of indices because they encompassed data from a broader area compared with the BT-FLA fishery. There has also been a marked reduction in the scale of the BT-FLA fishery in recent years due to the recent retirement of several vessels and considerably higher variability in the associated CPUE indices.

The scale of the increase in the BT-MIX CPUE indices is comparable with the overall increase in the biomass indices from the 30–400 m core area of the ECSI trawl survey, although there is some variability in the trends in the two sets of indices particularly during the 2010s (Figure 10).

A separate CPUE analysis was conducted for the FLA trawl fishery in the Otago and Southland area (Statistical Areas 024, 025, 026, and 030) (BT-SouthFLA). From 2000, the indices increased 3–4 fold, with generally similar annual trends in the indices as the BT-FLA and BT-MIX CPUE indices (Figure 11).
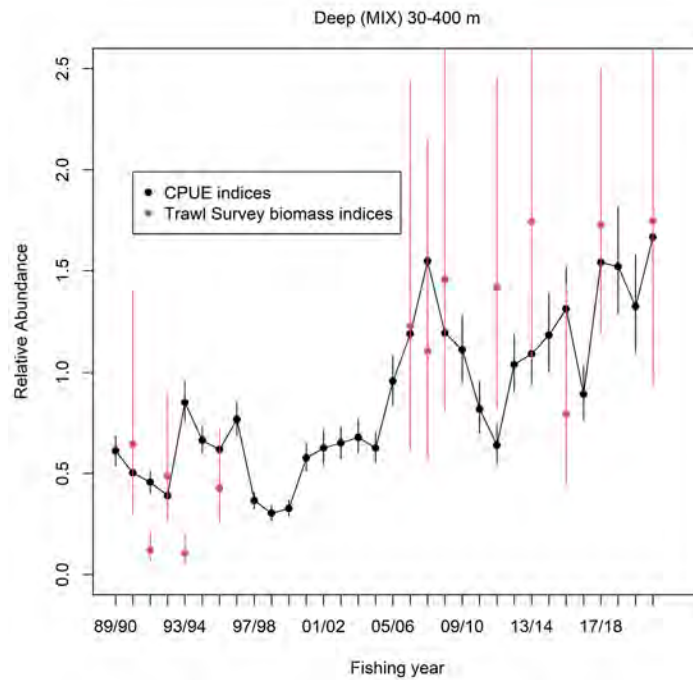
Figure 10: A comparison of the standardised BT-MIX CPUE indices and the trawl survey biomass estimates for red gurnard from the winter ECSI inshore trawl survey for the 30–400 m depth strata. Error bars show ±95% confidence intervals. Both sets of indices have been normalised to the average for the years with a survey biomass index.
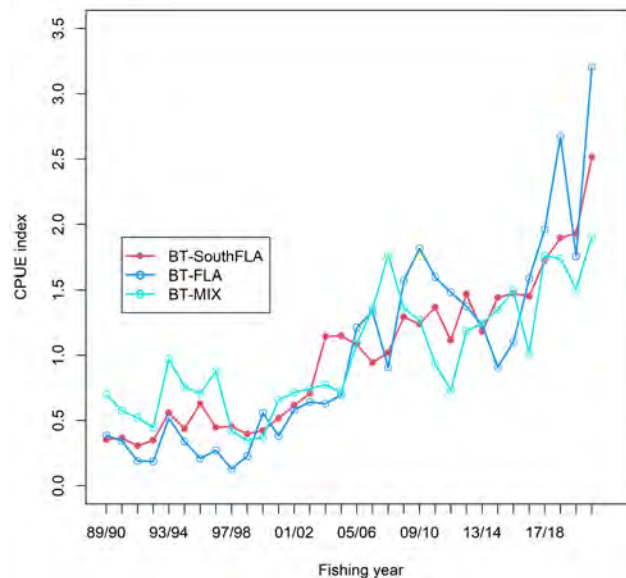
Figure 11: A comparison of the standardised BT-MIX, BT-FLA, and Southland/Otago FLA (BTSouthFLA) red gurnard CPUE indices.

GUR 7

Previously, CPUE indices were derived for the main trawl fisheries in GUR 7. The most recent analysis was completed in 2017 and included CPUE indices for the west coast South Island flatfish (WCSI-FLA) and mixed (WCSI-MIX) trawl fisheries. The trends in the CPUE indices deviated from the time series of red gurnard biomass indices from the WCSI trawl survey. In 2017, the Plenary adopted the trawl

1249

survey biomass indices as the main tool for monitoring GUR 7 and the CPUE indices have not been subsequently updated.

4.3   Stock assessments

GUR 3
The first fully quantitative stock assessment of GUR 3 was conducted in 2022. Previously, GUR 3 was assessed using partial quantitative stock assessments based on standardised CPUE indices.

The stock assessment was conducted using an age-structured population model implemented in Stock Synthesis. The model incorporated data to the 2020–21 fishing year (2021 model year). The input data were limited to commercial catches for 1985–2021, trawl CPUE indices (MIX), and *Kaharoa* ECSI trawl survey biomass indices and length/age compositions (1991–2021).

Catches
Commercial catch data are available for the GUR 3 fishery from 1931. However, the catch data are considered less reliable from the period prior to the introduction of the Quota Management System in 1986. The model was initialised in 1985 assuming equilibrium, exploited conditions. Commercial catch included in the stock assessment is shown in Figure 11. An initial model including the full catch series from 1931 did not perform as well due to implausibly high estimates of exploitation rates.
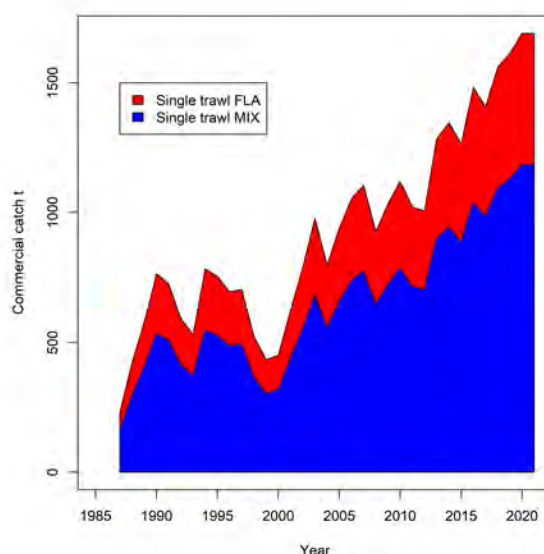
Figure 11: Commercial catch for GUR 3 included in the stock assessment models.

The model data set was configured to include the red gurnard catch from two commercial trawl fisheries: the flatfish trawl fishery and the deeper mixed trawl fishery. Reported annual catches were increased by 10% to account for an assumed level of under-reporting of catches from the commercial fishery. No length or age composition data are available from the commercial fishery.

Estimates of annual recreational catches of red gurnard from GUR 3 are small (< 5 t) and were not included in the assessment model.

There are no estimates of customary catch available for GUR 3. Recent customary catches are likely to have been a minor component of the total catch and are not explicitly included in the model catch history.

Trawl survey
The *Kaharoa* east coast South Island inshore trawl survey commenced in 1991. Red gurnard is one of the target species for the trawl survey and there is comprehensive biological sampling of the red gurnard catch (including the collection of otoliths). The survey was conducted in winter (April-May) during 1991–1996 and 2007–2021 (N=13). A separate set of trawl surveys was conducted in summer (December) during the intervening years (1997–2001, N= 6).

Initially, the trawl survey area encompassed the 30–400 m depth range. From 2007, the survey area was extended to include the 10–30 m depth range, primarily to improve the monitoring of red gurnard; approximately 50% of the red gurnard trawl survey biomass is within the shallower area of the survey although the proportion varies between surveys. Catches of red gurnard in the deeper portion (> 30 m) of the survey area generally comprised a higher proportion of larger male fish compared with the shallower area of the survey.

Age compositions were available from three early winter surveys (1992, 1993, and 1994) and length compositions were used for the remainder of the surveys.

CPUE indices

CPUE indices were derived from the daily catch and effort data from the mixed inshore bottom trawl fishery in Pegasus Bay/Canterbury Bight. The fishery included trawl records from targeting red cod, barracouta, and tarakihi (BT-MIX). The CPUE indices from the FLA trawl fishery were not included in the assessment modelling due to the recent retirement of several vessels and considerably higher variability in the associated CPUE indices.

Model structure and assumptions

A statistical age-structured population model for GUR 3 was implemented using Stock Synthesis (Methot & Wetzell 2013). Input data are listed in Table 8. The main model structural assumptions for the base model are as follows:

- The initial population (1985) was assumed to be an exploited, equilibrium state. The population is partitioned by sex and consists of 10 age classes, including a plus group. The model data period is 1985–2021 (the 2021 model year represents the 2020–21 fishing year) with no seasonal structure.
- Biological parameters for growth and natural mortality are available for GUR 3 and were fixed (Table 9). Estimated parameters are listed in Table 10.
- Recruitment was parameterised using a Beverton-Holt stock-recruitment relationship (SRR) with a steepness parameter (h) of 0.85. Recruitment deviates were estimated for 1985–2020. Recruitment for 2021 was assumed based on the average level of recruitment from the stock-recruitment relationship.
- For each *Kaharoa* trawl survey series, age based selectivities were parameterised using a sex-specific logistic function. Separate selectivities were estimated for the three sets of surveys: winter 30–400 m, summer 30–400 m, and winter 10–400 m. The trawl survey catchability coefficients (q) were freely estimated.
- A single commercial fishery selectivity was parameterised as an age-based logistic function, equivalent for both sexes. The selectivity parameters were fixed at values to approximate full selectivity of fish at a length of about 30 cm (TL), the minimum length of red gurnard in the landed catch.
- The initial (1985) fishery mortality rates for the two fisheries were estimated, informed by prior distributions that assumed relatively high initial levels of fishing mortality.
- The BT-MIX CPUE indices were assigned a CV of 0.20 based on the RMSE of the fit to the indices from preliminary model runs.
- The *Kaharoa* trawl survey length compositions were assigned an Effective Sample Size (ESS) of 10, while the age compositions were assigned a higher weighting (ESS 20). These ESS values generally approximate the relative weighting of the compositional data recommended following the approach of Francis (2011). Further evaluation of the relative weighting of the compositional data was conducted as sensitivities to the base assessment model.

The base model provided a good fit to the time series of CPUE indices. The model fitted the general increase in the 30–400 m winter trawl survey biomass indices, although it under-estimated the overall magnitude of the increase between the two time blocks (1991–1996 and 2007–2021) (Figure 12). The model also fitted the two shorter series of trawl survey biomass indices (summer 30–400 m and winter 10–400 m) and provided a reasonable fit to associated age and length composition data from the trawl surveys.

RED GURNARD (GUR)

Table 8: Summary of input data sets for the Base Case assessment model. The relative weighting includes the Effective Sample Size (ESS) of age/size composition data and the coefficient of variation (CV) associated with the abundance data. Note that model year 2021, is fishing year 2020–21, and includes the trawl survey conducted in March 2021. Nobs is number of observations.

Data set	Model years	Nobs	Error structure	CVs/ESS
CPUE indices BT-MIX	1990–2021	32	Lognormal	0.20
Trawl survey indices				
Winter 30-400m	1991, 1992, 1993, 1994, 1996, 2007, 2008, 2009, 2012, 2014, 2016, 2018, 2021	13	Lognormal	0.19–0.35
Summer 30-400m	1997, 1998, 1999, 2000, 2001	5	Lognormal	0.13–0.34
Winter 10-400m	2007, 2012, 2014, 2016, 2018, 2021	6	Lognormal	0.15–0.27
Trawl survey age comp				
Winter 30-400m	1992, 1993, 1994	3	Multinomial	ESS 20
Trawl survey length comp				
Winter 30-400m	1991, 1996, 2007, 2008, 2009, 2012, 2014, 2016, 2018, 2021	10	Multinomial	ESS 10
Summer 30-400m	1997, 1998, 1999, 2000, 2001	5	Multinomial	ESS 10
Winter 10-400m	2007, 2012, 2014, 2016, 2018, 2021	6	Multinomial	ESS 10

Table 9: Details of parameters that were fixed in the base model.

Natural mortality	female	$0.29 \, \text{y}^{-1}$
	male	$0.35 \, \text{y}^{-1}$
Stock-recruit steepness (Beverton & Holt)		0.85
Std deviation of rec devs (sigmaR)		0.6
Proportion mature		0 for age 1, 0.5 for age 2, 1 for ages > 2
Length-weight [mean weight (kg) = a (length (cm))^b]		$a = 5.3 \times 10\text{-}6, b = 3.19$
Growth parameters - female		$L\infty = 48.2, k = 0.44, \text{Length1} = 19.4$
	male	$L\infty = 42.2, k = 0.49, \text{Length1} = 19.4$
Coefficients of variation for length-at-age		0.10
Selectivity BT commercial		2

Table 10: Estimated parameters for the base model.

Parameter	Number of parameters	Parameterisation, priors, constraints
$\text{Ln}R_0$	1	Uniform, uninformative
Rec devs (1980–2020)	41	SigmaR 0.6
Selectivity trawl surveys (3)	8	Logistic, female offset
Trawl Survey ln q	3	Free
Initial F	2	Normal (0.4, 0.2)

The inclusion of data from the separate 10–400 m and 30–400 m trawl survey series duplicates the data from the deeper area of the survey from overlapping years (2007–2021) rather than configuring the recent data as a separate time series of 10–30 m trawl survey indices. The inclusion of the entire depth range of the recent trawl surveys enables the whole population of red gurnard to be monitored as a single index (with the assumption of full selectivity of older fish). A sensitivity run with the 10–30 m and 30–400 m trawl surveys gave similar results.

The CPUE and trawl survey indices indicate stock abundance has been higher since the late 2000s. The model estimates that the increase in abundance is attributable to higher recruitment in the mid-2000s and from 2010 to 2019, with exceptionally high recruitments in 2016 and 2019 (Figure 13). There are no age composition data available to inform the estimates of recruitment, although the increase in recruitment is consistent with the substantial increase in the trawl survey biomass indices for smaller (less than 30 cm) red gurnard from 2007 (the pre-recruit index was not explicitly fitted in the model).
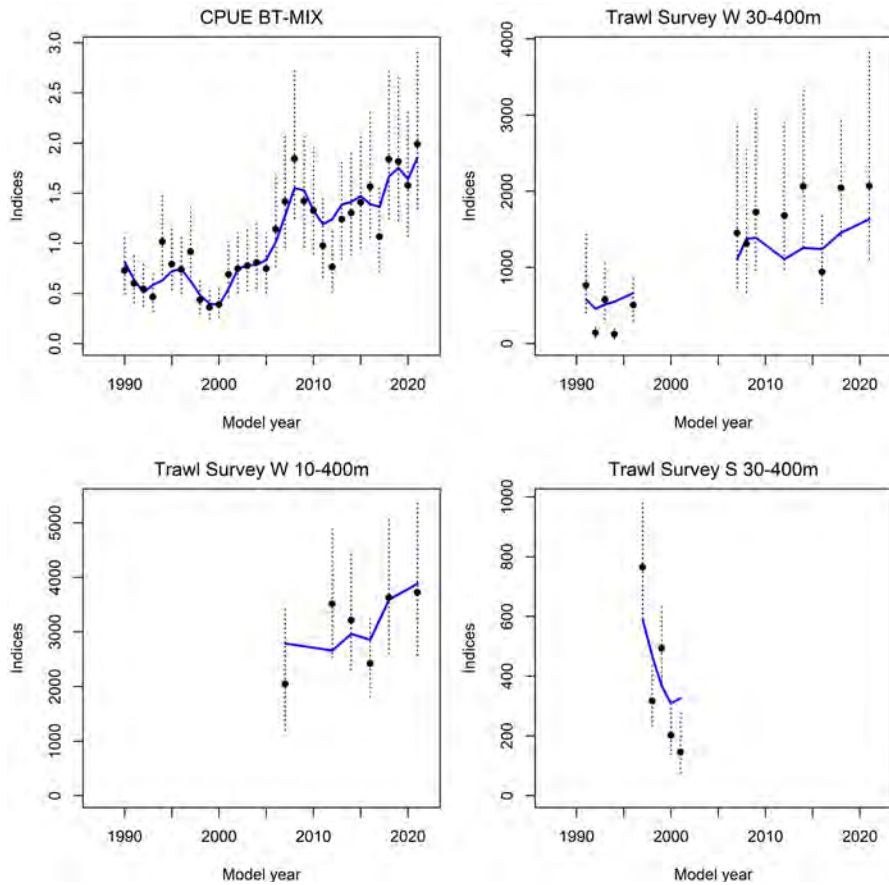
Figure 12: The fit (MPD) to the trawl survey biomass indices (points) for the base model option. W=winter and S=summer.
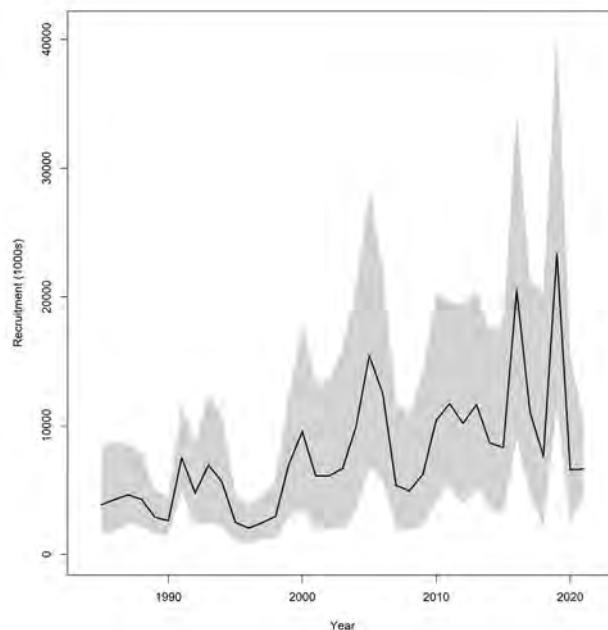
Figure 13: Annual recruitment for the base model (MCMC results). Recruitment deviates were estimated for 1985–2020. The line represents the median and the shaded area represents the 95% credible interval.

During the model development a wide range of model options were evaluated to investigate key model assumptions. A set of model options were retained as key sensitivities to capture plausible uncertainty in assessment results, including: a lower (0.25) value of natural mortality (compared with females = 0.29 and males = 0.35), excluding the CPUE indices from 2007 onwards, and limiting the model catch to the FMA 3 (ECSI) portion of GUR 3 (Table 11). FMA 5 has accounted for approximately 25% of the GUR 3 catch since the late 1990s, however, this area is not monitored by the CPUE and trawl survey abundance indices. The sensitivities were treated as single changes from the base model.

RED GURNARD (GUR)

Table 11: Description of model sensitivities.

Sensitivity run	Description
ExCPUE2007	Exclude 2007–2021 CPUE indices
FMA3catch	Exclude non FMA3 catch
LowM	Natural mortality M 0.25

Stock status (current 2021 = 2020–21 fishing year and forecast to 2025–26) for the GUR 3 spawning biomass was reported relative to the default hard limit of 10% SB_0 and the default soft limit of 20% SB_0 and interim target biomass level of 35% SB_0. Fishing mortality (2021) was reported relative to $F_{SB40\%}$ reference level. The reference points represent the default values for a medium productivity stock as described by the Harvest Strategy Standard Operational Guidelines.

For the base model and the range of model sensitivities, biomass is estimated to have increased considerably from 2007 and current (2021) stock status is estimated to be well above the target biomass level although there is considerable uncertainty associated with the estimate of current stock status (Table 12, Figure 14).

For all model options, current rates of fishing mortality are near the fishing mortality threshold ($F_{SB40\%}$) (Table 12, Figure 15).

For all model options, estimates of current and equilibrium yield were derived for the stock based on the fishing mortality rate that corresponds to the interim target biomass level (Table 13). Equilibrium yields at the interim target biomass level are estimated to be about 800–1000 t per annum (for GUR 3). $F_{SB40\%}$ yields at 2020–21 biomass levels are substantially higher than the equilibrium yields (about 1400–1800 t).

Table 12: Estimates of current (2020–21) and virgin spawning biomass (t) (median and the 95% confidence interval from the MCMCs) and probabilities of current biomass being above specified levels and probability of fishing mortality being below the level of fishing mortality associated with the interim target biomass level.

Model option	SB_0	SB_{2021}	SB_{2021}/SB_0	Pr($SB_{2021} >$ X% SB_0)	Pr($SB_{2021} <$ X% SB_0)	
				35%	20%	10%
Base	6 307	4 061	0.644	0.999	0	0
	(5 552–7 749)	(2 500–6 808)	(0.435–0.924)			
CatchFMA3	4 804	3 083	0.638	0.995	0	0
	(4 250–5 814)	(1 903–5 096)	(0.434–0.906)			
exCPUE2007	6 475	4 397	0.684	0.997	0.001	0.001
	(5 658–7 761)	(2 542–7 531)	(0.428–0.993)			
LowM	6 164	3 123	0.506	0.960	0.007	0.004
	(5 592–6 969)	(1 941–4 784)	(0.325–0.722)			

Model option	$F_{SB40\%}$	$F_{2021}/F_{SB40\%}$	Pr($F_{2021} < F_{SB40\%}$)
Base	0.2028	0.996	0.506
		(0.627–1.513)	
CatchFMA3	0.2028	1.004	0.492
		(0.645–1.517)	
exCPUE2007	0.2028	0.925	0.632
		(0.569–1.499)	
LowM	0.1857	1.297	0.087
		(0.884–1.987)	

Table 13: Estimates of equilibrium yield (t) at $F_{SB40\%}$ and yield at the 2020–21 biomass levels for the base model and the model sensitivities. The values represent the median and the 95% confidence interval from the MCMCs.

Model option	$F_{SB40\%}$	
	Equilibrium Yield	Yield at current biomass
Base	986	1 617
	(867–1211)	(1 411–1 855)
CatchFMA3	751	1 229
	(664–908)	(1 069–1 397)
exCPUE2007	1 012	1 655
	(884–1 213)	(1 451–1 888)
LowM	932	1 632
	(846–1 054)	(1 390–1 865)
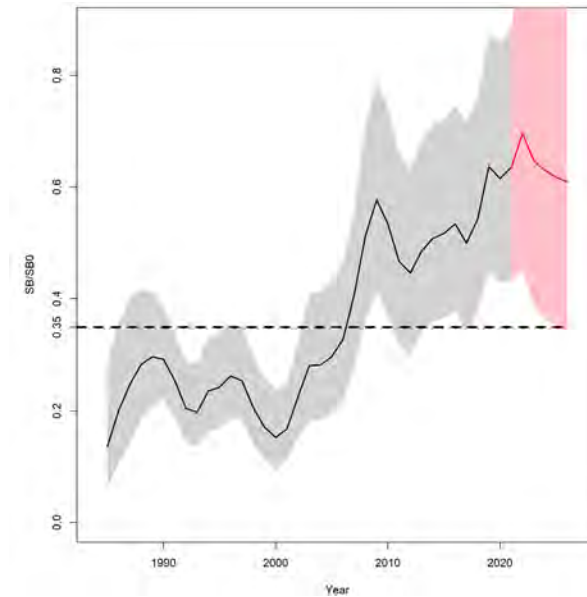
Figure 14: Annual trend in spawning biomass relative to the 35% *SB₀* interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% credible interval. The projection period (2022–2026) is in red. The dashed line represents the interim target level.
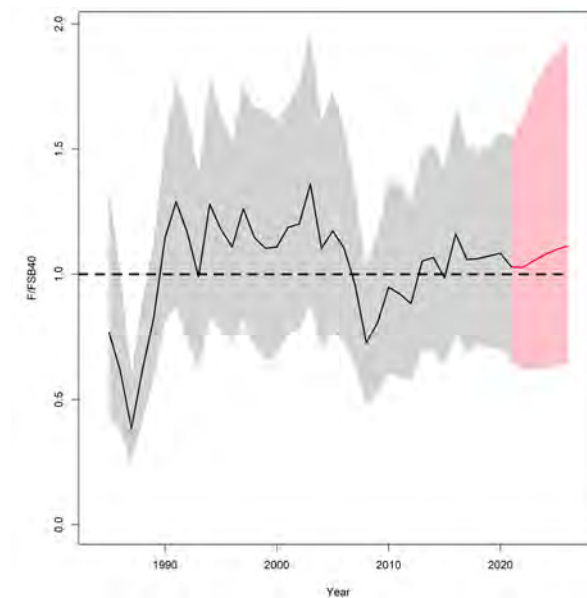
Figure 15: Annual trend in fishing mortality relative to the *F_SB40%* interim threshold exploitation level for the base model. The line represents the median and the shaded area represents the 95% credible interval. The projection period (2022–2026) is in red. The dashed line represents the interim threshold level.

Projections

Projections were conducted for the base model. Stock projections were conducted for the 5-year period following the terminal year of the model (i.e., 2022–2026). Projections assumed future recruitments were resampled from the average level of recent recruitment (2011–2020) and variation equivalent to sigmaR. Commercial catches in the projection period were held constant at the current TACC of 1500 t with an additional 10% allowance for unreported catch. There was no explicit allowance for unreported catch, recreational catch, or customary catch.

For the base case, stock abundance is predicted to remain at about the current level during the projection period, well above the target biomass level (Table 14). However, there is considerable uncertainty in the stock projections due to the uncertainty associated with the estimates of recent recruitment (especially the strong 2016 and 2019 year classes).

RED GURNARD (GUR)

Table 14: Estimates of projected (2025–26) spawning biomass (t) (median and the 95% confidence interval from the MCMCs) and probability of the spawning biomass being above default biomass limits and the interim target level in 2026 from the base model projections.

Model option	SB_{2026}/SB_0	$Pr(SB\ 2026 < X\%\ SB_0)$		$Pr(SB\ 2026 > X\%$
		10%	20%	35%
Base	0.609 (0.337–0.970)	0	0	0.970

Qualifying comments

The base model includes the catch from the entire GUR 3 QMA, whereas the trawl survey and CPUE indices are limited to FMA 3. Since 2000, approximately 25% of the GUR 3 catch has been taken from outside of FMA 3 (principally in Southland FMA 5). Limiting the model catch to FMA 3 did not appreciably change the estimate of current stock status.

There are no direct observations to determine the selectivity of the commercial fishery and the commercial catch is assumed to comprise fish larger than 30 cm.

Reference points (SB_0 based) are derived from the average level of recruitment during 1985–2020. There was an apparent shift in the productivity of GUR 3 from the mid-2000s. The increasing catches since the mid-2000s were sustained by the higher level of recruitment. Recent strong recruitments (in 2016 and 2019) are supported by higher abundance of pre-recruit red gurnard from recent trawl surveys but are yet to be confirmed from age sampling.

The model does not include GUR 3 catches prior to 1987 and the initial level of fishing mortality (in 1985) is estimated.

There are large differences between MPD and MCMC results for R_0 that require further investigation.

Future research considerations

- Determine the age compositions of red gurnard sampled by the ECSI trawl surveys, particularly for one or two of the most recent surveys. These data will improve estimates of recent recruitments, provide for more recent estimates of growth rate and the CV of length at age, and potentially resolve the differences between MPD and MCMC results. Also, consider re-examining the earlier 1992–1994 age estimates.

- Determine the length/age composition of the east coast commercial catch of GUR 3 from primarily the BT-MIX but also the BT-FLA trawl fisheries to inform the model regarding the selectivity of the two fisheries.

- Consider standardising the LF and age survey data outside the model.

- Consider spatio-temporal modelling of the trawl survey biomass data potentially including environmental covariates (INLA or VAST).

- Re-examine summer trawl survey data for maturity and the winter survey data for changes in the length-weight relationships.

- Investigate stock relationships between FMAs 3 and 5.

- Explore changes in commercial mesh sizes over time.

GUR 7

The first fully quantitative stock assessment of GUR 7 was conducted in 2022; previous assessments were partial quantitative assessments based on the WCSI trawl survey series. The stock assessment was conducted using an age-structured population model implemented in Stock Synthesis. The model incorporated data to the 2020–21 fishing year (2021 model year). The input data were limited to commercial catches (1987–2021) and *Kaharoa* WCSI trawl survey biomass indices and length/age compositions (1992–2021, N = 15).

Catches

Commercial catch data are available for the GUR 7 fishery from 1931. However, the catch data are considered less reliable from the period prior to the introduction of the Quota Management System in

1986. There are no other composition or abundance data available prior to 1987. The model was initialised in 1987 assuming equilibrium, exploited conditions. Catch data used in the stock assessment are presented in Figure 16.

The model data set was configured to include a single commercial trawl fishery. There was no allowance for the under-reporting of catches from the commercial fishery. No catch composition (length or age) data are available from the commercial fishery.

Estimates of annual recreational catches of red gurnard from GUR 7 are relatively small (10–48 t) and were not included in the assessment model.

There are no estimates of customary catch available for GUR 7. Recent customary catches are likely to have been a minor component of the total catch and are not explicitly included in the model catch history.
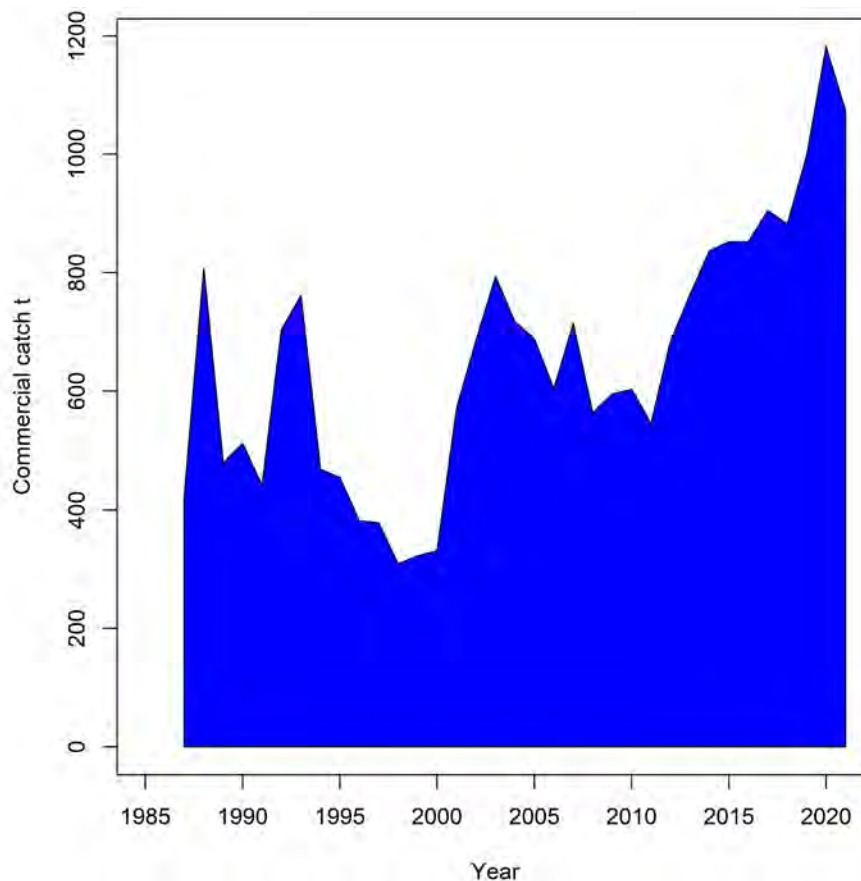
Figure 16: Commercial catch for GUR 7 included in the stock assessment models.

Trawl survey

The west coast South Island inshore trawl survey, including the Tasman Bay/Golden Bay area, commenced in 1992 and has been conducted biennially since 2002. Red gurnard is one of the target species for the trawl survey; red gurnard is one of the main species caught and there is comprehensive sampling of the red gurnard catch (including the collection of otoliths).

Age compositions were available from five surveys (1994, 1995, 2003, 2005, and 2007) and length compositions were available for the remainder of the surveys.

Model structure and assumptions

A statistical age-structured population model for GUR 7 was implemented using Stock Synthesis (Methot & Wetzell 2013). Input data are listed in Table 15. The main model structural assumptions for the base model were as follows:

RED GURNARD (GUR)

- The initial population (1987) was assumed to be in an exploited, equilibrium state. The population was partitioned by sex and consists of 10 age classes, including a plus group. The model data period was 1987–2021 (the 2021 model year represents the 2020–21 fishing year) with no seasonal structure.
- Biological parameters for growth and natural mortality are available for GUR 7 and were fixed (Table 16). Estimated parameters are listed in Table 17.
- Recruitment was parameterised using a Beverton-Holt stock-recruitment relationship (SRR) with a beta prior assumed for the steepness parameter. Recruitment deviates were estimated for 1987–2020. Recruitment for 2021 was assumed based on the average level of recruitment from the stock-recruitment relationship.
- Age based selectivity for the *Kaharoa* trawl survey was parameterised using a sex-specific logistic selectivity function. The trawl survey catchability coefficient (q) was parameterised with a relatively uninformative prior.
- Commercial fishery selectivity was an age-based logistic function with the two parameters informed by priors that approximate full selectivity of fish at a length of about 30 cm (TL), the minimum size of red gurnard in the landed catch. No length or age data were available from the commercial fishery.
- The initial (1987) fishing mortality rate was estimated, informed by a prior distribution that assumed a relatively high initial fishing mortality rate.
- The trawl survey age and length compositions were assigned a relative high weighting (Effective Sample Size (ESS) of 50). The high weighting reflected the comprehensive sampling conducted for each survey and ensured the model was informed by these data.

Table 15: Summary of input data sets for the Base Case assessment model. The relative weighting includes the Effective Sample Size (ESS) of age/size composition data and the coefficient of variation (CV) associated with the abundance data. Note that model year 2021, is fishing year 2020–21. Nobs is number of observations.

Data set	Model years	Nobs	Error structure	CV/ESS
Trawl survey indices	1992, 1994, 1995, 1997, 2000, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019, 2021	15	Lognormal	0.12–0.19
Trawl survey age comp	1994, 1995, 2003, 2005, 2007	5	Multinomial	ESS 50
Trawl survey length comp	1992, 1997, 2000, 2009, 2011, 2013, 2015, 2017, 2019, 2021	10	Multinomial	ESS 50

Table 16: Details of parameters that were fixed in the base model.

Natural mortality (male and female)	0.31 y^{-1}
Std deviation of rec devs (sigmaR)	0.6
Proportion mature	0 for age 1, 0.5 for age 2, 1 for ages > 2
Length-weight [mean weight (kg) = a (length (cm))^b]	$a = 5.3 \times 10{-6}$, $b = 3.19$
Growth parameters - female	$L\infty = 45.7$, $k = 0.40$, Length1=19.4
male	$L\infty = 40.3$, $k = 0.37$, Length1=19.4
Coefficients of variation for length-at-age	0.10

Table 17: Estimated parameters for the base model.

Parameter	Number of parameters	Parameterisation, priors, constraints
LnR_0	1	Uniform, uninformative
Stock-recruit steepness (Beverton & Holt)	1	Beta(0.80, 0.125)
Rec devs (1987–2020)	34	SigmaR 0.6
Selectivity trawl survey	3	Logistic, female offset
Selectivity BT commercial	2	Logistic
Trawl Survey ln q	1	Normal (-1.1, 1)
Initial F	1	Normal (0.4, 0.2)

For the base model option, the model also provides a good fit to the time series of trawl survey biomass indices, with the exception of the 2003 trawl survey index (Figure 17). The model also provides an acceptable fit to associated age and length composition data.

The trawl survey indices increased considerably from 2009 to 2021. The model estimates that the increase in abundance was due to a considerably higher level of recruitment from 2008 onwards. There are age data from 5 surveys (1994, 1995, 2003, 2005, 2007) but all remaining surveys have length data. These are used by the model to inform recruitment (Figure 18). Recruitments since 2007 are estimated with lower precision. The increase in recruitment is, however, consistent with the substantial (3–4 fold) increase in the trawl survey biomass indices for smaller (less than 30 cm) red gurnard from 2007.
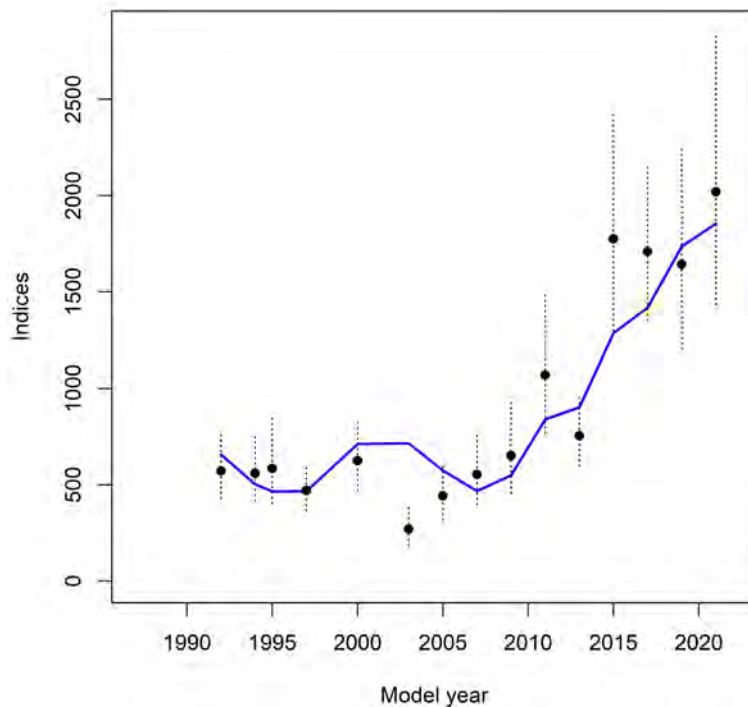
Figure 17: The fit (MPD) to the trawl survey biomass indices (points) for the base model option.
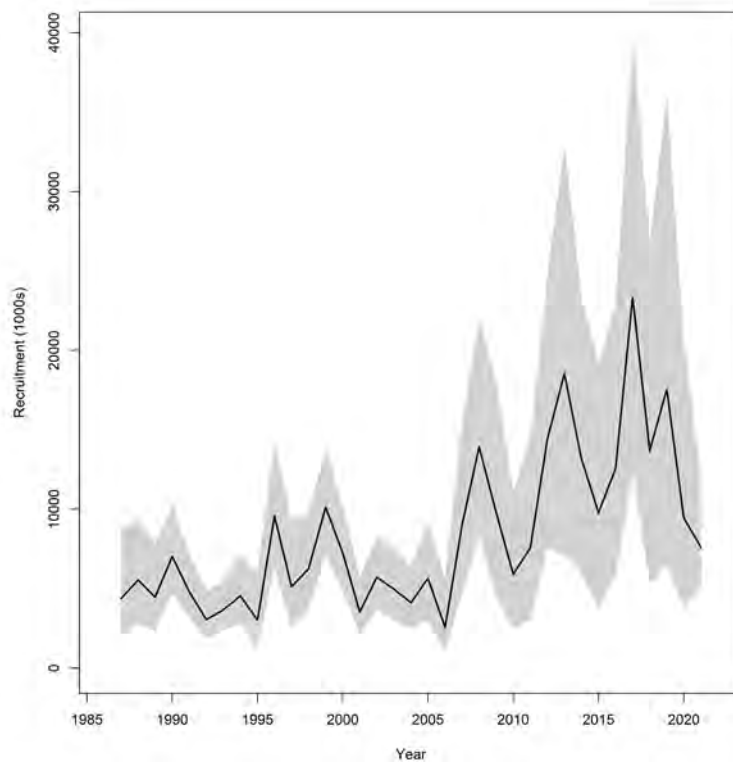
Figure 18: Annual recruitment for the base model (MCMC results). Recruitment deviates were estimated for 1987–2020. The line represents the median and the shaded area represents the 95% credible interval.

RED GURNARD (GUR)

A range of model sensitivities was undertaken to investigate the key model assumptions; these included: lower (0.25) and higher (0.35) values of natural mortality (compared with 0.31), the prior on the initial (1987) level of fishing mortality, and the precision of the trawl survey biomass indices (Table 18). The sensitivities were implemented as single changes from the base model.

Additional model trials were conducted relating to the selectivity of the commercial fishery, the relative weighting of the length/age composition data from the trawl survey, and relaxing the prior on trawl survey q. These changes did not appreciably change the model results.

Table 18: Description of model sensitivities.

Sensitivity run	Description
InitialFlow	Initial F prior Norm(0.2,0.2)
Mhigh	Natural mortality M 0.35
Mlow	Natural mortality M 0.25
Trawl Survey Indices Process Error	Process Error 0.1

Stock status (current 2021 = 2020–21 fishing year and forecast to 2025–26) for the GUR 7 spawning biomass was reported relative to the default hard limit of 10% SB_0 and the default soft limit of 20% SB_0 and interim target biomass level of 35% SB_0, and fishing mortality (2021) was reported relative to $F_{SB40\%}$. The interim reference points represent the default values for a medium productivity stock as described by the Harvest Strategy Standard Operational Guidelines.

For the base model and the range of model sensitivities, biomass is estimated to have increased considerably from 2010 and current (2021) stock status is estimated to be at about the equilibrium, unexploited level (i.e. SB_0) (Table 19, Figure 19).

For all model options, current rates of fishing mortality are well below the fishing mortality threshold ($F_{SB40\%}$) (Table 19, Figure 20).

Table 19: Estimates of current (2020–21) and virgin spawning biomass (t) (median and the 95% confidence interval from the MCMCs) and probabilities of current biomass being above specified levels and probability of fishing mortality being below the level of the fishing mortality threshold.

Model option	SB_0	SB_{2021}	SB_{2021}/SB_0	Pr(SB_{2021} > X% SB_0) 35%	Pr(SB_{2021} < X% SB_0) 20%	10%
Base	4 990	5 528	1.108	1.00	0	0
	(4 226–6 247)	(3 779–7 919)	(0.799–1.44)			
InitialFlow	4 933	5 528	1.125	1.00	0	0
	(4 217–6131)	(3 832–7 914)	(0.804–1.457)			
Mhigh	5 365	6 830	1.262	1.00	0	0
	(4318–7 346)	(4 369–10 504)	(0.921–1.605)			
Mlow	4 939	4 369	0.885	1.00	0	0
	(4313–5 981)	(3 045–6 070)	(0.63–1.147)			
TSurveyProcessError	4 421	4 034	0.901	1.00	0	0
	(3 772–5 411)	(2 499–6 482)	(0.616–1.297)			

Model option	$F_{SB40\%}$	$F_{2021}/F_{SB40\%}$	Pr(F_{2021} < $F_{SB40\%}$)
Base		0.44	
	0.2248	(0.296–0.686)	1.00
InitialFlow		0.44	
	0.2267	(0.294–0.691)	1.00
Mhigh		0.342	
	0.2342	(0.219–0.551)	1.00
Mlow		0.624	
	0.2016	(0.447–0.908)	0.99
TSurveyProcessError		0.593	
	0.2298	(0.359–0.957)	0.98
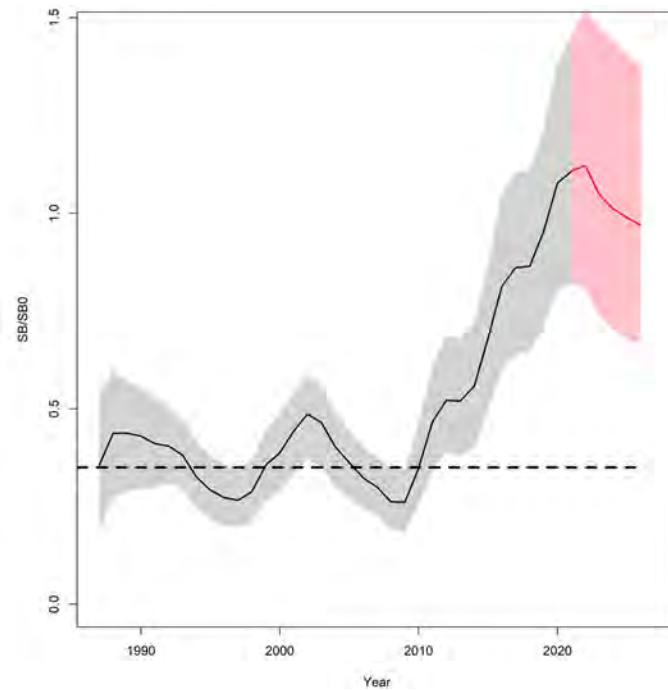
Figure 19: Annual trend in spawning biomass relative to the 35% *SB0* interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% confidence interval. The projection period (2022–2026) is in red. The dashed line represents the interim target level.
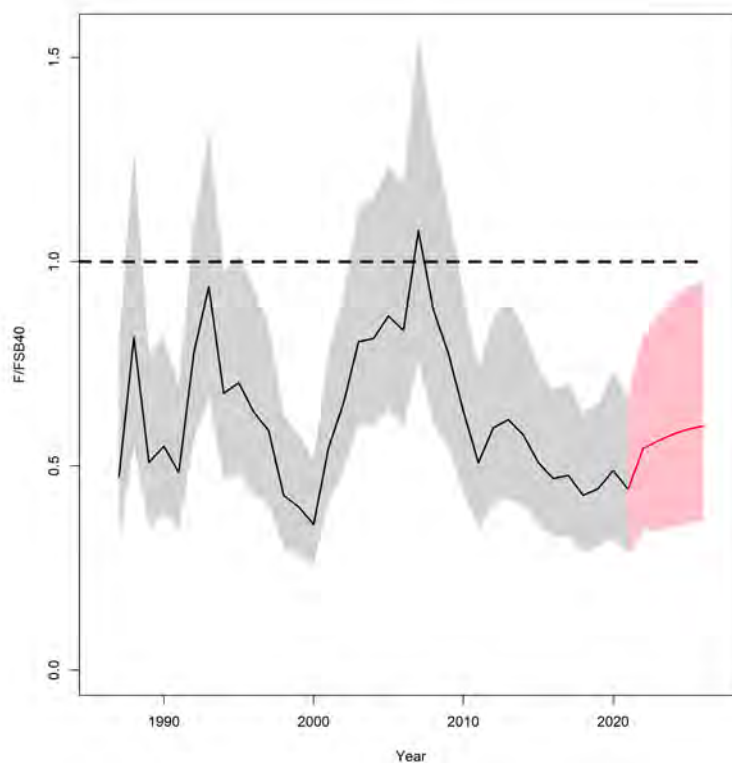
Figure 20: Annual trend in fishing mortality relative to the *FSB40%* threshold level for the base model. The line represents the median and the shaded area represents the 95% credible interval. The projection period (2022–2026) is in red. The dashed line represents the interim threshold level.

For all model options, estimates of current and equilibrium yield were derived for the stock based on the fishing mortality rate that corresponds to the interim target biomass level (Table 20). Equilibrium yields at the interim target biomass level are estimated to be about 800–1000 t per annum. $F_{SB40\%}$ yields at 2020–21 biomass levels are substantially higher than the equilibrium yields (about 2000–3000 t), although the magnitude of the current $F_{SB40\%}$ yields is highly uncertain (1100–6500 t).

RED GURNARD (GUR)

Table 20: Estimates of equilibrium yield (t) at $F_{SB40\%}$ and at the 2020–21 biomass levels for the base model and the model sensitivities. The values represent the median and the 95% confidence interval from the MCMCs.

Model option	$F_{SB40\%}$	
	Equilibrium Yield	Yield at current biomass
Base	953 (811–1 149)	2 748 (1 609–4 681)
InitialFlow	952 (808–1 160)	2 750 (1 583–4 957)
Mhigh	1 105 (891–1 453)	3 621 (1 964–6 547)
Mlow	807 (726–906)	1 875 (1 163–2 819)
TSurveyProcessError	861 (749–1 043)	2 020 (1 094–3 934)

Projections

Projections were conducted for the base model. Stock projections were conducted for the 5-year period following the terminal year of the model (i.e., 2022–2026). Projections assumed future recruitments were resampled from the average level of recent recruitment (2011–2020) and variation equivalent to sigmaR. Commercial catches in the projection period were held constant at the current TACC of 1298 t. There was no explicit allowance for unreported catch, recreational catch, or customary catch.

For the base case, stock abundance is predicted to decline during the projection period, although the biomass remains at about the SB_0 reference level throughout the period (Table 21).

Table 21: Estimates of projected (2025–26) spawning biomass (t) (median and the 95% confidence interval from the MCMCs) and probability of the spawning biomass being above default biomass limits and the interim target level in 2026 from the base model projections.

Model option	SB_{2026}/SB_0	$Pr(SB\ 2026 > X\%\ SB_0)$		$Pr(SB\ 2026 < X\%$
		10%	20%	35%
Base	0.969 (0.667–1.376)	0	0	1.00

Qualifying comments

There are no direct observations to determine the selectivity of the commercial fishery and the commercial catch is assumed to be composed of fish larger than 30 cm.

Reference points (SB_0 based) are derived from the average level of recruitment during 1987–2020. There was an apparent shift in the productivity of GUR 7 in the late 2000s. The increasing catches since 2012 were sustained by the higher level of recruitment.

The model does not include GUR 7 catches prior to 1987 and the initial level of fishing mortality (in 1987) is estimated. Prior to 1987, average annual catches were about 400 t from the early 1950s.

Because no allowance was made for unreported catch or for non-commercial harvest, the predicted yields relate only to the reported commercial catch.

Future research considerations

- Determine the age compositions of red gurnard sampled by the WCSI trawl surveys, particularly for one or two of the most recent surveys. Also consider re-examine age compositions for the earlier surveys.
- Determine length/age composition of the catch from the GUR 7 trawl fishery to inform the model regarding the selectivity of the fishery.
- Re-examine development of a CPUE series, potentially starting in 2008. This may help to calibrate *Kaharoa* replacement.

Management procedure (MP)

A range of management procedures were developed for GUR 7 based on the empirical linear relationship derived between the WCSI trawl survey biomass indices and the corresponding annual reported commercial catch (Figure 21). The relationship was forced through the origin to ensure catches were aligned with low survey biomass levels. The relationship provides a moderate fit to the observed data although there are a subset of records with a higher catch than predicted from the linear model.
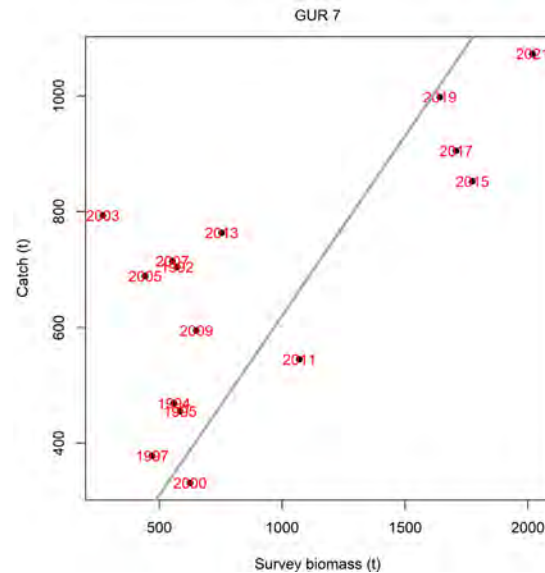
Figure 21: Comparison of red gurnard WCSI trawl survey biomass indices and GUR 7 commercial catch from the corresponding fishing year. The grey line represents the linear relationship constrained to the origin (zero intercept). The slope of the line is denoted F_{MSY} proxy.

Conceptually, the relationship represents a constant level of fishing mortality (F_{MSY} proxy). The simplest management procedures scaled the base fishing mortality level using a scalar applied to the slope coefficient (base) (0.8, 1.0, 1.2….2.0, 2.5). More complex management procedures incorporated declining levels of fishing mortality below threshold levels of the observed trawl survey biomass indices, with inflection points at the lower quartile, median or upper quartile (Figure 22).

Simulation-testing of the management procedures was carried out using the MCMC output from the 2022 GUR 7 assessment model. The individual (1000) MCMC samples were used to initialise the population age structure and projections were conducted over 100 years with recruitment resampled from the estimated recruitment deviates. Trawl surveys were conducted biennially during the projection period and the specific management procedure was applied to set the TACC for the next two years following each trawl survey (conducted in March-April).

$$\text{TACC}_{(\text{year}+1,\text{year}+2)} = \text{Scalar} * F_{MSY} \text{ proxy} * \text{TrawlSurveyBiomass}_{\text{year}}$$

Constraints were applied to investigate the effect of limiting the scale of the changes in the TACC (maximum change of -/+ 20% or 50%). Two alternative periods were applied to define the projected recruitments: the entire recruitment period (1987–2020) and the lower recruitment period 1987–2007. The MPs were also tested with different levels of autocorrelation between annual recruitments and additional process error associated with the trawl survey biomass estimates.

The results of the MP evaluation indicated that a Scalar of 1.6–2.0 would yield results that were consistent with fishing the stock at the $F_{SB40\%}$ fishing mortality level, maintaining the stock at or above the HSS default target biomass level of 35% SB_0 (moderate productivity) and well above the 20% SB_0 soft limit. There was no appreciable improvement in the performance of the MP with the inclusion of more complex relationships between trawl survey biomass and F_{MSY} proxy (i.e., inflection points at different biomass levels).

If recruitment was to revert to the lower (1987–2007) level, then the stock would fluctuate about the 30% SB_0 level with an increased probability of the stock declining below the soft limit. Nonetheless, since 2008 recruitment has been maintained at an appreciably higher level (approximately doubled) and future recruitment levels would continue to be monitored via the trawl survey. The MP could be modified if a sustained period of lower recruitment is observed (via a breakout rule).

This MP should be evaluated about every 5 years (after 2 surveys), which should include a new stock assessment.

RED GURNARD (GUR)
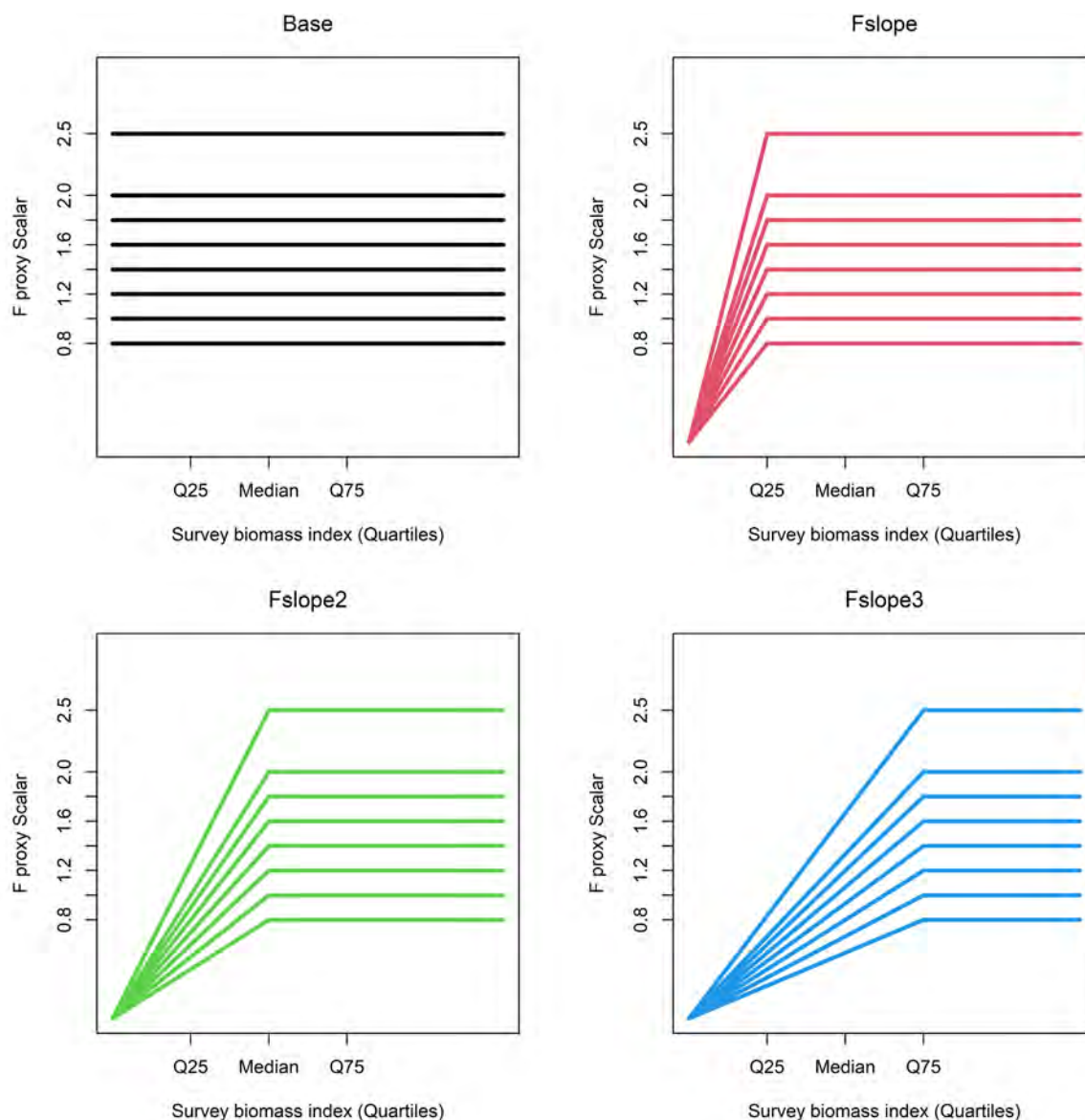
Figure 22: The range of scalars applied to the F_{MSY} proxy value in the suite of management procedures. The different functional forms of the scalars have inflection points at different levels of trawl survey biomass from on the reference data set (15 surveys).

Breakout rules
- Review of the biennial trawl survey results by the Inshore Working Group, including determination of the magnitude of recent recruitment (pre-recruit biomass), survey precision and investigation of extreme catchability.

4.4   Other factors
Red gurnard is a major bycatch of target fisheries for several different species, such as snapper and flatfish. The target species may differ between areas and seasons. The recorded landings are influenced directly by changes in the fishing patterns of fisheries for these target species and indirectly by the abundance of these target species. Some target fishing for gurnard also occurs.

5.   STATUS OF THE STOCKS

Stock Structure Assumptions
For the purpose of this summary GUR 1 is considered to be a single stock with three sub-stocks.

- **GUR 1W**

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Standardised CPUE and WCNI trawl survey series
Reference Points	Target: B_{MSY}-compatible proxy based on the mean CPUE from 1995–96 to 2011–12 of the bottom trawl GUR 1 west (tow) series Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: F_{MSY} compatible proxy based on the mean relative exploitation rate for the period: 1995–96 to 2011–12
Status in relation to Target	About as Likely as Not (40–60%) to be at or above the target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing is About as Likely as Not (40–60%) to be occurring

Historical Stock Status Trajectory and Current Status

Landings (dashed brown line), standardised CPUE combined model using tow by tow data (blue line), and trawl survey recruited biomass indices (purple with error bars ± two standard deviations). The green, orange, and red horizontal lines represent the target, soft, and hard limits, respectively. Trawl survey recruited biomass indices are scaled to have the same arithmetic mean value as the standardised CPUE indices, over the years they have in common.

Annual relative exploitation rate (landings divided by standardised CPUE and normalised to an arithmetic mean of one over the reference period 1996 to 2012) for red gurnard in the GUR 1 west coast sub-stock. The horizontal grey dashed line at one represents the average relative exploitation rate during the period used to define the reference points (depicted by vertical dotted green lines).

RED GURNARD (GUR)

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	- The CPUE has increased since 2008–09 and in 2020–21 was well above the long-term mean. - The WCNI trawl survey series shows that abundance in 2018–2020 was lower than it was during the early 1990s.
Recent Trend in Fishing Intensity or Proxy	Relative exploitation rate declined from 1995–96 to 2018–19, and then increased to 2020–21, but remained below the threshold.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Without information on recruitment, it is not possible to predict how the stock is going to respond in the next few years.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Current Catch Soft Limit: Unlikely ($< 40\%$) Hard Limit: Unlikely ($< 40\%$) TACC Unknown for both the Soft and Hard Limits
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%) if the catch remains at current levels Unknown if the catch were to increase to the level of the TACC

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from bottom trawl	
Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	Catch and effort data WCNI trawl survey series	1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Inclusion of WCSI trawl survey series	
Major Sources of Uncertainty	-	

Qualifying Comments
As the red gurnard fishery in FMAs 1 and 9 has a long history, it is difficult to infer stock status from recent abundance trends. The abundance of all three sub-stocks appears to be cyclical, probably in response to recruitment variation. This makes it difficult to predict future trends without recruitment information. The WCNI trawl survey series shows a substantial decline in abundance between the 1990s (prior to the commencement of the CPUE series) and 2018–2020, leading to the Working Group moderating assessment results based on CPUE alone. As the TACC for GUR 1 is substantially higher than the current catch, it is not possible to evaluate potential impacts if catches increased to the level of the TACC.

Fishery Interactions
Red gurnard is taken off the west coast by bottom trawl targeted at snapper and trevally. A Danish seine summer fishery for red gurnard and John dory also occurs off the west coast.

- **GUR 1E**

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	- Standardised CPUE - HG trawl survey series
Reference Points	Target: B_{MSY}-compatible proxy based on the mean CPUE from 1995–96 to 2011–12 for the bottom trawl GUR 1 East (tow) series Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: F_{MSY} compatible proxy based on the mean relative exploitation rate for the period: 1995–96 to 2011–12
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unlikely ($< 40\%$) to be below Hard Limit: Unlikely ($< 40\%$) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
 Red gurnard: ENHG Reference years: 1996-2012 **Landings (dashed brown line), standardised CPUE combined model using tow by tow data (blue line), and trawl survey recruited biomass indices (purple with error bars ± two standard deviations). The green, orange, and red horizontal lines represent the target, soft, and hard limits, respectively. Trawl survey recruited biomass indices are scaled to have the same arithmetic mean value as the standardised CPUE indices, over the years they have in common.**

RED GURNARD (GUR)

Annual relative exploitation rate (landings divided by standardised CPUE and normalised to an arithmetic mean of one over the reference period 1996 to 2012) for red gurnard in the GUR 1 east coast sub-stock. The horizontal grey dashed line at one represents the average relative exploitation rate during the period used to define the reference points (depicted by vertical dotted green lines). For fishing years 2018 to 2021, standardised CPUE and the annual relative exploitation rate are plotted with a cross (see Qualifying Comment below).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE declined strongly from 2017–18 to 2020–21, but the trawl survey series showed that abundance in 2020 and 2021 was close to the series mean for the period 1984–85 to 2021. The amount of data available for CPUE declined substantially in the last four years of the series.
Recent Trend in Fishing Intensity or Proxy	Relative exploitation rate declined from 1995–96 to 2002–03, then fluctuated without trend below the long-term average, until rising from 2017–18.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Without information on recruitment, it is not possible to predict how the stock is going to respond in the next few years.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown if the catch remains at current levels

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from bottom trawl	
Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	• Inclusion of HG trawl survey series	
Major Sources of Uncertainty	-	

1268

Qualifying Comments

- As the red gurnard fishery in FMAs 1 and 9 has a long history, it is difficult to infer stock status from recent abundance trends. The abundance of all three sub-stocks appears to be cyclical, probably in response to recruitment variation. This makes it difficult to predict future trends without recruitment information.

- Largely due to vessels switching to PSH gear, bottom trawl catch and effort declined substantially after 2016–17, and the standardised CPUE may not track abundance.

Fishery Interactions

Red gurnard is taken as a bycatch on the east coast mainly by bottom longlines targeted at snapper, with the balance taken almost equally by bottom trawl and Danish seine targeting snapper and John dory.

- **GUR 1 Bay of Plenty**

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	- Standardised CPUE - BoP trawl survey series
Reference Points	Target: B_{MSY}-compatible proxy based on the mean CPUE from 1995–96 to 2011–12 for the bottom trawl GUR 1 BoP (tow) series Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: F_{MSY} compatible proxy based on the mean relative exploitation rate for the period: 1995–96 to 2011–12
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unlikely ($< 40\%$) to be below Hard Limit: Very Unlikely ($< 10\%$) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status

Landings (dashed brown line), standardised CPUE combined model using tow by tow data (blue line), and trawl survey recruited biomass indices (purple with error bars ± two standard deviations). The green, orange and red horizontal lines represent the target, soft and hard limits, respectively. Trawl survey recruited biomass indices are scaled to have the same arithmetic mean value as the standardised CPUE indices, over the years they have in common.

RED GURNARD (GUR)

Red gurnard: BPLE
Reference years: 1996-2012

Annual relative exploitation rate (landings divided by standardised CPUE and normalised to an arithmetic mean of
one over the reference period 1996 to 2012) for red gurnard in the Bay of Plenty. The horizontal grey dashed line at
one represents the average relative exploitation rate during the period used to define the reference points (depicted
by vertical dotted green lines).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The CPUE index has fluctuated without trend, but the trawl survey series showed that abundance in 2019–20 and 2020–21 was below the mean for the period 1989–90 to 1998–99.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Without information on recruitment, it is not possible to predict how the stock is going to respond in the next few years.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown if the catch remains at current levels Unknown if the catch were to increase to the level of the TACC

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from bottom trawl	
Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	- Inclusion of the re-instated BoP trawl survey series.	
Major Sources of Uncertainty	-	

1270

Qualifying Comments

- As the red gurnard fishery in FMAs 1 and 9 has a long history, it is difficult to infer stock status from recent abundance trends. The abundance of all three sub-stocks appears to be cyclical, probably in response to recruitment variation. This makes it difficult to predict future trends without recruitment information.

- CPUE fluctuated without trend, whereas trawl survey biomass in 2020–21 was lower than the average for the period 1995–96 to 2020–21.

Fishery Interactions

Red gurnard is taken as a bycatch in the Bay of Plenty mainly by bottom longline targeted at snapper, with the balance taken almost equally by bottom trawl and Danish seine targeting snapper and John dory.

- **GUR 2**

Stock Structure Assumptions

For the purpose of this summary GUR 2 is considered to be a single stock.

Stock Status

Year of Most Recent Assessment	2022
Assessment Runs Presented	Standardised CPUE for BT.MIX
Reference Points	Target: B_{MSY}-compatible proxy based on the mean CPUE (BT(MIX)) for period 1990–91 to 2017–18 Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: F_{MSY} compatible proxy based on the mean relative exploitation rate for the period 1990–91 to 2017–18
Status in relation to Target	About as Likely as Not (40–60%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below
	Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status

(a) Annual removals for GUR 2; (b) the standardised catch per unit effort (CPUE) index, relative to the agreed reference points, for GUR 2 from bottom trawling targeting gurnard, snapper and trevally (BT-MIX) and combining data from all form types at a daily aggregation

RED GURNARD (GUR)

(c) annual relative exploitation rate (catch/CPUE) gurnard in GUR 2.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Standardised CPUE decreased to just above the target in 2016–17, increased to 2019–20 before dropping to the target level in 2020–21.
Recent Trend in Fishing Intensity or Proxy	Relative exploitation has been below the long-term average since 2017-18.
Other Abundance Indices	Tow based analysis of 2007–08 to 2020–21 data closely resembles the mixed form type analysis, as does the CPUE series including tarakihi target.
Trends in Other Relevant Indicators or Variables	Catch curve analysis indicated that fishing mortality was at or below M in 2010 (depending on the age at full recruitment).

Projections and Prognosis	
Stock Projections or Prognosis	Without information on recruitment, it is not possible to predict how the stock is going to respond in the next few years.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely ($< 40\%$) Hard Limit: Very Unlikely ($< 10\%$) Unknown if the catch were to increase to the level of the TACC
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%) for current catch Unknown if the catch were to increase to the level of the TACC

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	BT-Mix CPUE series	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Most of the GUR2 commercial catch is made in Hawke Bay, and the index of abundance is naturally weighted to abundance of GUR in this area.

Fishery Interactions
Red gurnard is taken in FMA 2 by the bottom trawl fishery targeting gurnard and tarakihi.

- **GUR 3**

Stock Structure Assumptions

No information is available on the stock separation of red gurnard. The Fishstock GUR 3 is treated in this summary as a unit stock.

Stock Status	
Year of Most Recent Assessment	2022
Assessment runs presented	Base case model
Reference Points	Interim Target: 35% B_0 (HSS default)
	Soft Limit: 20% B_0 (HSS default)
	Hard Limit: 10% B_0 (HSS default)
	Overfishing threshold: $F_{SB40\%}$ (HSS default)
Status in relation to Target	$B_{2020-21}$ was estimated to be 64% B_0; Very Likely ($> 90\%$) to be at or above the target
Status in relation to Limits	Soft limit: Very Unlikely ($< 10\%$) to be below
	Hard Limit: Exceptionally Unlikely ($< 1\%$) to be below
Status in relation to Overfishing	$F_{2020-21}$ was estimated to be at about $F_{SB40\%}$. Overfishing is About as Likely as Not (40–60%) to be occurring

Historical Abundance and Catch Trajectories
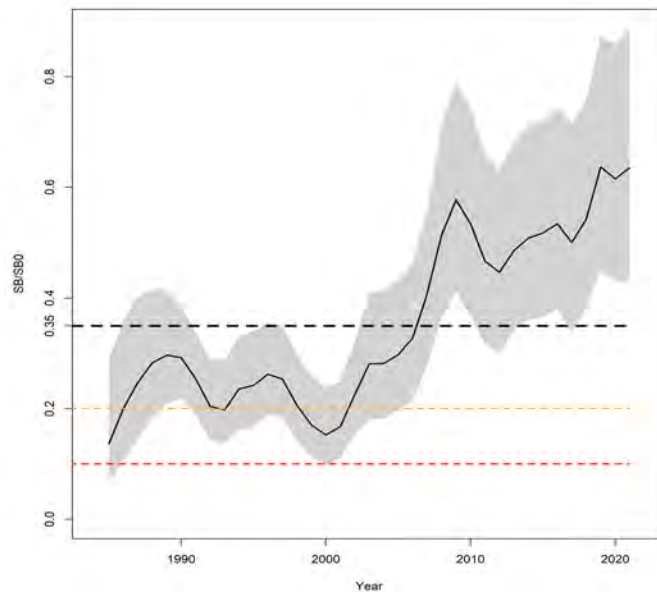
Annual trend in spawning biomass relative to the 35% SB_0 interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% credible interval. The dashed line represents the interim target level. The red and orange dashed lines represent the hard and soft biomass limits, respectively.

RED GURNARD (GUR)

Fishing Intensity Trajectory
Annual fishing mortality compared to the *FSB40%* interim target fishing mortality level (dashed line) for the base case model (median values from MCMCs).
Combined status
Annual spawning biomass and fishing mortality compared to the *SB35%* interim target biomass level and corresponding fishing mortality reference for the base case model (median values from MCMCs). The green dashed lines represent the biomass target and fishing mortality threshold levels. The red and orange dashed lines represent the hard and soft biomass limits, respectively.

Fishery and Stock Trends	
Recent trend in Biomass or Proxy	Spawning biomass was estimated to have increased from the late 2000s following above average recruitment since the mid-2000s.

Recent trend in Fishing Intensity or Proxy	Fishing mortality has been at about the target level since 2010.
Other Abundance Indices	- FLA BT CPUE indices have increased considerably from the early 1990s. These CPUE indices were not included in the 2022 assessment. - A Southland CPUE series also had generally similar levels of increase.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Abundance is Very Likely (> 90%) to remain above the target biomass level over the next five years at the current TACC or catch.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured Bayesian stock assessment implemented with Stock Synthesis software and uncertainty estimated by MCMC	
Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs	- Commercial catch (from 1985 onwards) - Survey biomass indices. - Survey age/length frequencies. - BT-MIX CPUE indices - Estimates of biological parameters (e.g., growth, natural mortality, age-at-maturity, and length/ weight)	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- First implementation of full quantitative assessment, which includes trawl survey data and a new CPUE series excluding FLA target; previous (2015) assessment was a partial quantitative assessment based on the CPUE series, BT(MIX+FLA)	
Major Sources of Uncertainty	- Choice of the period used to derive reference points, as it is unclear whether recent increases in recruitment represent an increase in productivity - Lack of recent age composition data from trawl survey and fishery - The trawl survey and CPUE indices are for the FMA 3 (ECSI) area only and do not cover the entire GUR 3 QMA; approximately 25% of the GUR3 catch is taken outside FMA 3	

Qualifying Comments
-

RED GURNARD (GUR)

Fishery Interactions
Red gurnard in GUR 3 are taken almost entirely by bottom trawl in fisheries targeted at red cod, barracouta, and flatfish. Some red gurnard are also taken in the target tarakihi and stargazer bottom trawl fisheries. The level of targeting of this species was historically low, averaging less than 10%, but has increased to approximately 25% since 2017–18.

- **GUR 7**

Stock Structure Assumptions
Stock boundaries are unknown, but for the purpose of this summary, GUR 7 is considered to be a single management unit.

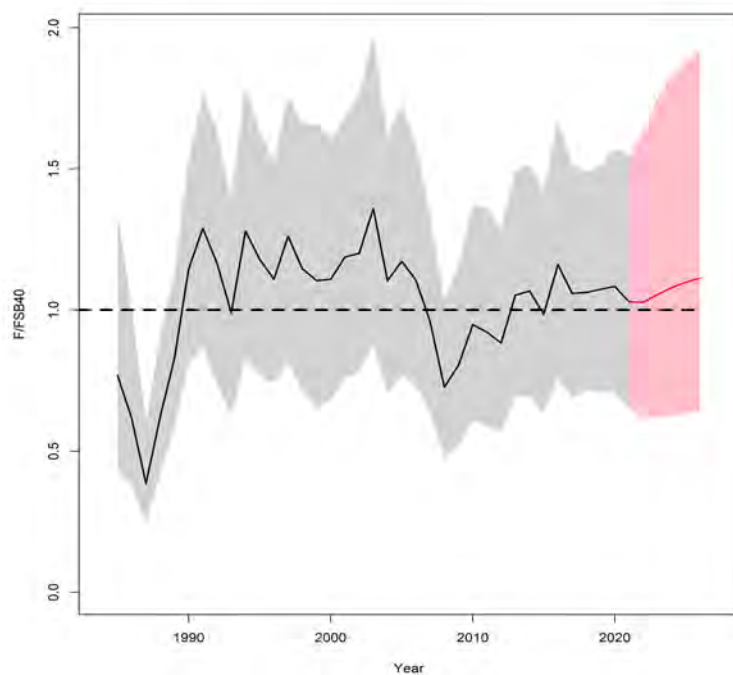| Stock Status	
Year of Most Recent Assessment	2022
Assessment runs presented	Base case
Reference Points	Interim Target: 35% B_0 (HSS default) Soft Limit: 20% B_0 (HSS default) Hard Limit: 10% B_0 (HSS default) Overfishing threshold: $F_{SB40\%}$ (HSS default)
Status in relation to Target	$B_{2020-21}$ was estimated to be 111% B_0. Virtually certain ($> 99\%$) to be at or above the target
Status in relation to Limits	Soft limit: Exceptionally Unlikely ($< 1\%$) to be below Hard Limit: Exceptionally Unlikely ($< 1\%$) to be below
Status in relation to Overfishing	$F_{2020-21}$ was estimated to be 44% $F_{SB40\%}$. Overfishing is Very Unlikely ($< 10\%$) to be occurring

Historical Abundance and Catch Trajectories
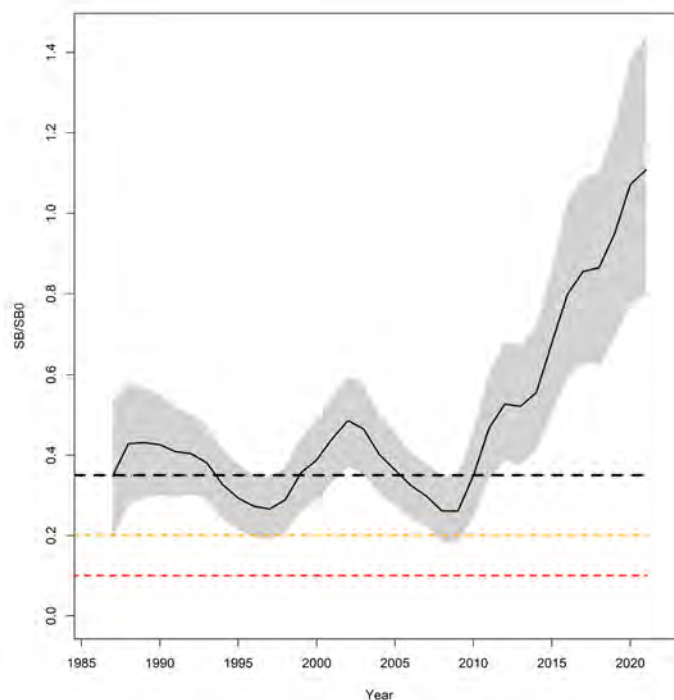
Annual trend in spawning biomass relative to the 35% SB_0 interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% credible interval. The dashed line represents the interim target level. The red and orange dashed lines represent the hard and soft biomass limits, respectively. |
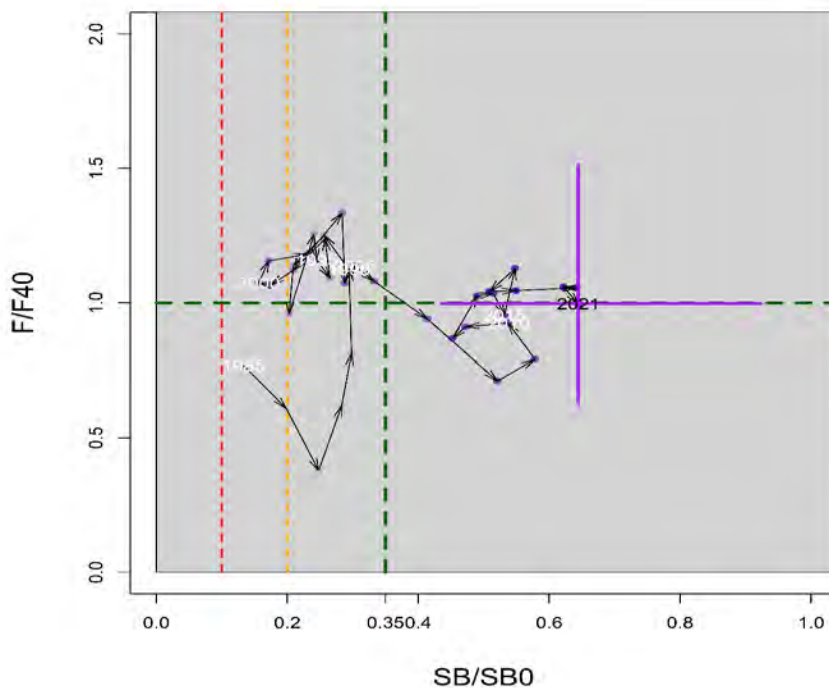
Fishing Intensity Trajectories
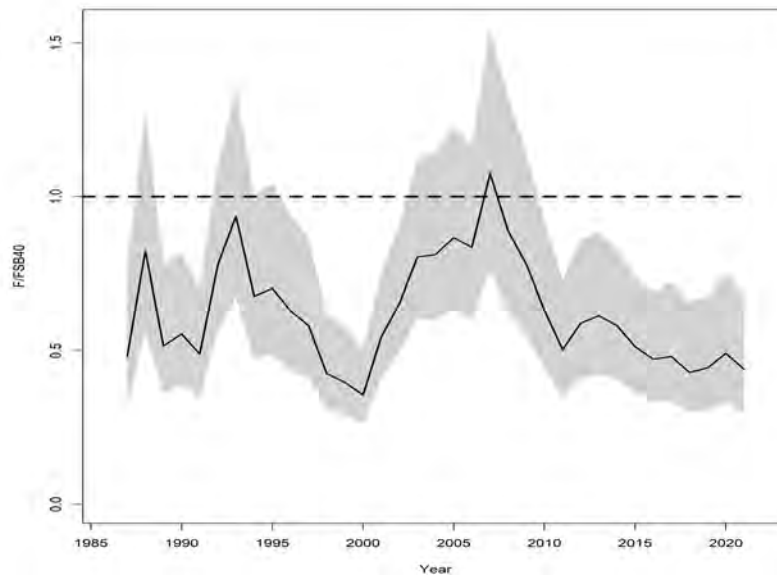
Annual fishing mortality compared to the $F_{SB40\%}$ interim threshold fishing mortality level (dashed line) for the interim base case model (median values from MCMCs). Grey shaded area represents 95% credible intervals.

Combined trajectories
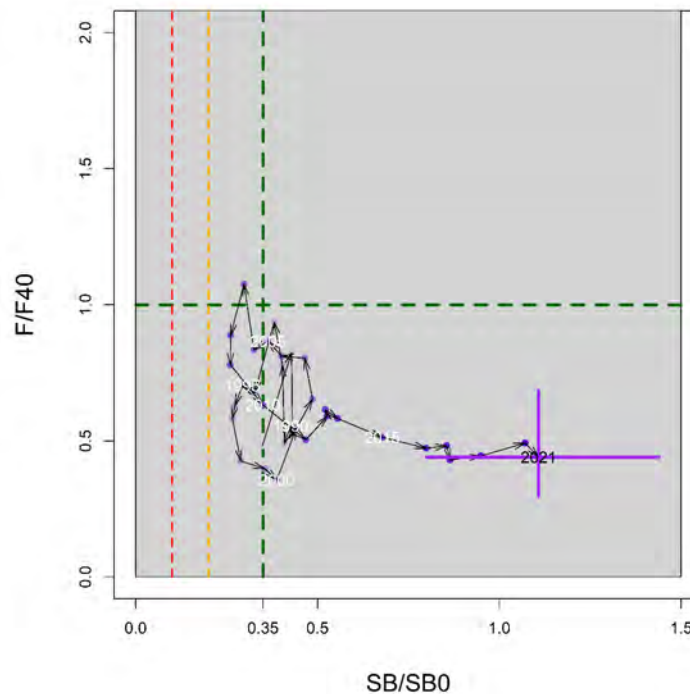
Annual spawning biomass and fishing mortality compared to the $SB_{35\%}$ interim target biomass level and corresponding fishing mortality threshold for the base case model (median values from MCMCs). The green dashed lines represent the biomass target and fishing mortality threshold levels. The red and orange dashed lines represent the hard and soft biomass limits, respectively. The 95% credible intervals are shown for the final year.

Fishery and Stock Trends	
Recent trend in Biomass or Proxy	Spawning biomass was estimated to have increased from 2010 following above average recruitment since the late 2000s, which has continued to be high over the last 5 years.
Recent trend in Fishing Intensity or Proxy	Fishing mortality has been well below the threshold level since 2010.

RED GURNARD (GUR)

Other Abundance Indices	The BT FLA and BT mixed CPUE indices increased from 2009–10 to 2015–16. The CPUE indices were not updated for the 2022 assessment.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Abundance is Very Likely (> 90%) to remain above the target biomass level over the next five years at the current catch or TACC.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured Bayesian stock assessment implemented with Stock Synthesis software and uncertainty estimated by MCMC	
Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs	- Commercial catch (from 1987 onwards) - Survey biomass indices - Survey age/length frequencies - Estimates of biological parameters (e.g., growth, natural mortality, age-at-maturity, and length/ weight)	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	- CPUE indices (to 2015– 16)	2 – Medium or Mixed quality: doesn't appear to be indexing abundance throughout the series
Changes to Model Structure and Assumptions	- First implementation of a full quantitative assessment; the previous partial quantitative assessment was based on WCSI trawl survey biomass indices relative to reference period	
Major Sources of Uncertainty	- Lack of recent age composition data from the trawl survey and age or length composition data from the fishery	

Qualifying Comments
- Reference points (SB_0 based) are derived from the average level of recruitment during 1987–2020. There was an apparent shift in the productivity of GUR 7 in the late 2000s. The increasing catches since 2012 were sustained by the higher level of recruitment. - Stock assessment and yield estimates apply only to the reported catch from the commercial fishery.

Fishery Interactions
Red gurnard are primarily taken in conjunction with the following QMS species: flatfish, barracouta, stargazer, red cod, tarakihi, and other species in the west coast South Island target bottom trawl fishery.

6.   FOR FURTHER INFORMATION

Beentjes, M P; MacGibbon, D; Lyon, W S (2015) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2014 (KAH1402). *New Zealand Fisheries Assessment Report 2015/14.*

Beentjes, M P; MacGibbon, D J; Ladroit, Y (in prep) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2021 (KAH2104). Draft New Zealand Fisheries Assessment Report.

Beentjes, M P; MacGibbon, D J; Parkinson, D (2016) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2016 (KAH1605). *New Zealand Fisheries Assessment Report 2016/61.* 135 p.

Blackwell, R (1988) Red gurnard. New Zealand Fisheries Assessment Research Document 1988/23: 18 p. (Unpublished report held by NIWA library, Wellington.)

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 national marine recreational fishing survey: diary results and harvest estimates. (Unpublished New Zealand Fisheries Assessment Research Report for the Ministry of Fisheries Project REC2000-01 held by Fisheries New Zealand, Wellington.) 92 p.

Boyd, R O; Reilly, J L (2004) 1999/2000 National Marine Recreational Fishing Survey: harvest estimates. (Unpublished New Zealand Fisheries Assessment Research Report for the Ministry of Fisheries Project REC9803 held by Fisheries New Zealand, Wellington.) 28 p.

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished report held by NIWA library, Wellington.)

Challenger Finfisheries Management Company (2003) Report to the Adaptive Management Programme Fishery Assessment Working Group. GUR 7 Adaptive Management Proposal for the 2004–05 fishing year. (Unpublished report held by Fisheries New Zealand, Wellington.)

Cordue, P L (1998) Designing optimal estimators for fish stock assessment. *Canadian Journal of Fisheries and Aquatic Sciences 55*: 376–386.

Davey, N; Hartill, B; Carter, M (2019) Mean weight estimates for recreational fisheries in 2017–18. *New Zealand Fisheries Assessment Report 2019/25.* 32 p.

Elder, R D (1976) Studies on age and growth, reproduction and population dynamics of red gurnard, *Chelidonichthys kumu* (Lesson and Garnot), in the Hauraki Gulf, New Zealand. *Fisheries Research Bulletin No: 12.* 62 p.

Francis, R I C C (1992) Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 26 p. (Unpublished report held by NIWA library, Wellington.)

Francis, R I C C; Hurst, R J; Renwick, J A (2001) An evaluation of catchability assumptions in New Zealand stock assessments. *New Zealand Fisheries Assessment Report 2001/1.* 37 p.

Francis, M P; Paul, L J (2013) New Zealand inshore finfish and shellfish commercial landings, 1931–82. *New Zealand Fisheries Assessment Report 2013/55.* 136 p.

Hartill, B; Bian, R; Armiger, H; Vaughan, M; Rush, N (2007) Recreational marine harvest estimates of snapper, kahawai, and kingfish in QMA 1 in 2004–05. *New Zealand Fisheries Assessment Report 2007/26.* 44 p.

Hartill, B; Bian, R; Davies, N M (Drafta) Review of methods used to estimate recreational harvests. Draft New Zealand Fisheries Assessment Report. (Unpublished report for Project code: REC2004-06 held by Fisheries New Zealand, Wellington.)

Hartill, B; Bian, R; Rush, N; Armiger, H (2013) Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2011–12. *New Zealand Fisheries Assessment Report 2013/70.* 44 p.

Hartill, B; Davey, N (2015) Mean weight estimates for recreational fisheries in 2011–12. *New Zealand Fisheries Assessment Report 2015/25.* 37 p.

Kendrick, T H (2009a) Fishery characterisation and catch-per-unit-effort indices for three sub-stocks of red gurnard in GUR 1; 1989–90 to 2004–05. *New Zealand Fisheries Assessment Report 2009/10.*

Kendrick, T H (2009b) Updated Catch-per-Unit effort indices for red gurnard in GUR 2; 1989–90 to 2004–05 *New Zealand Fisheries Assessment Report 2009/11.*

Kendrick, T H; Bentley, N (2011) Fishery characterisations and catch-per-unit-effort indices for three sub-stocks of red gurnard in GUR 1, 1989–90 to 2008–09. *New Zealand Fisheries Assessment Report 2011/4.*

Kendrick, T H; Bentley, N (in prep a) Updated CPUE Analyses for three substocks of red gurnard in GUR 1. (Working Group paper held by Fisheries New Zealand.)

Kendrick, T H; Bentley, N (in prep b) Fishery characterisation and standardised CPUE for FLA 2, GUR 2 and SNA 2. (Working Group paper held by Fisheries New Zealand.)

Kendrick, T H; Bentley, N; Langley, A (2011) Report to the Challenger Fishfish Company: CPUE analyses for FMA 7 Fishstocks of gurnard, tarakihi, blue warehou, and ghost shark. (Unpublished client report held by Trophia Limited, Kaikōura.)

Kendrick, T H; Walker, N (2004) Characterisation of the GUR 2 red gurnard (*Chelidonichthys kumu)* and associated inshore trawl fisheries, 1989–90 to 2000–01. *New Zealand Fisheries Assessment Report 2004/21.* 83 p.

Langley, A (2011) Characterisation of the Inshore Finfish fisheries of Challenger and South East coast regions (FMAs 3, 5, 7 & 8). (Unpublished client report available from http://www.seafoodindustry.co.nz/SIFisheries.)

Langley, A D (2014) Updated CPUE analyses for selected South Island inshore finfish stocks. *New Zealand Fisheries Assessment Report 2014/40.* 116 p.

Langley, A D (2015) Fishery characterisation and Catch-Per-Unit-Effort indices for John dory in JDO 1. *New Zealand Fisheries Assessment Report 2015/47.* 76 p.

Langley, A D (in prep) Fishery characterisation and standardised CPUE for red gurnard in GUR 3 to 2020–21. Draft New Zealand Fisheries Assessment Report.

Langley, A D (in prep) Fishery characterisation and standardised CPUE for red gurnard in GUR 7 to 2020–21. Draft New Zealand Fisheries Assessment Report.

Lydon, G J; Middleton, D A J; Starr, P J (2006) Performance of the GUR 3 Logbook Programme. AMP-WG-06/22. (Unpublished manuscript available from the New Zealand Seafood Industry Council, Wellington.)

Lyon, W S; Horn, P L (2011) Length and age of red gurnard (*Chelidonichthys kumu*) from trawl surveys off west coast South Island in 2003, 2005, and 2007, with comparisons to earlier surveys in the time series. *New Zealand Fisheries Assessment Report 2011/46.*

MacGibbon, D J (2019) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2019 (KAH1902) *New Zealand Fisheries Assessment Report 2019/64.* 87 p.

MacGibbon, D J; Beentjes, M P; Lyon, W; Ladroit, Y (2019) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2018 (KAH1803). *New Zealand Fisheries Assessment Report 2019/03.* 136 p.

MacGibbon, D J; Stevenson, M L (2013) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2013 (KAH1305). *New Zealand Fisheries Assessment Report 2013/66.* 115 p.

MacGibbon, D J; Walsh, C; Buckthought, D; Bian, R (2022) Inshore trawl survey off the west coast South Island and in Tasman Bay and Golden Bay, March–April 2021 (KAH2103). *New Zealand Fisheries Assessment Report 2022/11.* 9 p.

RED GURNARD (GUR)

McKenzie, A (in prep) Fishery characterisation and standardised CPUE for three sub-stocks of red gurnard in GUR 1 to 2020–21. Draft New Zealand Fisheries Assessment Report.

Methot, R D; Wetzel, C R (2013) Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research 142 (2013)*: 86–99.

Morrison, M A; Francis, M P; Parkinson, D M (2002) Trawl survey of the Hauraki Gulf, 2000 (KAH0012). *New Zealand Fisheries Assessment Report 2002/46.* 48 p.

Parker, S; Fu, D (2012) Length and age structure of commercial landings of red gurnard (*Chelidonichthys kumu*) in GUR 2 in 2009–10. *New Zealand Fisheries Assessment Report 2012/35.* 36 p.

Schofield, M I; Langley, A D; Middleton, D A J (2018a) Fisheries characterisation and catch-per unit-effort analyses GUR 2. *New Zealand Fisheries Assessment Report 2018/10.* 53 p.

Schofield, M I; Langley, A D; Middleton, D A J (2018b) Catch-per unit-effort (CPUE) update for FMA 2 gurnard (GUR 2). (Report for Fisheries Inshore New Zealand.) https://www.inshore.co.nz/fileadmin/Documents/Science/GUR2_rapidCPUEupdate_2018.pdf

Schofield, M I; Langley, A D; Middleton, D A J (2018c) Catch-per unit-effort (CPUE) update for FMA 3 gurnard (GUR 3). Report for Southern Inshore Fisheries Management Company.

Starr, P J; Kendrick, T H (2013) GUR 3 Fishery Characterisation and CPUE. *New Zealand Fisheries Assessment Report 2013/37.* 71 p.

Starr, P J; Kendrick, T H (2017) GUR 7 Fishery Characterisation and CPUE Report. *New Zealand Fisheries Assessment Report 2017/49.* 144 p.

Starr, P J; Kendrick, T H; Lydon, G J; Bentley, N (2007) Report to the Adaptive Management Fishery Assessment Working Group: Full term review of the GUR 3 Adaptive Management Programme. AMP-WG-07/11v2. (Unpublished manuscript available from the New Zealand Seafood Industry Council, Wellington.)

Stevenson, M L (2000) Assessment of red gurnard (*Chelidonichthys kumu*) stocks GUR 1 and GUR 2. *New Zealand Fisheries Assessment Report 2000/40.* 51 p.

Stevenson, M L (2004) Trawl survey of the west coast of the South Island and Tasman and Golden Bays, March–April 2003 (KAH0304). *New Zealand Fisheries Assessment Report 2004/4.*

Stevenson, M L (2006) Trawl survey of the west coast of the South Island and Tasman and Golden Bays, March–April 2005 (KAH0503). *New Zealand Fisheries Assessment Report 2006/4.*

Stevenson, M L (2007) Inshore trawl survey of the west coast of the South Island and Tasman and Golden Bays, March–April 2007 KAH0704. *New Zealand Fisheries Assessment Report 2007/41.*

Stevenson, M L (2009) Inshore trawl survey of the west coast of the South Island and Tasman and Golden Bays, March–April 2009. *New Zealand Fisheries Assessment Report 2010/11.*

Stevenson, M L (2012) Inshore trawl survey of the west coast of the South Island and Tasman and Golden Bays, March–April 2011. *New Zealand Fisheries Assessment Report 2012/50.* 77 p.

Stevenson, M L; MacGibbon, D J (2015). Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2015 (KAH1503). *New Zealand Fisheries Assessment Report 2015/67.* 94 p.

Sutton, C P (1997) Growth parameters, and estimates of mortality for red gurnard (*Chelidonichthys kumu*) from off the east and west coasts of the South Island, New Zealand. New Zealand Fisheries Assessment Research Document 1997/1. 15 p. (Unpublished report held by NIWA library, Wellington.)

Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991–92 to 1993–94 New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished report held by NIWA library, Wellington.)

Vignaux, M (1994) Catch per unit effort (CPUE) analysis of west coast South Island and Cook Strait spawning hoki fisheries, 1987–93. N.Z. Fisheries Assessment Research Document 94/11. 29 p. (Unpublished report held in NIWA library, Wellington, New Zealand.)

Vignaux, M (1997) CPUE analyses for fishstocks in the adaptive management programme. New Zealand Fisheries Assessment Research Document 1997/24. 68 p. (Unpublished report held by NIWA library, Wellington.)

Wright, P; McClary, D; Boyd, R O (2004) 2000/2001 National Marine Recreational Fishing Survey: direct questioning of fishers compared with reported diary data. (Final Research Report for Ministry of Fisheries Project REC2000–01: Objective 2 held by Fisheries New Zealand.)

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24.* 104 p.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67.* 139 p.

RED SNAPPER (RSN)

(Centroberyx affinis)
Kaorea
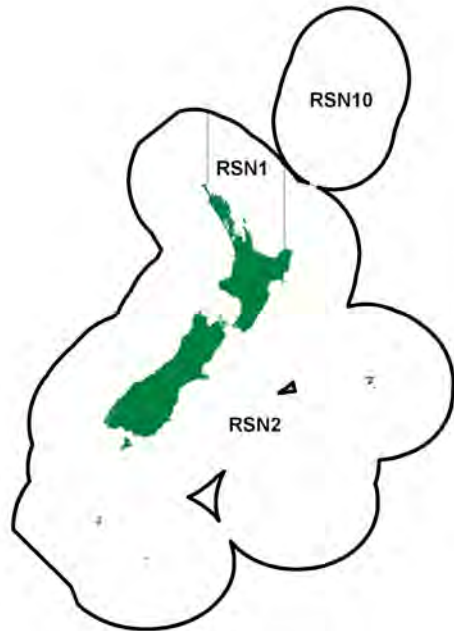
1. FISHERY SUMMARY

Red snapper was introduced into the Quota Management System on 1 October 2004 with the TACs, TACCs and allowances as shown in Table 1.

Table 1: Recreational and customary non-commercial allowances, TACCs and TACs of red snapper as at 1 October 2021.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other sources of mortality	TACC	TAC
RSN 1	13	2	1	64	80
RSN 2	2	1	1	81	85
RSN 10	1	1	1	1	4

1.1 Commercial fisheries

Small commercial catches of red snapper in New Zealand have almost certainly been made for decades, but would have been included among "assorted minor species" in reported landings. Historical estimated and recent reported red snapper landings and TACCs are shown in Tables 2, 3 and 4, while Figure 1 shows the historical and recent landings and TACC values for the main red snapper stocks.

Reported total annual landings increased to a peak of 212 t in 1996–97, and declined to an average of 50 t since the fishing year 2003–04. From 1989–90 to 2012–13 an average of 80% of total landings originated from RSN 1. Since 2013–14 landings in RSN 2 have increased, exceeding the TACCs in 2013–14, 2014–15, 2016–17, and 2017–18; in 2017–18 and 2018–19 similar amounts of landings were recorded in RSN 1 and RSN 2, and in 2019–20, landings in RSN 1 remained at the=is level while landings in RSN 2 increased to 38 t. RSN 10 landings have always been negligible, with no landing recorded at all since the late 1990s.

Red snapper is mostly taken as a bycatch of 1) the longline fishery for snapper off east Northland, 2) the trawl fisheries for tarakihi off east and west Northland, and 3) the setnet fishery for snapper and trevally in the Bay of Plenty.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	RSN 1	RSN 2	Year	RSN 1	RSN 2
1931–32	0	0	1957	0	0
1932–33	0	0	1958	0	0
1933–34	0	0	1959	0	0
1934–35	0	0	1960	0	0
1935–36	0	0	1961	0	0
1936–37	0	0	1962	0	0
1937–38	0	0	1963	0	0
1938–39	0	0	1964	0	0
1939–40	0	0	1965	0	0
1940–41	0	0	1966	0	0
1941–42	0	0	1967	0	0
1942–43	0	0	1968	0	0
1943–44	0	0	1969	0	0
1944	0	0	1970	0	0
1945	0	0	1971	0	0
1946	0	0	1972	0	0
1947	0	0	1973	0	0
1948	0	1	1974	0	1
1949	0	1	1975	0	0
1950	0	13	1976	0	4
1951	0	47	1977	0	7
1952	0	57	1978	0	4
1953	0	35	1979	0	1
1954	0	23	1980	0	9
1955	0	18	1981	0	3
1956	0	18	1982	0	3

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings.

Table 3: Reported landings (t) by commercial fishers of red snapper by FMA from 1989–90 to 2003–04. Data are derived from the landing section of CELRs and CLRs.

	FMA 1	FMA 2	FMA 3	FMA 4	FMA 7	FMA 8	FMA 9	FMA 10	Unknown	Total
1989–90	67.9	3	3.1	0	1.8	0.9	0	0	0.0	76.7
1990–91	107.3	1.2	2.8	0	0.6	0.7	0	0	0.0	112.7
1991–92	89.1	0.7	1.1	0	0	1.6	0	0.6	0.0	93.2
1992–93	98.2	2.1	0.4	0	0	0.6	0	0	0.3	101.6
1993–94	78.2	2.6	0.3	0.1	0.4	0.4	0.2	0	0.0	82.4
1994–95	78.2	1.8	0.3	0	0.2	0.6	0.5	0	1.0	82.6
1995–96	126.7	2.1	0.8	0.2	1.2	0.2	1	0	1.3	133.4
1996–97	186.4	17.4	0.9	0	1	0.3	2.9	0.2	2.8	211.8
1997–98	159.1	3.4	0.3	0	0.2	0.7	3.6	0	0.8	168.2
1998–99	134.4	1.5	0.4	0.1	0.3	1	4.7	0	0.4	142.8
1999–00	108.1	1.3	0.8	0	0.1	21.3	25.4	0	0.7	157.7
2000–01	140.0	1.1	2.3	0.8	0	0.8	51.5	0	0.0	196.5
2001–02	109.7	1.5	2.2	0.1	0	0.4	12.3	0	0.6	126.7
2002–03	117.5	2.2	0.3	0	0	0.6	37.5	0	14.2	172.5
2003–04	40.9	1.8	0.2	0	0.3	1.3	6.7	0	0	51.3

1.2 Recreational fisheries

None of the telephone-diary surveys of recreational fishers in 1994, 1996, and 2000 nor the National Panel Survey conducted over the 2011–12 fishing and 2017–18 years (Wynne-Jones et al 2014, 2019) provided estimates of the recreational catch of red snapper. However, recreational fishers periodically catch this species while line fishing on deep reefs in Northland, the outer Hauraki Gulf, and Bay of Plenty.

1.3 Customary Fisheries

There is no quantitative information available to allow the estimation of the amount of red snapper taken by customary non-commercial fishers.

Table 4: Reported domestic landings (t) of red snapper Fishstock and TACCs from 2004–05 to present.

	RSN 1 FMA 1		RSN 2 FMA 2–9		RSN 10 FMA 10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2004–05	43	124	11	21	0	1	54	146
2005–06	41	124	8	21	0	1	49	146
2006–07	44	124	10	21	0	1	53	146
2007–08	70	124	17	21	0	1	87	146
2008–09	30	124	12	21	0	1	42	146
2009–10	22	124	9	21	0	1	31	146
2010–11	27	124	8	21	0	1	35	146
2011–12	23	124	5	21	0	1	27	146
2012–13	38	124	7	21	0	1	45	146
2013–14	38	124	25	21	0	1	63	146
2014–15	33	124	25	21	0	1	58	146
2015–16	26	124	18	21	0	1	44	146
2016–17	43	124	23	21	0	1	66	146
2017–18	23	124	24	21	0	1	46	146
2018–19	22	124	16	21	0	1	38	146
2019–20	23	64	38	81	0	1	61	146
2020–21	23	64	57	81	0	1	80	146
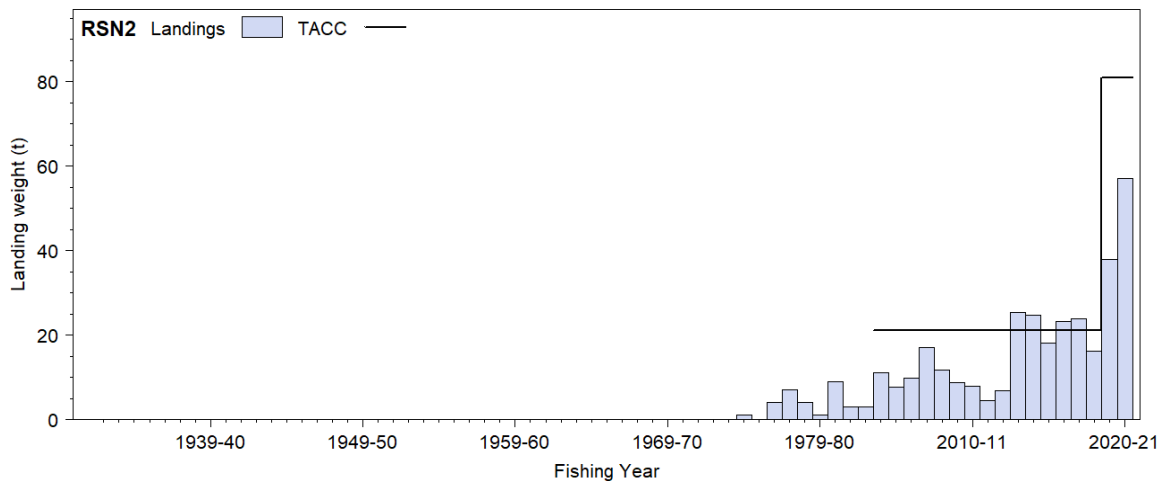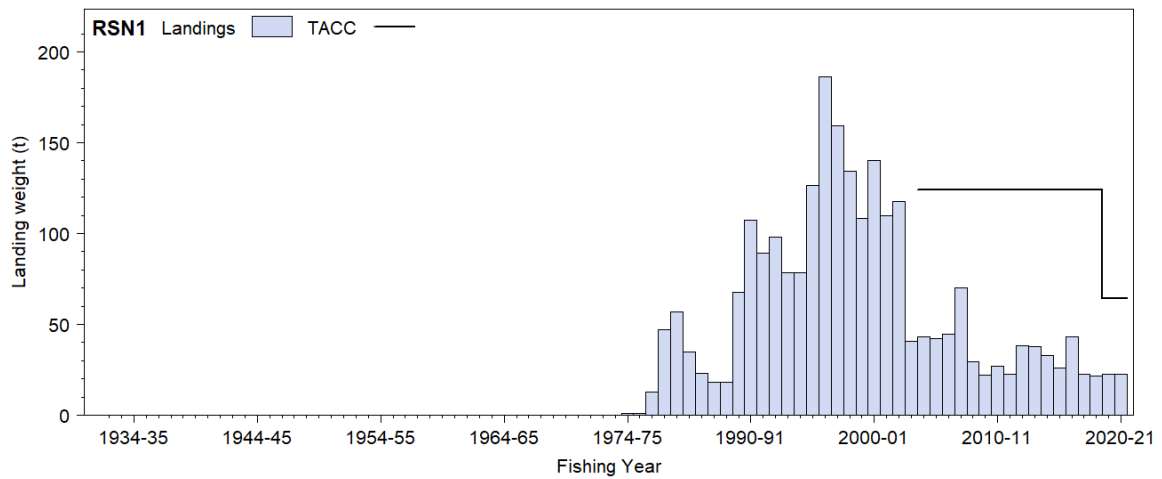
Figure 1: Reported commercial landings and TACC for the main RSN stock, RSN 1 (Auckland) and RSN 2 (Central East).

2. BIOLOGY

The red snapper (*Centroberyx affinis*) is present throughout New Zealand coastal waters, but is generally rare south of East Cape and Cape Egmont. In southeastern Australia (known as redfish) it occurs from Brisbane to Melbourne, and off northern Tasmania.

Red snapper occur in association with deep coastal reefs, in particular caves and overhangs, as well as in open water, to depths of about 400 m. Their relative abundance within this depth range is unknown. The southeastern Australian target fishery operates at depths of 100–250 m (Rowling 1994).

There have been no formal ageing studies of New Zealand red snapper, but Leachman et al (1978) reported a maximum ring count of 80, based on examination of a few broken and burned otoliths. These rings were not, however, validated. Research in Australia, based on tagging and thin otolith sections suggest unvalidated ages of at least 35 (Rowling 1994) and 40 years (Smith & Robertson 1992). Radiocarbon analysis supported an age of at least 37 years (Kalish 1995).

Red snapper attain 55 cm in New Zealand but average 30–40 cm. Nothing is known of their reproductive biology.

3. STOCKS AND AREAS

There has been no research to determine if there are separate biological stocks of red snapper.

4. STOCK ASSESSMENT

There has been no scientific stock assessment of the biomass that can support the Maximum Sustainable Yield (*MSY*) for red snapper.

5. STATUS OF THE STOCK

The reference or current biomass is not known for any red snapper stock. It is not known if the recent catch levels are sustainable. The status of RSN 1, 2 and 10 relative to B_{MSY} is unknown.

6. FOR FURTHER INFORMATION

Ayling, T; Cox, G J (1984) *Collins guide to the sea fishes of New Zealand*. Collins, Auckland. 343 p.

Francis, M (2001) *Coastal fishes of New Zealand. An identification guide*. Reed Books, Auckland. 103 p. + pls.

Kalish, J M (1995) Application of the bomb radiocarbon chronometer to the validation of redfish *Centroberyx affinis* age. *Canadian Journal of Fisheries and Aquatic Sciences* 52(7): 1399–1405.

Leachman, A; Ritchie, L; Robertson, D (1978) Should red moki be shot in New Zealand UA competitions? *New Zealand Diver* 3(2): 2.

Paul, L J (1992) Age and growth studies of New Zealand marine fishes, 1921–90: a review and bibliography. *Australian Journal of Marine and Freshwater Research* 43(5): 879–912.

Paul, L (2000) *New Zealand fishes. Identification, natural history and fisheries*. Reed Books, Auckland. 253 p.

Rowling, K R (1994) Redfish, *Centroberyx affinis. In* Tilzey, R D J (Ed), The south east fishery. A scientific review with particular reference to quota management. pp. 149–158. Bureau of Rural Resources, Australia.

Smith, D C; Robertson, S G (1992) Age determination for redfish, *Centroberyx affinis*, from samples submitted to the Central Ageing Facility: 1991/1992. Marine Science Laboratories, Queenscliff, Victoria, Australia. Internal Report 203 p.

Stewart, P (1993) Redfish, *Centroberyx affinis. In* Kailola et al (Eds.), Australian fisheries resources. pp. 232–234. Bureau of Resource Sciences, Canberra. 422 p.

Thompson, S (1981) *Fish of the Marine Reserve. A guide to the identification and biology of common coastal fish of north-eastern New Zealand*. Leigh Laboratory, University of Auckland. 364 p.

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. Draft New Zealand Fisheries Assessment Report held by Fisheries New Zealand.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*.

Yearsley, G K; Last, P R; Ward, R D (Eds.) (1999) *Australian seafood handbook: identification guide to domestic species*. CSIRO Marine Research, Australia. 461 p.

RIBALDO (RIB)

(*Mora moro*)
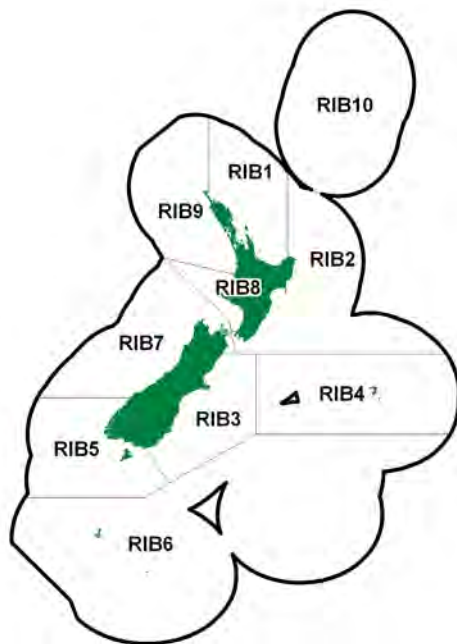
1.   FISHERY SUMMARY

1.1   Commercial fisheries

In New Zealand ribaldo is caught mainly on bottom longlines and as a bycatch of trawling. About 4 500 t catch was reported in 1977 by Japanese and Korean longline vessels target fishing for ling on the Chatham Rise and east coast of the South Island in the 1970s. Since 1982–83, overall reported catch has been mainly from the Chatham Rise, east coast South Island, and the Challenger Plateau (QMAs 3, 4 and 7). RIB 3 landings have fluctuated since entering the QMS, and have remained between 100 t and 220 t since the early 2000s, except in 2010–11 and 2018–19 when they were around 350 t. RIB 4 landings peaked at just under 850 t in 1996-97, and have fluctuated between 137 t and 492 t since. RIB 7 landings increased from 1994–95 until reaching a maximum at 456 t in 2008–09. Landings subsequently fluctuated between 434 t in 2014–15, and 151 t in 2018–2019. The reasons for these changes in catch levels are not well understood as ribaldo is mainly taken as bycatch. Levels of discarding and unreported catch are likely to have changed with the introduction of ribaldo into the QMS. Ribaldo are caught throughout the New Zealand Exclusive Economic Zone by a variety of fishing methods in different target fisheries but mainly as bycatch in bottom trawls targeting hoki (*Macruronus novaezelandiae*), hake (*Merluccius australis*) and ling (*Genypterus blacodes*) and bottom longlines for ling.

There is no seasonality of catch other than on the west coast South Island where catch is related to target fishing of hoki and hake during the winter spawning season. Catches by Japanese and Korean longliners in the mid 1970s are shown in Table 1. Landings from 1982–83 onwards are shown in Table 2, while Figure 1 shows the landings and TACC values for the main RIB stocks since the introduction of the QMS.

Table 1: Japanese and Korean longline catch (t) of ribaldo ("deep-sea cod[1]") from New Zealand waters, probably mostly Chatham Rise and east coast South island, by calendar year from 1975 to 1977.

Year	1975	1976	1977
Japan	2 417	4 920	4 283
Korea	-	-	286

1. Reported as "cods" but considered to be mainly ribaldo. The Korean fleet began fishing in April 1977.

Ribaldo was introduced into the QMS from 1 October 1998, no customary, recreational or other mortality allowances have been set. Historical catch limits up to the most recent fishing year are

shown in Table 2. TACCs were increased from 1 October 2006 in RIB 6 to 231 t and in RIB 7 to 330 t. In these stocks landings were above the TACC for a number of years and the TACCs were increased to the average of the previous seven years plus an additional 10%. Current levels of reported landings are below TACCs in most areas, but catches exceeded the TACCs by over a third for RIB 4 in 2013–14, and RIB 7 in 2014–15.

Table 2: Reported landings (t) of ribaldo by QMA for fishing years 1983–84 to present and TACCs (t). QMA 10 has no landings and a TACC of 0. Total includes catches from outside the NZ EEZ. [Continued next page]

	RIB 1		RIB 2		RIB 3		RIB 4		RIB 5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1982–83	0		8		15		33		111	
1983–84	0		3		24		21		68	
1984–85	0		4		17		61		21	
1985–86	1		1		26		13		35	
1986–87	4		1		44		20		41	
1987–88	19		4		65		31		56	
1988–89	1		2		33		41		6	
1989–90	8		9		23		28		6	
1990–91	15		15		177		119		34	
1991–92	95		40		160		169		73	
1992–93	131		54		217		228		67	
1993–94	87		70		217		186		23	
1994–95	116		136		437		303		68	
1995–96	121		168		286		253		26	
1996–97	114		188		365		843		64	
1997–98	78		122		141		375		80	
1998–99	24	121	55	176	161	394	290	357	71	52
1999–00	22	121	89	176	264	394	347	357	80	52
2000–01	5	121	107	176	269	394	306	357	78	52
2001–02	7	121	53	176	198	394	370	357	62	52
2002–03	12	121	98	176	211	394	183	357	50	52
2003–04	12	121	120	176	175	394	299	357	50	52
2004–05	28	121	127	176	156	394	379	357	44	52
2005–06	49	121	137	176	126	394	202	357	47	52
2006–07	39	121	125	176	149	394	312	357	49	52
2007–08	53	121	135	176	134	394	173	357	43	52
2008–09	45	121	74	176	216	394	216	357	31	52
2009–10	28	121	63	176	213	394	162	357	27	52
2010–11	42	121	67	176	348	394	137	357	30	52
2011–12	29	121	27	176	174	394	304	357	32	52
2012–13	16	121	74	176	182	394	234	357	35	52
2013–14	29	121	80	176	104	394	492	357	41	52
2014–15	35	121	154	176	122	394	341	357	47	52
2015–16	49	121	125	176	163	394	330	357	43	52
2016–17	43	121	160	176	139	394	212	357	46	52
2017–18	36	121	155	176	182	394	182	357	36	52
2018–19	40	121	118	176	358	394	199	357	36	52
2019–20	26	121	115	176	180	394	264	357	38	52
2020–21	30	121	64	176	182	394	205	357	51	52

	RIB 6		RIB 7		RIB 8		RIB 9		Total	
	Landing	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1982–83	0		58		0		0		225	
1983–84	1		25		0		0		142	
1984–85	13		18		0		0		134	
1985–86	2		37		0		0		115	
1986–87	10		6		0		0		126	
1987–88	12		68		0		0		255	
1988–89	6		69		1		10		169	
1989–90	13		21		0		0		108	
1990–91	106		55		0		0		521	
1991–92	98		40		0		0		675	
1992–93	96		106		0		0		899	
1993–94	92		42		1		0		718	
1994–95	122		39		2		6		1 231	
1995–96	109		62		0		0		1 025	
1996–97	158		77		1		0		1 824	
1997–98	262		110		1		1		1 214	
1998–99	223	124	243	55	1	1	0	2	1 081	1 282
1999–00	237	124	300	55	<1	1	<1	2	1 359	1 282
2000–01	191	124	275	55	<1	1	<1	2	1 242	1 282
2001–02	322	124	254	55	0	1	<1	2	1 311	1 282
2002–03	172	124	338	55	<1	1	1	2	1 209	1 282
2003–04	205	124	364	55	<1	1	2	2	1 302	1 282
2004–05	105	124	307	55	<1	1	2	2	1 240	1 282
2005–06	62	124	336	55	0	1	4	2	1 018	1 282
2006–07	61	231	404	330	0	1	9	2	1 162	1 664
2007–08	80	231	356	330	<1	1	14	2	992	1 664
2008–09	63	231	456	330	<1	1	10	2	1 111	1 664

Table 2: [Continued]

	RIB 6		RIB 7		RIB 8		RIB 9		Total	
	Landing	TACC	Landings	TACC	Landings	Landings	TACC	Landings	TACC	Landings
2009–10	104	231	137	330	< 1	1	21	2	755	1 664
2010–11	67	231	198	330	3	1	20	2	913	1 664
2011–12	76	231	177	330	3	1	12	21	835	1 683
2012–13	66	231	180	330	2	1	10	21	799	1 683
2013–14	133	231	291	330	2	1	22	21	1 194	1 683
2014–15	83	231	434	330	1	1	13	21	1 231	1 683
2015–16	67	231	322	330	< 1	1	28	21	1 127	1 683
2016–17	92	231	245	330	1	1	15	21	953	1 683
2017–18	182	231	290	330	< 1	1	14	21	1 094	1 683
2018–19	113	231	151	330	< 1	1	7	21	1 021	1 683
2019–20	110	231	182	330	< 1	1	5	21	921	1 683
2020–21	164	231	223	330	< 1	1	2	21	922	1 683
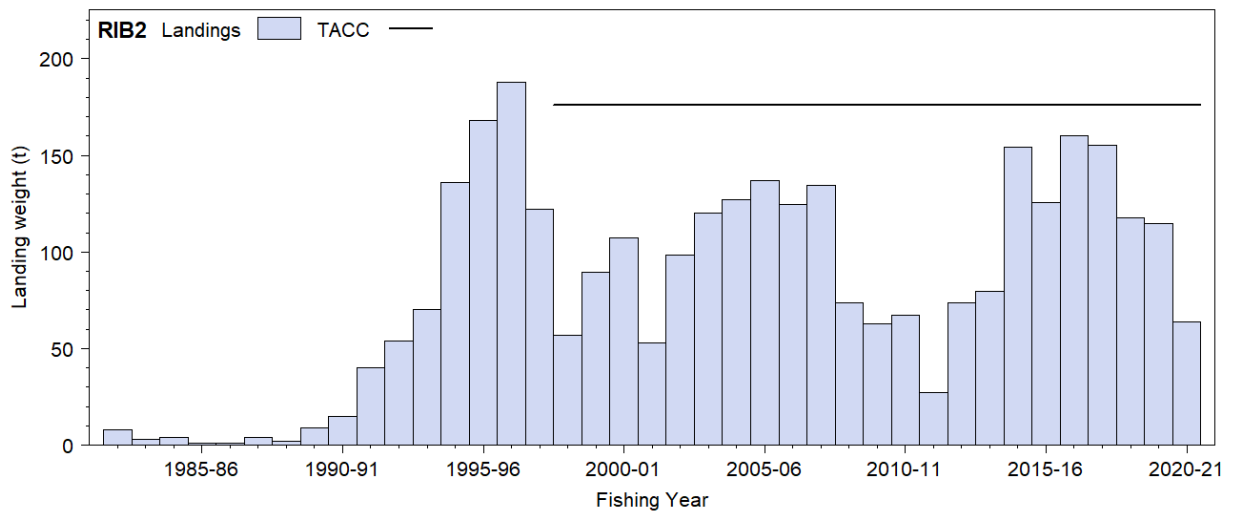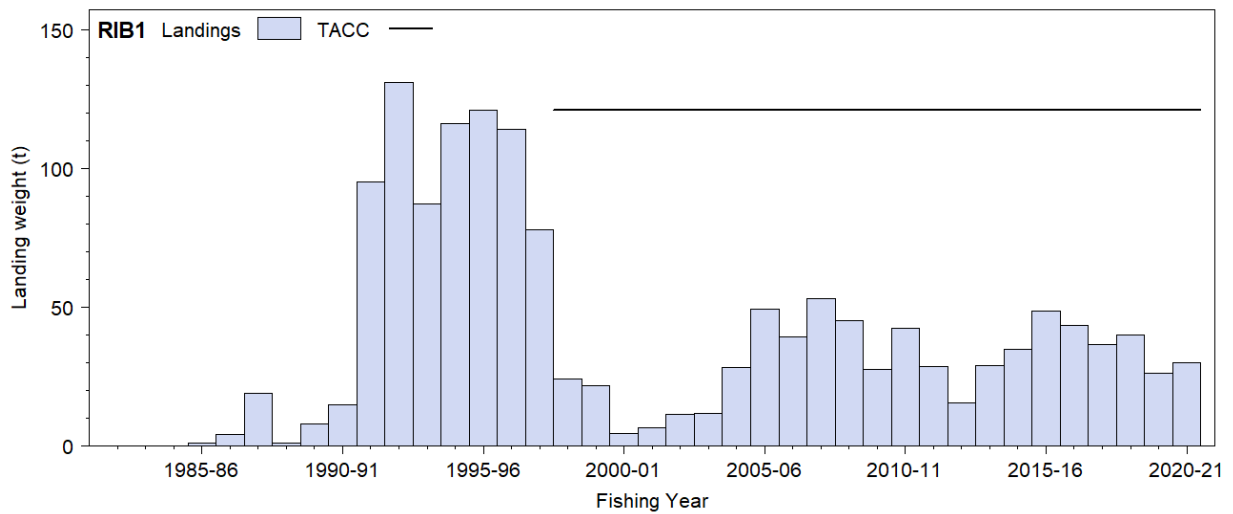
Figure 1: Reported commercial landings and TACC for the seven main RIB stocks. From top to bottom: RIB 1 (Auckland East), RIB 2 (Central East). [Continued on next page]
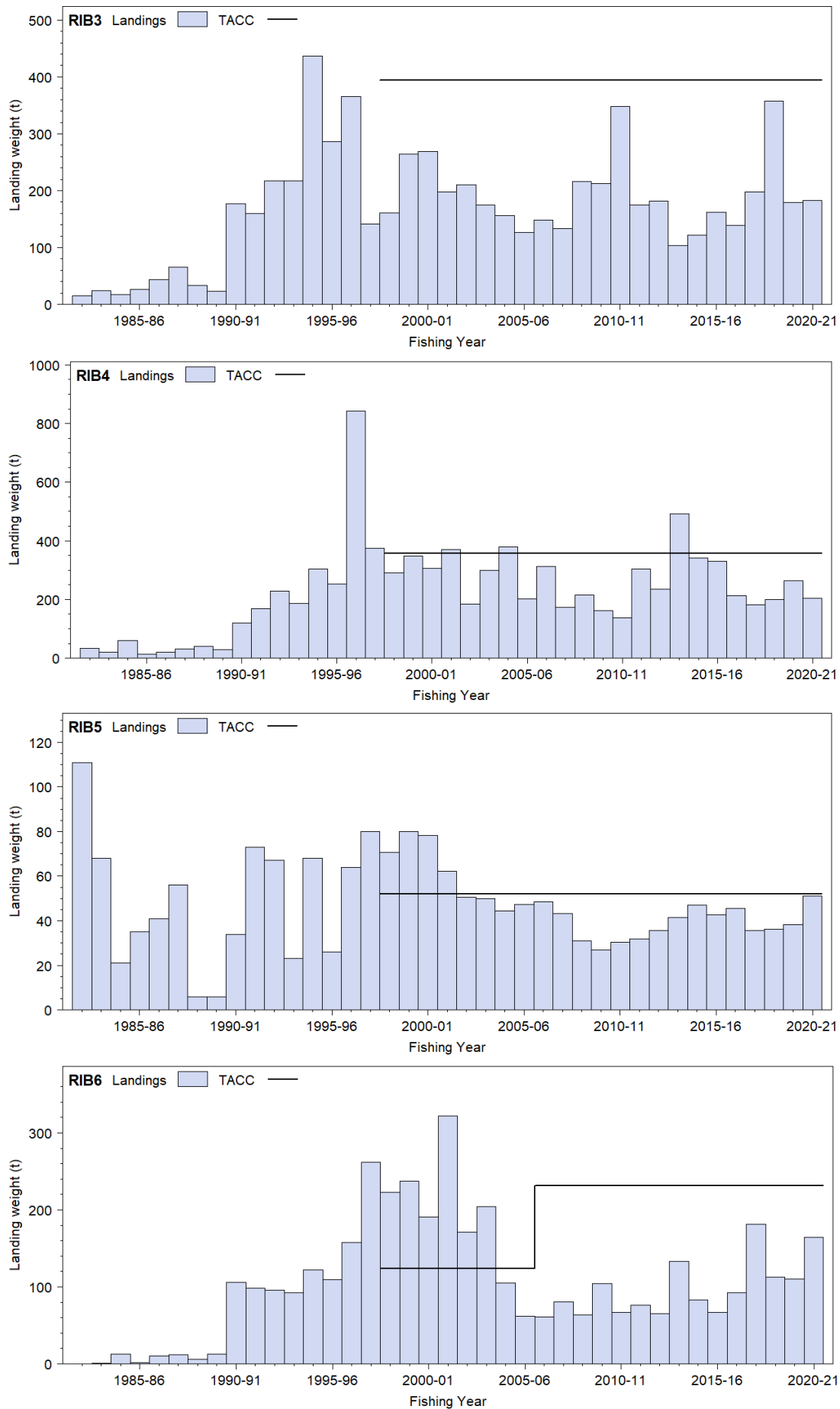
Figure 1 [Continued]: Reported commercial landings and TACC for the seven main RIB stocks. From top to bottom: RIB 3 (South East Coast), RIB 4 (South East Chatham Rise), RIB 5 (Southland), RIB 6 (Sub-Antarctic). [Continued on next page]
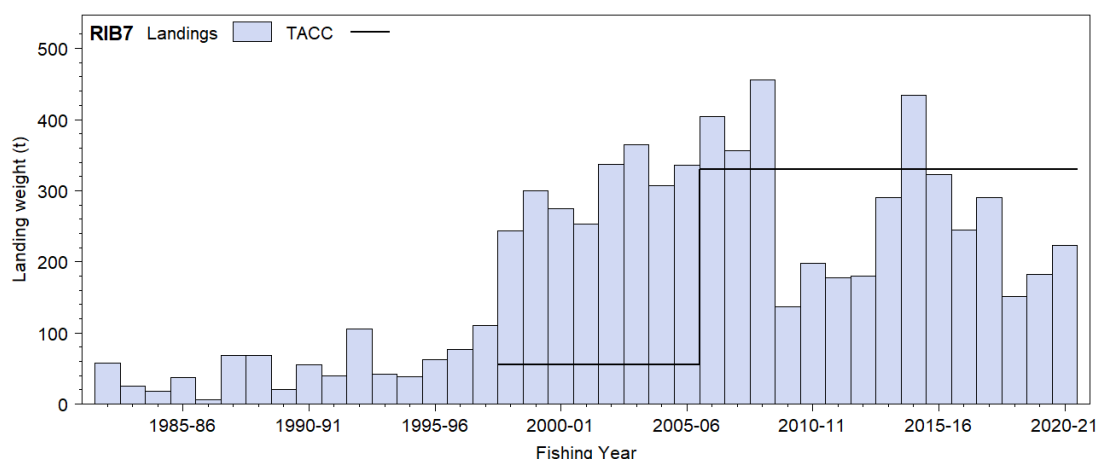
Figure 1 [Continued]: Reported commercial landings and TACC for the seven main RIB stocks. RIB 7 (Challenger).

In RIB 1, ribaldo are taken as bycatch primarily in the ling and to a lesser extent bluenose bottom longline fisheries. There is also some direct targeting of ribaldo by bottom longline. In RIB 2, ribaldo are taken as bycatch primarily in the ling and bluenose bottom longline fisheries and to a lesser extent the hoki and orange roughy bottom trawl fisheries. There is also some direct targeting of ribaldo by bottom longline. In RIB 9 very small amounts of ribaldo are taken as bycatch in orange roughy, cardinal and alfonsino target trawl fisheries and in the ling bottom longline fishery. In all areas, a variety of other fishing methods and target fisheries also report catching ribaldo but only in negligible amounts. Fisheries interactions are described in Section 5.

1.2 Recreational fisheries
Recreational catches are likely to be negligible given the depth and location of ribaldo.

1.3 Customary non-commercial fisheries
Customary catches are likely to be negligible given the depth and location of ribaldo.

1.4 Illegal catch
Estimates of illegal catch are not available. Given the low value of ribaldo illegal catch is likely to be negligible.

1.5 Other sources of mortality
There is no quantitative information on the level of other sources of mortality.

2. BIOLOGY

Ribaldo is known from the North Atlantic Ocean from Iceland to West Africa, the western Mediterranean Sea, the Indian Ocean south of Madagascar and the Pacific Ocean from Australia, New Zealand and Chile. In New Zealand it is widespread and has been caught by research trawl at depths from 200 to 1300 m. It appears to be most common at 500–1000 m. The relatively high catch by bottom longline suggests that it favours rough bottom habitats.

Ribaldo reach maximum fork lengths (FL) of about 75 cm and 65 cm for females and males respectively. Most research trawls have caught fish ranging from 30 to 70 cm FL. The 50% length at sexual maturity has been estimated at 45 cm total length for New Zealand ribaldo (O'Driscoll et al 2003). Analysis of data on female gonad development, collected by the Ministry of Fisheries Observer Programme, indicated a winter/early spring spawning season. Fish do not appear to form large spawning aggregations. Locations at which spawning fish have been observed are the upper North Island (extending outside the EEZ), north-east and west Chatham Rise, the area between the Snares and Auckland Islands shelves, and the west coast of the South Island. Early life history is largely unknown but a few individuals less than 10 cm FL were captured in plankton nets in the upper 200 m of the water column over bottom depths of about 1000 m at the south west end of Chatham Rise. The distribution of juveniles under 28 cm is similar to that of observed spawning females.

Juveniles up to 35 cm have been observed in all fished areas of the EEZ except for the Bounty Islands.

Ageing by zone counts of otoliths has been validated using radiometric techniques (Sutton et al 2010) using ribaldo caught on Chatham Rise trawl surveys by *Tangaroa* from 2001 to 2005. Maximum observed ages were 37 and 39 years for females and males respectively. Von Bertalanffy growth parameters are presented in Table 3, estimates of natural mortality (*M*) are presented in Table 4 and length-weight parameters in Table 5.

Ribaldo are caught in low numbers both in research trawl surveys and in observed commercial fisheries making tracking of cohorts by length frequencies difficult. Analyses of trawl survey and observer data has shown that the biomass of females is usually greater than that of males on the Chatham Rise although sex ratios by number are about 1:1. In the Sub-Antarctic and west coast South Island the biomass and numbers of females are significantly greater than males, often over 10:1. Sex ratios elsewhere in the EEZ are less clear.

Table 3: Von Bertalanffy growth parameter values for ribaldo. Source: Sutton et al 2010.

Von Bertalanffy growth parameters	K	t_0	L_∞
RIB 3 & 4 females	0.135	0.221	67.526
RIB 3 & 4 males	0.072	-5.246	61.444
RIB 3 & 4 combined sexes	0.14	-0.287	60.47

Table 4: Estimates of natural mortality (*M*). Source: Sutton et al 2010.

	Females	Males
Natural mortality (*M*)	0.106	0.112

Table 5: Length-weight parameter values for ribaldo.

Fishstock Weight = a(length)^b (Weight in g, length in cm total length)	Females		Males		Source
	a	b	a	b	
RIB 3 & 4	0.0037	3.27	0.0053	3.18	Sutton et al (2010)
RIB 5 & 6	-	-	-		
			Sexes combined		
			a	b	
RIB 3 & 4			0.004289	3.237753	Sutton et al (2010)
RIB 5 & 6			0.0039	3.15	Bagley et al (unpublished data)

3. STOCKS AND AREAS

It is not known whether different regional stocks of ribaldo occur in New Zealand waters but it is possible that there are separate stocks based on natural bathymetric boundaries. The Working Group had previously agreed on five fishstocks based on the four main fishing areas plus the Kermadec area, i.e., the east coast of the North Island (QMAs 1 and 2), Chatham Rise and east coast South Island (QMAs 3 and 4), Southland and Sub-Antarctic (QMAs 5 and 6), the west coast of New Zealand (QMAs 7, 8 and 9) and QMA 10. Reviews of all available information in 2010 and 2014 indicated that the main fishing areas are still as found previously. The reviews also indicated spawning activity in all areas, except RIB 8 and RIB 10 (for which there is no information). This is not inconsistent with the management of the fishery by the current 10 FMAs. Highly skewed sex ratios in the Sub-Antarctic and west coast South Island have unknown implications for stock structure.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

The Middle Depths Working Group agreed in February 2011 that relative biomass estimates of ribaldo from middle depth trawl surveys on the Chatham Rise and the Sub-Antarctic were suitable for monitoring major changes in ribaldo abundance for RIB 3 & 4 and RIB 5 & 6 respectively. The west

coast South Island trawl survey on *Tangaroa* may provide an index of abundance but with just three years of data points (2000, 2012, 2013) there was insufficient data with which to draw any conclusions. It is not certain that standardised CPUE indices from the hoki bottom trawl fisheries in RIB 3 & 4, and in RIB 5 & 6 track abundance. Standardised CPUE indices for these two areas are flat and indices from the corresponding trawl surveys are also flat, making it difficult to validate CPUE. CPUE indices from the spawning hoki and hake target fisheries in RIB 7 show a possible steady decline but with just three data points in the corresponding trawl survey and a lack of any other information it is not possible to validate the indices. There are no stock monitoring indices available for RIB 1, 2, 8 or 9.

4.2   Biomass estimates
Estimates of biomass are given in Table 6.

4.3   Yield estimates and projections
Neither *MCY* nor *CAY* can be estimated.

4.4   Other yield estimates and stock assessment results
No information is available.

Table 6: Biomass indices (t) and coefficients of variation (CV) of ribaldo from *Tangaroa* trawl surveys (Assumptions: areal availability, vertical availability and vulnerability = 1). NB: estimates are for the core strata only for the respective time series.

Chatham Rise	Vessel	Trip code	Date	Biomass (t)	%CV
	Tangaroa	TAN9106	Dec 91–Feb 92	417	12.2
		TAN9212	Dec 92–Feb 93	336	17.2
		TAN9401	Jan 94	602	10.8
		TAN9501	Jan–Feb 95	406	19.7
		TAN9601	Dec 95–Jan 96	470	18.2
		TAN9701	Jan 97	333	21.3
		TAN9801	Jan 98	510	14.3
		TAN9901	Jan 99	395	18
		TAN0001	Dec 99–Jan 00	387	20.8
		TAN0101	Dec 00–Jan 01	762	18.3
		TAN0201	Dec 01–Jan 02	417	13.2
		TAN0301	Dec 02–Jan 03	455	18.1
		TAN0401	Dec 03–Jan 04	535	15.6
		TAN0501	Dec 04–Jan 05	491	14.2
		TAN0601	Dec 05–Jan 06	313	16.9
		TAN0701	Dec 06–Jan 07	380	15
		TAN0801	Dec 07–Jan 08	479	14.3
		TAN0901	Dec 08–Jan 09	463	12.7
		TAN1001	Jan 10	416	19.9
		TAN1101	Jan 11	396	16.7
		TAN1201	Jan 12	469	14.6
		TAN1301	Jan 13	428	15.7
		TAN1401	Jan 14	477	18
Sub-Antarctic	*Tangaroa*	TAN9105	Nov–Dec 91	1 035	11.2
		TAN9211	Nov–Dec 92	389	18.6
		TAN9310	Nov–Dec 93	996	12.8
		TAN0012	Nov–Dec 00	873	14
		TAN0118	Nov–Dec 01	1 017	17.2
		TAN0219	Nov–Dec 02	656	17.5
		TAN0317	Nov–Dec 03	653	18.9
		TAN0414	Nov–Dec 04	951	16.5
		TAN0515	Nov–Dec 05	721	14.6
		TAN0714	Nov–Dec 07	1 062	13.5
		TAN0617	Nov–Dec 06	780	16.4
		TAN0813	Nov–Dec 08	658	18
		TAN0911	Nov–Dec 09	1 056	13.4
		TAN1117	Nov–Dec 11	1 017	17.2
		TAN1215	Nov–Dec 12	787	16.7
		TAN1412	Nov–Dec 14		
		TAN9204	Apr–May 92	768	17.1
		TAN9304	May–Jun 93	1 162	15.1
		TAN9605	Mar–Apr 96	989	16.7
		TAN9805	Apr–May 98	837	14.2
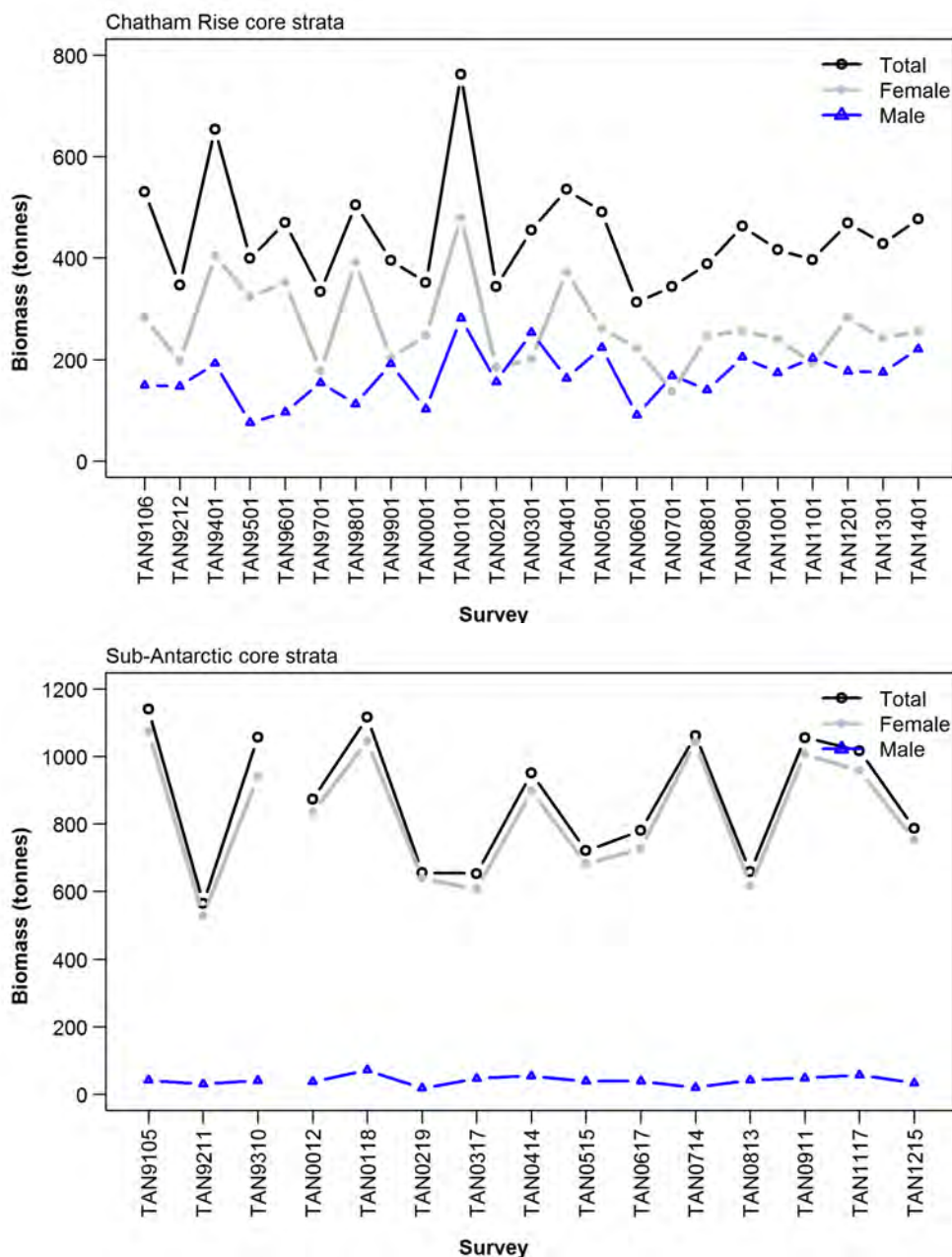
Figure 2: Doorspread biomass estimates of ribaldo by sex from the Chatham Rise 1991 to 2014 (upper) and Sub-Antarctic 1991 to 1993 and 2000 to 2012 (lower), from *Tangaroa* trawl surveys.

5. STATUS OF THE STOCKS

- **RIB 1, 2, 7, 8 and 9**

There are no accepted stock monitoring indices available for RIB 1, 2, 7, 8 or 9.

- **RIB 3 & 4**

Stock Status	
Year of Most Recent Assessment	2014
Reference Points	Target: Not established but 40% B_0 assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}

Status in relation to Target	Unknown
Status in relation to Limits	Unlikely (< 40%) to be below soft limit Unlikely (< 40%) to be below hard limit
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
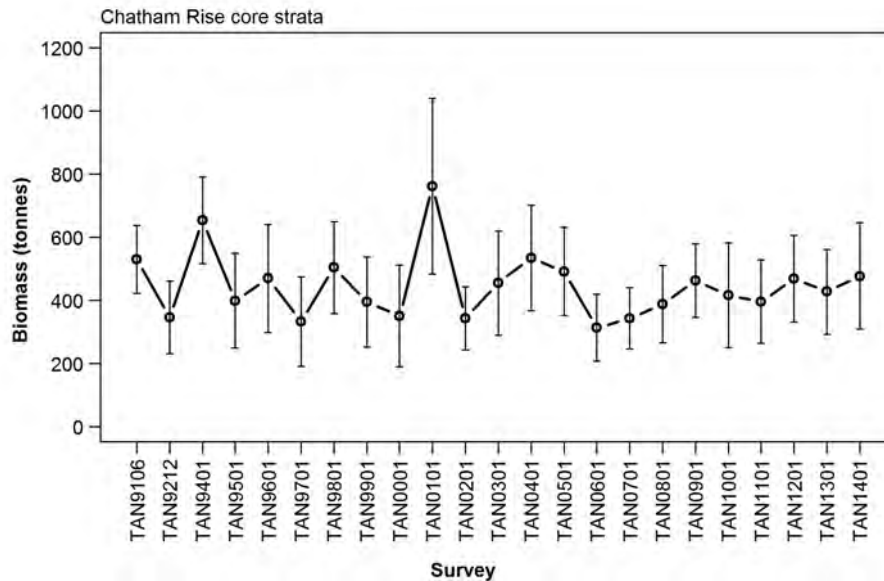
Doorspread biomass estimates of ribaldo (error bars are ± two standard deviations) from the Chatham Rise, from *Tangaroa* surveys from 1991 to 2014.

Fishery and Stock Trends

Recent Trend in Biomass or Proxy	The relative biomass index of ribaldo from summer middle depth trawl surveys of the Chatham Rise is relatively flat. Precision is generally good in this time series (< 20%). Although numbers of individual ribaldo caught are low the Working Group considered this index to be suitable to monitor major trends in this stock.
Recent Trend in Fishing Mortality or Proxy	-
Other Abundance Indices	-
Trends in Other Relevant Indicators of Variables	-

Projections and Prognosis

Stock Projections or Prognosis	Stock size is Likely (> 60%) to remain near current levels under recent catches, that were well below the current TACC before 2013–14
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft limit: Unlikely (< 40%) for recent catches Hard limit: Unlikely (< 40%) for recent catches
Probability of Current Catch or TACC causing Overfishing to continue or commence	Unknown as catches increased in 2013–14

Assessment Methodology and Evaluation

Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Evaluation of agreed trawl survey indices thought to index RIB 3 & 4 abundance	
Assessment Dates	Latest assessment: 2014	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	Data collected on trawl surveys	1 – High Quality

Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Low numbers of individuals caught on trawl surveys.	

Qualifying Comments
-

Fishery Interactions
In RIB 3 & 4, ribaldo are taken as bycatch primarily in the ling and hoki bottom trawl fisheries and ling bottom longline fishery. Interactions with other species are currently being characterised.

- **RIB 5 & 6**

Stock Status	
Year of Most Recent Assessment	2014
Reference Points	Target: Not established but 40% B_0 assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	Unknown
Status in relation to Limits	Unlikely ($< 40\%$) to be below Unlikely ($< 40\%$) to be below
Status in relation to Overfishing	Unknown
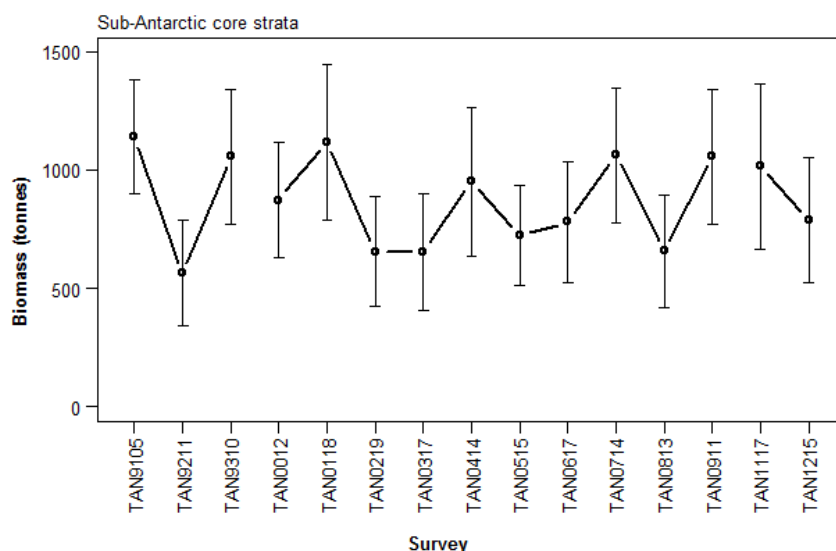
Historical Stock Status Trajectory and Current Status
Doorspread biomass estimates of ribaldo (error bars are ± two standard deviations) from the Sub-Antarctic, from *Tangaroa* surveys from 1991 to 1993, and 2000 to 2012.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Relative biomass estimates of ribaldo from summer middle depth surveys of the Sub-Antarctic show a relatively flat index. CVs are consistently low in this time series ($< 20\%$). Although numbers of individual ribaldo caught are low the Working Group considered this index to be suitable to monitor major trends in this stock.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Variables of Indicators	-

Projections and Prognosis

Stock Projections or Prognosis	Stock size is Likely (> 60%) to remain near current levels under current catches and TACCs
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft limit: Unlikely (< 40%) Hard limit: Unlikely (< 40%)
Probability of Current Catch or TACC causing Overfishing to continue or commence	Unknown

Assessment Methodology and Evaluation

|		
Assessment Type	Level 2 - Partial quantitative stock assessment	
Assessment Method	Evaluation of agreed trawl survey indices thought to index RIB 5 & 6 abundance	
Assessment Dates	Latest assessment: 2014	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Data collected on trawl surveys	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	Low numbers of individuals caught on trawl surveys; and unknown implications of highly skewed sex ratios (females usually make up > 90% of biomass) for stock structure. Observer data also shows skewed sex ratios favouring females.	

Qualifying Comments

-

Fishery Interactions

In RIB 5 & 6, ribaldo are mainly caught as bycatch in hoki and ling bottom trawl fisheries and ling bottom longline fisheries. Interactions with other species are currently being characterised.

6. FOR FURTHER INFORMATION

Bagley, N W; O'Driscoll, R L (2012) Trawl survey of middle depth species in the Southland and Sub-Antarctic areas, November–December 2009 (TAN0911). *New Zealand Fisheries Assessment Report 2012/05.* 70 p.

Cohen, D M; Inada, T; Iwamoto, T; Scialabba, N (1990) FAO species catalogue. Vol. 10. Gadiform fishes of the world (Order Gadiformes). An annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date. *Food and Agriculture Orginisation Fisheries Synopsis.* No. 125, Vol. 10. Rome, FAO. 442 p.

Dunn, M R (2006) Descriptive and catch per unit effort analyses for New Zealand ribaldo fisheries for the fishing years 1977–78 to 2002–03. *New Zealand Fisheries Assessment Report 2006/22.* 55 p.

Elder, R D; Taylor, J L (Comps.) (1979) Prospects and problems for New Zealand's demersal fisheries. Proceedings of the Demersal Fisheries Conference October 1978. *Fisheries Research Division Occasional Publication* No. 19. 123 p.

MacGibbon, D J (2015) Fishery characterisation and standardised CPUE analyses for ribaldo, *Mora moro* (Risso, 1810) (Moridae), 1989–90 to 2012–13 *New Zealand Fisheries Assessment Report 2015/31.* 314 p.

MacGibbon, D J; Hurst, R J (2011) Fishery characterisation and standardised CPUE analyses for ribaldo, *Mora moro*, (Risso, 1810) (Moridae), 1989–90 to 2008–09. *New Zealand Fisheries Assessment Report 2011/25.*

McMillan, P J; Hart, A C (1998) Summary of biology and commercial landings, and a stock assessment of ribaldo *Mora moro* (Risso, 1810), in New Zealand waters. New Zealand Fisheries Assessment Research Document 1998/9. 16 p. (Unpublished report held in NIWA library, Wellington.)

O'Driscoll, R L; Booth, J D; Bagley, N W; Anderson, O F; Griggs, L H; Stevenson, M L; Francis, M P (2003) Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand deepwater fish, pelagic fish, and invertebrates. *NIWA Technical Report 119.* 377 p.

Sutton, C P; Tracey, D M; Andrews, A H; Hart, A C; MacGibbon, D J (2010) Validated age and growth of ribaldo (*Mora moro*). *New Zealand Fisheries Assessment Report 2010/24.* 26 p.

(Mustelus lenticulatus)
Pioke, Makō

1.   FISHERIES SUMMARY

Rig was introduced into the Quota Management System on 1 October 1986. Table 1 gives the TACs, TACCs, and allowances that were applicable to the 2021–21 fishing year.

Table 1: TACs (t), TACCs (t), and allowances (t) for rig as at 1 October 2021.

Fishstock	Recreational allowance	Customary non-commercial allowance	Other sources of mortality	TACC	TAC
SPO 1	25	20	15	692	752
SPO 2	10	5	12	119	146
SPO 3	20	20	66	660	766
SPO 7	33	15	27	298	373
SPO 8	60	31	0	310	401
SPO 10	–	–	–	10	10

1.1   Commercial fisheries
Rig are caught in coastal waters throughout New Zealand. Most of the set net catch is taken in water less than 50 m deep during spring and summer, when rig aggregate inshore. Before the introduction of the QMS in 1986, 80% of the commercial catch was taken by bottom set net and most of the remainder by trawl. Total reported landings of rig increased rapidly during the 1970s and averaged about 3200 t per year during the late 1970s and early 1980s (Table 2, Table 3). Since then, a larger proportion has been taken by trawlers as bycatch. The most important bottom set net fisheries are at Ninety Mile Beach, Kaipara Harbour, Manukau Harbour, South Taranaki Bight–Tasman Bay/Golden Bay, Canterbury Bight, Kaikōura, and Hauraki Gulf. There is also an active set net fishery in Foveaux Strait where SPO is taken as a bycatch in the target SCH set net fishery.

Following the introduction of rig into the QMS in 1986, landings declined to less than half those of the previous decade in response to TACCs which were set at levels that were lower than previous catches. The total TACCs were subsequently increased to a maximum of 2098 t from 1994–95 to 1996–97, allowing landings to rise to 1888 t in 1996–97. Total landings subsequently declined steadily to a minimum of 1186 t during the fishing year 2008–09, before increasing to between 1300 t and 1450 t per year beginning in 2014–15 (Table 4). From 2006–07, the total TACC has been under 2000 t until 2019–20 and 2020–21 when it was increased to 2018 t and 2089 t, respectively.

Table 2: Reported total New Zealand landings (t) of rig for the calendar years 1965 to 1985. Sources: MAF and FSU data.

Year	Landings	Year	Landings	Year	Landings	Year	Landings	Year	Landings
1965	723	1970	930	1975	1 841	1980	3 000	1985	3 222
1966	850	1971	1 120	1976	2 610	1981	3 006		
1967	737	1972	1 011	1977	3 281	1982	3 425		
1968	677	1973	–	1978	3 300	1983	3 826		
1969	690	1974	2 040	1979	2 701	1984	3 562		

Table 3: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	SPO 1	SPO 2	SPO 3	SPO 7	SPO 8	Year	SPO 1	SPO 2	SPO 3	SPO 7	SPO 8
1931–32	28	0	0	0	0	1957	115	69	60	108	28
1932–33	30	0	0	0	0	1958	106	73	87	119	34
1933–34	29	0	0	0	0	1959	136	76	98	105	30
1934–35	33	0	0	0	0	1960	118	77	141	153	26
1935–36	31	0	0	0	0	1961	118	98	160	158	27
1936–37	73	0	8	0	0	1962	126	100	269	124	40
1937–38	56	1	5	0	0	1963	142	81	193	126	27
1938–39	32	1	70	0	0	1964	157	78	243	132	24
1939–40	10	1	12	0	0	1965	145	90	360	98	30
1940–41	13	1	54	1	0	1966	171	118	386	141	38
1941–42	18	0	32	0	0	1967	129	108	266	200	33
1942–43	49	1	33	1	0	1968	147	89	236	173	31
1943–44	42	6	44	5	1	1969	145	83	299	141	21
1944	60	10	14	7	4	1970	167	97	436	192	38
1945	56	5	24	10	8	1971	183	95	603	203	37
1946	71	12	8	19	9	1972	139	69	629	138	36
1947	73	27	28	45	7	1973	189	105	775	133	54
1948	51	26	51	43	7	1974	417	134	1 118	249	126
1949	57	33	60	49	9	1975	390	146	896	255	157
1950	87	48	62	73	17	1976	629	230	906	610	233
1951	94	46	101	68	22	1977	723	307	1 327	541	382
1952	115	41	132	63	21	1978	701	330	1 225	638	404
1953	117	56	95	45	20	1979	614	232	1 138	349	368
1954	103	68	40	58	39	1980	499	252	2 667	470	387
1955	93	49	42	84	47	1981	618	188	1 443	413	343
1956	106	54	38	77	29	1982	840	210	1 255	629	399

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

TACCs for all Fishstocks except SPO 10 were increased by 20% for the 1991–92 fishing year under the Adaptive Management Programme (AMP). Another TACC increase (from 454 t to 600 t) was implemented in SPO 3 for the 2000–01 fishing year. The TACCs for SPO 1, SPO 2, and SPO 8 reverted to the pre-AMP levels in the 1997–98 fishing year, when these Fishstocks were removed from the AMP in July 1997. All AMP programmes ended on 30 September 2009. The TACC for SPO 2 was increased from 72 t to 86 t from 1 October 2004 under the low knowledge bycatch framework (Table 4). In 2011–12 the SPO 2 TACC was further increased to 108 t and to 119 t in 2020–21. The TACC for SPO 7 was decreased to 221 t on 1 October 2006, as a result of a stock assessment based on a declining CPUE. The SPO 7 TACC was raised to 246 t for 1 October 2015 based on increased abundance and has since been raised to 271 t in 2018–19 and 298 t in 2019–20. The SPO 3 TACC was raised to 660 t in 2020–21 in response to increasing BT CPUE and increased ECSI survey indices.

SPO was introduced into Schedule 6 on 1 May 2012, which means that rig that are alive and likely to survive can be released (but must be reported as Destination "X"). Figure 1 shows the historical landings and TACC values for the main SPO stocks.

In October 1992, the conversion factors for headed and gutted, and dressed, rig were both reduced from 2.00 to 1.75. They were each further reduced to 1.55 in 2000–01. Landings and TACCs prior to 2000–01 have not been adjusted for the changes in the conversion factor in the accompanying tables.

Table 4: Reported landings (t) of rig by Fishstock from 1985–86 to present and actual TACCs (t) from 1986–87 to present. QMS data from 1986–present. [Continued on next page]

Fishstock	SPO 1		SPO 2		SPO 3		SPO 7		SPO 8	
FMA (s)	1 & 9		2		3,4,5, & 6		7		8	
	Landing	TACC	Landing	TACC	Landing	TACC	Landing	TACC	Landing	TACC
1985–86*	845	–	96	–	921	–	367	–	465	–
1986–87	366	540	55	60	312	330	233	240	125	240
1987–88	525	614	66	68	355	347	262	269	187	261
1988–89	687	653	68	70	307	352	239	284	212	295
1989–90	689	687	61	70	292	359	266	291	206	310
1990–91	656	688	63	71	284	364	268	294	196	310
1991–92	878	825	105	85	352	430	290	350	145	370
1992–93	719	825	90	86	278	432	324	350	239	370
1993–94	631	829	96	86	327	452	310	350	255	370
1994–95	666	829	88	86	402	454	341	350	273	370
1995–96	603	829	107	86	408	454	400	350	330	370
1996–97	681	829	99	86	434	454	397	350	277	370
1997–98	621	692	85	72	442	454	325	350	287	310
1998–99	553	692	86	72	426	454	336	350	235	310
1999–00	608	692	86	72	427	454	330	350	219	310
2000–01	554	692	81	72	458	600	338	350	174	310
2001–02	436	692	86	72	391	600	282	350	216	310
2002–03	477	692	86	72	417	600	264	350	209	310
2003–04	481	692	81	72	354	600	293	350	203	310
2004–05	429	692	108	86	366	600	266	350	208	310
2005–06	345	692	110	86	389	600	288	350	163	310
2006–07	400	692	101	86	423	600	265	221	176	310
2007–08	297	692	104	86	472	600	231	221	220	310
2008–09	297	692	106	86	328	600	233	221	222	310
2009–10	302	692	114	86	371	600	229	221	246	310
2010–11	311	692	106	86	395	600	229	221	220	310
2011–12	328	692	119	108	433	600	227	221	198	310
2012–13	369	692	106	108	463	600	226	221	120	310
2013–14	349	692	125	108	489	600	230	221	192	310
2014–15	324	692	117	108	556	600	235	221	181	310
2015–16	316	692	106	108	557	600	248	246	180	310
2016–17	318	692	101	108	543	600	258	246	197	310
2017–18	317	692	89	108	648	600	247	246	159	310
2018–19	238	692	105	108	615	600	265	271	142	310
2019–20	218	692	117	108	651	600	273	298	118	310
2020–21	234	692	109	119	632	660	284	298	47	310

Fishstock	SPO 10			
FMA (s)	10		Total	
	Landings	TACC	Landings§	TACC
1985–86*	0	–	2 906	–
1986–87	0	10	1 091	1 420
1987–88	0	10	1 395	1 569
1988–89	0	10	1 513	1 664
1989–90	0	10	1 514	1 727
1990–91	0	10	1 467	1 737
1991–92	0	10	1 770	2 070
1992–93	< 1	10	1 650	2 072
1993–94	0	10	1 619	2 097
1994–95	0	10	1 769	2 098
1995–96	0	10	1 848	2 098
1996–97	0	10	1 888	2 098
1997–98	0	10	1 760	1 888
1998–99	0	10	1 635	1 888
1999–00	0	10	1 670	1 888
2000–01	0	10	1 607	2 034
2001–02	0	10	1 411	2 034
2002–03	0	10	1 453	2 034
2003–04	0	10	1 412	2 034
2004–05	0	10	1 377	2 048
2005–06	0	10	1 295	2 048
2006–07	0	10	1 365	1 919
2007–08	0	10	1 324	1 919
2008–09	0	10	1 186	1 919
2009–10	0	10	1 262	1 919
2010–11	0	10	1 260	1 919
2011–12	0	10	1 305	1 941
2012–13	0	10	1 283	1 941
2013–14	0	10	1 386	1 941

Table 4 [continued]

Fishstock	SPO 10			
FMA (s)	10			Total
	Landings	TACC	Landings§	TACC
2014–15	0	10	1 413	1 941
2015–16	0	10	1 406	1 966
2016–17	0	10	1 417	1 966
2017–18	0	10	1 459	1 966
2018–19	0	10	1 364	1 991
2019–20	0	10	1 376	2 018
2020–21	0	10	1 306	2 089

*FSU data.

§Includes landings from unknown areas before

Within SPO 3, the Banks Peninsula Marine Mammal Sanctuary was established in 1988 by the Department of Conservation under the Marine Mammal Protection Act 1978, for the purpose of protecting Hector's dolphins. The sanctuary extended 4 nautical miles offshore from the coast from Sumner Head in the north to the Rakaia River mouth in the south. Before 1 October 2008, no set nets were allowed within the sanctuary from 1 November to the end of February. For the remainder of the year, set nets were allowed, but could only be set from an hour after sunrise to an hour before sunset, be no more than 30 metres long, with only one net per boat which was required to remain tied to the net while it was set.

Voluntary set net closures were implemented by the South East Fisheries Management Company (SEFMC) from 1 October 2000 to protect nursery grounds for rig and elephant fish and to reduce interactions between commercial set nets and Hector's dolphins in shallow waters. The closed area extended from the southernmost end of the Banks Peninsula Marine Mammal Sanctuary to the northern bank of the mouth of the Waitaki River. This area was closed for the entire year out to 1 nautical mile offshore and out to 4 nautical miles offshore for the period 1 October to 31 January.

From 1 October 2008, a suite of fisheries regulations intended to protect Māui and Hector's dolphins was implemented around the South Island and off the west coast of the North Island by the Minister of Fisheries. At the same time the Minister of Conservation established four new Marine Mammal Sanctuaries for Māui and Hector's dolphins (west coast North Island, Clifford Bay and Cloudy Bay, Catlins Coast, and Te Waewae Bay), and extended the Banks Peninsula Marine Mammal Sanctuary north to the Waipara River and to 12 nautical miles offshore.

For SPO 1 and SPO 8, there have been six changes to the management regulations affecting set net fisheries that target school shark or rig off the west coast of the North Island.
- The first was a closure to set net fishing from Maunganui Bluff to Pariokariwa Point out to 4 nautical miles offshore on 1 October 2003.
- Secondly, this closure was extended by the Minister of Fisheries to 7 nautical miles offshore on 1 October 2008 and in the entrances of the Kaipara Harbour, Manukau Harbour, Waikato River, and Raglan Harbour. An appeal was made by affected commercial fishers who were granted interim relief by the High Court, allowing commercial set net fishing (for rig and school shark) between 4 and 7 nautical miles offshore during daylight hours between 1 October and 24 December for three consecutive years: 2008–2010. The full closure (out to 7 nautical miles offshore all year round) was reinstated in March 2011.
- Thirdly, the west coast North Island set net closure to 7 nautical miles offshore was extended from Pariokariwa Point around Cape Egmont to Hawera in 2012, with commercial set net fishing only allowed between 2 and 7 nautical miles if an Observer was on board the vessel.
- In 2013, the Minister of Conservation varied the West Coast North Island Marine Mammal Sanctuary to prohibit commercial and recreational set net fishing from Pariokariwa Point to the Waiwhakaiho River (New Plymouth) between 2 and 7 nautical miles offshore.
- On 1 October 2020, new commercial and recreational set net fishing closures out to 4 nautical miles offshore took effect from Cape Reinga to Maunganui Bluff, and Hawera to Wellington. Set net fishing closures were also extended from Maunganui Bluff to the Waiwhakaiho River from 7 nautical miles to 12 nautical miles offshore, as well as from the Waiwhakaiho River to Hawera between 2 and 7 nautical miles offshore. Set net fishing closures within the Manukau Harbour were extended to Taumatarea Point in the north and Matakawau Point in the south within the harbour.

For SPO 1 and SPO 8, there have been three changes to management regulations affecting trawl fisheries off the west coast of the North Island.

- In October 2003, trawling was prohibited from Maunganui Bluff and Pariokariwa Point out to 1 nautical mile offshore, with the prohibition extending to 2 nautical miles offshore in areas adjacent to harbours and river mouths.
- In October 2008, trawling was prohibited from Maunganui Bluff to Pariokariwa Point out to 2 nautical miles, and within that area between the Manukau Harbour and Port Waikato out to 4 nautical miles offshore.
- In October 2020, there was an extension to commercial trawl closures from Maunganui Bluff south to the Waiwhakaiho River and to 4 nautical miles offshore.

For SPO 3, commercial and recreational set netting was banned on 1 October 2008 to 4 nautical miles offshore along the east coast of the South Island, from Cape Jackson in the Marlborough Sounds to Slope Point in the Catlins. Some exceptions were allowed, including an exemption for commercial and recreational set netting to only one nautical mile offshore around the Kaikōura Canyon, and permitting set netting in most harbours, estuaries, river mouths, lagoons, and inlets except for the Avon-Heathcote Estuary, Lyttelton Harbour, Akaroa Harbour, and Timaru Harbour. A seasonal exemption applies around Banks Peninsula allowing the use of commercial and recreational flatfish set nets between 1 April and 30 September in the inner portions of Akaroa Harbour, Lyttelton Harbour, Port Levy, and Pigeon Bay. In addition, trawl gear within 2 nautical miles of shore was restricted to flatfish nets with defined low headline heights. In the south, commercial and recreational set netting was banned to 4 nautical miles offshore, extending from Slope Point in the Catlins to Sand Hill Point east of Fiordland and in Te Waewae Bay. An exemption permitted set netting in harbours, estuaries, and inlets. In addition, trawl gear within 2 nautical miles of shore from Slope Point to Sand Hill Point (Te Waewae Bay) was restricted to flatfish nets with defined low headline heights.

On 1 October 2020, the commercial set net fishing closures off Kaikōura were extended slightly offshore but no change was made to the 4 nautical miles recreational closure. Commercial and recreational set net fishing closures were extended off the east coast to encompass Pegasus Bay (north of Banks Peninsula), approximately 19 nautical miles offshore southeast from the headland east of Motunau Beach offshore and then southwest to a point 7 nautical miles offshore from Goat Point. Commercial and recreational set net fishing closures were also extended from Snuffle Nose southwest to 12 nautical miles offshore across the Canterbury Bight to just south of Timaru to the existing 4 nautical miles offshore boundary. In the south, commercial and recreational set net fishing closures were extended within Te Waewae Bay (between Sand Hill Point and Wakaputa Point) to 10 nautical miles offshore.

For SPO 7, both commercial and recreational set netting were banned to 2 nautical miles offshore from the South Island west coast, with the recreational closure effective for the entire year and the commercial closure restricted to the period 1 December to the end of February. The closed area extends from Awarua Point north of Fiordland to the tip of Cape Farewell at the top of the South Island. Both sides of Farewell Spit were voluntarily closed to set nets, beginning in October 2006, to protect large females in a known pupping area. The net effect of these set net area closures was to greatly reduce the importance of the SPO 7 set net fishery, particularly off the west coast. Fifty-six percent of the average 2000–01 to 2002–03 annual set net catch came from the combined west coast statistical areas, and 36% came from Tasman Bay/Golden Bay. The equivalent percentages from 2015–16 to 2017–18 are 3% for the west coast areas and 96% from Tasman Bay/Golden Bay. Over the same period, the overall set net catch has declined from 64% of the catch to 31%, with the balance taken up by bottom trawl and (in the most recent three years) Danish seine nets.

On 1 October 2020, new commercial and recreational set net fishing closures out to 4 nautical miles offshore took effect within Golden Bay and Tasman Bay, from Farewell Spit to Cape Soucis (Raetihi).
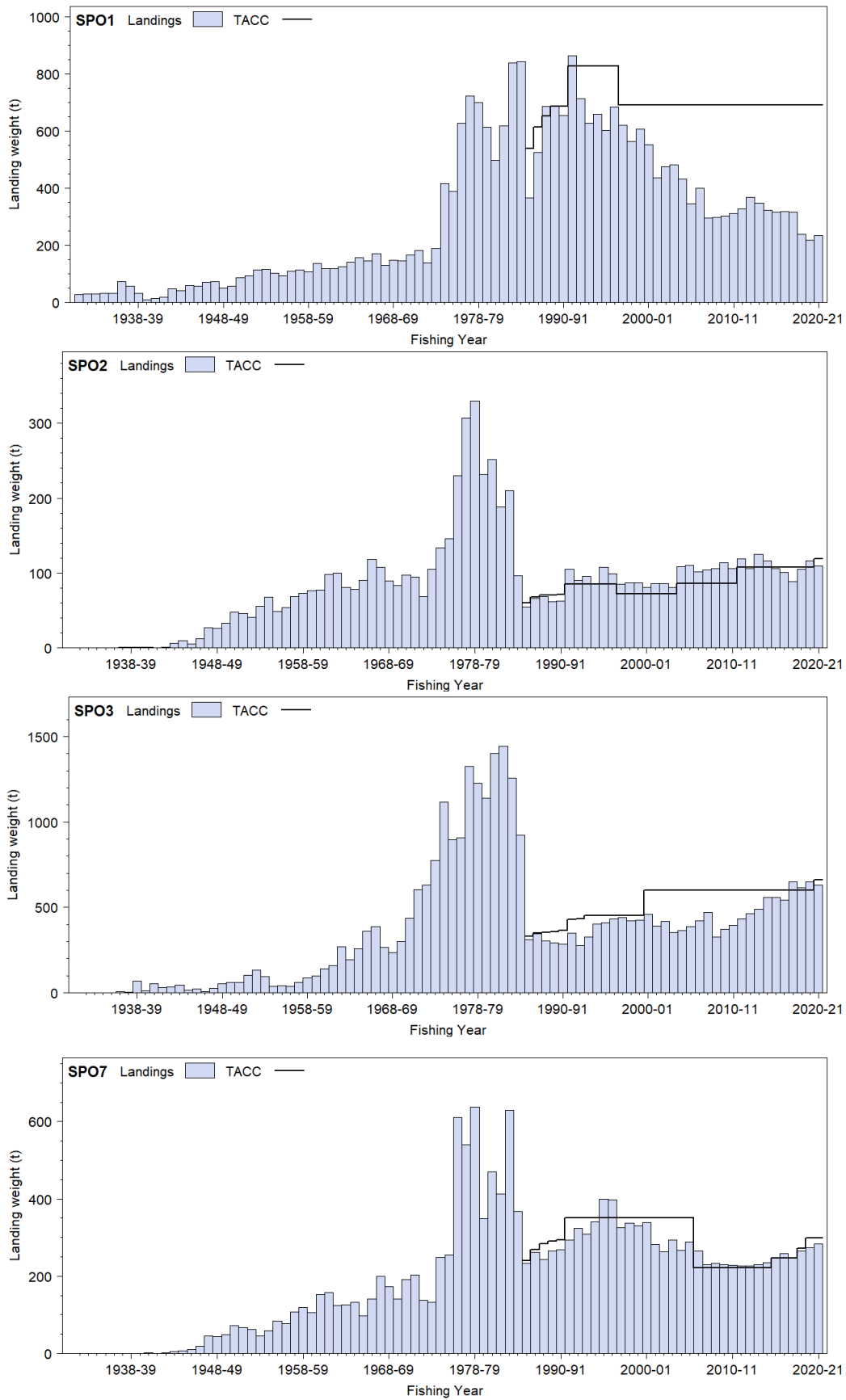
Figure 1: Historical landings and TACCs for the five main SPO stocks. From top to bottom: SPO 1 (Auckland East), SPO 2 (Central East), SPO 3 (South East Coast), and SPO 7 (Challenger). [Continued on next page]
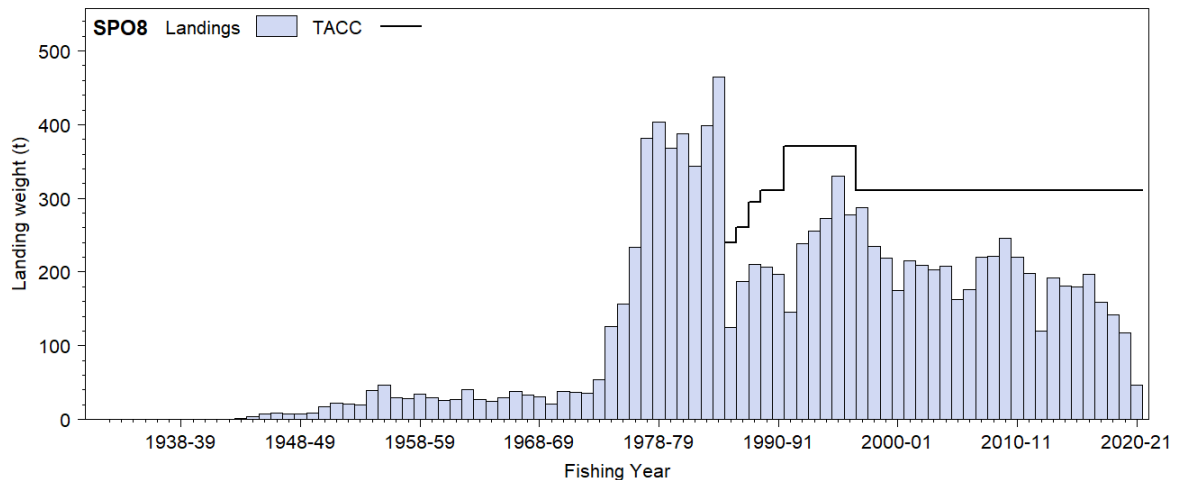
Figure 1 [Continued]: Historical landings and TACCs for the five main SPO stocks. SPO 8 (Central Egmont).

1.2   Recreational fisheries

Rig is the most commonly caught shark species by recreational fishers in New Zealand (Wynne-Jones et al 2014, 2019). Rig are caught by recreational fishers throughout New Zealand. From the 2011–12 national panel survey they were predominantly taken by rod and reel (75.2%) with some taken by longline (16.6%) and less in set net (7.2%). The rod and reel catch was taken predominantly from land (57.5%) and trailer boat (29.6%), highlighting the importance of this species to land-based fishers. In the 2017–18 national panel survey no set net catch was reported, with 76% of the catch taken by land-based fishers (Wynne-Jones et al 2019).

1.2.1   Management Controls

The main method used to manage recreational harvests of rig is daily bag limits. Spatial and method restrictions also apply. Fishers can take up to 20 rig as part of their combined daily bag limit in the Auckland and Kermadec, Central, and Challenger Fishery Management Areas. Fishers can take up to 5 rig as part of their combined daily bag limit in the Fiordland and South-East Fishery Management Areas. Fishers can take up to 3 rig as part of their combined daily bag limit in the Kaikōura Fishery Management Area. Spatial closures for set netting and minimum mesh sizes for rig are also in place in all areas. There is currently no bag limit in place for the Southland Fishery Management Area.

1.2.2   Estimates of recreational harvest

There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and offsite methods where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest for rig were calculated using an offsite approach, the offsite regional telephone and diary survey approach. Estimates for 1996 came from a national telephone and diary survey (Bradford 1998). Another national telephone and diary survey was carried out in 2000 (Boyd & Reilly 2004). The harvest estimates provided by these telephone diary surveys (Table 5) are no longer considered reliable.

In response to the cost and scale challenges associated with onsite methods, in particular the difficulties in sampling other than trailer boat fisheries, offsite approaches to estimating recreational fisheries harvest have been revisited. This led to the development and implementation of a national panel survey for the 2011–12 fishing year (Wynne-Jones et al 2014). The panel survey used face-to-face interviews of a random sample of New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information in standardised phone interviews. Estimated catches in numbers of fish were converted to weights using mean weights estimated from boat ramp surveys (Hartill & Davey 2015). The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly

comparable results (Wynne-Jones et al 2019, Davey et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 5. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 5: **Recreational harvest estimates for rig stocks. Early surveys were carried out in different years in the regions: South in 1991–92, Central in 1992–93, and North in 1993–94. Early survey harvests are presented as a range to reflect the considerable uncertainty in the estimates. The telephone/diary surveys were conducted from December to November but are denoted by the January calendar year. National panel surveys were conducted throughout the October to September fishing year but are denoted by the January calendar year.**

Stock	Year	Method	Number of fish	Total weight (t)	CV
SPO 1	1994	Telephone/diary	11 000	5–25	–
	1996	Telephone/diary	28 000	35	0.31
	2000	Telephone/diary	13 000	17	0.30
	2012	Panel survey	7 780	8.5	0.25
	2018	Panel survey	3 830	6.1	0.34
SPO 2	1993	Telephone/diary	5 000	5–15	–
	1996	Telephone/diary	4 000	–	–
	2000	Telephone/diary	16 000	21	0.58
	2012	Panel survey	7 172	7.8	0.26
	2018	Panel survey	3 044	4.8	0.32
SPO 3	1992	Telephone/diary	12 000	15–30	0.22
	1996	Telephone/diary	12 000	15	0.20
	2000	Telephone/diary	43 000	57	0.32
	2012	Panel survey	8 142	8.9	0.24
	2018	Panel survey	9 372	14.9	0.26
SPO 7	1993	Telephone/diary	8 000	10–25	0.39
	1996	Telephone/diary	19 000	24	0.20
	2000	Telephone/diary	33 000	33	0.38
	2012	Panel survey	19 126	20.9	0.25
	2018	Panel survey	11 688	18.6	0.27
SPO 8	1993	Telephone/diary	18 000	20–60	0.43
	1994	Telephone/diary	1 000	0–5	–
	1996	Telephone/diary	7 000	–	–
	2000	Telephone/diary	7 000	9	0.48
	2012	Panel survey	5 499	6.0	0.45
	2018	Panel survey	7 435	11.8	0.41

1.3   Customary non-commercial fisheries

Māori fishers traditionally caught large numbers of 'dogfish' during the last century and early this century. Rig was probably an important species, although spiny dogfish and school shark were also taken. The historical practice of having regular annual fishing expeditions, during which thousands of dogfish were sun-dried on wooden frames, is no longer prevalent. However, rig are still caught in small quantities by customary non-commercial fishers in parts of the North Island, especially the harbours of the Auckland region. Quantitative information on the current level of customary non-commercial take is not available.

1.4   Illegal Catch

Quantitative information on the level of illegal catch is not available.

1.5   Other sources of mortality

Unknown quantities of juvenile rig are caught by set nets placed in harbours and shallow bays. Quantitative information on the level of other sources of mortality is not available.

2.   BIOLOGY

Rig are born at a total length (TL) of 25–30 cm. Off the South Island male and female rig attain maturity at 5–6 y (about 85 cm) and 7–8 y (about 100 cm), respectively (Francis & Ó Maolagáin 2000). Rig in the Hauraki Gulf mature earlier (4 y for males and 5 y for females) and at smaller sizes (Francis & Francis 1992 a & b). Longevity is not known because few large fish have been aged. However, a male rig that was mature at tagging was recaptured after nearly 14 years of liberty, suggesting a longevity of 20 years or longer. Females reach an average maximum length of 151 cm and males 126 cm TL.

Rig give birth to young during spring and summer, following a 10–11 month gestation. Most females begin a new pregnancy immediately after parturition, and therefore breed annually. The number of young produced increases exponentially with the length of the mother and ranges from 2 to 37 (mean about 11). Young are generally born in shallow coastal waters, especially in harbours and estuaries, around the North Island and South Island. They grow rapidly during their first summer and then disappear as water temperatures drop in autumn, when they presumably move into deeper water.

Rig make extensive coastal migrations, with one tagged female moving at least 1160 km. Over half of the tagged rig that were recaptured had moved over 50 km, and over half of the females had moved more than 200 km. Females travel further than males, and mature females travel further than immature females. Biological parameters relevant to stock assessment are shown in Table 6.

Table 6: Estimates of biological parameters for rig.

Fishstock					Estimate	Source
1. Natural mortality (M)						
All					0.2–0.3	Francis & Francis (1992a)
2. Weight = a(length)^b (Weight in g, length in cm total length).						
	Females		Males			
	a	b	a	b		
SPO 3	3.67×10^{-7}	3.54	1.46×10^{-6}	3.22		Francis (1979)
SPO 7&8	9.86×10^{-7}	3.32	$3.85 \times 10^{-}$	3.01		Blackwell (unpubl. data)
3. von Bertalanffy growth parameters						
		Both Sexes				
	L	k	t_o			
SPO 3 &7	147.2	0.119	-2.35			Francis & Ó Maolagáin (2000)

3.   STOCKS AND AREAS

Information relevant to determining rig stock structure in New Zealand was reviewed in 2009 (Smith 2009, Blackwell & Francis 2010, Francis 2010). These reviews concluded that the existing QMAs are a suitable size for rig management, although the boundaries between biological stocks are poorly defined, especially in the Cook Strait region. Insufficient tagging had occurred in SPO 1 to determine whether division of that stock into separate 1E and 1W stocks is warranted. Genetic, biological, fishery, and tagging data were all considered, but the evidence available for the existence and geographical distribution of biological stocks is poor. Some differences were found in CPUE trends at a small spatial scale but stock separation at the indicated spatial scales seems unlikely, and the CPUE differences may have resulted from processes acting below the stock level, such as localised exploitation of different sexes or different size classes of sharks. Genetic and morphological evidence indicate that a separate undescribed species of *Mustelus* occurs at the Kermadec Islands, but it is not known if rig occur there.

The most useful source of information was a tagging programme undertaken mainly in 1982–84 (Francis 1988a). However, most tag releases were made around the South Island, so little information was available for North Island rig. Male rig rarely moved outside the release QMA, even after more than five years at liberty. Female rig were more mobile than male rig, with about 30% of recaptures reported beyond the release QMA boundaries within 2–5 years of release. The proportion reported beyond the release QMA increased steadily with time. However, few females moved more than one QMA away from the release point. Because males move shorter distances than females, a conservative management approach is to set rig QMAs at a size appropriate for male stock ranges.

4.   STOCK ASSESSMENT

4.1   Trawl surveys

Indices of relative biomass for rig are available from *Kaharoa* trawl surveys of the west coast North Island, east coast South Island, and west coast South Island.

West coast North Island (WCNI) inshore trawl survey

The west coast North Island trawl survey was reinstated in 2018 after a 19 year hiatus from the last previous survey in 1999, with the restored surveys conducted in three consecutive years from 2018. The decision to reinstate this survey was driven by the concern that it was not sufficient to rely on the analysis of commercial catch and effort for snapper in this region and that there was a requirement for a fishery independent biomass survey. However, the success of this reinstatement relied on the ability to define a consistent set of surveyed strata across all survey years, given that strata definitions have changed over the history of the survey as well as the imposition of new regulations that barred access to parts of the inner coast for the protection of Māui dolphins from incidental capture by trawl.

A review completed in 2021 (Jones et al in prep) identified eight surveys which covered a 'core' set of consistently surveyed strata that ranged from 10 to 100 m and extended from the central part of the North Taranaki Bight to Ninety Mile Beach. Two early surveys were dropped when the depth range was extended to 200 m in an 'extended core' series. Jones et al (in prep) determined that three species were adequately represented by these strata in terms of obtaining acceptable CVs while covering a representative spatial and depth range. These species were snapper, red gurnard, and John dory. Although tarakihi were considered well covered by the survey series, parts of the known tarakihi habitat in the southern region of the WCNI have never been covered by any WCNI survey. Rig were thought to have reasonable coverage with a caveat of: "restricted access to the inshore areas, and relatively low numbers caught". Biomass estimates for rig for each of the above stratum definitions are given in Figure 2 and Table 7.
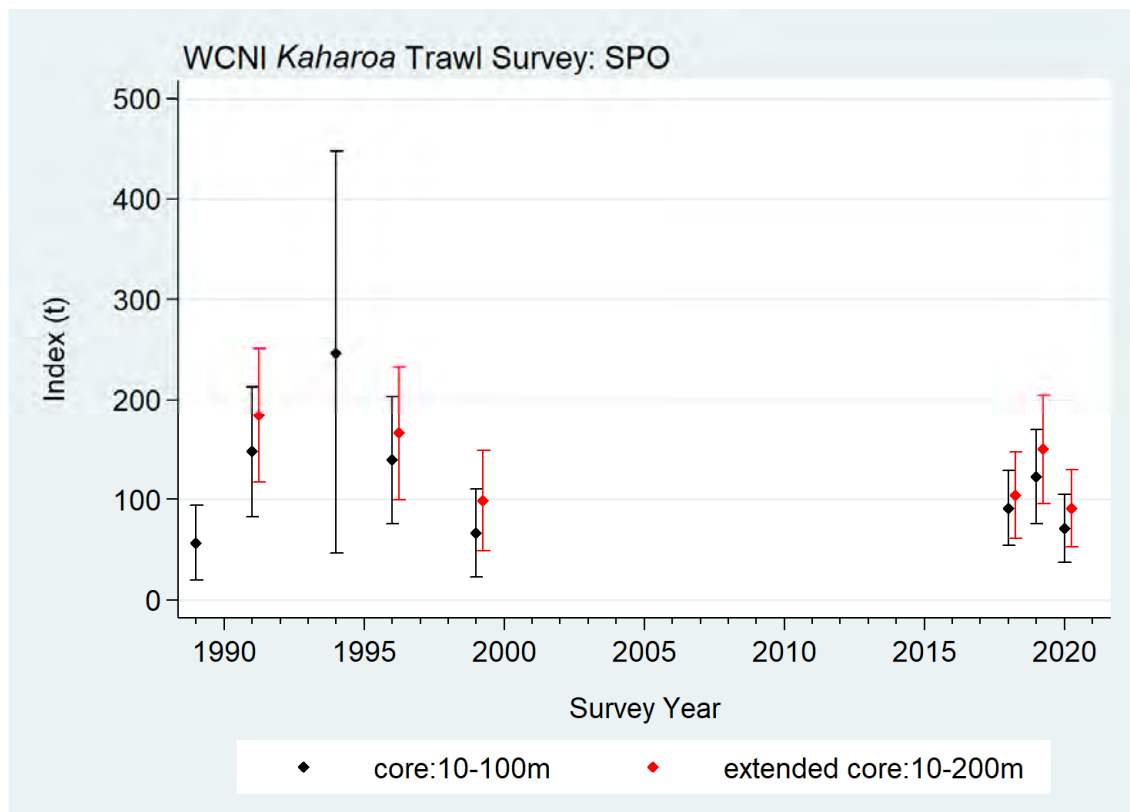
Figure 2: Total rig biomass indices (t) for the 'core' and 'extended core' stratum definitions adopted by Jones et al (in prep). Index values and CVs are given in Table 7.

The annual sample numbers by sex, survey year, and survey core type are given in Table 8. Length frequency distributions for the 10–100 n core strata, scaled by the survey CPUE and stratum area, are plotted by sex and survey year in Figure 3.

Table 7: Rig biomass estimates (t) and CVs for the 'core' and 'extended core' stratum definitions used for the restratified WCNI trawl survey. '−': not available.

Survey year	Core (10–100 m)				Extended Core (10–200 m)			
	Total	Males	Females	CV	Total	Males	Females	CV
1989	56.7	22.3	32.7	0.33	–	–	–	–
1991	147.9	95.1	52.8	0.22	183.9	111.0	72.9	0.18
1994	246.9	66.4	178.8	0.41	–	–	–	–
1996	139.1	72.0	66.7	0.23	165.9	78.3	87.2	0.20
1999	66.6	24.9	40.0	0.33	98.7	28.7	63.1	0.25
2018	91.1	–	–	0.20	104.0	–	–	0.21
2019	122.6	63.8	58.8	0.19	149.9	63.8	86.1	0.18
2020	70.9	40.9	30.0	0.24	90.9	40.9	50.0	0.21

Table 8: Number of unscaled rig captured and resulting scaled estimates of rig in numbers for the 'core' and 'extended core' stratum definitions used for the restratified WCNI trawl survey. '−': not available.

Survey year	Core (10–100 m)				Extended Core (10–200 m)			
	Males		Females		Males		Females	
	Unscaled	Scaled	Unscaled	Scaled	Unscaled	Scaled	Unscaled	Scaled
1989	16	14 497	21	19 912	–	–	–	–
1991	52	65 475	62	28 934	55	75 166	64	35 755
1994	40	42 303	74	104 150	–	–	–	–
1996	75	42 252	83	40 587	78	47 948	87	48 882
1999	20	22 908	30	20 648	23	25 593	38	29 150
2018	25	37 402	21	8 755	25	38 449	24	14 083
2019	55	36 476	45	26 603	55	36 726	50	36 226
2020	33	26 762	46	17 884	33	26 997	51	25 398
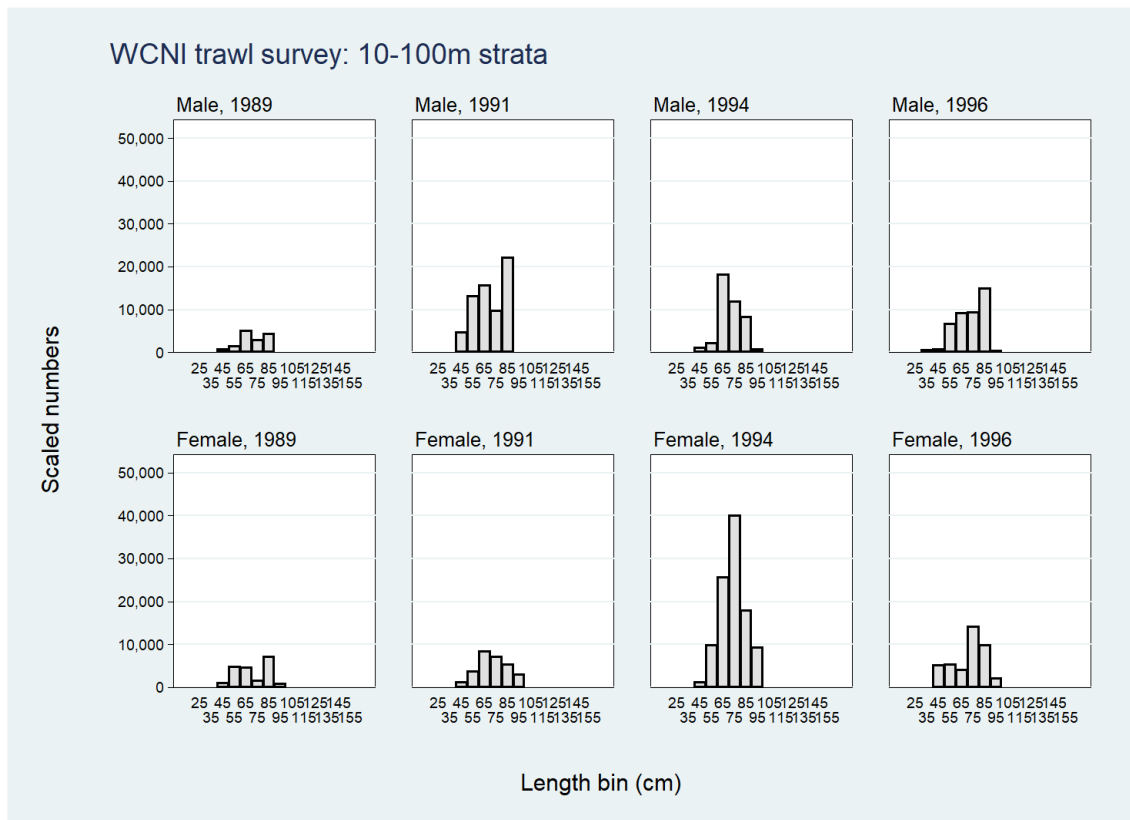
Figure 3: Scaled rig length frequency distributions by survey year for the eight core WCNI trawl surveys. Number of observations by sex are given in Table 8. [Continued on next page]

1307
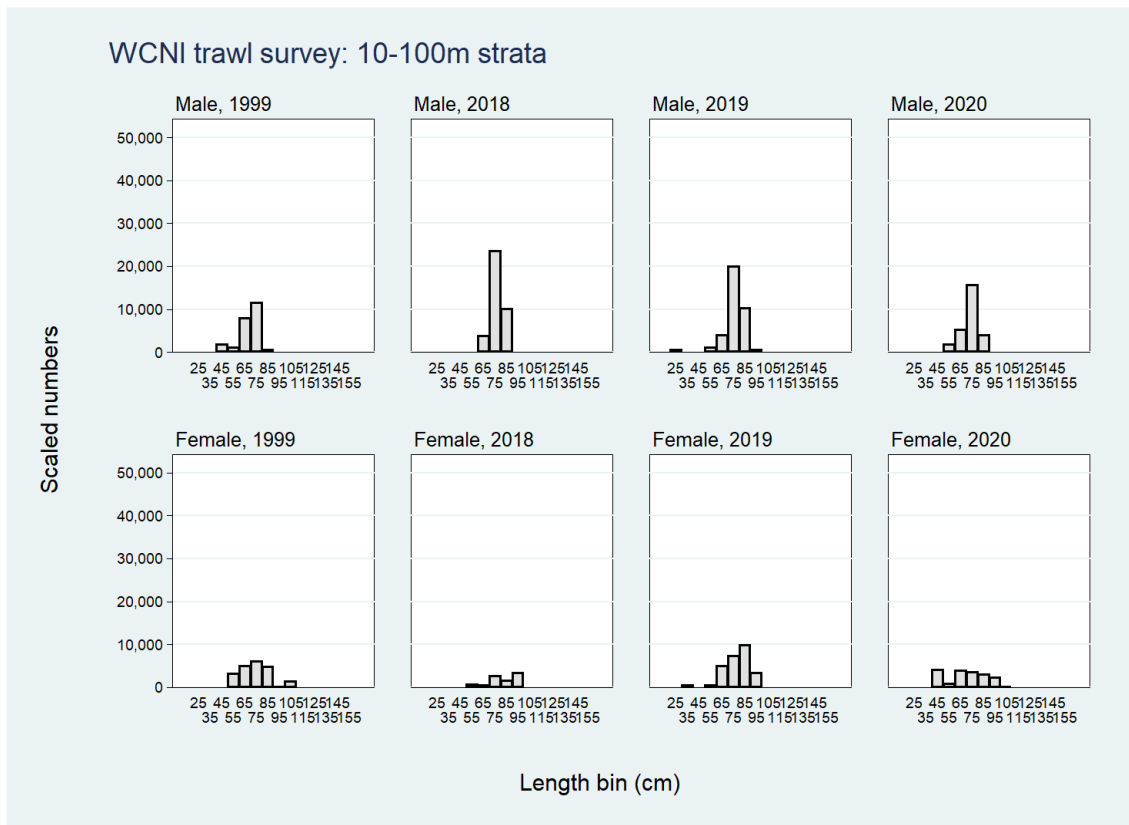
Figure 3: [Continued]. Scaled rig length frequency distributions by survey year for the eight core WCNI trawl
surveys. Number of observations by sex are given in Table 8.

East coast South Island (ECSI) inshore trawl survey

Rig biomass estimates in the east coast South Island winter trawl survey core strata (30–400 m) are
generally higher in recent years compared with the 1990s, particularly in 2021 when the biomass
estimate increased enormously but was associated with a very high CV (Table 9, Figure 4). The 10–
30 m depth range accounts for a relatively large, but variable, proportion of the total rig biomass,
ranging from 29% to 66% of the total survey biomass, indicating that these additional shallow strata are
important for monitoring rig in this area. The 2018 survey illustrates this point, with the 2018 SPO
estimate in the core strata dropping nearly 50% relative to the 2016 estimate, whereas the total 2018
estimate, which includes the shallow strata, was greater than the equivalent 2016 estimate (Table 9,
Figure 4). The core strata (30–400 m) of the ECSI winter trawl survey are not fully representative of
the rig population because there is a large and variable proportion of the rig biomass inside the 30 m
depth contour.

Table 9: Relative biomass indices (t) and coefficients of variation (CV) for rig for the east coast South Island (ECSI)
winter survey area. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata
(7 & 9 equivalent to current strata 13, 16, and 17). – , not measured; NA, not applicable.

Fishstock	Survey year	Trip number	Total biomass estimate 30–400m	CV (%) 30–400m	Total biomass estimate 10–400m	CV (%) 10–400m
SPO 3	1991	KAH9105	175	30	–	–
	1992	KAH9205	66	18	–	–
	1993	KAH9306	67	30	–	–
	1994	KAH9406	54	29	–	–
	1996	KAH9608	63	37	–	–
	2007	KAH0705	134	37	192	30
	2008	KAH0806	280	23	–	–
	2009	KAH0905	125	26	–	–
	2012	KAH1207	171	62	315	37
	2014	KAH1402	194	48	320	21
	2016	KAH1605	181	39	255	29
	2018	KAH1803	98	28	287	29
	2021	KAH2104	506	90	728	63
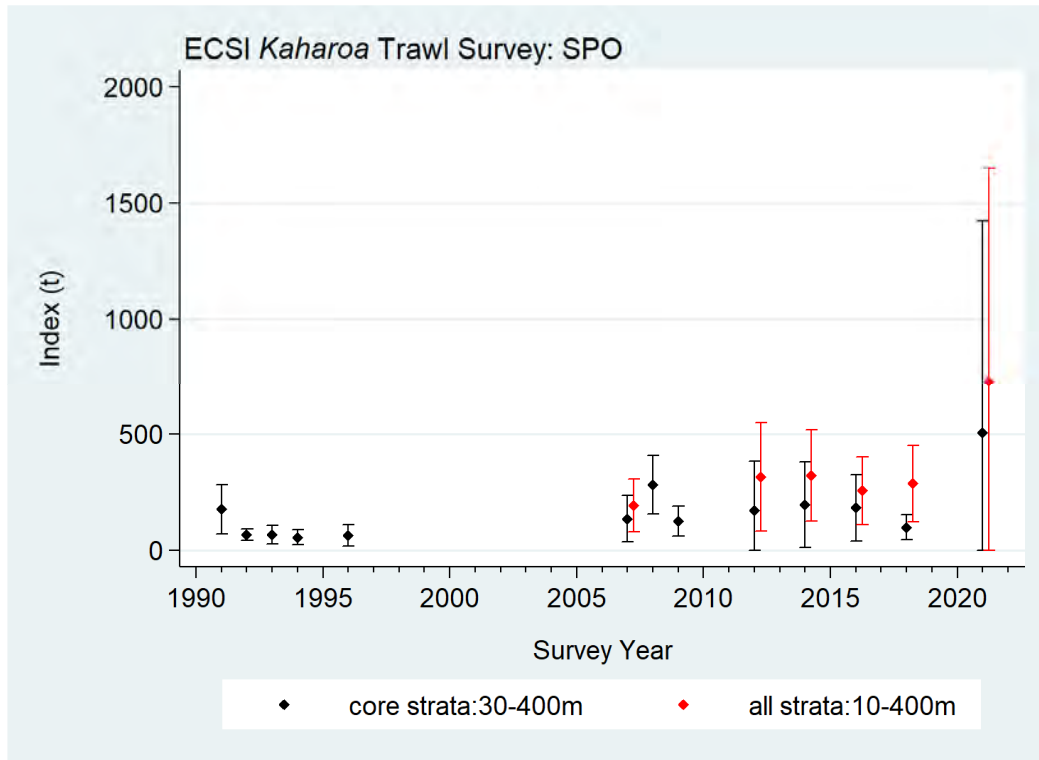
Figure 4: Rig total biomass (t) and 95% confidence intervals for all ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m) in 2007, 2012, 2014, 2016, 2018, and 2021.

Length frequency distributions: ECSI

The annual sample numbers by sex, survey year, and depth zone are given in Table 10. The length frequency distributions for the east coast South Island winter trawl surveys often have modes centred round 40 cm and 60 cm, most pronounced in the shallow 10–30 m depth range (Figure 5a, Figure 5b). These two modes correspond to pre-recruit rig of ages 1+ and 2+. Rig tended to be larger overall in the 30–400 m depth range in first four of the six survey years that covered 10–30 m strata (Figure 6). However, in 2018, rig were approximately the same size in the two strata and in 2021, rig were much larger in the 10–30 m strata than in the 30–400 m core strata definition (Figure 6). This survey appears to be monitoring pre-recruited cohorts (1+ and 2+) reasonably well, but probably not the full extent of the recruited (> 90 cm) size distribution, because the proportion of rig over 1 m long in the survey catch is low (Figure 5a, Figure 5b). Time series plots of length frequency distributions are spiky because of the low numbers caught, but the size range is reasonably consistent among surveys. The addition of the 10–30 m depth range changed the shape of the length frequency distribution, by increasing the proportion of fish under 70 cm in the survey catch. Figure 6 demonstrates that catches from the shallow (10–30 m) strata included a higher proportion of smaller rig than those in the core (30–400 m) strata in the first four surveys. High numbers of rig under 70 cm in both core and inshore strata in the 2012, 2014, and 2016 surveys were indicative of strong recruitment in recent years (Starr & Kendrick 2020).

Table 10: Number of unscaled rig captured and resulting scaled estimates of rig in numbers for the 30–400 m core and 10–30 m shallow stratum definitions used for the ECSI trawl survey. Only years with valid survey coverage in both stratum definitions are shown.

Survey year	Core (30–400 m)				Shallow (10–30 m)			
	Males		Females		Males		Females	
	Unscaled	Scaled	Unscaled	Scaled	Unscaled	Scaled	Unscaled	Scaled
2007	41	34 266	37	37 630	17	24 868	14	21 076
2012	82	57 074	63	42 570	176	78 393	221	107 109
2014	67	82 290	70	73 675	121	52 841	145	59 709
2016	68	63 209	55	50 441	98	57 318	106	61 071
2018	60	49 559	54	43 953	105	91 437	77	70 596
2021	244	149 113	216	124 452	82	111 184	76	101 502
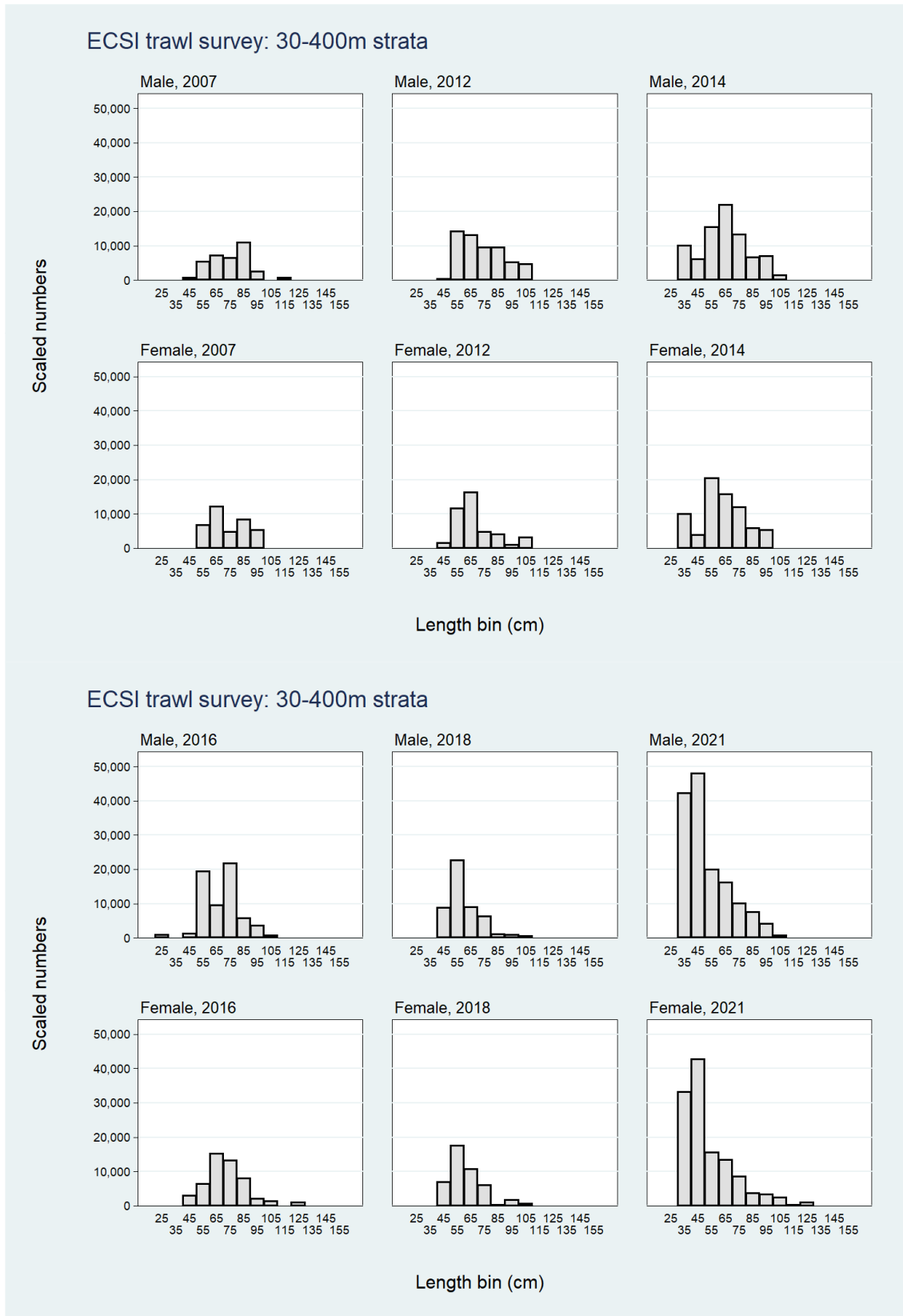
Figure 5a: Length frequency distributions for the total 30–400 m core strata for the 2007, 2012, 2014, 2016, 2018, and 2021 surveys. Number of observations by sex are given in Table 10.

ECSI trawl survey: 10-30m strata
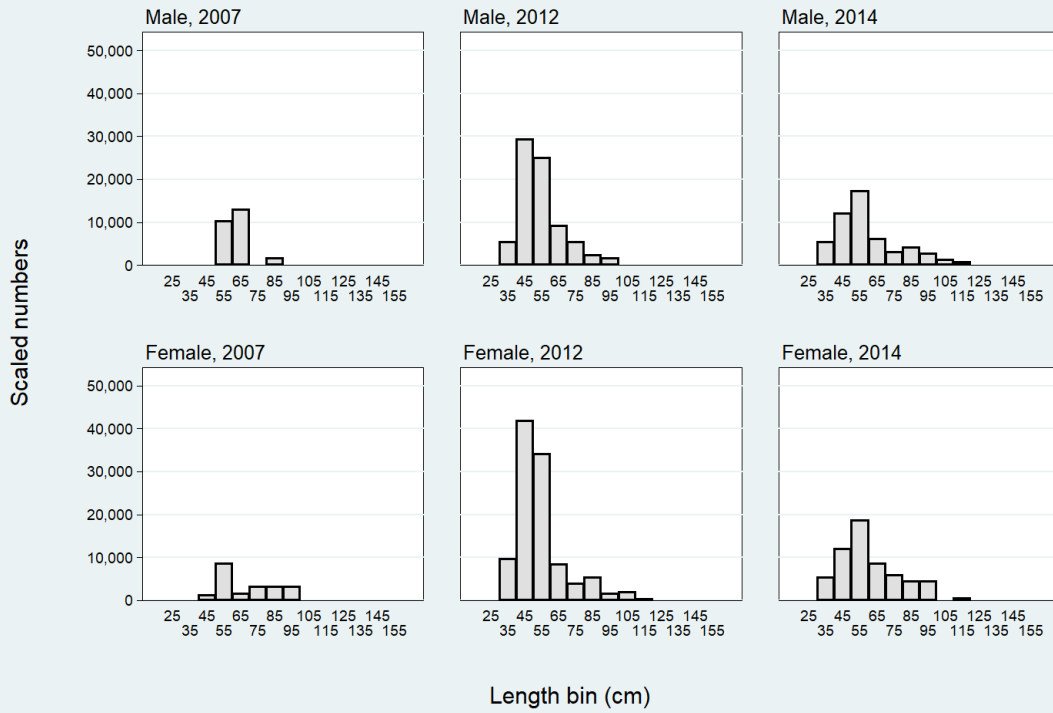
ECSI trawl survey: 10-30m strata
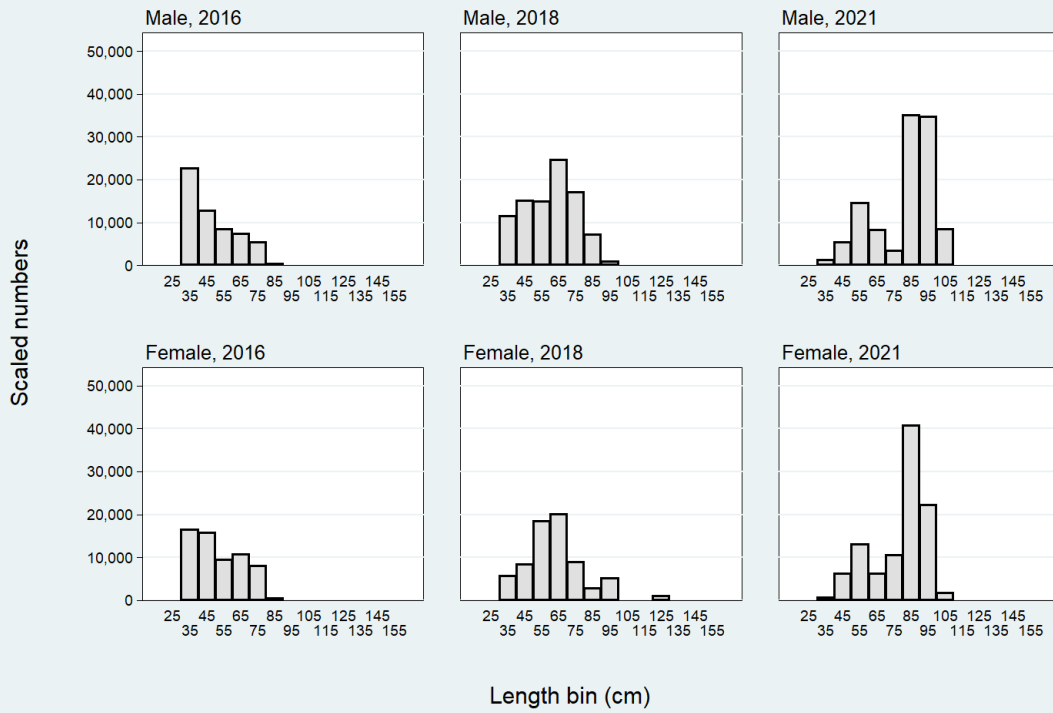
Figure 5b: Length frequency distributions for the total 10–30 m core strata for the 2007, 2012, 2014, 2016, 2018, and 2021 surveys. Number of observations by sex are given in Table 10.
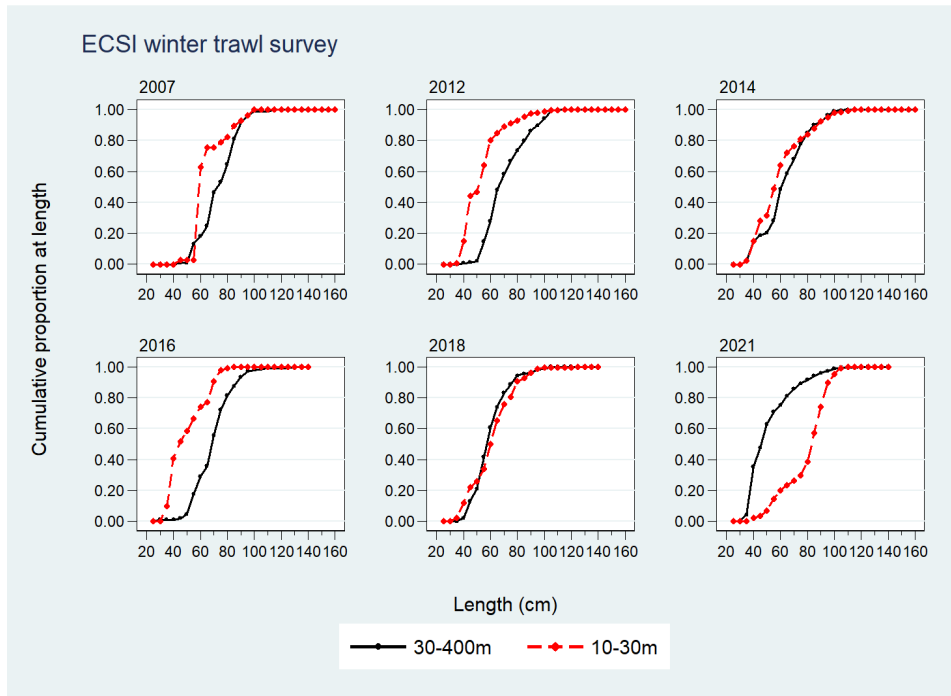
Figure 6: Empirical cumulative frequency plots for combined male and female rig comparing the cumulative length frequencies by year for the core (30–400 m) and shallow (10–30 m) strata across the six years (2007, 2012, 2014, 2016, 2018, 2021) with valid surveys in the shallow (10–30 m) strata.

West coast South Island (WCSI) inshore trawl survey
Although not optimised for rig, the west coast South Island inshore trawl survey provides useful abundance indices (Table 11, Figure 7). Stevenson & Hanchet (2000) reported that the survey is likely to provide a reasonable index of abundance for juveniles and pre-recruits less than 90 cm (Stevenson 2007). The depth range of the core survey (20–400 m) is suitable for rig but the lack of larger female rig in the length frequency distribution from the trawl survey suggests they may not be well sampled as noted by Stevenson & Hanchet (2000), but that pre-recruit and adult males are well sampled.

Total biomass has been relatively steady over time but has increased in the years up to 2015, after which the survey index values have dropped considerably with the 2021 estimate among the lowest in the series.

Length frequency distributions of rig show that distinct modes can be present in some years particularly for 0+ fish under 40 cm (e.g., 2007, 2011, 2013, and 2019) (Figure 8). Several distinct year classes are visible in some years (e.g., 2011). The distributions show that 0+ fish are relatively common in Tasman Bay and Golden Bay (e.g., 2007, 2009, 2017), but these fish are present in some years in strong numbers off the west coast as well (e.g., 2011, 2019).

Table 11: Relative biomass indices (t) and coefficients of variation (CV) for rig for the west coast South Island (WCSI) trawl survey.

Survey	Fishstock	Year	Trip number	Total biomass (t)	CV (%)
WCSI	SPO 7				
		1992	KAH9204	288	14
		1994	KAH9404	380	10
		1995	KAH9504	490	11
		1997	KAH9701	308	18
		2000	KAH0004	333	18
		2003	KAH0304	144	22
		2005	KAH0503	153	19
		2007	KAH0704	383	33
		2009	KAH0904	274	26
		2011	KAH1104	307	18
		2013	KAH1305	278	20
		2015	KAH1503	622	27
		2017	KAH1703	506	33
		2019	KAH1902	467	14
		2021	KAH2103	273	14
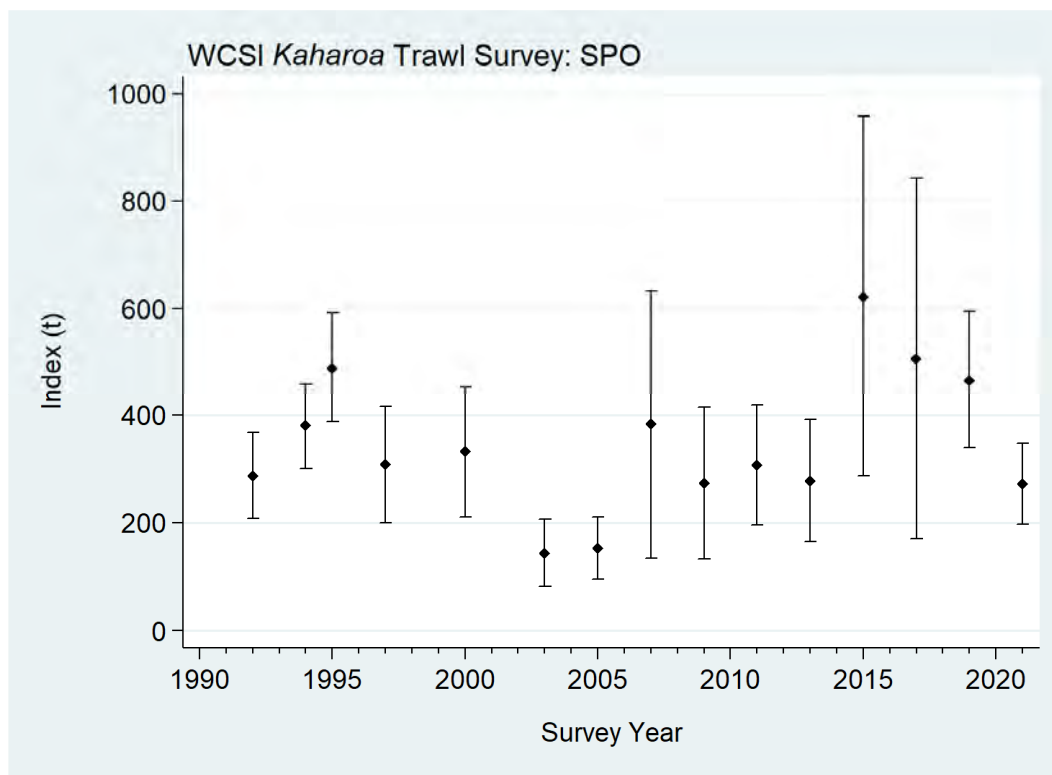
Figure 7: Plots of biomass estimates (t) for rig from the west coast South Island trawl survey by year. Error bars are ± two standard deviations.
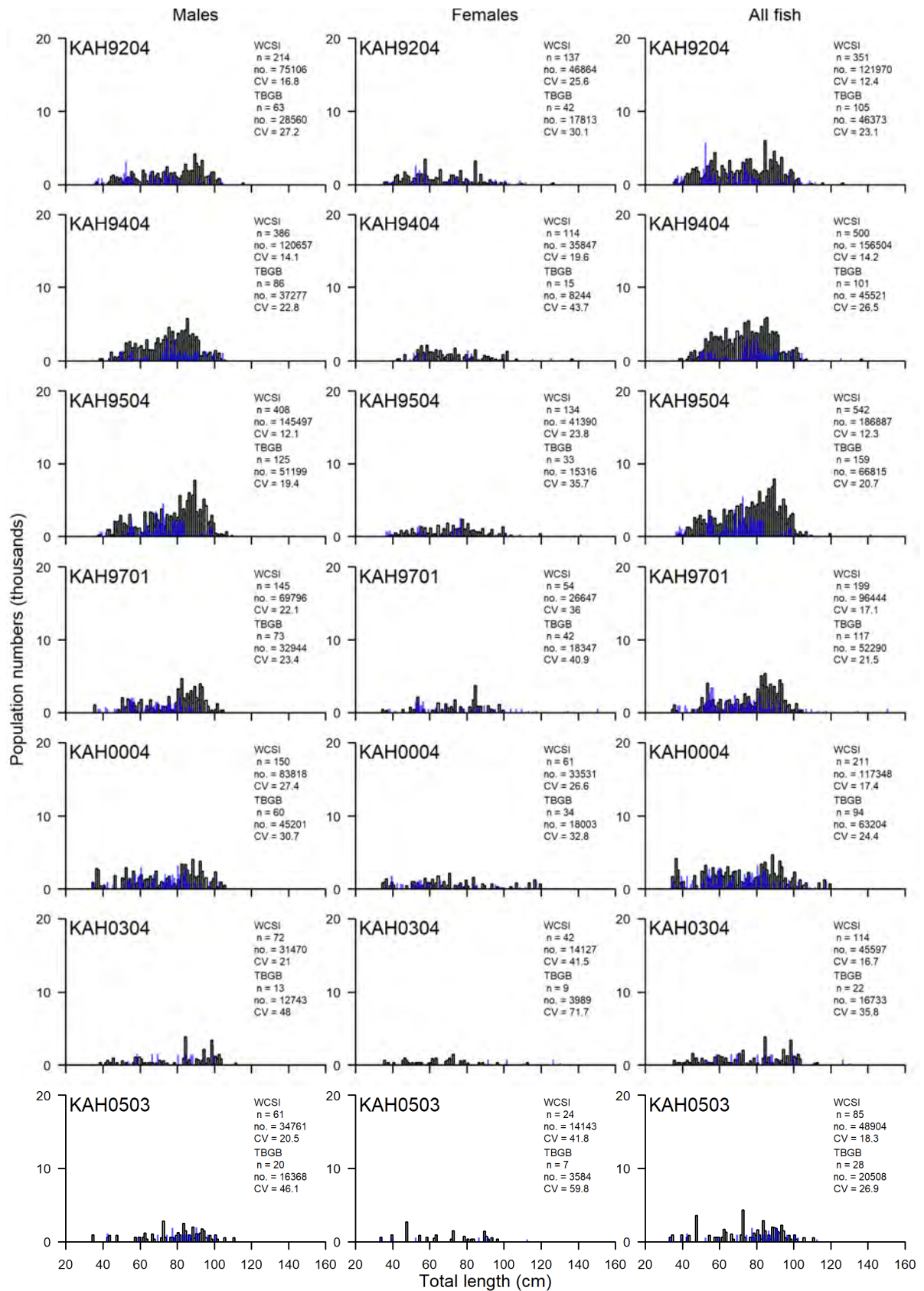
Figure 8: Scaled population length frequency distributions for rig from the west coast South Island inshore trawl survey time series core strata (20–400 m). Blue bars represent strata from Tasman Bay and Golden Bay; black bars represent the west coast of the South Island strata.
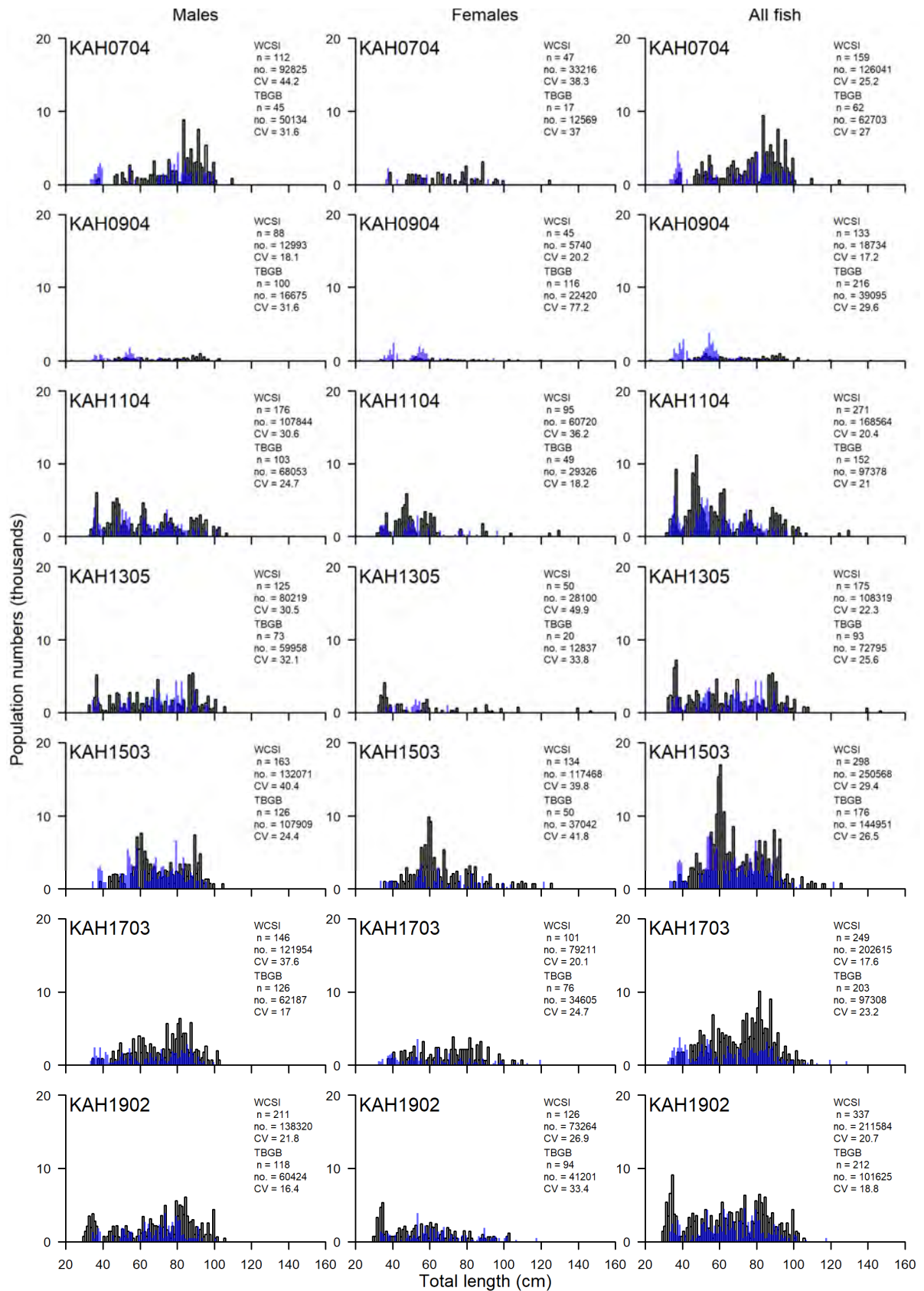
Figure 8 [Continued]

4.2   Estimates of fishery parameters and abundance

New Zealand rig stock status has been assessed based on standardised CPUE analyses of the set net and bottom trawl fisheries in SPO 3 and SPO 7 since the early 2000s. More recently, stock status for the east coast and west coast South Island rig have been evaluated against target definitions based the appropriate fishery independent trawl survey. A comprehensive CPUE analysis of the SPO 1 set net and bottom trawl fisheries was done in 2011 by Kendrick & Bentley (2012). Starr & Kendrick (2016) did an EEZ-wide CPUE analysis of all five rig QMAs in 2013. This review was repeated in 2016 (Starr & Kendrick 2017), in 2019 (Starr & Kendrick 2020), and in 2022 (Starr et al in prep).

All CPUE analyses presented here are based on commercial catch and effort data reported by fishers using compulsory statutory forms. These forms have changed over the period covered by these analyses, notably in 2006–07 for set net and 2007–08 for trawl, when the form changed from a daily report to an 'event' report, where an event is defined as a net or a collection of nets or a tow. Reporting changed again in 2019 with the introduction of electronic reporting of catch and effort. Paper forms were replaced with software installed on tablets or cell phones that controlled the recording of catch and effort data, based on specifications provided by Fisheries New Zealand. To derive a continuous series of relative abundance over these substantial changes in data collection protocols, the catch and effort data collected at an event-based level needed to be converted back into the equivalent daily form to create a series that adjusted for changes in reporting protocol. This procedure has become standard in New Zealand inshore fisheries CPUE analyses and is documented in an appendix of Starr et al (in prep).

A further complication in rig CPUE analyses is the requirement to use landed rather than estimated catch weight, because this species is processed at sea and many fishers report the estimated catch as processed weight instead of green [whole] weight. This is achieved by allocating the trip landings proportionately to each fishing day, based on the reported estimated catch by vessel, so the explanatory information associated with each day can be incorporated into the CPUE analysis. For trips when rig are landed and sold at the end of a trip, but there is no estimated rig catch information for the trip, the procedure defaults to using the effort to make the allocation. This occurs because fishers are only required to report the top five or eight species by weight per event or day (depending on the reporting format) and rig often do not reach this threshold. When this happens, it means that the CPUE for the trip is directly proportional to the effort expended, not where rig are caught. This is not usually a problem when only a small proportion (less than 10%) of the trips fall into this category, but can introduce bias when 50–80% of trips have no estimated catches, as occurs for rig caught in bottom trawl fisheries. Because of this problem, the 2016 Plenary agreed to use data amalgamated to the level of a complete trip for all rig bottom trawl CPUE analyses. The auxiliary information on location of capture and intended target species was retained by assigning each trip with the value of the most frequent statistical area occupied and the most common target species.

The set net CPUE data were prepared by amalgamating the estimated catch and effort data and other associated information (month, year, target species, vessel, statistical area) to represent a day of fishing. The procedure assigns the most frequent statistical area and target species for that day of fishing to the trip/date record. All estimated catches for the day were summed and the five species with the greatest catch were assigned to the date. Landings were then assigned to each daily record in one of two ways: 1) by allocating the landings for the trip proportionately to the estimated catch for each day of fishing; or 2) calculating a 'vessel correction factor' (*vcf*) for each vessel in a year (Kendrick & Bentley 2012). This factor is then applied to all estimated catches for that vessel in that year. Only *vcf* values in a specified range (0.75 to 2.0) were used, dropping all remaining vessels. This latter procedure is required in SPO 1 because fishers in that QMA tend to hold back their catch rather than deliver it to a Licensed Fish Receiver (LFR), thus breaking the link between the effort part of the form which holds the effort, location of catch, and the catch estimate and the landing part of the form which holds the verified catch information. The ERS protocol introduced a new QL code for fish held in temporary holding facilities on land; this is a final destination code and fishers can update their original landing records for a trip when deferred landings are sold to an LFR. However, this analysis treated deferred landing data from the paper and ERS systems in the same manner by scaling estimated catches using an annual vessel-specific ratio.

The set net and bottom trawl CPUE analyses were conducted in a similar manner and included: a) identification of core vessels which participated consistently in the fishery for a reasonably long period so that the analysis could be confined to these vessels; b) a stepwise selection of explanatory variables, with each step selecting the variable with the greatest remaining explanatory power, after forcing fishing year (the abundance variable) as the first variable. The available explanatory variables included fishing year (forced), month, vessel, statistical area, target species, duration of fishing, and length of net set (for the set net analysis) or number of tows (for the bottom trawl analysis). For the set net fishery, it was considered appropriate to sum the length of net set to move from an event report to a daily report because of how the instructions were given for NCELR and ERS reporting. However, it was determined that it was not appropriate to sum the duration of time that multiple nets were in the water when amalgamating this variable to a daily event. Instead a 'soak time' variable was implemented which calculated the time the first net was set in a day of fishing to the time when the last net was pulled. This 'soak time' variable returned better model diagnostics when compared with the same model using a summed duration variable or with dropping the duration variable.

The landing information had been corrected for changes in conversion factors that have occurred over the history of the dataset as well as to eliminate trips with unreasonably large landings (Starr & Kendrick 2016). Three standardised analyses were conducted for all bottom trawl fisheries: a) a lognormal non-zero catch model; b) a binomial presence/absence catch model; and c) a delta-lognormal model that combines the two series, using the method of Vignaux (1994). The Inshore Working Group agreed to use combined models which integrate the signal from the tows with positive catch with the signal from presence/absence models based on the same data. These methods are preferred for use as the basis for monitoring species that are taken by bottom trawl, especially those for species taken predominantly as bycatch. Simulation work has shown that the use of the combined series accounts for reporting trends as well as trends in the incidence of capture (Langley 2019). Only standardised models based on positive catch records were used for the SPO 1 set net CPUE analyses. This is because zero catch records are relatively rare (less than 5% in most instances and only rarely >10%). Experience has shown that models which combine positive and zero catch information are nearly indistinguishable from the positive catch model when the zero catch records are less than 10% of the total records. Combined models were introduced for the SPO 3 and SPO 7 set net analyses in 2022 because of a higher incidence of zero effort records than seen in SPO 1.

SPO 1
Standardised CPUE indices were calculated for five SPO 1 set net fisheries by modelling (GLM) non-zero catches by core vessels targeting rig and other shark species when this species was reviewed in 2016. Two coastal bottom trawl fisheries targeting a range of species were analysed by combining a non-zero catch series with a binomial presence/absence series. The SPO 1 set net analyses were complicated by the fact that up to 50% of the set net landings were accumulated using intermediate destination codes for subsequent landing to a Licensed Fish Receiver, thus breaking the link between effort and landing within a trip. Estimated catches are unreliable in rig fisheries because many fishers report the processed weight rather than the equivalent green weight. This problem was solved by applying a 'vessel correction factor' (*vcf*), calculated for each vessel and year, to correct the estimated catch observations (see above).

SPO 1E
In 2016, three CPUE analyses for SPO 1E were presented to the Working Group: a) a target shark (NSD, SPO, SHK, SPD) set net fishery operating in the Firth of Thames (Statistical Area 007) [SN(007)]; b) a target shark set net fishery operating in the remaining SPO 1E Statistical Areas (002 to 006 and 008 to 010) [SN(coast)]; and c) a mixed target species (SNA, TRE, GUR, JDO, BAR, TAR) bottom trawl fishery operating in all SPO 1E Statistical Areas (002 to 010) [BT(coast)].

The Southern Inshore Working Group (SINSWG) and Plenary gave the SN(007) series a research rating of '2' because, although this fishery targets mature female rig and the diagnostics were considered credible, it provides an index of abundance for only a portion of the total area. The Plenary gave the BT(coast) and SN(coast) series research ratings of '3' because annual catches were unacceptably low and, in the case of the set net index, the fishing locations were widely dispersed and occupied sporadically. The latter two series were not updated in 2019 or in 2022 (Starr & Kendrick 2019,

Starr et al in prep) because of their low research rating. The SN(007) analysis was updated, showing a relatively strong upturn from the 2013 to 2019, followed by a decline in 2020 and 2021 (Figure 9).
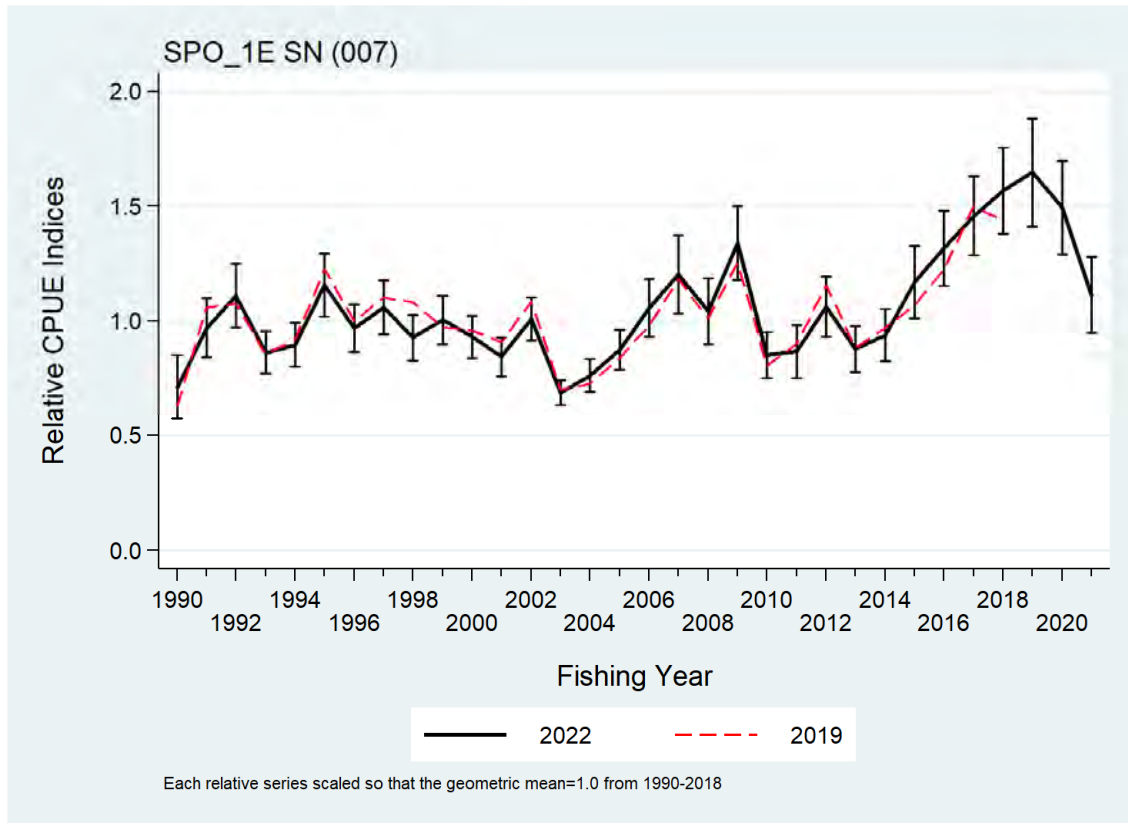
Figure 9: Standardised CPUE for SPO 1E in the target shark set net in the Firth of Thames (Statistical Area 007) [SN(007)]. Error bars show 95% confidence interval on the prediction.

SPO 1W

In 2016, four CPUE analyses for SPO 1W were presented to the Working Group: a) a target shark (NSD, SPO, SHK, SPD) set net fishery operating in Manukau Harbour (Statistical Area 043) [SN(043)]; b) a target shark set net fishery operating in Kaipara Harbour (Statistical Area 044) [SN(044)]; c) a target shark set net fishery operating in all the remaining SPO 1W Statistical Areas (042, 045–048) plus the most northerly SPO 8 Statistical Area (041) [SN(coast)]; and d) a mixed target species (SNA, TRE, GUR, JDO, BAR, TAR) bottom trawl fishery operating in all SPO 1W Statistical Areas (042, 045–048) [BT(coast)] outside the harbours plus the most northerly SPO 8 Statistical Area (041).

The 2016 Plenary assigned the BT index a quality ranking of '1', but noted that, although the analysis was credible, the method of capture does not representatively sample large female rig. The two harbour-based set net indices were given a ranking of '2' (medium or mixed quality) because they are probably indexing localised abundance. The Plenary rejected the coastal set net index as an index of abundance on account of the considerable impact the dolphin closures have had on this fishery.

The coastal set net index series was not updated in 2019 or in 2022 (Starr & Kendrick 2019, Starr et al in prep) because of its rejection in 2016. The other three series were updated in 2022. The coastal BT series has shown a slow increasing trend since the mid-2000s to about 2012, followed by a period of relative stability extending to 2021. The SN(043 Manukau Harbour) series showed a strong decline in the early part of the series while the SN(044 Kaipara Harbour) series declined in the first one or two years in the series. Both set net indices showed a slowly declining trend into the early 2000s, followed by a period of relative stability (Figure 10). The Manukau series has trended upward beginning in 2019 while the Kaipara series has remained stable.
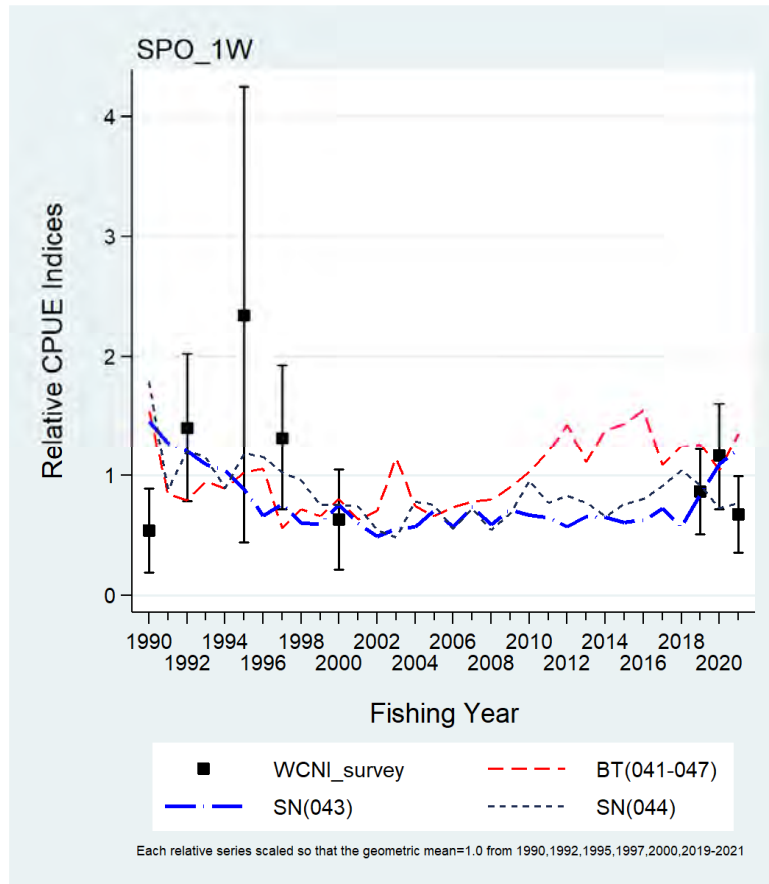
Figure 10: Comparison of standardised CPUE for SPO 1W in three fisheries: a) target shark set net in Manukau Harbour (Statistical Area 043) [SN(043)]; b) target shark set net in Kaipara Harbour (Statistical Area 044) [SN(044)]; c) coastal bottom trawl north of Cape Egmont [BT(041-047)]. Also shown are the WCNI trawl survey core 10–100 m biomass indices offset by one year to match the fishing year definition. Error bars are ±2 standard errors.

SPO 2

As done in 2016 and 2019, a trip-based bottom trawl series was used to index SPO 2 relative abundance from 1989–90 to 2020–21 (Starr et al in prep). The corresponding set net analysis was not repeated due to the small amount of available data. The SPO 2 landing data, regardless of the method of capture, did not exhibit the behaviour observed in SPO 1 of landing to temporary holding receptacles. Only one SPO 2 (BT) analysis was conducted in 2022; with this analysis defined by selecting trips which fished exclusively in the Statistical Areas 011–015 and targeted flatfish, red gurnard, or tarakihi.

The trip-based combined SPO 2 series constructed from bottom trawl data showed a gradually increasing trend from 1989–90 to 2011–12, after which the series showed an increasing trend to the end of the series (Figure 11). There was some year-to-year variability beginning around 2014, but the overall trajectory appeared to be upward. The Plenary gave the BT(trip) series an overall assessment quality rank of '1' but noted that, though the analysis was credible, the method of capture does not representatively sample large female rig. An event based (tow-by-tow) standardised analysis was introduced in 2022 as a diagnostic to test whether amalgamating the data to the level of a complete trip was introducing bias. This analysis determined that this series agreed well in the overlapping years.

Establishing B_{MSY} compatible reference points

The Plenary agreed to use a Proxy for B_{MSY} based on the average CPUE during 2005–2015, a period of relatively stable CPUE and catches.
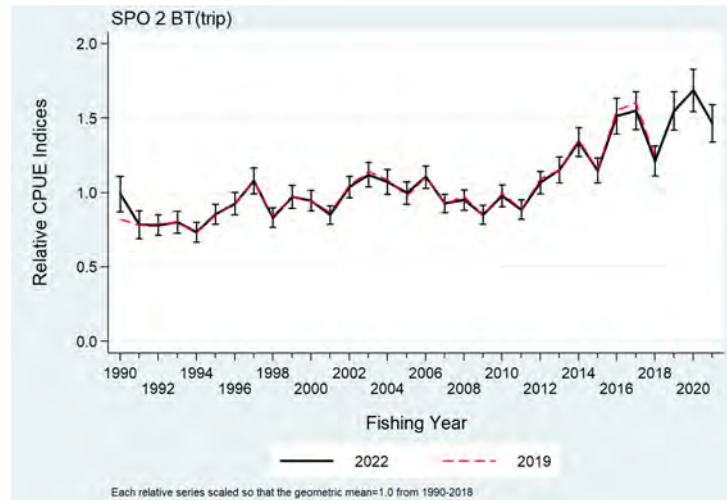
Figure 11: Standardised combined delta-lognormal CPUE series for SPO 2 bottom trawl based on trips which landed rig from Statistical Areas 011 to 015 and targeted flatfish, red gurnard, or tarakihi up to 2020–21. Also plotted is the equivalent series from the 2019 SPO 2 review. Error bars are ±2 standard errors.

SPO 3

Rig in SPO 3 are mostly landed in the shark set net and bottom trawl fisheries directed at a range of species, with additional small amounts landed by Danish seine vessels. Two CPUE standardisations were accepted by the Working Group in 2016, one based on a shark target set net fishery (SN[SHK]) and the other based on a mixed target species (flatfish, barracouta, red cod, tarakihi, stargazer, elephantfish, and red gurnard) bottom trawl fishery (BT[All]). Two bottom trawl series had previously been constructed from the bottom trawl data, separating the target flatfish data from other target species that are taken at deeper depths. However, the switch to a trip-based analysis showed that the two SPO 3 bottom trawl fisheries (FLA and MIX) had very similar CPUE trends for rig. The SINSWG agreed that it would be advisable to perform a single analysis on the full suite of bottom trawl target species, amalgamated at the level of a trip. The final two fisheries (set net and trawl) will have different selectivities, harvesting a different size range of rig, with the set net fishery taking larger fish and the trawl fishery taking juveniles and sub-adults.

The SPO 3 landing data, regardless of the method of capture, did not exhibit the behaviour observed in SPO 1 of landing to temporary holding receptacles.

While the 2019 review (Starr & Kendrick 2020) repeated the BT(All) and SN(SHK) analyses, the INSWG requested in 2022 to split the SPO 3 QMA into two parts: a) east coast, incorporating Statistical Areas 018 (Kaikōura/Motunau), 020 (Pegasus Bay), 022 (Canterbury Bight), 024 (Oamaru/Timaru), and 026 (Catlins) and b) Foveaux Strait, incorporating Statistical Areas 025 (eastern Foveaux St), 027 (south east side Stewart Island), 028 (south end Stewart Island), 029 (west side Stewart Island), 030 (western Foveaux St), and 031/032 (Fiordland). This decision was prompted by the diagnostics, with the implied residuals from the full SPO 3 SN (daily) model showing poor correlations for most of the statistical areas compared with the overall annual model trend. The same was true for the SCH and SPO target species, again showing low correlation with the overall annual model trend. Implied residual correlations between statistical areas and target species with the overall model annual trend were much better for the SPO 3 BT (trip) model. However, there were several anomalies which suggested that a split region model should be explored for this series as well.

The split SPO 3 BT east coast (trip) and the SPO 3 BT Foveaux St (trip) models showed implied residual correlations for all statistical areas that were equivalent to the full SPO 3 BT (trip) model, except for Statistical Area 025, which was improved under the split SPO 3 BT Foveaux St (trip) model. Similarly, the two split SPO 3 BT models and the full SPO 3 BT model had similar implied target species residuals, except for STA target, which again were better under the SPO 3 BT Foveaux St model because the majority of STA targeting was in the more southerly statistical areas. Figure 12 (top panel) shows that the SPO 3 BT east coast (trip) model closely resembles the full SPO 3 BT (trip) model while

the SPO 3 BT Foveaux St (trip) model is more variable (likely due to limited data for this model) but still provides good corroboration with the SPO 3 BT east coast (trip) model.

The implied residual comparisons were more problematic for the SPO 3 SN (daily) model, with none of the statistical areas in the full model showing strong correlations with the overall annual model trend, While the statistical area implied residual correlations were weaker for the SPO 3 SN split models than for the corresponding split SPO 3 BT models, they were nevertheless better in the spatially split models than in the full SPO 3 SN model. The INSWG accepted the two spatially split SPO 3 SN models over the full SPO 3 SN model, reasoning that the relatively poor implied residual statistical area correlations in all these models were likely to be evidence that there is spatial heterogeneity among mature rig in SPO 3 at a finer scale than the available data. As for the target species implied residuals in the spatially split SPO 3 SN models, the correlation was considerably improved for SPO (the dominant target species) in the SPO 3 SN east coast model while the SCH (again the dominant target species) correlation was much better in the SPO 3 SN Foveaux St model. As seen for the SPO 3 BT models, all three of the SPO 3 SN models resemble each other, with the SPO 3 SN east coast model (which has the majority of the data) closer to the full SPO 3 SN model while the SPO 3 SN Foveaux St model is more variable than the other two models (Figure 12, lower panel). The three SN models have similar relative levels in 2020 and 2021 even though they have different intermediate trajectories (Figure 12).
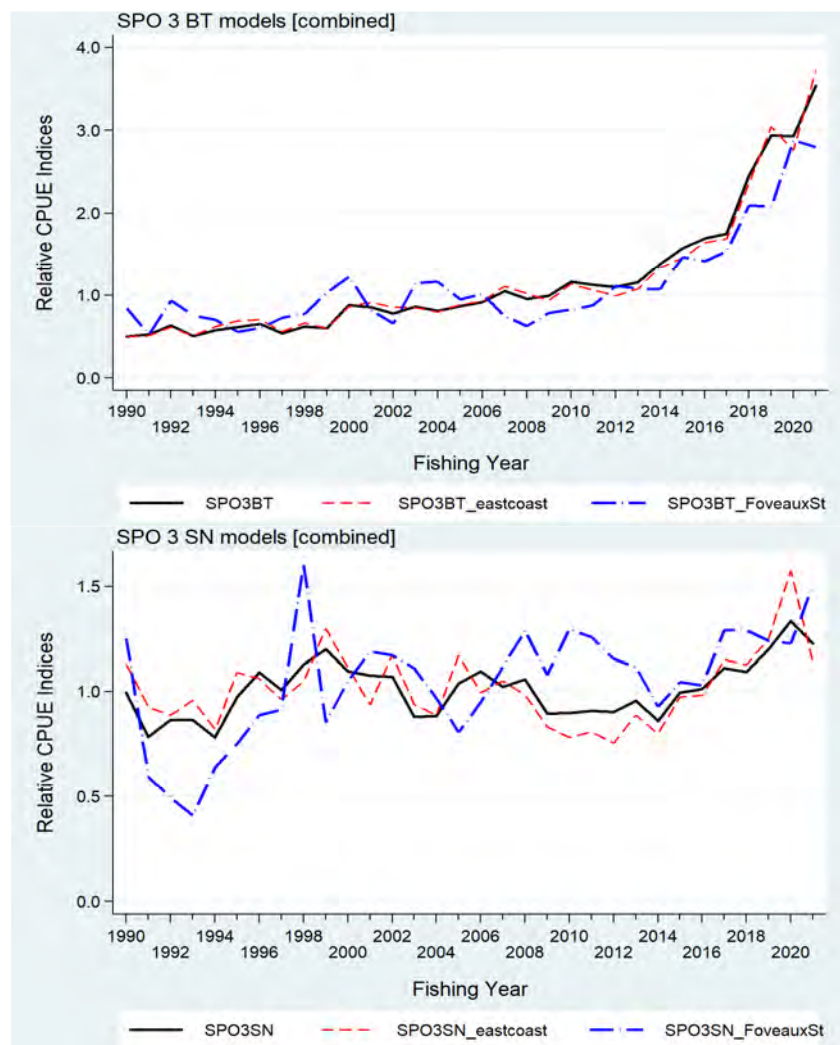
Figure 12: Comparison of the standardised combined indices for three SPO 3 BT CPUE series (top panel) and three combined SPO 3 SN CPUE series (bottom panel). For both BT and SN, the three models were defined in terms of the contributing statistical areas, with the 'full' SPO 3 model incorporating all the inshore Statistical Areas (018, 020, 022, 024, 026, 025, 027, 028, 029, 030, 031) while the 'east coast' models use Statistical Areas 018, 020, 022, 024, and 026 and the Foveaux St models use Statistical Areas 025, 027, 028, 029, 030, and 031.

SPO 3 east coast

The SPO 3 BT east coast (trip) series showed an increasing trend from 1989–90 to 2016–17, after which the trend accelerated, more than doubling the relative CPUE between 2018 and 2021 (Figure 13). The SPO 3 SN east coast (daily) series fluctuated without trend over the same period (Figure 13). The point estimates for rig from the east coast South Island (ECSI) winter trawl survey all strata (10–400 m) largely followed the pattern of the SPO 3 BT east coast (trip) series, except for the 2007 observation which doesn't match the equivalent SPO 3 BT east coast (trip) index very well. The 2021 ECSI point index value mirrors the large increase for the same year in the SPO 3 BT east coast series. Unfortunately, the associated CV for this index value (63%) was so large that this index must be considered unreliable.

Each relative series scaled so that the geometric mean=1.0 from 2007,2012,2014,2016,2018,2021
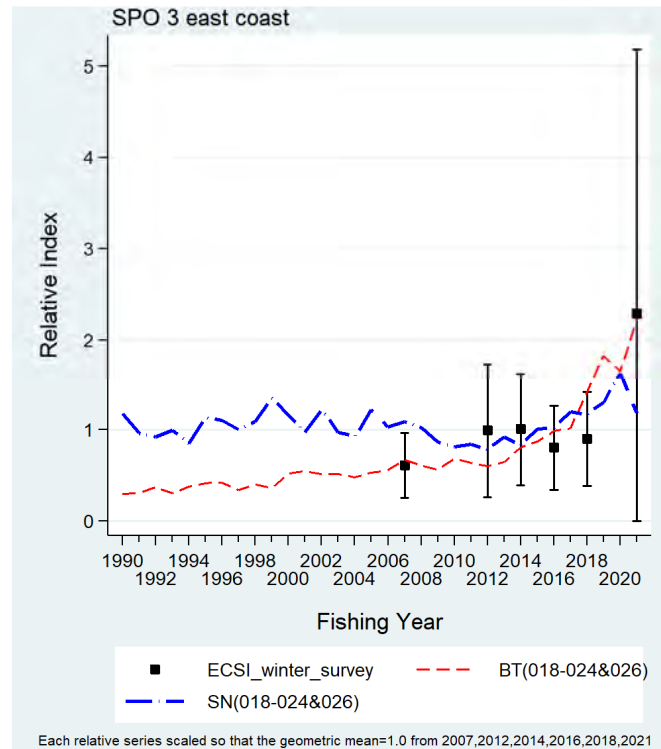
Figure 13: Comparison of two SPO 3 east coast (Statistical Areas 018, 020, 022, 024, and 026) standardised CPUE series: a) bottom trawl fishery (mix of targets in SPO 3 east coast statistical areas) [BT(018-024&026)]; b) shark target set net fishery [SN(018-024&026)]. Also shown are rig index values from the east coast South Island (ECSI) trawl survey (all strata, 10–400 m): 2007, 2012, 2014, 2016, 2018, and 2021, with error bars ± 2 standard errors.

By combining length frequency (LF) distributions across years to overcome small sample sizes, Figure 14 shows there were substantial differences in the mean LF distributions between the ECSI trawl survey, the SPO 3 BT east coast fishery, and the SPO 3 SN east coast fishery, with the set net LF distributions lying to the right of the bottom trawl LF distributions which are again to the right of the survey LF distributions. There is also a suggestion that the female set net LF distributions lie to the right of the equivalent male SN LF distributions, while the corresponding bottom trawl and survey LF distributions are reasonably similar between the two sexes.

Establishing B_{MSY} compatible reference points

The conclusion that the core strata (30–400 m) of the ECSI winter trawl survey were not fully representative of the rig population rendered the previously selected B_{MSY} proxy target reference point invalid because it was based on the core strata (see Figure 6 for comparative LFs by year and stratum definition). The INSWG agreed to revise the definition of the B_{MSY} proxy target reference point to be the geometric average of the five survey years which adequately covered the 10–30 m strata (2007, 2012, 2014, 2016, and 2018). It is not possible to use the 2021 index value in this definition given the very large CV (63%) associated with this index. The rationale for choosing this period was that abundance was stable and catches were relatively high, indicating high surplus production. The Soft Limit will be one-half of the B_{MSY} proxy and the Hard Limit will be one-quarter of the B_{MSY} proxy.
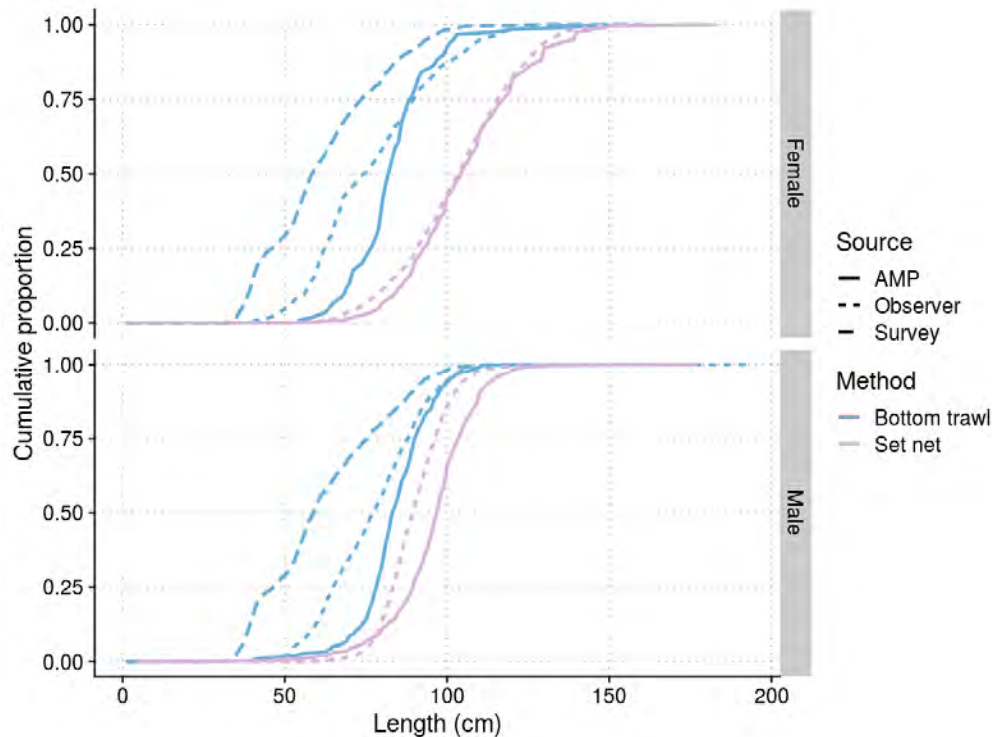
Figure 14: Empirical cumulative length frequencies for male and female rig from ECSI trawl surveys (2007, 2012, 2014, 2016, 2018, 2021; 10–400 m strata), observer sampling, and AMP data from Statistical Areas 018–024 and 026. The AMP data were collected in the 1995–2008 fishing years and the observer data in the 2008, 2010–2021 fishing years.

SPO 3 Foveaux Strait

The SPO 3 BT Foveaux St (trip) series showed a slow increasing trend from 1989–90 to 2013–14, after which the trend accelerated, doubling the relative CPUE between 2015 and 2021 (Figure 15). The SPO 3 SN Foveaux St (daily) series showed a slowly increasing trend over the same period (Figure 15). This difference in trends may be due to the different nature of the fisheries, with the set net fishery being primarily composed of the bycatch of rig when targeting school shark whereas the bottom trawl fishery is a mix of target flatfish and target stargazer fishing. It is likely that the set net fishery is capturing mature rig while the bottom trawl fishery will be taking immature and sub-adult rig.

By combining length distributions across years to overcome small sample sizes, Figure 16 shows there were substantial differences in the mean length frequency (LF) distributions between the SPO 3 BT Foveaux Strait fishery and the SPO 3 SN Foveaux Strait fishery, with the set net LF distributions lying to the right of the bottom trawl LF distributions. There is also a suggestion that the female LF distributions lie to the right of the equivalent male LF distributions for AMP SN and BT as well as the observer BT distributions.
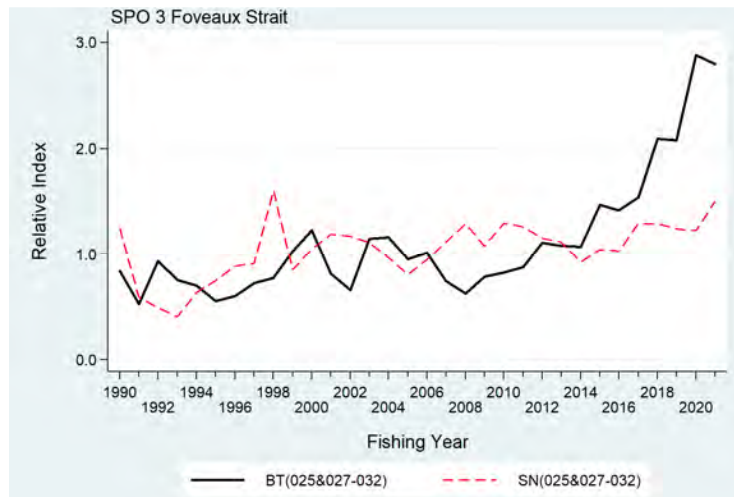
Figure 15: Comparison of two SPO 3 Foveaux Strait (Statistical Areas 025, 027, 028, 029. 030, 031, and 032) standardised CPUE series: a) bottom trawl fishery (mix of targets in SPO 3 east coast statistical areas) [BT(025&027–032)]; b) shark target set net fishery [SN(025&027–032)].

Establishing B_{MSY} compatible reference points

In 2022, the Inshore Working Group adopted the geometric mean CPUE from the SN(025&027–032) series for the period 2002–2012 as the target reference point for SPO 3 Foveaux Strait. This was a period with stable CPUE indices and relatively stable catch. The INSWG agreed that during this period the stock was likely to be between the 40% B_0 target and the 20% B_0 soft limit, leading to the conclusion that the average CPUE in this period nominally represented 30% B_0. Incorporating this biomass definition into the default Harvest Strategy Standard results in a 40% B_0 target that is 4/3 times (1.333) the defined reference period level, and two-thirds and one-third of the reference period level for the Soft (20% B_0) and Hard (10% B_0) Limits, respectively.
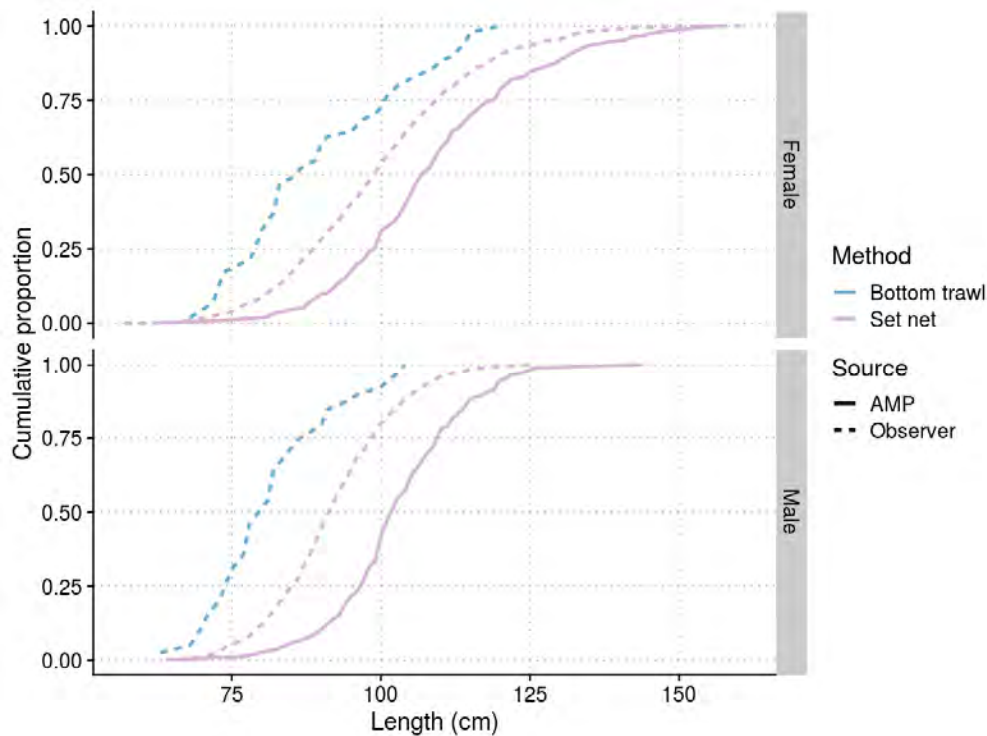
Figure 16: Empirical cumulative length frequencies for male and female rig from observer sampling and AMP data from Statistical Areas 025 and 027–031. The AMP data were collected in the 1996, 1997, 1999–2001, 2004 fishing years and the observer data in the 2008, 2010, 2012, 2015–2021 fishing years.

SPO 7

CPUE analyses standardising set net and bottom trawl catches for core vessels were undertaken in 2016 to assess relative abundance of rig in SPO 7. Two of these analyses were updates of analyses previously accepted by the Working Group: 1) set net fishery in Statistical Area 038 targeting rig, spiny dogfish, and school shark [SN(038)]; and 2) bottom trawl fishery in Statistical Areas 016–018, 032–037, 038, 039, and 040 targeting flatfish, red cod, rig, barracouta, tarakihi, red gurnard, snapper, blue warehou, and trevally [BT(ALL)]. An analysis of the set net fishery in Statistical Areas 032–037 was rejected by the SINSWG in 2016 (after being accepted in the 2006–2013 analyses) because of lack of sufficient data to create a reliable index. This lack was attributed to the movement of ACE to other SPO 7 fisheries and the management regulations imposed to protect Hector's dolphins. Examination of the distribution of set net effort off the west coast of the South Island showed that there had been a substantial decline in the number of vessels operating in these statistical areas since 2005–06, with less than 2% of the set net fishery catches originating from statistical areas other than Statistical Area 038 during 2015–16 to 2017–18. In 2016, an alternative set net fishery analysis was trialled (SN[STB]), covering the statistical areas of the South Taranaki Bight (037, 039, and 040). This was done after examining the fine scale spatial distribution of catches in these three statistical areas, showing that most of the catch came from the coastal section of South Taranaki Bight. This analysis also showed there was catch in Statistical Area 037 on the line separating Statistical Areas 037 and 038 (between D'Urville Island and Farewell Spit) which may belong more logically to the Statistical Area 038 analysis. However, spatial data at this level of detail are not available before October 2007 from the earlier daily forms. The SN(STB) series was rejected by the 2016 Plenary (quality ranking of '3') on account of the impact the dolphin closures have had on this fishery.

The SPO 7 landing data, regardless of the method of capture, did not exhibit the behaviour of landing to temporary holding receptacles observed in SPO 1.

The 2019 and 2022 reviews (Starr & Kendrick 2019, Starr et al in prep) repeated the BT(All) and SN(038) analyses. The SN(038) index, which was assigned a quality ranking of '1', showed a continuous declining trend from the beginning of the series to a low in the mid-2000s, approximately coincident with the lowering of the SPO 7 TACC. This low point was followed by an increasing trend to a peak in 2010–11, after which the series varied about the series mean up to 2018–19 when it trebled over the next two years (Figure 17). However, these increases are unreliable, given that only two vessels participated in this fishery in 2019–20, and just a single vessel in 2020–21. It is now likely this series will have to be abandoned from lack of supporting data.

The BT(ALL) series (with a quality ranking of '1') showed an increasing trend since the mid-2000s, with low points observed in both 2004–05 and 2006–07, but has since shown a generally increasing trend which, like the SPO 3 BT series, has accelerated in 2019–20 and 2020–21 to three and four times the long-term average index. The Plenary noted that the BT(All) index does not adequately sample large female rig. Event based (tow-by-tow) standardised analyses were undertaken in both 2019 and 2022 as diagnostics to test whether amalgamating the data to the level of a complete trip was introducing bias. These analyses determined that the series agreed well in the overlapping years.

Although large rig are not effectively targeted with bottom trawl gear, the WCSI trawl survey is believed to provide reliable indices of the relative biomass of males and younger females in SPO 7. Relative biomass declined by more than 50% between 1995 and 2005, and subsequently increased to a stable level from 2007 to 2013. It then increased sharply in 2015, with total biomass remaining high in the 2017 survey, but then dropping relative to the 2015 index in 2019 and even more in 2021 (Figure 7, Table 11). The 2021 WCSI survey rig biomass index contradicts the strong increase in CPUE observed in the BT(All) series.
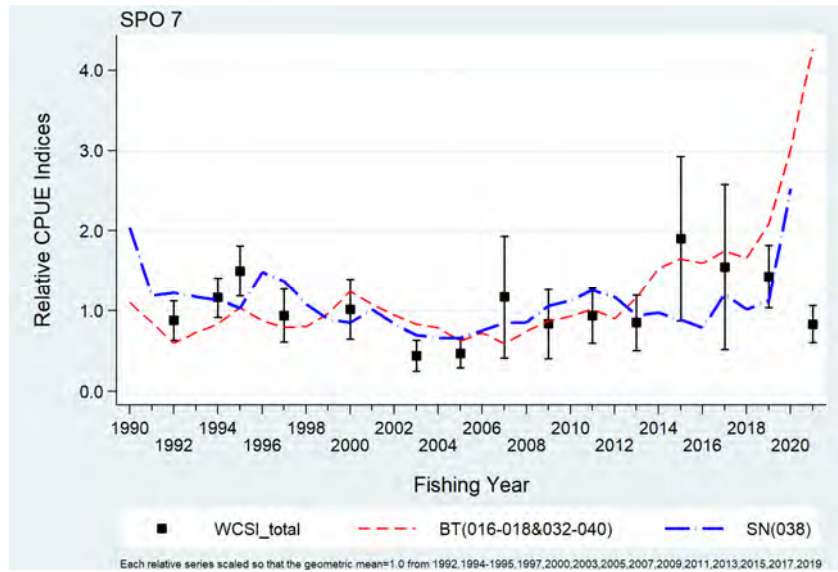
Figure 17: Comparison of two SPO 7 standardised CPUE series: a) bottom trawl fishery (mix of targets in all SPO 7) [BT(016-018&032-040)]; b) shark target set net fishery in Tasman Bay/Golden Bay [SN(038)]. Also shown are rig index values from the west coast South Island (WCSI) trawl survey: 1992–2021. The 2021 index value for the SN(038) analysis was dropped because it was based on a single vessel.

By combining length frequency (LF) distributions across years to overcome small sample sizes, Figure 18 shows there were substantial differences in the mean LF distributions between the WCSI trawl survey, the SPO 7 BT fishery, and the SPO 7 SN fishery, with the female set net LF distributions lying to the right of the bottom trawl LF distributions (AMP and observer) which are again to the right of the survey LF distributions. However, the male LF distributions from both the SN and BT fisheries are very similar while the survey distribution lies to the left of the commercial fishery LFs.
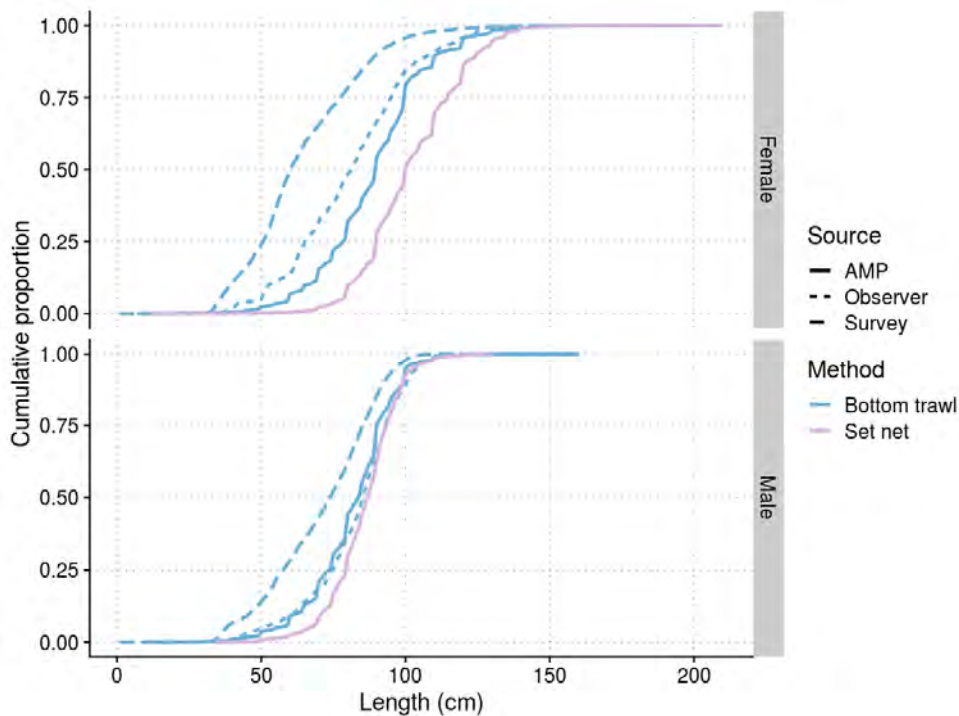
Figure 18: Empirical cumulative length frequencies for male and female rig from WCSI trawl surveys (1992, 1994, 1995, 1997, 2000, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019, 2021), observer sampling and AMP data from Statistical Areas 032–-038. The AMP data were collected in the 1996, 1997, 2001–2012, and 2014 fishing years and the observer data in the 1995, 2005, 2010-2013, 2016, and 2017 fishing years.

Establishing B_{MSY} compatible reference points

The Inshore Working Group agreed to use the two lowest survey biomass values (2003 and 2005: see Table 11) as a proxy for the SPO 7 Soft Limit. This definition establishes the B_{MSY} proxy target reference point as twice the average 2003–2005 biomass level and the Hard Limit as one-half the average 2003–2005 biomass level. These are based on the definitions from the default Harvest Strategy Standard where the Soft and Hard Limits are one-half and one-quarter the target, respectively.

SPO 8

SPO 8 landings are primarily from a set net fishery that operates along the coast from Kapiti to beyond New Plymouth. The SPO 8 bottom trawl fishery operates further offshore in the North and South Taranaki bights and takes rig as a bycatch in fisheries targeted at tarakihi, snapper, and red gurnard. Recent average set net landings in SPO 8 have been between 150 and 200 t per year, whereas bottom trawl landings average between 10 and 30 t per year. The SPO 8 landing data, regardless of the method of capture, did not exhibit the behaviour of landing to temporary holding receptacles.

The CPUE analyses previously completed for SPO 8 have been discontinued by agreement of the SINSWG. The SPO 8 BT analysis consisted of four Statistical Areas (037, 039, 040, and 041), three of which were also used in the SPO 7_BT(All) analysis. Examination of the spatial distributions of the Statistical Area 041 set net and bottom trawl catches indicated that rig catches in this area merge seamlessly with the equivalent catches in Statistical Area 042, immediately to the north of Statistical Area 041. As a result, it was decided that Statistical Area 041 should be amalgamated with the SPO 1W coastal bottom fishery, adding much needed data to these analyses. A new fishery to monitor the South Taranaki Bight was constructed from the remaining statistical areas that were included in the discontinued SPO 8_SN fishery, but this analysis was not accepted by the 2016 Plenary because of the disappearance of the set net fishery in all statistical areas other than Statistical Area 038 (Tasman Bay/Golden Bay).

4.3   Other factors

Stock mixing occurs in the South Taranaki Bight to the Cook Strait and South Westland regions, and probably elsewhere. Some regional fisheries therefore exploit more than one stock. This means that biological stock boundaries do not necessarily coincide with QMA boundaries. Consequently, management by quota within Fishstocks may be sub-optimal for individual stocks.

The use of small mesh commercials set nets (125 mm) in the Auckland FMA probably results in a large proportion of the rig catch being immature fish. Elsewhere, the minimum size is 150 mm.

There have been several changes to the rig conversion factors over the period that SPO has been managed within the QMS. The trend has been towards lower conversion factors. Although researchers correct catches for these changes when undertaking CPUE analyses, this has not been done for total landings reported in this Plenary chapter. These changes reduce the relative effect of catches in recent years compared with early years, e.g., if actual catch had been constant it would appear to be declining.

5.   STATUS OF THE STOCKS

A review of stock structure in 2009 concluded that the existing QMAs were suitable for rig management, although the boundaries between biological stocks were poorly defined, especially in the Cook Strait region (Francis 2010).

- **SPO 1 & SPO 8N**

Stock Structure Assumption

For the purposes of this summary SPO 1E is defined as the sum of Statistical Areas 002 to 010 and is treated as a discrete stock. SPO 1W is defined as the sum of Statistical Areas 041 to 048 and is treated as a discrete stock. Note that part of Statistical Area 041 is also in SPO 8. It is not known if the rig stocks on the west and east coasts of the North Island are separate.

Stock Status	
Year of Most Recent Assessment	2022

Assessment Runs Presented	Standardised CPUE indices:
	    SPO 1E: SN(007)
	    SPO 1W: BT(041-047), SN(043), SN(044)

Reference Points	Target (1E and W): 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	1E and 1W: Unknown
Status in relation to Limits	1E and 1W Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	1E: Unlikely to be overfishing 1W: Unlikely to be overfishing

Historical Stock Status Trajectory and Current Status
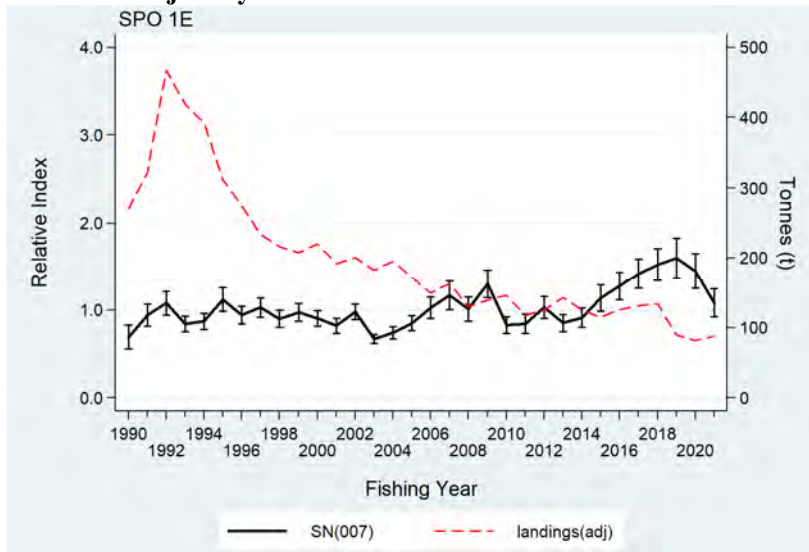
Accepted CPUE indices for SN(007) with the adjusted QMR/MHR landings for SPO 1E. Adjustments were made to ensure that all catch values in every year are based on a common conversion factor. Error bars are ±2 standard errors.
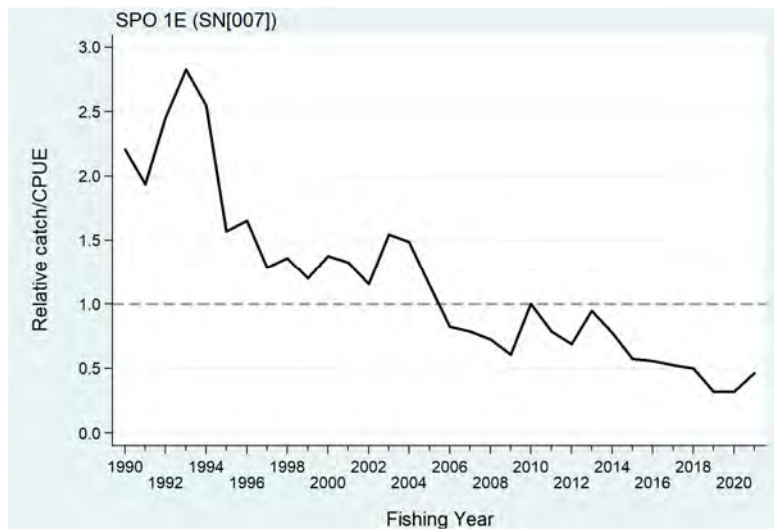
Relative fishing pressure for SPO 1E based on the ratio of QMR/MHR (adj) landings relative to the SN(007) CPUE series. Each series has been normalised so that its geometric mean=1.0 for all common years.
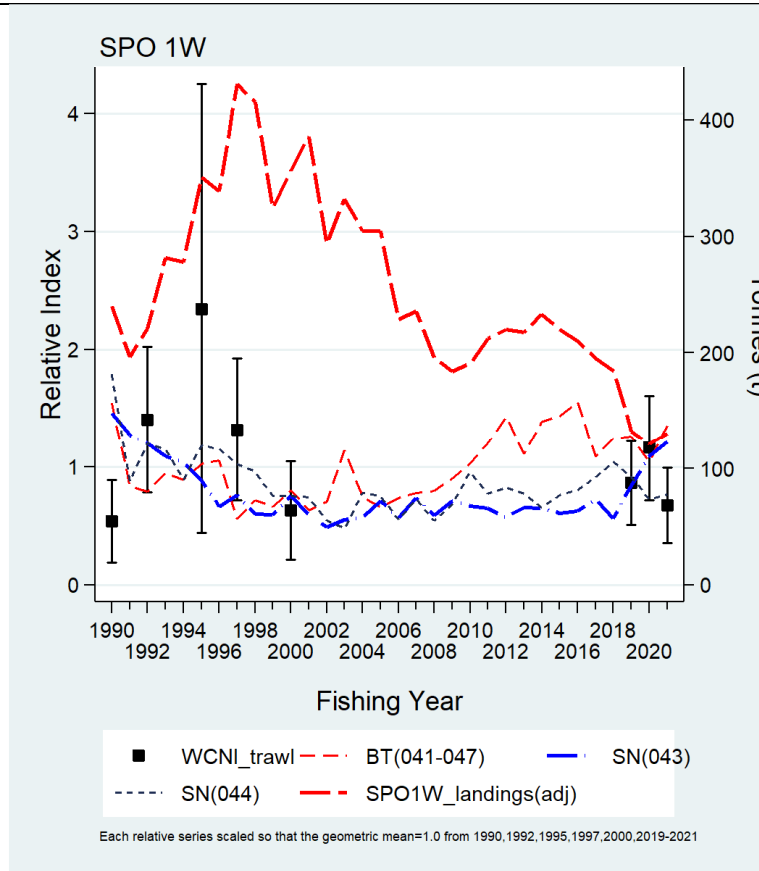
Comparison of three accepted CPUE indices [SN(043), SN(044), BT(041-047)] with the adjusted QMR/MHR landings for SPO 1W. Index values for 8 comparable WCNI trawl survey indices (10-100 m core) are also shown. Adjustments were made to ensure that all catch values in every year are based on a common conversion factor.
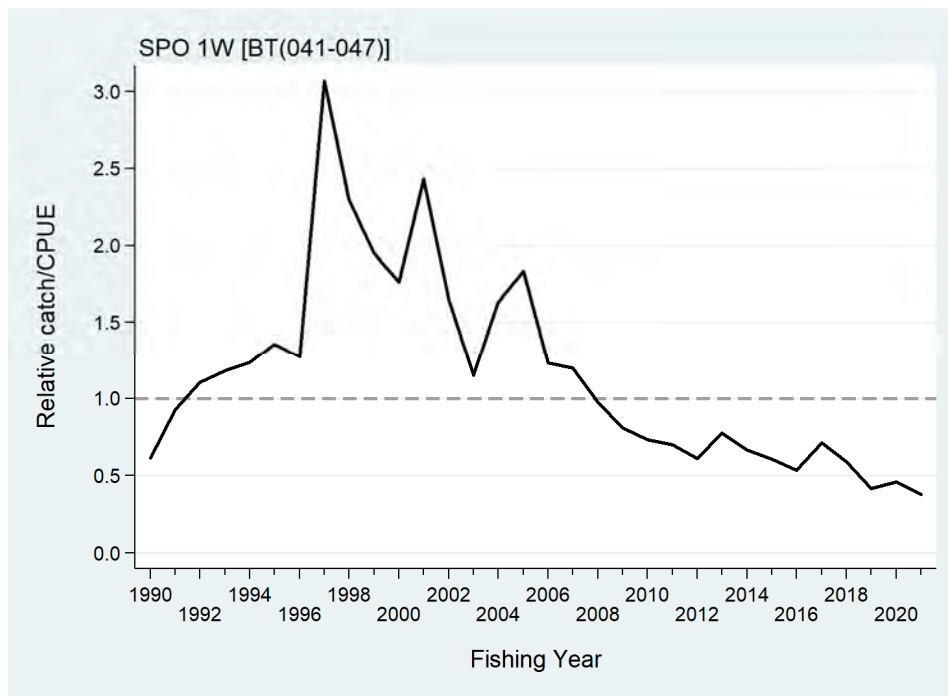
Relative fishing pressure for SPO 1W based on the ratio of QMR/MHR (adj) landings relative to the BT(041-047) CPUE series.

RIG (SPO)

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	- 1E: Adult biomass (as indexed by the set net fishery in Statistical Area 007) showed a relatively strong upturn from 2013 to 2019 followed by a decline in 2020 and 2021 but remains near the long-term series average. - 1W: The coastal BT series has been relatively stable from 2012 to 2021 but is above the long-term average index in 2021; both the SN(043 Manukau Harbour) series and the SN(044 Kaipara Harbour) series have been stable from the early 2000s to 2018, whereafter the Manukau series has shown an increase while the Kaipara has remained stable. Both set net series are near their long-term average in 2021.
Recent Trend in Fishing Intensity or Proxy	- 1E: Fishing intensity (as indexed by the set net fishery in Statistical Area 007) appears to have been declining since the mid-1990s and is well below the long-term average. - 1W: The coastal BT series indicates that fishing intensity increased to relatively high levels from the late 1990s to the early 2000s and has been declining to relatively low levels since and is now well below the long-term average.
Other Abundance Indices	- WCNI trawl survey (re-stratified) is reasonably consistent with all three WCNI CPUE series.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown (Catch) Hard Limit: Unknown (Catch) Since current catches are well below the TACC, it is Unknown if the TACC will cause the stock to decline.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%) for current catch (1E and 1W)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Fishery characterisation and standardised CPUE analysis	
Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	- 1E: 2 – Medium or Mixed Quality: decline in catch should have resulted in an increase in CPUE - 1W: 1 – High Quality	
Main data inputs (rank)	- 1E: Set net CPUE series: target shark in Statistical Area 007 (Firth of Thames)	2 – Medium or Mixed Quality: series only indexes a small proportion of area 1E
	- 1W: Bottom trawl CPUE series: mixed target species (Statistical Areas 042, 045–048)	1 – High Quality
	- Set net CPUE series: target shark in Statistical Area 043 (Manukau Harbour)	2 – Medium or Mixed Quality: series only indexes a small proportion of area 1W

1330

	- Set net CPUE series: target shark in Area 044 (Kaipara Harbour)	2 – Medium or Mixed Quality: series only indexes a small proportion of area 1W
Data not used (rank)	- 1E: - Bottom trawl CPUE series: mixed target species (Areas 002–010)	3 – Low Quality: few data
	- Set net CPUE series: target shark (Areas 002–006 and 008–010)	3 – Low Quality: few data
	- 1W: Set net CPUE series: shark target species (Areas 041–047)	3 – Low Quality: regulatory changes appear to have had a significant impact
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Lack of historical information relating to stock abundance during the 1970s–1980s when the stock was believed to have been heavily fished means that the current relative stock status is difficult to determine - SPO1W BT CPUE series does not index large mature females	

Qualifying Comments
-

Fishery Interactions
Rig are taken as a bycatch in bottom trawl fisheries targeting mainly snapper, tarakihi, red gurnard, John dory, barracouta, and trevally (SPO 1E) while the set net fisheries almost exclusively target rig in both SPO 1E and SPO 1W.

- **SPO 2**

Stock Structure Assumption

For the purposes of this summary SPO 2 is defined as the sum of Statistical Areas 011 to 015 and is treated as a discrete stock.

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Standardised CPUE: BT(stat area)
Reference Points	Target: Proxy for B_{MSY} based on the geometric mean CPUE during the period 2005–2015, a period of relatively stable CPUE and catches Soft Limit: 50% of the target Hard Limit: 50% of the soft limit Overfishing threshold: F_{MSY}; assumed to be the geometric mean fishing intensity over the period 2005–2015
Status in relation to Target	Very Likely (> 90%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below the soft limit Hard Limit: Very Unlikely (< 10%) to be below the hard limit
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status

Comparison of the accepted CPUE index[BT(trip)] with the adjusted QMR/MHR landings and TACC for SPO 2. Adjustments were made to ensure that all catch values in every year are based on a common conversion factor. The agreed B_{MSY} proxy (geometric average: 2005–2015) target is shown as a green line, the Soft Limit is shown as a purple line, and the Hard Limit is shown as a grey line. Error bars are ±2 standard errors.
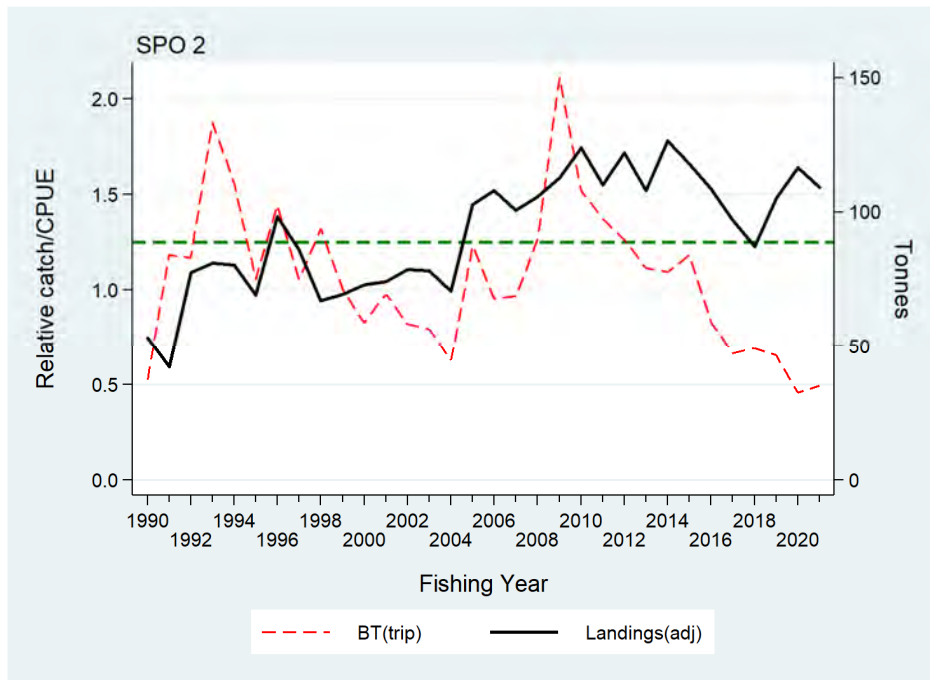
Relative fishing pressure for SPO 2 based on the ratio of QMR/MHR (adj) landings relative to the [BT(trip)] CPUE series. The fishing pressure series has been normalised so that its geometric mean=1.0.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has increased strongly since 2009, with some interannual variability. Biomass in 2021 was 2.5 times the B_{MSY} proxy target.

Recent Trend in Fishing Intensity or Proxy	Relative fishing intensity has been steadily decreasing from a peak in 2009 and was well below the threshold in 2021.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Current catches are Unlikely (< 40%) to cause the stock to decline
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Current catches are Very Unlikely (< 10%) to cause the stock to decline below the soft or hard limits
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%) for both

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Fishery characterisation and standardised CPUE analysis	
Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Bottom trawl standardised CPUE series: trip-based analysis	1 – High Quality
Data not used (rank)	- Set net standardised CPUE analysis	3 – Low Quality: This series was not updated in 2016 (not ranked in 2011) because there were insufficient data to produce a reliable index of abundance
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Lack of historical information relating to stock abundance during the 1970s–1980s when the stock was believed to have been heavily fished means that the current relative stock status is difficult to determine - BT CPUE series may not index large mature fish	

Qualifying Comments
The accepted BT(trip) CPUE series does not adequately sample large mature fish in the rig population; the Working Group agreed that the set net series was not credible due to lack of data, poor vessel overlap, and the fact that the set net fishery targets a mixed group of species, including blue moki and blue warehou.

Fishery Interactions
Rig are taken as a bycatch in bottom trawl fisheries targeted mainly flatfish, tarakihi, and red gurnard while the set net fisheries target rig, school shark, flatfish, blue warehou, and blue moki.

- **SPO 3 east coast**

Stock Structure Assumption

For the purposes of this summary, SPO 3 east coast is defined as the sum of Statistical Areas 018 to 024, 026, plus Statistical Areas 049 to 052 and is treated as a discrete stock.

Stock Status

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	ECSI trawl survey and two standardised CPUE indices: SN(east coast) and BT(east coast)
Reference Points	Target: Proxy for B_{MSY} based on geometric average ECSI trawl survey (all strata) indices for the period 2007–2018 Soft Limit: Half the B_{MSY} proxy Hard Limit: 25% of the B_{MSY} proxy Overfishing threshold: F_{MSY}; assumed to be the geometric average fishing intensity for the 2007–2018 survey indices
Status in relation to Target	About as Likely as Not (40–60%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below the soft limit Hard Limit: Very Unlikely (< 10%) to be below the hard limit
Status in relation to Overfishing	Overfishing is About as Likely as Not (40–60%) to be occurring

Historical Stock Status Trajectory and Current Status

Comparison of the East Coast South Island (ECSI) trawl survey (all strata) with two accepted east coast CPUE indices [BT(018-024&026) and SN(018-024&026)] and with the adjusted QMR/MHR landings for SPO 3. Adjustments were made to ensure that all catch values in every year are based on a common conversion factor. The B_{MSY} proxy (geometric average: 2007, 2012, 2014, 2016, 2018 ECSI total 10-400 m survey biomass estimates) is shown as a green line, and the calculated Soft Limit (= 0.5 x B_{MSY} proxy) is shown as a purple line and the calculated Hard Limit (= 0.25 x B_{MSY} proxy) is shown as a grey line.

Relative fishing pressure for east coast SPO 3 based on the ratio of QMR/MHR (adj) landings (areas 018–024,026) relative to the ECSI trawl survey which has been normalised so that its geometric mean=1.0. Indicated threshold is the geometric mean of the 2007, 2012, 2014, 2016, 2018 fishing pressure estimates.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Core strata biomass estimates from survey years 2012 to 2016 of the ECSI winter trawl survey series suggest that biomass has increased relative to the 1990s. Biomass in 2021 showed a very strong increase which must be considered unreliable, given the large associated CV (63%). However, this large increase, coupled with the increasing BT CPUE trend, likely indicates that current biomass has increased from 2017 to 2021.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has fluctuated around the overfishing threshold, and has possibly dropped in 2021.
Other Abundance Indices	There has been a strong increasing trend in the bottom trawl CPUE series dating from the late 2000s, but the set net CPUE series has increased more slowly up to 2020, followed by a 28% drop between 2020 and 2021.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	It is not known if the stock will continue to increase at current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Current catches are Unlikely (< 40%) to cause the stock to decline below the soft or hard limits.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%)

Assessment Methodology and Evaluation	
Assessment Type	Level 2 - Partial Quantitative Stock Assessment
Assessment Method	Fishery characterisation, trawl survey biomass and standardised CPUE analysis

Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- East coast South Island winter trawl survey	1 – High quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Split SPO 3 into SPO 3 east coast and SPO 3 Foveaux St	
Major Sources of Uncertainty	- The increasing trend in the trawl survey (core strata) and bottom trawl CPUE since 1990 are not well corroborated by the set net CPUE series, which has increased more slowly. - Lack of historical information relating to stock abundance during the 1970s–1980s when the stock was believed to have been heavily fished means that stock status relative to early levels of abundance is difficult to determine. - In some years the ECSI trawl survey indices have high CVs. - ECSI trawl survey and bottom trawl CPUE do not adequately sample large mature females.	

Qualifying Comments
The set net CPUE series is likely to be affected by the management measures introduced to protect Hector's dolphins and a consequent attenuation of the fleet.

Fishery Interactions
A 4 nautical mile set net closure has been in place since October 2008 for the entire area to reduce the bycatch of Hector's dolphins. Rig are largely targeted by set net but they are also caught as bycatch in target fisheries for school shark, flatfish, red cod, spiny dogfish, and elephantfish in set net, bottom trawl, and bottom longline fisheries.

- **SPO 3 Foveaux Strait**

Stock Structure Assumption
For the purposes of this summary, SPO 3 Foveaux Strait is defined as the sum of Statistical Areas 025, 027–031 and is treated as a discrete stock.

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Standardised SN CPUE (025,027–032) index series
Reference Points	A 30% B_0 proxy was based on the geometric mean SN(025,027–032) indices for the period 2002–2012 and then scaled up or down for the targets and limits Target (40% B_0): 1.333 x 30% B_0 proxy Soft Limit (20% B_0): 0.667 x 30% B_0 proxy Hard Limit (10% B_0): 0.333 x 30% B_0 proxy Overfishing threshold: F_{MSY}; assumed to be the geometric mean fishing intensity for the 2002–2012 SN (025,027–032) indices divided by 1.333
Status in relation to Target	About as Likely as Not (40–60%) to be at or above the target
Status in relation to Limits	Soft Limit: Unlikely (< 40%)
	Hard Limit: Very Unlikely (< 10%)
Status in relation to Overfishing	Overfishing is Likely (> 60%) to be occurring

Historical Stock Status Trajectory and Current Status

Comparison of two accepted Foveaux Strait CPUE indices [BT(025&027–032) and SN(025&027–032)] with the adjusted QMR/MHR landings for SPO 3 Foveaux St. Adjustments were made to ensure that all catch values in every year are based on a common conversion factor. The agreed B_{MSY} proxy of 1.33 x 30% B_0 proxy [=geometric average from 2002 to 2012 for the SN(025&027–032 series) is shown as a green line, and the calculated Soft Limit (= 0.67 x 30% B_0 proxy) is shown as a purple line and the calculated Hard Limit (=0.33 x 30% B_0 proxy) is shown as a grey line.
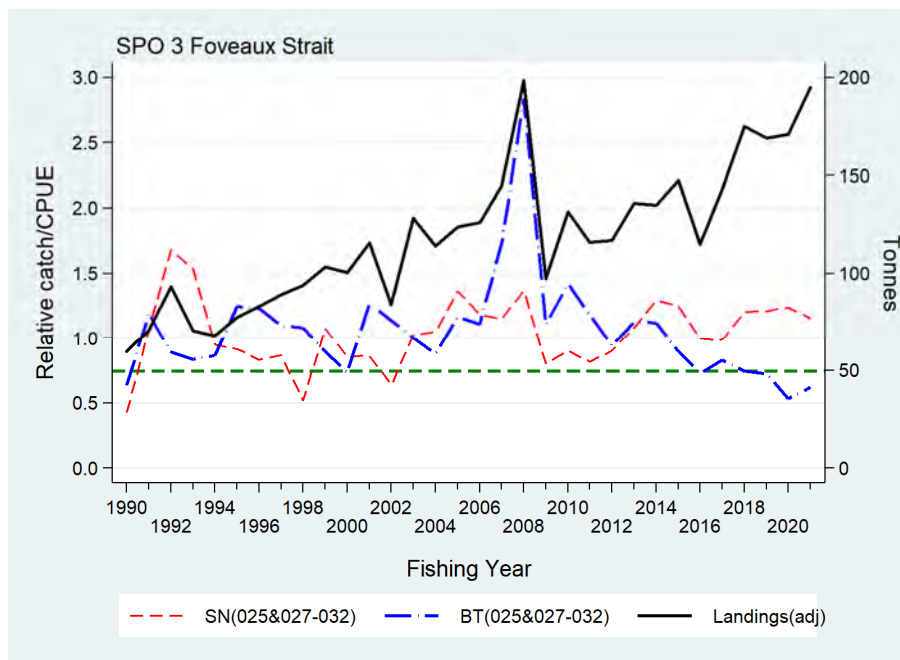
Relative fishing pressure for Foveaux Strait SPO 3 based on the ratio of QMR/MHR (adj) landings (sum of areas 025&027–032) relative to the SN(025&027–032) and BT(025&027–032) CPUE series which have been normalised so that the geometric mean=1.0. The indicated threshold (green dashed line) is geometric average fishing pressure from 2002 to 2012 for the SN(025&027–032) series divided by 1.333.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The SN CPUE series has increased gradually, rising 20% between 2015 and 2020 and another 20% between 2020 and 2021. The BT CPUE series has been increasing since 2008, nearly doubling between 2015 and 2021.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has fluctuated above the overfishing threshold.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Catches and CPUE have increased since the late 2000s. It is not known if the stock will continue to increase at current catch levels.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Current catches are Unlikely (< 40%) to cause the stock to decline below the soft or hard limits.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Likely (> 60%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Fishery characterisation, trawl survey biomass and standardised CPUE analysis	
Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Bottom trawl CPUE series: mixed target species	1 – High Quality
	- Set net CPUE series: target shark	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Split SPO 3 into SPO 3 east coast and SPO 3 Foveaux St	
Major Sources of Uncertainty	- The greater than threefold increase in the bottom trawl CPUE since the late 2000s is not matched by the set net CPUE series, which has only increased about 80% since 2005. - Lack of historical information relating to stock abundance during the 1970s–1980s when the stock was believed to have been heavily fished means that stock status relative to early levels of abundance is difficult to determine. - Bottom trawl CPUE do not adequately sample large mature females.	

Qualifying Comments
-

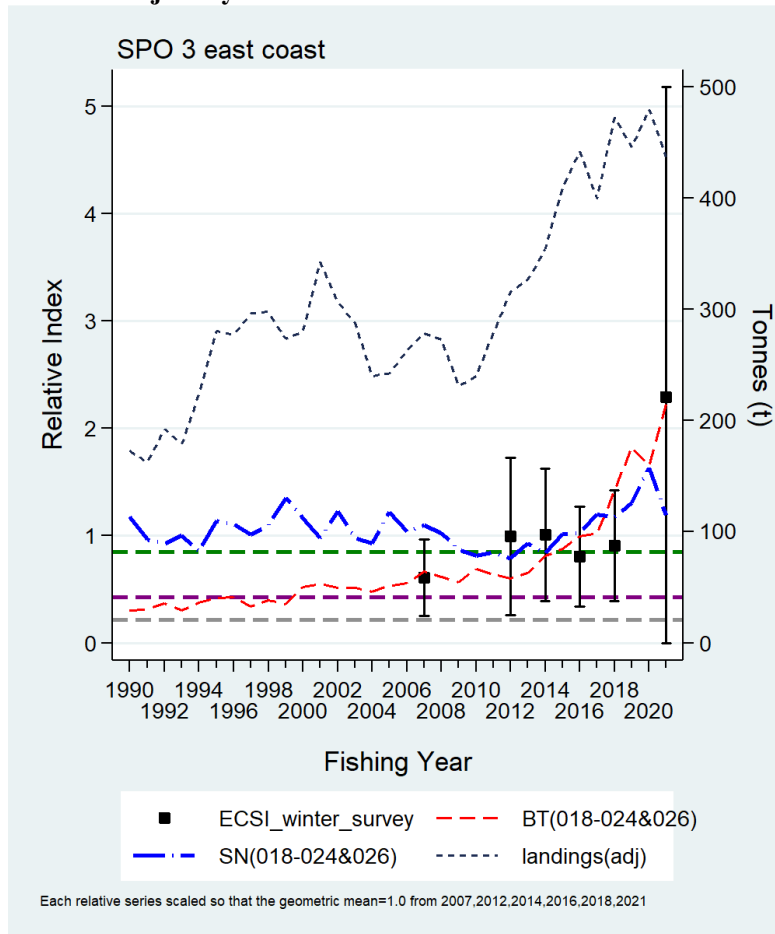| Fishery Interactions |
|---|
| A 4 nautical mile set net closure has been in place since October 2008 for the entire area to reduce the bycatch of Hector's dolphins. Rig are largely targeted by set net but they are also caught as bycatch in target fisheries for school shark, flatfish, red cod, spiny dogfish, and elephantfish in set net, bottom trawl, and bottom longline fisheries. |

- **SPO 7 & SPO 8S**

Stock Structure Assumption

For the purposes of this summary SPO 7 is defined as the sum of Statistical Areas 016, 017, 033 to 040 and is treated as a discrete stock. Note that Statistical Area 040 is shared with SPO 8.

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	WCSI trawl survey series and two standardised CPUE series: BT (All) and SN (038)
Reference Points	Target: Proxy for B_{MSY} based on twice the soft limit Soft Limit: Geometric mean WCSI trawl survey biomass estimates for 2003 and 2005 (148.6 t) Hard Limit: 50% of soft limit Overfishing threshold: F_{MSY}
Status in relation to Target	About As Likely As Not (40–60%) to be at or above the target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below the soft limit Hard Limit: Very Unlikely (< 10%) to be below the hard limit
Status in relation to Overfishing	Overfishing is About As Likely As Not (40–60%) to be occurring

Historical Stock Status Trajectory and Current Status

Comparison of the west coast South Island (WCSI) trawl survey and two accepted CPUE indices BT(All) and SN(038) with the adjusted QMR/MHR landings for SPO 7. Adjustments were made to ensure that all catch values in every year are based on a common conversion factor. The agreed Soft Limit (average: 2003 and 2005 WCSI survey biomass estimates=0.49) is shown as a purple line, and the calculated B_{MSY} proxy (=2×Soft Limit) is shown as a green line and the calculated Hard Limit (=0.5×Soft Limit) is shown as a grey line. The 2021 index value for the SN(038) analysis was dropped because it was based on a single vessel.
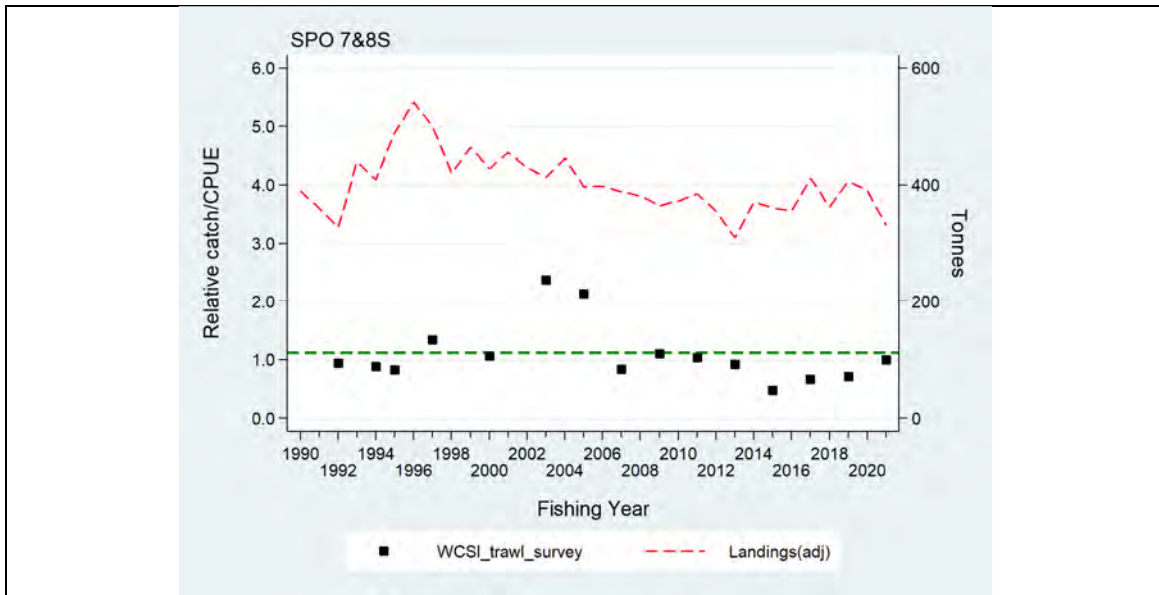
Relative fishing pressure for SPO 7 based on the ratio of QMR/MHR (adj) landings relative to the WCSI trawl survey which has been normalised so that its geometric mean=1.0. Target fishing pressure (1.10) is one-half of the fishing pressure associated with the low level of biomass observed in the 2003 and 2005 trawl survey indices.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Relative biomass from the WCSI trawl survey was stable, at around the target level, from 2007 to 2013, but increased sharply in 2015 and has since declined in three successive surveys.
Recent Trend in Fishing Intensity or Proxy	Relative fishing intensity has been declining since the early 2000s and has been increasing towards the overfishing threshold since 2015.
Other Abundance Indices	- The SPO 7_BT(All) CPUE series shows a strong increasing trend in recent years from a low point in 2004–05. The SPO 7 SN(038) series has also been recently increasing but is hampered by a lack of data.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis		
Stock Projections or Prognosis	Unknown	
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Unlikely (< 40%)	
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%)	

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	WCSI trawl survey series and two standardised CPUE abundance indices	
Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	2016: - West Coast South Island trawl survey index	1 – High Quality

Data not used (rank)	- SN(STB) CPUE series	3 – Low Quality: affected by dolphin management regulations
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- The drop in the 2021 WCSI survey index is in conflict with the increasing trend seen in the BT and SN CPUE series. - There is a lack of historical information relating to stock abundance during the 1970s–1980s when the stock was believed to have been heavily fished means that stock status relative to early levels of abundance is difficult to determine. - WCSI trawl survey and bottom trawl CPUE do not adequately sample large mature females.	

Qualifying Comments

The Statistical Area 038 SN fishery had nearly disappeared in 2020 and 2021 and may no longer provide information for this QMA.

Fishery Interactions

SPO 7 is caught in a targeted set net fishery, which also targets school shark and spiny dogfish, and in a bottom trawl fishery targeting flatfish, barracouta, red cod, and tarakihi. The set net fishery has historically been focused in Statistical Area 038 (Tasman Bay and Golden Bay).

6.   FOR FURTHER INFORMATION

Beentjes, M P; MacGibbon, D J (2013) Review of QMS species for inclusion in the east coast South Island winter trawl survey reports. *New Zealand Fisheries Assessment Report 2013/35*. 102 p.

Beentjes, M P; MacGibbon, D; Lyon, W S (2015) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2014 (KAH1402). *New Zealand Fisheries Assessment Report 2015/14*. 136 p.

Bentley, N; Kendrick, T H (2015) The inshore fisheries of the Central (East) fisheries management area (FMA2): characterisation and catch-per-unit-effort analyses, 1989–90 to 2009–10 Draft New Zealand Fisheries Assessment Report for Research Project INS2009/03. (Unpublished report held by Fisheries New Zealand, Wellington).

Blackwell, R G; Francis, M P (2010) Review of life–history and fishery characteristics of New Zealand rig and school shark. *New Zealand Fisheries Assessment Report 2009/02*. 38 p.

Blackwell, R G; Manning, M J; Gilbert, D G; Baird, S J (2006) Standardized CPUE analysis of the target rig (*Mustelus lenticulatus*) setnet fishery in northern New Zealand (SPO 1 and 8). *New Zealand Fisheries Assessment Report 2006/32*. 56 p.

Boyd, R O; Reilly, J L (2004) 1999/2000 National Marine Recreational Fishing Survey: harvest estimates. (Unpublished New Zealand Fisheries Assessment Research Report for the Ministry of Fisheries Project REC9803 held by Fisheries New Zealand, Wellington.) 28 p.

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16: 27 p. (Unpublished report held by NIWA library, Wellington.)

Challenger Finfish Management Company (CFMC) (2001) Performance of the SPO 7 Adaptive Management Programme dated 7 May 2001. (Unpublished report held by Fisheries New Zealand.)

Davey, N; Hartill, B; Carter, M (2019) Mean weight estimates for recreational fisheries in 2017–18. *New Zealand Fisheries Assessment Report 2019/25*. 32 p.

Ford, R B; Galland, A; Clark, M R; Crozier, P; Duffy, C AJ; Dunn, M R; Francis, M P, Wells, R (2015) Qualitative (Level 1) Risk Assessment of the impact of commercial fishing on New Zealand Chondrichthyans. *New Zealand Aquatic Environment and Biodiversity Report No. 157*. 111 p.

Francis, M P (1979) A biological basis for the management of New Zealand moki (*Latridopsis ciliaris*) and smoothhound (*Mustelus lenticulatus*) fisheries. (Unpublished MSc thesis, University of Canterbury.)

Francis, M P (1988a) Movement patterns of rig (*Mustelus lenticulatus*) tagged in southern New Zealand. *New Zealand Journal of Marine and Freshwater Research 22*: 259–272.

Francis, M P (1988b) Rig. New Zealand Fisheries Assessment Research Document 1988/24. 19 p. (Unpublished report held by NIWA library, Wellington.)

Francis, M P (2010) Movement of tagged rig and school shark among QMAs, and implications for stock management boundaries. *New Zealand Fisheries Assessment Report 2010/03*. 22 p.

Francis, M P; Francis, R I C C (1992a) Growth, mortality and yield estimates for rig (*Mustelus lenticulatus*). New Zealand Fisheries Assessment Research Document 1992/5. 32 p. (Unpublished report held by NIWA library, Wellington.)

Francis, M P; Francis, R I C C (1992b) Growth rate estimates for New Zealand rig (*Mustelus lenticulatus*). *Australian Journal of Marine and Freshwater Research 43*: 1157–1176.

Francis, M P; Mace, J T (1980) Reproductive biology of *Mustelus lenticulatus* from Kaikoura and Nelson. *New Zealand Journal of Marine and Freshwater Research 14*: 303–311.

Francis, M P; Ó Maolagáin, C (2000) Age, growth and maturity of a New Zealand endemic shark (*Mustelus lenticulatus*) estimated from vertebral bands. *Marine and Freshwater Research 51(1)*: 35–42.

Francis, M P; Paul, L (2013) New Zealand inshore finfish and shellfish commercial landings, 1931−82. *New Zealand Fisheries Assessment Report 2013/55*. 136 p.

RIG (SPO)

Francis, M P; Smith, D W (1988) The New Zealand rig fishery: Catch statistics and composition, 1974–85. *New Zealand Fisheries Technical Report No. 7*. 30 p.

Hartill, B; Davey, N (2015) Mean weight estimates for recreational fisheries in 2011–12. *New Zealand Fisheries Assessment Report 2015/25*. 37 p.

Jones, E.G.; Bian, R; MacGibbon, D J; McKenzie, J R; Escobar-Flores, P C; Stevens, D W; Walsh, C; O'Driscoll, R L (in prep) Inshore trawl surveys of the west coast North Island, October–November 2018, 2019 and 2020. Draft New Zealand Fisheries Assessment Report

Kendrick, T H; Bentley, N (2012) Fishery characterisation and setnet catch-per-unit-effort indices for rig in SPO 1 and SPO 8, 1989–90 to 2009–10. *New Zealand Fisheries Assessment Report 2012/44*.

Kendrick, T H; Starr, P J; Bentley, N (2011) CPUE analyses for rig in SPO 2 FMA 2. SINS-WG-2011-44-SPO 2. 13 p. (Unpublished document held by Fisheries New Zealand, Wellington).

Langley, A D (2019) An investigation of the performance of CPUE modelling approaches – a simulation study. *New Zealand Fisheries Assessment Report 2019/57*. 50 p.

Lydon, G J; Middleton, D A J; Starr, P J (2006) Performance of the SPO 3 Logbook Programme. AMP-WG-06/23. (Unpublished report held by Fisheries New Zealand.)

Massey, B R; Francis, M P (1989) Commercial catch composition and reproductive biology of rig (*Mustelus lenticulatus*) from Pegasus Bay, Canterbury, New Zealand. *New Zealand Journal of Marine and Freshwater Research 23*: 113–20.

Paul, L J (2003) Characterisation of the commercial and recreational fisheries for rig (*Mustelus lenticulatus*) in northern New Zealand (SPO 1 and SPO 8), and unstandardised CPUE analyses of the targeted setnet fisheries. *New Zealand Fisheries Assessment Report 2003/22*. 69 p.

Seafood Industry Council (SeaFIC) (2001) Performance of the SPO 7 Adaptive Management Programme dated 7 May 2000. (Unpublished report held by Fisheries New Zealand.)

Seafood Industry Council (SeaFIC) (2002a) Report to the Inshore Fishery Assessment Working Group. Performance of the SPO 3 Adaptive Management Programme (dated 18 March 2002). (Unpublished report held by Fisheries New Zealand.)

Seafood Industry Council (SeaFIC) (2002b) Report to the Inshore Fishery Assessment Working Group. Performance of the SPO 7 Adaptive Management Programme (dated 19 March 2002). (Unpublished report held by Fisheries New Zealand.)

Seafood Industry Council (SeaFIC) (2003a) Report to the Adaptive Management Fishery Assessment Working Group: Performance of the SPO 3 Adaptive Management Programme. AMP-WG-2003/03. 42 p. (Unpublished report held by Fisheries New Zealand.)

Seafood Industry Council (SeaFIC) (2003b) 2003 performance report SPO 7 Adaptive Management Programme. AMP-WG-2003/08 4 p. (Unpublished report held by Fisheries New Zealand.)

Seafood Industry Council (SeaFIC) (2004a) Report to the Adaptive Management Fishery Assessment Working Group: Performance of the SPO 7 Adaptive Management Programme. AMP-WG-2004/04. 54 p. (Unpublished report held by Fisheries New Zealand.)

Seafood Industry Council (SeaFIC) (2004b) 2003 performance report SPO 3 Adaptive Management Programme. AMP-WG-2004/16. 6 p. (Unpublished report held by Fisheries New Zealand.)

Seafood Industry Council (SeaFIC) (2005a) 2005 Report to the Adaptive Management Programme Fishery Assessment Working Group: Review of the SPO 3 Adaptive Management Programme. AMP-WG-2005/15. (Unpublished report held by Fisheries New Zealand.)

Seafood Industry Council (SeaFIC) (2005b) 2005 Performance Report to the Adaptive Management Programme Fishery Assessment Working Group: SPO 7 Adaptive Management Programme. AMP-WG-2005/10 (Unpublished report held by Fisheries New Zealand.)

Seafood Industry Council (SeaFIC) (2005c) SPO3: Additional Analysis. AMP-WG-05/25. (Unpublished report held by Fisheries New Zealand.)

Smith, P J (2009) Review of genetic studies of rig and school shark. New Zealand Final Research Report for Ministry of Fisheries Project No. INS200803. 16 p. (Unpublished report held by Fisheries New Zealand.)

Starr, P J (2011) SPO 2 CPUE for the setnet fishery – Take 2. SINS-WG-2011-46-SPO 2. 13 p. (Unpublished document held by Fisheries New Zealand, Wellington)

Starr, P J; Hicks, A (2006) SPO 7 Stock Assessment. 57 p. (Unpublished report held by Fisheries New Zealand.)

Starr, P J; Kendrick, T H (2009) SPO 2 Catch/Effort Analysis. NINS-WG-2009-27 (v2). 48 p. (Unpublished document held by Fisheries New Zealand.)

Starr, P J; Kendrick, T H (2011) Report To Southeast Finfish Management Ltd: Review Of The SPO 3 Fishery. SINS-WG-2011-45-SPO 3. 65 p. (Unpublished document held by Fisheries New Zealand, Wellington.)

Starr, P J; Kendrick, T H (2016) SPO 1, 2, 3, 7 and 8 Fishery Characterisation and CPUE Report *New Zealand Fisheries Assessment Report 2016/34*. 242 p.

Starr, P J; Kendrick, T H (2017) SPO 1, 2, 3, 7 and 8 Fishery Characterisation and CPUE Report. *New Zealand Fisheries Assessment Report 2017/62*. 244 p.

Starr, P J; Kendrick, T H (2020) SPO 1, 2, 3, 7, and 8 Fishery Characterisation and CPUE Report. *New Zealand Fisheries Assessment Report. 2020/40*. 298 p.

Starr, P J; Tornquist, M; Middleton, D; Large, K (in prep) SPO 1, 2, 3, 7, and 8 Fishery Characterisation and CPUE Report. Draft New Zealand Fisheries Assessment Report.

Starr, P J; Kendrick, T H; Bentley, N (2010) Report to the Adaptive Management Programme Fishery Assessment Working Group: Characterisation, CPUE analysis and logbook data for SPO 7. Document 2010/10-v2, 93 p. (Unpublished document held by Fisheries New Zealand, Wellington.)

Starr, P J; Kendrick, T H; Lydon, G J (2006) Full Term Review of the SPO 7 Adaptive Management Programme. 90 p. (Unpublished manuscript available from Seafood New Zealand, Wellington.)

Starr, P J; Kendrick, T H; Lydon, G J; Bentley, N (2007) Report to the Adaptive Management Programme Fishery Assessment Working Group: Review of the SPO 3 Adaptive Management Programme. AMP-WG-2007/06. 87 p. (Unpublished report held by Fisheries New Zealand.)

Stevenson, M L (2007) Review of data collected by the WCSI series to determine for which species relative abundance trends and size comparison information should be provided in each survey. Final Research Report for the Ministry of Fisheries Research Project INT2006-01. (Unpublished report held in NIWA Wellington library.)

Stevenson, M L; Hanchet, S M (2000) Review of the inshore trawl survey series of the west coast of the South Island and Tasman and Golden Bays, 1992–97. *NIWA Technical Report 82*. 79 p.

Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94 New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished report held by NIWA library, Wellington.)

Vignaux, M (1994) Catch per unit effort (CPUE) analysis of west coast South Island and Cook Strait spawning hoki fisheries, 1987–93. N.Z. Fisheries Assessment Research Document 94/11. 29 p. (Unpublished report held by NIWA library, Wellington.)

Vignaux, M (1997) CPUE analyses for stocks in the adaptive management programme. New Zealand Fisheries Assessment Research Document 1997/24. 68 p. (Unpublished report held by NIWA library, Wellington.)

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24*. 104 p.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.

RUBYFISH (RBY)

(*Plagiogeneion rubiginosum*)
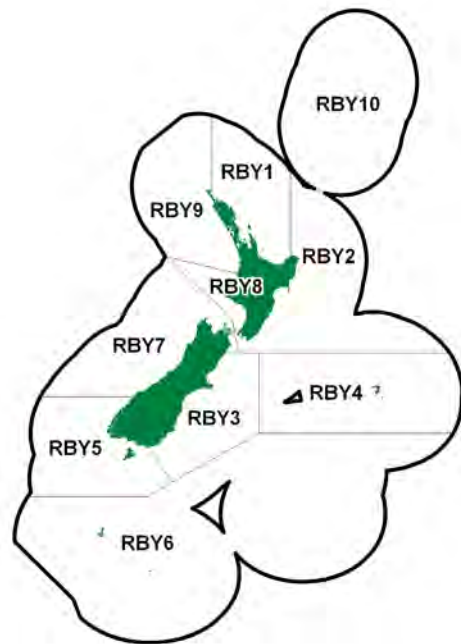
1. FISHERY SUMMARY

1.1 Commercial fisheries

Rubyfish catches were first reported in 1982–83. In 1990–91, 245 t were landed (Table 1), mainly as bycatch in the trawl fisheries for alfonsino, gemfish, barracouta, hoki, and jack mackerel. Landings doubled in the following year, and from 1992–93 to 1994–95 landings were about 600 t, taken mainly as bycatch of gemfish in the Bay of Plenty and from target midwater trawling in Statistical Areas 012 and 013 (RBY 2). In 1995–96, total landings increased to 735 t, before decreasing to 247 t by 1998–99. Since the late 1990s landings have fluctuated between about 200 t and 750 t (Table 2).

The main rubyfish grounds (target species and alfonsino bycatch) are the banks or "hills" off the east coast of the North Island in RBY 2, and the Bay of Plenty (RBY 1). Although landings from RBY 1 increased from the mid-2000s, in most years landings have been greater in RBY 2 (which accounted for 70% of total landings during the 1990s), other than 2011–12 when RBY 1 accounted for 83% of landings. The level of direct targeting on rubyfish has increased over the history of the fishery, and most target catch is now taken from underwater features around East Cape and the Bay of Plenty.

Rubyfish are also taken as a bycatch of tarakihi tows (between 50 and 300 m bottom depth) from around all coasts of the North Island, Chatham Islands, and the upper part of the South Island. Bycatch of rubyfish in the hoki fishery is also widely distributed in deeper waters (200 to 450 m), including the Chatham Rise and the southeast coast of the South Island. Rubyfish have also been reported as an intermittent bycatch with barracouta, jack mackerel, bluenose, black cardinalfish, orange roughy, silver warehou, trevally, and scampi. Commercial concentrations of rubyfish probably also exist in areas that have not been fished in appropriate depths, especially in the northern half of New Zealand.

Rubyfish was introduced into the QMS on 1 October 1998. Initially allowances were not made for non-commercial catch. The historical landings and TACC values for the two main RBY stocks are shown in Figure 1.

RUBYFISH (RBY)

Table 1: Reported landings (t) of rubyfish by QMA and fishing year, 1983–84 to 1997–98. The data in this table has been updated from that published in previous Plenary Reports by using the data through 1996–97 in table 35 on p. 270 of the "Review of Sustainability Measures and Other Management Controls for the 1999–00 Fishing Year - Final Advice Paper" dated 6 August 1998.

	QMA 1	QMA 2	QMA 3	QMA 4	QMA 5	QMA 6	QMA 7	QMA 8	QMA 9	QMA 10	Other	Total
1990–91	66	159	5	3	0	0	9	0	3	0		245
1991–92	147	390	0	0	0	0	20	1	6	0		564
1992–93	90	491	0	0	0	0	31	0	0	0		612
1993–94	116	379	3	0	0	0	72	0	5	0		575
1994–95	43	500	3	12	0	0	13	0	10	0		581
1995–96	106	595	2	0	0	0	9	0	23	0		735
1996–97	128	297	2	1	< 1	0	14	< 1	21	< 1	1	463
1997–98	50	308	< 1	1	0	0	6	< 1	13	< 1	< 1	380

† QMS data.

Table 2: Reported landings (t) of rubyfish by Fishstock and TACCs from 1998–99 to present. [Continued next page]

Fishstock FMA	RBY 1 1		RBY 2 2		RBY 3 3		RBY 4 4		RBY 5 5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1998–99	55	104	180	433	< 1	2	< 1	2	0	0
1999–00	138	104	321	433	6	2	< 1	2	0	0
2000–01	39	109	433	433	< 1	3	2	3	0	0
2001–02	36	109	414	433	1	3	8	3	1	0
2002–03	21	300	233	433	< 1	3	11	3	1	0
2003–04	19	300	343	433	< 1	3	2	3	< 1	0
2004–05	109	300	217	433	< 1	3	10	3	1	0
2005–06	135	300	303	433	< 1	3	33	3	0	0
2006–07	293	300	198	433	4	3	37	6	0	0
2007–08	120	300	427	433	< 1	3	11	6	< 1	0
2008–09	192	300	467	433	< 1	3	19	6	0	0
2009–10	351	300	309	433	2	3	11	6	< 1	0
2010–11	297	300	435	433	< 1	3	9	18	< 1	0
2011–12	278	300	73	433	< 1	3	4	18	< 1	0
2012–13	95	300	331	433	2	3	21	18	< 1	0
2013–14	223	300	349	433	< 1	3	15	18	< 1	0
2014–15	132	300	270	433	14	3	22	18	< 1	0
2015–16	145	300	286	433	30	30	19	18	< 1	0
2016–17	180	300	213	433	< 1	30	13	18	0	0
2017–18	71	300	104	433	< 1	30	17	18	1	0
2018–19	47	300	141	433	3	30	16	18	< 1	0
2019–20	302	300	207	433	< 1	30	59	18	< 1	0
2020–21	272	300	131	433	< 1	30	10	24	< 1	2

Fishstock FMA	RBY 6 6		RBY 7 7		RBY 8 8		RBY 9 9		RBY 10 10	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1998–99	0	0	4	27	< 1	0	7	9	< 1	0
1999–00	0	0	13	27	< 1	0	15	9	0	0
2000–01	< 1	0	7	27	0	1	16	19	0	0
2001–02	0	0	35	27	< 1	1	3	19	0	0
2002–03	< 1	0	32	27	2	1	2	19	0	0
2003–04	< 1	0	9	27	8	1	1	19	0	0
2004–05	< 1	0	99	27	< 1	1	3	19	0	0
2005–06	< 1	0	8	27	8	1	20	19	0	0
2006–07	0	0	13	33	< 1	5	1	19	0	0
2007–08	< 1	0	4	33	1	6	1	19	0	0
2008–09	< 1	0	14	33	< 1	6	2	19	0	0
2009–10	0	0	4	33	< 1	6	< 1	19	0	0
2010–11	0	0	5	33	< 1	6	< 1	19	0	0
2011–12	0	0	18	33	< 1	6	<1	19	0	0
2012–13	< 1	0	2	33	< 1	6	1	19	0	0
2013–14	0	0	48	33	< 1	6	< 1	19	0	0
2014–15	< 1	0	4	33	< 1	6	1	19	0	0
2015–16	0	0	3	33	< 1	6	1	19	0	0
2016–17	0	0	9	33	< 1	6	< 1	19	0	0
2017–18	0	0	5	33	< 1	6	1	19	0	0
2018–19	< 1	0	16	33	< 1	6	2	19	0	0
2019–20	0	0	1	33	< 1	6	3	19	0	0

1344

Table 2: [Continued]

Fishstock	RBY 6		RBY 7		RBY 8		RBY 9		RBY 10	
FMA	6		7		8		9		10	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2020–21	0	1	5	33	< 1	6	2	19	0	0

	Total	
	Landings	TACC
1998–99	247	577
1999–00	493	577
2000–01	358	595
2001–02	498	595
2002–03	302	595
2003–04	382	595
2004–05	439	595
2005–06	507	786
2006–07	546	849
2007–08	564	800
2008–09	694	800
2009–10	677	800
2010–11	747	812
2011–12	374	812
2012–13	452	812
2013–14	635	812
2014–15	444	812
2015–16	482	839
2016–17	415	839
2017–18	198	839
2018–19	225	839
2019–20	573	839
2020–21	421	848

In the 2002–03 fishing year, the TACC for RBY 1 was increased under the Adaptive Management Programme (AMP) to 300 t. At the same time a customary allowance of 1 t, a recreational allowance of 2 t, and an allowance of 15 t for fishing-related mortality took the TAC to 318 t. All AMP programmes ended on 30 September 2009. The RBY 1 TACC remains unchanged at 300 t, and with the exception of the fishing year 2009–10 landings have remained below the TACC (Table 2). In RBY 2 the TACC has remained unchanged at 433 t since 1998, with landings only slightly exceeding the TACC in 2008–09 and 2010–11. Landings in both areas were below average in 2017–18 and 2018–19, but increased in 2019–20.

The RBY 3 TACC was increased from 3 t to 30 t for the fishing year 2015–16 (when the TACC was met), but landings have been 3 t or less since 2016–17. RBY 4, 7, and 8 stocks landings were above the TACCs for a number of years, so the TACCs were increased to the average of the previous 7 years plus an additional 10% from the 1 October 2006; the TACCs for RBY 4, 7, and 8 were increased to 6, 33, and 5 t respectively. Landings continued to exceed the TACCs after 2006–07, resulting in a further TACC increase to 18 t for RBY 4 from 1 October 2010. An allowance of 1 t was allocated to RBY 4 at the same time, bringing the TAC to 19 t. A TACC of 19 t has been allocated to RBY 9 since the 2000–01 fishing year, but landings have fluctuated between <1 t and 2 t since 2007.
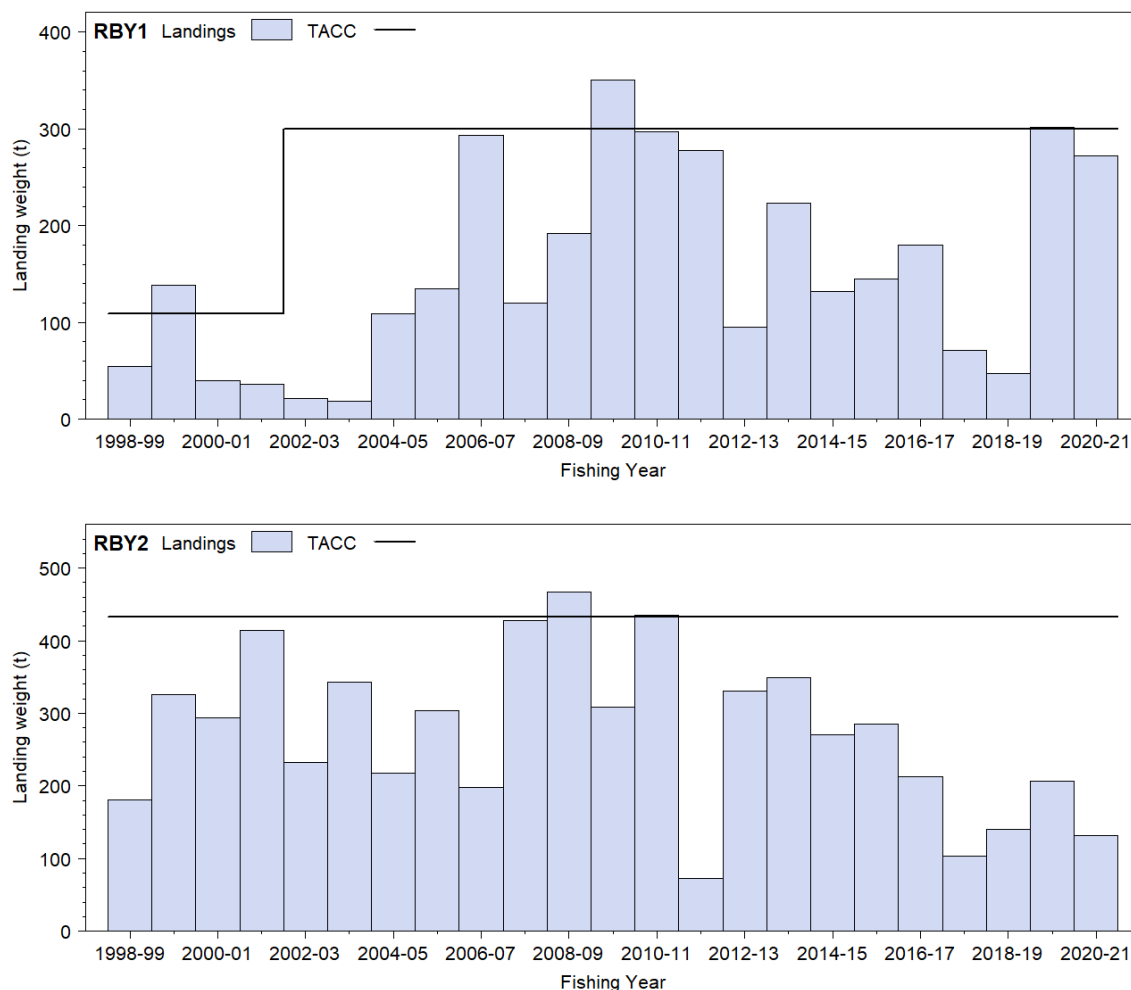
Figure 1: Reported commercial landings and TACC for the two main RBY stocks. RBY 1 (Auckland East) and RBY 2 (Central East). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries

There is no reported recreational catch.

1.3 Customary non-commercial fisheries

There is no quantitative information on the current level of customary non-commercial take.

1.4 Illegal catch

There is no quantitative information on the level of illegal catch.

1.5 Other sources of mortality

There is no quantitative information on the level of other sources of mortality.

2. BIOLOGY

Rubyfish are recorded from southern Australia, South Africa, and from banks in the southern Indian and south-east Atlantic oceans. They occur in the subtropical water around northern and central New Zealand, but are absent from the southern Chatham Rise and Campbell Plateau. Rubyfish occur at depths ranging from 50 m to at least 800 m. Most commercial catch is taken between 200 m and 400 m.

Rubyfish have been recorded up to 58 cm in length. Small catches of rubyfish in research tows have been of similar-sized fish, suggesting schooling by size.

Ageing research based on simple counts of otolith structures indicate that rubyfish are a slow-growing and long-lived species (Paul et al 2000). Paul et al (2003) and Horn et al (2012) used radiocarbon

dating techniques on otoliths from 10 rubyfish to determine that the oldest fish in the sample were born prior to the beginning of the period of atmospheric testing and therefore were at least 45 years old. The ages they determined using an age-length-key derived from a catch sampling programme showed that although rubyfish could live to 100+ years, the commercial catch was dominated by young fish (8–15 years).

Horn et al (2012) analysed stable isotopes (oxygen and carbon) from rubyfish otoliths. They showed changes in mean depth with age, with rubyfish near the surface as juveniles, moving deeper with age, and adult rubyfish appearing to reside in 600–1000 m, with some apparent depth through the vertical water column (or possibly changes in geographic location) migrations within this range. They hypothesised that most rubyfish caught commercially are late juveniles and early adults in a transitional phase between early life in near surface semi-pelagic water and adult life in deeper water inaccessible to fishing. However, the suggestion by Bentley et al (2013) that rubyfish populations on distinct topographic features have been serially depleted is supportive of an alternative hypothesis that the exploited fish are part of a transient population which move up sporadically from deeper water to these features for an unknown length of time, probably to feed, thereby becoming vulnerable to fishing operations.

There is little information on rubyfish spawning cycles or areas. Sparse observer records of female gonad stages suggest a November to February spawning season, but that is based on the percentage of fish that are mature. Actual observations of reproductive stage four and five fish during those months are rare, suggesting that they are largely unavailable to the commercial fishery.

Observations on gut contents show that rubyfish feed on midwater crustaceans, salps, and myctophid fishes. Stable oxygen isotope chemistry of samples taken from the core to the outer edge of the otoliths of large fish indicate that juvenile rubyfish feed on significantly lower trophic levels than the adults, but that their metabolic rates declines between age 5 and 10, and trophic level increases as they descend through the water column to depths of about 600 m (Horn et al 2012).

Horn et al (2012) further refined the growth estimates using a four parameter model fitted to the length-age data for ages 8 years and older, while constraining t_0 to be 0.5 (to remove the influence of the younger aged fish). The resulting unweighted length-at-age data were fitted using the von Bertalanffy growth model:

$$L_t = L_\infty [1 - \exp(-K \times (t - t_0))]^P$$

Note that when $P = 1$ the growth model becomes the often-used three-parameter von Bertalanffy equation.

Biological parameter estimates are given in Table 3.

Table 3: Estimates of biological parameters for rubyfish.

Fishstock	Estimate				Source
1. Natural mortality (*M*)					
All	$M = 0.03 – 0.1$				Paul et al (2000, 2003)
2. Weight = a (length)^b (Weight in g, length in cm fork length)					
				Both sexes	
	a	b			
RBY 2	0.0255	2.9282			NIWA (unpub. data)
3. von Bertalanffy growth parameters					
				Both sexes	
	L_∞	K	t_0	P	
RBY 2	48.68	0.045	-16.53		Paul et al (2003)
	47.7	0.031	-0.5(constrained)	0.216	Horn et al (2012)

3. STOCKS AND AREAS

It is not known whether different regional stocks of rubyfish occur in New Zealand waters.

Although landings are reported by Fishstocks which align with the standard QMAs, for stock assessment purposes it may be more appropriate to consider Fishstocks RBY 1 and RBY 9 as one (northern) unit, Fishstock RBY 2 (the main fishery) as an eastern unit, Fishstocks RBY 3–5 as a minor southern unit, and Fishstocks RBY 7 and RBY 8 as a western unit.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance
A biomass index derived from a standardised CPUE (log linear, kg/day) analysis of the target trawl fishery represented by 10 main vessels (Blackwell 2000) was calculated for RBY 2. However, the results were highly uncertain, mainly due to the limited amount of data available, and were not accepted by the Inshore Working Group.

Since 2000–01, most of the rubyfish catch has come from target trawling and since 2008–09, most has come from a single vessel. Furthermore, the target fishery is focused on, and has shifted effort between, relatively few underwater features. This provides the potential for aggregate catch per unit effort to mask localised depletion. For these reasons, QMA wide CPUE standardisations have not been attempted in recent analyses. Summaries of catch, effort, and unstandardised CPUE from the target midwater trawl fishery for eight separate groups of underwater features in RBY 1 and RBY 2 suggest serial depletion both between, and within, groups of features. Initially high catch rates at the southernmost features that were the earliest focus of targeting, declined sharply after only a few years of fishing, and both effort and catch subsequently shifted northward. There is evidence of ongoing "test" fishing on southern features, but catches and catch rates have remained low. In the more recently developed fisheries further north at East Cape and in the Bay of Plenty, catch rates appear to have been maintained by shifts in effort within each group prompted by the discovery of new features within them (Bentley et al 2013).

4.2 Biomass estimates
No information is available.

4.3 Estimation of Maximum Constant Yield (*MCY*)
MCY cannot be determined.

4.4 Estimation of Current Annual Yield (*CAY*)
CAY cannot be determined.

4.5 Other yield estimates and stock assessment results
No information is available.

4.6 Other factors
A substantial catch of rubyfish has been taken in conjunction with alfonsino by the trawl fishery off the North Island east coast. Future quotas and catch restraints imposed on rubyfish could, in turn, constrain the alfonsino fishery. Rubyfish is taken in smaller, irregular quantities in other target trawl fisheries and these fisheries could also be affected by future rubyfish management policy.

Catch sampling has occurred in RBY 2 for four years 1998–99 to 2000–01, and 2006–07 and 2007–08 though data for the recent years are of little value. It is likely that the age composition of RBY varies across features and as the exact location of the samples is not known it is unclear whether the samples have come from the areas that have been consistently fished over time. The earlier catch sampling data show that the fishery is comprised of a large number of age classes with a reasonable proportion of the catch coming from fish of greater than 50 years old (Horn & Sutton 2009).

5. ANALYSIS OF ADAPTIVE MANAGEMENT PROGRAMMES (AMP)

The Ministry of Fisheries revised the AMP framework in December 2000. The AMP framework is intended to apply to all proposals for a TAC or TACC increase, with the exception of fisheries for which there is a robust stock assessment. In March 2002, the first meeting of the new Adaptive Management Programme Working Group was held. Two changes to the AMP were adopted:

* a new checklist was implemented with more attention being made to the environmental impacts of any new proposal;
* the annual review process was replaced with an annual review of the monitoring requirements only. Full analysis of information is required a minimum of twice during the five year AMP.

RBY 1

The TACC for RBY 1 was increased from 109 t to 300 t under the Adaptive Management Programme (AMP) in October 2002.

Full-term Review of RBY 1 AMP in 2007

In 2007 the AMP FAWG reviewed the performance of the AMP (Starr et al 2007). The WG noted:

Fishery characterisation

* Fish are landed as green weight, so there are no conversion factor issues.
* Historical landings have been primarily taken as a bycatch of the bottom trawl fishery targeted at gemfish in the Bay of Plenty. These landings have nearly disappeared as a result of the decline in that fishery.
* The main target fishery has been a midwater trawl fishery associated with features in the Bay of Plenty which operated in 2004–05 and 2005–06.
* It was noted that there may be some merit in considering management options like feature limits in this fishery.

CPUE analysis

* There are insufficient data to use for a standardised analysis so four unstandardised analyses were presented, three from bycatch trawl fisheries for gemfish, tarakihi, and hoki, and one from a bycatch bottom longline fishery directed at hapuku and bluenose. No series was constructed from the target rubyfish fishery because there were sufficient data in only three years. The CPUE trends in the four bycatch fisheries showed variable trends which appeared to reflect effort trends in the respective fisheries rather than RBY biomass trends.

Logbook programme

* There are no logbook data in the database, except 1 trip and 4 tows. There is a problem in obtaining samples because it is difficult to sample the fish, because they are directly dumped into sea water tanks on the ship.
* Recommend a shed sampling programme, or a similar approach to obtain biological data, but the programme will endeavour to collect data that will allow the fish to be linked to a tow.

Environmental effects

* Catch has never exceeded the TACC over the term of the AMP. The target gemfish fishery, the primary bycatch fishery for this species, has diminished considerably in recent years.
* No code of practice in RBY fishery.

Conclusion

* If the AMP continues, there is a need to improve the collection of information. There is a need for more biological data, such as otoliths and lengths from every large landing of this species.
* There is also a need for improved fine-scale catch and effort information for smaller areas.
* The Working Group indicated that a catch curve analysis approach is likely to be the most effective way to monitor this Fishstock.

6.   STATUS OF THE STOCKS

RBY 1

In 2002, RBY 1 was included in the AMP on the basis that the stock had been lightly fished and it seemed likely that the stock was above B_{MSY}. There has been an increase in targeted midwater trawling in RBY 1 and in the 2011–12 fishing most of the national catch was taken in this QMA. It is not known whether the level of recent commercial catches in this QMA is sustainable. The status of RBY 1 relative to B_{MSY} is unknown.

RBY 2

Catch sampling between 1998–99 and 2000–01 indicated that the fishery was then comprised of a large number of age classes with a reasonable proportion of the catch coming from fish of greater than 50 years old. Although relatively high catches were made prior to this period there was no obvious truncation of the age distribution to indicate high and unsustainable levels of fishing mortality. However, catch rates have since declined and there is evidence of serial depletion of underwater features. The catch age structure has not been adequately sampled since then.

Historically, most of the RBY catch came from RBY 2 but have since declined due to reductions in both gemfish and rubyfish targeted midwater trawling effort in the QMA. It is not known whether the level of recent commercial catches in this QMA is sustainable. The status of RBY 2 relative to B_{MSY} is unknown.

Other areas

For most other areas it is not known if recent catches are sustainable. Commercial concentrations of rubyfish probably also exist in areas that have not been fished. The status of other RBY stocks relative to B_{MSY} is unknown.

7.   FOR FURTHER INFORMATION

Bentley, N; Kendrick, T H; MacGibbon, D J (2013). Fishery characterisation and catch-per-unit-effort analyses for rubyfish (*Plagiogeneion rubiginosum*), 1989–90 to 2010–11. (2013 Draft New Zealand Fisheries Assessment Report held by Fisheries New Zealand.)

Blackwell, R (2000) Rubyfish (*Plagiogeneion rubiginosum*) abundance indices from standardised catch per unit effort (CPUE) analysis for the east coast North Island target trawl fishery 1988–89 to 1997–98. *New Zealand Fisheries Assessment Report 2000/54. 24 p.*

Heemstra, P C; Randall, J E (1977) A revision of the Emmelichthyidae (Pisces: Perciformes). *Australian Journal of Marine and Freshwater Research 28(3)*: 361–396.

Hoenig, J M (1983) Empirical use of longevity data to estimate mortality rates. *Fisheries Bulletin 82*: 898–903.

Horn, P L; Neil, H L; Paul, L J; McMillan, P J (2012) Age verification, growth and life history of rubyfish *Plagiogeneion rubiginosum*, *New Zealand Journal of Marine and Freshwater Research, 46:3*: 353–368.

Horn, P L; Sutton, C P (2009) Commercial catch sampling for length and age of gemfish, alfonsino and rubyfish in QMA 2 in the 2006–07 and 2007–08 fishing years. *New Zealand Fisheries Assessment Report. 2009/19.* 38 p.

Mel'nikov, Y S; Ivanin, H A (1995) Age–size composition and mortality of *Plagiogeneion rubiginosum* (Emmelichthyidae) in West Indian Submarine Ridge. *Journal of Ichthyology 35(6)*: 20–27.

Parin, N V (1991) Three new species of the bentho-pelagic fish genus *Plagiogeneion* from the southern Pacific and Indian oceans (Teleostei: Emmelichthyidae). *Proceedings of the Biological Society of Washington 104(3)*: 459–467.

Paul, L J (1997) A summary of biology and commercial landings, and a stock assessment of rubyfish, *Plagiogeneion rubiginosum* (Hutton, 1875) (Percoidei: Emmelichthyidae). New Zealand Fisheries Assessment Research Document 1997/27. 22 p. (Unpublished report held by NIWA library, Wellington.)

Paul, L J; Horn, P L; Francis, M P (2000) Development of an ageing methodology, and first estimates of growth parameters and natural mortality for rubyfish (*Plagiogeneion rubiginosum*) off the east coast of the North Island (QMA 2*). New Zealand Fisheries Assessment Report. 2000/22. 28 p.*

Paul, L J; Sparks, R; Neil, H L; Horn, P L (2003) Maximum ages for bluenose (*Hyperoglyphe antarctica*) and rubyfish (*Plagiogeneion rubiginosum*) determined by the bomb chronometer method of radiocarbon ageing, and comments on the inferred life history of these species). Final Research Report to the Ministry of Fisheries for Project INS2000-02. 70 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

SeaFIC (2005) Report to the Adaptive Management Programme Fishery Assessment Working Group: Performance of the RBY1 Adaptive Management Programme. AMP-WG-2005/04. . (Unpublished report held by Fisheries New Zealand, Wellington.)

Starr, P J (2006) Performance of the RBY 1 Adaptive Management Programme. AMP-WG-2006/12. (Unpublished report held by Fisheries New Zealand, Wellington.)

Starr, P J; Kendrick, T H; Lydon, G J (2007) Report to the Adaptive Management Programme Fishery Assessment Working Group: Full term review of the RBY 1 Adaptive Management Programme. AMP-WG-2007/32. (Unpublished report held by Fisheries New Zealand, Wellington.)

<div align="center">

SCAMPI (SCI)

(*Metanephrops challengeri*)

</div>
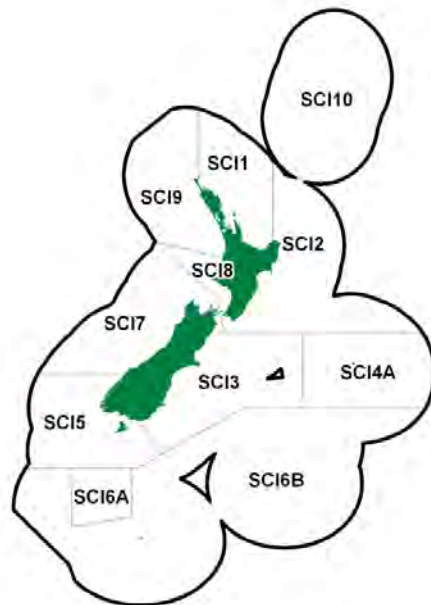
1.   FISHERY SUMMARY

Scampi were introduced into the QMS on 1 October 2004. At this time, management areas for scampi on the Chatham Rise (SCI 3 and 4) and in the Sub-Antarctic (SCI 6A and 6B) were substantially modified. The TACs and TACCs by Fishstock as of 1 October 2021 are shown in Table 1.

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for scampi as of 1 October 2021.

				Allowances	
Fishstock	TAC	Customary	Recreational	Other*	TACC
SCI 1	139	0	0	7	132
SCI 2	161	0	0	8	153
SCI 3	428	0	0	20	408
SCI 4A	126	0	0	6	120
SCI 5	42	0	0	2	40
SCI 6A	321	0	0	15	306
SCI 6B	53	0	0	3	50
SCI 7	79	0	0	4	75
SCI 8	5	0	0	0	5
SCI 9	37	0	0	2	35
SCI 10	0	0	0	0	0

1.1   Commercial fisheries
Target trawl fisheries for scampi developed first in the late 1980s and, until the 1999–2000 fishing year, there were restrictions on the vessels that could be used in each stock. Between October 1991 and September 2002, catches were restrained using a mixture of competitive and individually allocated catch limits but, between October 2001 and September 2004, all scampi fisheries were managed using competitive catch limits—i.e., there were no individual allocations (Figure 1).

Estimated landings and TACCs are given by scampi QMA for 1986–87 to 2018–19 in Table 2.

SCAMPI (SCI)
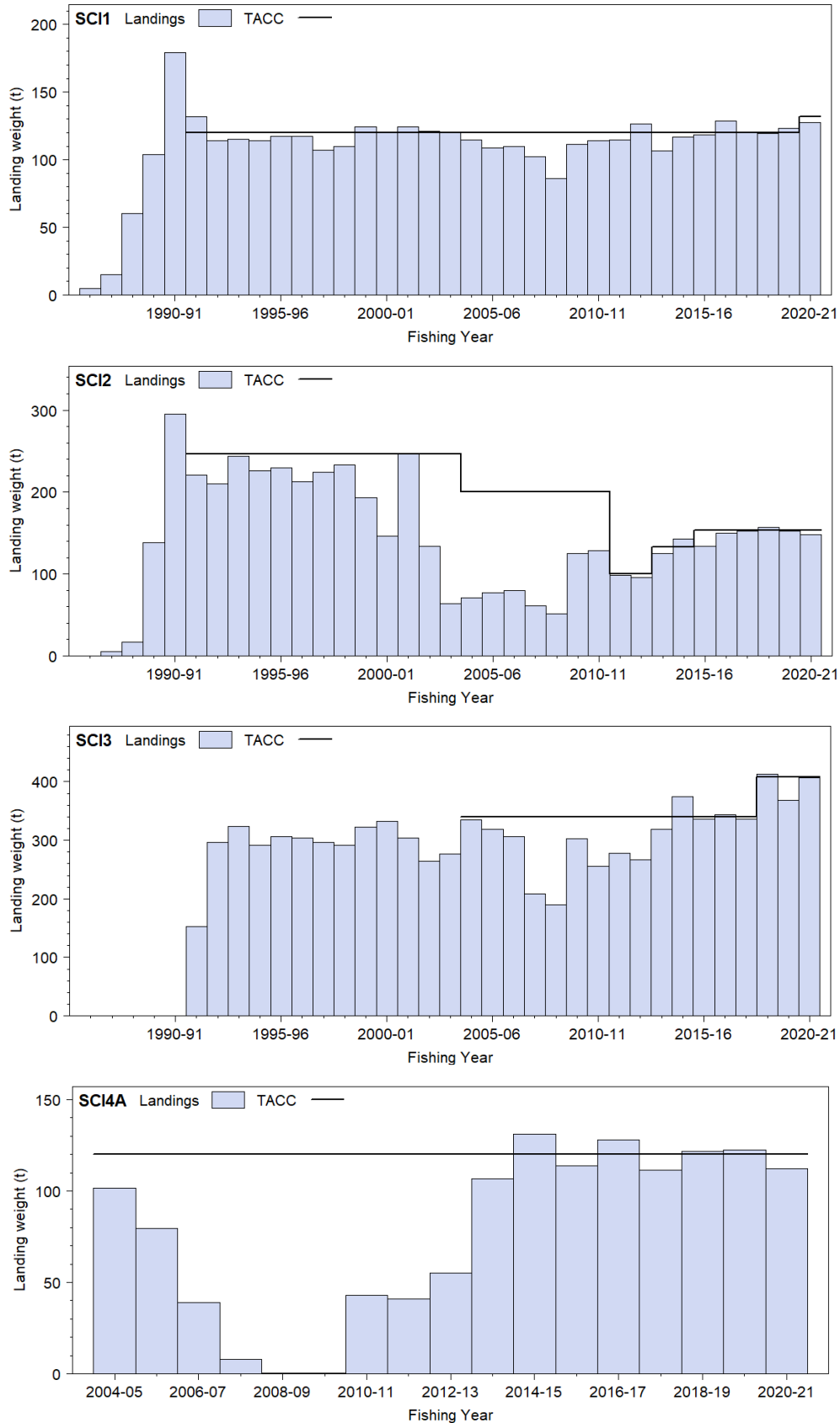
Figure 1: Reported commercial landings and TACCs (or catch limits prior to 2004–05) for the five main SCI stocks from fishing years 1986–87 to present. SCI 1 Bay of Plenty, SCI 2 Wairarapa coast, SCI 3 Chatham Rise, and SCI 4A Chatham Islands. [Continued on next page]
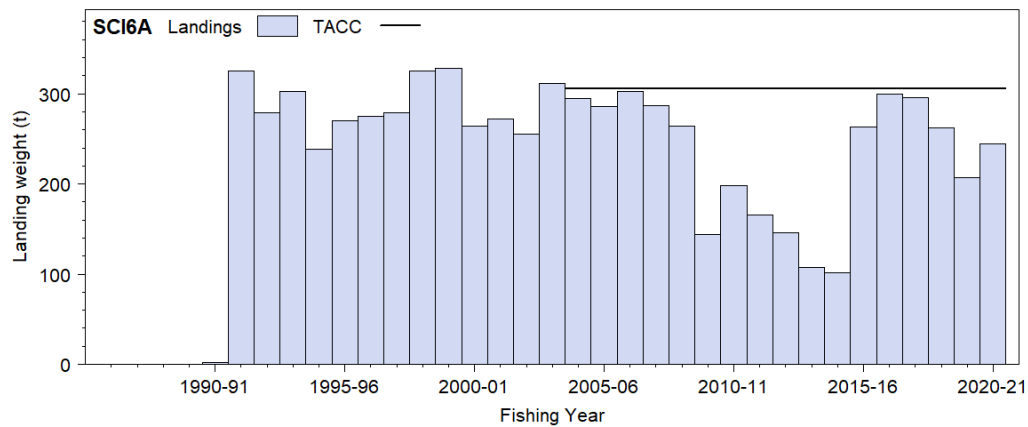
Figure 1: [Continued] Reported commercial landings and TACCs (or catch limits prior to 2004–05) for the five main SCI stocks from fishing years 1986–87 to present: SCI 6A Auckland Islands.

Table 2: Estimated commercial landings (t) from the 1986–87 to present (based on management areas in force since introduction to the QMS in October 2004) and catch limits (t) by Fishstock (from CLR and TCEPR forms and data reported electronically, Fisheries New Zealand landings and catch effort databases, early years may be incomplete). No limits before 1991–92 fishing year, (†) catch limits allocated individually until the end of 2000–01. *Note that management areas SCI 3, 4A, 6A, and 6B changed in October 2004, and the catch limits applied to the old areas are not relevant to the landings, which have been reallocated to the revised areas on a pro rata basis in relation to the TCEPR data, which has previously been found to match landings well. [Continued on next page]

Fishing year	SCI 1 Landings	SCI 1 Limit (†) /TACC	SCI 2 Landings	SCI 2 Limit (†) /TACC	SCI 3 Landings	SCI 3 Limit (†) /TACC	SCI 4A Landings	SCI 4A Limit(†) /TACC	SCI 5 Landings	SCI 5 Limit (†) /TACC
1986–87	5	–	0	–	0	–	0	–	0	–
1987–88	15	–	5	–	0	–	0	–	0	–
1988–89	60	–	17	–	0	–	0	–	0	–
1989–90	104	–	138	–	0	–	0	–	0	–
1990–91	179	–	295	–	0	–	32	–	0	–
1991–92	132	120	221	246	153	–	78	–	0	60
1992–93	114	120	210	246	296	–	11	–	2	60
1993–94	115	120	244	246	324	–	0	–	1	60
1994–95	114	120	226	246	292	–	0	–	0	60
1995–96	117	120	230	246	306	–	0	–	0	60
1996–97	117	120	213	246	304	–	0	–	2	60
1997–98	107	120	224	246	296	–	0	–	0	60
1998–99	110	120	233	246	292	–	28	–	30	60
1999–00	124	120	193	246	322	–	23	–	9	40
2000–01	120	120	146	246	333	–	0	–	7	40
2001–02	124	120	247	246	304	–	30	–	< 1	40
2002–03	121	120	134	246	264	–	79	–	7	40
2003–04	120	120	64	246	277	–	41	–	5	40
2004–05	114	120	71	200	335	340	101	120	1	40
2005–06	109	120	77	200	319	340	79	120	< 1	40
2006–07	110	120	80	200	307	340	39	120	< 1	40
2007–08	102	120	61	200	209	340	8	120	< 1	40
2008–09	86	120	52	200	190	340	1	120	< 1	40
2009–10	111	120	125	200	302	340	< 1	120	< 1	40
2010–11	114	120	128	100	256	340	43	120	< 1	40
2011–12	114	120	99	100	278	340	41	120	< 1	40
2012–13	126	120	96	100	300	340	55	120	< 1	40
2013–14	107	120	125	133	319	340	107	120	< 1	40
2014–15	117	120	143	133	374	340	131	120	< 1	40
2015–16	118	120	134	153	336	340	114	120	< 1	40
2016–17	129	120	150	153	344	340	129	120	< 1	40
2017–18	120	120	152	153	337	340	111	120	< 1	40
2018–19	119	120	157	153	413	408	122	120	< 1	40
2019–20	123	120	152	153	369	408	123	120	< 1	40
2020–21	127	132	148	153	406	408	112	120	<1	40

Table 2: [Continued]

Fishing year	SCI 6A Landings	SCI 6A Limit (†) /TACC	SCI 6B Landings	SCI 6B Limit (†) /TACC	SCI 7 Landings	SCI 7 Limit (†) /TACC	SCI 8 Landings	SCI 8 Limit (†) /TACC	SCI 9 Landings	SCI 9 Limit (†) /TACC
1986–87	0	–	0	–	0	–	0	–	0	–
1987–88	0	–	0	–	0	–	0	–	0	–
1988–89	0	–	0	–	0	–	0	–	0	–
1989–90	0	–	0	–	0	–	0	–	0	–
1990–91	2	–	0	–	0	–	0	–	0	–
1991–92	325	–	0	–	0	75	0	60	0	60
1992–93	279	–	0	–	2	75	0	60	2	60
1993–94	303	–	0	–	0	75	0	60	1	60
1994–95	239	–	0	–	2	75	0	60	0	60
1995–96	270	–	0	–	1	75	0	60	0	60
1996–97	275	–	0	–	0	75	0	60	0	60
1997–98	279	–	0	–	0	75	0	60	0	60
1998–99	325	–	< 1	–	1	75	0	60	< 1	60
1999–00	328	–	0	–	1	75	0	5	0	35
2000–01	264	–	0	–	< 1	75	0	5	0	35
2001–02	272	–	0	–	< 1	75	0	5	0	35
2002–03	255	–	0	–	< 1	75	0	5	0	35
2003–04	311	–	0	–	1	75	0	5	0	35
2004–05	295	306	0	50	1	75	0	5	0	35
2005–06	286	306	0	50	1	75	0	5	0	35
2006–07	302	306	0	50	< 1	75	0	5	0	35
2007–08	287	306	0	50	1	75	0	5	0	35
2008–09	264	306	< 1	50	1	75	0	5	0	35
2009–10	144	306	0	50	2	75	0	5	0	35
2010–11	198	306	< 1	50	4	75	0	5	0	35
2011–12	166	306	< 1	50	6	75	0	5	< 1	35
2012–13	146	306	0	50	7	75	0	5	< 1	35
2013–14	107	306	< 1	50	4	75	0	5	< 1	35
2014–15	102	306	< 1	50	9	75	0	5	< 1	35
2015–16	263	306	< 1	50	9	75	0	5	< 1	35
2016–17	300	306	< 1	50	3	75	0	5	< 1	35
2017–18	295	306	< 1	50	4	75	0	5	< 1	35
2018–19	262	306	0	50	1	75	0	5	< 1	35
2019–20	207	306	< 1	50	< 1	75	0	5	< 1	35
2020–21	245	306	0	50	1	75	0	5	<1	35

Fishing has been conducted by 20–40 m vessels using light, bottom trawl gear but over the last ten years all vessels are less than 32 m long. All vessels use multiple rigs of two or three nets of very a low headline height. The main fisheries are in waters 300–500 m deep in SCI 1 (Bay of Plenty), SCI 2 (Hawke Bay, Wairarapa Coast), SCI 3 (Mernoo Bank), SCI 4A (western Chatham Rise and Chatham Islands), and 350–550 m in SCI 6A (Sub-Antarctic). Some fishing has been reported on the Challenger Plateau outside the EEZ. Minimal fishing for scampi has taken place in SCI 5, 6B, 7, 8, and 9.

1.2 Recreational fisheries
There is no recreational fishery for scampi.

1.3 Māori customary fisheries
There is no customary fishery for scampi.

1.4 Illegal catch
There is no quantitative information on the level of illegal catch. It is assumed to be zero.

1.5 Other sources of mortality
Other sources of fishing related mortality in scampi could include incidental effects of trawl gear on the animals and their habitat.

2. BIOLOGY

Scampi are widely distributed around the New Zealand coast, principally in depths between 200 and 500 m on the continental slope. Like other species of *Metanephrops* and *Nephrops*, *M. challengeri* builds a burrow in the sediment and may spend a considerable proportion of time within this burrow. From trawl catch rates, it appears that there are daily and seasonal cycles of emergence from burrows

onto the sediment surface. Catch rates are typically higher during the hours of daylight than night, and patterns vary seasonally between sexes and areas, dependent on the moult cycle.

Scampi moult several times per year in early life and probably about once a year after sexual maturity (at least in females). Early work suggested that female *M. challengeri* achieve sexual maturity at about 40 mm orbital carapace length (OCL) in the Bay of Plenty and on the Chatham Rise, about 36 mm OCL off the Wairarapa coast, and about 56 mm OCL around the Auckland Islands (approximately age 3 to 4 years). Examination of ovary maturity on more recent trawl surveys suggest that 50% of females were mature at 30 mm OCL in SCI 1 and 2, and at about 38 mm in SCI 6A. The peak of moulting and spawning activity seems to occur in spring or early summer. Larval development of *M. challengeri* is probably very short and may be less than three days in the wild. The abbreviated larval phase may, in part, explain the low fecundity of *M. challengeri* compared with *N. norvegicus* (that of the former being about 10–20% that of the latter).

Relatively little is known of the growth rate of any of the *Metanephrops* species in the wild. Males grow to a larger size than females. Tagging of *M. challengeri* to determine growth rates was undertaken in the Bay of Plenty in 1995, and the bulk of recaptures were made late in 1996. About 1% of tagged animals were recaptured, similar to the average return rate of similar tagging studies for scampi and prawns in the UK and Australia. Many more females than males were recaptured, and small males were almost entirely absent from the recapture sample. The reasons for this are not understood but may relate to the timing of moulting in relation to the study and tag retention. Scampi captured and tagged at night were much more likely to be recaptured than those exposed to sunlight. Estimates from this work of growth rate and mortality for females are given in Table 3. The data for males were insufficient for analysis, although the average annual increment with size appeared to be greater than in females.

Table 3: Estimates of biological parameters.

Population		Estimate	Source
1. Weight = a(orbital carapace length)^b (weight in g, OCL in mm)			
All males: SCI 1	$a = 0.000373$	$b = 3.145$	Cryer & Stotter (1997)
Ovigerous females: SCI 1	$a = 0.003821$	$b = 2.533$	Cryer & Stotter (1997)
Other females: SCI 1	$a = 0.000443$	$b = 3.092$	Cryer & Stotter (1997)
All females: SCI 1	$a = 0.000461$	$b = 3.083$	Cryer & Stotter (1997)
2. von Bertalanffy growth parameters			
	K (y^{-1})	L_∞ (OCL, mm)	
Females: SCI 1 (tag)	0.11–0.14	48.0–49.0	Cryer & Stotter (1999)
Females: SCI 2 (aquarium)	0.31	48.8	Cryer & Oliver (2001)
Males: SCI 2 (aquarium)	0.32	51.2	Cryer & Oliver (2001)
3. Natural mortality (*M*)			
Females: SCI 1		$M = 0.20$–0.25	Cryer & Stotter (1999)

Note: Estimates of *M* are based on the relationship between growth rate and natural mortality and are subject to considerable uncertainty. Analytical assessment models have been examined for *M*=0.2 and *M*=0.3.

Scampi from SCI 2 were successfully reared in aquariums for over 12 months in 1999–2000. Results from these growth trials suggested a Brody coefficient of about 0.3 for both sexes, compared with less than 0.15 from the tagging trial. Extrapolating the length-based results to age-based curves suggests that scampi are about 3–4 years old at 30 mm carapace length and may live for 15 years. There are many uncertainties with captive reared animals, and these estimates should not be regarded as definitive. In particular, the rearing temperature was 12 ºC compared with about 10 ºC in the wild (in SCI 1 and 2), and the effects of captivity are largely unknown.

The maximum age of New Zealand scampi is not known, although analysis of tag return data and aquarium trials suggest that this species may be quite long lived. *Metanephrops* spp. in Australian waters may grow rather slowly and take up to 6 years to recruit to the commercial fishery (Rainer 1992), consistent with estimates of growth in *M. challengeri* (Table 3). *Nephrops norvegicus* populations in some northern European populations achieve a maximum age of 15–20 years (Bell et al 2006), consistent with the estimates of natural mortality, *M*, for *M. challengeri*.

A tagging project has been conducted in SCI 6A, with six release events (March 2007, 2008, 2009, 2013, 2016, and 2019). Most recaptures occur within a year of release. Tagging work has also more

recently been conducted in SCI 1, 2, and 3, although recapture rates have been low. Tag recaptures are fitted within assessment models to estimate growth.

3. STOCKS AND AREAS

Stock structure of scampi in New Zealand waters is not well known. Preliminary electrophoretic analyses suggest that scampi in SCI 6A are genetically distinct from those in other areas, and there is substantial heterogeneity in samples from SCI 1, 2, and 4A. Studies using newer mitochondrial DNA and microsatellite approaches are underway and are likely to be more sensitive to differences between stocks. The abbreviated larval phase of this species may lead to low rates of gene mixing. Differences among some scampi populations in average size, size at maturity, the timing of diel and seasonal cycles of catchability, catch to bycatch ratios, and CPUE trends also suggest that treatment as separate management units is appropriate.

A review of stock boundaries between SCI 3 and SCI 4A and between SCI 6A and SCI 6B was conducted in 2000, prior to introduction of scampi into the Quota Management System. Following the recommendation of this review, the boundaries were changed on 1 October 2004, to reflect the distribution of scampi stocks and fisheries more appropriately.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

Tables and accompanying text in this section have been updated for the 2022 Fishery Assessment Plenary where possible. A more detailed summary from an issue-by-issue perspective is available in the Aquatic Environment and Biodiversity Annual Review 2021 (Fisheries New Zealand 2021), online at https://www.mpi.govt.nz/dmsdocument/51472-Aquatic-Environment-and-Biodiversity-Annual-Review-AEBAR-2021-A-summary-of-environmental-interactions-between-the-seafood-sector-and-the-aquatic-environment.

4.1 Role in the ecosystem
Scampi are thought to prey mainly on invertebrates (Meynier et al 2008) or carrion. A 3-year diet study of the Chatham Rise showed that scampi was the first, third, and fourth most important item (by IRI, Index of Relative Importance) in the diet of smooth skate, ling, and sea perch, respectively (Dunn et al 2009). Scampi build and maintain burrows in the sediment and this bioturbation is thought to influence oxygen and nutrient fluxes across the sediment-water boundary, especially when scampi density is high (e.g., Hughes & Atkinson 1997, who studied *Nephrops norvegicus* at densities of 1–3 m^{-2}). Observed densities from photographic surveys in New Zealand have been 0.02–0.1 m^{-2} (Tuck 2010), similar to densities of *N. norvegicus* in comparable depths.

4.2 Bycatch (fish and invertebrates)
In the 2002–03 to 2015–16 fishing years, total annual bycatch was estimated to range from 2400–5600 t compared with total landed scampi catches of 550–893 t, and scampi accounted for 19% of the total estimated catch by weight from all observed tows (Anderson & Edwards 2018). Nearly 500 bycatch species or species groups were identified by observers, and the main bycatch species were javelinfish (18%), rattails (12%), and sea perch (10%), which were mostly discarded (Figure 2). Smaller catches of hoki (5%), ling (4%), and dark ghost shark (3%) were also recorded. Invertebrate species made up a much smaller fraction of the bycatch overall (about 7%), with crustaceans (3%), echinoderms (2%), and squid (0.9%) being the main invertebrate bycatch species groups.

Total annual discard estimates from 2002–03 to 2015–16 showed no trend over time, ranging from a low of 940 t in 2003–04 to 4070 t in the following year (Anderson & Edwards 2018). Non-QMS species were the main group discarded, often at a magnitude of two to three times that of QMS species discards. Annual estimated discards of scampi were generally low but exceeded 10 t in two years (2002–03 and 2009–10). The species discarded in the greatest amounts were those caught in the greatest amounts, javelinfish (95%), rattails (91%), and sea perch (68%). From 2002–03 to 2015–16, the overall discard fraction value was 3.6 kg, with little trend over time. Discards ranged from 1.2 to 4.9 kg of discarded fish for every 1 kilogram of scampi caught.
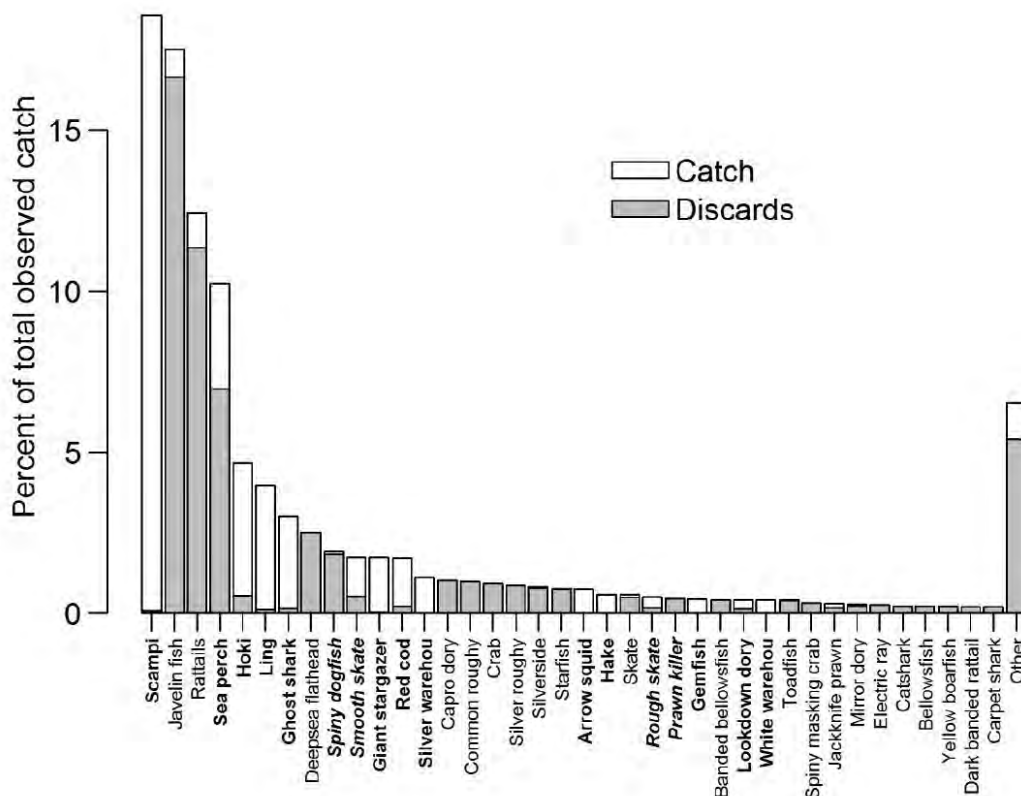
Figure 2: Percentage of the total catch contributed by the main bycatch species (those representing 0.02% or more of the total catch) in the observed portion of the target scampi trawl fishery for fishing years 2002–03 to 2015–16, and the percentage discarded. The Other category is the sum of all bycatch species representing less than 0.02% of the total catch (Anderson & Edwards 2018).

4.3   Incidental catch (seabirds, mammals, and protected fish)

For protected species, capture estimates presented here include all animals recovered to the deck (alive, injured, or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds struck by a warp but not brought onboard the vessel, Middleton & Abraham 2007). Risk assessments results, which also include estimation of cryptic mortality, are also presented here when relevant.

Marine mammal captures

Scampi trawlers occasionally catch marine mammals, including New Zealand sea lions (rāpoka), *Phocarctos hookeri,* and New Zealand fur seals (which were classified as 'Nationally Vulnerable' and 'Not Threatened', respectively, under the New Zealand Threat Classification System in 2013, Baker et al 2016).

In the 2017–18 fishing year there were two observed New Zealand sea lion captures in scampi trawl fisheries, and one in 2018–19 (Table 4). Captures in previous years all occurred near the Auckland Islands in SCI 6A (Thompson et al 2011).

Since the 2002–03 fishing year there have been 10 observed New Zealand fur seal captures in scampi trawl fisheries, based on an average of 9% observer coverage (Table 5). Since 2002–03, only about 0.7% of the estimated total fur seal captures in all commercial fisheries have been taken in scampi fisheries; these have been on the western Chatham Rise and off the Auckland Islands.

Capture rates for both sea lions and fur seals have been low and have fluctuated without obvious trend.

Table 4: Number of tows (commercial and observed) by fishing year, observed and estimated New Zealand sea lion captures, and capture rate in scampi trawl fisheries, 2002–03 to 2019–20 (Abraham et al 2021). Estimates are available online at https://protectedspeciescaptures.nz/PSCv6/released/. Observed and estimated protected species captures in this table derive from the PSC database version PSCV6.

Fishing year	Fishing effort			Obs. captures		Est. captures		Est. capture rate	
	Tows	No. Obs	% obs	Captures	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	5 130	512	10.0	0	0.00	7	2-15	0.14	0.04-0.29
2003–04	3 753	412	11.0	3	0.73	10	5-18	0.27	0.13-0.48
2004–05	4 648	143	3.1	0	0.00	8	2-16	0.17	0.04-0.34
2005–06	4 867	331	6.8	1	0.30	8	3-16	0.17	0.06-0.33
2006–07	5 135	389	7.6	1	0.26	8	3-16	0.16	0.06-0.31
2007–08	4 804	524	10.9	0	0.00	8	2-15	0.16	0.04-0.31
2008–09	3 975	396	10.0	1	0.25	10	3-18	0.24	0.08-0.45
2009–10	4 248	348	8.2	0	0.00	5	1-11	0.12	0.02-0.26
2010–11	4 447	536	12.1	0	0.00	7	2-15	0.16	0.04-0.34
2011–12	4 509	459	10.2	0	0.00	7	2-14	0.15	0.04-0.31
2012–13	4 565	270	5.9	0	0.00	6	1-12	0.13	0.02-0.26
2013–14	4 421	254	5.7	0	0.00	5	1-11	0.11	0.02-0.25
2014–15	4 423	342	7.7	0	0.00	3	0-8	0.07	0-0.18
2015–16	5 210	144	2.8	0	0.00				
2016–17	4 707	447	9.5	0	0.00				
2017–18	4 345	545	12.5	2	0.37				
2018–19	4 377	679	15.5	1	0.15				
2019–20	4 562	528	11.6	0	0.00				

Table 5: Number of tows (commercial and observed) by fishing year, observed and estimated New Zealand fur seal captures, and capture rate in scampi trawl fisheries, 2002–03 to 2019–20 (Abraham et al 2021). Estimates are available online at https://protectedspeciescaptures.nz/PSCv6/released/. Observed and estimated protected species captures in this table derive from the PSC database version PSCV6.

Fishing year	Fishing effort			Obs. captures		Est. captures		Est. capture rate	
	Tows	No. Obs	% obs	Captures	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	5 130	512	10.0	2	0.39	8	2–18	0.15	0.04–0.35
2003–04	3 753	412	11.0	1	0.24	5	1–14	0.15	0.03–0.37
2004–05	4 648	143	3.1	0	0.00	13	2–37	0.27	0.04–0.80
2005–06	4 867	331	6.8	0	0.00	7	1–20	0.15	0.02–0.41
2006–07	5 135	389	7.6	0	0.00	7	1–20	0.14	0.02–0.39
2007–08	4 804	524	10.9	1	0.19	8	2–20	0.16	0.04–0.42
2008–09	3 975	396	10.0	1	0.25	5	1–13	0.13	0.03–0.33
2009–10	4 248	348	8.2	1	0.29	8	2–20	0.18	0.05–0.47
2010–11	4 447	536	12.1	0	0.00	4	0–12	0.09	0.00–0.27
2011–12	4 509	459	10.2	1	0.22	7	2–18	0.16	0.04–0.40
2012–13	4 565	270	5.9	0	0.00	5	0–15	0.11	0.00–0.33
2013–14	4 421	254	5.7	0	0.00	4	0–12	0.08	0.00–0.27
2014–15	4 423	342	7.7	1	0.29	7	2–20	0.17	0.05–0.45
2015–16	5 210	144	2.8	0	0.00	5	0–14	0.09	0.00–0.27
2016–17	4 707	447	9.5	1	0.22	6	1–16	0.13	0.02–0.34
2017–18	4 345	545	12.5	0	0.00	3	0–10	0.08	0.00–0.23
2018–19	4 377	679	15.5	0	0.00				
2019–20	4 562	528	11.6	1	0.19				

Seabird captures

Observed seabird capture rates in scampi fisheries have ranged from about 1 to 20 per 100 tows and fluctuate without obvious trend (Table 6). In the 2017–18 fishing year there were 19 observed captures of birds in scampi trawl fisheries, with 130 (95% c.i.: 99–165) estimated captures, with the estimates made using a consistent modelling framework (Abraham et al 2016, Abraham & Richard 2017, 2018; Table 6). There were 11 observed captures in the 2016–17, with estimates of total captures of 127 (95% c.i.: 95–163, Table 6). The estimates are based on relatively low observer coverage and include all bird species and should, therefore, be interpreted with caution. The average observed capture rate in scampi trawl fisheries for 2002–03 to 2019–20 (all areas combined) is about 4 birds per 100 tows, a moderate rate relative to trawl fisheries for squid (12.94 birds per 100 tows) and hoki (2.3-2.9 birds per 100 tows) over the same years.

Observed seabird captures in the SCI target trawl fishery since 2002–03 have been dominated by four species: Salvin's and white-capped albatrosses make up 44% and 28% of the albatrosses captured, respectively; white-chinned petrel, flesh-footed shearwater, and common diving petrel make up 29%, 23%, and 19% of other birds, respectively. The total and fishery risk ratios are presented in Table 7. Most of the captures occur near the Auckland Islands (39%), in the Bay of Plenty (36%), or on the Chatham Rise (21%). These numbers should be regarded as only a general guide on the distribution of captures because observer coverage is not uniform across areas and may not be representative.

Table 6: Number of tows by fishing year and observed seabird captures in scampi trawl fisheries, 2002–03 to 2019–20. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described by Abraham & Richard (2020) and are available online at https://protectedspeciescaptures.nz/PSCv6/released/. Observed and estimated protected species captures in this table derive from the PSC database version PSCV6.

	Fishing effort			Obs. captures		Est. captures		Est. capture rate	
Fishing year	**Tows**	**No. Obs**	**% obs**	**Captures**	**Rate**	**Mean**	**95% c.i.**	**Mean**	**95% c.i.**
2002–03	5 130	512	10.0	7	1.37	140	94–198	2.73	1.83–3.86
2003–04	3 753	412	11.0	7	1.70	105	68–153	2.81	1.81–4.08
2004–05	4 648	143	3.1	9	6.29	145	102–197	3.12	2.19–4.24
2005–06	4 867	331	6.8	11	3.32	152	106–209	3.12	2.18–4.29
2006–07	5 135	389	7.6	24	6.17	153	109–204	2.98	2.12–3.97
2007–08	4 804	524	10.9	11	2.10	126	87–176	2.62	1.81–3.66
2008–09	3 975	396	10.0	19	4.80	135	96–184	3.41	2.42–4.63
2009–10	4 248	348	8.2	5	1.44	111	72–158	2.61	1.69–3.72
2010–11	4 447	536	12.1	109	20.34	240	196–297	5.41	4.41–6.68
2011–12	4 509	459	10.2	9	1.96	125	86–173	2.78	1.91–3.84
2012–13	4 565	270	5.9	6	2.22	132	91–183	2.89	1.99–4.01
2013–14	4 421	254	5.7	7	2.76	129	89–177	2.93	2.01–4.00
2014–15	4 423	342	7.7	8	2.34	120	82–166	2.71	1.85–3.75
2015–16	5 210	144	2.8	3	2.08	152	108–204	2.92	2.07–3.92
2016–17	4 707	447	9.5	12	2.68	127	89–173	2.70	1.89–3.68
2017–18	4 345	545	12.5	19	3.49	131	94–177	3.01	2.16–4.07
2018–19	4 377	679	15.5	17	2.50	115	80–156	2.63	1.83–3.56
2019–20	4 562	528	11.6	9	1.70	117	81–162	2.57	1.78–3.55

Table 7: Risk ratio of seabirds predicted by the level two risk assessment for the SCI target trawl fishery and all fisheries included in the level two risk assessment, 2006–07 to 2016–17, showing seabird species with a risk ratio of at least 0.001 of PST. The risk ratio is an estimate of aggregate potential fatalities (inclusive of cryptic mortality) across trawl and longline fisheries relative to the Population Sustainability Threshold, PST (from Richard et al 2017 and Richard et al 2020, where full details of the risk assessment approach can be found). The 2018–19 and 2019–20 data were unavailable at the time of publication. The DOC threat classifications are shown (Robertson et al 2017 at http://www.doc.govt.nz/documents/science-and-technical/nztcs19entire.pdf).

		Risk ratio			
Species name	**PST (mean)**	**SCI target trawl***	**Total**	**Risk category**	**DOC Threat Classification**
Salvin's albatross	3 460	0.077	0.65	High	Threatened: Nationally Critical
Flesh-footed shearwater	1 450	0.033	0.49	High	Threatened: Nationally Vulnerable
Northern Buller's albatross	1 640	0.030	0.26	Medium	At Risk: Naturally Uncommon
Black petrel	447	0.011	1.23	Very high	Threatened: Nationally Vulnerable
Northern giant petrel	337	0.008	0.15	Medium	At Risk: Naturally Uncommon
New Zealand white-capped albatross	10 800	0.008	0.29	Medium	At Risk: Declining
Southern Buller's albatross	1 360	0.007	0.37	High	At Risk: Naturally Uncommon
White-chinned petrel	25 800	0.006	0.07	Low	At Risk: Declining
Chatham Island albatross	428	0.003	0.28	High	At Risk: Naturally Uncommon
Campbell black-browed albatross	2 000	0.003	0.05	Low	At Risk: Naturally Uncommon

* SCI target trawl from Richard et al (2017).

4.4 Benthic interactions

The spatial extent of seabed contact by trawl fishing gear in New Zealand's EEZ and Territorial Sea has been estimated and mapped in numerous studies for trawl fisheries targeting deepwater species (Baird et al 2011, Black et al 2013, Black & Tilney 2015, Black & Tilney 2017, Baird & Wood 2018, and Baird & Mules 2019, 2021a, 2021b), species in waters shallower than 250 m (Baird et al. 2015, Baird & Mules 2020a), and all trawl fisheries combined (Baird & Mules 2021a, 2021b). The most recent assessment of the deepwater trawl footprint was from 1989–90 to 2018–19 (Baird & Mules 2021b).

During 1989–90 to 2018–19, about 135 300 scampi bottom trawls were reported on TCEPRs, TCERs, and ERS (Baird & Mules 2021b). The total footprint generated from these tows was estimated at about 20 938 km^2. This footprint represented coverage of 0.5% of the seabed of the combined EEZ and the Territorial Sea areas; 1.5% of the 'fishable area', that is, the seabed area open to trawling, in depths of less than 1600 m. For the 2018–19 fishing year, 5375 scampi bottom tows had an estimated footprint of 4598 km^2 which represented coverage of 0.1% of the EEZ and Territorial Sea and 0.3% of the fishable area (Baird & Mules 2021b).

The overall trawl footprint for scampi (1989–90 to 2018–19) covered < 1.0% of seabed in depths less than 200 m, 9.6% in 200–400 m, and 3.5% of 400–600 m seafloor (Baird & Mules 2021b). The scampi footprint contacted < 0.1%, 2.2%, and 1% of those depth ranges, respectively, in 2018–19 (Baird & Mules 2021b). The BOMEC areas with the highest proportion of area covered by the scampi footprint were classes H (Chatham Rise) and L (deeper waters off the Stewart-Snares shelf and around the main sub-Antarctic islands). In 2018–19, the scampi footprint covered ≤ 0.01% of each BOMEC class (Baird & Mules 2021b).

Bottom trawling for scampi, like trawling for other species, is likely to have effects on benthic community structure and function (e.g., Cryer et al 2002 for a specific analysis and Rice 2006 for an international review) and there may be consequences for benthic productivity (e.g., Jennings et al 2001, Hermsen et al 2003, Hiddink et al 2006, Reiss et al 2009). These consequences are not considered in detail here but are discussed in the Aquatic Environment and Biodiversity Annual Review 2021 (Fisheries New Zealand 2021).

4.5 Other considerations

None considered by the Aquatic Environment Working Group.

5. STOCK ASSESSMENT

In 2011 the Shellfish Fishery Assessment Working Group (SFWG) accepted the stock assessments for SCI 1 and SCI 2, undertaken using a length-based population model. A length-based assessment was also accepted for SCI 3 in 2015, and for SCI 6A in 2017. No stock assessment has been undertaken for SCI 4A, but a stock characterisation and CPUE standardisation were completed in 2019.

In 2022, the Deepwater Fisheries Assessment Working Group (DWWG) rejected an updated assessment of SCI 1 because the results were considered overly sensitive to the choice of prior for the trawl survey catchability, and to choices around data weighting and the estimation of process error. A 2022 update of the SCI 2 assessment was accepted as a quality 2 assessment because the available base case, while robust to the choice of prior for trawl survey catchability, provided insufficient exploration of differing recent trends in the trawl survey and CPUE indices.

Section 5.2 summarises the stock assessments that have to date been accepted by Fisheries New Zealand working groups.

Attempts have been made to index scampi abundance using CPUE and trawl survey indices and photographic surveys of visible scampi and scampi burrows. In 2022 the burrow count estimates were rejected by the DWWG for SCI 1 and SCI 2 due to inconsistencies in reader interpretation of burrows. All three indices were included in the length-based assessment models for SCI 3 and SCI 6A.

5.1 Estimates of fishery parameters and abundance

Standardised CPUE indices

Standardised CPUE indices are calculated for each stock every three years, as part of the stock assessment process. Unstandardised CPUE indices for each area (total catch divided by total effort in hours of trawling) are updated annually, using the data from all vessels that fished (Figure 3). The SFWG has raised concerns in the past that potential variability in catchability related to burrow emergence between years mean that standardised CPUE may not provide a reliable index of abundance, although consistent changes shown by different types of indices for the same area provide more confidence in the data. The standardised indices for areas SCI 3, 4A, 6A, and 6B have been recalculated over the time series in light of the alterations of some stock boundaries, following the review mentioned in Section 3. All discussions below relate to standardised CPUE.

In SCI 1, CPUE increased in the early 1990s, and then declined between 1995–96 and 2001–02, showed a slight increase in 2002–03 and 2003–04, but generally remained stable until 2016–17, with an increase since then. In SCI 2, CPUE increased in 1994–95, then declined steadily to 2001–02, remained at quite a low level until 2007–08, increased until 2013–14 (with CPUE comparable with that recorded in the mid–1990s), declining slightly after this to levels comparable with the late 1990s, remaining stable after 2015–16 with a slight increase in 2018–19 followed by a decline in 2019–20 and 2020–21. In SCI 3, CPUE rose steadily through the early 1990s, fluctuated around a slowly declining trend in the late 1990s and early 2000s, showed a steeper decline to 2007–08, increased to 2010–11, and then remained stable until increasing in 2016–17 to a level that has been maintained to 2020–21 In SCI 4A, CPUE observations were intermittent between 1991–92 and 2002–03, showing a dramatic increase over this period. Since 2002–03 CPUE has been far lower, but since 2010–11 data show an increase, with a steep increase since 2016–17. In SCI 6A, after an initial decline in the early 1990s, CPUE has fluctuated around a gradually declining trend. With the revision of the stock boundaries, data are only available for one year for SCI 6B and are therefore not presented. For both SCI 5 and SCI 7, observations have been intermittent, and consistently low.

Trawl Surveys

Since scampi are only available to trawl catches when out of their burrows, trawl survey indices are subject to the same potential concerns as CPUE indices relating to changes in scampi emergence. A time series of trawl surveys designed to measure relative biomass of scampi in SCI 1 and 2 ran between January 1993 and January 1995 (Table 8). Research trawling for other purposes has been conducted in both SCI 1 and SCI 2 in several other years, and catch rates from appropriate hauls within these studies have been plotted alongside the dedicated trawl survey data in Figure 4a and Figure 4b. In SCI 1 the additional trawling was conducted in support of a tagging programme (in 1995 and 1996), which was conducted by a commercial vessel in the peak area of the fishery, whereas work to assess trawl selectivity (1996) and in support of photographic surveys (since 1998) may have been more representative of the overall area. This later index has remained relatively stable through the series. In SCI 2 the additional trawling was conducted in support of a growth investigation using length frequency data (1999 and 2000) and in support of photographic surveys (since 2003). All the work was carried out by the same research vessel, but, whereas the work in support of photographic surveys was carried out over the whole area, the work related to the growth investigation was concentrated in a small area in the south of the SCI 2 area. Only the additional trawl survey work in support of photographic surveys has been included in Table 8, because the other studies did not have comparable spatial coverage. The trawl survey index shows an increase from the low levels in the mid-2000s to 2015, and a slight decrease by 2018 followed by a sharp increase in 2020–21. The trends observed are similar to the trends in commercial CPUE (Figure 3) for both stocks except for the last point in SCI 2.

Surveys have been conducted in SCI 3 in 2001 (two surveys, pre- and post- fishery), 2009, 2010, 2013, 2016, and 2019. The trawl component of the surveys did not suggest any difference between the pre- and post-fishery periods in 2001, but the photographic survey observed more scampi burrows after the fishery. These indices were analysed spatially with respect to three sub-areas that are used in the stock assessment to reflect differences in the dynamics of the fishery (Figure 5). Trawl, photographic, and CPUE data indicate a significant decline in scampi abundance between 2001 and 2009, but an increase in more recent years (Figure 6).

SCAMPI (SCI)
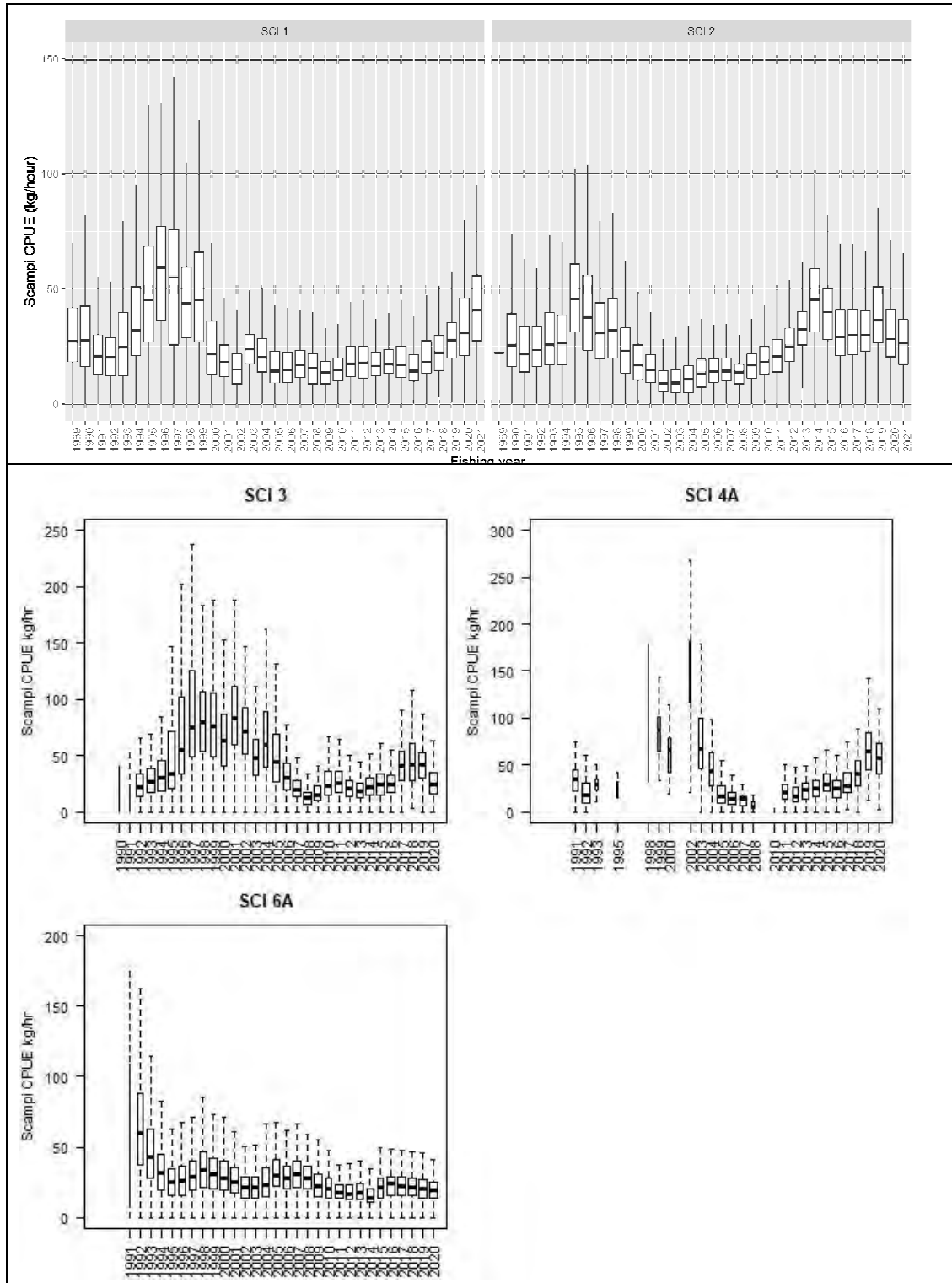
Figure 3: Box plots (with outliers removed) of individual observations of unstandardised catch rate for scampi (tow catch (kilogram) divided by tow effort (hours)) with tows of zero scampi catch excluded, by fishing year for main stocks. Box widths are proportional to square root of the number of observations. Note different scales between plots. Horizontal bars within boxes represent distribution median. Upper and lower limits of boxes represent upper and lower quartiles. Whisker extends to largest (or smallest) observation which is less than or equal (greater than or equal) to the upper quartile plus 1.5 times the interquartile range (lower quartile less 1.5 times the interquartile range). Outliers (removed from this plot) are values outside the whiskers. Box width proportional to square root of number of observations.

1362

Table 8: Trawl survey indices of biomass (t) for scampi in survey strata within SCIs 1, 2, 3, and 6A. CVs of estimates in parentheses. Trawl surveys between 1998 and 2015 were conducted in support of the photographic surveys.

Year	SCI 1	SCI 2	SCI 3	SCI 6A
1993	217.3 (0.12)	238.2 (0.12)		
1994	288.2 (0.19)	170.0 (0.16)		
1995	391.6 (0.18)	216.2 (0.18)		
1996				
1997				
1998	174.0 (0.17)			
1999				
2000	181.3 (*)			
2001	179.5 (0.27)		272.5 (0.24) (strata 902–3)**	
2002	130.6 (0.24)			
2003		28.0 (*)		
2004		46.9 (0.20)		
2005		50.8 (0.35)		
2006		22.9 (0.19)		
2007				1073.5 (0.18)
2008	211.9 (*)			1229.1 (0.18)
2009			40.2 (0.37) (strata 902–3) 418.1 (0.26)	821.6 (0.09)
2010			49.0 (0.11) (strata 902–3) 596.1 (0.04)	
2011				
2012	150.0 (0.25)	164.2 (0.28)		
2013			126.5 (0.27) (strata 902–3) 551.3 (0.12)	1258.0 (0.06)
2014				
2015	118.5 (0.17)	224.5 (0.19)		
2016			139.6 (0.14) (strata 902–3) 913.1 (0.12)	593.3 (0.09)†
2017				
2018	188.6 (0.21)	183.3 (0.29)		
2019			158.3 (0.19) (strata 902–3) 1219.9 (0.06)	710.9 (0.12)†
2020				
2021	480.76 (0.23)	529.20 (0.25)		

* Where no CV is provided, one stratum had only one valid station. Strata included: SCI 1 – 302, 303, 402, 403; SCI 2 – 701, 702, 703, 801, 802, 803; SCI 3 – 902, 903, 904; SCI 6A (main area) – 350 m, 400 m, 450 m, 500 m. SCI 3 survey in 2009 and 2010 split into area surveyed in 2001, and new area (strata 902A–C & 903A).

** SCI 3 pre-season survey.

† 2016 and 2019 surveys in SCI 6A conducted with a different vessel from previous surveys in this area.
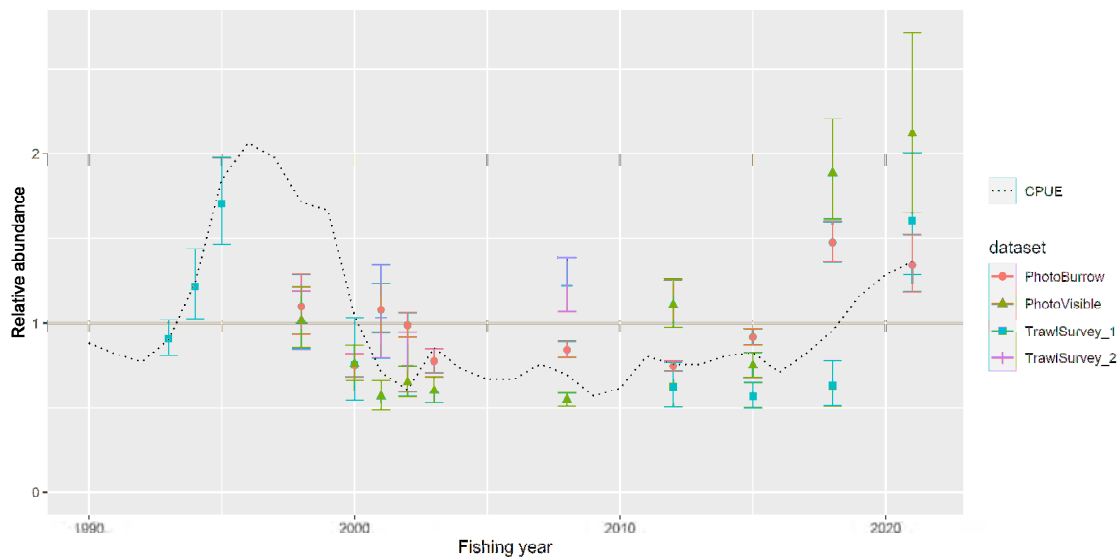
Figure 4a: Mean catch rates and relative abundance (± one standard error) of research trawling, visible animal photo survey counts, and burrow survey counts counts in the core area of SCI 1. Symbols represent different survey observations. PhotoBurrow, PhotoVisible and TrawlSurvey_1 indices were from a subset of survey strata; TrawlSurvey_2 was from all survey strata. Dotted line represents annual standardised CPUE for SCI 1.
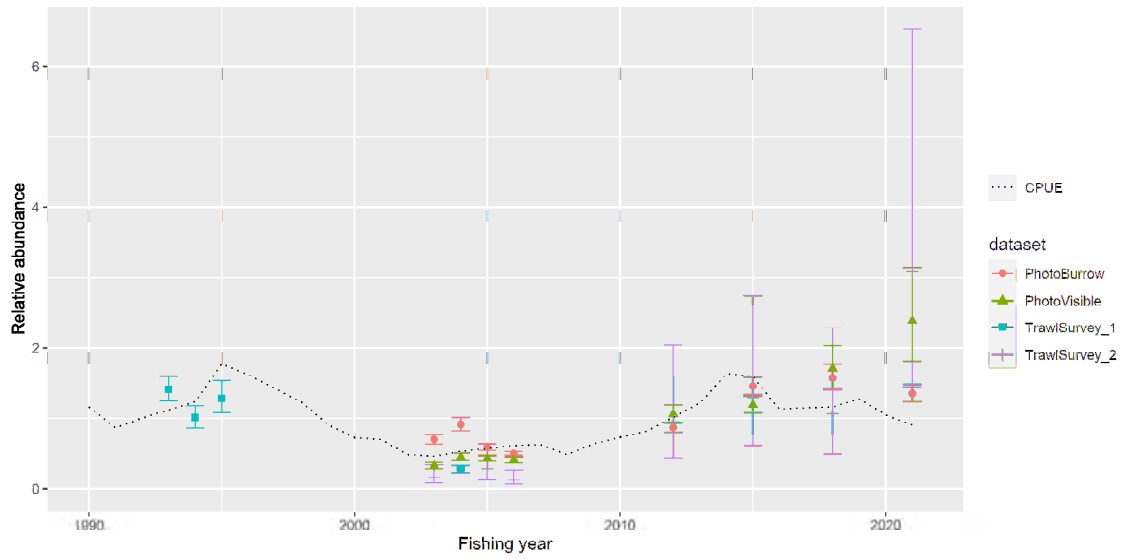
Figure 4b: Mean catch rates and relative abundance (± one standard error) of research trawling, visible animal photo survey counts, and burrow photo survey counts in SCI 2. Symbols represent different survey observations. TrawlSurvey_1 is in model timestep 1 (October-January), TrawlSurvey_2, PhotoBurrow and PhotoVisible are in model timestep 2 (February-April). Dotted line represents annual standardised CPUE for SCI 2.
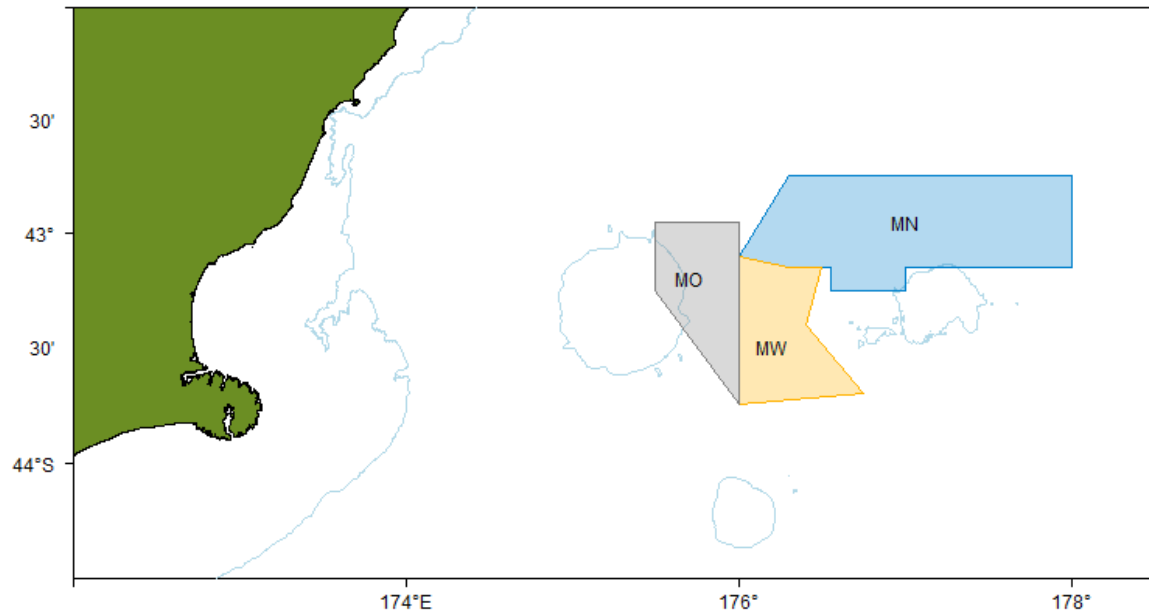
Figure 5: Subareas within SCI 3 used in the stock assessment.
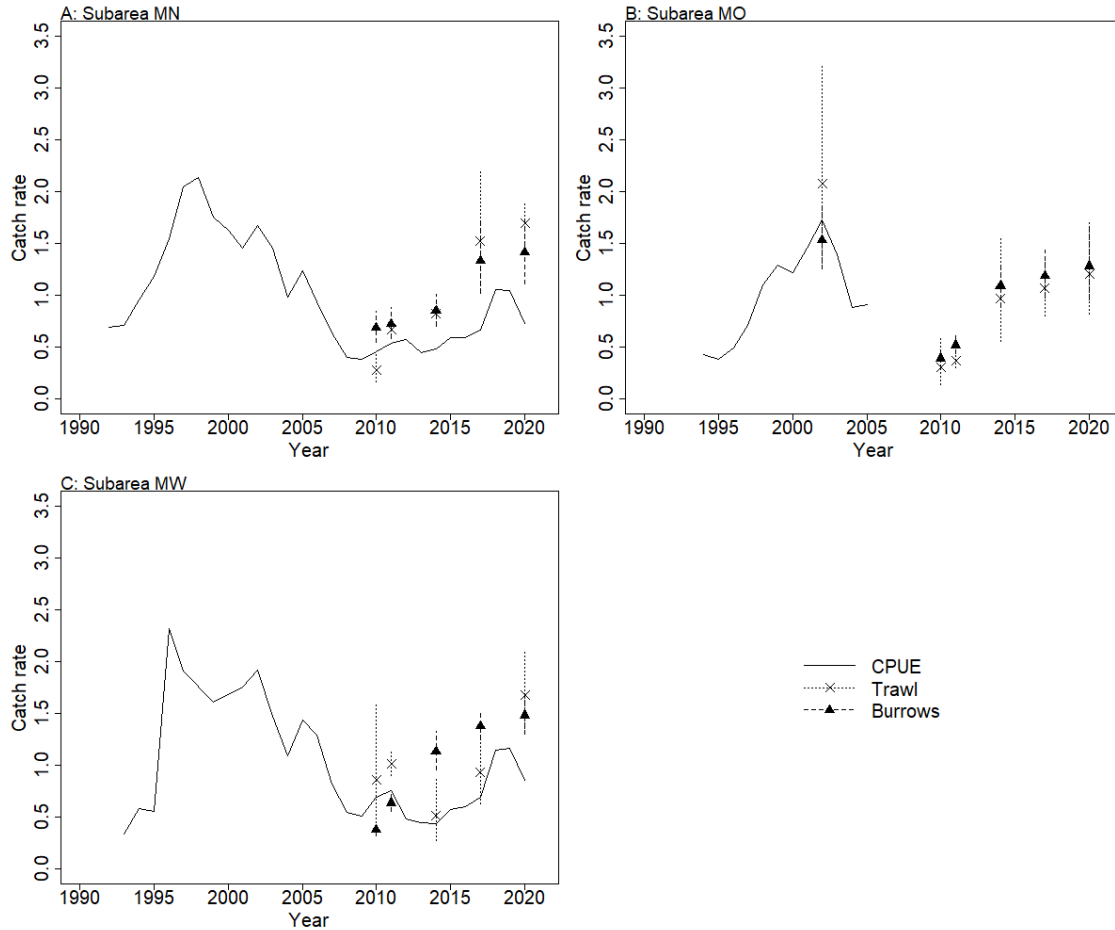
Figure 6: Catch rates (standardised CPUE) and relative abundance (± one standard error) of research trawling and photo survey counts in the core area of SCI 3 by subareas MN (A), MO (B), and MW (C). Symbols represent different aims of survey work (×- trawling within photo survey, ▲-scaled photo survey abundance). Solid line represents standardised CPUE indices as they were defined for the stock assessment model.

There have been no targeted scampi surveys of SCI 4A, but the Chatham Rise *Tangaroa* survey has conducted standardised trawl sampling in the region since 1992. Although the trawl gear used on this survey is not designed to catch scampi, it provides the only fishery-independent abundance index for this stock. Survey catch rates follow a very similar pattern to unstandardised CPUE indices (Figure 7), increasing rapidly from the early 1990s to the early 2000s, declining to 2008, and then increasing more steadily since this time.

Surveys have been conducted in SCI 6A in 2007–2009, 2013, 2016, and 2019 (although with a different vessel after 2013). The trawl component of the photo surveys suggests that the biomass has fluctuated in recent years, although modelling indicated that the fishing power of the vessel used since 2016 was substantially less than that of the vessel used in earlier years. The photographic survey (burrows) suggested a considerable decline in abundance between 2007 and 2008, an increase in 2009 back towards the 2007 level, followed by a decline to lower levels of abundance in 2013 and 2016, but an increase in 2019. Over the longer term, the CPUE data indicate fluctuations around a gradually declining trend (Figure 8).

SCAMPI (SCI)
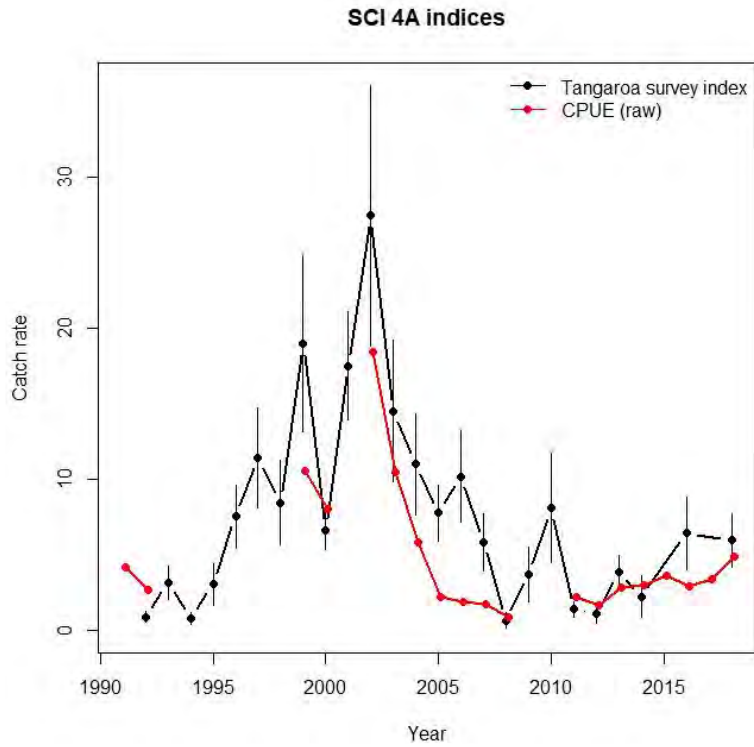
Figure 7: **Mean catch rate (± one standard error) of Chatham Rise *Tangaroa* research trawling and unstandardised CPUE in the core area of SCI 4A. The CPUE index has been scaled to the geometric mean of the survey catch rates.**
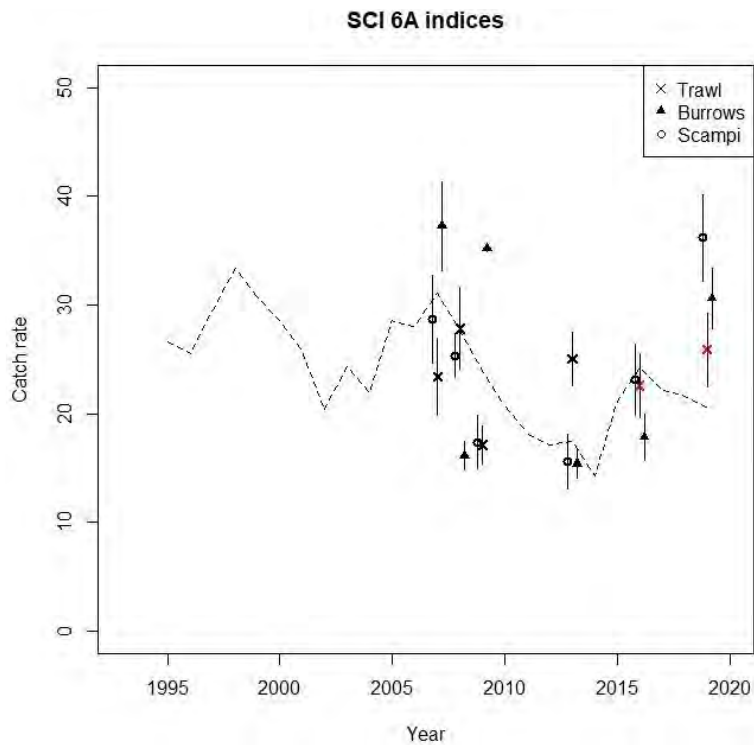
Figure 8: **Mean catch rates and relative abundance (± one standard error) of research trawling and photo survey counts in the core area of SCI 6A. Symbols represent different aims of survey work (×- trawling within photo survey, ▲-scaled photo survey abundance). The last two trawl survey indices (denoted by a red ×) used a different vessel and have been scaled separately from the earlier series. The dotted line represents median of annual unstandardised CPUE for SCI 6A from Figure 3.**

Photographic surveys

Photographic surveying (usually by video) has been used extensively to estimate the abundance of the European scampi *Nephrops norvegicus*. Photographic surveys indexing burrow abundance were developed as an abundance index independent of scampi emergence patterns. In New Zealand, development of photographic techniques, including surveys, has been underway since 1998. To date, nine surveys have been undertaken in SCI 1 (between Cuvier Island and White Island at a depth of 300–500 m), seven surveys have been undertaken in SCI 2 (Mahia Peninsula to Castlepoint at 200–500 m depth), six surveys have been undertaken in SCI 3 (north eastern Mernoo Bank only at 200–600 m depth), and six surveys in SCI 6A (to the east of the Auckland Islands at 350–550 m depth). The association between scampi and burrows in SCI 6A appears to be different to other areas examined.

Three indices are calculated from photographic surveys: the density of visible scampi (all visible animals, either observed within a burrow entrance (doorkeepers) or emerged from a burrow, walking free on the seabed); the density of emerged scampi (animals fully emerged from a burrow); and the density of major burrow openings (counts of which are now consistent among experienced readers, and repeatable, following development of a between reader standardisation process). While counts of visible and emerged scampi are sensitive to burrow emergence patterns, counts of burrows are independent of this. Burrow counts are sensitive to reader interpretation however, and concerns over this led to the exclusion of the burrow indices from SCI 1 and SCI 2 assessments in 2022. Each of these can be used to estimate indices of abundance or biomass, using estimates of mean individual weight or the size distribution of animals in the surveyed population. The Bayesian length-based assessment model used for SCI 3 uses the estimated abundance of major burrow openings as an abundance index, which was also the case for SCI 1 and 2 up until the 2022 assessment, but only the emerged scampi index was used in the SCI 6A assessment.

Estimates of major burrow opening and visible scampi abundance are provided in Table 9. Acoustic tagging approaches (undertaken during surveys) have been used, in conjunction with burrow and scampi density estimates, to estimate emergence patterns and priors for scampi catchability. A revised approach to estimating priors on the basis of these data, taking greater account of uncertainty in observed burrow and animal density and emergence rates, was adopted in 2016 (Tuck et al 2015).

Length frequency distributions from trawl surveys and from scientific observers do not show a consistent increase in the proportion of small individuals in any SCI stock following the development of significant fisheries for scampi. Analyses of information from trawl survey and scientific observers in SCI 1 and 6A, up to about 1996, suggested that the proportion of small animals in the catch declined markedly in both areas, despite the fact that CPUE declined markedly in SCI 6A and increased markedly in SCI 1. Where large differences in the length frequency distribution of scampi measured by observers have been detected (as in SCI 1 and 6A), detailed analysis has shown that the spatial coverage of observer samples has varied with time, and this may have influenced the nature of the length frequency samples. The length composition of scampi is known to vary with depth and geographical location, and fishers may deliberately target certain size categories.

Some commercial fishers reported that they experienced historically low catch rates in SCI 1 and 2 between 2001 and 2004. They further suggest that this reflects a decrease in abundance of scampi in these areas. Other fishers consider that catch rates do not necessarily reflect changes in abundance because they are influenced by management and fishing practices.

SCAMPI (SCI)

Table 9: Photographic survey estimates of abundance (millions) based on major openings and visible scampi in survey strata within SCIs 1, 2, 3, and 6A. CVs of estimates in parentheses. Major burrow openings are openings on the seabed that are considered to be main entrance of a scampi burrow. Visible scampi represents all scampi seen in photographs (either in a burrow entrance, or walking free on the seabed). Burrow estimates were not used in the 2022 assessment for SCI 1 and SCI 2.

Year	SCI 1 Major openings	SCI 1 Visible scampi	SCI 2 Major openings	SCI 2 Visible scampi	SCI 3 Major openings	SCI 3 Visible scampi	SCI 6A Major openings	SCI 6A Visible scampi	Comments
1998	144.3 (0.15)	24.5 (0.17)							
1999									
2000	98.2 (0.12)	18.2 (0.18)							
2001	142.0 (0.12)	13.7 (0.26)			224.0 (0.09) (strata 902–3)	48.2 (0.16) (strata 902–3)			
2002	130.0 (0.07)	15.6 (0.21)							
2003	101.8 (0.12)	14.5 (0.21)	106.2 (0.13)	10.4 (0.37)					
2004			137.2 (0.11)	14.1 (0.26)					
2005			90.0 (0.14)	13.5 (0.20)					
2006			76.6 (0.09)	13.0 (0.24)					
2007							305.5 (0.11)	60.4 (0.14)	SCI 6A estimate for main area*
2008	110.8 (0.07)	13.2 (0.13)					132.3 (0.08)	55.4 (0.08)	
2009					54.4 (0.14) (strata 902–3) 285.8 (0.07) (larger survey)	18.4 (0.17) (strata 902–3) 122.6 (0.10) (larger survey)	288.8 (0.10)	36.6 (0.14)	SCI 3, estimates provided for 2001 survey coverage (strata 902–3) and new larger survey
2010					72.0 (0.11) (strata 902–3) 378.0 (0.05) (larger survey)	8.7 (0.22) (strata 902–3) 92.8 (0.11) (larger survey)			SCI 3, estimates provided for 2001 survey coverage (strata 902–3) and new larger survey
2012	97.9 (0.05)	26.6 (0.11)	130.8 (0.09)	32.7 (0.12)					
2013					144.1 (0.11) (strata 902–3) 592.6 (0.06) (larger survey)	20.5 (0.17) (strata 902–3) 130.8 (0.09) (larger survey)	126.5 (0.09)	32.8 (0.16)	
2015	120.8 (0.06)	18.0 (0.13)	220.1 (0.06)	37.0 (0.09)					
2016					152.1 (0.10) (strata 902–3) 747.5 (0.05) (larger survey)	36.7 (0.16) (strata 902–3) 206.9 (0.08) (larger survey)	146.6 (0.12)	48.7 (0.14)	
2018	194.3 (0.05)	45.4 (0.08)	137.8 (0.07)	52.8 (0.10)					
2019					179.42 (0.15) (strata 902–3) 871.1 (0.17) (larger survey)	74.52 (0.15) (strata 902–3) 360.66 (0.07) (larger survey)	251.1 (0.09)	76.2 (0.11)	
2021	176.9 (0.09)	50.9 (0.12)	204.7 (0.07)	73.8 (0.12)					

* SCI 6A estimate provided for main area because future surveys may not survey secondary area. SCI 1 estimate provided for strata 302, 303, 402, 403.

5.2   Stock assessment methods

The 2022 updated assessment for SCI 1 was rejected because the results were considered overly sensitive to the choice of prior for the trawl survey catchability, and to choices around data weighting and the estimation of process error. The status of the stock was assessed using a partial-quantitative method based on all available abundance indices; trawl survey, photo survey (visible scampi), photo survey (burrow count), and CPUE.

2019: SCI 1

In 2011 the first stock assessment for SCI 1, undertaken using the length-based population model that had been under development for several years (Tuck & Dunn 2012), and updated assessments were accepted in 2013, 2016, and 2019.

A number of model runs were presented, examining sensitivities to M, data weighting, and a combined area model with SCI 2 (two stock model with no migration, sharing growth and selectivity parameters). For both stocks, the absolute biomass levels and the state of the stock relative to SSB_0 was relatively consistent between models. A base model was agreed upon for SCI 1 (M=0.25 and CPUE process error fixed at 0.15) with sensitivities also presented.

The model's annual cycle is based on the fishing year and is divided into three time steps (Table 10). The choice of three time steps was based on the current understanding of scampi biology and the sex ratio in catches. Note that model references to 'year' refer to the modelled or fishing year and are labelled as the most recent calendar year, i.e., the fishing year 1998–99 is referred to as '1999' throughout.

Table 10: Annual cycle of the population model for SCI 1, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur together within a time step occur after all other processes, with 50% of the natural mortality for that time step occurring before and 50% after the fishing mortality.

Step	Period	Process	Proportion in time step
1	Oct–Jan	Growth (both sexes)	
		Natural mortality	0.33
		Fishing mortality	From TCEPR
2	Feb–Apr	Recruitment	1.0
		Maturation	1.0
		*Growth (males)**	
		Natural mortality	0.25
		Fishing mortality	From TCEPR
3	May–Sep	Natural mortality	0.42
		Fishing mortality	From TCEPR

* The main period of male moulting appears to be from February to April. In the model both sexes are assumed to grow at the start of step 1, and this male growth period (February to April) is ignored.

Investigations into factors affecting scampi catch rates and size distributions (Cryer & Hartill 2001, Tuck 2009) have identified significant depth and regional effects, and regional (strata) and depth stratification were applied in previous models. Preliminary examination of patterns in CPUE indices and other input data suggested that this may not be necessary, and a simplified single area model was developed in 2013. Catches generally occur throughout the year and were divided among the time steps according to the proportion of estimated catches recorded on Trawl Catch, Effort, and Processing Returns (TCEPRs). Recreational catch, customary catch, and illegal catch are ignored. The maximum exploitation rate (i.e., the ratio of the maximum catch to biomass in any year) is not known, but was constrained to no more than 0.9 in a time step. Individuals are assumed to recruit to the model at age 1, with the mean expectation of recruitment success predicted by a Beverton-Holt stock-recruitment relationship. Length-at-recruitment is defined by a normal distribution with mean of 10 mm OCL with a CV of 0.4. Relative year class strengths are encouraged to average 1.0. Growth is estimated in the model, fitting to the tag (Cryer & Stotter 1997, Cryer & Stotter 1999) and aquarium data (Cryer & Oliver 2001) from SCI 1 and SCI 2.

The model uses logistic length-based selectivity curves for commercial fishing, research trawl surveys, and photographic surveys, assumed constant over years but allowed to vary with sex and time step. Although the sex ratio data suggest that the relative catchability of the sexes varies through the year

(hence the model time structure adopted), there is no reason to suggest that (assuming equal availability) selectivity-at-size would be different between the sexes. Therefore the selectivity implementation used allowed the L_{50} and a_{95} selectivity parameters to be estimated as single values shared by both sexes in a particular time step, but allowed for different availability between the sexes through estimation of different a_{max} values for each sex. In SCI 1 and SCI 2, selectivity is assumed to be the same in time steps 1 and 3, because of the relative similarity in sex ratio.

Data inputs included CPUE, trawl and photographic survey indices, and associated length frequency distributions. Informed priors are available for survey catchability estimates based on acoustic tagging of scampi and investigations into burrow emergence patterns. These have been updated since the last assessment based on working group discussions.

The assessment reports SSB_0 and $SSB_{CURRENT}$ and used the ratio of current and projected spawning stock biomass ($SSB_{CURRENT}$ and SSB_{2018}) to SSB_0 as preferred indicators. Projections were conducted up to 2024 on the basis of a range of catch scenarios. The probability of exceeding the default Harvest Strategy Standard target and limit reference points are reported.

2022: SCI 1
The fully quantitative assessment for SCI 1was not accepted in 2022 and is not reported here. Instead, the Plenary proposed assessing the status of the stock in a partial-quantitative method that involved examination of the trends in the available abundance indices since the 2019 assessment of the stock.

5.2.1 Standardised CPUE
A CPUE model was fitted for catch per tow with response variables *fishing_year, time-of-day, fishing_duration, statistical-area, model-timestep*. The model explained 41% of the null deviance. Alternative models were explored and presented to the DWWG, with little change to the resulting abundance index. These alternative models included using a subset of the 'core' vessels (10 years in the fishery as the minimum requirement rather than 5 years), catch per vessel-day rather than including fishing duration as a response variable, and attempts at classifying a vessel:gear_width categorical variable. Figure 9 shows the raw and standardised CPUE index for SCI 1.
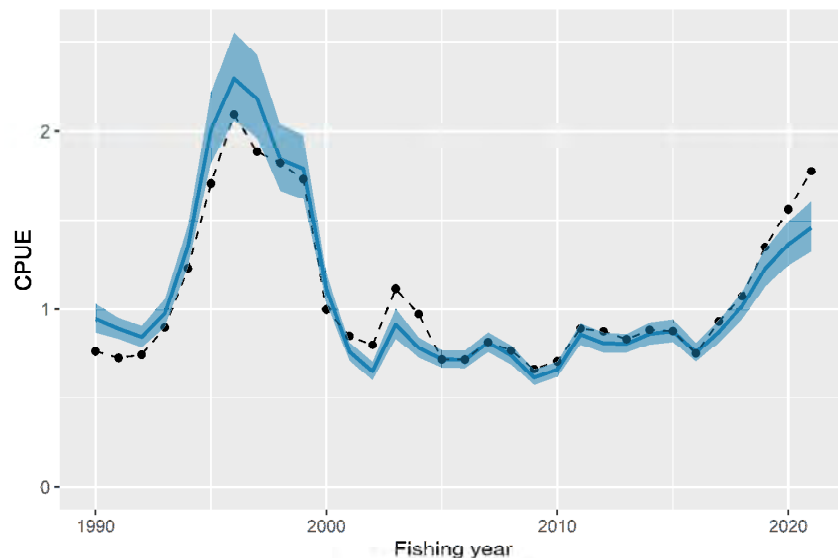
Figure 9: Standardised CPUE for SCI 1 (blue line) with 95% confidence intervals (blue shaded) and raw CPUE (black dashed line and dots).

5.2.2 Survey indices
Ten years of trawl and photo survey estimates of abundance are available. The photo survey provides two indices: major burrow counts and visible scampi counts. The major burrow counts index has the advantage of being insensitive to scampi emergence patterns and dynamics, but it suffers from subjectivity in interpreting the photos. The visible scampi counts index is less susceptible to subjectivity

in interpreting the photos because the scampi are more obvious than burrows, but it is affected by emergence patterns and dynamics which will affect the abundance estimates and which we are not equipped to account for. The trawl survey is also affected by emergence of scampi and has the additional complication of catchability.

Figure 10 shows the available photo survey abundance indices for the core survey strata (longer series with the full 10 years) and the full survey area (in years 2012, 2015, 2018, and 2021). Trawl survey abundance indices are in Figure 11. The earlier years in the trawl survey included the full survey area (1993, 1994, 1995, and 2000) whereas these years only covered the core strata for the photo survey. Survey strata are shown in Figure 12.

A: Core strata
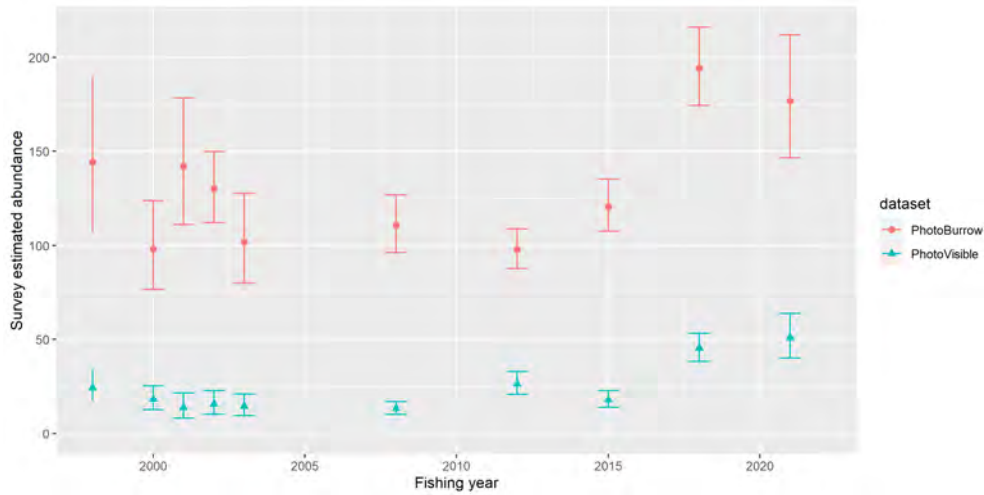
B: All strata
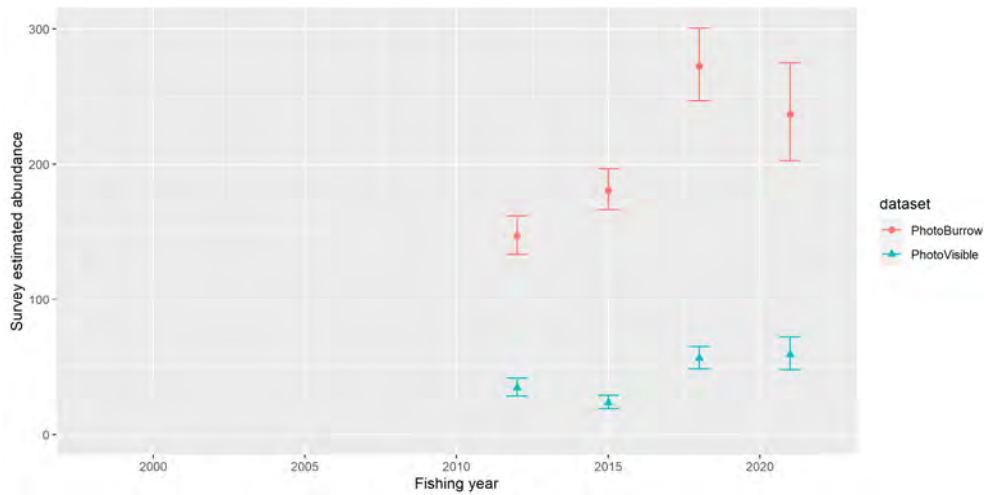
Figure 10: SCI 1 abundance indices from photo survey (+/- 1 standard error) for A: Core survey strata; B: All survey strata.
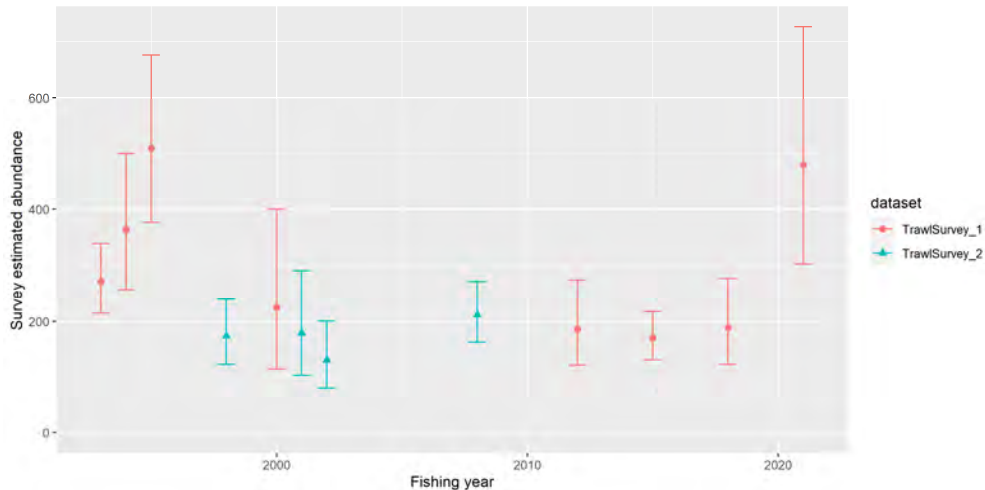
Figure 11: SCI 1 abundance indices from trawl survey (+/- 1 standard error) for: Core survey strata (TrawlSurvey_2); All survey strata (TrawlSurvey_1).
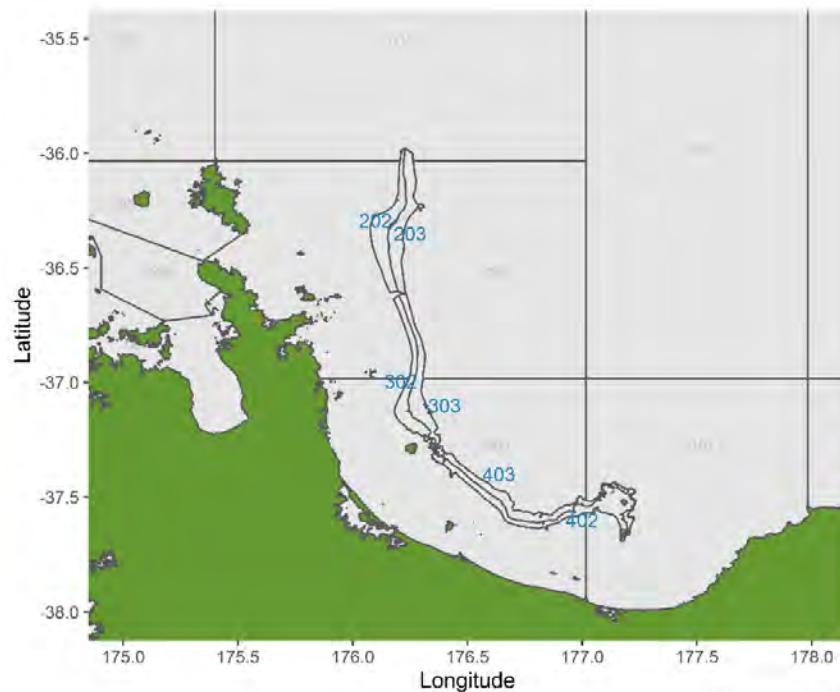
Figure 12: SCI 1 survey strata. 'Core' strata are 302, 303, 402 and 403; 'All' strata are 202, 203, 302, 303, 402, and 403.

SCI 2

In 2011 the first stock assessments for SCI 2, undertaken using the length-based population model that had been under development for several years (Tuck & Dunn 2012), and updated assessments were accepted in 2013, 2016, 2019, and 2022.

For the 2022 assessment, a number of model runs were presented, examining sensitivities to the trawl survey q prior, data weighting, and combinations of including or excluding data inputs. The absolute biomass levels and the state of the stock relative to SSB_0 was relatively consistent between models. A base model and two alternatives were taken forward to MCMC, with the trawl survey q prior such that the mean was shifted to the lower and upper quartile for the two alternatives.

The SCI 2 model structure matches that described for SCI 1 in the previous section, including specification of the annual cycle, spawning stock recruitment, growth, maturation, and natural mortality. Model inputs also follow the same structure, except that the trawl survey indices for SCI 2

SCAMPI (SCI)

were split between time steps 1 and 2 in the SCI 2 model, whereas it was entirely in time step 1 in the SCI 1. The photo survey was not included in the 2022 SCI 2 assessment, although utility of including these data will be re-explored.

Data inputs included CPUE and trawl survey indices, and associated length frequency distributions. Informed priors are available for survey catchability estimates based on acoustic tagging of scampi and investigations into burrow emergence patterns. These have been updated since the last assessment based on working group discussions.

The assessment reports SSB_0 and $SSB_{CURRENT}$ and used the ratio of current and projected spawning stock biomass ($SSB_{CURRENT}$ and SSB_{2018}) to SSB_0 as preferred indicators.

SCI 3

In 2015 the SFWG accepted a stock assessment for SCI 3 (Tuck 2016), undertaken using the length-based population model, an updated assessment was accepted in 2018 (Tuck 2019), and in 2021 the DWWG accepted a further updated assessment (McGregor in press). A number of model runs were presented, examining sensitivities to assumptions about photo survey qs, whether to include the initial increasing part of the CPUE indices, process error on the CPUE indices and M. The absolute biomass levels were sensitive to the alternative model structures and assumptions, but the state of the stock relative to B_0 was generally consistent between models. A base model was taken with a fixed $M = 0.25$ and CPUE process error $= 0.2$, with sensitivities to these assumptions considered. The alternative model that omitted the initial increasing years from CPUE indices provided the most pessimistic results for the stocks, particularly for subarea MN.

The model's annual cycle is slightly adjusted from the fishing year and is divided into two time steps (Table 11). The choice of two time steps was based on the current understanding of scampi biology and the sex ratio in catches. Note that model references to 'year' refer to the modelled year and are labelled as the most recent calendar year, i.e., the modelled year 1998–99 is referred to as '1999' throughout.

Table 11: Annual cycle of the population model for SCI 3, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur together within a time step occur after all other processes, with 50% of the natural mortality for that time step occurring before and 50% after the fishing mortality.

Step	Period	Process	Proportion in time step
1	Aug–Dec	Growth (both sexes)	
		Natural mortality	0.5
		Fishing mortality	From TCEPR
2	Jan–Jul	Recruitment	1.0
		Maturation	1.0
		Natural mortality	0.5
		Fishing mortality	From TCEPR

The SCI 3 fishery is divided into three distinct areas on the Chatham Rise (an area to the east of 176º E on the Mernoo Bank – MO; an area to the west of 176º E on the Mernoo Bank – MW; and a separate region to the north east, centred about 177º E – MN) (Figure 5), and differences in management between these areas over time have led to different fishing histories. Scampi are not thought to undertake large-scale migrations, and so these three areas were considered distinct stocks within the assessment model, sharing some parameters (growth, selectivity, and catchability). The seasonal patterns of catches vary between stocks and over time and were divided among the stocks and time steps according to the proportion of estimated catches recorded on TCEPRs. Recreational catch, customary catch, and illegal catch are ignored. The maximum exploitation rate (i.e., the ratio of the maximum catch to biomass in any year) is not known but was constrained to no more than 0.9 in a time step. Individuals are assumed to recruit to the model at age 1, with the mean expectation of recruitment success predicted by a Beverton-Holt stock-recruitment relationship. Length-at-recruitment is defined by a normal distribution with mean of 10 mm OCL with a CV of 0.4. Relative year class strengths are encouraged to average 1.0. Growth is estimated in the model.

As with the SCI 2 model, the SCI 3 model uses logistic length-based selectivity curves for commercial fishing, research trawl surveys, and for SCI 3 also photographic surveys, assumed constant over years and stocks, but allowed to vary with sex and time step. Data inputs for each stock included CPUE, trawl and photographic survey indices, and associated length frequency distributions.

The assessment reported B_0 and B_{2021} (at both the sub-area and overall FMA level) and used the ratio of current and projected spawning stock biomass (B_{2021} and B_{2025}) to B_0 as preferred indicators. Projections were conducted up to 2025 on the basis of a range of catch scenarios. The probability of exceeding the default Harvest Strategy Standard target and limit reference points are reported.

SCI 4A

In 2019 a CPUE standardisation was conducted for SCI 4A (Tuck 2020a). A targeted scampi fishery started in 1991 and was intermittent through the 1990s and early 2000s, but has been more consistent since 2011. Fishing effort increased from very low levels in 2010 to a peak in 2015 (comparable with previous high levels in this fishery in the early 1990s and mid 2000s), but declines to about half this level by 2018. Scampi have been caught in low numbers across most of the SCI 4A area within the depth range (200–600 m), but the targeted fishery has focused on two distinct patches, one to the north and one to the west of the Chatham Islands (fished between 2005 and 2007). Catch rates appear similar between the two patches, and there are insufficient observer samples to examine length composition by patch. Overall observer coverage has been low (4% of scampi target tows) but varies considerably between years. Scampi length data were not recorded on the earliest *Tangaroa* surveys but have been routinely recorded since 1997. Size-at-female maturity estimated from the proportion of ovigerous females was comparable with other stocks ($L_{50} = 38.2$ mm).

SCI 6A

In 2016 the Plenary accepted a stock assessment for SCI 6A, undertaken using the length-based population model, and an updated assessment was accepted in 2019 (Tuck 2021). Preliminary models suggested a discrepancy between photo survey (increasing) and CPUE (decreasing) indices, which led to a reconsideration of the most appropriate index to be used from the photographic survey. The previously used visible scampi index includes both emerged animals and doorkeepers. Doorkeepers may include a high proportion of very small scampi that do not appear in commercial catches (and therefore may provide a useful index of recruitment). Also the length composition of scampi from photographs is unlikely to be representative of these smaller individuals (because they are often not visible enough to measure). An emerged animal index was considered more appropriate to use within the assessment model and was more consistent with the CPUE index. A number of model runs were presented, including a base model (M=0.25; survey q prior mean=0.582, CV=0.21; CPUE, trawl and photo survey) and examining sensitivities to two alternative prior distributions for survey catchability (mean=0.3 and 0.8), two alternative values of M (0.20 and 0.3), and CPUE only and CPUE excluded models. Estimates of absolute biomass and stock status were sensitive to q priors and exclusion of abundance indices, but less sensitive to M. All models including the CPUE data suggested SSB has fluctuated around a gradually declining trend through the history of the fishery, whereas the CPUE excluded model suggests SSB declined to around 2000, but has slightly increased since this time. The DWWG agreed that the base, low q, low M, and CPUE excluded models represented the range of possibilities of the status of the SCI 6A stock, with the CPUE excluded model considered less likely.

The model's annual cycle is slightly adjusted from the fishing year and is divided into three time steps (Table 12). The choice of the three time steps was based on the current understanding of scampi biology and the sex ratio in catches. Note that model references to 'year' refer to the modelled year, and are labelled as the most recent calendar year, i.e., the modelled year 1998–99 is referred to as '1999' throughout.

Table 12: Annual cycle of the population model for SCI 6A, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur together within a time step occur after all other processes, with 50% of the natural mortality for that time step occurring before and 50% after the fishing mortality.

Step	Period	Process	Proportion in time step
1	Mid Nov–mid Apr	Growth (both sexes)	
		Maturation	1.0
		Natural mortality	0.417
		Fishing mortality	From TCEPR
2	mid Apr–Jun	Recruitment	1.0
		Natural mortality	0.208
		Fishing mortality	From TCEPR
3	Jul–mid Nov	Natural mortality	0.375
		Fishing mortality	From TCEPR

The SCI 6A fishery occurs southeast of the Auckland Islands (between 166° E and 168° E, and between 50° 15′ S and 51° 15′ S). Scampi are not thought to undertake large scale migrations, and this is considered to be a distinct stock, for which a simplified single area model was developed in 2016. Catches generally occur throughout the year and were divided among the time steps according to the proportion of estimated catches recorded on TCEPRs. Recreational catch, customary catch, discards, and illegal catch are thought to be zero and are therefore ignored in the model. The maximum exploitation rate (i.e., the ratio of the maximum catch to biomass in any year) is not known, but was constrained to no more than 0.9 in a time step. Individuals were assumed to recruit to the model at 10 mm, with the mean expectation of recruitment success predicted by a Beverton-Holt stock-recruitment relationship. Length-at-recruitment was defined by a normal distribution with mean of 10 mm OCL and a CV of 0.4. There was no penalty on year class strength. Growth is estimated in the model from tag recapture data.

The model used logistic length-based selectivity curves for commercial fishing and research trawl surveys, which were assumed to be constant over years but allowed to vary with sex and time step. Although the sex ratio data suggest that the relative catchability of the sexes varies through the year (hence the model time structure adopted), there is no reason to suggest that (assuming equal availability) selectivity-at-size would be different between the sexes. Therefore the selectivity implementation used allowed the L_{50} and a_{95} selectivity parameters to be estimated as single values shared by both sexes in a particular time step, but allowed for different availability between the sexes through estimation of different a_{max} values for each sex. A combined sex double normal selectivity curve was used when fitting photo survey length frequency data for visible scampi.

The assessment reported SSB_0 and $SSB_{CURRENT}$ and used the ratio of current and projected spawning stock biomass ($SSB_{CURRENT}$ out to SSB_{2025}) to SSB_0 as preferred indicators. Projections were conducted up to 2025 for two future catch scenarios. The probability of exceeding the default Harvest Strategy Standard target and limit reference points are reported.

5.3 Stock assessment results

2019: SCI 1

For SCI 1, model outputs suggest that spawning stock biomass increased to a peak in about 1995, declined to the early 2000s and has remained relatively stable since this time. The SSB in SCI 1 in 2018 was estimated to be 72%–76% of SSB_0 (Table 13, Figure 13). Historical changes in biomass in SCI 1 appear to be related to fluctuations in recruitment rather than catches, and likelihood profiles suggest that the priors have more influence than the abundance indices in determining SSB_0. Estimated year class strength seems to be driven largely by the abundance indices with little signal from the length frequency distributions. Investigations into the sensitivity of excluding the survey indices showed that removing the photo survey increased the estimate of SSB_0, whereas removing the trawl survey had a lesser opposite effect, although stock trajectory and current status ($SSB_{CURRENT}/SSB_0$) was only slightly affected.

Table 13: Results from MCMC runs showing SSB_0**,** $SSB_{CURRENT}$**, and** $SSB_{CURRENT}/SSB_0$ **estimates for the base model** **(***M***=0.25, CV=0.15) and sensitivities for SCI 1.**

Model	M=0.25, CV=0.15	M=0.25, CV=0.25	M=0.2, CV=0.15	M=0.2, CV=0.25
SSB_0	4 620	4 650	4 627	4 777
$SSB_{CURRENT}$	3 498	3 539	3 368	3 521
$SSB_{CURRENT}/SSB_0$	0.76	0.76	0.72	0.74

The default management target for scampi of 40% B_0 is below the range of % B_0 estimated for SCI 1.
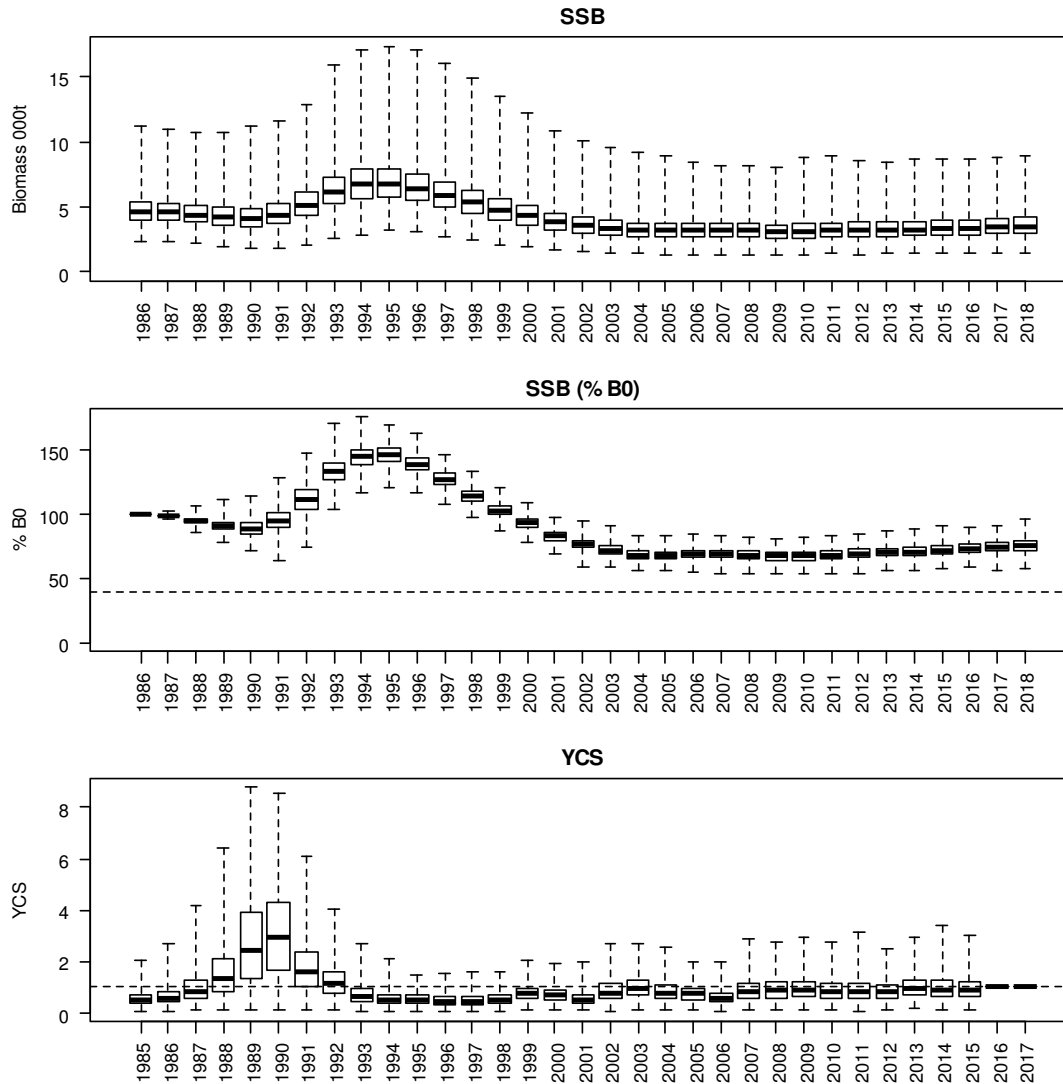
Figure 13: Posterior trajectory from SCI 1 base model (*M***=0.25, CV=0.15) of spawning stock biomass and YCS. Upper** **plot shows boxplots of** *SSB* **and the middle plot shows** *SSB* **as a percentage of** B_0**. On the middle plot, target** **reference points are shown as the grey dashed line. Box shows the median of the posterior distribution** **(horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the** **distribution.**

2022: SCI 1

The available abundance indices for SCI 1 suggest the stock is higher or as high as it has been over the period 2001 to 2021. CPUE had in a large peak in the mid-late 1990s, followed by a decline until 2001 then a stable period from 2001 to 2017, which was also the lowest period for this index. The CPUE index then increased from 2017 until 2021. The trawl survey indices also showed a stable period from 1998 through to 2018. This stable period began earlier than the CPUE which was still declining until 2001 and ended slightly later than the CPUE which was increasing by 2017. There were no surveys in 2019 and 2020, and the 2021 estimate showed a large increase in estimated abundance, more extreme than seen in the CPUE. The photo survey suggested 2018 was a high point in the series, with 2021 either similarly high (visible scampi) or slightly lower (burrow count).

SCI 2

A 2022 update of the SCI 2 assessment was accepted as a quality 2 assessment, because the available base case, while robust to the choice of prior for trawl survey catchability, provided insufficient exploration of differing recent trends in the trawl survey and CPUE indices. For SCI 2, model outputs suggest that spawning stock biomass decreased slightly until 1990, increased to a peak in the early 1990s, declined to the early 2000s, increased slightly until about 2008, but increased more rapidly to 2013, declined until 2019 after which it has been fairly flat; however, the model was essentially averaging between the most recent high trawl survey estimate and a decreasing CPUE index. The SSB in SCI 2 in 2021 was estimated to be 70%–74% SSB_0 (Table 14, Figure 14).

Table 14: Results from MCMC runs showing SSB_0, $SSB_{CURRENT}$, and $SSB_{CURRENT}/ SSB_0$ estimates for the base and sensitivities of the trawl survey q prior for SCI 2.

Model	Base	q-lower	q-upper
SSB_0	2 354	2 501	2 322
$SSB_{CURRENT}$	1 664	1 846	1 632
$SSB_{CURRENT}/SSB_0$	0.71	0.74	0.70

The default management target for scampi of 40% B_0 is below the range of % B_0 estimated for SCI 2.

SCI 3

For SCI 3, a base model was taken with fixed $M = 0.25$ and CPUE process error = 0.2, with sensitivities to these assumptions considered. SSB trajectories and 5-year projections are shown for the MN (Figure 15), MO (Figure 16), and MW (Figure 17) subareas, with the combined SCI 3 trajectory presented in Figure 18. Subarea and overall SCI 3 data are summarised in Table 15. Model outputs suggest that SCI 3 spawning stock biomass (SSB) increased to a peak in about 1999, declined to 2010, and then remained more stable, increasing after 2014 (Figure 18). The SSB in SCI 3 in 2021 was estimated to be 88% (95% CI 61–121%) of B_0 at the FMA level for the base case, with median estimates ranging between 0.82 to 0.94 for the three sensitivities (Figure 18, **Error! Reference source not found.**15).

The default management target for scampi of 40% B_0 is below the range of % B_0 estimated for the SCI 3 base model, or any of the sensitivities (Figure 18, Table 15).
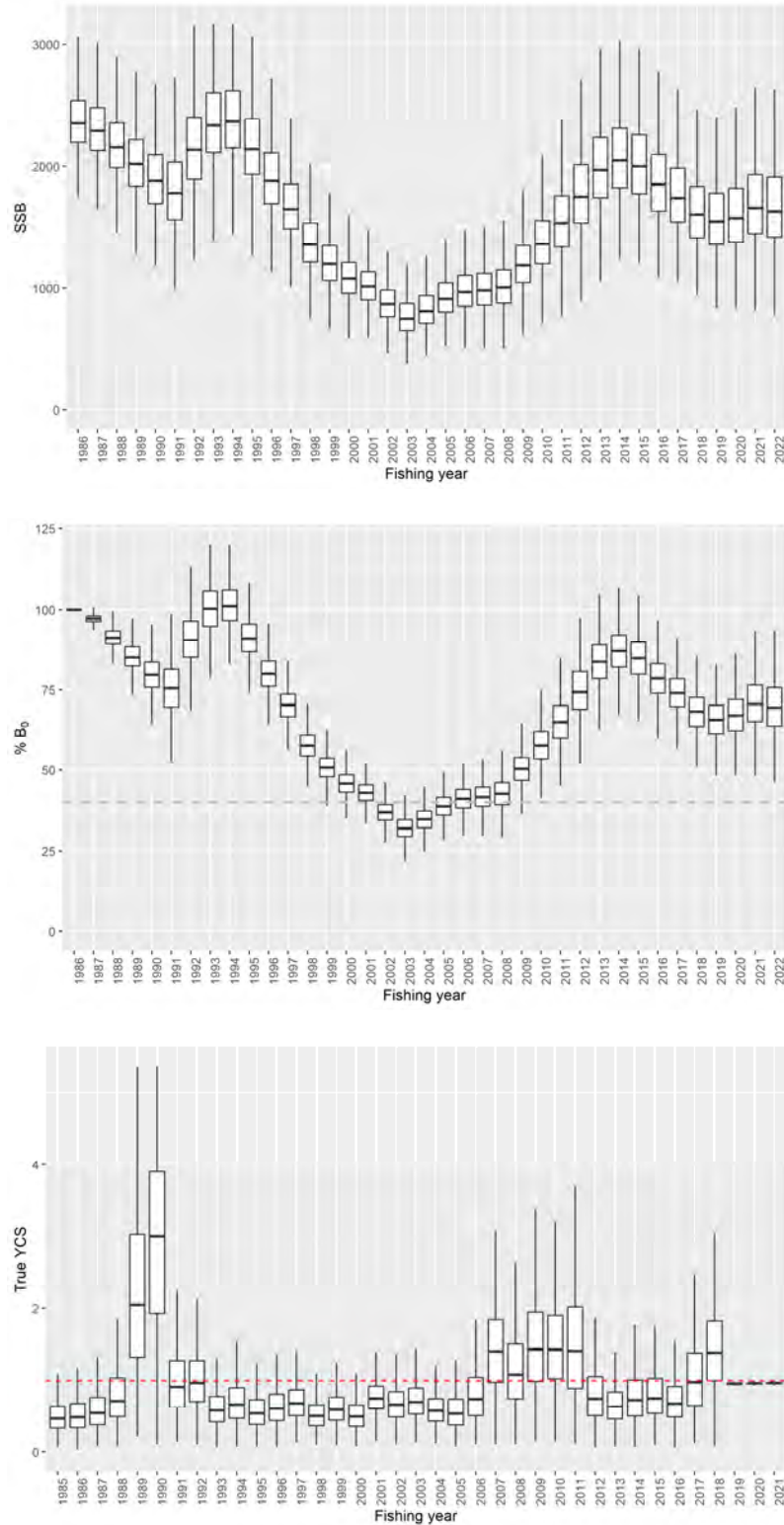
Figure 14: Posterior trajectory from the SCI 2 base model of spawning stock biomass and YCS. Upper plot shows boxplots of *SSB* and middle plot shows *SSB* as a percentage of B_0. On middle plot, target reference points are shown as the grey dashed line. Box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.
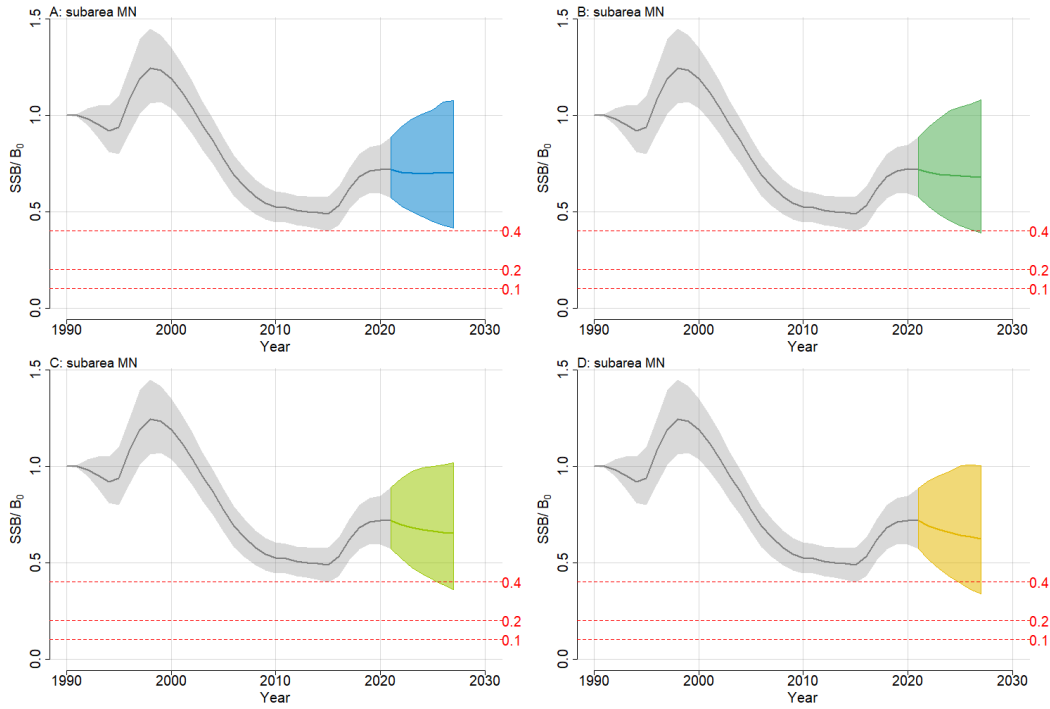
Figure 15: Posterior trajectory from subarea MN in SCI 3 base model (*M*=0.25) of spawning stock biomass, including 5-year projections out to 2026. Solid line shows the median of the posterior distribution, and the shaded polygons the 95th percentiles. Horizontal red lines show reference points 0.1, 0.2, 0.4 *B₀*.
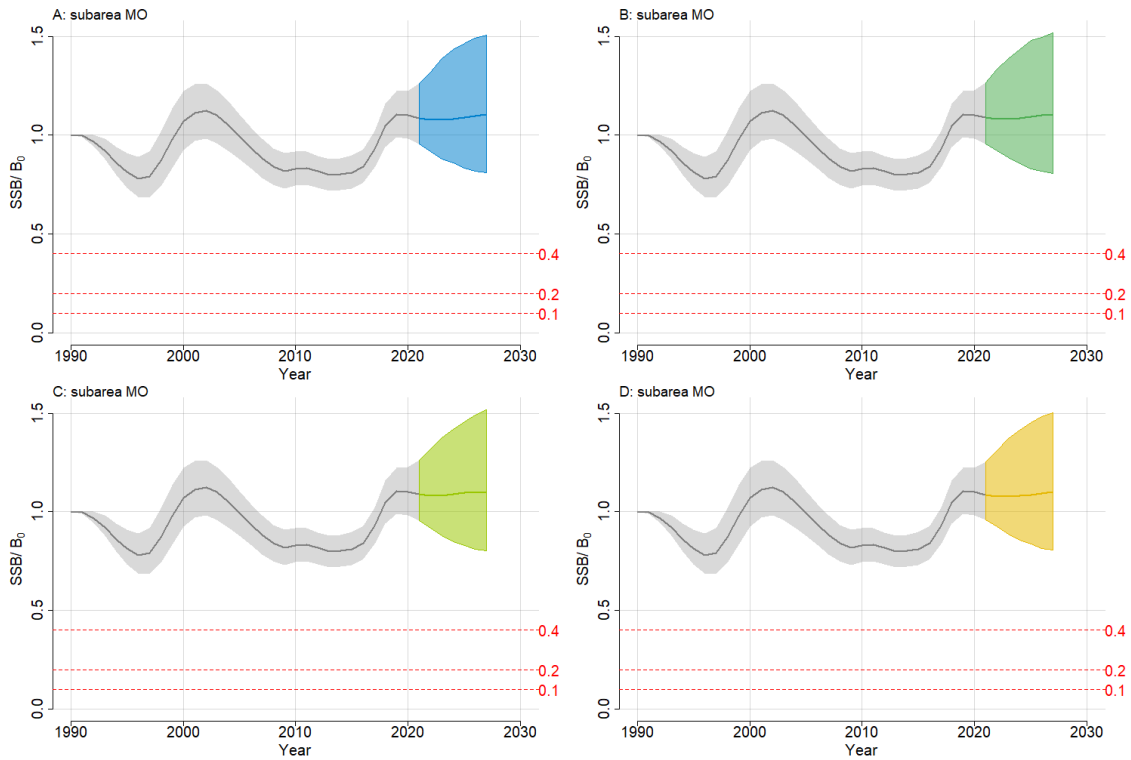
Figure 16: Posterior trajectory from subarea MO in SCI 3 base model (*M*=0.25) of spawning stock biomass, including 5-year projections out to 2026. Solid grey line shows the median of the posterior distribution, and the shaded polygons the 95th percentiles. Horizontal red lines show reference points 0.1, 0.2, 0.4 *B₀*.
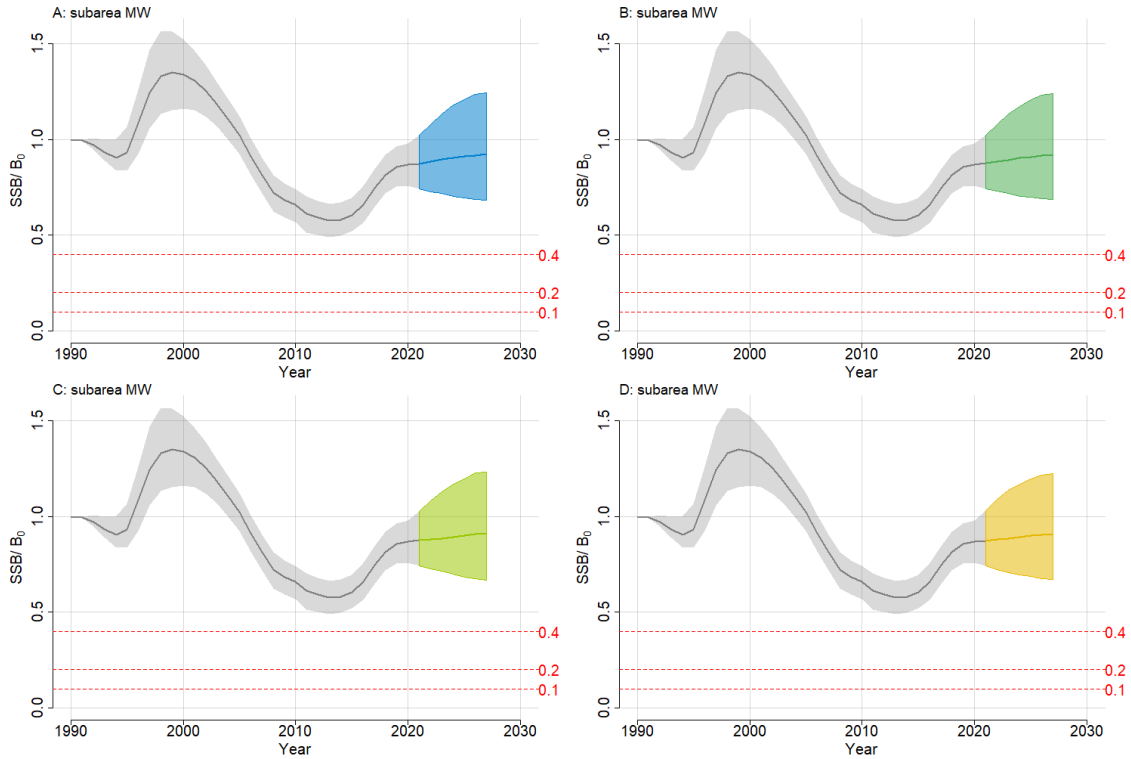
Figure 17: Posterior trajectory from subarea MW in SCI 3 base model (*M*=0.25) of spawning stock biomass, including 5-year projections out to 2026. Solid grey line shows the median of the posterior distribution, and the shaded polygons the 95th percentiles. Horizontal red lines show reference points 0.1, 0.2, 0.4 *B₀*.
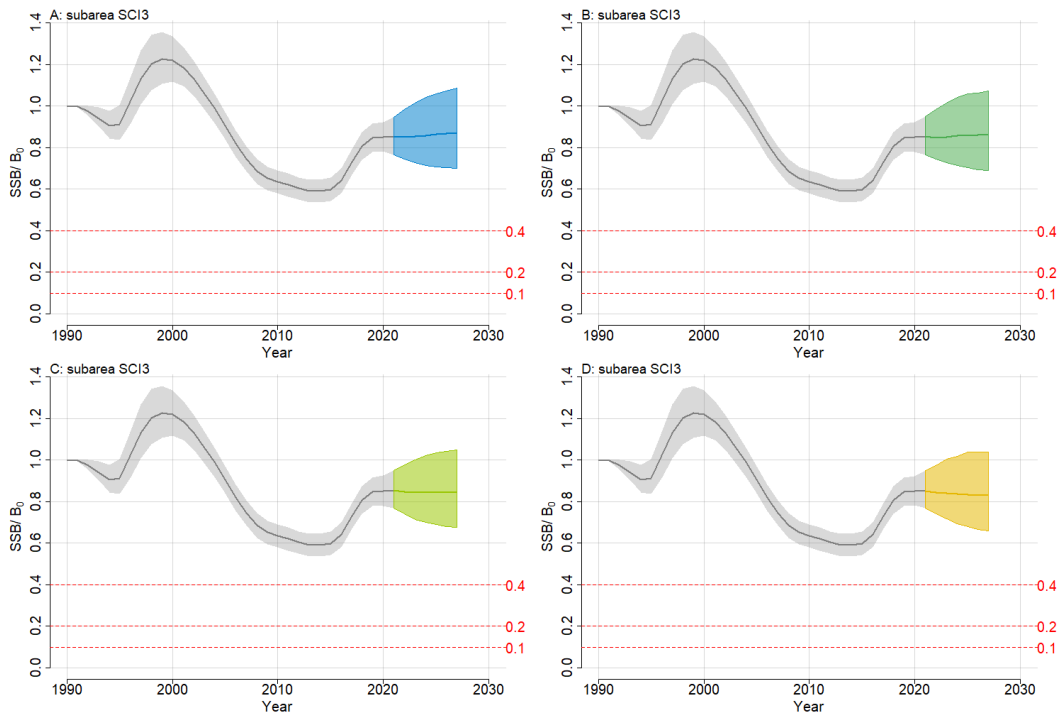
Figure 18: Posterior trajectory from SCI 3 base model (*M*=0.25) of spawning stock biomass, including 5-year projections out to 2026. Solid grey line shows the median of the posterior distribution, and the shaded polygons the 95th percentiles. Horizontal red lines show reference points 0.1, 0.2, 0.4 *B₀*.

Table 15: Results from MCMC runs showing B_0, B_{2021}/B_0 estimates (t) for the base model and four sensitivities for SCI3.

Base, M=0.25	MN	MO	MW	SCI 3
SSB_0	4 622 (3 389, 6 769)	2 109 (1 299, 3 574)	3 524 (2 100, 6 120)	10 506 (8 080, 13 987)
SSB_{2021}	3 333 (2 001, 5 660)	2 288 (1 348, 4 012)	3 092 (1 691, 5 644)	9 016 (6 429, 12 589)
SSB_{2021}/SSB_0	0.72 (0.57, 0.89)	1.08 (0.96, 1.26)	0.87 (0.74, 1.02)	0.88 (0.61, 1.21)
$P(SSB_{2021} > 40\% \ SSB_0)$	1	1	1	1
$P(SSB_{2021} < 20\% \ SSB_0)$	0	0	0	0
Sensitivity: M=0.20	MN	MO	MW	SCI 3
SSB_0	4 719 (3 596, 6 714)	2 154 (1 359, 3 628)	3 095 (1 984, 5 290)	10 207 (8 072, 13 350)
SSB_{2021}	3 177 (1 968, 5 307)	2 329 (1 405, 4 081)	2 600 (1 462, 4 788)	8 371 (6 165, 11 689)
SSB_{2021}/SSB_0	0.67 (0.53, 0.82)	1.08 (0.97, 1.22)	0.84 (0.71, 0.97)	0.84 (0.57, 1.17)
$P(SSB_{2021} > 40\% \ SSB_0)$	1	1	1	1
$P(SSB_{2021} < 20\% \ SSB_0)$	0	0	0	0
Sensitivity: *M=0.30*	MN	MO	MW	SCI 3
SSB_0	4 549 (3 211, 7 038)	2 112 (1 233, 3 712)	3 959 (2 261, 7 006)	10 841 (7 999, 15 406)
SSB_{2021}	3 448 (2 019, 6 158)	2 301 (1 294, 4 203)	3 552 (1 882, 6 598)	9 492 (6 616, 14 276)
SSB_{2021}/SSB_0	0.75 (0.59, 0.94)	1.09 (0.93, 1.3)	0.9 (0.75, 1.06)	0.9 (0.63, 1.24)
$P(SSB_{2021} > 40\% \ SSB_0)$	1	1	1	1
$P(SSB_{2021} < 20\% \ SSB_0)$	0	0	0	0
Sensitivity: *Cut CPUE*	MN	MO	MW	SCI 3
SSB_0	3 653 (2 736, 5 421)	1 762 (1 053, 2 988)	2 383 (1 569, 4 347)	7 999 (6 146, 10 849)
SSB_{2021}	2 380 (1 376, 4 240)	2 064 (1 194, 3 635)	1 936 (1 127, 3 854)	6 580 (4 612, 9 573)
SSB_{2021}/SSB_0	0.65 (0.48, 0.83)	1.17 (1.03, 1.36)	0.81 (0.68, 0.97)	0.82 (0.53, 1.3)
$P(SSB_{2021} > 40\% \ SSB_0)$	1	1	1	1
$P(SSB_{2021} < 20\% \ SSB_0)$	0	0	0	0
Sensitivity: *q photo same*	MN	MO	MW	SCI 3
SSB_0	6 242 (3 907, 11 249)	3 619 (2 045, 6 668)	8 367 (4 734, 15 835)	18 271 (10 844, 33 304)
SSB_{2021}	4 946 (2 526, 10 095)	3 943 (2 214, 7 338)	7 804 (4 302, 14 704)	16 644 (9 380, 32 134)
SSB_{2021}/SSB_0	0.79 (0.63, 0.97)	1.09 (0.95, 1.26)	0.93 (0.81, 1.07)	0.94 (0.67, 1.2)
$P(SSB_{2021} > 40\% \ SSB_0)$	1	1	1	1
$P(SSB_{2021} < 20\% \ SSB_0)$	0	0	0	0

SCI 4A

Standardised CPUE indices were estimated for the whole SCI 4A region and for the (core) patch to the north, on the basis of TCEPR records from vessels that had been active in the respective areas for at least 5 years. Both indices showed very similar patterns to the unstandardised CPUE data (Figure 3), increasing rapidly from the early 1990s to a peak in 2002, declining rapidly to 2005 and then more slowly to 2008, and then increasing steadily since this time. The standardised CPUE indices (only core area presented) show a very similar pattern to the Chatham Rise *Tangaroa* survey index for scampi (Figure 19).

Mean size in observed catches was markedly higher between 2003 and 2005 compared with other years, but length composition data from the Chatham Rise *Tangaroa* trawl survey did not show any patterns over time. The patchiness of observer sampling over time and the trawl gear used on the middle depths survey adds uncertainty about the representativeness of both data sets.

SCI 6A

For SCI 6A, a base model and three sensitivities were presented. Base model outputs suggest that spawning stock biomass (*SSB*) fluctuated around a declining trend between 1991 and 2013, increased slightly after this and has remained stable since 2016. The low *M* and low *q* models indicate very similar stock trends, but with the low *M* model estimating a slightly lower stock status throughout the fishery, and the low *q* model a higher SSB_0 and higher stock status throughout the fishery, and a slightly increasing trend in the most recent years. The model excluding the CPUE data estimated a different trend, with *SSB* declining to the early 2000s, and then showing a slightly increasing trend. The *SSB* in SCI 6A in 2019 was estimated to be 53% of SSB_0 for the base and between 47 and 66% of SSB_0 for the range of sensitivities considered (**Error! Reference source not found.**16, Figure 20). Historical changes in biomass in SCI 6A appear to be related to small fluctuations in recruitment rather than catches, but landings have been lower than the TACC in recent years, coinciding with an increase in recent year class strengths. All four of the models considered produce estimates of current stock status which are above the default management target of 40% B_0.
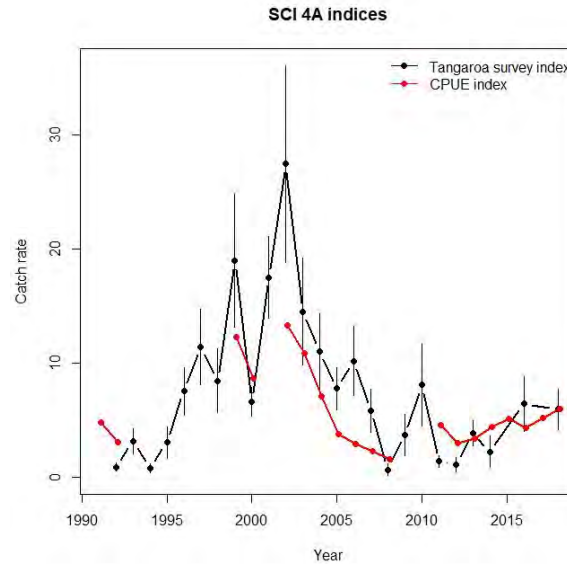
Figure 19: Mean catch rate (± one standard error) of Chatham Rise *Tangaroa* survey index and standardised CPUE in the core area of SCI 4A. The CPUE index has been scaled to the geometric mean of the survey catch rates.

Table 16: Results from MCMC runs showing B_0, B_{curr} and B_{curr}/B_0 for four alternative models for SCI 6A.

Model	Base	Low q	Low M	CPUE excluded
B_0	3 661	5 847	3 906	4 005
B_{2019}	1 950	3 994	1 849	2 623
B_{2019}/B_0	0.53	0.68	0.47	0.66
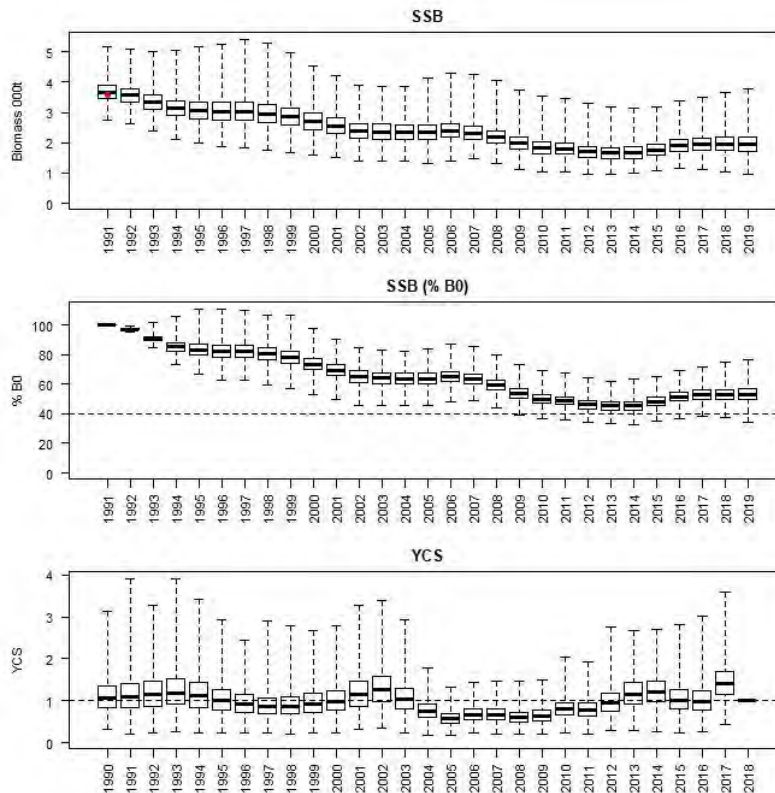
Figure 20: Posterior trajectory from the base SCI 6A model of spawning stock biomass and YCS. Upper plot shows boxplots of *SSB*, and the middle plot shows *SSB* as a percentage of B_0. On the middle plot, the 40% SSB_0 target reference point is shown as a dashed line. Box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The 2018 year class was not estimated.

5.4   Yield estimates and projections

SCI 1
No yield estimates and projection are available for SCI 1.

SCI 2
Projections were not carried out for the SCI 2 assessment model due to the conflict in recent trends of the CPUE and trawl survey abundance indices and the quality 2 rating.

SCI 3
Projections were examined for the base model, with recruitment sampled from the most recent 10 years of estimated recruitment, and with constant annual catch remaining at current levels (status quo; average of the last 5 years excluding 2020), at the TACC, or increasing to 10% or 20% above the current TACC. Median estimates of stock status from the projections are presented in Table 17 and suggested that under the current TACC scenario the stock would be around 87% B_0 by 2025. Medians from the sensitivities ranged from 86% to 87%. Alternative projections with recruitment sampled from all estimated years produced similar results. These are presented in the Fisheries Assessment Report for this stock assessment (McGregor in press).

On the basis of the outputs for the base model for SCI 3, and the annual catches examined, the probability of *SSB* being below either the soft or hard limit is zero, and the probability of remaining above the 40% B_0 target remains very high over the next 5 years (Table 18).

Table 17: Results from MCMC runs showing B_0, B_{2021}, and B_{2025} estimates at varying catch levels for SCI 3 for the base model.

Catch		MN	MW	MO	SCI 3
366 tonnes (5 year average	B_0	4622	3524	2109	10506
excluding 2020, and status quo)	B_{2021}	3328	3096	2296	8965
	B_{2021}/B_0	1.02	1.02	0.88	1.02
	B_{2025}/B_0	0.70	0.91	1.09	0.86
	B_{2025}/B_{2021}	0.97	1.04	1.00	1.01
408 tonnes (TACC)	B_{2025}/B_0	0.69	0.91	1.09	0.86
	B_{2025}/B_{2021}	0.95	1.04	1.00	1.00
449 tonnes (+10% TACC)	B_{2025}/B_0	0.66	0.90	1.10	0.85
	B_{2025}/B_{2021}	0.92	1.03	1.00	0.99
490 tonnes (+20% TACC)	B_{2025}/B_0	0.64	0.90	1.09	0.83
	B_{2025}/B_{2021}	0.89	1.03	1.00	0.98

Table 18: Results from MCMC runs the base model and three sensitivities for SCI 3, showing probabilities of projected spawning stock biomass exceeding the default Harvest Strategy Standard target reference point and being below the limit reference points. [Continued on next page]

Base: (*M*=0.25)	366 tonnes (average)				408 tonnes (TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B_{2025}< 10% B_0)	0	0	0	0	0	0	0	0
P(B_{2025}< 20% B_0)	0	0	0	0	0	0	0	0
P(B_{2025}> 40% B_0)	1	0.99	1	1	1	0.99	1	1
P(B_{2025}> B_{2021})	0.5	0.42	0.66	0.55	0.52	0.39	0.65	0.52
	449 tonnes (+10% TACC)				490 tonnes (+20% TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B_{2025}< 10% B_0)	0	0	0	0	0	0	0	0
P(B_{2025}< 20% B_0)	0	0	0	0	0	0	0	0
P(B_{2025}> 40% B_0)	1	0.98	1	1	1	0.97	1	1
P(B_{2025}> B_{2021})	0.51	0.31	0.61	0.44	0.51	0.26	0.6	0.38
Cut CPUE: (*M*=0.25)	366 tonnes (average)				408 tonnes (TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B_{2025}< 10% B_0)	0	0	0	0	0	0	0	0
P B_{2025} < 20% B_0)	0	0	0	0	0	0	0	0
P(B_{2025}> 40% B_0)	1	0.95	1	1	1	0.93	1	1
P(B_{2025}> B_{2021})	0.55	0.43	0.72	0.59	0.52	0.35	0.69	0.51

Table 18 [continued]

	449 tonnes (+10% TACC)				490 tonnes (+20% TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
$P(B_{2025} < 10\% \; B_0)$	0	0	0	0	0	0	0	0
$P(B_{2025} < 20\% \; B_0)$	0	0	0	0	0	0	0	0
$P(B_{2025} > 40\% \; B_0)$	1	0.9	1	1	1	0.86	1	1
$P(B_{2025} > B_{2021})$	0.55	0.29	0.68	0.46	0.55	0.22	0.67	0.39

Sens M: (M=0.20)

	366 tonnes (average)				408 tonnes (TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
$P(B_{2025} < 10\% \; B_0)$	0	0	0	0	0	0	0	0
$P(B_{2025} < 20\% \; B_0)$	0	0	0	0	0	0	0	0
$P(B_{2025} > 40\% \; B_0)$	1	0.99	1	1	1	0.98	1	1
$P(B_{2025} > B_{2021})$	0.57	0.43	0.77	0.63	0.57	0.37	0.76	0.58

	449 tonnes (+10% TACC)				490 tonnes (+20% TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
$P(B_{2025} < 10\% \; B_0)$	0	0	0	0	0	0	0	0
$P(B_{2025} < 20\% \; B_0)$	0	0	0	0	0	0	0	0
$P(B_{2025} > 40\% \; B_0)$	1	0.96	1	1	1	0.95	1	1
$P(B_{2025} > B_{2021})$	0.59	0.29	0.73	0.49	0.59	0.25	0.71	0.43

Sens M: (M=0.30)

	366 tonnes (average)				408 tonnes (TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
$P(B_{2025} < 10\% \; B_0)$	0	0	0	0	0	0	0	0
$P(B_{2025} < 20\% \; B_0)$	0	0	0	0	0	0	0	0
$P(B_{2025} > 40\% \; B_0)$	1	0.99	1	1	1	0.99	1	1
$P(B_{2025} > B_{2021})$	0.47	0.42	0.57	0.5	0.45	0.37	0.56	0.45

	449 tonnes (+10% TACC)				490 tonnes (+20% TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
$P(B_{2025} < 10\% \; B_0)$	0	0	0	0	0	0	0	0
$P(B_{2025} < 20\% \; B_0)$	0	0	0	0	0	0	0	0
$P(B_{2025} > 40\% \; B_0)$	1	0.98	1	1	1	0.98	1	1
$P(B_{2025} > B_{2021})$	0.45	0.29	0.54	0.39	0.44	0.26	0.53	0.36

Sens: q photo same

	366 tonnes (average)				408 tonnes (TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
$P(B_{2025} < 10\% \; B_0)$	0	0	0	0	0	0	0	0
$P(B_{2025} < 20\% \; B_0)$	0	0	0	0	0	0	0	0
$P(B_{2025} > 40\% \; B_0)$	1	1	1	1	1	1	1	1
$P(B_{2025} > B_{2021})$	0.52	0.46	0.62	0.6	0.51	0.4	0.61	0.55

	449 tonnes (+10% TACC)				490 tonnes (+20% TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
$P(B_{2025} < 10\% \; B_0)$	0	0	0	0	0	0	0	0
$P(B_{2025} < 20\% \; B_0)$	0	0	0	0	0	0	0	0
$P(B_{2025} > 40\% \; B_0)$	1	1	1	1	1	0.99	1	1
$P(B_{2025} > B_{2021})$	0.51	0.37	0.58	0.52	0.51	0.32	0.6	0.49

SCI4A

No yield estimates and projection are available for SCI 4A.

SCI 6A

Projections were examined for the base model with constant annual catch remaining at current levels (status quo; average catch 2016 to 2019), or at the current TACC. Future recruitments were resampled from the last 10 estimated years (2008–2017). Median estimates of stock status from the projections are presented in Table 19 and suggest that under a TACC scenario the stock would remain above 50% SSB_0 by 2025.

The estimated probability of SSB being below either of the limits is zero, and the probability of remaining above the 40% B_0 target remains high through to 2025 (Table 20).

Table 19: Results from MCMC runs showing SSB_0, SSB_{2019}, and SSB projection estimates for future years at varying catch levels for the base model for SCI 6A.

	Status quo (278 t)	TACC (306 t)
SSB_0	3 661	3 661
SSB_{2019}	1 950	1 950
SSB_{2019}/SSB_0	0.53	0.53

	Status (proportion of SSB_0)	Status (proportion of SSB_{2019})	Status (proportion of SSB_0)	Status (proportion of SSB_{2019})
SSB_{2020}	0.55	1.03	0.55	1.03
SSB_{2021}	0.56	1.06	0.56	1.04
SSB_{2022}	0.56	1.05	0.55	1.03
SSB_{2023}	0.55	1.04	0.54	1.00
SSB_{2024}	0.54	1.02	0.52	0.98
SSB_{2025}	0.53	1.00	0.51	0.95

Table 20: Results from MCMC runs for the base for SCI 6A, showing probabilities of projected spawning stock biomass exceeding the default Harvest Strategy Standard target and limit reference points.

	Status quo (278 t)				TACC (306 t)			
	Pr < 10% SSB_0	Pr < 20% SSB_0	Pr > 40% SSB_0	Pr > SSB_{2019}	Pr < 10% SSB_0	Pr < 20% SSB_0	Pr > 40% SSB_0	Pr > SSB_{2019}
2020	0.00	0.00	1.00	0.84	0.00	0.00	1.00	0.82
2021	0.00	0.00	0.99	0.76	0.00	0.00	0.99	0.69
2022	0.00	0.00	0.98	0.68	0.00	0.00	0.96	0.60
2023	0.00	0.00	0.95	0.61	0.00	0.00	0.92	0.52
2024	0.00	0.00	0.93	0.55	0.00	0.00	0.88	0.45
2025	0.00	0.00	0.89	0.49	0.00	0.00	0.83	0.39

5.5 Future research considerations

For all stocks
- Re-examine spatial and temporal patterns in grade length and sex composition (in the light of continued grade data collection by observers) with a view to reconstructing historical length composition data.
- Conduct additional tagging to improve growth estimates.
- Consider the incidence and distribution of *Microsporidian* spp. and its effects on survival and growth rates of scampi (both tagged individuals and in general).
- Explore evidence for the effects of recent fishing activity on catch rate, through flattening of bioturbation mounds and improved seabed contact (increased catchability) or disturbance of scampi leading to reduced emergence (reduced catchability).
- Examine recruitment patterns in more detail by obtaining better information on size composition. This could be accomplished by:
  - re-examining the photo survey data to allocate the animals seen into size ranges and differentiating doorkeepers from emerged animals;
  - investigating the utility of grade data for elucidating recruitment patterns;
  - investigating the potential for developing a juvenile index from ling and sea perch stomach contents.
- Improve the coverage and representativeness of observer data.

For SCI 1
- Consider combining the SCI 1 and 2 models (separate stocks but sharing of information, in particular around trawl survey catchability).
- Further analyse growth parameterisation and the influence on the assessment model's ability to fit the size composition data.
- Review the necessity for a highly informed trawl survey q prior.
- Review the utility of the photo survey and the interpretation of the images in generating abundance indices for the various scampi stock assessments.
- Review the selectivity ogive structures, in particular with respect to the model timesteps and the commercial size structure.

- Review the potential impact of changes in emergence and catchability.
- Explore CPUE standardisations, including spatial patterns and vessel overlap. Consider interviewing fleet managers and skippers about gear changes over time.

For SCI 2
- Investigate the conflict between the declining CPUE series from 2019 to 2021 and the significant increase in the trawl survey abundance in 2021.

For SCI 3
- Test for the possibility that it is the abundance indices rather than the length frequency data that are driving differences in year class strength in the three sub-regions: use the same abundance indices in all three models so that the only difference between the three is the length frequency data. This will determine whether the abundance indices or the length frequency data are the driving factors in determining year class strength.

For SCI4A
- Consider establishing reference points based on CPUE information.
- Consider designing and conducting a trawl survey in this area.

For SCI 6A
- Explore development of a 2-stock, 2-area model, splitting the fishery by depth to account for differences in length structure and growth

6. STATUS OF THE STOCKS

Stock Structure Assumptions
Assessments have been conducted for areas considered to be the core regions of SCI 1, SCI 2, SCI 3, and SCI 6A.

- **SCI 1**

Stock Status	
Year of Most Recent Assessment	2019; Preliminary 2022 results
Assessment Runs Presented	Base case; Updated abundance indices for 2022
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	2019: Very Likely (> 90%) to be at or above target 2022: Updated abundance indices indicate increases since 2019
Status in relation to Limits	2019: Exceptionally Unlikely (< 1%) to be below the soft or hard limits 2022: Updated abundance indices indicate increases since 2019
Status in relation to Overfishing	2019: Overfishing is Very Unlikely (< 10%) to be occurring 2022: Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status

SCI 1
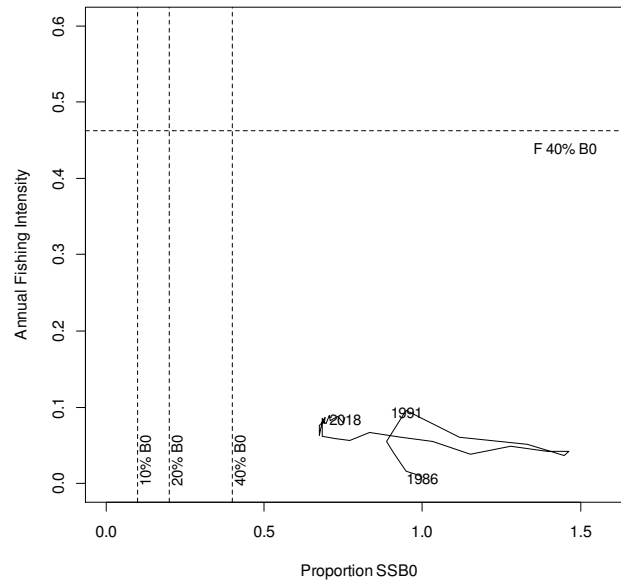
2019: Trajectories of biomass as a proportion of B_0 and annual equivalent fishing intensity for SCI 1 (M=0.25, CV=0.15).
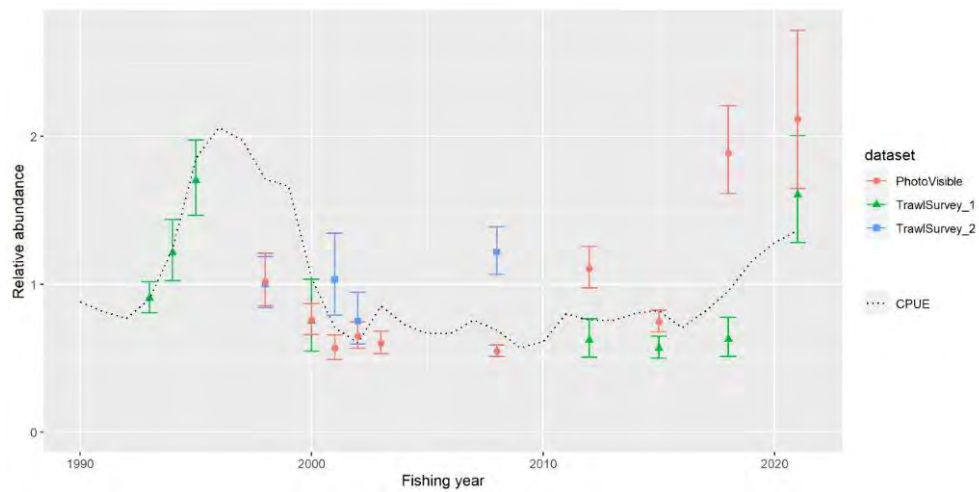
2022: Mean catch rates and relative abundance (+/- one standard error) of research trawling and photo survey counts for SCI 1. TrawlSurvey_1 is whole survey area, TrawlSurvey_2 and PhotoVisible are from the core survey strata, with PhotoVisible the visible scampi index). Dotted line represents median of annual unstandardised CPUE for SCI 1.

Fishery and Stock Trends

Recent Trend in Biomass or Proxy	2019: Spawning stock biomass increased to a peak in about 1995, declined to the early 2000s, and then remained relatively stable since this time. The 2018 photo survey showed a slight increase in the biomass and the CPUE showed a slight increase too. Trawl survey indices remained stable between 2000 and 2018. 2022: The Standardised CPUE index has increased steadily since 2016. The trawl survey index has more than doubled since 2018. The visible scampi index has more than tripled since 2015.

Recent Trend in Fishing Intensity or Proxy	2019: Fishing intensity fluctuated without trend since the early 1990s. 2022: Fishing intensity has probably declined since 2016 based on increasing abundance indices and little increase in catch.	
Other Abundance Indices	-	
Trends in Other Relevant Indicators or Variables	-	

Projections and Prognosis		
Stock Projections or Prognosis		
Probability of Current Catch or TACC causing biomass to remain below or to decline below Limits	2019: Soft Limit: Exceptionally Unlikely (< 1%) 2019: Hard Limit: Exceptionally Unlikely (< 1%) 2022: Soft Limit: Very Unlikely (< 10%) 2022: Hard Limit: Very Unlikely (< 10%)	
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Overfishing: Very Unlikely (< 10%)	

Assessment Methodology and Evaluation		
Assessment Type	2019: Level 1 - Full Quantitative Stock Assessment 2022: Preliminary results	
Assessment Method	2019: Length-based Bayesian Model 2022: Updated abundance series for 2022	
Assessment Dates	Latest assessment: 2019 Preliminary results: 2022	Next assessment: November 2022
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank): 2019	- Standardised catch and effort data (TCEPR) - Length frequency data from FNZ observer sampling - Photographic survey abundance index - Trawl survey abundance index - Length frequency data from research sampling - Length frequency predicted from burrow sizes	1 – High Quality 2 – Medium or Mixed Quality: data not representative in some years 1 – High Quality 1 – High Quality 1 – High Quality 2 – Medium or Mixed Quality: estimation of length structure uncertain, and not fitted well in model
Main data inputs (rank): 2022	- Standardised catch and effort data (TCEPR) - Photographic visible scampi survey abundance index - Trawl survey abundance index	1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank): 2022	Photographic survey burrow indices	2 – Medium or Mixed Quality: inconsistencies in burrow count interpretation

Changes to Model Structure and Assumptions: 2019	- Revised catchability priors developed
Major Sources of Uncertainty	2019: - Growth, burrow occupancy and catchability - Early CPUE (potential time varying q) - Early (large) YCSs - Absolute biomass determined by the q prior - Calculation of equivalent annual Fs and reference points

Qualifying Comments
2022: All abundance indices included in this assessment are sensitive to any changes in scampi emergence behaviour and consequent catchability (by trawl) or observability (in photographs). There are indications from model fits in 2019 that catchability varies between years.

Fishery Interactions
Main QMS bycatch species include ling, hoki, sea perch, red cod, silver warehou, and giant stargazer. Discards are dominated by rattails, javelinfish, skates and crabs, ling, red cod, hoki, spiny dogfish, and sea perch. Interactions with seabirds have been recorded. A wide range of benthic invertebrate species are taken as bycatch.

- **SCI 2**

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Base case
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Very Likely (> 90%) to be at or above target
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft or hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring.

Historical Stock Status Trajectory and Current Status

Trajectories of biomass as a proportion of B_0 and annual equivalent fishing intensity for SCI 2.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass increased during the early 1990s, but declined steadily after this until the early 2000s. Biomass increased steadily between 2008 and 2014, declining slightly since then.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality increased through the 1990s, peaking in 2002, but declined considerably by 2005, and has fluctuated without trend since this time.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The stock is predicted to remain well above 40% B_0 up to 2024 under TACC and increased catches.
Probability of Current Catch or TACC causing biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Overfishing: Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Length-based Bayesian Model	
Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	2 – Medium or Mixed Quality: conflicts between abundance indices were not adequately explored	
Main data inputs (rank)	- Standardised catch and effort data (TCEPR)	1 – High Quality 2 – Medium or Mixed Quality: data not representative in some years
	- Length frequency data from FNZ observer sampling	
	- Photographic survey abundance index	1 – High Quality
	- Trawl survey abundance index	1 – High Quality
	- Length frequency data from research sampling	1 – High Quality
	- Length frequency predicted from burrow sizes	2 – Medium or Mixed Quality: estimation of length structure uncertain
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Revised catchability priors developed	
Major Sources of Uncertainty	- Growth, burrow occupancy and catchability - Early CPUE (potential time varying q) - Early and recent (large) YCSs - Absolute biomass determined by the q prior - Calculation of equivalent annual Fs and reference points - Conflict exist between recent CPUE and trawl survey indices and therefore recent abundance trajectories are more uncertain than the model results indicate	

Qualifying Comments
-

Fishery Interactions
Main QMS bycatch species include ling, hoki, sea perch, red cod, silver warehou, and giant stargazer. Discards are dominated by rattails, javelinfish, skates and crabs, ling, red cod, hoki, spiny dogfish, and sea perch. Interactions with seabirds have been recorded. A wide range of benthic invertebrate species are taken as bycatch.

- **SCI 3**

Stock Status	
Year of Most Recent Assessment	2021
Assessment Runs Presented	Bayesian length-based model, base model: M=0.25, CPUE CV=0.2
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	B_{2021} was estimated to be 88% B_0. Very Likely (> 90%) to be at or above the target.
Status in relation to Limits	B_{2021} is Exceptionally Unlikely (< 1%) to be below the soft or hard limits
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status

Trajectories of biomass as a proportion of B_0 and annual equivalent fishing intensity for SCI 3.
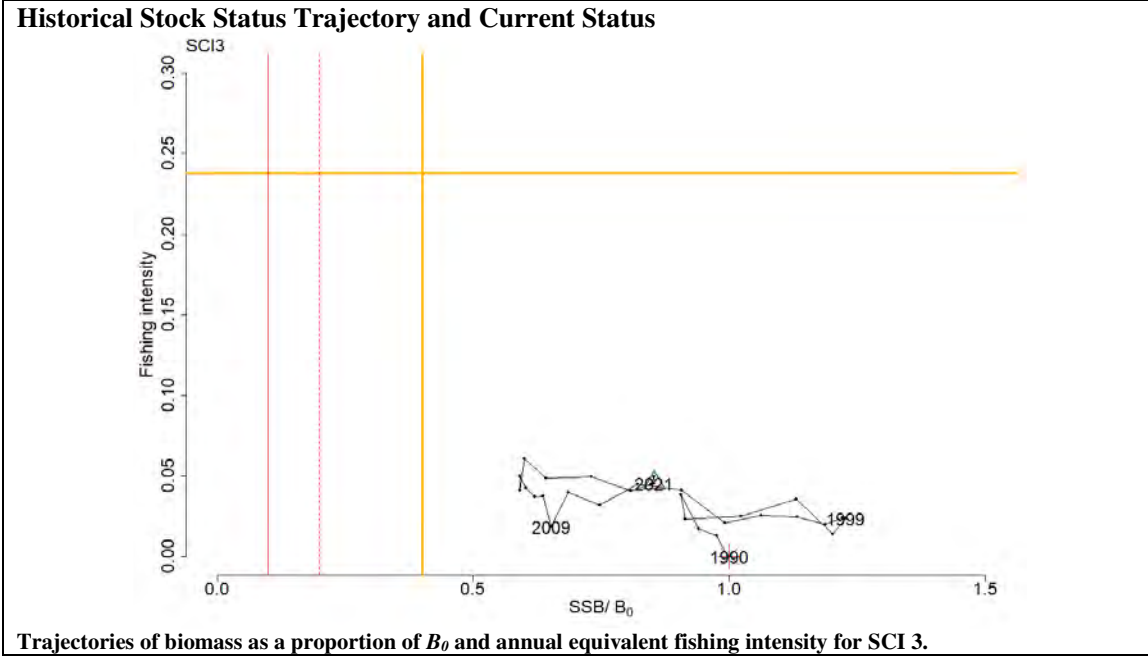
Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Recent biomass has increased and then stabilised since about 2018.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has been low and without trend throughout the time series
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The stock is predicted to remain above 40% B_0 for the next 5 years under current catches (TACC) and increases in TACC of up to 20%.
Probability of Current Catch or TACC causing biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Length-based Bayesian model	
Assessment Dates	Latest assessment: 2021	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Standardised fisheries CPUE index of abundance - Length frequency data from FNZ observer sampling - Photographic survey abundance index - Trawl survey abundance index - Length frequency data from research sampling - Length frequency predicted from burrow sizes	1 – High Quality 2 – Medium or Mixed Quality: data not representative in some years 1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Revised trawl survey q priors - Shared or separate photo qs between areas - Separate trawl qs between areas - Used photo q priors developed for SCI 1 & 2	
Major Sources of Uncertainty	- Growth, burrow occupancy and catchability - Early CPUE (potential time varying q) - Early (large) YCSs - Absolute biomass determined by the q prior - Calculation of equivalent annual Fs and reference points	

Qualifying Comments
Model scaling is highly dependent on the q priors without much updating by posteriors. Their influence should be investigated further. CPUE is highly influential and may be driving recruitment. This contributes to generating large early YCS(s) that are not fully supported by data.

Fishery Interactions
Main QMS bycatch species include ling, hoki, sea perch, red cod, silver warehou, and giant stargazer. Discards are dominated by rattails, javelinfish, skates and crabs, ling, red cod, hoki, spiny dogfish, and sea perch. Interactions with seabirds have been recorded. A wide range of benthic invertebrate species are taken as bycatch.

- **SCI 4A**

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	Standardised CPUE

Reference Points	Target: 40% B_0
	Soft Limit: 20% B_0
	Hard Limit: 10% B_0
	Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status

Trajectories of CPUE and *Tangaroa* trawl survey catch rate for SCI 4A.
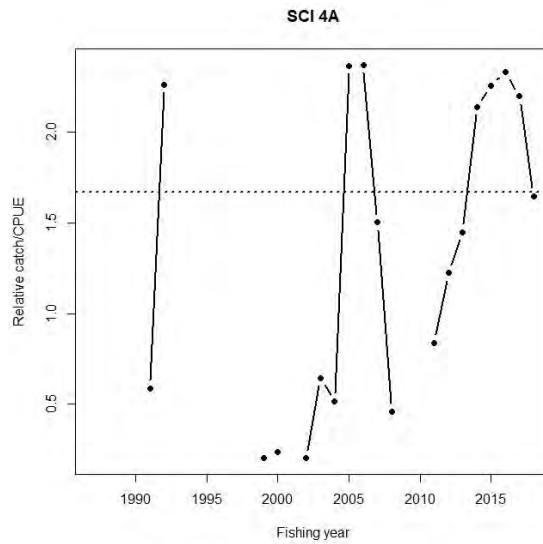
Relative fishing pressure for SCI 4A based on the ratio of QMR/MHR landings relative to the SCI 4A CPUE series which has been normalised so that its geometric mean=1.0. Horizontal dotted line is the geometric mean fishing pressure from 20010–11 to 2017–18.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE shows an increasing trend between 2012 and 2018.
Recent Trend in Fishing Intensity or Proxy	Recent relative exploitation rate has been higher than the series mean, but has decreased from a recent peak since 2016.
Other Abundance Indices	The Chatham Rise *Tangaroa* trawl survey index shows a very similar pattern to the standardised CPUE index.
Trends in Other Relevant Indicators or Variables	Fishing effort increased from 2012–2015 but declined to the 2012 level by 2018.

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2019	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality. The Shellfish WG agreed the CPUE index was a credible measure of abundance	
Main data inputs	- Standardised catch and effort data (TCEPR) - Length frequency data from FNZ observer sampling - Trawl survey abundance index - Length frequency data from trawl survey abundance index	1 – High Quality 2 – Medium or Mixed Quality: variable representativeness of sampling 1 – High Quality 2 – Medium or Mixed Quality: uncertain representativeness of sampling and small sample sizes
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
The Chatham Rise *Tangaroa* survey records relatively low catches of scampi, and though it provides the only fishery-independent index for scampi in SCI 4A, it was not designed to target this species.

Fishery Interactions
Main QMS bycatch species include ling, hoki, sea perch, red cod, silver warehou, and giant stargazer. Discards are dominated by rattails, javelinfish, skates and crabs, ling, red cod, hoki, spiny dogfish, and sea perch. Interactions with seabirds and mammals (fur seals and sea lions) have been recorded. A wide range of benthic invertebrate species are taken as bycatch.

- **SCI 6A**

Stock Status	
Year of Most Recent Assessment	2020

Assessment Runs Presented	Bayesian length based model with M=0.25, informed survey catchability priors, and survey and CPUE abundance indices (base model run)
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Very Likely (> 90%) to be at or above the target
Status in relation to Limits	Exceptionally Unlikely (< 1%) to be below the soft or hard limits
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status
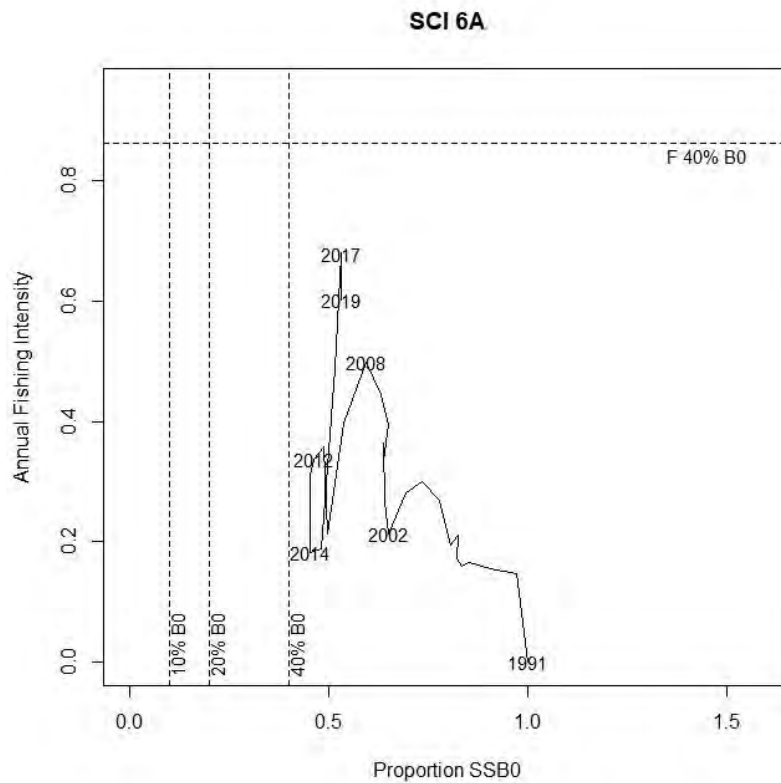
Trajectories of biomass as a proportion of SSB_0 and annual equivalent fishing intensity for SCI 6A.

Fishery and Stock Trends

Recent Trend in Biomass or Proxy	Estimated spawning stock biomass has been stable for the last 4 years.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality showed an increasing trend between 2014 and 2019.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis

Stock Projections or Prognosis	The stock is predicted to remain above 40% SSB_0 through to 2025 at current levels of catch and the TACC. Projected stock status when catches are at the TACC level is predicted to be about 51% B_0 in 2025.

Probability of Current Catch or TACC causing biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Overfishing Exceptionally Unlikely (< 1%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Length-based Bayesian model	
Assessment Dates	Latest assessment: 2020	Next assessment: 2023
Overall assessment quality rank	1 – High Quality	
Main data inputs	- Standardised catch and effort data (TCEPR)	1 – High Quality
	- Length frequency data from FNZ observer sampling	2 – Medium or Mixed Quality: variable representativeness of sampling
	- Photographic survey abundance index	1 – High Quality
	- Trawl survey abundance index	1 – High Quality
	- Length frequency data from trawl survey abundance index	1 – High Quality
	- Length frequency data from photos of visible scampi	2 – Medium or Mixed Quality: high level of uncertainty
	- Growth rates predicted from tag release recapture data	2 – Medium or Mixed Quality: limited recaptures and within a limited time span
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	Revised prior distributions estimated for survey catchability Model was fitted to emerged abundance index rather than the visible index	
Major Sources of Uncertainty	- Growth, differential selectivity by sex, and sex ratios - Relationship between CPUE and abundance (potential time varying *q*) -YCS estimation	

Qualifying Comments
Photo surveys in SCI 6A observe a higher number of scampi out of burrows, relative to burrows counted, than has been observed in other areas. This may be related to animal size or sediment characteristics. If emergence is greater, this may imply that scampi in SCI 6A are more vulnerable to trawling than in other areas.

Fishery Interactions
Main QMS bycatch species include ling, hoki, sea perch, red cod, silver warehou, and giant stargazer. Discards are dominated by rattails, javelinfish, skates and crabs, ling, red cod, hoki, spiny dogfish, and sea perch. Interactions with seabirds and mammals (fur seals and sea lions) have been recorded. A wide range of benthic invertebrate species are taken as bycatch.

7.   FOR FURTHER INFORMATION

Abraham, E R; Pierre, J P; Middleton, D A; Cleal, J; Walker, N A; Waugh, S M (2009) Effectiveness of fish waste management strategies in reducing seabird attendance at a trawl vessel. *Fisheries Research 95(2)*: 210–219.

Abraham, E R; Richard, Y (2017) Summary of the capture of seabirds in New Zealand commercial fisheries, 2002–03 to 2013–14. *New Zealand Aquatic Environment and Biodiversity Report No. 184*. 88 p.

Abraham, E R; Richard, Y (2018) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2014–15. *New Zealand Aquatic Environment and Biodiversity Report No. 197*. 97 p.

Abraham, E R; Richard, Y (2020) Estimated capture of seabirds in New Zealand trawl and longline fisheries, to 2017–18. *New Zealand Aquatic Environment and Biodiversity Report* No. *249*. 86 p

Abraham, E R; Richard, Y; Berkenbusch, K; Thompson, F (2016) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 2002–03 to 2012–13. *New Zealand Aquatic Environment and Biodiversity Report No. 169*. 205 p.

Abraham, E R; Thompson, F N (2011) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report No. 80*.

Abraham, E R; Thompson, F N; Berkenbusch, K (2013) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2010–11. Final Research Report for Ministry for Primary Industries project PRO2010-01 (Unpublished report held by Fisheries New Zealand, Wellington).

Abraham, E R; Tremblay-Boyer, L; Berkenbusch, K (2021) Estimated captures of New Zealand fur seal, common dolphin, and turtles in New Zealand commercial fisheries, to 2017–18. *New Zealand Aquatic Environment and Biodiversity Report No. 258*. 94 p.

Anderson, O F; Edwards, C T T (2018) Fish and invertebrate bycatch and discards in New Zealand arrow squid and scampi trawl fisheries from 2002–03 until 2015–16. *New Zealand Aquatic Environment and Biodiversity Report No. 199*. 135 p.

Baird, S J (Ed) (2001) Report on the International Fishers' Forum on Solving the Incidental Capture of Seabirds in Longline Fisheries, Auckland, New Zealand, 6-9 November 2000. Department of Conservation.

Baird, S J (2004a) Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1999–2000. *New Zealand Fisheries Assessment Report 2004/41*. 56 p.

Baird, S J (2004b) Incidental capture of seabird species in commercial fisheries in New Zealand waters,2000–01. *New Zealand Fisheries Assessment Report 2004/58*. 63 p.

Baird, S J (2004c) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2001–02. *New Zealand Fisheries Assessment Report 2004/60*. 51 p.

Baird, S J (2005a) Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2002–03. *New Zealand Fisheries Assessment Report 2005/13*. 36 p.

Baird, S J (2005b) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002–03. *New Zealand Fisheries Assessment Report 2005/12*. 50 p.

Baird, S J; Doonan, I J (2005) *Phocarctos hookeri* (New Zealand sea lions): incidental captures in New Zealand commercial fisheries during 2000–01 and in-season estimates of captures during squid trawling in SQU 6T in 2002. *New Zealand Fisheries Assessment Report 2005/17*. 20 p.

Baird, S J; Hewitt, J E; Wood, B A (2015) Benthic habitat classes and trawl fishing disturbance in New Zealand waters shallower than 250 m. New *Zealand Aquatic Environment and Biodiversity Report No. 144*. 184 p.

Baird, S J; Mules, R (2019) Extent of bottom contact by New Zealand commercial trawl fishing for deepwater Tier 1 and Tier 2 target species determined using CatchMapper software, fishing years 2008–17. *New Zealand Aquatic Environment and Biodiversity Report No. 229*. 106 p.

Baird, S J; Mules, R (2021a) Extent of bottom contact by commercial fishing activity in New Zealand waters, for 1989–90 to 2017–18. *New Zealand Aquatic Environment and Biodiversity Report No. 259*. 143 p.

Baird, S J; Mules, R (2021b) Extent of bottom contact by commercial trawling and dredging in New Zealand waters, 1989–90 to 2018–19. *New Zealand Aquatic Environment and Biodiversity Report. No. 260*. 157 p

Baird, S J; Smith, M H (2007) Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2003–04 to 2004–05. *New Zealand Aquatic Environment and Biodiversity Report No. 14*. 98 p.

Baird, S J; Wood, B A (2012) Extent of coverage of 15 environmental classes within the New Zealand EEZ by commercial trawling with seafloor contact. *New Zealand Aquatic Environment and Biodiversity Report No. 89*. 43 p.

Baird, S J; Wood, B A (2018) Extent of bottom contact by New Zealand commercial trawl fishing for deepwater Tier 1 and Tier 2 target fishstocks, 1989–90 to 2015–16. *New Zealand Aquatic Environment and Biodiversity Report No. 193*. 102 p.

Baird, S J; Wood, B A; Bagley, N W (2011) Nature and extent of commercial fishing effort on or near the seafloor within the New Zealand 200 n. mile Exclusive Economic Zone, 1989–90 to 2004–05. *New Zealand Aquatic Environment and Biodiversity Report No. 73*. 143 p.

Baker, C S; Chilvers, B L; Childerhouse, S; Constantine, R; Currey, R; Mattlin, R; van Helden, A; Hitchmough, R; Rolfe, J (2016) Conservation status of New Zealand marine mammals, 2013. *New Zealand Threat Classification Series 14*. Department of Conservation, Wellington. 18 p.

Baker, C S; Chilvers, B L; Constantine, R; DuFresne, S; Mattlin, R H; van Helden, A; Hitchmough, R (2010) Conservation status of New Zealand marine mammals (suborders Cetacea and Pinnipedia), 2009. *New Zealand Journal of Marine and Freshwater Research 44*: 101–115.

Ballara, S L; Anderson, O F (2009). Fish discards and non-target fish catch in the trawl fisheries for arrow squid and scampi in New Zealand waters. *New Zealand Aquatic Environment and Biodiversity Report No. 38*. 102 p.

Bell, M C; Redant, F; Tuck, I D (2006) Nephrops species. *In:* Phillips, B (Ed) pp. 412–461, *Lobsters: Biology, management, Aquaculture and Fisheries*. Oxford, Blackwell Publishing.

Black, J; Tilney, R (2015) Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989– 1990 to 2010–2011. *New Zealand Aquatic Environment and Biodiversity Report No. 142*. 56 p.

Black, J; Tilney, R (2017) Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989–90 to 2012–13. *New Zealand Aquatic Environment and Biodiversity Report No. 176*. 65 p.

Black, J; Wood, R; Berthelsen, T; Tilney, R (2013) Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989–1990 to 2009–2010. *New Zealand Aquatic Environment and Biodiversity Report No. 110*. 57 p.

Chapman, C J (1979) Some observations on populations of Norway Lobster, *Nephrops norvegicus* (L.), using diving, television, and photography. *Rapports et process verbeaux de la Reunion Conseil international pour l'Exploration de la Mer 175*: 127–133.

Chapman, C J (1980) Ecology of juvenile and adult Nephrops. *In*: Cobbs, S; Phillips, B. (Eds), pp 143–178. *The biology and management of lobster*, Vol. 1. Academic Press, New York.

Chapman, C J; Howard, F G (1979) Field observations on the emergence rhythm of the Norway Lobster *Nephrops norvegicus*, using different methods. *Marine Biology 51*: 157–165.

Chapman, C J; Howard, F.G. (1988) Environmental influences on Norway lobster (*Nephrops norvegicus*) populations and their implications for fishery management. *Symposium of the Zoological Society, London 59*: 343–353.

Cryer, M (2000) A consideration of current management areas for scampi in QMAs 3, 4, 6A and 6B. Final Research Report for Ministry of Fisheries Research Project MOF199904K, Objective 1. (Unpublished report held by Fisheries New Zealand, Wellington.)

Cryer, M; Coburn, R (2000) Scampi assessment for 1999. *New Zealand Fisheries Assessment Report 2000/7*. 60 p.

Cryer, M; Coburn, R; Hartill, B; O'Shea, S; Kendrick, T; Doonan, I (1999) Scampi stock assessment for 1998 and an analysis of the fish and invertebrate bycatch of scampi trawlers. New Zealand Fisheries Assessment Research Document 1999/4. 75 p. (Unpublished report held by NIWA library, Wellington.)

Cryer, M; Doonan, I; Coburn, R; Hartill, B (1998) Scampi assessment for 1997. New Zealand Fisheries Assessment Research Document 1998/28. 78 p. (Unpublished report held by NIWA library, Wellington.)

Cryer, M; Dunn, A; Hartill, B (2005) Length-based population model for scampi (*Metanephrops challengeri*) in the Bay of Plenty (QMA 1). *New Zealand Fisheries Assessment Report 2005/27*. 55 p.

Cryer, M; Hartill, B (1998) Final Research Report to Ministry of Fisheries on an experimental comparison of trawl and photographic methods of estimating the biomass of scampi. Final Research Report for Project SCI9701. 26 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Cryer, M; Hartill, B (2001) Scampi assessment for 2000 and unstandardised CPUE 1988–89 to 1999–00. (Draft FAR dated December 2000, held by Fisheries New Zealand, Wellington.)

Cryer, M; Hartill, B; Drury, J; Armiger, H J; Smith, M D; Middleton, C J (2003) Indices of relative abundance for scampi, *Metanephrops challengeri*, based on photographic surveys in QMA 1 (1998–2003) and QMA 2 (2003). Final Research Report for Project SCI2002/01 (Objectives 1–3). 18 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Cryer, M; Hartill, B; Drury, J; Tuck, I; Cadenhead, H J; Smith, M D; Middleton, C J (2002) Indices of relative abundance for scampi, *Metanephrops challengeri*, based on photographic surveys in QMA 1, 1998–2002. (Final Research Report for Projects SCI2000/02 (Objectives 1 & 2) and SCI2001/01 (Objectives 1 & 2), dated November 2002, held by Fisheries New Zealand, Wellington.)

Cryer, M; Hartill, B W; O'Shea, S (2002) Modification of marine benthos by trawling: toward a generalization for the deep ocean? *Ecological Applications 12*: 1824–1839.

Cryer, M; Hartill, B W; O'Shea, S (2005) Deepwater trawl fisheries modify benthic community structure in similar ways to fisheries in coastal systems. *American Fisheries Society Symposium 41*: 695–696.

Cryer, M; Oliver, M (2001) Estimating age and growth in New Zealand scampi, *Metanephrops challengeri*. Final Research Report for Ministry of Fisheries Project SCI9802 (Objective 2). (Unpublished report held by Fisheries New Zealand, Wellington.)

Cryer, M; Stotter, D R (1997) Trawling and tagging of scampi off the Alderman Islands, western Bay of Plenty, September 1995 (KAH9511). *New Zealand Fisheries Data Report No. 84*. 26 p.

Cryer, M; Stotter, D R (1999) Movements and growth rates of scampi inferred from tagging, Aldermen Islands, western Bay of Plenty. *NIWA Technical Report 49*. 35 p.

Cryer, M; Vignaux, M; Gilbert, D J (1995) Assessment of the scampi fishery for 1995. Draft New Zealand Fisheries Assessment Research Document.

Dunn, M; Horn, P; A. Connell, A; Stevens, D; Forman, J; Pinkerton, M; Griggs, L; Notman, P; Wood, B (2009) Ecosystem-scale trophic relationships: diet composition and guild structure of middle-depth fish on the Chatham Rise. Final Research Report for Ministry of Fisheries Research Project, ZBD2004-02. (Unpublished report held by Fisheries New Zealand, Wellington.)

Farmer, A S D (1974) Reproduction in *Nephrops norvegicus* (Decapoda: Nephropidae). *Journal of Zoology, London 174*: 161–183.

Fenaughty, C (1989) Reproduction in *Metanephrops challengeri*. (Unpublished report held by Fisheries New Zealand, Wellington.)

Fisheries New Zealand (2021) Aquatic Environment and Biodiversity Annual Review 2021. Compiled by the Aquatic Environment Team, Fisheries Science and Information, Fisheries New Zealand, Wellington, New Zealand. 779 p.

Hartill, B; Cryer, M (2000) A review of the adequacy of the current observer coverage and practices for scampi. Final Research Report for Ministry of Fisheries Research Project MOF1999104J. 46 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Hartill, B; Cryer, M (2001) Unstandardised CPUE indices for scampi 1988–2001. Final Research Report for Project SCI2001/02, dated November 2001. (Unpublished report held by Fisheries New Zealand, Wellington.)

Hartill, B; Cryer, M (2002) Unstandardised CPUE indices for scampi 1988–2002. Final Research Report for Project SCI2001/02 (Objective 2), dated December 2002. (Unpublished report held by Fisheries New Zealand, Wellington.)

Hartill, B; Cryer, M (2004) Unstandardised scampi CPUE indices update for scampi 1988–2003. Final Research Report for Ministry of Fisheries Research Project SCI2001/02, Obj. 2. 35 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Hartill, B; Cryer, M; MacDiarmid, A D (2006) Reducing bycatch in scampi trawl fisheries. *New Zealand Aquatic Environment and Biodiversity Report No. 4. 53 p.*

Hartill, B; Tuck, I D (2010) Potential utility of scampi processor grade data as a source of length frequency data. Final Research Report for Ministry of Fisheries Project SCI2007-03. (Unpublished report held by Fisheries New Zealand, Wellington.)

Hermsen, J M; Collie, J S; Valentine, P C (2003) Mobile fishing gear reduces benthic megafaunal production on Georges Bank. *Marine Ecology Progress Series 260*: 97–108.

Hiddink, J G; Jennings, S; Kaiser, M J; Queiros, A M; Duplisea, D E; Piet, G J (2006) Cumulative impacts of seabed trawl disturbance on benthic biomass, production, and species richness in different habitats. *Canadian Journal of Fisheries and Aquatic Sciences 63*: 721–36.

Hore A J (1992) Management of the New Zealand Scampi Fishery: an interim report to the Director General of Agriculture and Fisheries. Unpublished Report. MAF Fisheries, Wellington. (Unpublished report held by NIWA library, Wellington.)

Hughes, D; Atkinson, R (1997) A towed video survey of megafaunal bioturbation in the north-eastern Irish Sea. *Journal of the Marine Biological Association of the United Kingdom 77(3)*: 635–653.

Jennings, S; Dinmore, T A; Duplisea, D E; Warr, K J; Lancaster, J E (2001) Trawling disturbance can modify benthic production processes. *Journal of Animal Ecology 70*: 459–475.

Kelleher, K (2005) Discards in the world's marine fisheries. An update. *FAO Fisheries Technical Paper 470*. 131 p.

Large, K; Roberts, J; Francis, M; Webber, D N (2019) Spatial assessment of fisheries risk for New Zealand sea lions at the Auckland Islands. *New Zealand Aquatic Environment and Biodiversity Report No. 224*. 85 p.

Leathwick, J R; Rowden, A; Nodder, S; Gorman, R; Bardsley, S; Pinkerton, M; Baird, S J; Hadfield, M; Currie, K; Goh, A (2012) A Benthic–optimised Marine Environment Classification (BOMEC) for New Zealand waters. *New Zealand Aquatic Environment and Biodiversity Report No. 88*. 54 p.

MacKenzie, D; Fletcher, D (2006) Characterisation of seabird captures in NZ fisheries. Final Research Report for Ministry of Fisheries project ENV2004/04. 99 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

McGregor, V L (in press) Length-based population model for scampi (*Metanephrops challengeri*) in Mernoo Bank (SCI 3). Draft New Zealand Fisheries Assessment Report.

Meyer, S (2019) Desktop estimation of New Zealand sea lion cryptic mortality in trawls using SLEDs. *New Zealand Aquatic Environment and Biodiversity Report No. 222*. 25 p.

Meynier, L; Morel, P C H; Mackenzie, D S; MacGibbon, A; Chilvers, B L; Duignan, P J (2008) Proximate composition, energy content, and fatty acid composition of marine species from Campbell Plateau, New Zealand. *New Zealand Journal of Marine and Freshwater Research 42(4)*: 425–437.

Middleton, D A J; Abraham, E R (2007) The efficacy of warp strike mitigation devices: Trials in the 2006 squid fishery. Final Research Report for research project IPA2006/02. (Unpublished report held by Fisheries New Zealand, Wellington.)

Rainer, S F (1992) Growth of Australian scampi, *Metanephrops australiensis*. The fisheries biology of deepwater crustacea and finfish on the continental slope of Western Australia. Final Report FRDC Project 1988/74. 308 p.

Reiss, H; Greenstreet, S P R; Sieben, K; Ehrich, S; Piet, G J; Quirijns, F; Robinson, L; Wolff, W J; Kröncke, I (2009) Effects of fishing disturbance on benthic communities and secondary production within an intensively fished area. *Marine Ecology Progress Series 394*: 201–213.

Rice, J (2006) Impacts of Mobile Bottom Gears on Seafloor Habitats, Species, and Communities: A Review and Synthesis of Selected International Reviews. *Canadian Science Advisory Secretariat Research Document 2006/057*. 35 p. (available from http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2006/RES2006_057_e.pdf)

Richard, Y; Abraham, E R (2013). Risk of commercial fisheries to New Zealand seabird populations. *New Zealand Aquatic Environment and Biodiversity Report No. 109*. 58 p.

Richard, Y; Abraham, E R (2015) Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2012–13. *New Zealand Aquatic Environment and Biodiversity Report No. 162*. 85 p

Richard, Y; Abraham, E R; Berkenbusch, K (2017) Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2014–15. *New Zealand Aquatic Environment and Biodiversity Report No. 191*. 133 p.

Richard, Y; Abraham, E R; Berkenbusch, K (2020). Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2016–17. *New Zealand Aquatic Environment and Biodiversity Report No. 237*. 57 p.

Robertson, H A; Baird, K; Dowding J E; Elliott, G P; Hitchmough, R A; Miskelly, C M; McArthur, N; O'Donnell, C F J; Sagar, P M; Scofield, R P; Taylor, G A (2017) Conservation status of New Zealand birds, 2016. *New Zealand Threat Classification Series 19*. Department of Conservation, Wellington. 23 p.

Thompson, F N; Abraham, E R (2009) Six Monthly Summary of the Capture of Protected Species in New Zealand Commercial Fisheries, Summer 2007–08. *New Zealand Aquatic Environment and Biodiversity Report No. 35*.

Thompson, F N; Abraham, E R; Berkenbusch, K (2011) Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2009–10. Final Research Report for Ministry for Primary Industries project PRO2010-01 (Unpublished report held by Fisheries New Zealand, Wellington.) 68 p.

Thompson, F N; Berkenbusch, K; Abraham, E R (2013) Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11. *New Zealand Aquatic Environment and Biodiversity Report No. 105*. 73 p.

Tuck, I; Cryer, M; Hartill, B; Drury, J; Armiger, H; Smith, M; Parkinson, D; Middleton, C (2006) Measuring the abundance of scampi - Indices of abundance for scampi, *Metanephrops challengeri*, based on photographic surveys in SCI 2 (2003–2005). Final Research Report for Ministry of Fisheries Research Project SCI2004/01 (Objectives 1 & 2). (Unpublished report held by Fisheries New Zealand, Wellington.)

Tuck, I D (2007) A medium term research plan for scampi (*Metanephrops challengeri*). Final Research Report for Ministry of Fisheries Research Project SAP200607. (Unpublished report held by Fisheries New Zealand, Wellington.)

Tuck, I D (2009) Characterisation of scampi fisheries and the examination of catch at length and spatial distribution of scampi in SCI 1, 2, 3, 4A and 6A. *New Zealand Fisheries Assessment Report 2009/07*. 102 p.

Tuck, I D (2010) Scampi burrow occupancy, burrow emergence, and catchability. *New Zealand Fisheries Assessment Report 2010/13*. 58 p.

Tuck, I D (2013) Characterisation and length-based population model for scampi (*Metanephrops challengeri*) on the Mernoo Bank (SCI 3). *New Zealand Fisheries Assessment Report 2013/24*. 165 p.

Tuck, I (2016) Characterisation and a length-based assessment model for scampi (Metanephrops challengeri) on the Mernoo Bank (SCI 3). New Zealand Fisheries Assessment Report 2016/55. 221 p.

Tuck, I (2019) Characterisation and a length-based assessment model for scampi (Metanephrops challengeri) on the Mernoo Bank (SCI 3). New Zealand Fisheries Assessment Report 2019/61. 248 p.

Tuck, I D (2020a) Characterisation and CPUE standardisation of scampi in SCI 4A. *New Zealand Fisheries Assessment Report 2020/04*. 52 p.

Tuck, I D (2020b) Characterisation and length-based assessment model for scampi (*Metanephrops challengeri*) in the Bay of Plenty (SCI 1) and Hawke Bay-Wairarapa (SCI 2). *New Zealand Fisheries Assessment Report 2020/06*. 299 p.

Tuck, I.D. (2021). Characterisation and a length-based assessment model for scampi (*Metanephrops challengeri*) at the Auckland Islands (SCI 6A), for 1989–90 to 2018–19.

Tuck, I D; Dunn, A (2009) Length-based population model for scampi (*Metanephrops challengeri*) in the Bay of Plenty (SCI 1) and Wairarapa / Hawke Bay (SCI 2). Final Research Report for Ministry of Fisheries research projects SCI2006-01 & SCI2008-03W. (Unpublished report held by Fisheries New Zealand, Wellington.)

Tuck, I D; Dunn, A (2012) Length-based population model for scampi (*Metanephrops challengeri*) in the Bay of Plenty (SCI 1), Wairarapa / Hawke Bay (SCI 2), and Auckland Islands (SCI 6A). *New Zealand Fisheries Assessment Report 2012/01*.

Tuck, I D; Hartill, B; Drury, J; Armiger, H; Smith, M; Parkinson, D (2006) Measuring the abundance of scampi – Indices of abundance for scampi, *Metanephrops challengeri*, based on photographic surveys in SCI 2 (2003–2006). Final Research Report for Ministry of Fisheries Research Project SCI2005-01 (Objective 1). (Unpublished report held by Fisheries New Zealand, Wellington.)

Tuck, I D; Hartill, B; Parkinson, D; Harper, S; Drury, J; Smith, M; Armiger, H (2009) Estimating the abundance of scampi - Relative abundance of scampi, *Metanephrops challengeri*, from a photographic survey in SCI 1 and SCI 6A (2008). Final Research Report for Ministry of Fisheries research project SCI2007-02. (Unpublished report held by Fisheries New Zealand, Wellington.)

Tuck, I D; Parsons, D M; Hartill, B W; Chiswell, S M (2015) Scampi (*Metanephrops challengeri*) emergence patterns and catchability. *ICES Journal of Marine Science: Journal du Conseil 72(Suppl 1):* 199–210. doi: 10.1093/icesjms/fsu244

Vignaux, M; Gilbert, D J (1993) A production model for the QMA 1 scampi fishery 1989–1991. New Zealand Fisheries Assessment Research Document 1993/18. (Unpublished report held by NIWA library, Wellington.)

Vignaux, M; Gilbert, D J (1994) A production model for the QMA 1 scampi fishery 1989–1992. New Zealand Fisheries Assessment Research Document 1994/8. (Unpublished report held by NIWA library, Wellington.)

Wear, R G (1976) Studies on the larval development of *Metanephrops challengeri* (Balss, 1914) (Decapoda, Nephropidae). *Crustaceana 30*: 113–122.

SCHOOL SHARK (SCH)

(*Galeorhinus galeus*)
Tupere, Tope, Makohuarau
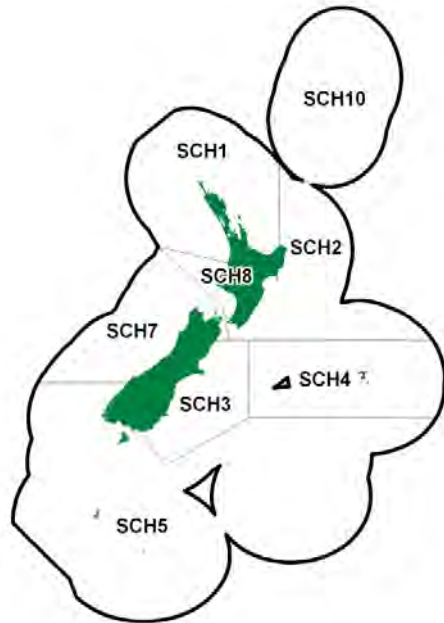
1. FISHERY SUMMARY

School shark was introduced into the QMS on 1 October 1986. The recreational, customary, and other mortality allowances as well as TACCs and TACs applicable from the fishing year 2018–19 are shown in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACCs, and TACs for school shark by Fishstock.

Fish Stock	Recreational allowance	Customary non-commercial allowance	Other sources of mortality	TACC	TAC
SCH 1	68	102	34	689.0	893.0
SCH 2	–	–	–	198.6	198.6
SCH 3	48	48	19	387.0	502.0
SCH 4	–	–	–	238.5	238.5
SCH 5	7	7	37	743.0	794.0
SCH 7	58	58	32	641.0	789.0
SCH 8	21	21	26	529.0	597.0
SCH 10	–	–	–	10.0	10.0

1.1 Commercial fisheries

This moderate-sized shark has supported a variety of fisheries around New Zealand from the early 1940s onwards. Landings rose steeply from the late 1970s until 1983 (Table 2), with the intensification of setnets targeting this and other shark species, and a general decline in availability of other, previously more desirable, coastal species. However, because of earlier discarding and under-reporting, this recorded rise in landings did not reflect an equivalent rise in catches. Landings decreased by about 50% from 1986 onwards because quotas were set below previous catch levels when this species was introduced into the QMS (Table 3). From 1987–88 to 1991–92 total reported landings were around 2200–2500 t annually. In 1995–96, total landings increased to above the level of the TACC (3106 t) to 3412 t, exceeding the TACC for the first time. Total landings remained near the level of the TACC from 1995–96 to 2012–13, decreasing slightly thereafter with 2613 t landed in 2019–20.

TACCs were increased by 5% for SCH 5, and 20% for SCH 3, 7, & 8 under AMP management in October 2004. From 1 October 2007, the TACC for SCH 1 was increased to 689 t, also setting a TAC for the first time at 893 t with 102 t, 68 t, and 34 t allocated to customary, recreational, and other sources of mortality respectively. In 2004, SCH 3, 5, 7, & 8 were allocated recreational and customary non-commercial allowances of 48 t, 7 t, 58 t, and 21 t, respectively, and other sources of mortality were allocated 19 t, 37 t,

1401

32 t, and 26 t, respectively. All AMP programmes ended on 30th September 2009. School shark was added to the 6th schedule on the 1st of January 2013 which allows school shark that are alive when caught, and likely to survive, to be released. Table 2 shows total New Zealand historical (pre-1984) SCH landings by calendar year; TACCs and landings by fishing year are provided by Fishstock in Table 3 and Figure 1.

Table 2: Reported domestic landings (t) of school shark from 1948 to 1983.

Year	Landings	Year	Landings	Year	Landings	Year	Landings
1948	75	1957	301	1966	316	1975	518
1949	124	1958	323	1967	376	1976	914
1950	147	1959	304	1968	360	1977	1 231
1951	157	1960	308	1969	390	1978	161
1952	179	1961	362	1970	450	1979	481
1953	142	1962	354	1971	597	1980	1 788
1954	185	1963	380	1972	335	1981	2 716
1955	180	1964	342	1973	400	1982	2 965
1956	164	1965	359	1974	459	1983	3 918

Source: Fisheries New Zealand data.

During the period of high landings in the mid-1980s, setnetting was the main fishing method, providing about half the total catch, with lining accounting for one-third of the catch, and trawling the remainder. There were large regional variations. These proportions have shifted somewhat in more recent years, with setnets still accounting for just under 50% of the landings, and bottom longline and bottom trawl approximately splitting the remaining 50%. Small amounts of school shark are also caught by the foreign charter tuna longliners fishing offshore in the EEZ to well beyond the shelf edge.

The Banks Peninsula Marine Mammal Sanctuary was established in 1988 by the Department of Conservation under the Marine Mammal Protection Act 1978, for the purpose of protecting Hector's dolphins. The sanctuary extends 4 nautical miles from the coast from Sumner Head in the north to the Rakaia River mouth in the south. Before 1 October 2008, no setnets were allowed within the sanctuary between 1 November and the end of February. For the remainder of the year, setnets were allowed but could only be set from an hour after sunrise to an hour before sunset, be no more than 30 metres long, with only one net per boat, and the boat was required to remain tied to the net while it was set.

Voluntary setnet closures were implemented by the Southeast Finfish Management Company (SEFMC) from 1 October 2000 to protect nursery grounds for rig and elephant fish and to reduce interactions between commercial setnets and Hector's dolphins in shallow waters. The closed area extended from the southernmost end of the Banks Peninsula Marine Mammal Sanctuary to the northern bank of the mouth of the Waitaki River. This area was closed permanently for a distance of 1 nautical mile offshore and for 4 nautical miles offshore for the period 1 October to 31 January.

From 1 October 2008, a new suite of regulations intended to protect Māui and Hector's dolphins was implemented for all New Zealand by the Minister of Fisheries.

For SCH 1, setnet fishing was closed from Maunganui Bluff to Pariokariwa Point for a distance of 4 nautical miles on 1 October 2003. This closure was extended by the Minister to 7 nautical miles on 1 October 2008. An appeal was made by affected fishers who were granted interim relief by the High Court, allowing setnet fishing beyond 4 nautical miles during daylight hours between 1 October and 24 December during three consecutive years: 2008–2010.

For SCH 3, commercial and recreational setnetting was banned in most areas from 1 October 2008 to 4 nautical miles off the east coast of the South Island, extending from Cape Jackson in the Marlborough Sounds to Slope Point in the Catlins. Some exceptions were allowed, including an exemption for commercial and recreational setnetting to only 1 nautical mile offshore around the Kaikōura Canyon, and permitting setnetting in most harbours, estuaries, river mouths, lagoons, and inlets except for the Avon-Heathcote Estuary, Lyttelton Harbour, Akaroa Harbour, and Timaru Harbour. In addition, trawl gear within 2 nautical miles of shore was restricted to flatfish nets with defined low headline heights.

For SCH 5, commercial and recreational setnetting was banned in most areas from 1 October 2008 to 4 nautical miles offshore, extending from Slope Point in the Catlins to Sandhill Point east of Fiordland

and in Te Waewae Bay. An exemption which permitted setnetting in harbours, estuaries, and inlets was allowed. In addition, trawl gear within 2 nautical miles of shore was restricted to flatfish nets with defined low headline heights.

For SCH 7, both commercial and recreational setnetting were banned to 2 nautical miles offshore from 1 October 2008, with the recreational closure effective for the entire year and the commercial closure restricted to 1 December to the end of February. The closed area extends from Awarua Point north of Fiordland to the tip of Cape Farewell at the top of the South Island. There is no equivalent closure in SCH 8, with the southern limit of the Māui dolphin closure beginning north of New Plymouth at Pariokariwa Point.

Table 3: Reported landings (t) of school shark by Fishstock from 1931–32 to present and actual TACCs (t) from 1986–87 to present. QMS data from 1986 to present. [Continued on next page]

Fishstock FMA (s)	SCH 1 1 & 9		SCH 2 2		SCH 3 3		SCH 4 4		SCH 5 5 & 6	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1931–32	0	–	0	–	0	–	0	–	0	–
1932–33	0	–	0	–	0	–	0	–	0	–
1933–34	0	–	0	–	0	–	0	–	0	–
1934–35	0	–	0	–	0	–	0	–	0	–
1935–36	0	–	0	–	0	–	0	–	0	–
1936–37	0	–	0	–	0	–	0	–	0	–
1937–38	0	–	0	–	0	–	0	–	0	–
1938–39	0	–	0	–	0	–	0	–	0	–
1939–40	0	–	0	–	0	–	0	–	0	–
1940–41	0	–	0	–	0	–	0	–	0	–
1941–42	0	–	0	–	0	–	0	–	0	–
1942–43	0	–	0	–	0	–	0	–	0	–
1943–44	0	–	0	–	0	–	0	–	0	–
1944–45	0	–	0	–	0	–	0	–	0	–
1945–46	53	–	2	–	0	–	0	–	0	–
1946–47	73	–	3	–	7	–	0	–	3	–
1947–48	40	–	2	–	0	–	0	–	0	–
1948–49	48	–	3	–	0	–	0	–	0	–
1949–50	92	–	4	–	1	–	0	–	0	–
1950–51	105	–	6	–	1	–	0	–	0	–
1951–52	131	–	5	–	4	–	0	–	0	–
1952–53	144	–	7	–	5	–	0	–	0	–
1953–54	108	–	4	–	10	–	0	–	0	–
1954–55	121	–	10	–	8	–	0	–	0	–
1955–56	124	–	12	–	8	–	0	–	0	–
1956–57	92	–	19	–	5	–	0	–	0	–
1957–58	197	–	28	–	11	–	0	–	0	–
1958–59	211	–	24	–	17	–	0	–	1	–
1959–60	203	–	21	–	18	–	0	–	1	–
1960–61	219	–	19	–	23	–	0	–	1	–
1961–62	268	–	21	–	25	–	1	–	4	–
1962–63	252	–	23	–	29	–	0	–	2	–
1963–64	249	–	42	–	23	–	1	–	3	–
1964–65	186	–	51	–	30	–	1	–	1	–
1965–66	229	–	36	–	37	–	0	–	1	–
1966–67	189	–	31	–	36	–	0	–	1	–
1967–68	211	–	56	–	33	–	0	–	2	–
1968–69	195	–	57	–	41	–	0	–	4	–
1969–70	179	–	46	–	110	–	0	–	7	–
1970–71	157	–	82	–	99	–	0	–	13	–
1971–72	163	–	112	–	109	–	0	–	6	–
1972–73	136	–	59	–	30	–	0	–	3	–
1973–74	103	–	73	–	52	–	0	–	9	–
1974–75	120	–	75	–	98	–	0	–	18	–
1975–76	121	–	64	–	62	–	1	–	29	–
1976–77	389	–	88	–	54	–	0	–	70	–
1977–78	508	–	99	–	68	–	0	–	118	–
1978–79	52	–	28	–	13	–	0	–	6	–
1979–80	197	–	53	–	89	–	0	–	42	–
1980–81	690	–	127	–	295	–	2	–	229	–
1981–82	686	–	199	–	461	–	0	–	497	–
1982–83	598	–	245	–	544	–	1	–	264	–
1983–84*	1 087	–	298	–	630	–	8	–	792	–
1984–85*	861	–	237	–	505	–	12	–	995	–
1985–86*	787	–	214	–	370	–	23	–	647	–
1986–87	416	560	123	162	283	270	19	120	382	610
1987–88	528	668	123	199	320	322	22	239	531	694
1988–89	477	668	136	199	220	322	26	239	501	694
1989–90	585	668	156	199	272	322	27	239	460	694
1990–91	554	668	139	199	227	322	20	239	480	694
1991–92	596	668	161	199	255	322	34	239	622	694
1992–93	819	668	202	199	216	322	38	239	594	694

Table 3 [continued]

Fishstock FMA (s)	SCH 1 1 & 9		SCH 2 2		SCH 3 3		SCH 4 4		SCH 5 5 & 6	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1993–94	657	668	157	199	202	322	41	239	624	694
1994–95	640	668	161	199	238	322	86	239	656	694
1995–96	802	668	214	199	296	322	229	239	714	694
1996–97	791	668	228	199	290	322	179	239	662	694
1997–98	764	668	214	199	270	322	126	239	623	694
1998–99	784	668	275	199	335	322	106	239	714	694
1999–00	820	668	250	199	343	322	97	239	706	694
2000–01	799	668	178	199	364	322	100	239	724	694
2001–02	694	668	208	199	324	322	93	239	676	708
2002–03	689	668	225	199	410	322	130	239	746	708
2003–04	758	668	187	199	323	322	149	239	729	708
2004–05	695	668	201	199	424	387	206	239	743	743
2005–06	634	668	175	199	325	387	183	239	712	743
2006–07	661	668	200	199	376	387	88	239	738	743
2007–08	708	689	227	199	345	387	133	239	781	743
2008–09	713	689	232	199	364	387	145	239	741	743
2009–10	589	689	213	199	426	387	191	239	784	743
2010–11	777	689	187	199	366	387	174	239	701	743
2011–12	689	689	188	199	351	387	201	239	729	743
2012–13	602	689	200	199	320	387	127	239	748	743
2013–14	659	689	183	199	363	387	126	239	725	743
2014–15	595	689	157	199	362	387	218	239	646	743
2015–16	497	689	152	199	434	387	206	239	623	743
2016–17	530	689	138	199	339	387	238	239	696	743
2017–18	633	689	165	199	357	387	180	239	710	743
2018–19	557	689	168	199	389	387	202	238	608	743
2019–20	537	689	131	199	375	387	168	239	656	743
2020–21	518	689	156	199	324	387	187	239	806	743

Fishstock FMA (s)	SCH 7 7		SCH 8 8		SCH 10 10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings§	TACC
1931–32	0	–	0	–	–	–	0	–
1932–33	0	–	0	–	–	–	0	–
1933–34	0	–	0	–	–	–	0	–
1934–35	0	–	0	–	–	–	0	–
1935–36	0	–	0	–	–	–	0	–
1936–37	0	–	0	–	–	–	0	–
1937–38	0	–	0	–	–	–	0	–
1938–39	0	–	0	–	–	–	0	–
1939–40	0	–	0	–	–	–	0	–
1940–41	0	–	0	–	–	–	0	–
1941–42	0	–	0	–	–	–	0	–
1942–43	0	–	0	–	–	–	0	–
1943–44	0	–	0	–	–	–	0	–
1944–45	0	–	0	–	–	–	0	–
1945–46	8	–	3	–	–	–	66	–
1946–47	16	–	3	–	–	–	105	–
1947–48	13	–	3	–	–	–	58	–
1948–49	18	–	5	–	–	–	74	–
1949–50	24	–	4	–	–	–	125	–
1950–51	29	–	6	–	–	–	147	–
1951–52	14	–	4	–	–	–	158	–
1952–53	17	–	5	–	–	–	178	–
1953–54	16	–	4	–	–	–	142	–
1954–55	36	–	10	–	–	–	185	–
1955–56	26	–	10	–	–	–	180	–
1956–57	34	–	14	–	–	–	164	–
1957–58	42	–	23	–	–	–	301	–
1958–59	41	–	29	–	–	–	323	–
1959–60	32	–	29	–	–	–	304	–
1960–61	24	–	21	–	–	–	307	–
1961–62	26	–	15	–	–	–	360	–
1962–63	21	–	26	–	–	–	353	–
1963–64	29	–	34	–	–	–	381	–
1964–65	31	–	41	–	–	–	341	–
1965–66	26	–	30	–	–	–	359	–
1966–67	25	–	22	–	–	–	304	–
1967–68	51	–	23	–	–	–	376	–
1968–69	35	–	26	–	–	–	358	–
1969–70	28	–	20	–	–	–	390	–

Table 3 [continued]

Fishstock FMA (s)	SCH 7 7		SCH 8 8		SCH 10 10			Total
	Landings	TACC	Landings	TACC	Landings	TACC	Landings§	TACC
1970–71	69	–	30	–	–	–	450	–
1971–72	159	–	48	–	–	–	597	–
1972–73	77	–	30	–	–	–	335	–
1973–74	75	–	42	–	–	–	354	–
1974–75	144	–	94	–	–	–	549	–
1975–76	153	–	90	–	–	–	520	–
1976–77	220	–	102	–	–	–	923	–
1977–78	280	–	164	–	–	–	1 237	–
1978–79	22	–	44	–	–	–	165	–
1979–80	94	–	44	–	–	–	519	–
1980–81	350	–	106	–	–	–	1 799	–
1981–82	480	–	393	–	–	–	2 716	–
1982–83	947	–	367	–	–	–	2 966	–
1983–84*	1 039	–	694	–	0	–	4 776	–
1984–85*	1 030	–	698	–	0	–	4 501	–
1985–86*	851	–	652	–	0	–	3 717	–
1986–87	454	470	224	310	0	10	1 902	2 513
1987–88	516	534	374	441	0	10	2 413	3 106
1988–89	540	534	419	441	0	10	2 319	3 106
1989–90	516	534	371	441	0	10	2 387	3 106
1990–91	420	534	369	441	0	10	2 209	3 106
1991–92	431	534	409	441	0	10	2 508	3 106
1992–93	482	534	484	441	0	10	2 835	3 106
1993–94	473	534	451	441	0	10	2 605	3 106
1994–95	369	534	417	441	0	10	2 567	3 106
1995–96	636	534	521	441	0	10	3 412	3 106
1996–97	543	534	459	441	0	10	3 152	3 106
1997–98	473	534	446	441	0	10	2 917	3 106
1998–99	682	534	533	441	0	10	3 429	3 106
1999–00	639	534	469	441	0	10	3 324	3 106
2000–01	576	534	453	441	0	10	3 193	3 106
2001–02	501	534	449	441	0	10	2 946	3 120
2002–03	512	534	448	441	0	10	3 161	3 120
2003–04	574	534	405	441	0	10	3 126	3 120
2004–05	546	641	554	529	0	10	3 369	3 416
2005–06	569	641	503	529	0	10	3 100	3 416
2006–07	583	641	534	529	0	10	3 180	3 416
2007–08	606	641	497	529	0	10	3 297	3 436
2008–09	694	641	588	529	0	10	3 478	3 436
2009–10	606	641	460	529	0	10	3 269	3 436
2010–11	677	641	587	529	0	10	3 469	3 436
2011–12	612	641	506	529	0	10	3 276	3 436
2012–13	656	641	512	529	0	10	3 165	3 436
2013–14	620	641	459	529	0	10	3 135	3 436
2014–15	610	641	523	529	0	10	3 110	3 436
2015–16	552	641	458	529	0	10	2 920	3 436
2016–17	559	641	352	529	0	10	2 852	3 436
2017–18	596	641	373	529	0	10	3 014	3 436
2018–19	534	641	277	529	0	10	2 734	3 436
2019–20	510	641	236	529	0	10	2 613	3 436
2020–21	622	641	217	529	0	10	2 830	3 436

* FSU data.

§ Includes landings from unknown areas before 1986–87.

Note: Data from 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

SCHOOL SHARK (SCH)
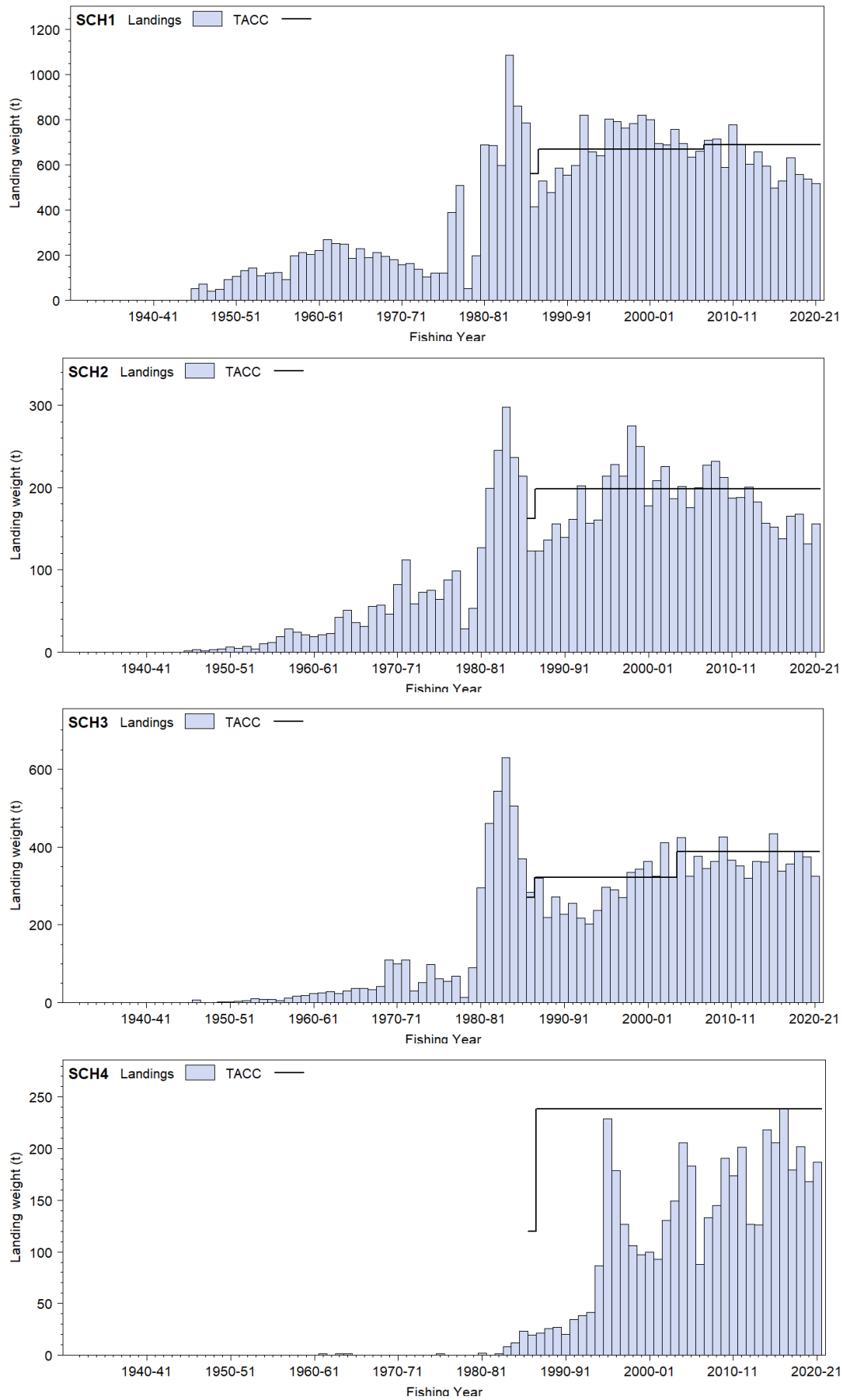
Figure 1: Reported commercial landings and TACC for the seven main SCH stocks. Above: SCH 1 (Auckland East), SCH 2 (Central East), SCH 3 (South East coast), and SCH 4 (South East Chatham Rise). [Continued on next page]

1406
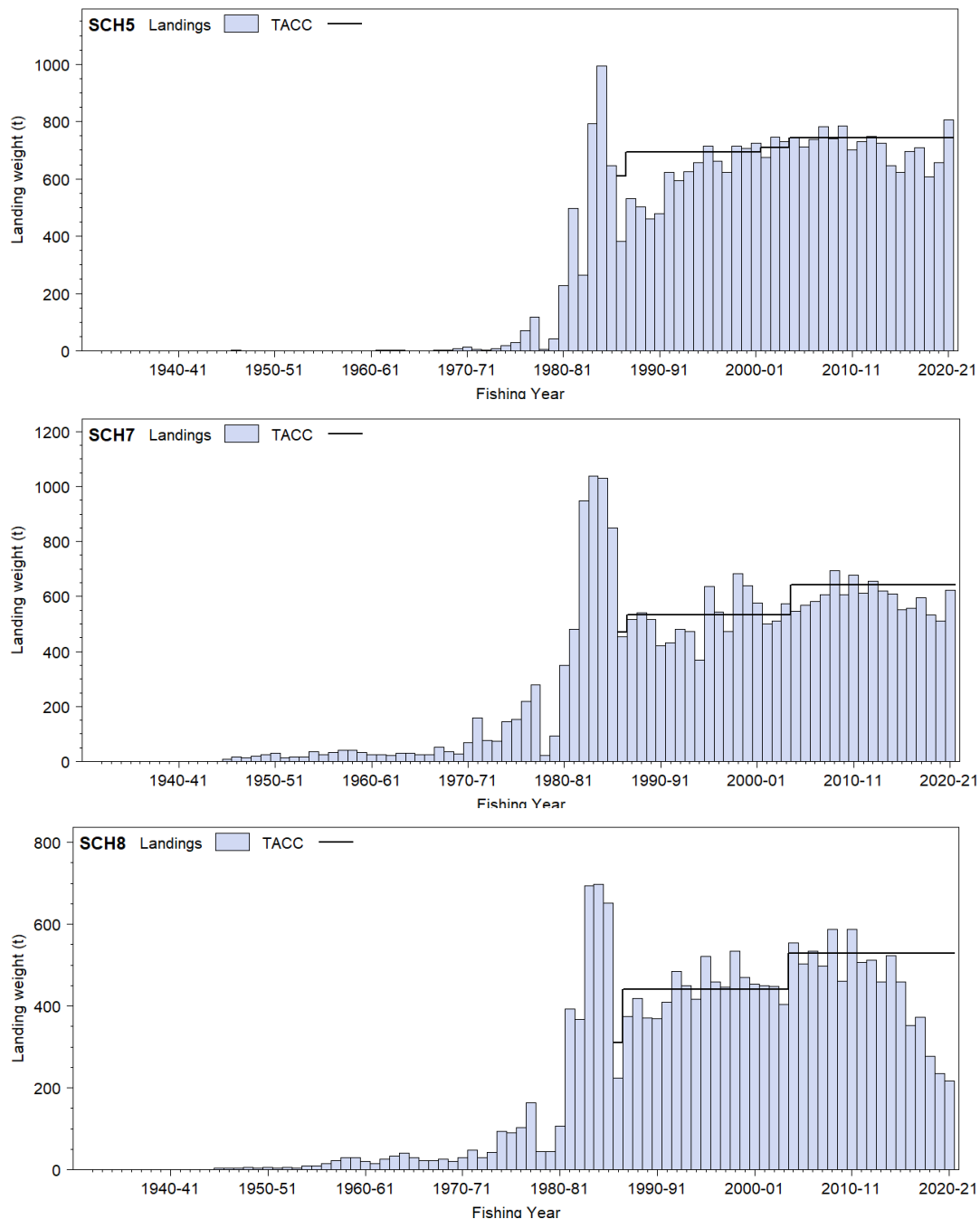
Figure 1: [Continued] Reported commercial landings and TACC for the seven main SCH stocks. From top to bottom: SCH 5 (Southland), SCH 7 (Challenger), and SCH 8 (Central Egmont).

1.2 Recreational fisheries

Although school shark is a listed gamefish and is regularly caught by recreational fishers, it is not considered to be a particularly desirable target species.

1.2.1 Management controls

The main method used to manage recreational harvests of school shark is daily bag limits. Fishers can take up to 20 school sharks as part of their combined daily bag limit in the Auckland and Kermadec, Central, and Challenger Fishery Management Areas. Fishers can take up to 5 school sharks as part of their combined daily bag limit in the Southland and South-East Fishery Management Areas.

1.2.2   Estimates of recreational harvest

There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and, offsite methods where some form of post-event interview and/or diary is used to collect data from fishers.

The first estimates of recreational harvest for school shark were calculated using an offsite approach, the offsite regional telephone and diary survey approach. Estimates for 1996 came from a national telephone and diary survey (Bradford 1998). Another national telephone and diary survey was carried out in 2000 (Boyd & Reilly 2002). The harvest estimates provided by these telephone diary surveys (Table 4) are no longer considered reliable.

In response to the cost and scale challenges associated with onsite methods, in particular the difficulties in sampling other than trailer boat fisheries, offsite approaches to estimating recreational fisheries harvest have been revisited. This led to the development and implementation of a national panel survey for the 2011–12 fishing year (Wynne-Jones et al 2014). The panel survey used face-to-face interviews of a random sample of New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys (in numbers of fish, no mean weights being available from concurrent boat ramp surveys) are given in Table 4. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 4: **Recreational harvest estimates for school shark stocks. The telephone/diary surveys ran from December to November and are denoted by the January calendar year. National panel surveys ran throughout the October to September fishing year and is denoted by the January calendar year.**

Stock	Year	Method	Number of fish	Total weight (t)	CV
SCH 1	1996	Telephone/diary	23 000	46	0.17
	2000	Telephone/diary	27 000	66	0.42
	2012	Panel survey	9 788	–	0.24
	2018	Panel survey	1 198	–	0.51
SCH 2	1996	Telephone/diary	5 000	–	–
	2000	Telephone/diary	7 000	18	0.30
	2012	Panel survey	2 739	–	0.54
	2018	Panel survey	1 804	–	0.79
SCH 3	1996	Telephone/diary	3 000	–	–
	2000	Telephone/diary	19 000	48	0.46
	2012	Panel survey	5 381	–	0.37
	2018	Panel survey	627	–	0.43
SCH 5	1996	Telephone/diary	1 000	–	–
	2000	Telephone/diary	3 000	7	0.66
	2012	Panel survey	443	–	0.60
	2018	Panel survey	349	–	1.00
SCH 7	1996	Telephone/diary	8 000	16	0.24
	2000	Telephone/diary	23 000	58	0.56
	2012	Panel survey	10 311	–	0.36
	2018	Panel survey	2 001	–	0.31
SCH 8	1996	Telephone/diary	11 000	21	0.22
	2000	Telephone/diary	3 000	8	0.55
	2012	Panel survey	1 892	–	0.32
	2018	Panel survey	847	–	0.39

1.3   Customary non-commercial fisheries

Māori fishers made extensive use of school shark in pre-European times for food, oil, and skin. There is no quantitative information on the current level of customary non-commercial take.

1.4 Illegal catch

There is no quantifiable information on the level of illegal catch. There is an unknown amount of unreported offshore trawl and pelagic longline catch of school shark, either landed (under another name, or in 'mixed') or discarded.

1.5 Other sources of mortality

There is an unknown discarded bycatch of juvenile, mainly first-year, school shark taken in harbour and bay setnets. Quantitative information is not available on the level of other sources of mortality.

2. BIOLOGY

School sharks are distributed across the shelf, generally being inshore in summer and offshore in winter. They extend in smaller numbers near the seafloor down the upper continental slope, to at least 600 m. The capture of school sharks by tuna longliners shows that their distribution extends well offshore, up to 180 nautical miles off the South Island, and 400 nautical miles off northern New Zealand towards the Kermadec Islands. They feed predominantly on small fish and cephalopods (octopus and squid).

Growth rates have not been estimated for New Zealand fish, but in Australia and South America school sharks are slow growing and long-lived (Grant et al 1979, Olsen 1984, Peres & Vooren 1991). They are difficult to age by conventional methods, but up to 45 vertebral rings can be counted. Growth is fastest for the first few years, slows appreciably between 5 and 15 years, and is negligible at older ages, particularly after 20. Results from an Australian long-term tag recovery suggest a maximum age of at least 50 years. Age-at-maturity has been estimated at 12–17 years for males and 13 to 15 years for females (Francis & Mulligan 1998). The size range of commercially caught maturing and adult school shark is 90–170 cm total length (TL), with a broad mode at 110–130 cm TL, which varies with area, season, and depth.

Breeding is not annual; it has generally been assumed to be biennial, but work on a Brazilian stock suggests that females have a 3-year cycle in the South Atlantic (Peres & Vooren 1991). Fecundity (pup number) increases from 5–10 in small females to over 40 in the largest females. Mating is believed to occur in deep water, probably in winter. Release of pups occurs during spring and early summer (November–January), apparently earlier in the north of the country than in the south. Nursery grounds include harbours, shallow bays, and sheltered coasts. The pups remain in the shallow nursery grounds during their first one or two years and subsequently disperse across the shelf. The geographic location of the most important pupping and nursery grounds in New Zealand is not known.

Table 5: Estimates of biological parameters for school shark.

Fishstock	Estimate		Source
1. Weight = a (length)^b (Weight in g, length in cm fork length)			
	Both sexes combined		
	a	b	
SCH 1	0.0003	3.58	McGregor (unpub.)
SCH 3	0.0035	3.08	McGregor (unpub.)
SCH 5	0.0181	2.72	McGregor (unpub.)
SCH 5	0.0068	2.94	Hurst et al (1990)
SCH 7	0.0061	2.94	Blackwell (unpub.)
SCH 8	0.0104	2.84	Blackwell (unpub.)
2. Estimate of M for Australia			
	0.1		Grant et al (1979), Olsen (1984)

The combination of late maturity, slow growth, and low fecundity gives a relatively low overall productivity. In Australia, M has been estimated as 0.1.

New Zealand tagging studies have shown that school shark may move considerable distances, including trans-Tasman migrations (for details see Hurst et al 1999).

Biological parameters relevant to stock assessment are shown in Table 5.

3.   STOCKS AND AREAS

Information relevant to determining school shark stock structure in New Zealand was reviewed in 2009 (Smith 2009, Blackwell & Francis 2010, Francis 2010). Primarily based on the tagging evidence, there is probably a single biological stock in the New Zealand EEZ. Genetic, biological, fishery, and tagging data were all considered, but the evidence for the existence of distinct biological stocks is poor. Some differences were found in CPUE trends between QMAs, but stock separation at the QMA level seems unlikely, and the CPUE differences may have resulted from processes acting below the stock level, such as localised exploitation of different sexes or different size classes of sharks. An apparent lack of juvenile school shark nursery areas in SCH 4 and SCH 5 suggests that these Fishstocks are not distinct, but are instead maintained by recruitment from other QMAs.

The most useful source of information was an opportunistic tagging programme undertaken mainly on research trawlers since 1985 (Hurst et al 1999). However, most tag releases were made around the South Island and little information is provided for North Island school sharks. Female school sharks were slightly more mobile than males, with higher proportions of the former moving to non-adjacent QMAs and to Australia. About 30% of school shark recaptures were reported from outside the release QMA within a year of release, and this was maintained in the second year after release. After 2–5 years at liberty about 60% of recaptured school sharks (both sexes) were reported from outside the release QMA. After more than 5 years at liberty, 8% of males and 19% of females were recaptured from Australia. A large proportion of tagged school sharks moved outside the QMA of release within 5 years, and a significant proportion eventually moved to Australia. These trends in apparent movement are consistent across two decades of tagging. The relative importance of various breeding grounds around New Zealand (e.g., aggregations of breeding females in Kaipara Harbour) and whether females return to the area in which they were born are unknown.

The current stock management units are a precautionary measure to spread fishing effort; amalgamation of all QMAs into one QMA for the whole EEZ could create local depletion or sustainability risks for sub-stock components.

4.   STOCK ASSESSMENT

4.1   Estimates of fishery parameters and abundance

Fishery characterisations and CPUE analyses for SCH 1, SCH 2, SCH 3, SCH 4, SCH 5, SCH 7, and SCH 8 were updated in 2021 following a previous 2017–18 update and a full review in 2014. The 2014 review noted that, for many fisheries, the fishery definitions were constructs of administrative boundaries and often created artificially divided fisheries that should be linked. The result of this review was the creation of revised fishery definitions for monitoring school shark, with boundaries between fisheries drawn in areas where there were gaps in catches, and, as much as possible, the same area definitions were used to define setnet and bottom longline fisheries for monitoring purposes. Table 6 lists the definitions of the fisheries selected for monitoring school shark. The fisheries were selected on the basis of fine scale positional data but use general statistical areas to apply these definitions to the period before fine scale positional data became available. This approach also assumes that the fine scale positional information from 2007 to the present is representative of the distribution of fishing before that year.

Table 6: List of fisheries selected to monitor NZ school shark. Core statistical areas are shown as well as any additional statistical areas needed to complete the fishery definition by capture method. There is no recorded fishing for school shark using setnets (SN) around the Chatham Islands (SCH 4). BLL, bottom longline.

Region	Code	Core Statistical Areas	SN	BLL
Far North & SCH 1E	N/1E	043–010	same as core	same as core
SCH 2 & top of SCH 3	2/3N	011–015	add 018, 020	same as core
Chatham Rise (SCH 4)	SCH4	049–051, 401–412	NA	add 019, 020, 021
lower SCH 3 & SCH 5	3S/5	022–033	same as core	same as core
SCH 7, SCH 8 & lower SCH 1W	7/8/1W	034–042, 801	add 016, 017	add 016, 017, 018

The main difficulty in finalising these definitions was how to deal with Cook Strait. The decision was made to assign all Cook Strait catches, even those from the eastern end of Cook Strait, to the central west coast fishery (SCH 7, SCH 8, and lower SCH 1W). Setnet landings from Kaikōura and Pegasus Bay were assigned to the northern east coast fishery and bottom longline landings from the western end of the Chatham Rise were assigned to SCH 4.

Characterisation comments by SCH QMA

Statistics and trends in target species reported here refer to the 2016–17 to 2018–19 fishing years.

SCH 1
About 48% of the SCH 1 landings were taken by bottom trawl when targeting tarakihi, with smaller catches reported when targeting snapper and trevally. The bottom longline SCH 1 fishery caught about 27% of the total landings and was primarily directed at snapper and hāpuku and bass, with tarakihi and school shark being other important targets. The setnet fishery, which took about 8% of the landings following a long-term decline in setnet effort in this region, was mainly targeted at school shark, with some additional targeting of rig, trevally, red gurnard, and snapper.

SCH 2
SCH 2 were caught primarily in the bottom trawl fishery (41%) targeting tarakihi, red gurnard, hoki, and gemfish and the bottom longline fishery (36%) targeting school shark, hāpuku/bass, ling, and bluenose. About 7% of the catch was taken in setnets targeting rig, school shark, blue moki, and butterfish.

SCH 3
School shark in SCH 3 were predominantly caught in the setnet fishery (53%) targeting school shark and rig, with some targeting of tarakihi and hāpuku/bass; and in the bottom trawl fishery (31%) with mixed targeting of tarakihi, barracouta, elephant fish, and red cod. Mixed target bottom longlines took about 11% of the catch.

SCH 4
SCH 4 catches were primarily (92%) from a bottom longline fishery targeting school shark, hāpuku/bass and ling. There was also a small bottom trawl fishery (8% of catches) which targeted a range of species including tarakihi, barracouta, stargazer, hoki, and scampi. The setnet fishery has been small (under 1% of the catch) and cannot be used to monitor the Fishstock.

SCH 5
School shark in SCH 5 were mostly caught in the setnet fishery that targeted school shark (81%), with some minor targeting of rig. About 10% was taken by bottom longline primarily targeting school shark, hāpuku/bass, and ling, and 8% by bottom trawl primarily targeting squid, stargazer, and ling.

SCH 7
SCH 7 were caught in bottom trawl (44%) targeting tarakihi, red gurnard, John dory, flatfish, and others, and in bottom longline (41%) targeting school shark, hāpuku/bass, and ling. There were some catches by the setnet fishery (13%) targeting school shark, rig, and butterfish.

SCH 8
School shark catches in SCH 8 were mainly caught by setnets that targeted school shark and rig (44%) and by bottom longlines (37%) targeting school shark and hāpuku/bass. About 16% was caught by bottom trawl targeting tarakihi, school shark, red gurnard, and John dory.

4.2   Biomass estimates

WCNI
The west coast North Island (WCNI) inshore trawl survey core area spans the area extending along the northern west coast of the North Island from Scott Point to Airedale Reef in the 10–200 m depth range. It is primarily aimed at estimating relative abundance and distribution for snapper, tarakihi, red gurnard,

and John dory. There were five surveys between 1989 and 1999, and the series was recently resumed with surveys in 2018, 2019, and 2020.

The lack of a continuous time series for the west coast North Island prevents the detection of a long-term trend, but recent biomass estimates are lower than historical ones (Figure 2).

WCSI

The west coast South Island (WCSI) inshore trawl survey covered depths of 20–200 m off the west coast of the South Island from Cape Farewell to Karamea; 25–400 m from Karamea to Cape Foulwind; 20–400 m from Cape Foulwind to the Haast River mouth; and 10–70 m within Tasman Bay and Golden Bay inside a line drawn between Farewell Spit and Stephens Island.

Survey biomass for school shark in the WCSI survey was considered separately for the west coast area (Cape Farewell to the Haast River mouth) and the Tasman / Golden bays area. For the west coast area, biomass in the core strata has been variable, but relatively low in 2003 (a year when catchability was low for most species (Stevenson & MacGibbon 2018), and relatively high around 1997 and 2011 (Figure 2). Estimated school shark biomass in the Tasman / Golden bays area has been stable over time.
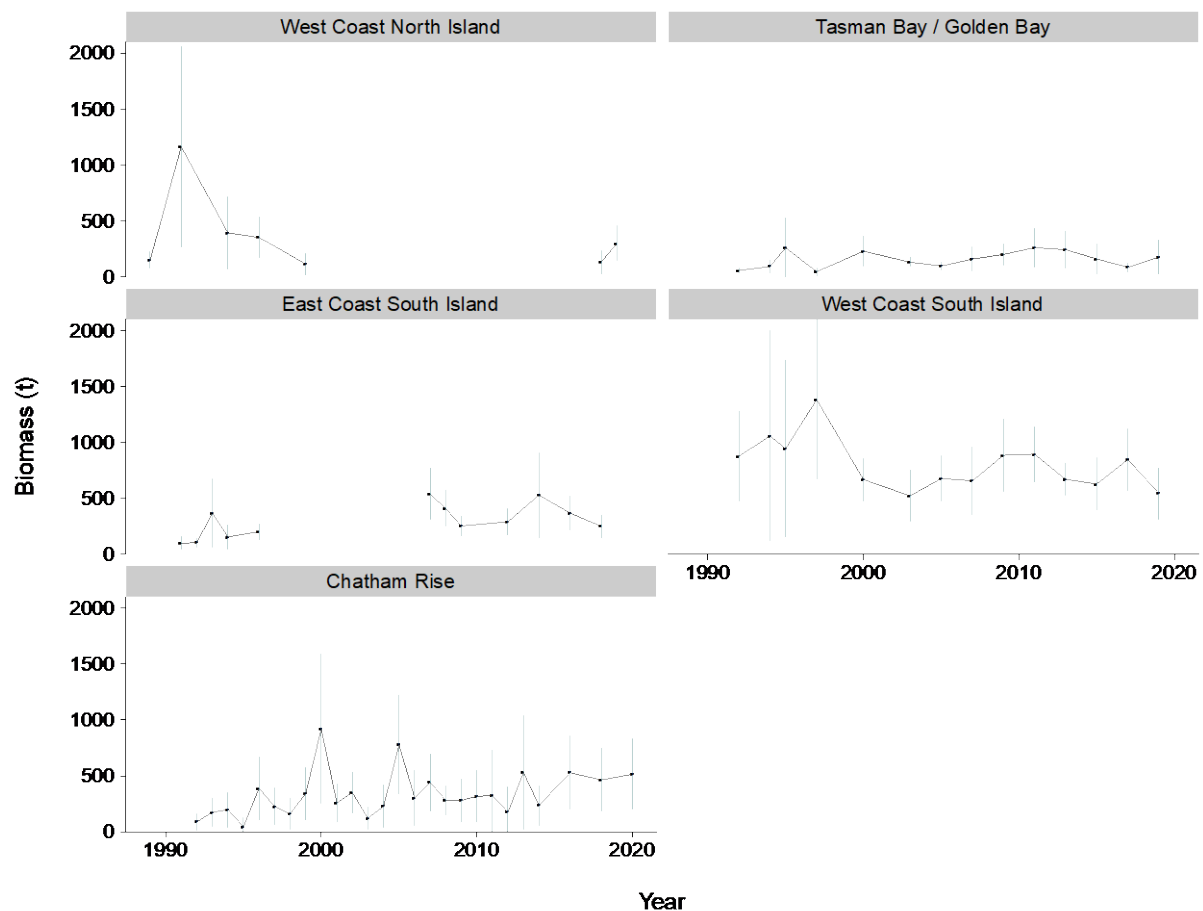
Figure 2: School shark total biomass and 95% confidence intervals for the east coast South Island (ECSI) winter, Chatham Rise, and west coast South Island (WCSI) surveys in core strata. Results for the WCSI survey are presented separately for the Tasman and Golden bays and the west coast portions. Surveys separated by three years or less are connected by a solid line.

ECSI

The east coast South Island (ECSI) winter trawl surveys from 1991 to 1996 in 30–400 m were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range, but these were discontinued after the fifth survey in the annual time series because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007 and this time included additional 10–30 m strata in an attempt to index elephant fish and red gurnard which were included in the list of target species. Only the 2007, 2012, 2014, 2016, and 2018 surveys provide full coverage of the 10–30 m depth range.

Biomass in the core strata (30–400 m) for the ECSI surveys has been variable but was generally higher in years 2007 onward compared with the 1990s (Figure 2, Table 7). The additional biomass captured in the 10–30 m depth range accounted for only about 3% to 6% of the biomass in the core plus shallow strata (10–400 m) for the 2007, 2012, 2014, and 2016 surveys, and hence the shallow strata (10–30 m) are probably not essential for monitoring school shark biomass.

Chatham Rise

The main survey area for this survey includes strata spread over 200–800 m depths on the Chatham Rise. School sharks were only observed in the shallower strata. The estimated school shark biomass has been increasing over time.

Table 7: **Relative total biomass indices (t) and coefficients of variation (CV) for school shark for the west coast North Island inshore trawl survey, the Tasman and Golden bays (TBGB) inshore trawl survey, the east coast South Island (ECSI) winter trawl survey, the west coast South Island (WCSI) autumn trawl survey, and the Chatham Rise trawl survey. Estimates are shown for the core strata only, as defined within each survey design.**

Region	Year	Trip number	Core strata biomass estimate	CV (%)	Region	Year	Trip number	Core strata biomass estimate	CV (%)
WCNI	1989	KAH8918	149	26	WCSI (autumn)	1992	KAH9204	878	23
	1991	KAH9111	1162	39		1994	KAH9404	1 058	44
	1994	KAH9410	392	41		1995	KAH9504	945	42
	1996	KAH9615	352	26		1997	KAH9701	1 385	26
	1999	KAH9915	114	44		2000	KAH0004	668	15
	2018	KAH1806	131	41		2003	KAH0304	523	22
	2019	KAH1906	299	27		2005	KAH0503	677	15
TBGB (winter)	1992	KAH9204	56	26		2007	KAH0704	657	23
	1994	KAH9404	93	32		2009	KAH0904	885	18
	1995	KAH9504	259	52		2011	KAH1104	895	14
	1997	KAH9701	47	41		2013	KAH1305	670	11
	2000	KAH0004	228	31		2015	KAH1503	628	19
	2003	KAH0304	131	17		2017	KAH1703	848	16
	2005	KAH0503	97	19		2019	KAH1902	544	21
	2007	KAH0704	159	36	Chatham Rise (summer)	1992	TAN9106	89	44
	2009	KAH0904	199	25		1993	TAN9212	175	37
	2011	KAH1104	260	34		1994	TAN9401	198	41
	2013	KAH1305	242	34		1995	TAN9501	43	100
	2015	KAH1503	160	43		1996	TAN9601	389	37
	2017	KAH1703	85	25		1997	TAN9701	226	37
	2019	KAH1902	176	44		1998	TAN9801	159	44
ECSI (winter)	1991	KAH9105	100	30		1999	TAN9901	344	34
	1992	KAH9205	104	21		2000	TAN0001	923	36
	1993	KAH9306	369	42		2001	TAN0101	258	34
	1994	KAH9406	155	36		2002	TAN0201	351	27
	1996	KAH9606	202	18		2003	TAN0301	121	43
	2007	KAH0705	538	22		2004	TAN0401	228	43
	2008	KAH0806	411	20		2005	TAN0501	778	28
	2009	KAH0905	254	18		2006	TAN0601	304	41
	2012	KAH1207	292	20		2007	TAN0701	442	29
	2014	KAH1402	529	36		2008	TAN0801	283	23
	2016	KAH1605	369	21		2009	TAN0901	281	34
	2018	KAH1803	251	20		2010	TAN1001	317	36
						2011	TAN1101	325	63
						2012	TAN1201	176	65
						2013	TAN1301	531	48
						2014	TAN1401	236	39
						2016	TAN1601	529	31
						2018	TAN1801	465	31
						2020	TAN2001	515	31

CPUE trends by SCH Region (Table 6)

School shark is considered to be a New Zealand-wide stock, but B_{MSY}–based reference points are not currently able to be established for the stock as a whole.

Far North & SCH 1E

Bottom longline and bottom trawl fisheries in Far North & SCH 1E catch a range of sizes including juveniles, pre-adult, and mature individuals according to commercial samples (Tremblay-Boyer 2021). There were no setnet or Adaptive Management Programme (AMP) samples available for this region. The North Island west coast trawl survey caught mostly juveniles and sub-adults, with modes corresponding to ages 0+, 1+, and 2+.

Standardised CPUE series were developed for setnet at the daily resolution, bottom longline at the daily resolution, and bottom trawl at the trip resolution. The combined setnet series shows a shallow increasing trend to 2008–09, followed by variable but flat-overall CPUE up to 2014–15 and a sharp increase to a higher plateau since (Figure 16). The overall increasing trend is mirrored by the combined bottom longline series, although this series reaches a higher biomass plateau in 2002–03 and a slow increase in biomass since, with some variability. The combined bottom trawl series shows a similar trend to the combined setnet series, with increasing biomass since 2015–16.

Establishing interim B_{MSY}-compatible reference points

In 2020, the Working Group accepted the setnet combined series, the bottom longline combined series, and the combined bottom trawl series as valid measures of biomass. Because the trends were similar, a mean of the three series was adopted as the biomass index, and a mean CPUE for the period 2008–09 to 2015–16 was adopted as an interim B_{MSY}-compatible proxy for Far North & SCH 1E. The Working Group considered that the stock was rebuilding slowly from a low level following larger (largely unreported) historical catches prior to the introduction of the QMS. The Working Group adopted the default Harvest Strategy Standard definitions for the Soft and Hard Limits of one half and one quarter the target, respectively.

SCH 2 & top of SCH 3

Commercial observer samples for SCH 2 & top of SCH 3 were from setnet, bottom longline, and bottom trawl methods (Tremblay-Boyer 2021). All three gears captured a wide range of sizes, including pre-recruits and mature individuals. Bottom trawls appeared to catch smaller individuals than setnet and bottom longline but there were few observations per year. Bottom longlines sampled larger individuals but there were also few observations per year. Samples from the setnet Adaptive Management Programme also included a range of sizes, with a high proportion of mature individuals in some years. The east coast South Island survey (spanning Pegasus Bay and Canterbury Bight) sampled almost exclusively juveniles and pre-recruits, with few individuals over 100 cm.

A new bottom trawl index was developed in SCH 2 & top of SCH 3 to attempt to resolve the previous conflict in trends in the bottom longline and setnet capture methods in this region observed in the 2018 analysis. The results revealed a setnet series that was increasing and longline series that was decreasing (Figure 17). The bottom trawl series increased until 2000 and then declined—thereby matching the setnet series initially and the bottom trawl series latterly. The reason for the contradiction in trends between gear types is unknown.

Establishing interim B_{MSY}-compatible reference points

Because of the unexplained contradictory trends in the CPUE series, in 2020 the Working Group rejected CPUE as a biomass index for this region.
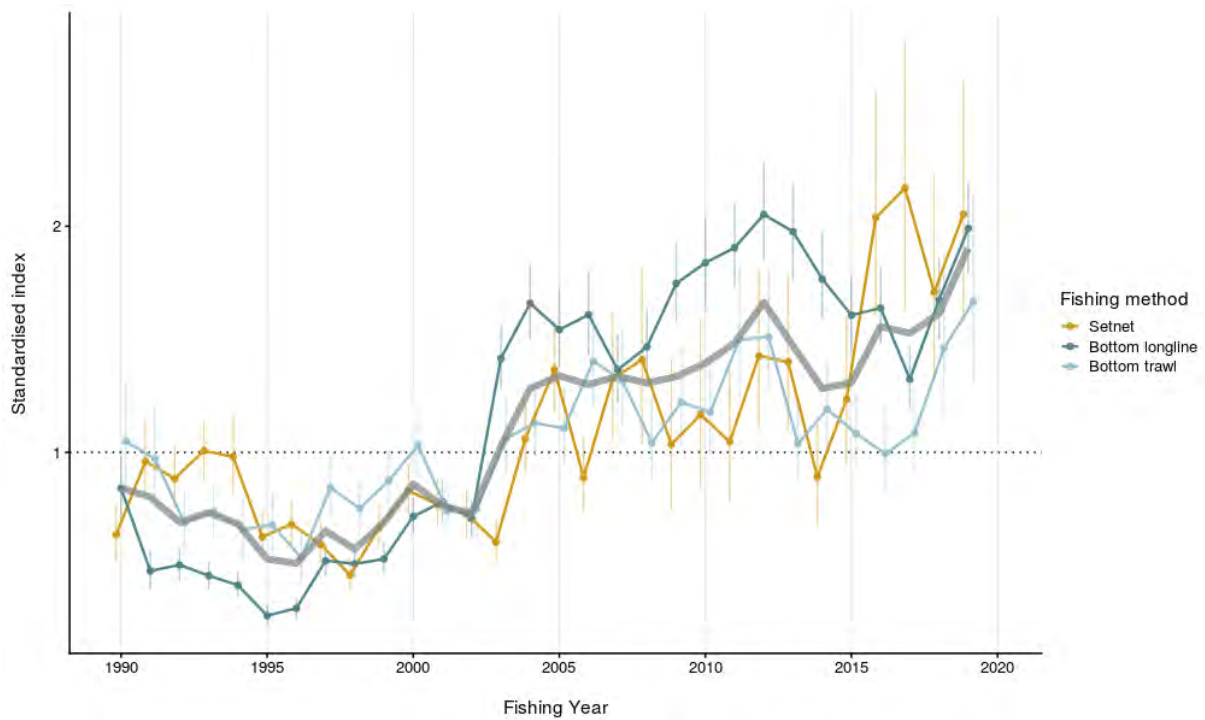
Figure 3: Far North/SCH 1E region (see Table 6): comparison of the combined SN series, the combined BLL series, and the combined BT (bottom trawl) series. All combined series use the delta-lognormal method. The bold grey line shows the average of the series for all three methods. The points show the point estimates for each year and the vertical lines span the 95% confidence intervals.
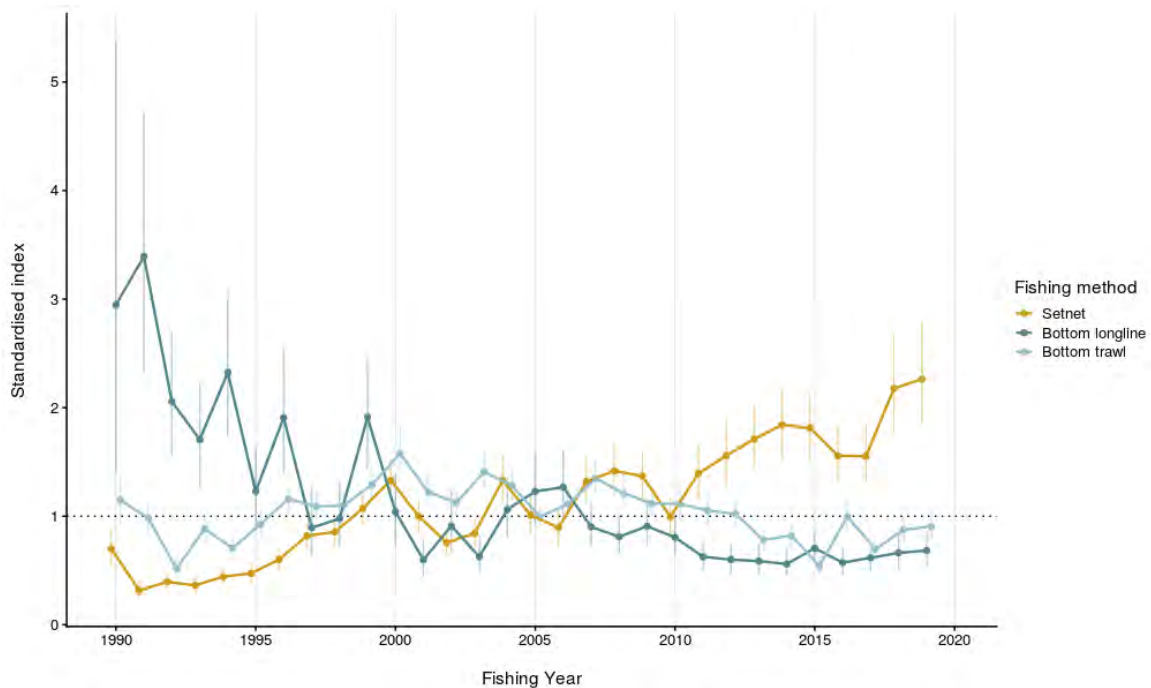
Figure 4: SCH 2 & top of SCH 3 region (see Table 6): comparison of the combined SN series, the combined BLL series, and the combined BT series. All combined series use the delta-lognormal method. The points show the point estimates for each year and the vertical lines span the 95% confidence intervals.

Chatham Rise (SCH 4)

There is no available setnet or bottom trawl series to contribute to the monitoring of the Chatham Rise region. Commercial samples for both bottom longline and bottom trawl predominantly catch mature individuals in most years; the Chatham Rise trawl survey also mostly catches large, mature individuals (Tremblay-Boyer 2021). A standardised CPUE series was constructed from the recent (since 2003–04) bottom longline catch and effort data (Figure 18). This series shows no overall trend over the 16 years.

Although earlier data are available, there was a fleet change in 2003–04 and data prior to this period were sparse.

Establishing interim B_{MSY}-compatible reference points

In 2021, the Working Group adopted CPUE from the bottom longline combined model as a biomass index for this region. However, because the CPUE series was relatively short and without trend, no reference period or reference points were adopted.
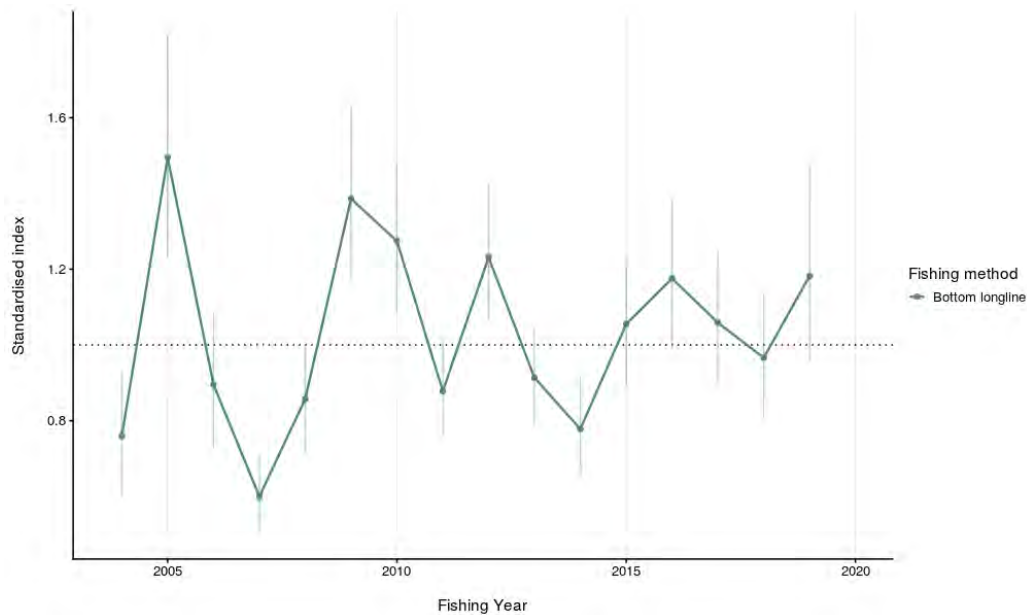
Figure 5: Chatham Rise (SCH 4) region (see Table 6): Combined series for bottom longline using the delta-lognormal method. The points show the point estimates for each year and the vertical lines span the 95% confidence intervals.

Lower SCH 3 & SCH 5

Commercial observer samples for school shark in Lower SCH 3 & SCH 5 showed a wide range of sizes captured, with pre-recruit and mature individuals observed on most years for all gears (but with sparse bottom longline samples, Tremblay-Boyer 2021). Bottom trawls caught a length range comparable with, or wider than, those caught by bottom longline or setnet. The AMP setnet samples included a high proportion of mature individuals, with median size 110 cm TL or higher for most years. The east coast South Island survey (spanning Pegasus Bay and Canterbury Bight) sampled almost exclusively juveniles and pre-recruits, with few individuals over 100 cm.

The combined setnet series for lower SCH 3 & SCH 5 showed a long and gradual declining trend (Figure 19). There was high variability, and therefore no clear trends, in the combined bottom longline series. The combined bottom trawl index declined gradually from 2000 to 2014 but subsequently increased. The setnet fishery is known to target large mature fish, but there is no known nearby spawning or nursery ground (Francis 2010 and Section 3 above). The inconclusive bottom longline series is likely to be the result of small amounts of available data, leading to low reliability.

Establishing interim B_{MSY}-compatible reference points

In 2021, the Plenary accepted the setnet combined series as a valid measure of relative biomass and rejected the bottom longline series due to the large fluctuations in CPUE which are unlikely to reflect abundance. The combined setnet index was favoured over the bottom trawl index because it covers a broad spatial area whereas the bottom trawl index only includes shallow waters off the east coast below Banks Peninsula and around Foveaux Strait. Mean setnet CPUE for t1989–90 to 1998–99 was adopted as an interim B_{MSY}-compatible proxy for Lower SCH 3 & SCH 5. This period was chosen because CPUE was stable, followed by a decline in CPUE as catches increased after 1999. Based on the catch history prior to the reference period, it was assumed the stock was not in a depleted state at the start of the time series of relative abundance. The Plenary adopted the default Harvest Strategy Standard definitions for the Soft and Hard Limits of one half and one quarter the target, respectively.
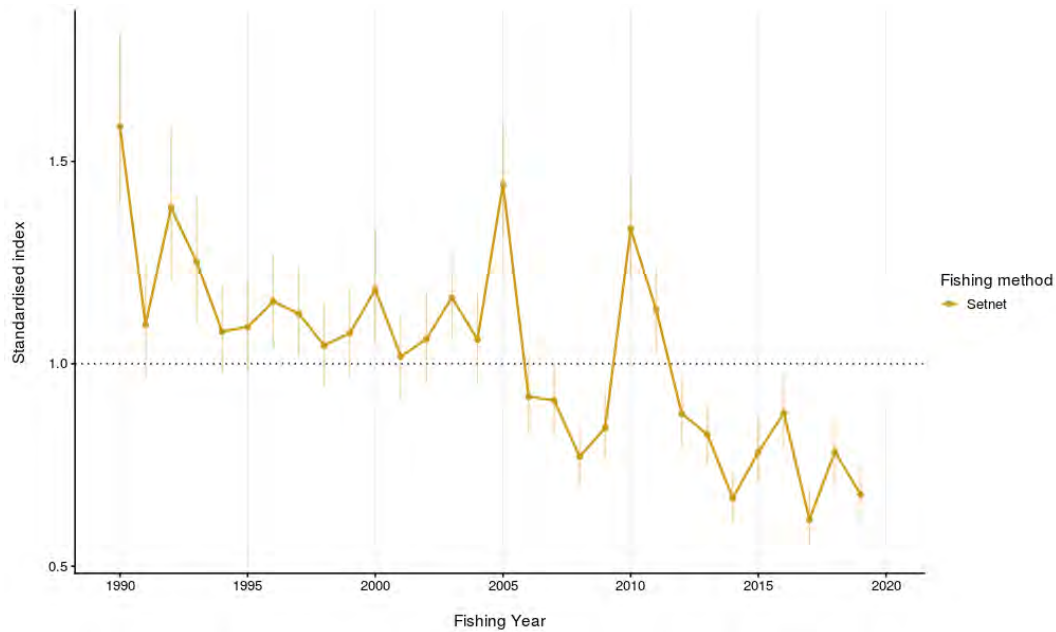
Figure 6: Lower SCH 3 & SCH 5 region (see Table 6): combined index for the setnet fishery. The combined index uses the delta-lognormal method. The points show the point estimates for each year and the vertical lines span the 95% confidence intervals.

SCH 7, SCH 8, & lower SCH 1W

School shark observer samples for SCH 7, SCH 8, & lower SCH 1W were available for setnet, bottom longline, and bottom trawl (Tremblay-Boyer 2021). Both bottom trawl and setnet samples included pre-recruits and mature individuals in most years, with some variability. The Tasman/Golden bays component of the west coast South Island trawl survey sampled juveniles and pre-adults only; no mature individuals were caught in any of the surveys. The west coast component caught a higher proportion of pre-adults in comparison, with mature individuals often present.

The combined setnet series is variable with a gradual increase since 1998–99, because of a decrease in the proportion of fishing days with zero catch of school shark (Figure 20). This series has been compromised by extensive dolphin closures implemented in 2008, 2019, and 2020. The combined bottom longline index includes a pronounced biomass peak in 2001–02 that the standardisation was unable to account for; this biomass peak is unlikely to be representative of true biomass trends. The bottom trawl index shows variable but stable biomass trends since 1997–98. A research trawl survey time series is available for the west coast South Island and shows stable population abundance since 2000 following an earlier decline.

Establishing interim B_{MSY}-compatible reference points

In 2021, the Working Group accepted biomass estimates from the west coast South Island research trawl survey (excluding TBGB) as a valid measure of biomass. The survey estimates were favoured over the fishery biomass indices because of the high sample size and the wide range of school shark sizes. Issues with spatial management measures might have also impacted the validity of the setnet combined index. The period 2005 to 2017 was adopted to set the interim B_{MSY}-compatible proxy for SCH 7, SCH 8, & lower SCH 1W. This period was chosen because abundance fluctuated without trend, and catch was high and relatively stable. The Plenary adopted the default Harvest Strategy Standard definitions for the Soft and Hard Limits of one half and one quarter the target, respectively.
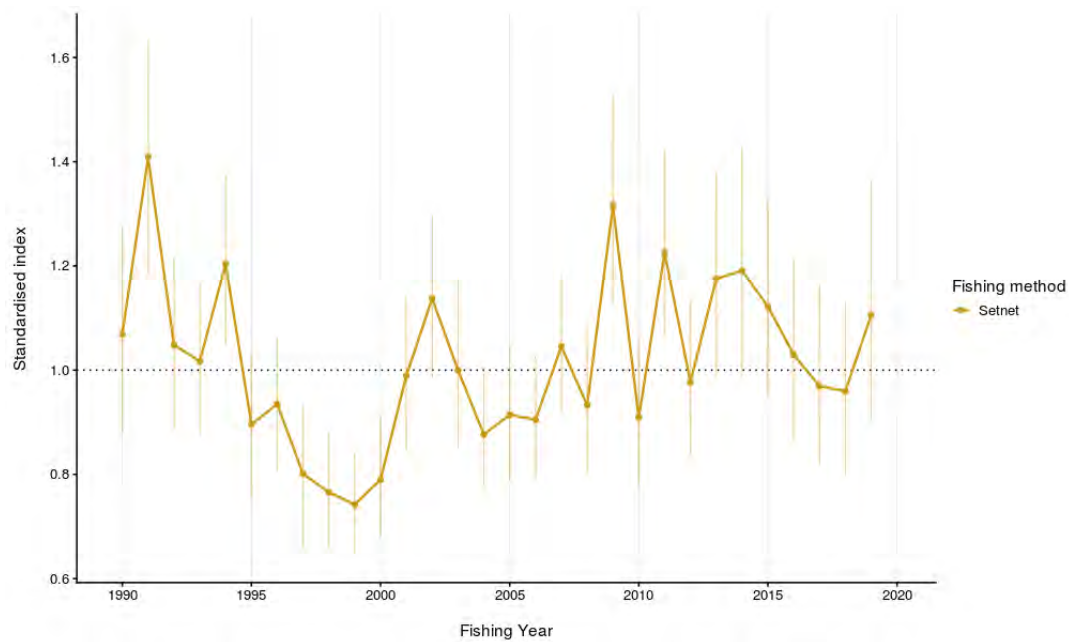
Figure 7: SCH 7, SCH 8, & lower SCH 1W region (see Table 6): combined series for the setnet fishery. The combined index uses the delta-lognormal method. The points show the point estimates for each year and the vertical lines span the 95% confidence intervals.

4.3   Other factors

In Australia, recruitment overfishing occurred to such an extent that the stock was considered seriously threatened and a series of conservative management measures (TAC reductions) were progressively imposed between 1996 and 2007 (Wilson et al 2008). Wilson et al (2008) noted that the stock had been in an overfished state and overfishing was occurring from 1992 to 2004. A 2009 assessment estimated that the stock was at 12% B_0 (Thomson & Punt 2009). An assessment update, in 2012, concluded that the school shark stock remained below 20% B_0, but was recovering (Thomson 2012). A stock recovery has been supported by recent survey work (McAlister et al 2015), but the latest assessment still lists school shark as overfished with uncertainty as to whether overfishing is ongoing. A recent close-kin study found the Australian school shark biomass to be much lower than that estimated in the previous stock assessment by Thomson & Punt (2009) (Thomson et al 2020). They suggested there might be multiple school shark stocks such that the DNA samples informing the close-kin analysis might not be representative of all assessed stocks. The New Zealand stock is known to mix with the Australian stock (Hurst et al 1999), but the degree of mixing is unlikely to be large.

4.4   Future research considerations

- Further investigate the conflicts in SCH 2 & 3N in a dedicated study that includes examination of whether conflicts are due to spatial or temporal structuring and augment this analysis through discussions with stakeholders. Similar analyses may be needed for other areas.
- Conduct further work to better understand stock structure and movements of stocks.
  - Collect more comprehensive information on the length and sex composition of school shark around New Zealand to obtain a clearer picture of the size and sex structuring of the population(s) by area.
  - Commercial length samples should be analysed under a modelling framework to identify environmental and operational covariates likely to influence length distributions and spatial structuring.
  - Conduct a feasibility study on the use of tags to determine more about stock movements and stock structure.
- Investigate the utility of conducting adequate ageing to determine the age structure in different areas.
- Improve information and analysis on the size-at-maturity based on trawl survey data. This will likely require more staging data, particularly for females.
- Seek out observer data from setnet vessels.

- Investigate BP/HG survey data from recent trawl surveys with a view to determining the amount of school shark information.
- Derive a total length to fork length relationship for converting lengths.
- Compile and examine information on the perceived or potential status of various components of the stock at the time of its introduction to the QMS, with a view to revisiting reference points; this should be completed before the next stock assessment.

5.   STATUS OF THE STOCKS

Stock Structure Assumptions
SCH are known from tagging studies to be highly mobile, moving between the North Island and South Island, and as far as Australia. From the tagging evidence, there is probably a single biological SCH stock in the New Zealand EEZ. However, differences in average modal length and CPUE trends between FMAs indicate that movement between areas may be variable, with components of the stock aggregating in different areas. Therefore, the current stock management units are a precautionary measure to spread fishing effort and mortality across components of the stock. Conclusions about the assessment units (see map below) have also been formulated under the assumption that there is some level of persistence in the spatial population structure.

In the 2014 assessment, five proposed New Zealand school shark regions were used, as shown in the map below and described in Table 6. These boundaries follow existing statistical area boundaries so that the regions can be defined before the availability of fine scale positional data. The Cook Strait boundaries differ by method of capture as defined in Table 6. These school shark regions were also used for the 2018 and 2021 assessments.
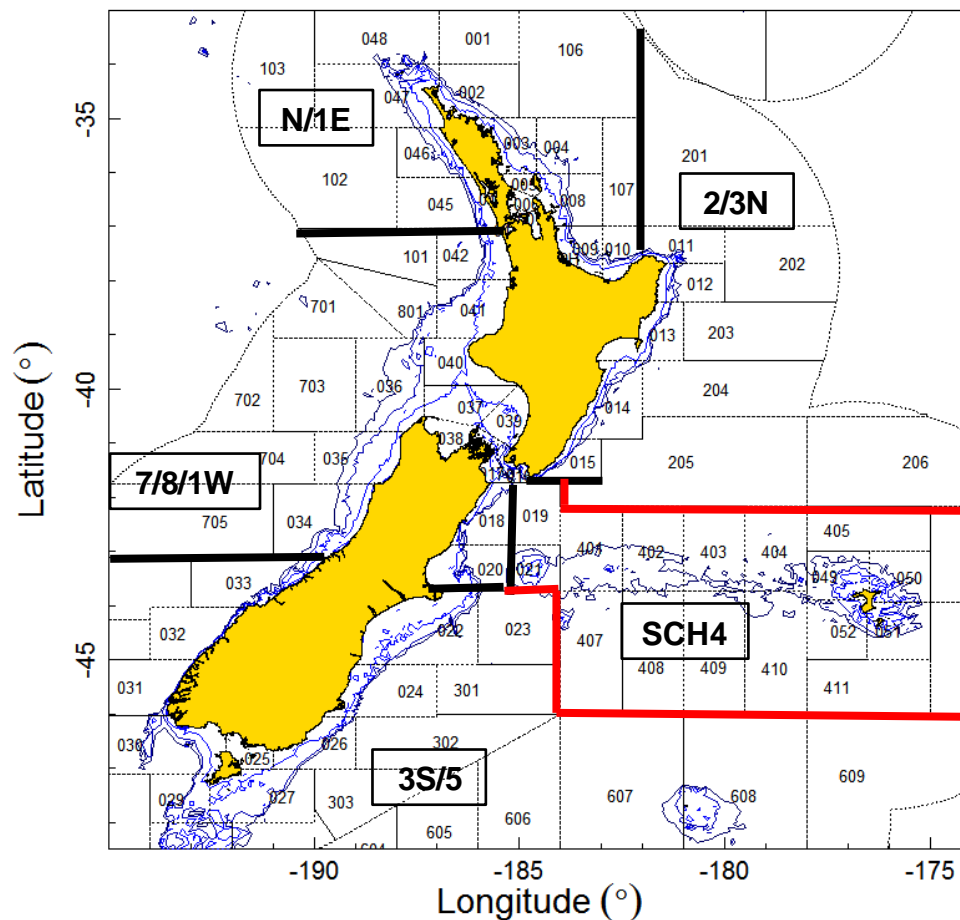
- **Far North & SCH 1E (N/1E on the map)**

Stock Status	
Year of Most Recent Assessment	2021
Assessment Runs Presented	Standardised CPUE based on the average of the combined setnet, bottom longline, and trip-based bottom trawl series
Reference Points	Target: Interim B_{MSY}-compatible proxy based on the mean CPUE from 2008–09 to 2015–16 for the average of the lognormal setnet and combined bottom longline series Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: Interim F_{MSY}-compatible proxy based on the mean relative exploitation rate for the period: 2008–09 to 2015–16
Status in relation to Target	Likely ($> 60\%$) to be at or above B_{MSY}
Status in relation to Limits	Soft Limit: Unlikely ($< 40\%$) to be below Hard Limit: Very Unlikely ($< 10\%$) to be below
Status in relation to Overfishing	About as Likely as Not ($40–60\%$) to be occurring

Historical Stock Status Trajectory and Current Status

Left panel: Biomass index for school shark in SCH N/1E as the average of the standardised CPUE from the combined setnet, bottom longline, and bottom trawl series (solid line). Also shown is the trajectory of total landed SCH by all methods from the sub-stock area (grey line). Horizontal lines represent the target (green dashed line), the soft limit (yellow dashed line), and hard limit (red dashed line). The reference period is shown in beige. Right panel: Annual relative exploitation rate for school shark in SCH N/1E from the averaged setnet, bottom longline, and trawl CPUE series. The interim F_{MSY}-compatible target is shown by the green dashed line.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE trebled since 1995
Recent Trend in Intensity or Proxy	Relative fishing intensity declined by 75% since 1995
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The stock is Unlikely ($< 40\%$) to decline at current catch
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely ($< 40\%$) for current catch Hard Limit: Very Unlikely ($< 10\%$) for current catch
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not ($40–60\%$) at current catch

Assessment Methodology	
Assessment Type	Level 2 - Partial Quantitative Stock Assessment

Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2021	Next assessment: 2024
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Changes to Model Structure and Assumptions	The average of the combined setnet, bottom longline, and bottom trawl CPUE series was used to index stock status.	

Major Sources of Uncertainty	- The components of the population fished by each gear type - Relationship between stock monitoring areas

Qualifying Comments
-

Fishery Interactions
Region Far North/SCH 1E catches are primarily taken by bottom trawl while targeting tarakihi and snapper, with smaller catches when targeting trevally and red gurnard. The bottom longline Far North/SCH 1E fishery is primarily directed at school shark, with hāpuku, snapper, and bluenose being other important targets. The setnet fishery is also primarily targeted at school shark, with some targeting of rig, trevally, red gurnard, and snapper.

- **SCH 2 & top of SCH 3 (Kaikōura and Pegasus Bay); (2/3N on the map)**

Stock Status	
Year of Most Recent Assessment	2021
Assessment Runs Presented	None
Reference Points	Target: Not established Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: Not established
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unlikely
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	-
Recent Trend in Fishing Intensity or Proxy	-
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	None of the CPUE series were accepted as indices of abundance.

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unlikely ($< 40\%$)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2021	Next assessment: 2024
Overall assessment quality rank	3 – Low Quality: contradictory CPUE indices	
Main data inputs (rank)	N/A	
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	None	
Major Sources of Uncertainty	- The components of the population fished by each gear type - Relationship between stock monitoring areas	

Qualifying Comments
-

Fishery Interactions
Region SCH 2/SCH 3 North school shark are caught primarily in the bottom trawl fishery targeting tarakihi, red cod, gemfish, and red gurnard, and the setnet fishery targeting school shark, rig, tarakihi, blue warehou, and blue moki. About one fifth of the catch is taken by the bottom longline fishery targeting school shark, hāpuku/bass, ling, and bluenose.

- **Lower SCH 3 (Canterbury Bight) & SCH 5 (3S/5 on the map)**

Stock Status	
Year of Most Recent Assessment	2021
Assessment Runs Presented	Standardised CPUE based on the combined setnet series
Reference Points	Target: Interim B_{MSY}-compatible proxy based on the mean CPUE from 1989–90 to 1998–99 for the setnet combined series Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: Interim F_{MSY}-compatible proxy based on the mean relative exploitation rate for the period: 1989–90 to 1998–99
Status in relation to Target	Unlikely (< 40%) to be at or above the target
Status in relation to Limits	Soft Limit: About as Likely as Not (40–60%) to be below Hard Limit: Unlikely (< 40%) to be below
Status in relation to Overfishing	Overfishing is Very Likely (> 90%) to be occurring

Historical Stock Status Trajectory and Current Status
Left panel: Standardised CPUE for school shark in SCH 3S/5 from the combined setnet series (solid line). Also shown is the trajectory of total landed SCH from the sub-stock area (grey line). Horizontal lines represent the target (green dashed line), the soft limit (yellow dashed line), and hard limit (red dash line). The reference period is shown in beige. **Right panel: Annual relative exploitation rate for school shark in SCH 3S/5. The interim F_{MSY}-compatible target is shown by the green dashed line.**

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has declined by at least 50% since 2005.
Recent Trend in Fishing Mortality or Proxy	Fishing mortality has doubled since 1990 and has been above the fishing mortality proxy since 1998.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	- The east coast South Island trawl survey biomass index has been relatively stable, but it monitors sub-adult fish and does not cover the southern end of the South Island.

Projections and Prognosis	
Stock Projections or Prognosis	The stock is Very Likely (> 90%) to remain below the target at current catch levels.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: About as Likely as Not (40–60%) for current catch Hard Limit: Unlikely (< 40%) for current catch
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Likely (> 90%) for current catch

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2021	Next assessment: 2024
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Relationship between stock monitoring areas	

Qualifying Comments
There is a possibility that the stock may have already been in a depleted state at the beginning of the time series. Catches from this fishery include the highest proportions of large school sharks in New Zealand.

Fishery Interactions
Region SCH 3S/5 is predominantly a setnet fishery targeting school shark and small amounts of rig, with other species being very minor; and in the bottom trawl fishery targeting red cod, flatfish, barracouta, and stargazer. Mixed targeted bottom longline takes only a small part of the catch.

- **SCH 4**

Stock Status	
Year of Most Recent Assessment	2021
Assessment Runs Presented	Standardised CPUE based on the combined bottom longline series
Reference Points	Target: Not established Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: Not established
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unlikely
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status

Left panel: Standardised CPUE for school shark in SCH 4 from model of catch rate in bottom longline trips (solid line). Also shown is the trajectory of total landed SCH from the sub-stock area (grey line). Right panel: Annual relative exploitation rate for school shark in SCH 4.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The bottom longline CPUE series has fluctuated without trend. The series is short due to a fleet change and sparse data in the earlier period.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has been increasing since about 2010.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Biomass estimates from the Chatham Rise research trawl survey have been increasing over time but few school shark observations are made. Only large individuals are sampled due to the depth span of this survey.
Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unlikely
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2021	Next assessment: 2024
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)		
Changes to Model Structure and Assumptions	None	
Major Sources of Uncertainty	- Relationship between stock monitoring areas	

Qualifying Comments
-

Fishery Interactions
Region SCH 4 (Chatham Rise) catches are caught primarily in the bottom longline fishery targeting school shark, ling, hapuku/bass and bluenose.

- **SCH 7, SCH 8 & lower SCH 1W (7/8/1W on the map)**

Stock Status	
Year of Most Recent Assessment	2021
Assessment Runs Presented	Biomass estimates based on the west coast South Island research trawl survey
Reference Points	Target: Interim B_{MSY}-compatible proxy based on the mean biomass from 2005 to 2015 for west coast South Island research trawl survey Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: Interim F_{MSY}-compatible proxy based on the mean relative exploitation rate for the period: 2004–05 to 2015
Status in relation to Target	About as Likely as Not (40–60%) to be at or above B_{MSY}
Status in relation to Limits	Soft Limit: Unlikely ($< 40\%$) Hard Limit: Very Unlikely ($< 10\%$)
Status in relation to Overfishing	Overfishing is Unlikely ($< 40\%$) to be occurring

Historical Stock Status Trajectory and Current Status
 Left panel: Biomass index for school shark in 7/8/1W from the West Coast South Island research trawl survey (solid line). Also shown is the trajectory of total landed SCH by all methods from the substock area (grey line). Horizontal lines represent the target (green dashed line), the soft limit (yellow dashed line), and hard limit (red dashed line). The reference period is shown in beige. Right panel: Annual relative exploitation rate for school shark in 7/8/1W from the combined setnet CPUE series. The interim F_{MSY}-compatible target is shown by the green dashed line.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The west coast South Island trawl survey biomass has been fluctuating without trend since 2005 after declining from an initial high in the 1990s, with no substantive change in catch-at-length.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality has been near target levels since 2007.
Other Abundance Indices	- The combined setnet CPUE has been increasing slowly since 1998–99, with some variability. However, this series is being compromised due to area closures.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely ($< 40\%$) Hard Limit: Very Unlikely ($< 10\%$)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Research trawl survey biomass	
Assessment Dates	Latest assessment: 2021	Next assessment: 2024
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Estimated biomass from trawl survey	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Research trawl survey biomass was used instead of the average of the combined setnet and combined longline CPUE series that was previously accepted to monitor stock status. - The setnet combined index could be used as an auxiliary index, but it has probably been impacted by spatial management measures aimed at the conservation of Māui and Hector's dolphins.	
Major Sources of Uncertainty	- Relationship between stock monitoring areas	

Qualifying Comments
-

Fishery Interactions
Region SCH 7/8/1W are caught by setnet targeting school shark and rig; bottom longline targeting school shark and hāpuku/bass; and bottom trawl targeting tarakihi, barracouta, red gurnard, flatfish, hoki, and others.

7.   FOR FURTHER INFORMATION

Anon (1990) Management meets industry. Papers from the Southern Shark Fishery seminars held in Victor Harbour, Phillip Island and Hobart, October 1989. Australia. Bureau of Rural Resources and Australian Fisheries Service, Australian Fisheries Services, Canberra.

Ayers, D; Paul, L J; Sanders, B M (2004) Estimation of catch per unit effort analyses for school shark (*Galeorhinus galeus*) from bycatch and target fisheries in New Zealand, 1989–90 to 2001–02. *New Zealand Fisheries Assessment Report 2006/26*. 121 p.

Beentjes, M P; MacGibbon, D J (2013) Review of QMS species for inclusion in the east coast South Island winter trawl survey reports. *New Zealand Fisheries Assessment Report 2013/35*. 102 p.

Beentjes, M P; MacGibbon, D J; Lyon, W S (2015) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2014 (KAH1402). *New Zealand Fisheries Assessment Report 2015/14*.

Blackwell, R G; Francis, M P (2010) Review of life-history and fishery characteristics of New Zealand rig and school shark. *New Zealand Fisheries Assessment Report 2010/02*. 38 p.

Boyd, R O; Reilly, J L (2002) 1999–2000 national marine recreational fishing survey: harvest estimates. Draft New Zealand Fisheries Assessment Report. (Unpublished report held by Fisheries New Zealand, Wellington.)

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document. 1998/16. 27 p. (Unpublished report held by NIWA library, Wellington.)

Bradford, E (2001) Standardised catch rate indices for New Zealand school shark, *Galeorhinus galeus,* in New Zealand, 1989–90 to 1998–99. *New Zealand Fisheries Assessment Report 2001/33*. 75 p.

Campbell, D; Battaglene, T; Pascoe, S (1991) Management options for the Southern Shark Fishery - an economic analysis. *Australian Bureau of Agricultural and Resource Economics Discussion Paper 91.12*. 43 p.

Coutin, P; Bruce, B; Paul, L (1992) New Zealand school sharks cross the Tasman Sea. *Australian Fisheries 51*(3): 24–25.

Dunn, M R; Bian, R (2018) School shark fishery characterisation and CPUE. *New Zealand Fisheries Assessment Report 2018/35*. 112 p.

Ford, R B; Galland, A; Clark, M R; Crozier, P; Duffy, C AJ; Dunn, M R; Francis, M P, Wells, R (2015) Qualitative (Level 1) Risk Assessment of the impact of commercial fishing on New Zealand Chondrichthyans. *New Zealand Aquatic Environment and Biodiversity Report No. 157*. 111 p.

Francis, M P (1998) New Zealand shark fisheries: development, size and management. *Marine and Freshwater Research 49*: 579–591.

Francis, M P (2010) Movement of tagged rig and school shark among QMAs, and implications for stock management boundaries. *New Zealand Fisheries Assessment Report 2010/3*. 22 p.

Francis, M P; Mulligan, K P (1998) Age and growth of New Zealand school shark, *Galeorhinus galeus*. *New Zealand Journal of Marine and Freshwater Research 32(3)*: 427–440.

Francis, M P; Paul, L J (2013) New Zealand inshore finfish and shellfish commercial landings, 1931–82. *New Zealand Fisheries Assessment Report 2013/55*. 136 p.

Francis, R I C C; Hurst, R J; Renwick, J A (2001) An evaluation of catchability assumptions in New Zealand stock assessments. *New Zealand Fisheries Assessment Report 2001/1*. 37 p.

Grant, C J; Sandland, R L; Olsen, A M (1979) Estimation of growth, mortality and yield per recruit of the Australian school shark, *Galeorhinus australis* (Macleay), from tag recoveries. *Australian Journal of Marine and Freshwater Research 30(5)*: 625–637.

Hurst, R J; Bagley, N W (1994) Trawl survey of middle depth and inshore bottom species off Southland, February-March 1993 (TAN9301). *New Zealand Fisheries Data Report No. 52*. 61 p.

Hurst, R J; Bagley, N W; McGregor, G A; Francis, M P (1999) Movements of the New Zealand school shark, *Galeorhinus galeus*, from tag returns. *New Zealand Journal of Marine and Freshwater Research 33(1)*: 29–48.

Hurst, R J; Bagley, N W; Uozumi, Y (1990) New Zealand-Japan trawl survey of shelf and upper slope species off southern New Zealand, June 1986. *New Zealand Fisheries Technical Report No. 18*. 50 p.

Livingston, M E; Uozumi, Y; Berben, P H (1991) Abundance, distribution, and spawning condition of hoki and other mid-slope fish on the Chatham Rise, July 1986. *New Zealand Fisheries Technical Report No. 25*. 47 p.

Lydon, G J; Middleton, D A J; Starr, P J (2006) Performance of the SCH 7 and SCH 8 Logbook Programmes. AMP-WG-06-06. (Unpublished manuscript available from the NZ Seafood Industry Council, Wellington.)

McAlister, J D; Barnett, A; Lyle, J; Semmens, J (2015) Examining the functional role of current area closures used for the conservation of an overexploited and highly mobile fishery species. *ICES Journal of Marine Science 72(8)*: 2234–2244.

Olsen, A M (1984) Synopsis of biological data on the school shark, *Galeorhinus australis* (Macleay 1881). *FAO Fisheries Synopsis No. 139*. 42 p.

Paul, L J (1988) School shark. New Zealand Fisheries Assessment Research Document 1988/27. 32 p. (Unpublished report held by NIWA library, Wellington.)

Paul, L J (1991) Overseas travel report: "Sharks Down Under" conference, Taronga Zoo, Sydney, February 1991. MAF Fisheries Greta Point Internal Report No. 176. 137 p. (Unpublished report held by NIWA library, Wellington).

Paul, L J; Saunders, B (2001) A description of the commercial fishery for school shark, *Galeorhinus galeus*, in New Zealand, 1945 to 1999. *New Zealand Fisheries Assessment Report 2001/32*. 63 p.

Peres, M B; Vooren, C M (1991) Sexual development, reproductive cycle, and fecundity of the school shark *Galeorhinus galeus* off southern Brazil. *Fishery Bulletin 89(4)*: 655–667.

Seafood Industry Council (SeaFIC) (2003a) SCH 3 Adaptive Management Programme Proposal for the 2004–05 Fishing year. 50 p. (Unpublished report held by Seafood New Zealand, Wellington).

Seafood Industry Council (SeaFIC) (2003b) SCH 5 Adaptive Management Programme Proposal for the 2004–05 Fishing year. 49 p. (Unpublished report held by Seafood New Zealand, Wellington).

Seafood Industry Council (SeaFIC) (2003c) SCH 7 Adaptive Management Programme Proposal for the 2004–05 Fishing year. 42 p. (Unpublished report held by Seafood New Zealand, Wellington).

Seafood Industry Council (SeaFIC) (2003d) SCH 8 Adaptive Management Programme Proposal for the 2004–05 Fishing year. 42 p. (Unpublished report held by Seafood New Zealand, Wellington).

Smith, P J (2009) Review of genetic studies of rig and school shark. Final Research Report for Ministry of Fisheries research project No. INS200803. 16 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Starr, P J (2005) CPUE indices for groper, *Polyprion* spp., when targeted and as a bycatch in four New Zealand fisheries, 1990–2003. *New Zealand Fisheries Assessment Report 2005/51*. 29 p.

Starr, P J; Kendrick, T H (2010a) Report to the Adaptive Management Programme Fishery Assessment Working Group: Characterisation and CPUE analysis for SCH 1. Document 2010/05-v3. 85 p. (Unpublished document held by Fisheries New Zealand, Wellington.)

Starr, P J; Kendrick, T H (2010b) Report to the Adaptive Management Programme Fishery Assessment Working Group: Characterisation and CPUE analysis for SCH 2. Document 2010/06-v2, 64 p. (Unpublished document held by Fisheries New Zealand, Wellington.)

Starr, P J; Kendrick, T H (2016) SCH 1, 2, 3, 4, 5, 7 and 8 fishery characterisation and CPUE report. *New Zealand Fisheries Assessment Report 2016/64*. 251 p.

Starr, P J; Kendrick, T H; Bentley, N (2010a) Report to the Adaptive Management Programme Fishery Assessment Working Group: Characterisation, CPUE analysis and logbook data for SCH 3. Document 2010/07-v2, 62 p. (Unpublished document held by Fisheries New Zealand, Wellington.)

Starr, P J; Kendrick, T H; Bentley, N (2010b) Report to the Adaptive Management Programme Fishery Assessment Working Group: Characterisation, CPUE analysis and logbook data for SCH 5. Document 2010/08-v2, 65 p. (Unpublished document held by Fisheries New Zealand, Wellington.)

Starr, P J; Kendrick, T H; Bentley, N (2010c) Report to the Adaptive Management Programme Fishery Assessment Working Group: Characterisation, CPUE analysis and logbook data for SCH 7 and SCH 8. Document 2010/09-v2, 149 p. (Unpublished document held by Fisheries New Zealand, Wellington.)

Starr, P J; Kendrick, T H; Lydon, G J; Bentley, N (2007a) Report to the Adaptive Management Programme Fishery Assessment Working Group: Two year review of the SCH 3 Adaptive Management Programme. AMP-WG-07-08. (Unpublished manuscript available from the Seafood New Zealand, Wellington.)

Starr, P J; Kendrick, T H; Lydon, G J; Bentley, N (2007b) Report to the Adaptive Management Programme Fishery Assessment Working Group: Two year review of the SCH 5 Adaptive Management Programme. AMP-WG-07-09. (Unpublished manuscript available from Seafood New Zealand, Wellington.)

Starr, P J; Kendrick, T H; Lydon, G J; Bentley, N (2007c) Report to the Adaptive Management Programme Fishery Assessment Working Group: Two year review of the SCH 7 Adaptive Management Programme. AMP-WG-07-15. (Unpublished manuscript available from Seafood New Zealand, Wellington.)

Starr, P J; Kendrick, T H; Lydon, G J; Bentley, N (2007d) Report to the Adaptive Management Programme Fishery Assessment Working Group: Two year review of the SCH 8 Adaptive Management Programme. AMP-WG-07-16. (Unpublished manuscript available from the NZ Seafood Industry Council, Wellington.).

Stevenson, M L; MacGibbon, D J (2018) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2017 (KAH1703). *New Zealand Fisheries Assessment Report 2018/18*. 93 p.

Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991–92 to 1993–94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished report held by NIWA library, Wellington.)

Thomson, R (2012) Projecting the School Shark model into the future: rebuilding timeframes and auto-longlining in South Australia. *In*: Tuck, G (Ed) *Stock assessment for the Southern and Eastern scalefish and shark fishery: 2012*. Chapter 22. Presented to SharkRAG, 13-14 November 2012. CSIRO.

Thomson, R; Punt, A (2009) Stock assessment update for school shark *Galeorhinus galeus* based on data to 2008, reanalysis for SharkRAG meeting 17–18 November 2009, final draft, CSIRO, Hobart.

Thomson, R B; Bravington M V; Feutry, P; Gunasekera, R; Grewe, P (2020) Close kin mark recapture for School Shark in the SESSF. *FRDC Project No 2014/024*. CSIRO, Hobart, August 2020. 110 p.

SCHOOL SHARK (SCH)

Tremblay-Boyer, L. (2021). Characterisation and CPUE standardisation for school shark in New Zealand. Draft New Zealand Fisheries Assessment Report 281 p.

Wilson, D; Curtotti, R; Begg, G; Phillips, K (Eds) (2008) Fishery status reports 2008: status of fish stocks and fisheries managed by the Australian Government, Bureau of Rural Sciences & Australian Bureau of Agricultural and Resource Economics, Canberra. 395 p.

Woodhams, J; Emery, T; Curtotti, R (2020) Chapter 12: Shark Gillnet and Shark Hook sectors. *In*: Fishery status reports 2020, pp. 266–292. Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, Australia.

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019) National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24*. 104 p.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.

SEA CUCUMBER (SCC)

(*Australostichopus mollis*)
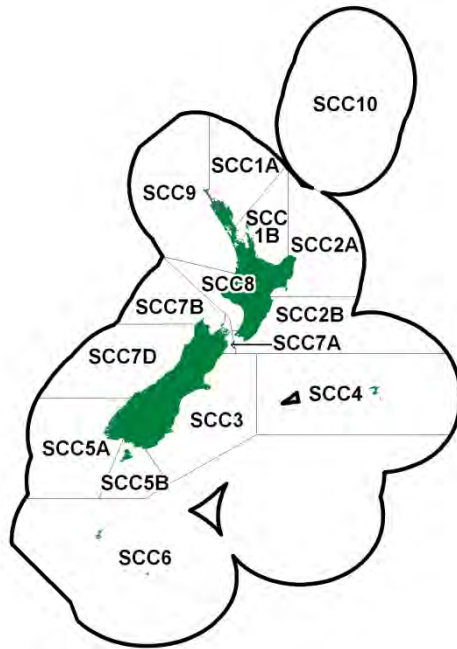
1.   FISHERY SUMMARY

Sea cucumbers were introduced into the Quota Management System on 1 April 2004. The fishing year is from 1 April to 31 March. A breakdown of the Total Allowable Catch (TAC) for each Quota Management Area (QMA) is listed in Table 1 and shown in Figure 1. Each TAC is made up of a Total Allowable Commercial Catch (TACC) plus customary and recreational allowances and, in SCC 3, an allowance for mortality associated with fishing. Most TACs have remained unchanged since entering the QMS, but TACs for SCC 3 and SCC 7B were increased on 1 April 2018 and the TAC for SCC 7A was increased in 2019.

1.1   Commercial fisheries

More than 100 species of sea cucumber are found in New Zealand waters, but *Australostichopus mollis* is the only species of commercial value, and the only species for which exploratory commercial fishing has taken place. Sea cucumbers are targeted mainly by diving, although some targeted dredging and beam trawling occurs (e.g., in SCC 3), and they are also a common bycatch of bottom trawl and scallop dredge fisheries. Sea cucumber landings of all species are reported as a single code (SCC), although most reported landings are probably *A. mollis*. Sea cucumbers are on Schedule 6 of the Fisheries Act 1996, and as such can be returned to the sea if expected to survive.

Table 1: Recreational and customary non-commercial allowances (t), Total Allowable Commercial Catches (TACC, t), and Total Allowable Catch (TAC, t) as declared for SCC on introduction into the QMS in October 2004.

Fishstock	Description	TACC	Recreational allowance	Customary allowance	Other sources of mortality	TAC
SCC 1A	East Northland	2	3	2	–	7
SCC 1B	Hauraki Gulf and Bay of Plenty	2	4	2	–	8
SCC 2A	East coast and Gisborne	2	1	1	–	4
SCC 2B	Wairarapa and Wellington	5	4	2	–	11
SCC 3	South-East (Coast)	48	2	1	3	54
SCC 4	South East (Chatham Rise)	2	1	1	–	4
SCC 5A	Fiordland	2	1	1	–	4
SCC 5B	Southland and Stewart Island	2	1	1	–	4
SCC 6	Sub-Antarctic	0	0	0	–	0
SCC 7A	Challenger (Marlborough Sounds)	15	2	1	–	18
SCC 7B	Challenger (Nelson)	14	2	1	–	17
SCC 7D	Challenger (Westland)	2	1	1	–	4
SCC 8	Central (West)	2	1	1	–	4
SCC 9	Auckland (West)	2	1	1	–	4
SCC 10	Kermadec	0	0	0	–	0

Table 2: TACCs and reported landings (t) of sea cucumber by Fishstock. From 1990–91 to 2000-01 the reported landings are those landings that went to Licensed Fish Receivers (LFRs), and from 2001-02 to present, reported landings are as reported on Monthly Harvest Returns (MHRs). Until 2003–04, management areas were the same as FMAs; since then FMAs 1, 2, 5, and 7 were subdivided. [Continued on next pages]

	SCC 1		SCC 1A		SCC 1B	
Fishing year	Landings	TACC	Landings	TACC	Landings	TACC
1990–91	0	–	–	–	–	–
1991–92	0	–	–	–	–	–
1992–93	0	–	–	–	–	–
1993–94	0	–	–	–	–	–
1994–95	0	–	–	–	–	–
1995–96	0	–	–	–	–	–
1996–97	0	–	–	–	–	–
1997–98	0	–	–	–	–	–
1998–99	0	–	–	–	–	–
1999–00	0	–	–	–	–	–
2000–01	0.04	–	–	–	–	–
2001–02	0.16	–	–	–	–	–
2002–03	0.41	–	–	–	–	–
2003–04*	0.07	N/A	0	2	0	2
2004–05	N/A	N/A	0	2	1.49	2
2005–06	N/A	N/A	0	2	1.43	2
2006–07	N/A	N/A	0	2	2.09	2
2007–08	N/A	N/A	0.12	2	2.18	2
2008–09	N/A	N/A	0.12	2	0.53	2
2009–10	N/A	N/A	0.18	2	1.78	2
2010–11	N/A	N/A	0.01	2	1.40	2
2011–12	N/A	N/A	1.47	2	2.01	2
2012–13	N/A	N/A	0.36	2	1.68	2
2013–14	N/A	N/A	0	2	1.61	2
2014–15	N/A	N/A	0.70	2	1.84	2
2015–16	N/A	N/A	0.09	2	1.78	2
2016–17	N/A	N/A	0.04	2	2.00	2
2017–18	N/A	N/A	0.29	2	1.98	2
2018–19	N/A	N/A	0.14	2	1.82	2
2019–20	N/A	N/A	0.01	2	1.57	2
2020–21	N/A	N/A	0.01	2	2.04	2
2021–22	N/A	N/A	0.09	2	0.18	2

	SCC 2		SCC 2A		SCC 2B	
Fishing year	Landings	TACC	Landings	TACC	Landings	TACC
1990–91	0	–	–	–	–	–
1991–92	0	–	–	–	–	–
1992–93	0	–	–	–	–	–
1993–94	0	–	–	–	–	–
1994–95	0	–	–	–	–	–
1995–96	0	–	–	–	–	–
1996–97	0	–	–	–	–	–
1997–98	0	–	–	–	–	–
1998–99	0	–	–	–	–	–
1999–00	0	–	–	–	–	–
2000–01	0	–	–	–	–	–
2001–02	0.36	–	–	–	–	–
2002–03	0.03	–	–	–	–	–
2003–04*	N/A	N/A	0	2	0	5
2004–05	N/A	N/A	0	2	0	5
2005–06	N/A	N/A	0	2	0	5
2006–07	N/A	N/A	0	2	0	5
2007–08	N/A	N/A	0	2	0	5
2008–09	N/A	N/A	0	2	0	5
2009–10	N/A	N/A	0	2	0.19	5
2010–11	N/A	N/A	0	2	0.05	5
2011–12	N/A	N/A	0	2	0.67	5
2012–13	N/A	N/A	0	2	0.11	5
2013–14	N/A	N/A	0	2	0.19	5
2014–15	N/A	N/A	0	2	2.37	5
2015–16	N/A	N/A	0	2	0.56	5
2016–17	N/A	N/A	0	2	1.49	5
2017–18	N/A	N/A	0.14	2	0.87	5
2018–19	N/A	N/A	0	2	1.00	5
2019–20	N/A	N/A	0	2	0.95	5
2020–21	N/A	N/A	0	2	0.47	5
2021–22	N/A	N/A	0	2	0.15	5

Table 2 [continued]

Fishing year	SCC 3 Landings	TACC	SCC 4 Landings	TACC	SCC 6 Landings	TACC
1990–91	0	–	–	–	0	–
1991–92	0	–	–	–	0	–
1992–93	0	–	–	–	0	–
1993–94	0	–	–	–	0	–
1994–95	0	–	–	–	0.12	–
1995–96	0	–	–	–	0	–
1996–97	0	–	–	–	0	–
1997–98	0	–	–	–	0	–
1998–99	0	–	0.01	–	0	–
1999–00	0	–	0	–	0.05	–
2000–01	0.01	–	0	–	0	–
2001–02	0.68	–	1.48	–	9.28	–
2002–03	0.65	–	0.13	–	12.56	–
2003–04*	1.54	2	0.12	2	4.07	0
2004–05	1.14	2	0	2	4.77	0
2005–06	2.85	2	0	2	0.31	0
2006–07	2.70	2	0	2	0	0
2007–08	3.67	2	0	2	0	0
2008–09	3.80	2	0	2	0	0
2009–10	0.37	2	0.01	2	0	0
2010–11	0.78	2	0.01	2	0	0
2011–12	3.40	2	0	2	0	0
2012–13	8.54	2	0	2	0	0
2013–14	6.72	2	0.01	2	0	0
2014–15	2.18	2	0	2	0	0
2015–16	7.20	2	0.19	2	0	0
2016–17	1.84	2	0.08	2	0	0
2017–18	0.34	2	0.08	2	0	0
2018–19	18.31	48	0	2	0	0
2019–20	24.32	48	0.01	2	0	0
2020–21	16.34	48	0.32	2	0	0
2021–22	23.82	48	0	2	0	0

Fishing year	SCC 5 Landings	TACC	SCC 5A Landings	TACC	SCC 5B Landings	TACC
1990–91	0	–	–	–	–	–
1991–92	0	–	–	–	–	–
1992–93	0	–	–	–	–	–
1993–94	0	–	–	–	–	–
1994–95	0	–	–	–	–	–
1995–96	0	–	–	–	–	–
1996–97	0	–	–	–	–	–
1997–98	0	–	–	–	–	–
1998–99	0	–	–	–	–	–
1999–00	0	–	–	–	–	–
2000–01	0	–	–	–	–	–
2001–02	0	–	–	–	–	–
2002–03	5.82	–	–	–	–	–
2003–04*	0.27	–	0	2	0	2
2004–05	–	–	0	2	0.01	2
2005–06	–	–	0	2	0	2
2006–07	–	–	0	2	0	2
2007–08	–	–	0	2	0	2
2008–09	–	–	0	2	0.02	2
2009–10	–	–	0	2	0	2
2010–11	–	–	0	2	0.01	2
2011–12	–	–	0.31	2	0.37	2
2012–13	–	–	0	2	0.11	2
2013–14	–	–	0	2	1.81	2
2014–15	–	–	0.70	2	2.14	2
2015–16	–	–	1.85	2	1.80	2
2016–17	–	–	1.26	2	2.00	2
2017–18	–	–	1.79	2	2.13	2
2018–19	–	–	0.37	2	0.86	2
2019–20	–	–	1.42	2	2.13	2
2020–21	–	–	1.41	2	1.94	2
2021–22	–	–	1.40	2	1.63	2

SEA CUCUMBER (SCC)

Table 2 [continued]

Fishstock	SCC 7		SCC 7A		SCC 7B		SCC 7D	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1990–91	0.07	–	–	–	–	–	–	–
1991–92	0.06	–	–	–	–	–	–	–
1992–93	0.32	–	–	–	–	–	–	–
1993–94	0	–	–	–	–	–	–	–
1994–95	0.56	–	–	–	–	–	–	–
1995–96	3.31	–	–	–	–	–	–	–
1996–97	0.12	–	–	–	–	–	–	–
1997–98	0	–	–	–	–	–	–	–
1998–99	0	–	–	–	–	–	–	–
1999–00	0.02	–	–	–	–	–	–	–
2000–01	0	–	–	–	–	–	–	–
2001–02	0	–	–	–	–	–	–	–
2002–03	0.19	–	–	–	–	–	–	–
2003–04*	–	–	0	5	0	5	0	2
2004–05	–	–	2.97	5	1.01	5	0	2
2005–06	–	–	5.47	5	0.12	5	0	2
2006–07	–	–	0.17	5	0.04	5	0	2
2007–08	–	–	8.34	5	0	5	0.02	2
2008–09	–	–	4.19	5	0	5	0	2
2009–10	–	–	4.31	5	1.36	5	0	2
2010–11	–	–	5.09	5	5.46	5	0	2
2011–12	–	–	4.78	5	4.70	5	2.15	2
2012–13	–	–	4.97	5	4.27	5	0	2
2013–14	–	–	5.10	5	5.23	5	0	2
2014–15	–	–	4.97	5	5.06	5	0	2
2015–16	–	–	5.45	5	5.03	5	0	2
2016–17	–	–	4.98	5	4.96	5	0	2
2017–18	–	–	5.04	5	5.04	5	0	2
2018–19	–	–	4.92	5	13.45	14	0	2
2019–20	–	–	14.29	15	13.56	14	0	2
2020–21	–	–	13.27	15	7.97	14	0	2
2021–22	–	–	15.79	15	5.27	14	0	2

Fishing year	SCC 8		SCC 9		Total	
	Landings	TACC	Landings	TACC	Landings	TACC
1990–91	0	–	0	–	0.07[+]	–
1991–92	0	–	0	–	0.06[+]	–
1992–93	0	–	0	–	0.32[+]	–
1993–94	0	–	0	–	0[+]	–
1994–95	0	–	0	–	0.68[+]	–
1995–96	0	–	0	–	3.31[+]	–
1996–97	0	–	0	–	0.12[+]	–
1997–98	0	–	0.05	–	0.05	–
1998–99	0	–	0	–	0.01	–
1999–00	0	–	0	–	0.07	–
2000–01	0	–	0	–	0.05	–
2001–02	0	–	0	–	11.96	–
2002–03	0	–	0	–	19.79**	–
2003–04*	0	–	0	2	6.07	35
2004–05	0	2	0.02	2	11.41	35
2005–06	0	2	0	2	10.18	35
2006–07	0	2	0.01	2	5.01	35
2007–08	0	2	0	2	14.33	35
2008–09	0	2	0.07	2	8.73	35
2009–10	0	2	0.03	2	8.23	35
2010–11	0	2	0.14	2	12.95	35
2011–12	0.23	2	0.14	2	20.23	35
2012–13	0.91	2	0.13	2	21.08	35
2013–14	1.11	2	0	2	21.78	35
2014–15	2.04	2	0.16	2	22.16	35
2015–16	1.99	2	0	2	25.94	35
2016–17	2.00	2	0.14	2	20.79	35
2017–18	2.00	2	0.06	2	19.76	35
2018–19	2.01	2	0.01	2	42.89	90
2019–20	0.21	2	0	2	58.47	100
2020–21	0.35	2	0	2	44.12	100
2021–22	0.15	2	0	2	48.48	100

*The 2003-04 fishing year occurred between 01/10/03 – 31/03/04. SCC was introduced into the QMS on 1 April 2004 at which point it changed from an October to April fishing year.

**In 2002–03 50 kg were reportedly landed, but the QMA was not recorded. This amount is included in the total landings for that year,

[+]In 1990–1997, catch was reported, but no QMA was, therefore only the total is shown.
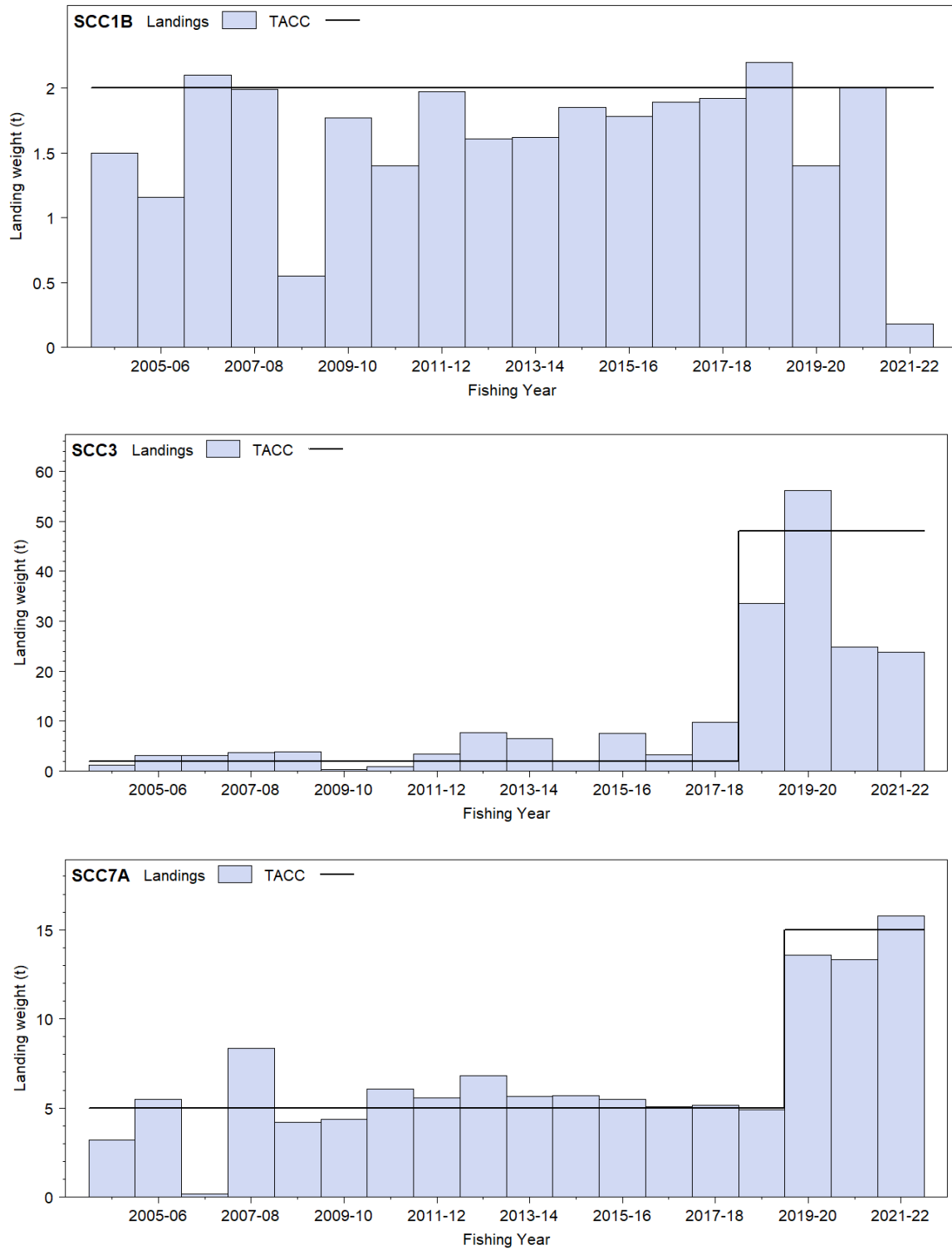
Figure 1: Reported commercial landings and TACC for SCC 1B (Hauraki Gulf, Bay of Plenty), SCC 3 (South East Coast) and SCC 7A (Challenger Marlborough Sounds), Note that these figures do not show data prior to entry into the QMS. [Continued on next page]
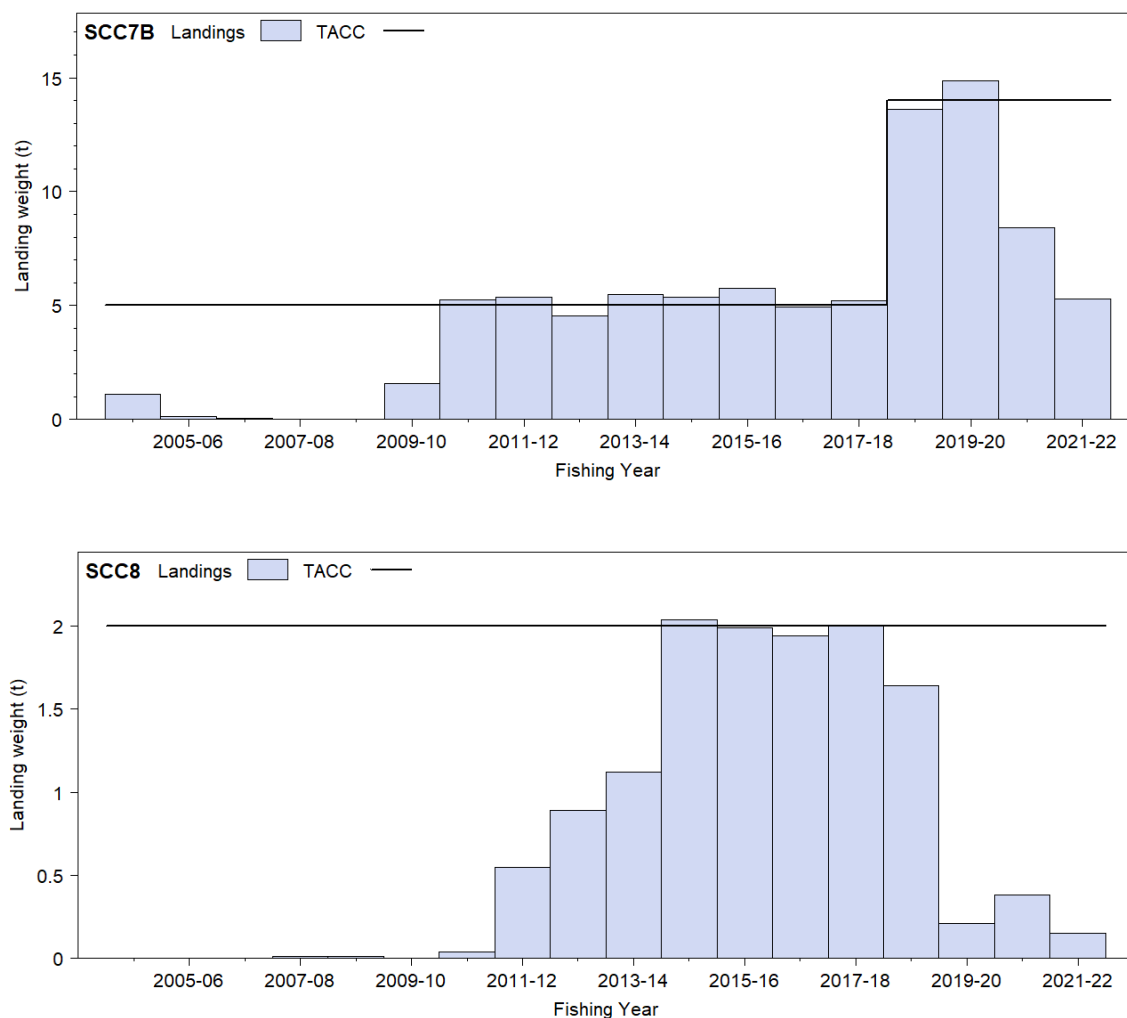
Figure 1 [Continued]: Reported commercial landings and TACC for SCC 7B (Challenger Nelson), and SCC 8 (Central).

Between 1990 and 2001 about 45% of the catch was taken as bycatch in scallop dredging in Tasman Bay and Golden Bay. About 13% was taken as bycatch in bottom trawling around the Auckland Islands, and about 38% was taken by diving. The remainder of the bycatch has been reported from midwater trawls, rock lobster pots, and bottom longlines. Catches were taken by diving from Fisheries Statistical Area 031 (Fiordland) in 1990–91 (when a special permit was being operated), and 1995–96.

Prior to 2000–01 reported total landings did not exceed 5 t, however landings increased rapidly to almost 22 t by 2003–04, declined to 5 t in 2006–07, before increasing to about 20 t in 2011–12. Landings were maintained around this level (except for a drop to 14 t in 2016–17, before increasing to 41 t in 2018–19 and 58 t in 2019–20 (Table 2). Most of these landings came from SCC 3, SCC 7A and SCC 7B. Fishing for sea cucumber within the Marlborough Sounds (SCC 7A) has been managed under a voluntary catch spreading plan. The historical landings and TACC for the main SCC stocks are depicted in Figure 1.

1.2   Recreational fisheries
Recreational fishing surveys indicate that sea cucumbers are not caught by recreational fishers. It is likely that members of the Asian and Pacific Island communities harvest sea cucumber, but their fishing activity is poorly represented in the recreational surveys.

1.3   Customary non-commercial fisheries
There is very limited quantitative information on customary non-commercial use of sea cucumber. In 2010, the harvest of 100 sea cucumbers was permitted in SCC1B and 100 were reported caught.

1.4   Illegal catch

There is qualitative evidence to suggest significant illegal, unreported, unregulated (IUU) activity in this fishery.

1.5   Other sources of mortality

There is no quantitative information on other sources of mortality, although sea cucumbers are often taken as a bycatch in bottom trawl and dredge fisheries.

2.   BIOLOGY

Australostichopus mollis is distributed throughout New Zealand waters, as far south as the Snares Islands. It also occurs off the west and south coasts of Australia. It is found in shallow water of sheltered coastline in a wide range of habitats from rocky shores to sandy bottoms. It is common off north-east New Zealand, Fiordland, the Marlborough Sounds, and Stewart Island, and displays a preference for sheltered coastlines with complex and diverse habitats. *A. mollis* is less common on exposed coasts, but, if present, tends to be in deeper water.

Sea cucumbers are mobile detritus feeders and form part of the benthic epifaunal community. If disturbed, they can eviscerate their entire gut which can then be regenerated. They tend to be sedentary in suitable habitat, but can move away relatively quickly if stressed.

Little is known about the biology of *A. mollis*. They have an annual reproductive cycle and spawn between November and February. The sexes are separate and develop synchronously. They are broadcast spawners (eggs and sperm are released into the water column) and, following fertilisation, they undergo a 3- to 4-week larval phase before settlement. Populations from sheltered areas such as fiords and sheltered bays may be largely 'self-seeding', whereas larvae released on open coasts may disperse more widely.

There is some evidence that recruitment and growth are both patchy and variable. Recruited individuals appear in the adult population at about 10–12 cm (40–60 g) and adults grow to about 18–20 cm (180 g). During an exploratory fishing survey in Fiordland (SCC 5A) in 1989, divers observed small *A. mollis* under rubble, suggesting that pre-recruit sea cucumbers may have different habitat preferences to adults. By contrast, comprehensive surveying in the Mahurangi Harbour (SCC 1B) showed the substratum at sites with high densities of juveniles to be dominated by silt and mud with large shell fragments (over 10 cm) of the horse mussel *Atrina zelandica* (Morrison 2000). The restricted distribution of juveniles at this locality was shown to be unrelated to sediment type and was theorised to be a consequence of localised effects such as predation or larval settlement (Slater & Jeffs 2010). Caging studies comparing growth at different densities underneath and away from a Coromandel mussel farm (SCC 1B) showed that growth ranged from a 15.4% increase in weight over 6 months, at a density of 2.5 per m^2 under a mussel farm, to a 13.9% decrease in weight over 2 months, at a density of 15 per m^2 away from the mussel farm (Slater & Carton 2007). Age at maturity is thought to be about 2 years, and the life span of *A. mollis* is thought to be between 5 and 15 years.

3.   STOCKS AND AREAS

The management of sea cucumbers is based on 15 QMAs, which are a combination of existing and sub-divided FMAs. Although there is currently little biological or fishery information which could be used to identify stock boundaries, the QMAs recognise that sea cucumbers are a sedentary shallow water species, and that many sheltered populations may be isolated and vulnerable to localised depletion. Finer scale QMAs, therefore, provide a mechanism whereby stocks can be managed more appropriately. Also, because it is likely that the same group of commercial fishers will be targeting kina and sea cucumbers, and because there are some similarities in their respective habitats, the QMAs for sea cucumber are the same as those for kina.

4.   STOCK ASSESSMENT

4.1   Estimates of fishery parameters and abundance
There are no estimates of fishery parameters or abundance for any sea cucumber fishstock.

4.2   Biomass estimates
There are no biomass estimates for any sea cucumber fishstock overall, although estimates exist for some discrete subareas.

For Fiordland, crude biomass estimates of 59, 89, 97, and 134 t for Thompson, Bradshaw, Charles, and Doubtful sounds respectively are reported by Mladenov & Gerring (1991), and Mladenov & Campbell (1998). Their survey did not include the outer coastline, but, extrapolating to all fiords between Puysegur Point and Cascade Point, they estimated a total biomass of 1937 t in the 0 to 20 m depth range.

Dive transect surveys were conducted in Queen Charlotte Sound (SCC 7A) and in the Hauraki Gulf (SCC 1B) in 2014 (Williams et al. 2016). The two locations were identified by fishers as important areas that currently support commercial sea cucumber harvesting by breath-hold diving. The objective of the surveys was to estimate sea cucumber biomass in key fishery areas to inform fisheries management on sustainable harvest limits. The surveys included estimated coastline lengths of 109 km (within SCC 7A) and 78 km (within SCC 1B), and covered the depth range 2–15 m. A stratum area method of biomass estimation generated commercial size sea cucumber biomass estimates of 88 t split weight[1] (95% CI = 58–115 t) in SCC 7A and 38 t split weight (95% CI = 22–59 t) in SCC 1B within the areas surveyed. These estimates may be conservative because the transect searches did not account for cryptic sea cucumbers hidden from the divers (*e.g.*, in inaccessible reef cracks and crevices). The surveys did not account for sea cucumbers in waters deeper than 15 m, which could be available to fishers using underwater breathing apparatus (UBA), and the areas surveyed represent only small proportions of the overall SCC stock areas, for which catch limits are set.

In 2017 a dredge survey of *A. mollis* was conducted in deeper water (60–120 m) off the north Canterbury coast in SCC 3 (Tuck et al. 2017). The total population biomass estimated for the survey area was 3207 t green weight or 1329 t split weight; considering only sea cucumbers with a split weight of 63 g or greater (on the basis of a previously estimated marketable SCC selectivity curve) led to a commercial biomass of 619 t split weight. The survey area was considerably smaller than the QMA.

4.3   Yield estimates and projections
There are no estimates of *MCY* for any sea cucumber fishstock.

There are no estimates of *CAY* for any sea cucumber fishstock.

5.   STATUS OF THE STOCKS

There are no estimates of reference or current biomass for any sea cucumber fishstock.

6.   FOR FURTHER INFORMATION

Alcock, N (2000) Brooding behaviour of two New Zealand cucumariids (Echinodermata: Holothuroidea) (Abstract). 10th International Echinoderm Conference 31 January– 4th February 2000 University of Otago, Dunedin, New Zealand.
Beentjes, M P (2003) New species into the QMS - sea cucumber. Final Research Report for Ministry of Fisheries Research Project MOF200203D, Objective 1. 13 p. (Unpublished report held by Fisheries New Zealand, Wellington).
Bradford, E (1998) Harvest estimates from the 1996 national marine recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished report held by NIWA library, Wellington).
Bradford, E; Fisher, D; Bell, J (1998) National marine recreational fishing survey 1996: overview of catch and effort results. *NIWA Technical Report* 18. 55 p.
Chantal, C; Byrne, M (1993) A review of recent developments in the world sea cucumber fisheries. *Marine Fisheries Review* 55: 1–13.
Conrad, C; Sloan, N A (1989) World Fisheries for echinoderms. *In* Caddy, J.F. (Eds). Marine Invertebrate Fisheries, pp. 647–663. Wiley and sons, New York.

---

[1] Split weight is an industry processed state where the abdomen is cut to release internal water and gut contents.

Dawbin, W H (1948) Auto–evisceration and regeneration of the viscera in the holothurian *Stichopus mollis* (Hutton). *Transactions of the Royal Society of New Zealand* 77: 497–523.

Mladenov, P V; Campbell, A (1998) Resource evaluation of the sea cucumber (*Stichopus mollis*) in the environmentally sensitive Fiordland region of New Zealand. Proceedings of the 9th International Echinoderm Conference San Francisco. 481–487.

Mladenov, P V; Gerring, P (1991) Resource evaluation of the sea cucumber (*Stichopus mollis*) in Fiordland, New Zealand. Marine Science and Aquaculture Research Centre, University of Otago. 34 p.

Morgan, A (1999) Overview: aspects of sea cucumber industry research and development in the South Pacific. *SPC Bêche–de–mer Information Bulletin* 12: 15–17.

Morgan, A (2000a) Sea cucumber farming in New Zealand. *Australasia Aquaculture* August–September 2000: 54–55.

Morgan, A (2000b) Sea cucumbers in demand. *Seafood New Zealand* July 2000: 69–70.

Morgan, A (2003) Variation in reproduction and development of the temperate sea cucumber *Stichopus mollis*. PhD thesis, University of Auckland, Auckland.

Morrison, M A (2000) Mahurangi Harbour Habitat Map. NIWA Information Series no. 13., National Institute of Water and Atmospheric Research, Wellington, NZ: Map 1 p. colour.

Pawson, D L (1970) The marine fauna of New Zealand: Sea cucumbers (Echinodemata: Holothuroidea). *Bulletin of the New Zealand Department of Scientific and Industrial Research Bulletin* 201. 69 p.

Pawson, D L (2002) A new species of bathyal elasipod sea cucumber from New Zealand (Echinodermata: Holothuroidea). *New Zealand Journal of Marine and Freshwater Research* 36: 333–338.

Sewell, M A (1990) Aspects of the ecology of *Stichopus mollis* (Echinodermata: Holothuroidea) in north eastern New Zealand. *New Zealand Journal of Marine and Freshwater Research* 24: 87–93.

Sewell, M A (1992) Reproduction of the temperate aspidochirate *Stichopus mollis* (Echinodermata: Holothuroidea) in New Zealand. *Ophelia* 35: 103–121.

Slater, M J; Carton, A G (2007) Survivorship and growth of the sea cucumber *Australostichopus (Stichopus) mollis* (Hutton 1872) in polyculture trials with green-lipped mussel farms. *Aquaculture* 272(1–4): 389–398.

Slater, M J; Jeffs, A G (2010) Do benthic sediment characteristics explain the distribution of juveniles of the deposit-feeding sea cucumber Australostichopus mollis? *Journal of Sea Research* 64(3): 241–249.

Tuck, I D; Williams, J R; Fenwick, M; Roberts, C L (2017) Dredge survey of sea cucumbers in SCC 3, 2017. *New Zealand Fisheries Assessment Report 2017/53*. 23 p.

van Eys, S; Philipson, P W (1986) The market for beche-de-mer from the Pacific Islands. Chapter 11, *Marine Products Marketing*. p. 207–223.

Williams, J R; Roberts, C L; Middleton, C J (2016) Dive surveys of sea cucumbers in Queen Charlotte Sound (SCC 7A) and Hauraki Gulf (SCC 1B), 2014. *New Zealand Fisheries Assessment Report* 2016/58. 26 p.

SEA PERCH (SPE)

(*Helicolenus percoides, H. barathri*)
Pōhuiakaroa
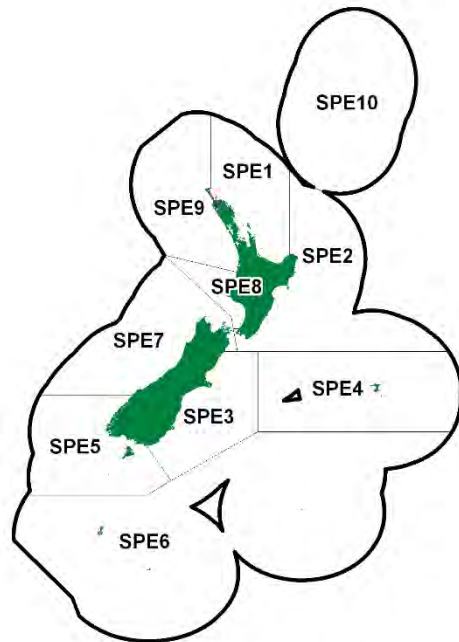
1.   FISHERY SUMMARY

Sea perch was introduced into the QMS from 1 October 1998. Current TACs, TACCs, and allowances for non-commercial fishers are displayed in Table 1. There are two species of sea perch around New Zealand: *Helicolenus percoides* and *H. barathri* (Roberts et al 2015). *Helicolenus percoides* occur in depths shallower than 250 m with a peak at around 150 m, whereas *H. barathri* occur in about 300–1000 m, with a peak at around 600 m (Bentley et al 2014).

Table 1: **Recreational and customary non-commercial allowances (t) and current TACCs (t) and TACs (t), by Fishstock, for sea perch.**

	Recreational	Customary non-commercial	Other sources	TACC	TAC
SPE 1	1	1	3	53	58
SPE 2	9	5	0	79	93
SPE 3	11	11	0	1 000	1 022
SPE 4	0	0	46	910	956
SPE 5	1	1	0	36	38
SPE 6	0	0	0	9	9
SPE 7	8	8	0	82	98
SPE 8	4	2	0	15	21
SPE 9	1	1	0	10	8
SPE 10	0	0	0	0	0

1.1   Commercial fisheries

From 1 October 2000 the TACC for SPE 3 was increased from 738 t to 1000 t under the Adaptive Management Programme (AMP). The TACC for SPE 4 was increased from 533 t to 910 t from 1 October 2004 under the low knowledge bycatch framework. The TACC for SPE 1 was increased from 18 t to 33 t from 1 October 2006, and to 53 t from October 2013. TACCs in SPE 2, 5&6, 7, and 8 have remained unchanged since their introduction in 1998.

In SPE 1 landings were above the TACC for a number of years prior to 2006 and 2013; the TACC was consequently increased to the average of the previous 7 years plus an additional 10%. In SPE 2, landings were above the TACC for a number of years from 1999–00 to 2010–11 but landings have since decreased, averaging about 50 t annually from 2012. In SPE 3, landings have been well below the TACC since it was increased in 2001, and in SPE 4 landings have been below the TACC since it was increased in 2004. In SPE 7, landings have been above the TACC in most years since the introduction

of the TACC, but only 47 t were recorded in 2018–19, 57 t in 2019–20, and 62 t in 2020–21. The TACC for SPE 9 was increased from 6 t to 10 t in 2020–21.

Reported landings for 1931 to 1982 are given by sea perch QMAs 1, 2, 3, and 4 in Table 2. Reported landings and TACCs of sea perch by Fishstock are given in Table 3, and Figure 1 shows historical landings and TACC values for the five main sea perch stocks.

Very small quantities of sea perch have been landed for local sale for many years but were largely unreported. Catches have been made by foreign vessels since the 1960s, but were also not recorded (they were most probably included within a "mixed" or "other finfish" category), and most were probably discarded. Despite poor reporting rates, estimated landings are thought to have increased from 400 t in the early 1980s to approximately 1300 t in recent years (Table 3); an unknown quantity has been discarded over this period.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	SPE 1	SPE 2	SPE 3	SPE 4	Year	SPE 1	SPE 2	SPE 3	SPE 4
1931	0	0	0	0	1957	0	0	1	0
1932	0	0	0	0	1958	0	0	1	0
1933	0	0	0	0	1959	0	0	1	0
1934	0	0	0	0	1960	0	0	1	0
1935	0	0	0	0	1961	0	0	1	0
1936	0	0	0	0	1962	0	0	0	0
1937	0	0	0	0	1963	0	0	0	0
1938	0	0	0	0	1964	0	0	1	0
1939	0	0	0	0	1965	0	0	2	0
1940	0	0	0	0	1966	0	0	1	0
1941	0	0	0	0	1967	0	0	1	0
1942	0	0	0	0	1968	1	0	1	0
1943	0	0	0	0	1969	1	0	3	0
1944	0	0	4	0	1970	1	2	7	0
1945	0	0	2	0	1971	6	0	7	0
1946	0	0	2	0	1972	1	1	2	0
1947	0	0	2	0	1973	0	0	0	0
1948	0	0	1	0	1974	0	0	0	0
1949	0	0	2	0	1975	0	0	0	0
1950	0	0	1	0	1976	0	0	0	0
1951	0	0	5	0	1977	0	0	0	0
1952	0	0	2	0	1978	0	0	2	11
1953	0	0	1	0	1979	0	18	92	248
1954	0	0	0	0	1980	0	1	8	100
1955	0	0	1	0	1981	6	0	70	253
1956	0	0	0	0	1982	22	1	176	164
1931	0	0	0	0	1957	0	0	0	0
1932	0	0	0	0	1958	0	0	0	0
1933	0	0	0	0	1959	0	0	0	0
1934	0	0	0	0	1960	0	0	0	0
1935	0	0	0	0	1961	0	0	0	0
1936	0	0	0	0	1962	0	0	0	0
1937	0	0	0	0	1963	0	0	0	0
1938	0	0	0	0	1964	0	0	0	0
1939	0	0	0	0	1965	0	0	0	0
1940	0	0	0	0	1966	0	0	0	0
1941	0	0	0	0	1967	0	0	0	0
1942	0	0	0	0	1968	0	0	0	0
1943	0	0	0	0	1969	0	1	0	0
1944	29	0	0	0	1970	0	13	0	0
1945	0	0	0	0	1971	0	0	0	0
1946	0	0	0	0	1972	0	0	0	0
1947	0	0	0	0	1973	0	0	0	0
1948	0	0	0	0	1974	0	0	0	0
1949	2	0	0	0	1975	0	0	0	0
1950	2	0	0	0	1976	0	0	0	0
1951	1	0	0	0	1977	0	0	0	0
1952	0	0	0	0	1978	13	11	0	0
1953	0	0	0	0	1979	54	14	1	3
1954	0	0	0	0	1980	40	38	0	0
1955	0	0	0	0	1981	32	15	0	1
1956	0	0	0	0	1982	31	17	1	1

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

About 75% of New Zealand's landed sea perch is taken as a bycatch in trawl fisheries off the east coast of the South Island, including the Chatham Rise. A small catch is made in some central and southern line fisheries, e.g., for groper. The most important QMAs in most years are QMA 3 (east coast South Island) and QMA 4 (Chatham Rise) (Table 3).

The catch from SPE 3 is spread throughout the fishing year. There is a variable seasonal distribution between years. A higher proportion of the catch is taken during April, May, and September and catches are lower from December to February, and in July. Most of the SPE 3 catch is taken as a bycatch from the red cod (about 30%) and hoki fisheries (15%) and from the sea perch target fishery (21%). The remainder is taken as a bycatch from the target barracouta, flatfish, ling, squid, and tarakihi fisheries. Virtually all the SPE 3 catch is taken by bottom trawling, with a small proportion taken by bottom longline. SPE 3 catch rates are highest in 150–400 m depths.

Table 3: Reported landings (t) of sea perch by Fishstock and fishing year, 1983–84 to present. The data in this table have been updated from that published in previous Plenary Reports by using the data up to 1996–97 in table 38 on p. 278 of the "Review of Sustainability Measures and Other Management Controls for the 1998–99 fishing year - Final Advice Paper" dated 6 August 1998. [Continued on next page]

Fishstock FMA	SPE 1 1		SPE 2 2		SPE 3 3		SPE 4 4		SPE 5 & 6 5 &6	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84	14	–	2	–	150	–	58	–	36	–
1984–85	10	–	2	–	290	–	70	–	26	–
1985–86	14	–	2	–	213	–	218	–	28	–
1986–87	19	–	2	–	507	–	71	–	19	–
1987–88	20	–	1	–	544	–	63	–	18	–
1988–89	14	–	1	–	262*	–	36	–	18	–
1989–90	2	–	6	–	287*	–	177	–	9	–
1990–91	5	–	9	–	559*	–	68	–	33	–
1991–92	12	–	8	–	791*	–	222	–	36	–
1992–93	15	–	15	–	783*	–	317	–	55	–
1993–94	16	–	26	–	690*	–	223	–	28	–
1994–95	25	–	66	–	626*	–	415	–	18	–
1995–96	23	–	50	–	1 047*	–	404	–	62	–
1996–97	19	–	77	–	655*	–	435	–	45	–
1997–98	24	–	54	–	913	–	656	–	29	–
1998–99	21	18	79	79	903	738	872	533	27	45
1999–00	27	18	82	79	862	738	821	533	28	45
2000–01	25	18	81	79	798	738	840	533	19	45
2001–02	41	18	89	79	720	1 000	910	533	22	45
2002–03	19	18	78	79	696	1 000	1 685	533	25	45
2003–04	30	18	80	79	440	1 000	1 287	533	28	45
2004–05	27	18	104	79	372	1 000	894	910	24	45
2005–06	40	18	73	79	436	1 000	502	910	24	45
2006–07	30	33	98	79	519	1 000	591	910	31	45
2007–08	38	33	91	79	422	1 000	568	910	20	45
2008–09	27	33	46	79	328	1 000	338	910	13	45
2009–10	47	33	53	79	428	1 000	345	910	21	45
2010–11	53	33	83	79	644	1 000	572	910	24	45
2011–12	50	33	55	79	349	1 000	555	910	17	45
2012–13	40	33	43	79	495	1 000	492	910	27	45
2013–14	47	53	69	79	500	1 000	332	910	22	45
2014–15	32	53	42	79	734	1 000	475	910	15	45
2015–16	38	53	44	79	774	1 000	436	910	37	45
2016–17	44	53	49	79	589	1 000	424	910	24	45
2017–18	52	53	54	79	625	1 000	490	910	14	45
2018–19	53	53	46	79	555	1 000	432	910	23	45
2019–20	42	53	33	79	497	1 000	442	910	16	45
2020–21	41	53	34	79	412	1 000	405	910	22	45

Fishstock FMA	SPE 7 7		SPE 8 8		SPE 9 9		SPE 10 10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84	16	–	2	–	55	–	0	–	333	–
1984–85	14	–	1	–	2	–	0	–	415	–
1985–86	12	–	2	–	4	–	0	–	493	–
1986–87	11	–	3	–	1	–	0	–	633	–
1987–88	8	–	6	–	0	–	0	–	660	–
1988–89	5	–	2	–	1	–	0	–	339	–
1989–90	14	–	1	–	0	–	0	–	496	–
1990–91	28	–	1	–	0	–	0	–	703	–
1991–92	20	–	2	–	0	–	0	–	1 091	–
1992–93	71	–	18	–	0	–	2	–	1 276	–
1993–94	52	–	10	–	0	–	0	–	1 045	–
1994–95	67	–	7	–	0	–	0	–	1 224	–
1995–96	78	–	7	–	1	–	0	–	1 672	–
1996–97	64	–	7	–	1	–	< 1	–	1 304	–
1997–98	118	–	5	–	7	–	< 1	–	1 807	

Table 3 [Continued]

	SPE 7 7		SPE 8 8		SPE 9 9		SPE 10 10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1998–99	109	82	< 1	15	2	6	0	0	2 014	1 516
1999–00	80	82	2	15	5	6	0	0	1 907	1 516
2000–01	80	82	4	15	3	6	0	0	1 850	1 778
2001–02	95	82	6	15	3	6	0	0	1 886	1 778
2002–03	103	82	4	15	4	6	0	0	2 614	1 778
2003–04	95	82	6	15	3	6	0	0	1 969	1 778
2004–05	47	82	5	15	2	6	0	0	1 475	2 155
2005–06	75	82	5	15	2	6	0	0	1 157	2 155
2006–07	67	82	2	15	2	6	0	0	1 340	2 170
2007–08	103	82	2	15	2	6	0	0	1 246	2 170
2008–09	96	82	2	15	4	6	0	0	854	2 170
2009–10	117	82	4	15	3	6	0	0	1 018	2 170
2010–11	124	82	3	15	2	6	0	0	1 505	2 170
2011–12	82	82	3	15	3	6	0	0	1 115	2 170
2012–13	89	82	4	15	4	6	0	0	1 197	2 170
2013–14	100	82	4	15	5	6	0	0	1 077	2 190
2014–15	118	82	4	15	7	6	0	0	1 427	2 190
2015–16	89	82	4	15	7	6	0	0	1 428	2 190
2016–17	90	82	3	15	9	6	0	0	1 232	2 190
2017–18	118	82	4	15	11	6	0	0	1 368	2 190
2018–19	47	82	3	15	8	6	0	0	1 166	2 190
2019–20	57	82	2	15	6	6	0	0	1 097	2 190
2020–21	62	82	2	15	5	10	< 1	0	984	2 194

The trawl fisheries operating in SPE 4 catch sea perch along the northern and southern edge of the Chatham Rise in the 200–700 m depth range. The majority of the SPE 4 catch is taken as a bycatch of the hoki target fishery (about 59%), with the ling and hake fisheries accounting for around 25% and 10% of the total SPE 4 catch, respectively.
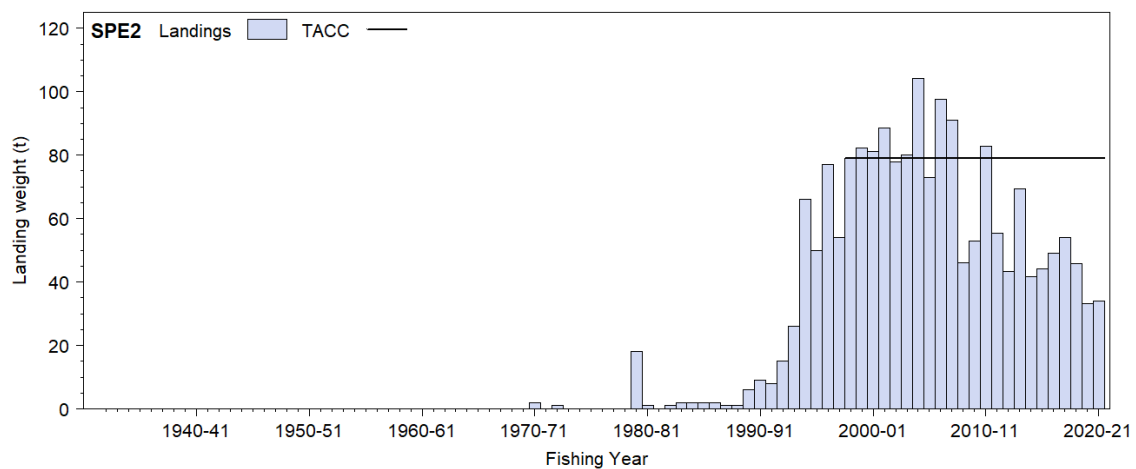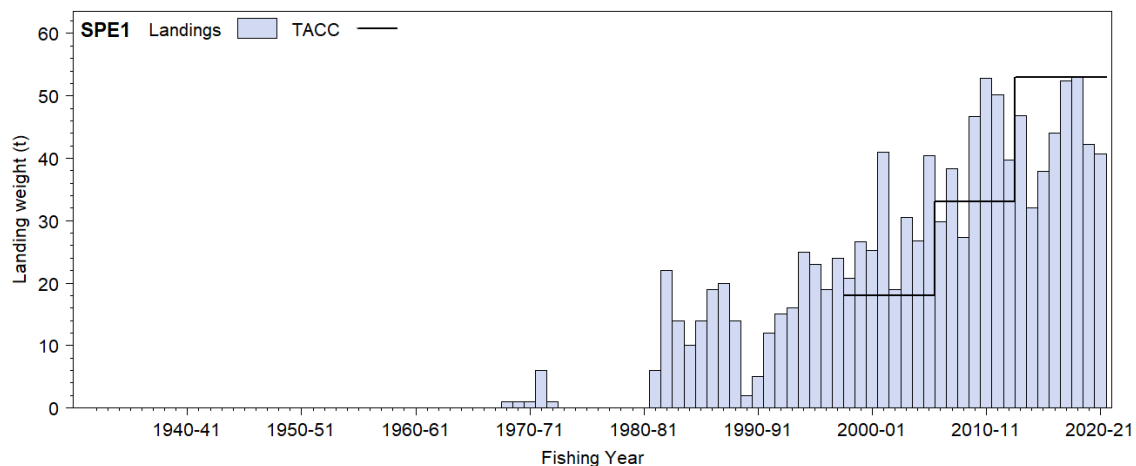
Figure 1: Reported commercial landings and TACC for the five main SPE stocks. SPE 1 (Auckland East) and SPE 2 (Central East)) [Continued on next page]
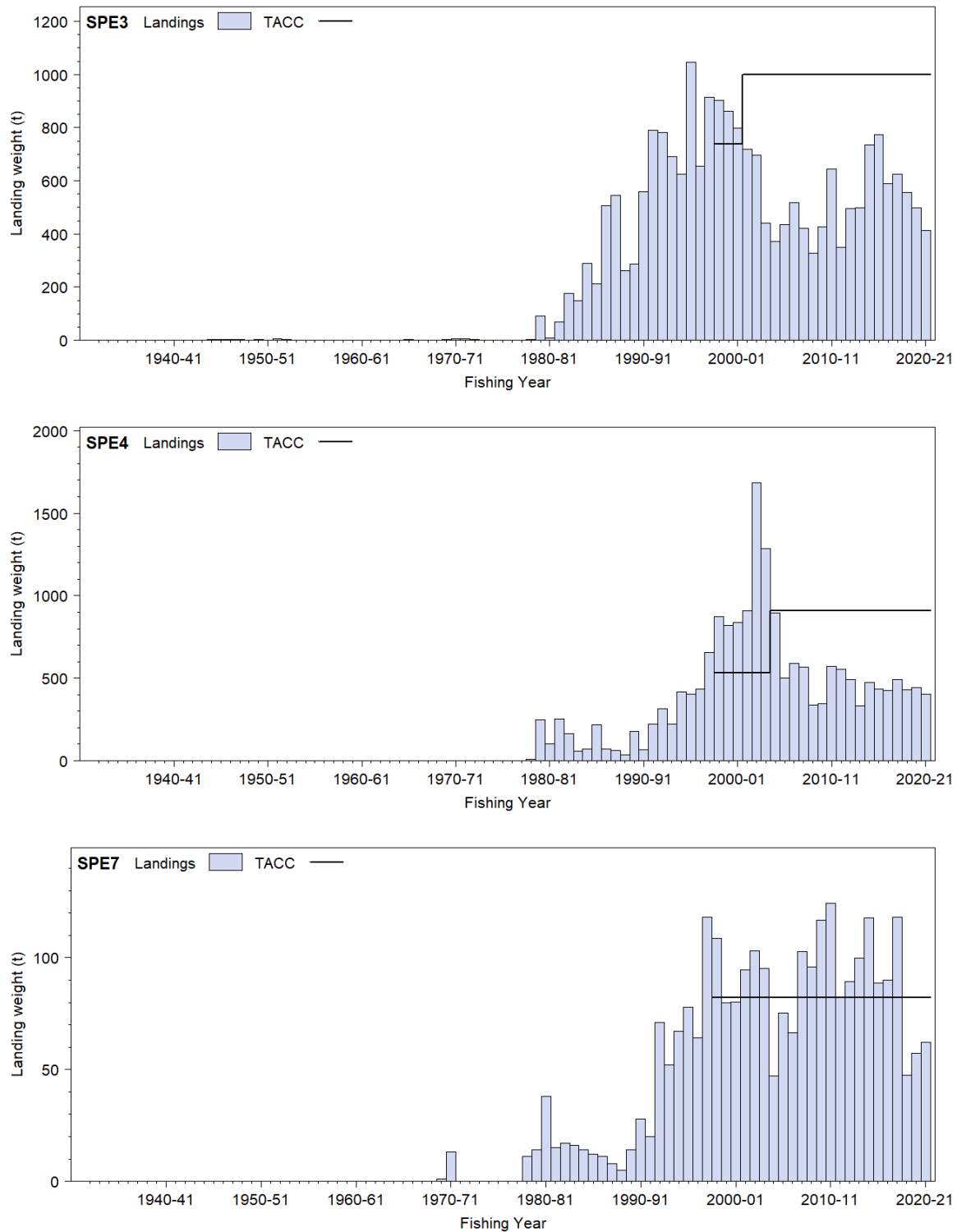
Figure 1 [Continued]: Reported commercial landings and TACC for the five main SPE stocks. SPE 3 (South East Coast), SPE 4 (South East Chatham Rise), and SPE 7 (Challenger).

1.2 Recreational fisheries

Sea perch are seldom targeted by recreational fishers but are widely caught in reasonable numbers. Some are used for bait, and many were likely to have been discarded in the past. The quality of sea perch as an eating fish has been increasingly recognised and they are now less likely to be discarded. They are predominantly taken by rod and reel (98.6%) with a small proportion taken by longline (1%). The catch is taken predominantly from boats (93.7%) with a small proportion from land based fishers (3%). The allowances within the TAC for each Fishstock are shown in Table 1.

1.2.1 Management controls

The main method used to manage recreational harvests of sea perch are minimum legal size (MLS) and daily bag limits. General spatial and method restrictions also apply. A sea perch MLS for recreational fishers of 26 cm applies only in the Kaikōura Marine Area. Fishers can take up to 20 sea perch as part of their combined daily bag limit in Kaikōura Marine Area. Fishers can take up to 10 sea perch as part of their combined daily bag limit in the Fiordland Marine Area. No bag limit is currently in place in the Auckland, Central, Challenger, South-East, or Southland Fishery Management Areas.

1.2.2 Estimates of recreational harvest

There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and offsite methods where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest for sea perch were calculated using offsite telephone-diary surveys between 1991 and 2000 (Table 4, from Teirney et al 1997, Bradford 1998, Boyd & Reilly 2004). The harvest estimates provided by these telephone-diary surveys are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries.

Table 4: Estimated number and weight of sea perch recreational harvest by Fishstock and survey. Regional surveys were carried out in different years in the MAF Fisheries regions: South in 1991–92, Central in 1992–93, North in 1993–94 (Teirney et al 1997), and national surveys took place in 1996 (Bradford 1998) and 1999–00 (Boyd & Reilly 2004). National panel surveys were conducted in 2011–12 and 2017–18 (Wynne-Jones et al 2014, 2019) using mean weights from boat ramp surveys (Hartill & Davey 2015, Davey et al 2019).

Fishstock	Survey	Number	Harvest (t)	CV%
1991–92				
SPE 3	South	110 000		25
SPE 5	South	18 000		35
SPE 7	South	16 000		–
1992–93				
SPE 2	Central	27 000		–
SPE 3	Central	< 500		–
SPE 5	Central	< 500		–
SPE 7	Central	65 000		40
SPE 8	Central	11 000		–
1993–94				
SPE 1 + 9	North	< 500		–
SPE 2	North	< 500		–
SPE 8	North	< 500		–
1996				
SPE 1 + 9	National	2000		37
SPE 2	National	23 000		–
SPE 3	National	28 000		17
SPE 5	National	3000		–
SPE 7	National	20 000		17
SPE 8	National	11 000		–
1999–00				
SPE 2	National	10 000		94
SPE 2	National	16 000		64
SPE 3	National	154 000		38
SPE 5	National	10 000		58
SPE 7	National	63 000		46
SPE 8	National	< 500		101
2011–12				
SPE 1	Panel	1 464	0.7	40
SPE 2	Panel	8 165	4.3	33
SPE 3	Panel	113 955	57.1	25
SPE 5	Panel	4 517	2.1	57
SPE 7	Panel	28 781	12.6	39
SPE 8	Panel	3 699	1.7	48
2017–18				
SPE 1	Panel	478	0.2	87
SPE 2	Panel	3 287	1.6	40
SPE 3	Panel	67 712	40.5	24
SPE 5	Panel	27 993	13.2	89
SPE 7	Panel	13 824	5.4	29
SPE 8	Panel	3 654	1.7	67

In response to these problems and the cost and scale challenges associated with onsite methods, a national panel survey was conducted for the first time throughout the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year (Wynne-Jones et al 2014). The panel members were contacted regularly about their fishing activities and harvest information in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 4. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

1.3 Customary non-commercial fisheries
The customary non-commercial take has not been quantified.

1.4 Illegal catch
There is no quantitative information on illegal fishing activity or catch, and given the low commercial value of sea perch, such activity is unlikely.

1.5 Other sources of mortality
No quantitative estimates are available about the impact of other sources of mortality on sea perch stocks. However, they are commonly caught as bycatch and a moderate quantity, particularly of small fish, is undoubtedly discarded.

2. BIOLOGY

Sea perch are widely distributed around most of New Zealand, but are rare on the Campbell Plateau. They inhabit waters ranging from the shoreline to 1200 m and are most common between 150 and 500 m. *Helicolenus percoides* occur in depths shallower than 250 m, with a peak at around 150 m, whereas *H. barathri* occur in about 300–1000 m, with a peak at around 600 m (Bentley et al 2014).

Sea perch are viviparous, extruding small larvae in floating jelly masses during an extended spawning season. Sex ratios observed in trawl survey samples show more males, generally in the range 1:0.7 to 1:0.8. Sea perch are opportunistic feeders and prey on a variety of animals on or close to the seafloor.

Table 5: Estimates of biological parameters for sea perch. ECSI = East Coast South Island, CR = Chatham Rise. Sea perch from SPE 3 are predominantly *H. percoides* and those from the SPE4 are predominantly *H. barathri*. Ageing material was collected from the Chatham Rise (SPE 4) and East Coast South Island inshore trawl survey.

Fishstock	Estimate	Source
1. Natural mortality (*M*)		
SPE 3 (ECSI)	0.12 (Hoenig method)	Paul & Horn (2009)
SPE 4 (CR)	0.07 (Hoenig method)	Paul & Horn (2009)

2. Weight = a (length)^b (Weight in g, length in cm fork length)

		Both sexes	
	a	b	
SPE 3	0.007767	3.219132	Schofield & Livingston (1996)

3. von Bertalanffy growth parameters

	Females			Males			
	K	t_0	L_∞	K	t_0	L_∞	
SPE 3 (ECSI)	0.123	-1.05	38.7	0.119	-0.79	42.13	Paul & Horn (2009)
SPE 4 (CR)	0.062	-3.93	46.34	0.074	-2.51	45.5	Paul & Horn (2009)

For both species, growth is relatively slow throughout life. After about age 5 years, male *H. percoides* grow faster than females. Males mature at 19–25 cm, about 5−7 years, whereas females mature at between 15 and 20 cm, around 5 years (Paul & Francis 2002). Male and female *H. barathri* appear to grow at similar rates. Maximum observed ages estimated for sea perch from the east coast South Island (*H. percoides*) and Chatham Rise (*H. barathri*) were 35 and 59 years, respectively. The natural mortality

estimates derived from these are 0.12 and 0.07 (using the Hoenig method) (Paul & Horn 2009). The maximum size for sea perch is about 56 cm.

Biological parameters relevant to stock assessment are shown in Table 5.

3. STOCKS AND AREAS

There are no data relevant to stock boundaries. However, regional variation in colouration suggests that separate populations could exist.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

4.1.1 Biomass estimates

Indices of relative biomass are available from recent *Tangaroa* and *Kaharoa* trawl surveys of the Chatham Rise, east coast South Island (ECSI), and west coast South Island (WCSI) (Figures 2–5, Table 6).

West coast South Island inshore trawl survey

Although the depth range of *H. percoides* is appropriately covered by the WCSI inshore time series, the survey is not optimised for them and they are not a target species. The depth range for this survey is 30–400 m off the west coast of the South Island and >10 m in Tasman Bay and Golden Bay (MacGibbon & Stevenson 2013). Nearly all the sea perch caught during the WCSI winter time series are likely to have been *H. percoides* because only small numbers of *H. barathri* were caught in 2021, and these were in depths over 330 m. No distinction has been made between *H. percoides* and *H. barathri* on previous surveys. Biomass estimates increased from 1991 to 1995, declined to well below the series average by 2003, increased to a second peak in 2011, and then dropped 10-fold from then until 2021 (Figure 2).
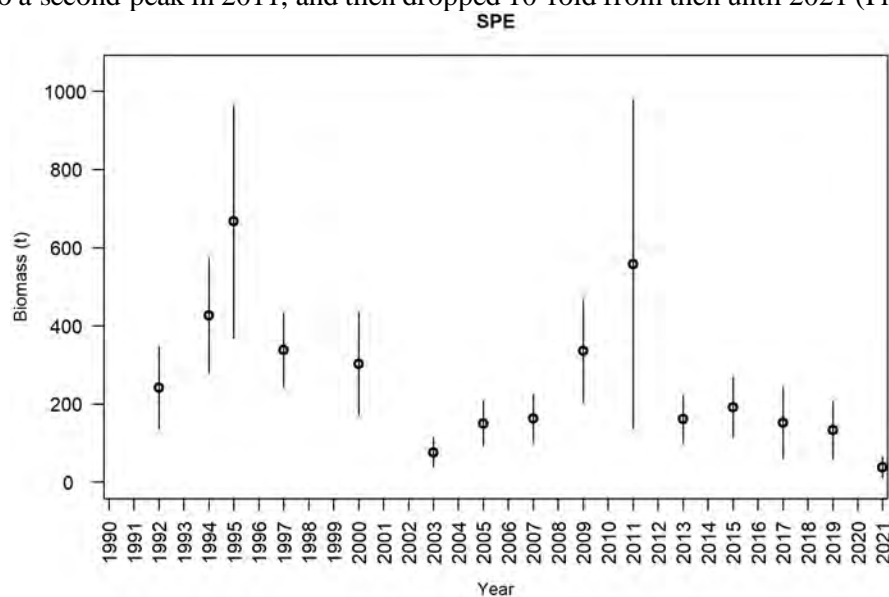
Figure 2: Biomass estimates from the West Coast South Island inshore trawl survey. Error bars are ±2 standard errors.

Chatham Rise trawl survey

The Chatham Rise trawl survey was designed primarily for hoki and covers the core depth range 200–800 m. It therefore excludes a small portion of sea perch habitat around the Mernoo Bank in less than 200 m. *Helicolenus barathri* comprised 89% of the 2020 and 97% of 2022 sea perch biomass estimates. No distinction has been made between *H. percoides* and *H. barathri* on previous surveys. The survey biomass estimates for sea perch have fluctuated without trend since 1999 (Figure 3). The size composition of sea perch caught by the Chatham Rise survey includes a substantial proportion of fish in the 30–45 cm total length range.
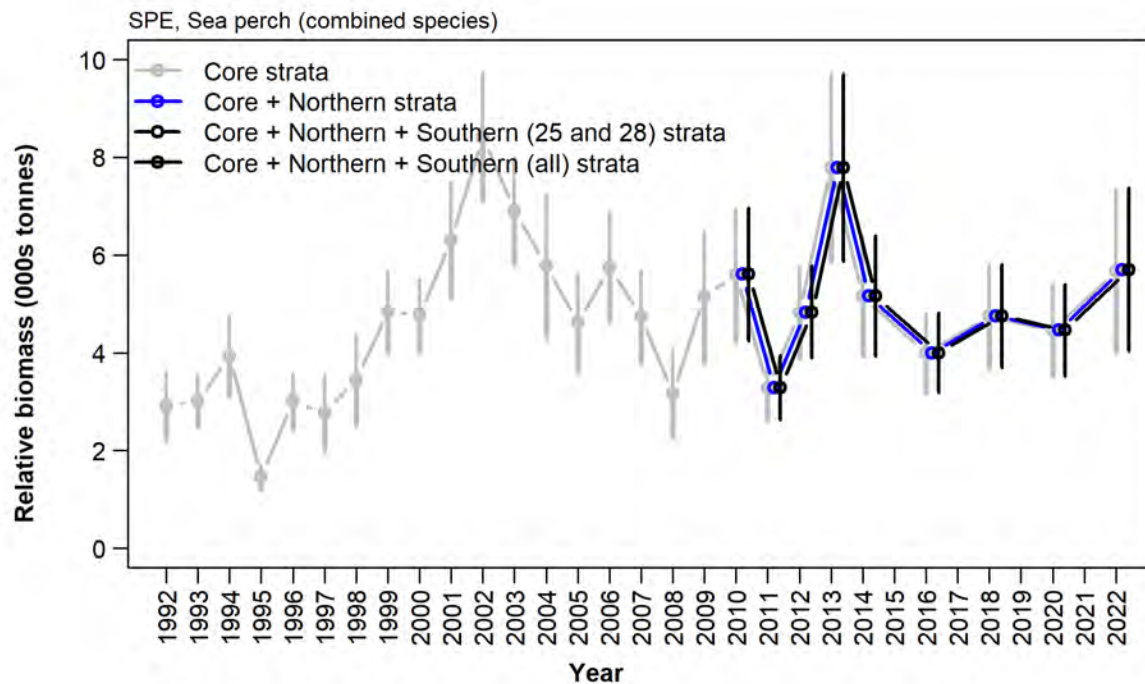
Figure 3: Biomass estimates from the Chatham Rise survey. Error bars are ± 2 standard errors. Core strata are 200–800 m. The other estimates include deeper strata (800–1300 m), where few sea perch are caught.

East coast South Island trawl survey

The ECSI winter surveys from 1991 to 1996 (depth range 30–400 m) were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range, but these were discontinued after the fifth in the annual time series because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007, and this time included strata in the 10–30 m depth range to monitor elephantfish and red gurnard which were officially included in the list of target species in 2012. Six surveys (2007, 2012, 2014, 2016, 2018, and 2021) provide full coverage of the 10–30 m depth range. Sea perch are, however, not caught in the shallow strata.

Nearly all the sea perch caught during the ECSI winter time series are likely to have been *H. percoides* because only small numbers of *H. barathri* were caught in 2021, and these were in depths greater than 330 m. No distinction has been made between *H. percoides* and *H. barathri* on previous surveys.

Sea perch biomass shows no trend over the core strata time series although biomass fluctuates with strong peaks and troughs (see Table 6, Figure 4) (Beentjes et al in prep). The biomass declined by 33% in 2018 following the time series high in 2016 and declined again by 28% in 2021. Pre-recruit biomass has remained a small and reasonably constant component of the total biomass estimate on all surveys (3–8% of total core strata biomass) and in 2021 it was 8%. The juvenile to adult biomass ratio (based on length-at-50% maturity) was relatively constant over the time series at 23–36% juvenile, and in 2021 it was 29% juvenile (Figure 5). There was no sea perch catch in the 10–30 m strata and hence the addition of the shallow strata in 2007 is of no value for monitoring sea perch.

The spatial distribution of sea perch hot spots within the survey area varies, but overall this species is consistently well represented over the entire survey area, most commonly from about 70 to 300 m. The size distributions of sea perch on each of the thirteen ECSI winter surveys were similar and generally unimodal with a right hand tail reflecting the large number of age classes (Beentjes et al in prep).
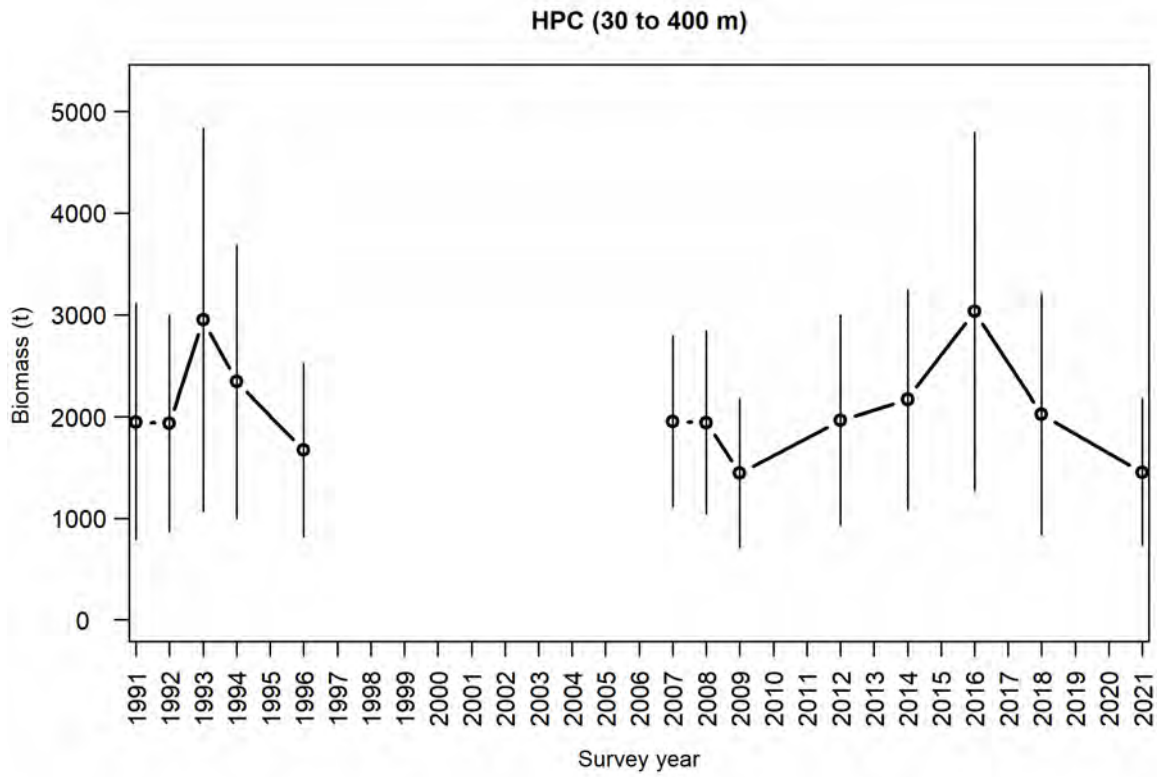
Figure 4: Sea perch total biomass for ECSI winter surveys in core strata (30–400m). Error bars are ± 2 standard errors. The scientific species code for sea perch (*Helicolenus percoides*) has been changed from SPE to HPC.
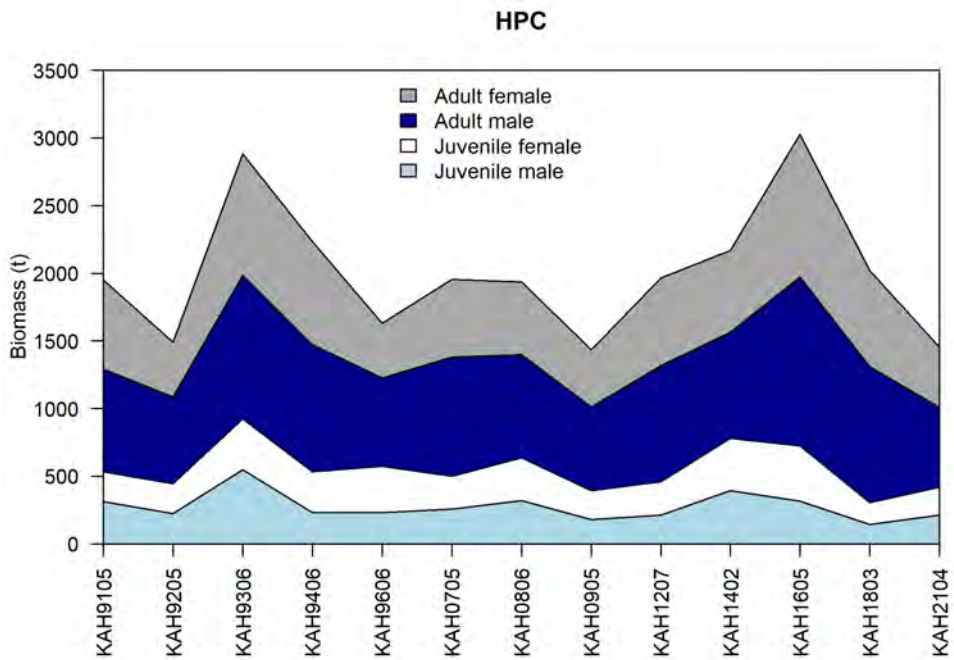
Figure 5: Sea perch juvenile and adult biomass for ECSI winter surveys in core strata (30–400 m), where juvenile is below and adult is equal to or above length at which 50% of fish are mature. The scientific species code for sea perch (*Helicolenus percoides*) has been changed from SPE to HPC.

Table 6: Relative biomass indices (t) and coefficients of variation (CV) for sea perch for east coast South Island (ECSI) summer and winter, west coast South Island (WCSI), the Stewart-Snares islands survey areas, and the Chatham Rise*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16, and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. –, not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (20 cm). [Continued on next page]

Region	Fishstock	Year	Trip number	Biomass estimate	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)
ECSI(winter)	SPE 3				30–400 m		30–400 m		30–400 m
		1991	KAH9105	1 716	30	70	44	1 483	30
		1992	KAH9205	1 934	28	51	28	1 441	28
		1993	KAH9306	2 948	32	178	76	2 770	30
		1994	KAH9406	2 342	29	78	24	2 264	29
		1996	KAH9606	1 671	26	58	45	1 613	25
		2007	KAH0705	1 954	22	74	18	1 880	22
		2008	KAH0806	1 944	23	144	20	1 800	24
		2009	KAH0905	1 444	25	82	18	1 363	26
		2012	KAH1207	1 964	26	66	25	1 898	27
		2014	KAH1402	2 168	25	182	29	1 986	26
		2016	KAH1605	3 032	29	109	25	2 923	30
		2018	KAH1803	2 023	29	64	19	1 959	30
		2021	KAH2104	1 453	25	120	28	1 333	26
ECSI(summer)	SPE 3	1996–97	KAH9618	4 041	47	–	–	–	–
		1997–98	KAH9704	1 638	25	–	–	–	–
		1998–99	KAH9809	3 889	41	–	–	–	–
		1999–00	KAH9917	2 203	27	–	–	–	–
		2000–01	KAH0014	1 792	20	–	–	–	–
WCSI	SPE 7	1992	KAH9204	293	24	–	–	–	–
		1994	KAH9404	510	18	–	–	–	–
		1995	KAH9504	667	23	–	–	–	–
		1997	KAH9701	338	14	–	–	–	–
		2000	KAH0004	302	22	–	–	–	–
		2003	KAH0304	76	25	–	–	–	–
		2005	KAH0503	150	20	–	–	–	–
		2007	KAH0704	163	19	–	–	–	–
		2009	KAH0904	336	20	–	–	–	–
		2010	KAH1004	558	39	–	–	–	–
		2013	KAH1305	161	20	–	–	–	–
Stewart-Snares	SPE 5	1993	TAN9301	469	33				
		1994	TAN9402	443	26				
		1995	TAN9502	450	27				
		1996	TAN9604	480	29				
Chatham Rise	SPE 4	1991	TAN9106	3 050	12				
		1992	TAN9212	3 110	9				
		1994	TAN9401	3 914	11				
		1995	TAN9501	1 490	9				
		1996	TAN9601	3 006	10				
		1997	TAN9701	2 713	14				
		1998	TAN9801	3 448	14				
		1999	TAN9901	4 842	9				
		2000	TAN0001	4 776	8				
		2001	TAN0101	6 310	10				
		2002	TAN0201	8 417	8				
		2003	TAN0301	6 904	8				
		2004	TAN0401	5 786	13				
		2005	TAN0501	4 615	11				
		2006	TAN0601	5 752	10				
		2007	TAN0701	4 737	10				
		2008	TAN0801	3 081	14				
		2009	TAN0901	5 149	13				
		2010	TAN1001	5 594	12				
		2011	TAN1101	3 278	10				
		2012	TAN1201	4 827	10				
		2013	TAN1301	7 785	13				
		2014	TAN1401	5 158	12				
		2016	TAN1601	3 989	10				

Table 6 [continued]

Region	Fishstock	Year	Trip	Biomass	CV (%)
Chatham Rise	SPE 4	2018	TAN1801	4 749	11
		2020	TAN2001	4 460	11
		2022	TAN2201	5 671	15

4.2 Yield estimates and projections

Factors influencing yield estimates (species identification, catch history, biomass estimates, longevity/mortality, and natural fluctuations in population size) are poorly known for sea perch and preclude any reliable yield estimates at present.

5. FUTURE RESEARCH CONSIDERATIONS

- Investigate methods for apportioning historical survey catch by species for the ECSI, WCSI, and Chatham Rise surveys.
- Develop reference points and undertake partial quantitative stock assessments for *H. percoides* in SPE 3 and SPE 7 and *H. barathri* in SPE 4.

6. STATUS OF THE STOCKS

No estimates of current and reference biomass are available. For all SPE Fishstocks, it is not known if recent catch levels are sustainable.

7. FOR FURTHER INFORMATION

Bagley, N W; Hurst, R J (1996) Trawl survey of middle depth and inshore bottom species off Southland, February-March 1995 (TAN9502). *New Zealand Fisheries Data Report No. 73.* 48 p.

Beentjes, M P; Horn, P L; Bagley, N W (2007) Characterisation of the Chatham Rise sea perch fishery. *New Zealand Fisheries Assessment Report 2007/16.* 84 p.

Beentjes, M P; MacGibbon, D J; Ladroit, Y (in prep) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2021 (KAH2104). Draft New Zealand Fisheries Assessment Report.

Beentjes, M P; MacGibbon, D; Parkinson, D (2016) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2016 (KAH1605). *New Zealand Fisheries Assessment Report 2016/61.* 135 p.

Bentley, N; Kendrick, T H; MacGibbon, D J (2014). Fishery characterisation and catch-per-unit-effort analyses for sea perch (*Helicolenus* spp.) in New Zealand, 1989–90 to 2009–10. *New Zealand Fisheries Assessment Report 2014/27* 181 p.

Boyd, R O; Reilly, J L (2004) 1999/2000 National Marine Recreational Fishing Survey: harvest estimates. (Unpublished New Zealand Fisheries Assessment Research Report for the Ministry of Fisheries Project REC9803 held by Fisheries New Zealand, Wellington.) 28 p.

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished report held by NIWA library, Wellington.)

Challenger Finfish Management Company (CFMC) (2001) Performance of the SPO 7 Adaptive Management Programme dated 7 May 2001. (Unpublished report held by Fisheries New Zealand.)

Davey, N; Hartill, B; Carter, M (2019) Mean weight estimates for recreational fisheries in 2017–18. *New Zealand Fisheries Assessment Report 2019/25.* 36 p.

DOC, MFish. (2007) Department of Conservation and Ministry of Fisheries. Hector's and Maui's dolphin Threat Management Plan, 29 August 2007. Available at www.fish.govt.nz/en-nz/Environmental.

Francis, R I C C; Hurst, R J; Renwick, J A (2001) An evaluation of catchability assumptions in New Zealand stock assessments. *New Zealand Fisheries Assessment Report 2001/1.* 37 p.

Francis, M P; Paul, L J (2013) New Zealand inshore finfish and shellfish commercial landings, 1931–82. *New Zealand Fisheries Assessment Report 2013/55.* 136 p.

Hart, A M; Walker, N A (2004) Monitoring the recreational blue cod and sea perch fishery in the Kaikoura - North Canterbury area. *New Zealand Fisheries Assessment Report 2004/45.* 88 p.

Hartill, B; Davey, N (2015) Mean weight estimates for recreational fisheries in 2011–12. *New Zealand Fisheries Assessment Report 2015/25.* 37 p.

Livingston, M E; Bull, B; Stevens, D W; Bagley, N W (2002) A review of hoki and middle depths trawl surveys of the Chatham Rise, January 1992–2001. *NIWA Technical Report 113.* 146 p.

MacGibbon, D J; Beentjes, M P; Lyon, W L; Ladroit, Y (2019) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2018 (KAH1803). *New Zealand Fisheries Assessment Report 2019/03.* 136 p.

MacGibbon, D J; Stevenson, M L (2013) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2013 (KAH1305). *New Zealand Fisheries Assessment Report 2013/66.* 115 p.

MacGibbon, D J; Walsh, C; Buckthought, D; Bian, R (2022) Inshore trawl survey off the west coast South Island and in Tasman Bay and Golden Bay, March–April 2021 (KAH2103). *New Zealand Fisheries Assessment Report 2022/11.* 97 p.

Park, T J (1994) Ocean perch, *Helicolenus* sp. In: Tilzey, R D J (Ed.), pp. 237–246. *The South East Fishery. A scientific review with particular reference to quota management.* Bureau of Resource Sciences, Canberra. 360 p.

Paul, L J (1998) A summary of biology and commercial landings, and a stock assessment of the sea perches, *Helicolenus* spp. (Scorpaenidae) in New Zealand waters. New Zealand Fisheries Assessment Research Document 1998/29. 30 p. (Unpublished report held by NIWA library, Wellington.)

Paul, L J; Francis, M P (2002) Estimates of age, growth, and mortality parameters of sea perch (*Helicolenus percoides*) off the east coast of the South Island, New Zealand. Final Research Report for Ministry of Fisheries Research Project SPE2000/01 Objectives 1 & 2. (Unpublished document held by Fisheries New Zealand.)

Paul, L J; Horn, P L (2009) Age and growth of sea perch (*Helicolenus percoides*) from two adjacent areas off the east coast of South Island, New Zealand. *Fisheries Research 95*: 169–180.

Paulin, C D (1982) Scorpion fishes of New Zealand. *New Zealand Journal of Zoology 9(4)*: 437–450.

Paulin, C D (1989) Redescription of *Helicolenus percoides* (Richardson) and *H. barathri* (Hector) from New Zealand (Pisces, Scorpaenidae). *Journal of the Royal Society of New Zealand 19(3)*: 319–325.

Roberts C D; Stewart, A L; Struthers C D (Eds) (2015) *The Fishes of New Zealand*. Te Papa Press, Wellington. Vols. 1–4. 2008 p.

Schofield, K A; Livingston, M E (1996) Trawl survey of hoki and middle depth species on the Chatham Rise, January 1996 (TAN9601). *New Zealand Fisheries Data Report No. 71*. 50 p.

Seafood Industry Council (SeaFIC) (2003a) 2003 performance report SPE 3 Adaptive Management Programme. AMP-WG-2003/05 11 p. (Unpublished report held by Fisheries New Zealand.)

Seafood Industry Council (SeaFIC) (2003b) 2004 performance report SPE 3 Adaptive Management Programme. AMP-WG-2004/05 11 p. (Unpublished report held by Fisheries New Zealand.)

Seafood Industry Council (SeaFIC) (2004) Report to the Adaptive Management Fishery Assessment Working Group: Performance of the SPE 3 Adaptive Management Programme. AMP-WG-2004/07 53 p. (Unpublished report held by Fisheries New Zealand.)

Smith, P (1998) Molecular identification of sea perch species. Final Report to the Ministry of Fisheries for Project MOF706. 17p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Southeast Finfish Management Company (SEFMC) (2001) SPE 3 Adaptive Management Programme Proposal - 2001 dated 7 May 2001.

Starr, P; Langley, A (2000) Inshore fishery observer programme for Hector's dolphins in Pegasus Bay, Canterbury Bight, 1997/98. Published client report on contract, 3020.

Starr, P J; Kendrick, T H; Bentley, N; Lydon, G J (2008) Review of the SPE 3 Adaptive Management Programme. 82 p. (Unpublished manuscript available from the NZ Seafood Industry Council, Wellington.)

Starr, P J; Kendrick, T H; Lydon, G J (2006) Full Term Review of the SPE 3 Adaptive Management Programme. 71 p. (Unpublished manuscript available from the NZ Seafood Industry Council, Wellington.)

Stevens, D W; O'Driscoll, R L; Ballara, S L; Ladroit, Y (2017) Trawl survey of hoki and middle-depth species on the Chatham Rise, January 2016 (TAN1601). *New Zealand Fisheries Assessment Report 2017/08*. 131 p.

Stevens, D W; O'Driscoll, R L; Dunn, M R; Ballara, S L; Horn, P L (2012) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2011 (TAN1101). *New Zealand Fisheries Assessment Report 2012/10*. 98 p.

Stevens, D W; O'Driscoll, R L; Ladroit, Y; Ballara, S L; MacGibbon, D J; Horn, P L (2015) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2014 (TAN1401). *New Zealand Fisheries Assessment Report 2015/19*. 119 p.

Stevens, D W; O'Driscoll, R L; Oeffner, J; Ballara, S L; Horn, P L (2014) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2013 (TAN1301). *New Zealand Fisheries Assessment Report 2014/02*. 110 p.

Stewart, P (Comp.) (1993) Ocean perch. *In:* Kailola, P J; Williams, M J; Stewart, P C; Reichelt, R E; McNee, A; Grieve, C (Eds.), pp. 241–242. *Australian Fisheries Resources*. Bureau of Resource Sciences, Canberra. 422 p.

Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94 New Zealand. Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished report held by NIWA library, Wellington.)

Withell, A F; Wankowski, J W (1988) Estimates of age and growth of ocean perch. *Helicolenus percoides* Richardson, in south-eastern Australian waters. *Australian Journal of Marine and Freshwater Research 39(4)*: 441–457.

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/14*. 108 p

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*.

SILVER WAREHOU (SWA)

(*Seriolella punctata*)
Warehou
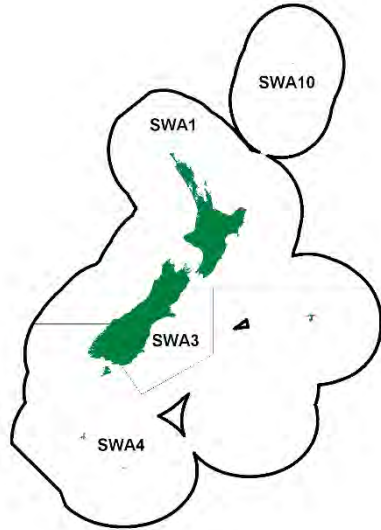
1. FISHERY SUMMARY

1.1 Commercial fisheries

Silver warehou entered the Quota Management System (QMS) on 1 October 1986. Silver warehou are common around the South Island and on the Chatham Rise in depths of 200–800 m. The majority of the commercial catch is taken from the Chatham Rise, Canterbury Bight, southeast of Stewart Island, and off the west coast of the South Island. Reported landings by nation from 1974 to 1987–88 are shown in Table 1.

Table 1: Reported landings (t) by nation from 1974 to 1987–88. Source: 1974–1978 (Paul 1980); 1978 to 1987–88 (FSU).

Fishing Year	New Zealand				Foreign Licensed				Grand Total
	Domestic	Chartered	Total	Japan	Korea	USSR	Total		
1974*									7 412
1975*									6 869
1976*	estimated as 70% of total warehou landings								13 142
1977*									12 966
1978*									12 581
1978–79**	?	629	629	3 868	122	212	4 203		4 832
1979–80**	?	3 466	3 466	4 431	217	196	4 843		8 309
1980–81**	?	2 397	2 397	1 246	-	13	1 259		3 656
1981–81**	?	2 184	2 184	1 174	186	3	1 363		3 547
1982–83**	?	3 363	3 363	1 162	265	189	1 616		4 979
1983†	?	1 556	1 556	510	98	3	611		2 167
1983–84§#	303	3 249	3 552	418	194	3	615		4 167
1984–85§#	203	4 754	4 957	1 348	387	15	1 749		6 706
1985–86§#	276	5 132	5 408	1 424	217	5	1 646		7 054
1986–87§#	261	4 565	4 826	1 169	29	100	1 299		6 125
1987–88§#	499	7 008	7 507	431	111	39	581		8 088

* Calendar year.
**1 April to 31 March.
†1 April to 30 September.
§1 October to 30 September.
Totals do not match those in Table 2. Data were collected independently and there was known under-reporting to the FSU in 1987–88. This needs to be resolved.

Commercial fishing for silver warehou developed in the late 1960s and early 1970s. Before the establishment of the Exclusive Economic Zone (EEZ), silver warehou, common or blue warehou, and white warehou were all lumped under the category of "warehous". Estimated total annual catches of silver warehou based on area of capture were about 13 000 t in 1976, 1977, and 1978 (Paul 1980, Livingston 1988; Table 1). Concern about overfishing on the eastern Stewart-Snares shelf led to closure of this area to trawlers between October 1977 and January 1978. Initially, effort shifted to the Chatham

Rise and total estimated catch did not change (Ministry of Fisheries 2010). The catches did drop significantly after the establishment of the EEZ, and the reported landings fluctuated between 3000 t and 8000 t from 1978–79 to 1986–87 (Livingston 1988; Table 1 and Table 2).

Some target fishing for silver warehou does still occur, predominantly on the Mernoo Bank and along the Stewart-Snares shelf. Recent reported landings are shown in Table 2, and Figure 1 shows the historical landings and TACC values for the main SWA stocks.

SWA 1

In recent years, most of the silver warehou catch has been taken as a bycatch of the hoki, squid, barracouta and jack mackerel trawl fisheries. Landings from SWA 1 increased substantially after 1985–86 following the development of the west coast South Island hoki fishery. Overruns of the TAC probably partly reflected the hoki fleet fishing in relatively shallow water (northern grounds) in the later part of the season, but could also have reflected changes in abundance.

The TACC in SWA 1 was increased in 1991–92 under the Adaptive Management Programme (AMP). A review of this Fishstock at the completion of 5 years in the AMP concluded that it was not known if the current TACC would be sustainable and an appropriate monitoring programme was not in place. Under the criteria developed for the AMP the Minister therefore removed this Fishstock from the AMP in October 1997 and set the TACC at 2132 t. A new AMP proposal in 2002 resulted in the TACC being increased to 3000 t from 1 October 2002, with 1 t customary and 2 t recreational allowances within a TAC of 3003 t. Landings have not approached the new TACC level in recent years because reductions in the hoki quota have resulted in much less effort on the WCSI in winter; under 550 t were landed annually from 2017–18 to 2019–20.

SWA 3 and 4

In most years from 2000–01 to 2006–07, landings in SWA 3 and SWA 4 were well above the TACCs because fishers landed catches well in excess of ACE holdings and paid deemed values for the overcatch. From 1 October 2007 the deemed values were increased to $1.22 per kg for all SWA stocks and two differential rates were also introduced. The second differential rate applies to all catch over 130% of ACE holding at which point the deemed value rate increased to $3 per kg. The effect of these measures was seen immediately in 2007–08 as fishing without ACE was reduced and catch fell below the TACCs in both SWA 3 and SWA 4. Landings have generally been fluctuating around the TACCs in SWA 3 since then. SWA 4 landings consistently exceeded the TACC during the fishing years 2016–17 to 2018–19, but fell to just below the TACC in 2019–20.

Table 2: Reported landings (t) of silver warehou by Fishstock from 1983–84 to present and TACCs (t) from 1986–87 to present. QMS data from 1986–present. [Continued on next page]

Fishstock	SWA 1		SWA 3		SWA 4		SWA 10			
FMA (s)	1, 2, 7, 8 & 9		3		4, 5 & 6		10			Total
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	541	–	725	–	1 829	–	0	–	3 095§	–
1984–85*	587	–	1 557	–	4 563	–	0	–	6 707§	–
1985–86*	806	–	2 284	–	3 966	–	0	–	7 056§	–
1986–87	1 337	1 800	1 931	2 600	2 779	3 600	0	10	6 047§	8 010
1987–88	2 947	1 815	3 810	2 601	2 600	3 600	0	10	9 357§	8 026
1988–89	1 605	1 821	1 476	2 640	2 789	3 745	0	10	5 870	8 216
1989–90	2 316	2 128	2 713	3 140	3 596	3 855	0	10	8 625	9 133
1990–91	2 121	2 128	1 889	3 144	3 176	3 855	0	10	7 186	9 137
1991–92	1 388	2 500	2 661	3 144	3 018	3 855	0	10	7 066	9 509
1992–93	1 231	2 504	2 432	3 145	3 137	3 855	0	10	6 800	9 514
1993–94	2 960	2 504	2 724	3 145	2 993	3 855	0	10	8 677	9 514
1994–95	2 281	2 504	2 336	3 280	2 638	4 090	0	10	7 255	9 884
1995–96	2 884	2 504	2 939	3 280	3 581	4 090	0	10	9 404	9 884
1996–97	3 636	2 504	4 063	3 280	5 336	4 090	0	10	13 035	9 884
1997–98	3 380	2 132	3 721	3 280	3 944	4 090	0	10	11 045	9 512
1998–99	1 980	2 132	2 796	3 280	4 021	4 090	0	10	8 797	9 512
1999–00	2 525	2 132	4 129	3 280	4 606	4 090	0	10	11 260	9 512

Table 2 [Continued]

Fishstock	SWA 1 1, 2, 7, 8 & 9		SWA 3 3		SWA 4 4, 5 & 6		SWA 10 10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2000–01	3 025	2 132	3 664	3 280	4 650	4 090	0	10	11 339	9 512
2001–02	1 004	2 132	2 899	3 280	4 648	4 090	0	10	8 551	9 512
2002–03	1 029	3 000	3 772	3 280	4 746	4 090	0	10	9 547	10 380
2003–04	1 595	3 000	3 606	3 280	5 529	4 090	0	10	10 730	10 380
2004–05	1 467	3 000	3 797	3 280	4 279	4 090	0	10	9 543	10 380
2005–06	1 023	3 000	4 524	3 280	5 591	4 090	0	10	11 138	10 380
2006–07	2 093	3 000	6 059	3 280	6 022	4 090	0	10	14 174	10 380
2007–08	1 679	3 000	2 918	3 280	3 510	4 090	0	10	8 107	10 380
2008–09	1 366	3 000	3 264	3 280	4 213	4 090	0	10	8 843	10 380
2009–10	712	3 000	2 937	3 280	3 429	4 090	0	10	7 078	10 380
2010–11	938	3 000	3 559	3 280	3 507	4 090	0	10	8 004	10 380
2011–12	1 029	3 000	3 318	3 280	2 783	4 090	0	10	7 130	10 380
2012–13	748	3 000	3 788	3 280	4 128	4 090	0	10	8 664	10 380
2013-14	903	3 000	3 201	3 280	3 885	4 090	0	10	7 989	10.380
2014–15	878	3 000	3 820	3 280	4 355	4 090	0	10	9 053	10 380
2015–16	1 225	3 000	2 734	3 280	3 555	4 090	0	10	7 515	10 380
2016–17	696	3 000	3 667	3 280	4 307	4 090	0	10	8 670	10 380
2017–18	543	3 000	3 396	3 280	4 714	4 090	0	10	8 653	10 380
2018–19	463	3 000	3 270	3 280	4 879	4 090	0	10	8 612	10 380
2019–20	460	3 000	3 356	3 280	3 954	4 090	0	10	7 769	10 380
2020–21	216	3 000	4 076	3 610	4 193	4 500	0	10	8 486	11 120

§Totals do not match those in Table 1 because the data were collected independently and there was known under-reporting to the FSU in 1987–88. This needs to be resolved.
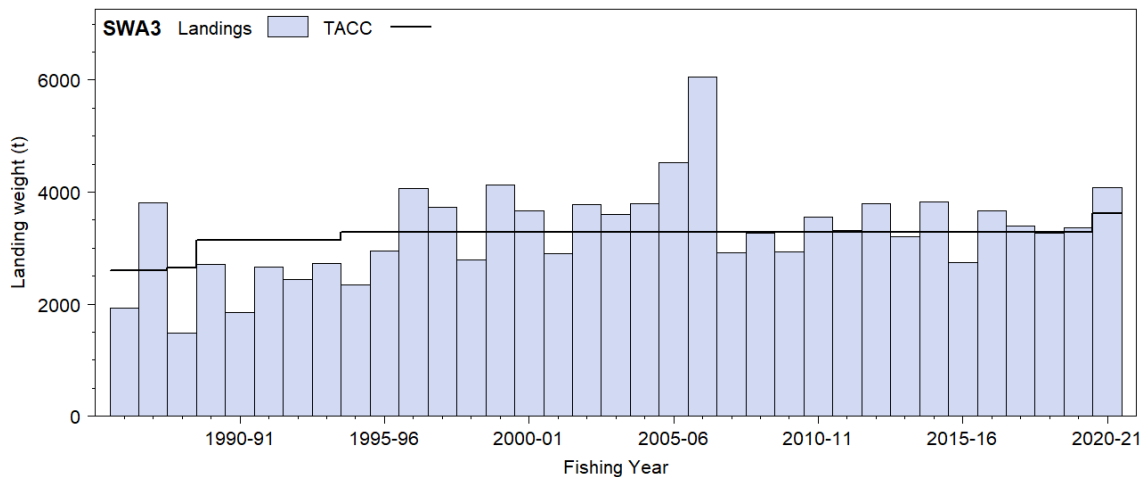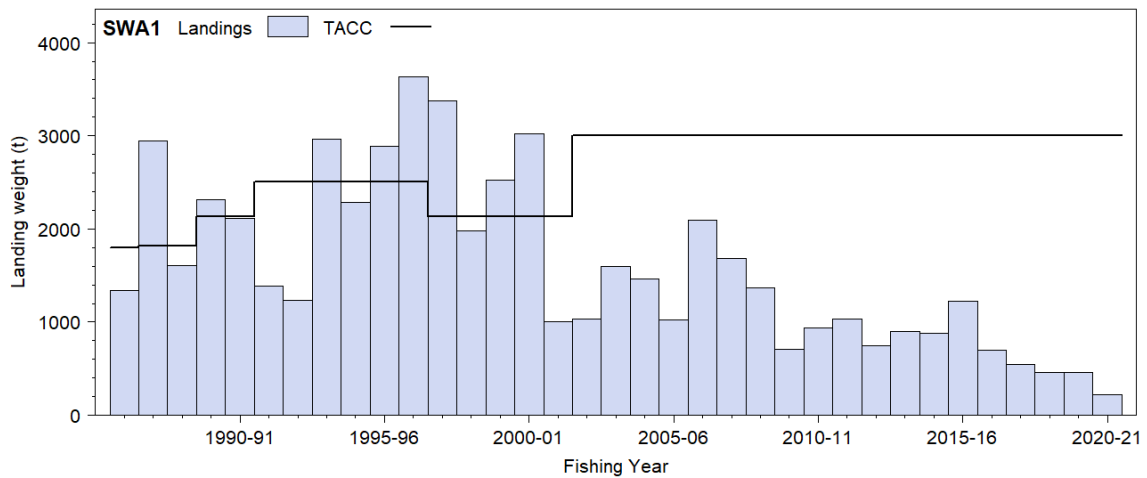

Figure 1: Reported commercial landings and TACCs for the three main SWA stocks. From top to bottom: SWA 1 (Auckland East) and SWA 3 (South East Coast). Note that these figures do not show data prior to entry into the QMS. [Continued on next page]
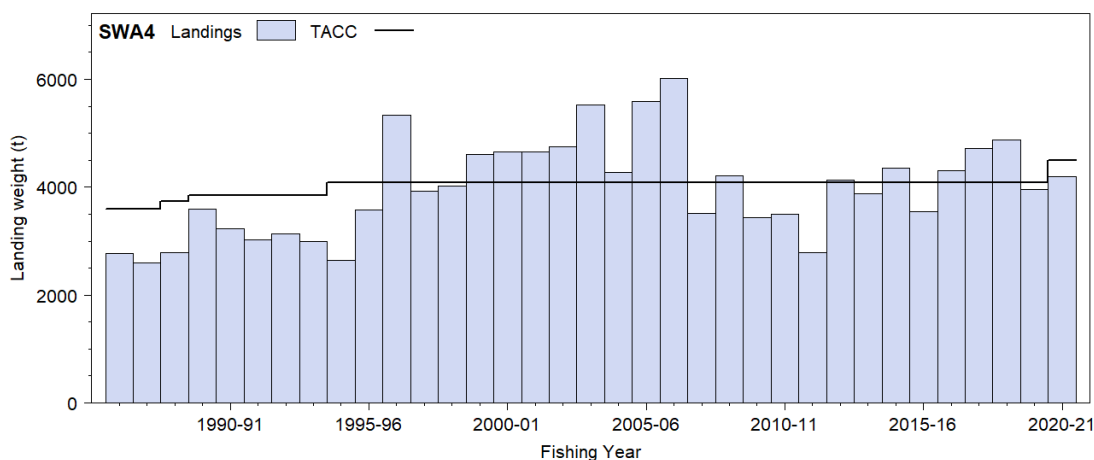
Figure 1 [Continued]: Reported commercial landings and TACCs for the three main SWA stocks. SWA 4 (South East Chatham Rise). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries

There are no current recreational fisheries for silver warehou.

1.3 Customary non-commercial fisheries

Quantitative information on the current level of customary non-commercial take is not available.

1.4 Illegal catch

Silver warehou have been misreported as white and blue warehou in the past. The extent of this practice is unknown and could lead to under-reporting of silver warehou catches.

1.5 Other sources of mortality

Other sources of mortality are unknown.

2. BIOLOGY

Initial growth is rapid and fish reach sexual maturity at around 45 cm fork length in 4 years. Based on a study of ageing methodology and growth parameters (Horn & Sutton 1995), maximum age is considered to be 23 years for females and 19 years for females. An estimate of instantaneous natural mortality (M) was derived by using the equation $M = \log_e 100/A_{MAX}$, where A_{MAX} is the age reached by 1% of the virgin population. From their study, A_{MAX} of 19 years for female silver warehou and 17 years for males produced estimates of M of 0.24 and 0.27, respectively. Horn & Sutton (1995) qualified this result because the samples used in their study were not from virgin populations and the sampling method did not comprehensively sample the whole population. Based on these results M is likely to fall within the range 0.2–0.3.

Horn & Sutton (1995) also calculated von Bertalanffy growth curve parameters from their sample of fish from off the south and southeast coasts of the South Island (Table 3). Other biological parameters relevant to the stock assessment are shown in Table 3. Length weight regressions were calculated from two series of research trawl surveys using *Tangaroa*. One series was conducted on the Chatham Rise in January 1992–97 and the other in Southland during February–March 1993–96.

Silver warehou is a schooling species, aggregating to both feed and spawn. During spring-summer, both adult and juvenile silver warehou migrate to feed along the continental slope off the east and southeast coast of the South Island. Late-stage silver warehou eggs and larvae have been identified in plankton samples, and the early life history of silver warehou appears typical of many teleosts. Juvenile silver warehou inhabit shallow water at depths of 150–200 m and remain apart from sexually mature fish. Few immature fish are consequently taken by trawlers targeting silver warehou. Juveniles have been caught in Tasman Bay, off the east coast of the South Island and around the Chatham Islands. Once sexually mature, fish move out to deeper water along the shelf edge, such that mature fish dominate catches at depths greater than about 300 m.

Table 3: Estimates of biological parameters of silver warehou.

Fishstock			Estimate			Source
1. Weight = a(length)[b] (Weight in g, length in cm, total length).						
				Both sexes		
			a	b		*Tangaroa* Survey:
Chatham Rise			0.00848	3.214		January 1992–97
Southland			0.00473	3.380		February–March 1993–96

		Female			**Males**		
2. von Bertalanffy growth parameters							
	L_∞	k	t_0	L_∞	k	t_0	
All areas	54.5	0.33	-1.04	51.8	0.41	-0.71	Horn & Sutton (1995)

3. STOCKS AND AREAS

The stock structure is not well known.

Horn et al (2001) suggest four distinct spawning areas: off west coast South Island, southern South Island, eastern North Island, and on the Chatham Rise, with possible sub-areas of spawning within these. For example, Livingston (1988) inferred from voyage reports the time of spawning on the Chatham Islands was later (spring-summer) than that at the Mernoo Bank (winter-spring). The peak timing for spawning appears to be earliest on the WCSI (winter), then proceeding in a southeast direction, at the Mernoo Bank (winter-spring), Stewart-Snares shelf, and around the Chatham Islands (spring-summer). It is uncertain whether the same stock migrates from one area to another, spawning whenever conditions are appropriate, or if there are several separate stocks. The current management areas bear little relation to known spawning areas and silver warehou distribution. Horn et al (2001) investigated growth rates, gonad staging information, and age structure with regard to stock structure, but found no evidence from these characteristics for separate reproductive units.

4. STOCK ASSESSMENT

The following biological stocks have been considered for the purpose of stock assessment:

- West Coast South Island (WCSI, part of SWA 1).
- East Coast South Island (ECSI): the northern part of SWA 3 and Chatham Rise west of 180° (part of SWA 4).
- East Chatham Rise (ECR): the Chatham Rise east of 180° (part of SWA 4).
- Southland: the southern part of SWA 3 and SWA 4 excluding the Chatham Rise.

An assessment of the East Coast South Island silver warehou stock was attempted in 2018 (McGregor 2019a, b). Although the assessment was not accepted by the Deepwater Working Group, biomass information derived from the assessment was considered adequate to provide sustainability advice on this stock. This assessment was based on the following biological stock structure assumption: there was a break in the spatial distribution of catches between the fishery on Chatham Rise and East Coast South Island down to roughly 45.4° S, and the Stewart-Snares shelf comprising the northwestern side of QMA 4 and the northern part of QMA 3, and known timing and location of spawning.

Further work was completed in 2019–20 to describe the distribution of fish and fishing within the East Coast South Island biological stock area and to examine the hypothesis that changes in CPUE may have resulted from operational changes in the fishery (Dutilloy & Dunn 2020). These analyses concluded that the inshore and offshore fisheries within the stock area should have different fishery selectivities, that the trend in revised CPUE analyses was similar to that reported by McGregor (2019a), and that a peak in CPUE around 2006–07 was most likely a consequence of increased abundance.

4.1 Estimates of fishery parameters and abundance

Bottom trawl surveys have been conducted since the early 1990s using either the *Tangaroa* (Chatham Rise survey, Sub-Antarctic survey, and WCSI) or the *Kaharoa* (inshore east and east coasts of the South Island). These surveys all encounter silver warehou, and the station allocation for the *Tangaroa* surveys on the WCSI have taken into account SWA from 2012 (Table 4). However, for the other surveys the average CVs are high, and they have not been considered suitable for stock assessment or as good monitoring tools for these stocks. They may, nonetheless, be useful in interpreting CPUE analyses.

Table 4: Biomass indices (t) and estimated coefficients of variation (CV) for core survey areas

Fishstock	Area	Vessel	Trip code	Date	Biomass	CV (%)
SWA 3&4	Chatham Rise	*Tangaroa*	TAN9106	Jan–Feb 1992	4 489	54
			TAN9212	Jan–Feb 1993	2 694	51
			TAN9401	Jan 1994	11 640	49
			TAN9501	Jan 1995	3 737	28
			TAN9601	Jan 1996	1 707	28
			TAN9701	Jan 1997	2 101	32
			TAN9801	Jan 1998	4 708	48
			TAN9901	Jan 1999	6 760	34
			TAN0001	Jan 2000	5 425	46
			TAN0101	Jan 2001	2 728	22
			TAN0201	Jan 2002	6 410	81
			TAN0301	Jan 2003	7 815	74
			TAN0401	Jan 2004	20 548	40
			TAN0501	Jan 2005	6 671	22
			TAN0601	Jan 2006	7 704	48
			TAN0701	Jan 2007	14 646	32
			TAN0801	Jan 2008	15 546	36
			TAN0901	Jan 2009	15 061	34
			TAN1001	Jan 2010	80 469	58
			TAN1101	Jan 2011	82 075	62
			TAN1201	Jan 2012	16 055	52
			TAN1301	Jan 2013	6 945	29
			TAN1401	Jan 2014	2 658	61
			TAN1601	Jan 2016	14 983	25
			TAN1801	Jan 2018	12 953	44
			TAN2001	Jan 2020	9 659	53
SWA 3	ECSI	*Kaharoa*	KAH9105	May–Jun 1991	29	21
			KAH9205	May–Jun 1992	32	22
			KAH9306	May–Jun 1993	256	44
			KAH9406	May–Jun 1994	35	28
			KAH9606	May–Jun 1996	231	32
			KAH0705	May–Jun 2007	445	44
			KAH0806	May–Jun 2008	319	32
			KAH0905	May–Jun 2009	446	42
			KAH1207	Apr–Jun 2012	438	46
			KAH1402	Apr–Jun 2014	626	83
			KAH1605	Apr–Jun 2016	428	53
			KAH1803	Apr–Jun 2018	191	42
SWA 1	WCSI	*Tangaroa*	TAN0007	Aug 2000	1 507	25
			TAN1210	Aug 2012	617	32
			TAN1308	Aug 2013	313	23
			TAN1609	Aug 2016	271	37
			TAN1807	Aug 2018	91	21
SWA4	Subantarctic	*Tangaroa*	TAN9105	Nov–Dec 1991	1 113	47
			TAN9211	Nov–Dec 1992	225	64
			TAN9310	Nov–Dec 1993	164	63
			TAN0012	Nov–Dec 2000	21	65
			TAN0118	Nov–Dec 2001	1 069	59
			TAN0219	Nov–Dec 2002	141	62
			TAN0317	Nov–Dec 2003	22	72
			TAN0414	Nov–Dec 2004	171	34
			TAN0515	Nov–Dec 2005	1 198	99
			TAN0617	Nov–Dec 2006	71	56
			TAN0714	Nov–Dec 2007	514	38
			TAN0813	Nov–Dec 2008	4 122	55
			TAN0911	Nov–Dec 2009	3 620	98
			TAN1117	Nov–Dec 2011	136	61
			TAN1215	Nov–Dec 2012	13	75
			TAN1412	Nov–Dec 2014	29	72
			TAN1614	Nov–Dec 2016	85	115
			TAN1811	Nov–Dec 2018	2 694	41
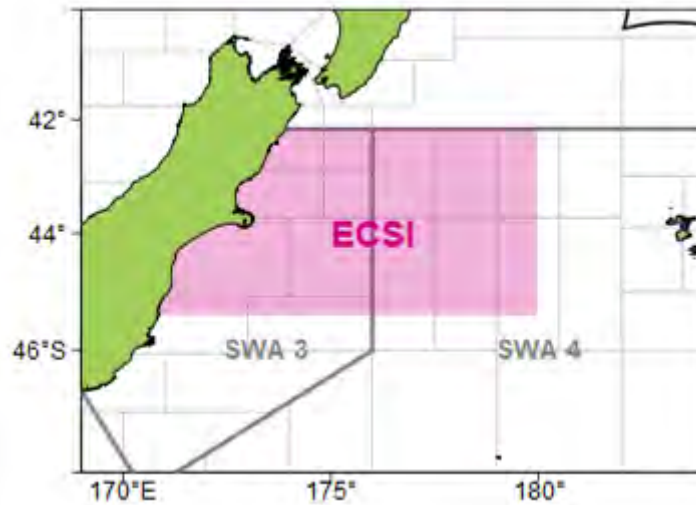
Figure 2: Map showing East Coast South Island in red and SWA 1, 3, and 4 boundaries (grey).

Merged (stratified) and unmerged (tow-level) datasets were modelled separately to derive relative biomass indices based on CPUE data (McGregor 2019a, Dutilloy & Dunn 2020). McGregor (2019a) estimated CPUE for the target and bycatch trawl fisheries, including the recorded target species as a covariate in the analyses. Dutilloy & Dunn (2020) concluded that the target fishery in the ECSI stock was not well defined and estimated CPUE for silver warehou caught as bycatch in the domestic vessel offshore bottom trawl fishery (targeting hoki) and inshore bottom trawl fishery (often targeting barracouta). All analyses used the delta-lognormal generalised linear modelling approach and allowed for spatial, seasonal, and vessel influences on catch rate.

Length and age data have been collected during the course of trawl surveys and by the Observer Programme from commercial fishing vessels. A feature of these time series, especially with the Chatham Rise and ECSI surveys, is that the size distributions are extremely variable among years. The Chatham Rise survey sometimes completely lack the typical 50 cm size class, and often lacks the 25 cm or 35 cm modes even though the appropriate mode is present in the subsequent year. The variability is highest in the ECSI survey, which shows up to four distinct size modes, but usually only one or two simultaneously. Beentjes et al (2004) noted that variability in adult size classes captured in the ECSI survey had been a common feature and considered it to be a result of either environmental influences on fish distribution, fish schooling by size, or the result of problems with gear performance (Beentjes et al 2004). McGregor (NIWA unpublished 2020) noted that the relatively high catches of silver warehou in the ECSI survey were only taken close to the deep boundary (400 m) of the survey region.

East Chatham Rise (part of SWA 4)

Trawl survey and CPUE indices
The most recent update of CPUE analyses for the East Chatham Rise was by McGregor (2016), using data to the end of the 2010–11 fishing year. The Chatham Rise trawl survey index suggested an overall upward trend (Figure 3), although the 2010 and 2011 years were difficult to interpret given very large CIs.

Both the stratified and un-stratified CPUE series (Figure 3) showed a very slight increasing trend from 1998 to 2011. A large proportion of tows with zero catch were found in the tow by tow unmerged data, which has a strong influence on the combined index. CPUE was not considered likely to be a good index here, and the years in which there are peaks in the CPUE and survey biomass index do not match. However, the slight overall increase in CPUE matched the trend in the trawl survey data for eastern Chatham Rise.

Length and age data

The age and length frequency data may prove useful in interpreting trends in the trawl survey and CPUE relative abundance indices in the future.
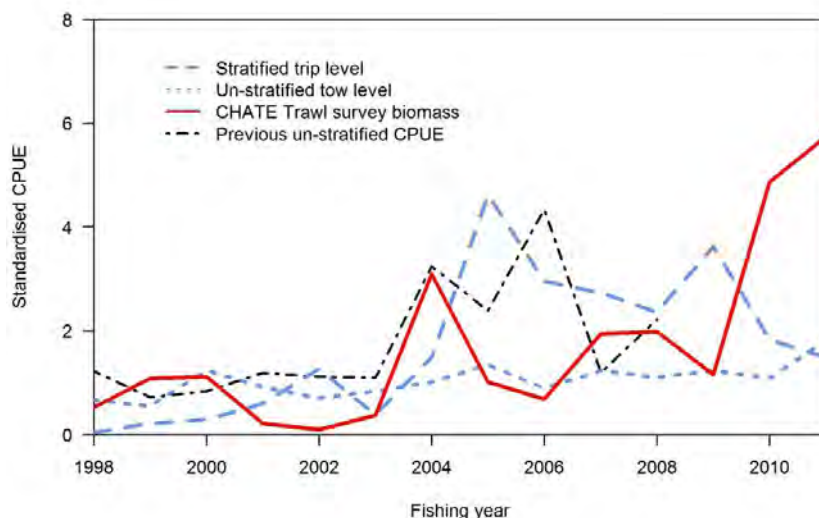
Figure 3: East Chatham Rise standardised CPUE (1998–2011) for merged (stratified, trip level) and unmerged (un-stratified, tow level) data; previous un-stratified CPUE (1998–2008) data; and biomass estimates from Chatham Rise East *Tangaroa* trawl surveys 1998–2011.

East Coast South Island (parts of SWA 3 and SWA 4)

Trawl survey and CPUE indices

The most recent update of CPUE for the ECSI was by McGregor (2019a) using data to the end of the 2015–16 fishing year, and Dutilloy & Dunn (2020) using data to the end of the 2018–19 fishing year.

All CPUE indices showed an overall slight increasing trend, with a peak around 2007–08 (Figure 4). CPUE after 2007–08 remained relatively high. The ECSI trawl survey showed a similar broad upward trend, until a decline in 2018. Biomass in the core strata (30–400 m) for the years since 2007 was higher overall than in the 1990s by about two-fold. The Chatham Rise trawl survey also showed a general increase, until very high biomass estimates in 2010 and 2011; these were associated with a small number of large catches and resulted in the estimates having a particularly high CV (Table 4). These estimates were subsequent to the increase in CPUE around 2006–07. The hoki research survey strata on the West Chatham Rise showed a similar trend to the East Chatham Rise with higher abundance and high CVs in 2010 and 2011. Because of the influence of large occasional catches of silver warehou, the trawl surveys are not currently considered a useful stock monitoring tool.

Length and age data

The *Kaharoa* trawl survey is monitoring pre-recruited cohorts, but not fish in the recruited size range. Plots of time series length frequency distributions consistently show the presence of the pre-recruited cohorts on nearly all surveys, with indications that these could be tracked through time (modal progression). Therefore, the age and length frequency data may prove useful in interpreting trends in the trawl survey and CPUE indices in the future.

Length data have been collected from the Observer Programme and some tracking of length modes is possible (Figure 5), suggesting the passage of strong and weak year classes. Otoliths collected by the Observer Programme were aged for fishing years 2000–01, 2004–05, 2006-07, 2009–10, 2010-11, 2012–13, 2013–14, and 2015–16 (Horn et al 2012, Horn & McGregor 2018), with 300 otolith pairs read for each of these years except 2004–05 which was slightly lower due to fewer samples collected in this year. The age compositions suggest strong year classes in spawned in 2000, 2005, and 2006 (Horn & McGregor 2018, McGregor 2019b; Figure 6).
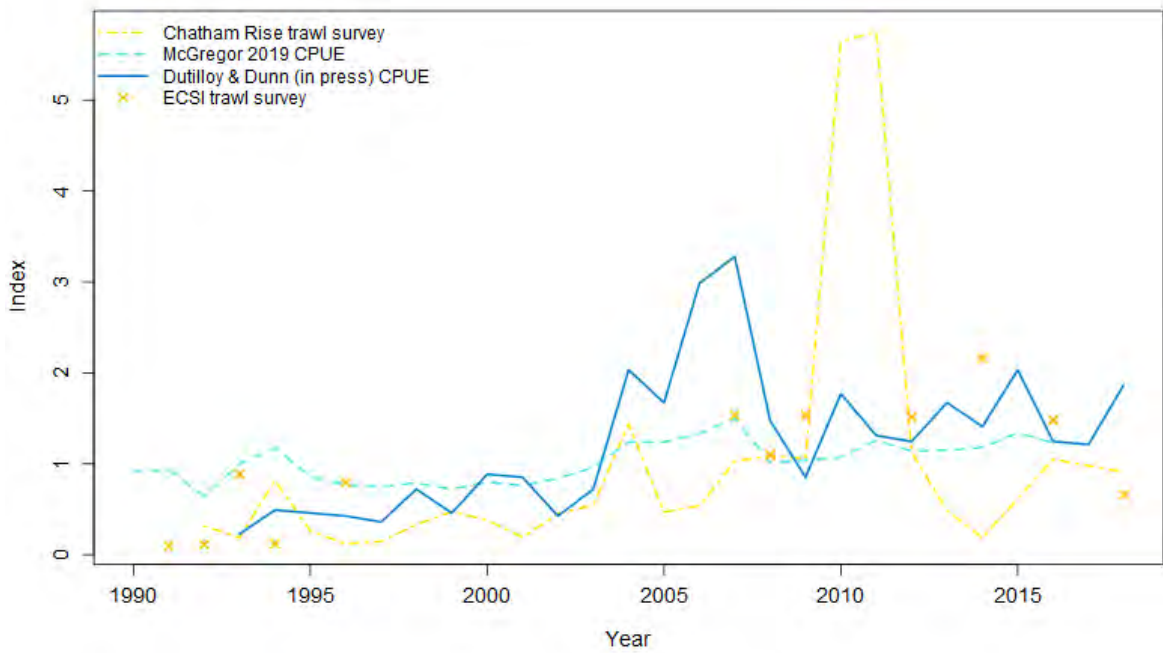
Figure 4: CPUE indices for the ECSI stock standardised CPUE (1989–90 to 2017–18) and biomass estimates from the Chatham Rise and ECSI trawl survey. Note that the Chatham Rise trawl survey series has been biennial since 2014 (see Table 4).
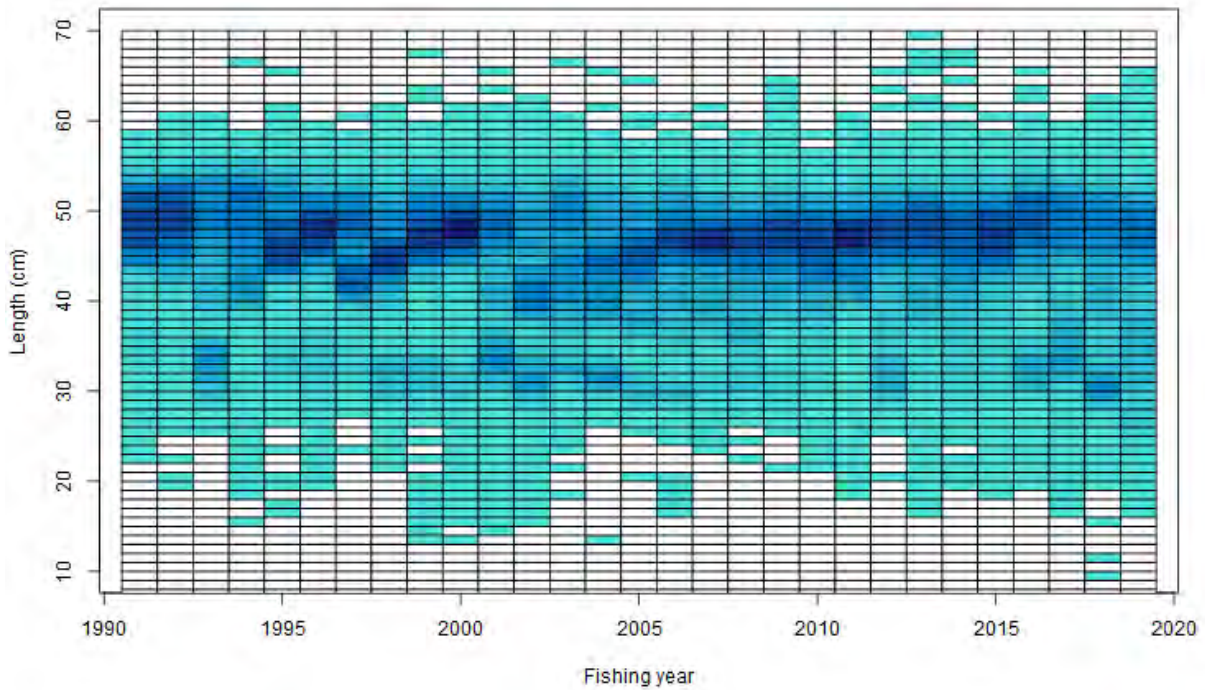
Figure 5: Raw proportions at length from observer data from East Coast South Island stock (blue rectangles). Darker blue indicates higher proportion.

SILVER WAREHOU (SWA)
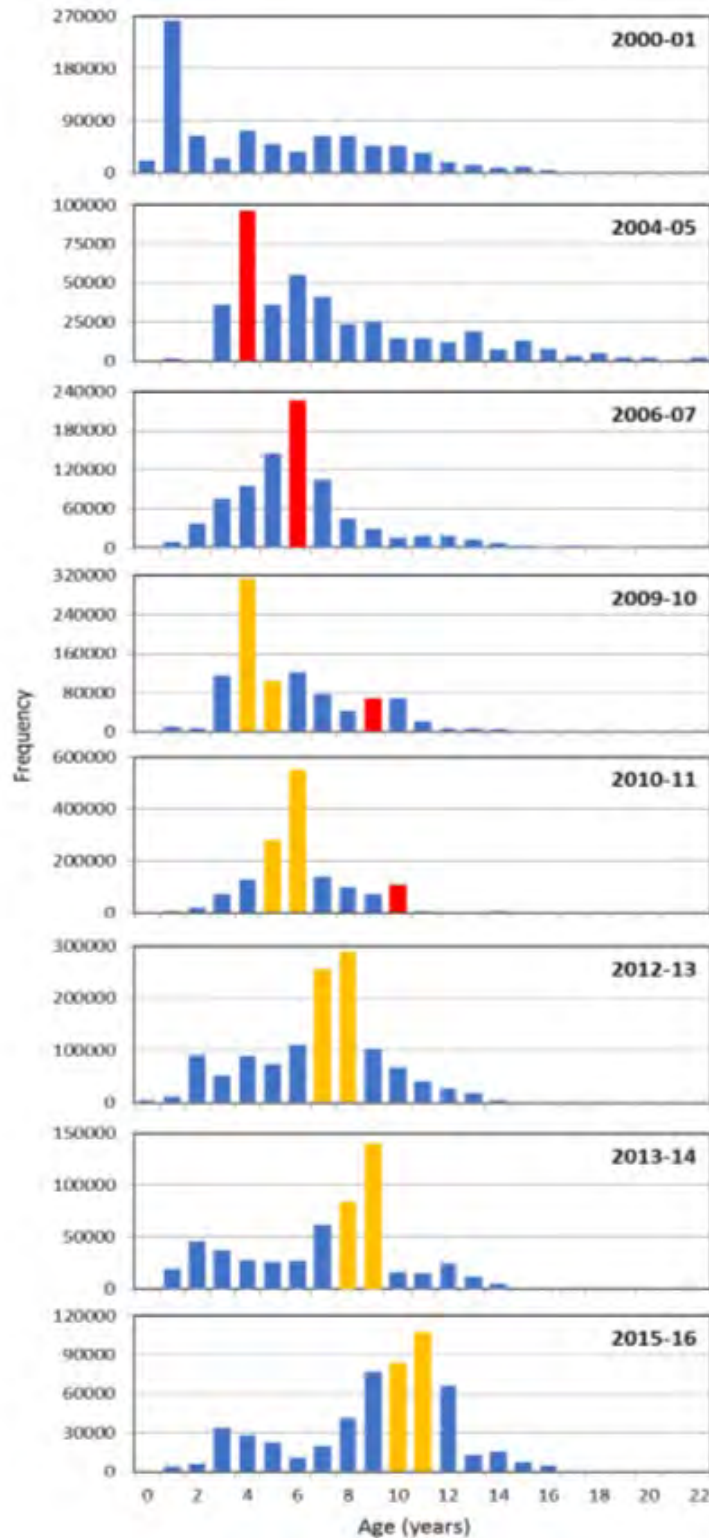
Figure 6: Scaled commercial catch-at-age distributions for the trawl catch of silver warehou sampled from the East Coast South Island (ECSI) (Horn & McGregor 2018). The 2000 (red bars), and 2005 and 2006 (orange bars) year classes are indicated.

Southland (parts of SWA 3 and SWA 4)

Trawl survey and CPUE indices

The most recent update of CPUE for the Southland stock was by McGregor (2019a) using data to the end of the 2015–16 fishing year. The Sub-Antarctic trawl survey index and CPUE indices (Figure 7) have been generally flat, except that the increase in 2008 and 2009 in the trawl survey is not reflected in the CPUE index. Intermittent peaks in biomass have occurred in the trawl survey, and the survey is not currently considered a reliable index.

1462

Length and age data

The age and length frequency data may prove useful in interpreting trends in the trawl survey and CPUE relative abundance indices in the future. Length data from the Observer Programme show some tracking of length modes (Figure 8), and these may indicate strong and weak year classes.

Otoliths collected by the Observer Programme were aged for years 1993 to 1996, and again in 2012 and 2014 (Horn et al 2001, Horn & McGregor 2018) (Figure 9). For each of the years 2012 and 2014, 300 otolith pairs were read. The age compositions suggest strong year classes in spawned in 1991, 1992, 2003, and 2010 (Horn & McGregor 2018).
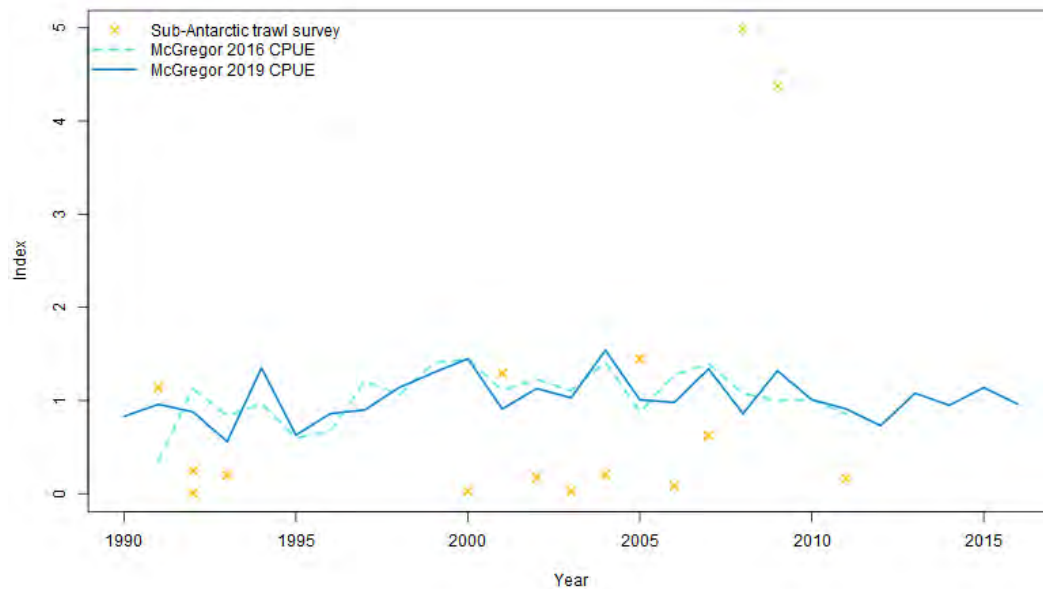
Figure 7. Southland standardised CPUE indices and trawl survey biomass estimates from Sub-Antarctic *Tangaroa* trawl surveys.
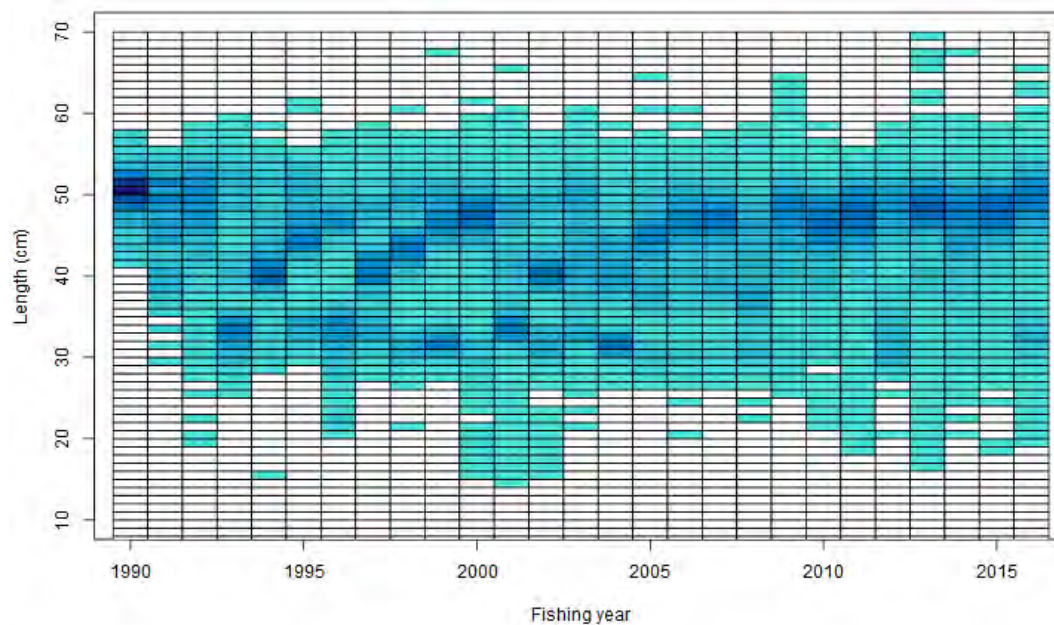
Figure 8: Raw proportions at length from observer data from Sub-Antarctic (blue rectangles).
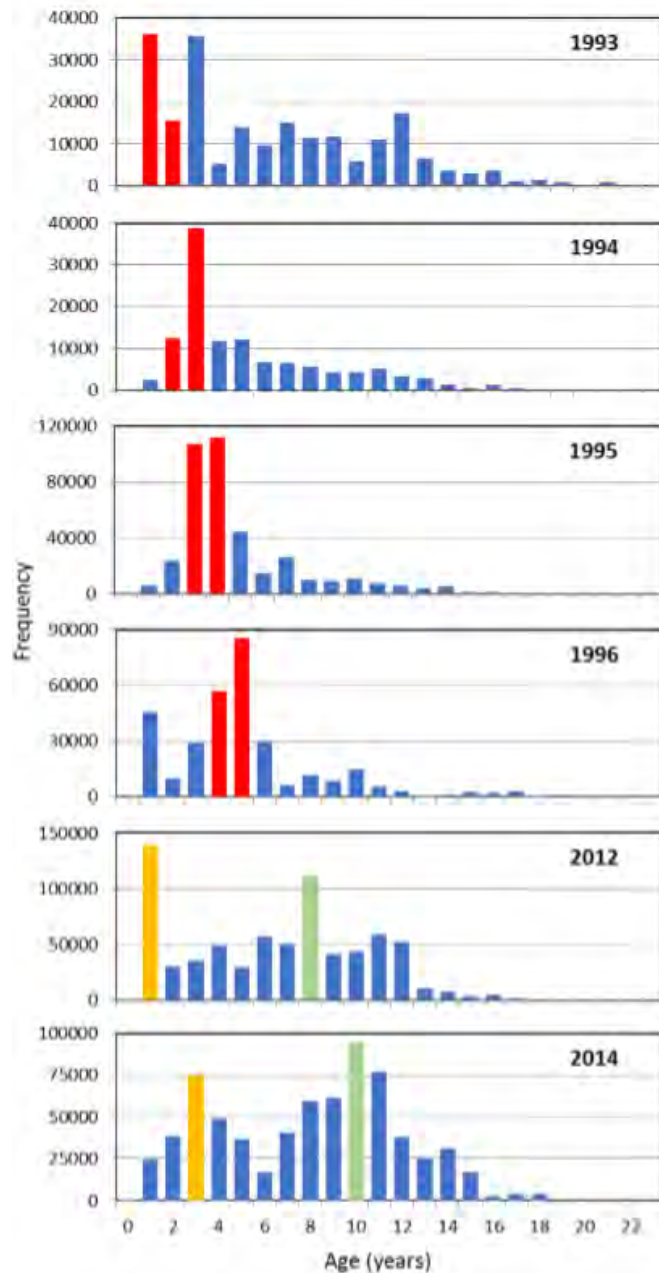
Figure 9: Scaled commercial catch-at-age distributions from samples of silver warehou off Southland. The 1991 and 1992 (red bars), 2003 (green bars), and 2010 (orange bars) year classes are indicated (Horn & McGregor 2018).

West Coast South Island (part of SWA 1)

Trawl survey and CPUE indices

CPUE analyses for the WCSI were most recently updated by McGregor (2016), using data to end of the 2010–11 fishing year (Figure 10). McGregor (2016) suggested that the West Coast South Island CPUE time series was promising as an index of abundance, and that Observer length data may help interpret patterns in the CPUE. The inshore *Kaharoa* trawl surveys were not considered a good monitoring tool or useful for stock assessment for this area.

The WCSI *Kaharoa* survey includes the TBGB (Tasman Bay and Golden Bay) area, which is a shallow area and dominated by juvenile SWA. When separated out, the TBGB index showed a downward trend while the WCSI index with TBGB omitted was fairly flat, with highly variable CIs.

The WCSI *Tangaroa* survey biomass estimate indicates a substantial biomass decline (Table 4).
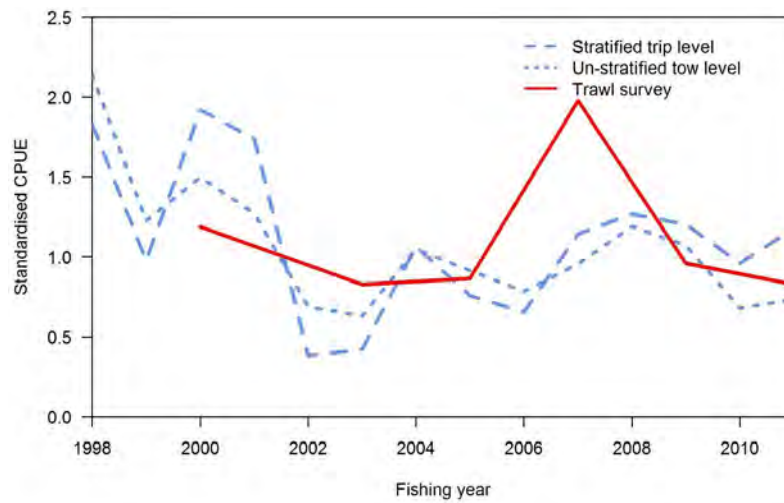
Figure 10: West Coast South Island standardised CPUE (1997–98 to 2010–11) for merged (stratified, trip level) and unmerged (un-stratified, tow level) data; and biomass estimates from Tasman Bay–Golden Bay *Kaharoa* trawl surveys 1998–2011.

A CPUE analysis for this stock, covering years before 1997–98, was also conducted in 2009 (Cordue 2009) using selected observer catch and effort data for a core fleet of vessels for positive bottom and midwater trawl SWA catches in area FMA 7 for winter fishing within a WCSI box (40.2° S–43.3° S). The resulting index (Figure 11) is noisy but shows a general trend of slow CPUE decline from 1986 to 1992, a steep increase from 1992 to 1996 and high levels through to 2000, followed by a steep decline back to low levels by 2002 and a stable trend at slightly above historically lowest levels through to 2008. This CPUE index was possibly consistent with strong year classes in 1993–94 and in 1997 (evident in the length frequency data), and the resulting increased abundance over the ensuing few years. This CPUE standardisation might be indexing SWA 1 abundance and, given the substantial amount of catch-at-age data for this stock, it was recommended that a stock assessment should now be conducted to investigate the coherence between catch-at-age data and this abundance index.
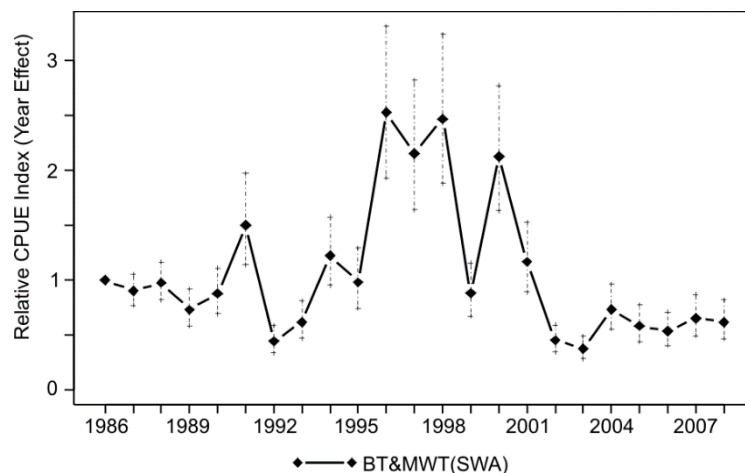
Figure 11: Standardised CPUE index (year effects) for SWA 1 from an analysis of Scientific Observer Programme trawl records (Cordue 2009).

Length and age data

The WCSI inshore trawl series typically has a dominant 20 cm mode and a smaller mode around 35 cm. Age frequency distributions from otoliths collected by the Scientific Observer Programme from the west coast South Island hoki fishery indicate that a wide range of year classes were present in the catch for all seasons 1992–96. Catch curve analysis based on the age structure of annual catches made from 1992–2005 suggested that fishing mortality was lower than natural mortality (SeaFIC 2007). Observer length data may help interpret patterns in CPUE.

The Working Group noted that this Fishstock sustained catches which averaged 2800 t y^{-1} from 1993–94 to 2000–01 without resulting in high estimates of total mortality, Z, but that this occurred over a period where CPUE indices indicate abundance of more than double current levels. A stock assessment is considered to be a more appropriate methodology to assess this Fishstock than relying on analyses of catch curve (Middleton 2009).

Future research considerations

- The stock structure for silver warehou remains poorly known. A holistic approach using all available information for all areas of New Zealand should be used to identify the most likely biological stocks.
- A trip level CPUE analyses for inshore fisheries, which represents about 7–18% of the total annual catch, should be investigated. Research by Dutilloy and Dunn (2020) suggested that the ECSI inshore trawl fishery CPUE provided a trend similar to the ECSI trawl survey when analysed at the trip level.
- The trawl survey estimates should be re-evaluated. Research by McGregor (2019a) indicated large catches of silver warehou in the Chatham Rise trawl surveys occurred in areas outside of the commercial trawl fishing footprint. Biomass estimated from the trawl surveys excluding these areas may provide a biomass trend more comparable with the CPUE.
- Consider updating the CPUE for the WCSI. The WCSI commercial CPUE has not been updated since 2011; the *Tangaroa* trawl survey has indicated a large biomass decline.
- Reassess the WCSI *Tangaroa* and *Kahaora* trawl surveys in light of the spatial and depth understanding developed for the surveys in SWA 3 and 4.
- Review all options and approaches to providing stock status advice (including but not limited to the possibility of again attempting a Level 1 fully quantitative stock assessment for the ECSI stock. An assessment was attempted but rejected (McGregor 2019b). Since then, further research has been conducted on the spatial structure of the fish stock and fisheries, CPUE indices have been refined, and additional age data have been collected.

6. STATUS OF THE STOCKS

- **WCSI (part of SWA 1)**

Stock Status	
Year of Most Recent Assessment	2018
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The *Tangaroa* trawl survey indicates a substantial decline in biomass between 2000 and 2018.
Recent Trend in Fishing Intensity or Proxy	-
Other Abundance Indices	CPUE indices were relatively high between 1996 and 2001, but have not been updated since 2011.
Trends in Other Relevant Indicators or Variables	Age-frequency estimates for the period 1992–2005 indicated fishing mortality rate was lower than the assumed natural mortality rate. This has not been updated since.

Projections and Prognosis

Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation

Assessment Type	Level 3 - Qualitative Evaluation	
Assessment Method	-	
Assessment Dates	Latest assessment: 2018	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	- *Tangaroa* trawl survey index - CPUE - age frequency (up to 2005) - *Kaharoa* WCSI inshore survey	2 – Medium or Mixed Quality: only 5 data points and may not be appropriate for monitoring SWA 2 – Medium or Mixed Quality: needs to be updated 2 – Medium or Mixed Quality: needs to be updated 2 – Medium or Mixed Quality: needs further evaluation
Data not used (rank)		
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	There is currently no reliable way of tracking abundance due to the characteristics and behaviour of the fish and the fishing fleet.	

Qualifying Comments

-

Fishery Interactions

-

- **East Coast South Island (northern part of SWA 3 and west Chatham Rise part of SWA 4)**

Stock Status

Year of Most Recent Assessment	2020
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Soft limit: Unknown Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status

-

SILVER WAREHOU (SWA)

Fishery and Stock Trends

Recent Trend in Biomass or Proxy	CPUE and biomass indices for the ECSI stock have increased or been relatively high in recent years. The total catches also increased in recent years, and are around the TACC. Age composition data suggest that the increase in catch rates and catches was consistent with the recruitment of some relatively large year classes. Preliminary stock assessment analyses suggested that stock status has not declined at recent catch levels.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity is unlikely to be increasing.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis

Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unlikely
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation

Assessment Type	Level 2 - Partial Quantitative Stock Assessment.	
Assessment Method	Examination of relative abundance indices	
Assessment Dates	Latest assessment: 2020	Next assessment: Unknown
Overall assessment quality rank	2 – Medium or Mixed Quality	
Main data inputs (rank)	- *Tangaroa* trawl survey index - CPUE - age frequency (2001–2016) - *Kaharoa* ECSI inshore survey - Length frequencies	2 – Medium or Mixed Quality: high CVs 2 – Medium or Mixed Quality: mixture of verified and unverified data 1 – High Quality 2 – Medium or Mixed Quality: survey doesn't cover full depth range 1 – High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	There is currently not a reliable way of tracking abundance due to the characteristics and behaviour of the fish and the fishing fleet.	

Qualifying Comments

-

Fishery Interactions

-

1468

- **Eastern Chatham Rise (part of SWA 4)**

Stock Status	
Year of Most Recent Assessment	2015
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE showed a slight increasing trend from 1998 to 2011.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	The Chatham Rise trawl survey index for this area suggested an overall upward trend, although the 2010 and 2011 years were difficult to interpret given very large CIs.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 3 - Qualitative Evaluation	
Assessment Method	Examination of trends in CPUE and trawl survey estimates	
Assessment Dates	Latest assessment: 2015	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	- *Tangaroa* trawl survey index - CPUE	2 – Medium or Mixed Quality: high CVs 2 – Medium or Mixed Quality: high proportion of zero catches and may not be a reliable index of abundance
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	There is currently no reliable way of tracking abundance due to the characteristics and behaviour of the fish and the fishing fleet. Indices are only available until 2011.	

Qualifying Comments
-

Fishery Interactions
-

- **Southland (Southern part of SWA3 and Sub Antarctic SWA4)**

Stock Status	
Year of Most Recent Assessment	2019
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\% B_0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The CPUE index has been generally flat.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	The trawl survey biomass index has been generally flat.
Trends in Other Relevant Indicators or Variables	The age compositions suggest relatively strong year classes from 1991, 1992, 2003 and 2010.

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 3 - Qualitative Evaluation	
Assessment Method	Examination of trends in CPUE, trawl survey estimates and age composition data	
Assessment Dates	Latest assessment: 2019	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	- *Tangaroa* trawl survey index - CPUE - age frequency (1993–1996, 2012–2014) - length frequency	2 – Medium or Mixed Quality: high CVs 2 – Medium or Mixed Quality: not accepted as an index of abundance 1 – High Quality 1 – High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	There is currently no reliable way of tracking abundance due to the characteristics and behaviour of the fish and the fishing fleet.	

Qualifying Comments
-

Fishery Interactions
-

- **SWA 10**

No information is available for SWA 10.

7. FOR FURTHER INFORMATION

Beentjes, M P; Smith, M; Phillips, N L (2004) Analysis of catchability for east coast South Island trawl surveys and recommendations on future survey design. New Zealand Fisheries Assessment Report 2004/5. 68 p

Cordue, P (2009) SWA 1 CPUE analysis. AMPWG09/11. (Unpublished powerpoint presentation held by Fisheries New Zealand.)

Dutilloy, A; Dunn, M R (2020) Fishery and stock structure for silver warehou (*Seriolella punctata*) in SWA 3 and SWA 4. *New Zealand Fisheries Assessment Report 2020/19*. 70 p.

Fisheries New Zealand (2019). Fisheries Assessment Plenary, May 2019: stock assessments and stock status. Compiled by the Fisheries Science and Information Group, Fisheries New Zealand, Wellington, New Zealand. 1641p

Horn, P H; Bagley, N W; Sutton, C P (2001) Stock structure of silver warehou (*Seriolella punctata*) in New Zealand waters, based on growth and reproductive data. *New Zealand Fisheries Assessment Report 2001/13*. 29 p.

Horn, P H; McGregor, V L (2018) Catch-at-age for silver warehou (*Seriolella punctate*) on the western Chatham Rise in the 2000–01, 2012–3 and 2015–16 fishing years. Final Research Report for Ministry of Fisheries Research Project DEE2016-20.

Horn, P H; Sutton, C P (1995) An ageing methodology, and growth parameters for silver warehou (*Seriolella punctata*) from off the southeast coast of the South Island, New Zealand. New Zealand Fisheries Assessment Research Document 1995/15. 16 p. (Unpublished document held by NIWA library, Wellington.)

Horn, P L; Sutton, C; Hulston, D; Marriott, P (2012) Catch-at-age for jack mackerels (*Trachurus* spp.) in the 2009–10 fishing year, and barracouta (Thyrsites atun) and silver warehou (Seriolella punctata) in the 2004–05 and 2009–10 fishing years. Final Research Report for Ministry of Fisheries Research Project MID201001A, Objectives 6 & 8. 19 p.

Livingston, M E (1988) Silver warehou. New Zealand Fisheries Assessment Research Document 1988/36. (Unpublished document held by NIWA library, Wellington.

McGregor, V (2016) Fishery characterisation and standardised CPUE analyses for silver warehou (*Seriolella punctata*) in SWA 1, 3, and 4, 1997–98 to 2010–11. *New Zealand Fisheries Assessment Report 2016/07*. 220 p.

McGregor, V (2019a) Fishery characterisation and standardised CPUE analyses for silver warehou (*Seriolella punctata*) in SWA 3 and 4, 1989–90 to 2015–16. *New Zealand Fisheries Assessment Report 2019/59*. 57 p.

McGregor, V (2019b) Silver warehou (*Seriolella punctata*) western Chatham Rise preliminary stock assessment. *New Zealand Fisheries Assessment Report 2019/60*. 21 p.

Middleton, D A J (2009) Characterisation of the silver warehou (*Seriolella punctata*) fishery in SWA 1, and catch curve estimation of total mortality. AMP-WG-2009/10. (Unpublished document held by Fisheries New Zealand, Wellington.)

Paul, L. (1980) Warehous – facts and figures. *Catch '80 7(7):* 5–6.

Seafood Industry Council (SeaFIC) (2007) Silver Warehou: SWA 1 Adaptive Management Programme Full-term Review Report. AMP-WG-2007/22. (Unpublished document held by Fisheries New Zealand, Wellington.)

Stevens, D W; O'Driscoll, R L; Dunn, M R; MacGibbon, D; Horn, P L; Gauthier, S (2011) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2010 (TAN1001). *New Zealand Fisheries Assessment Report 2011/10*. 112 p.

Stevens, D W; O'Driscoll, R L; Gauthier, S (2008) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2007 (TAN0701). *New Zealand Fisheries Assessment Report 2008/52*. 81 p.

Stevens, D W; O'Driscoll, R L; Horn, P L (2009a) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2008 (TAN0801). *New Zealand Fisheries Assessment Report 2009/18*. 86 p.

Stevens, D W; O'Driscoll, R L; Horn, P L (2009b) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2009 (TAN0901). *New Zealand Fisheries Assessment Report 2009/55*. 91 p.

Stevens, D W; O'Driscoll, R L; Ladroit, Y; Ballara, S L; MacGibbon, D J; Horn, P L (2015) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2014 (TAN1401). *New Zealand Fisheries Assessment Report 2015/19*. 119 p.

Stevens, D W; O'Driscoll, R L; Ladroit, Y; Ballara, S L; MacGibbon, D J; Horn, P L (2017) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2016 (TAN1601). *New Zealand Fisheries Assessment Report 2017/18*. 131 p.

Stevens, D W; O'Driscoll, R L; Oeffner, J; Ballara, S L; Horn, P L (2014) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2013 (TAN1301). *New Zealand Fisheries Assessment Report 2014/02*. 110 p.

ROUGH SKATE (RSK)

(*Zearaja nasuta*)

Waewae, Uku

1. FISHERY SUMMARY

1.1 Commercial fisheries

Rough skates (*Zearaja nasuta*, RSK), which are also known as barndoor skates, are fished commercially in New Zealand in close association with smooth skates. Although rough skates reach considerably smaller sizes than smooth skates, RSK is still landed and processed. Two other species of deepwater skate (*Bathyraja shuntovi* and *Raja hyperborea*) are large enough to be of commercial interest but are relatively uncommon and probably comprise a negligible proportion of the landings.

Skate flesh ammoniates rapidly after death, so the wings are removed at sea, and chilled or frozen. On arrival at the shore factories, the wings are machine-skinned, graded, and packed for sale. Most of the product is exported to Europe, especially France and Italy. Skates of all sizes are processed, although some factories impose a minimum weight limit of about 1 kg (200 g per wing), and occasionally wings from very large smooth skates are difficult to market.

Rough skates occur throughout New Zealand but are most abundant around the South Island in depths down to 500 m. Most of the catch is taken as bycatch by bottom trawlers, but skates are also taken by longliners. Significant longline bycatch has been reported from the Bounty Plateau in QMA 6. There is no clear separation of the depth ranges inhabited by rough and smooth skates; however, smooth skates tend to occur slightly deeper than rough skates (Beentjes & Stevenson 2000, 2001, Stevenson & Hanchet 2000).

Many fishers and processors did not previously distinguish rough and smooth skates in their landing returns, and coded them instead as 'skates' (SKA). Because it is impossible to determine the species composition of the catch from landings data prior to introduction of these species into the QMS in 2003, all pre-QMS data reported here consist of the sum of the three species codes RSK, SSK, and SKA. Landings have been converted from processed weight to whole weight by application of conversion factors. Further, following introduction into the QMS in 2003, the two skate species were not always correctly identified and a considerable, but unknown, catch of either species is misidentified with over-reporting of rough skate and, correspondingly, under-reporting of smooth skate (Beentjes 2005). Neither fishers nor processors were distinguishing between the two skate species or reporting catches of each species correctly at the time of the study in 2004. It is not known if reporting has improved since this time.

There have been historical changes to the conversion factors applied to skates by MAF Fisheries and Ministry of Fisheries. No record seems to have been kept of the conversion factors in use before 1987, so it is not possible to reconstruct the time series of landings data using the currently accepted factors. Consistent and appropriate conversion factors have been applied to skate landings since the end of the 1986–87 fishing year. Before that, it appears that a lower conversion factor was applied, resulting in an underestimation of landed weight by about 20%. No correction has been made for that in this report.

New Zealand annual skate landings, estimated from a variety of sources, are shown in Table 1. No FSU deepwater data were available before 1983, and it is not known whether deepwater catches, including those of foreign fishing vessels, were significant during that period. CELR and CLR data are provided by inshore and deepwater trawlers respectively. 'CELR estimated' landings were always less than 'CELR landed' landings, because the former include only the top five fish species (by weight) caught by trawlers, whereas the latter include all species landed. As a relatively minor bycatch, skates frequently do not fall into the top five species. The sum of the 'CELR landed' and CLR data provides an estimate of the total skate landings. This estimate usually agreed well with LFRR data supplied by fish processors, especially in 1993–94 and 1994–95, but in 1992–93 the difference was 467 t. The 'best estimate' of the annual historical landings comes from FSU data up to 1985–86, and LFRR data thereafter.

Table 1: New Zealand skate landings for calendar years 1974–1983, and fishing years (1 October–30 September) 1983–84 to 1995–96. Values in parentheses are based on part of the fishing year only. Landings do not include foreign catch before 1983, or unreported discards. FSU = Fisheries Statistics Unit; CELR = Catch, Effort and Landing Return; CLR = Catch Landing Return; LFRR = Licensed Fish Receivers Return; Best Estim. = best available estimate of the annual skate catch; - = no data.

Year	Inshore	Deepwater	FSU Total	CELR Estim.	CELR Landed	CLR	CELR Landed +CLR	LFRR	Best Estim.
1974	23	–	–	–	–	–	–	–	23
1975	30	–	–	–	–	–	–	–	30
1976	28	–	–	–	–	–	–	–	28
1977	27	–	–	–	–	–	–	–	27
1978	36	–	–	–	–	–	–	–	36
1979	165	–	–	–	–	–	–	–	165
1980	441	–	–	–	–	–	–	–	441
1981	426	–	–	–	–	–	–	–	426
1982	648	–	–	–	–	–	–	–	648
1983	634	178	812	–	–	–	–	–	812
1983–84	686	298	983	–	–	–	–	–	983
1984–85	636	250	886	–	–	–	–	–	886
1985–86	613	331	944	–	–	–	–	–	944
1986–87	723	285	1 007	–	–	–	–	1 019	1 019
1987–88	1 005	421	1 426	–	–	–	–	1 725	1 725
1988–89	(530)	(136)	(665)	(252)	(265)	(28)	(293)	1 513	1 513
1989–90	–	–	–	780	1 171	410	1 581	1 769	1 769
1990–91	–	–	–	796	1 334	359	1 693	1 820	1 820
1991–92	–	–	–	1 112	1 994	703	2 698	2 620	2 620
1992–93	–	–	–	1 175	2 595	824	3 418	2 951	2 951
1993–94	–	–	–	1 247	2 236	788	3 024	2 997	2 997
1994–95	–	–	–	956	1 973	829	2 803	2 789	2 789
1995–96	–	–	–	–	–	–	–	2 789	2 789

Total skate landings (based on the 'best estimate' in Table 1) were negligible up to 1978, presumably because of a lack of suitable markets and the availability of other more abundant and more desirable species. Landings then increased linearly to reach nearly 3000 t in 1992–93 and 1993–94, and remained between 2600 and 3100 t until the separation of skate species under the QMS. Reported landings of rough skate are provided in Table 2.

Rough skates were introduced into the QMS as a separate species from 1 October 2003 with allowances, TACCs, and TACs as given in Table 3. Figure 1 shows the historical landings and TACC values for the main RSK stocks. Owing to problems associated with identification of rough and smooth skates, reported landings of each species are probably not accurate (Beentjes 2005). Initiatives to improve identification of these species begun in 2003 may have resulted in more accurate data. About 83% of

rough skate landings since the fishing year 2003–04 have come from RSK 3. Landings recorded for RSK 3 have generally been below the TACC, averaging just under 1500 t annually from 2003–04 to 2019–20 and landings in 2019–20 and 2020–21 are the lowest since inclusion in the QMS. In contrast RSK 8 has been consistently over caught, relative to the TACC, since it was introduced to the QMS. It was put on Schedule 6 on 1 October 2006. Owing to discarding and misidentification of the two skate species, RSK and SSK, catches are likely to be inaccurate.

Table 2: Reported landings (t) of SKA and RSK by QMA and fishing year, 1996–97 to present.

Fishstock	RSK 1		RSK 3		RSK 7		RSK 8		RSK 10		
FMA	1–2		3–6		7		8–9		10		All
Skate (SKA)*	Land.	TACC	Land.	TACC	Land.	TACCl	Land.	TACC	Land.	TACC	Total
1996–97	43	-	894	-	380	-	30	-	0	-	1 347
1997–98	44	-	855	-	156	-	31	-	0	-	1 086
1998–99	48	-	766	-	228	-	12	-	0	-	1 054
1999–00	75	-	775	-	253	-	25	-	0	-	1 128
2000–01	88	-	933	-	285	-	28	-	0	-	1 334
2001–02	132	-	770	-	311	-	35	-	0	-	1 248
2002–03	121	-	857	-	293	-	32	-	0	-	1 303
2003–04	< 1	-	< 1	-	< 1	-	< 1	-	0	-	1
Rough skate (RSK)											
1996–97	15	-	265	-	69	-	3	-	0	-	352
1997–98	32	-	493	-	44	-	5	-	0	-	574
1998–99	22	-	607	-	33	-	4	-	0	-	666
1999–00	20	-	720	-	37	-	2	-	0	-	779
2000–01	27	-	569	-	42	-	4	-	0	-	642
2001–02	24	-	607	-	25	-	3	-	0	-	659
2002–03	18	-	1 060	-	27	-	11	-	0	-	1 118
2003–04	48	111	1 568	1 653	191	-	33	-	0	-	1 840
2004–05	72	111	1 815	1 653	173	201	55	21	0	0	2 115
2005–06	72	111	1 446	1 653	153	201	28	21	0	0	1 699
2006–07	68	111	1 475	1 653	197	201	35	21	0	0	1 768
2007–08	80	111	1 239	1 653	206	201	46	21	0	0	1 573
2008–09	79	111	1 591	1 653	226	201	46	21	0	0	1 942
2009–10	87	111	1 546	1 653	225	201	46	21	0	0	1 905
2010–11	91	111	1 547	1 653	199	201	45	21	0	0	1 882
2011–12	76	111	1 257	1 653	189	201	41	21	0	0	1 563
2012–13	92	111	1 573	1653	180	201	44	21	0	0	1 889
2013–14	105	111	1 798	1 653	166	201	54	21	0	0	2 122
2014–15	88	111	1 324	1 653	151	201	41	21	0	0	1 605
2015–16	87	111	1 263	1 653	171	201	31	21	0	0	1 553
2016–17	106	111	1 528	1 653	165	201	37	21	0	0	1 836
2017–18	120	111	1 345	1 653	153	201	39	21	0	0	1 657
2018–19	84	111	1 185	1 653	136	201	26	21	0	0	1 432
2019–20	71	111	1 054	1 653	163	201	39	21	0	0	1 326
2020–21	57	111	1 054	1 653	173	201	47	21	0	0	1 331

*Use of the code SKA ceased once skates were introduced into the QMS in October 2003 and rough skates and smooth skates were recognised as separate species. From this time all landings of skates have been reported against either the RSK or SSK code.

Table 3: Recreational, customary, and other mortality allowances (t), Total Allowable Commercial Catches (TACC, t) and Total Allowable Catches (TAC, t) declared for RSK on introduction into the QMS in October 2003.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other Mortality	TACC	TAC
RSK 1 (FMAs 1–2)	1	1	1	111	114
RSK 3 (FMAs 3–6)	1	1	17	1 653	1 672
RSK 7	1	1	2	201	205
RSK 8 (FMAs 8–9)	1	1	1	21	24
RSK 10	0	0	0	0	0

ROUGH SKATE (RSK)
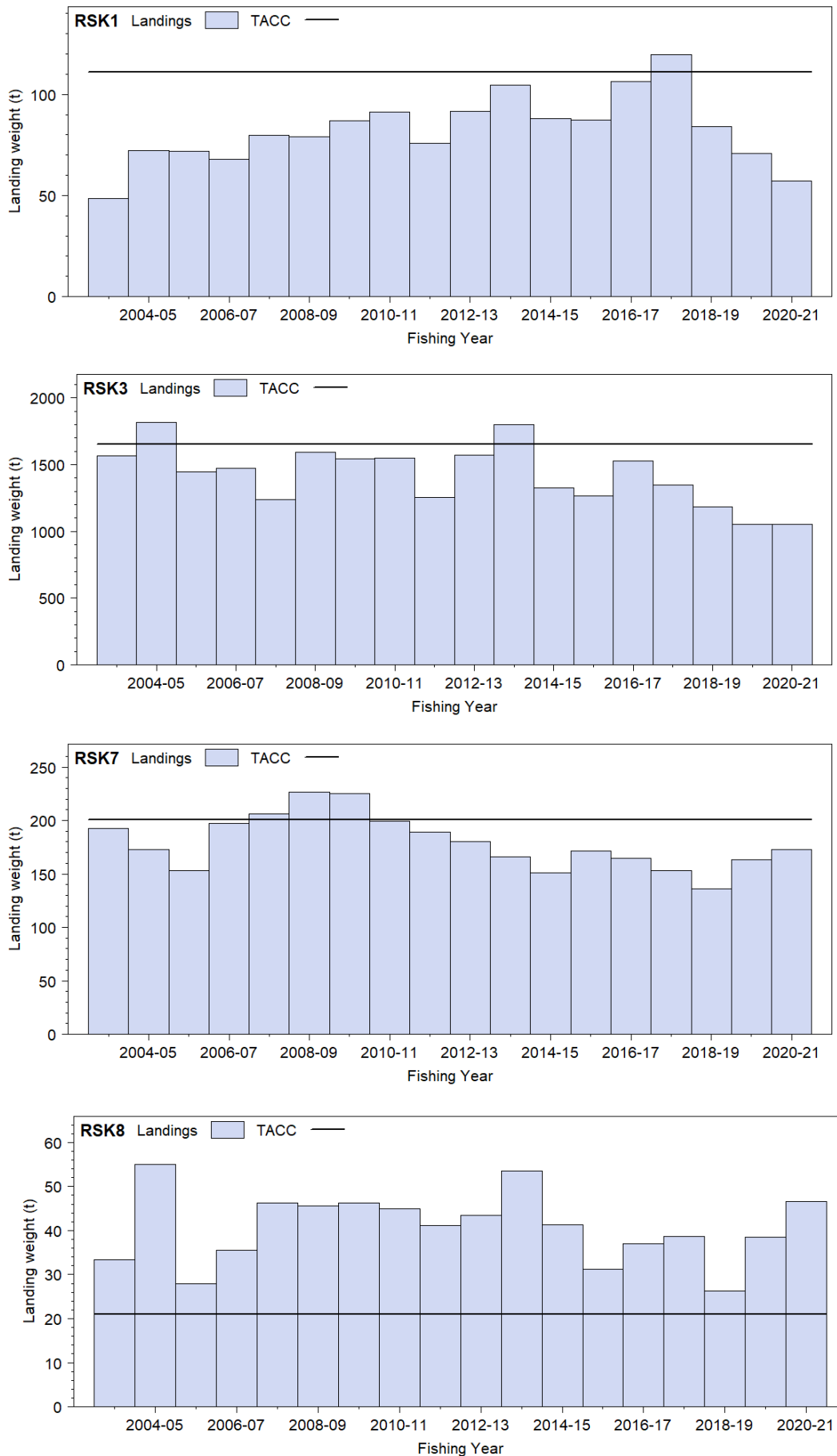
Figure 1: Reported commercial landings and TACC for the four main RSK stocks. From top to bottom: RSK 1 (Auckland East), RSK 3 (South East Coast, South East Chatham Rise, Sub-Antarctic, Southland), and RSK 7 (Challenger), and RSK 8 (Central Egmont, Auckland West).

1.2   Recreational fisheries

Recreational fishing surveys indicate that rough skates are very rarely caught by recreational fishers.

1.3   Customary non-commercial fisheries

Quantitative information on the level of customary non-commercial take is not available.

1.4   Illegal catch

Quantitative information on the level of illegal catch is not available.

1.5   Other sources of mortality

Because skates are taken mainly as bycatch of bottom trawl fisheries, historical catches have probably been proportional to the amount of effort in the target trawl fisheries. Past catches were probably higher than historical landings data suggest, because of unrecorded discards and unrecorded foreign catch before 1983.

2.   BIOLOGY

Little is known about the reproductive biology of rough skates. Rough skates reproduce by laying yolky eggs, enclosed in leathery cases, on the seabed. Rough skates lay their eggs in spring-summer (Francis 1997). Two eggs are laid at a time, but the number of eggs laid annually by a female is unknown. A single embryo develops inside each egg case and the young hatch at about 10–15 cm pelvic length (body length excluding the tail) (Francis 1997).

Rough skates grow to at least 79 cm pelvic length, and females grow larger than males. The greatest reported age is 9 years for a 70 cm pelvic length female, and females may live longer than males (Francis et al 2001a, b). There are no apparent differences in growth rate between the sexes. Males reach 50% maturity at about 52 cm and 4 years, and females at 59 cm and 6 years. The most plausible estimate of M is 0.25–0.35. Biological parameters relevant to stock assessment are shown in Table 4.

Table 4: Estimates of biological parameters for Rough skates (RSK).

Fishstock		Estimate		Source
1. Natural mortality (M)				
RSK 3		0.25–0.35		Francis et al (2001b)
2. Weight $= a$ (length)^b (weight in g, length in cm pelvic length)				
	a		b	
RSK males	0.0393		2.838	Francis (1997)
RSK females	0.0218		3.001	Francis (1997)
3. von Bertalanffy growth parameters				
	K	t_0	L_∞	
RSK 3 (both sexes)	0.16	-1.2	91.3	Francis et al (2001b)
RSK 3 (both sexes)	0.096	-0.78	151.8	Francis et al (2004)

3.   STOCKS AND AREAS

Nothing is known about stock structure or movement patterns in skates. Inshore trawl surveys of the east and west coasts of the South Island used to tag and release live rough skate, but this has been discontinued. Tag returns have been low and data from what returns there have been have not been analysed. Rough skates are distributed throughout most of New Zealand, from the Three Kings Islands to Campbell Island and the Chatham Islands, including the Challenger Plateau, Chatham Rise, and Bounty Plateau. Rough skates have not been recorded from QMA 10.

In this report, rough skate landings have been presented by QMA. QMAs would form appropriate management units in the absence of any information on biological stocks.

4. STOCK ASSESSMENT

4.1 Biomass estimates

4.1.1 Trawl Surveys

Relative biomass estimates are available for rough skates from a number of trawl survey series (Table 5). In the first survey (1991) of each of two series (east coast South Island and Chatham Rise), the two skate species were not (fully) distinguished. Furthermore, there are doubts about the accuracy of species identification in some other earlier surveys (prior to 1996).

All potential surveys were reviewed to determine which might provide reliable indices for abundance (Holmes et al in prep). Surveys rejected are listed in Table 6 together with the main reasons for their exclusion. Indices taken forward for consideration for partial quantitative assessment were:
- east coast South Island (ECSI) *Kaharoa* trawl survey, and
- west coast South Island (WCSI) *Kaharoa* trawl survey.

Estimates of biomass for RSK from the ECSI *Kaharoa* and WCSI *Kaharoa* trawl surveys are provided in Figures 2 and 3. Biomass estimates have been relatively stable for the ECSI time series since the latter was reinstated in 2007. Biomass estimates have fluctuated for the WCSI time series. CVs are relatively low for both time series (generally < 30%).

ECSI trawl surveys

The east coast South Island winter surveys from 1991 to 1996 (30–400 m) were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range; but these were discontinued after the fifth in the annual time series because of the extreme fluctuations in catchability between surveys (Beentjes & Stevenson 2001). The winter surveys were reinstated in 2007, and this time were expanded to include the 10–30 m depth range, in order to monitor elephantfish and red gurnard which were officially included in the list of target species in 2012. The 2007, 2012, 2014, 2016, 2018, and 2021 surveys provide full coverage of the 10–30 m depth range.

The additional biomass captured in the 10–30 m depth range accounted for 30%, 20%, 38%, 27%, 19%, and 16% of the biomass in the core plus shallow strata (10–400 m) for 2007, 2012, 2014, 2016, 2018, and 2021 respectively, indicating that, in terms of biomass, it is essential to monitor the core plus shallow strata (10–400 m). The core strata biomass series does indicate biomass to be higher in the period since the reinstatement of the survey in 2007 than in the 1990s. Estimated biomasses in 2014 and 2016 were more than double that of the highest biomass estimate of the 1990s (Table 5, Figure 2) (MacGibbon et al 2019). The biomass estimate in 2021 is the highest in the series for both core and core plus shallow strata (Figure 2).

The rough skate length distributions for the east coast South Island winter trawl survey core strata (30–400 m) have no clear modes, comprise multiple year classes, and very small skate tend to be found in shallow water in some surveys (Beentjes & MacGibbon 2013, Beentjes et al 2015, 2016, McGibbon et al 2019). The survey appears to be monitoring pre-recruited lengths down to 1+ age and the full recruited distribution, but no individual cohorts are discernible. Length frequency distributions are reasonably consistent among surveys with no lengths measured before 1996. The addition of the 10–30 m depth range has changed the shape of the length frequency distribution only slightly for some surveys, with more smaller skate present (Beentjes et al 2015, 2016, Beentjes & MacGibbon 2013, MacGibbon et al 2019).

Table 5: Doorspread biomass estimates (t) and coefficients of variation (CV %) of rough skates.

Year	Trip Code	Biomass	CV		Year	Trip	Biomass	CV
East coast North Island (RSK 1) Autumn 20–400m					Chatham Rise (RSK 3) Summer 200–800 m			
1993	KAH9304	76	28		1991–92	TAN9106	–	–
1994	KAH9402	189	12		1992–93	TAN9212	55	83.1
1995	KAH9502	52	20		1994	TAN9401	221	44.3
1996	KAH9602	309	24		1995	TAN9501	76	43.2
Discontinued					1996	TAN9601	11	100
					1997	TAN9701	12	58.4
East coast South Island (RSK 3) Winter 30–400 m (10–400 m)					1998	TAN9801	10	100
1991	KAH9105	–	–		1999	TAN9901	34	60.1
1992	KAH9205	224	24		2000	TAN0001	0	–
1993	KAH9306	335	21		2001	TAN0101	72	58.5
1994	KAH9406	517	20		2002	TAN0201	37	64.5
1996	KAH9606	177	19		2003	TAN0301	32	63.9
2007	KAH0705	878 (1 261)	22 (16)		2004	TAN0401	22	60.4
2008	KAH0806	858	19		2005	TAN0501	89	45.4
2009	KAH0905	1 029	30		2006	TAN0601	56	59
2012	KAH1207	1 113 (1 414)	20 (16)		2007	TAN0701	29	94.9
2014	KAH1402	1 153 (1 597)	38 (28)		2008	TAN0801	0	–
2016	KAH1605	1 142 (1 576)	30 (22)		2009	TAN0901	23	66.8
2018	KAH1803	978 (1 213)	16 (14)		2010	TAN1001	0	–
2021	KAH2104	2 097 (2 486)	22 (19)		2011	TAN1101	154	54.9
					2012	TAN1201	0	–
East coast South Island (RSK 3) Summer 30–400 m					2013	TAN1301	38	78.5
1996–97	KAH9618	1 336	15		2014	TAN1401	37	69.1
1997–98	KAH9704	1 082	13		2016	TAN1601	47	64.7
1998–99	KAH9809	1 175	10		2018	TAN1801	10	83
1999–00	KAH9917	329	23		2020	TAN2001	0	–
2000–01	KAH0014	222	34		2022	TAN2201	9	100
Sub-Antarctic (RSK 3) Summer 300–800m					Stewart-Snares shelf (RSK 3) Summer 30–600m			
1991	TAN9105	42	72.8		1993	TAN9301	592	20
1992	TAN9211	52	68.8		1994	TAN9402	1 064	15
1993	TAN9310	133	56.9		1995	TAN9502	801	7
2000	TAN0012	201	56.4		1996	TAN9604	1 055	11
2001	TAN0118	158	51.3		Discontinued			
2002	TAN0219	55	47.4					
2003	TAN0317	78	42.9					
2004	TAN0414	25	72.4					
2005	TAN0515	116	45.9					
2006	TAN0617	159	74.1					
2007	TAN0714	115	67.3					
2008	TAN0813	362	56.9					
2009	TAN0911	190	52.4					
2011	TAN1117	106	61.6					
2012	TAN1215	68	75.4					
2014	TAN1412	11	93.4					
2016	TAN1614	6	100					
2018	TAN1811	466	89.6					
2020	TAN2014	130	57.1					
South Island west coast and Tasman Bay/Golden Bay (RSK 7)					West Coast South Island (*Tangaroa*) (RSK 7) 200–800m			
1992	KAH9204	173	27		2012	TAN1210	12	39
1994	KAH9404	196	23		2013	TAN1308	8	40
1995	KAH9504	251	22		2016	TAN1609	4	48
1997	KAH9701	185	30		2018	TAN1807	5	51
2000	KAH0004	186	23		2021	TAN2107	5	48
2003	KAH0304	43	34					
2005	KAH0503	58	30					
2007	KAH0704	256	23					
2009	KAH0904	114	21					
2011	KAH1104	347	23					
2013	KAH1305	243	24					
2015	KAH1503	150	20					
2017	KAH1703	270	21					
2019	KAH1902	132	26					
2021	KAH2103	123	26					

Table 6: Surveys considered but rejected for providing indices of abundance of rough skates and main reason(s) for their rejection.

FMA	Survey	Reason(s) for rejection
RSK 1	HAGU Hauraki Gulf	Very low biomass of rough skate present. Only very shallow strata (< 75 m) in recent surveys.
RSK 1	BPLE Bay of Plenty	Very low biomass of rough skate present. Only very shallow strata (< 100 m) in recent surveys.
RSK 3	Chatham Rise	Very low occurrence of rough skate in catches. Relative biomass CVs always > 40%.
RSK 3	Sub-Antarctic Summer	Shallowest strata too deep (>300m). Relative biomass CVs always > 40% (often much higher).
RSK 3	Sub-Antarctic Autumn	Discontinued survey.
RSK 3	Stewart-Snares shelf	Discontinued survey.
RSK 7	WCSI (*Tangaroa*)	Very low occurrence of rough skate in catches. Relative biomass CVs always 40% or higher.
RSK 8	WCNI	Few of the historical surveys go >100 m and cover the area south of Cape Egmont*

* There is potential to use the WCNI (west coast North Island) survey in future if strata remain consistent with the 2020 survey (including southern strata).
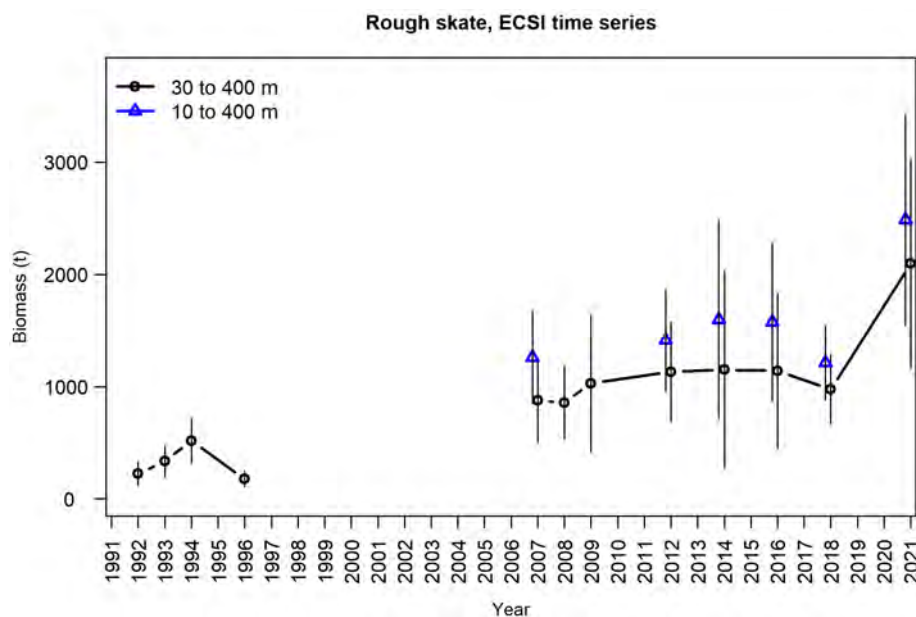
Figure 2: Rough skate total biomass for the ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m). Error bars are ± two standard deviations.

WCSI trawl surveys

The west coast South Island autumn trawl surveys have been undertaken since 1992 and regularly catch rough skate (MacGibbon 2019). However, biomass has fluctuated with no apparent trend throughout the time series and CVs are relatively modest, ranging from 20% to 34%, making it unclear to what degree the survey monitors abundance. The amount of rough skate caught in Tasman Bay and Golden Bay (TBGB) can be significant, but it is highly variable between years and shows a different trend to the west coast (Figure 3).
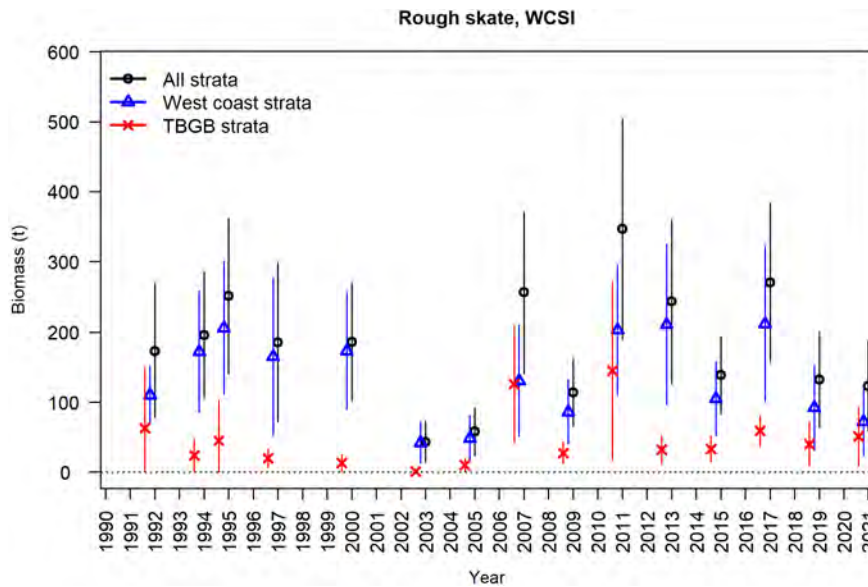
Figure 3: Rough skate biomass for the west coast South Island inshore trawl survey time series (error bars are ± two standard deviations).

Establishing B_{MSY} compatible reference points

In 2022 the Working Group accepted the mean of relative biomass estimates from the core plus shallow strata (10–400 m) ECSI *Kaharoa* survey over the years 2007–2018 as a B_{MSY} proxy for rough skate in RSK 3. This period was chosen because both biomass and catch were relatively stable over this period (Figure 4A). It was also evident (from the core series) that biomass had increased substantially since the 1990s, and this was correlated with a reduction in fishing effort in the mixed species inshore trawl fishery for FMA 3 (Starr et al in prep).

It was not possible to agree on a target period for RSK 7 because the survey series had high interannual variability during the period when catch information was available, i.e., after 2004 when the two species were introduced to the QMS (Figure 4B). It has already been noted that fluctuations in biomass estimates of rough skate from the WCSI suggest that abundance is probably not being monitored adequately (Stevenson & Hanchet 2000). There was a period of stability in the survey series from 1993 to 2000, but there are no catch data for those years. The WG recommended investigating reasons for the high variability (the biomass estimates have relatively low CVs) of survey biomass in the latter part of the series, with a view to identifying strata with consistent biomass estimates with lower interannual variability.

A)

B)
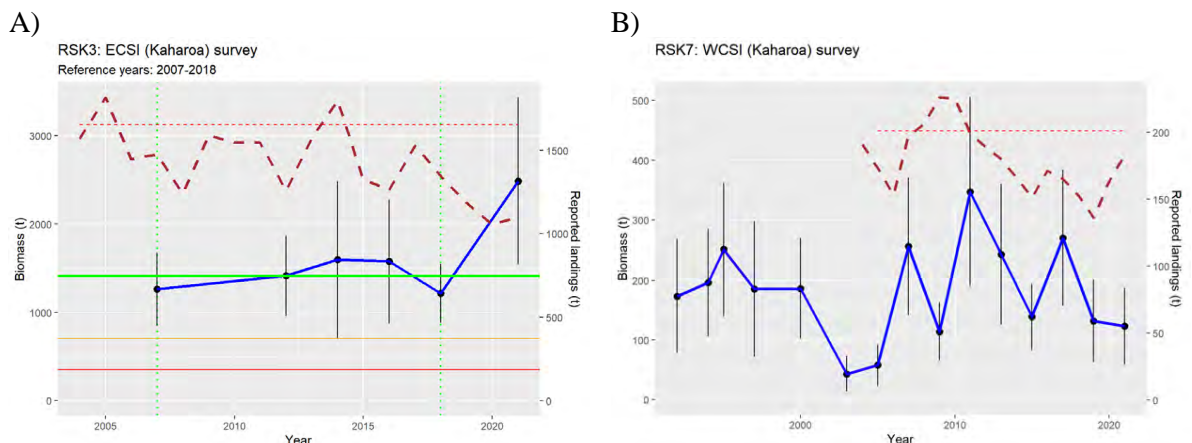
Figure 4: Relative biomass, blue line plus vertical lines showing ± 2 s.d. (left axis) from A) ECSI *Kaharoa* trawl survey and B) WCSI *Kaharoa* trawl survey. In each plot QMR/MHR landings are shown by dashed line and TACC for the management area by red dotted line, with scale on right axis. For ECSI *Kaharoa* trawl survey, the green line represents the accepted B_{MSY} proxy of mean abundance over the years indicated at the top of the figure, the orange line shows soft limit (50% B_{MSY} proxy), and the red line shows hard limit (25% B_{MSY} proxy).

4.2   Other factors

Species that constitute a minor bycatch of trawl fisheries are often difficult to manage using TACCs and ITQs. Skates are widely and thinly distributed and would be difficult for trawlers to avoid after the quota had been caught. A certain level of incidental bycatch is therefore inevitable. However, skates are relatively hardy and frequently survive being caught in trawls (though mortality would depend on the length of the tow and the weight of fish in the cod end). Skates returned to the sea alive probably have a greater chance of survival than most other fishes.

A data informed qualitative risk assessment was completed on all chondrichthyans (sharks, skates, rays, and chimaeras) at the New Zealand scale in 2014 (Ford et al 2015). Rough skate was ranked number one (highest) in terms of risk of the eleven QMS chondrichthyan species. Data were described as existing but poor for the purposes of the assessment, and consensus over this risk score was achieved by the expert panel. This risk assessment does not replace a stock assessment for this species but may influence research priorities across species.

4.3   Future research considerations

- Work to determine the extent of current misidentification of RSK and SSK in commercial fisheries (the study of Beentjes 2005 was conducted not long after RSK and SSK were required to be reported separately under the QMS).
- Investigate alternative stratum combinations in compiling the WCSI *Kaharoa* survey index with a view to understanding the high variability of survey biomass results from the current series and identifying strata with consistent biomass estimates with lower interannual variability. This may be informed by spatio-temporal modelling of survey data (e.g., VAST, or INLA).
- Nothing is known about the stock structure or movement patterns of rough skates. It would be beneficial to improve our understanding of stock structure, particularly in relation to the links between Tasman Bay and Golden Bay and the west coast of South Island.
- Investigate currently available maturity information (largely for males), to determine whether more information on female maturity should be collected from trawl surveys.
- Reliable catch information at species level limits our current determination of a stable reference period for RSK 7, as well as estimation of relative exploitation rate for all stocks; but trend in effort could be used to infer historical catches or relative fishing mortality to identify stable periods.
- The estimation of catches based on models using species mix data from landings or observer data could be explored, particularly where the TACC may be limiting landings. This would be particularly useful for estimating relative exploitation rate.

5.   STATUS OF THE STOCKS

No estimates of current and reference biomass are available for RSK 1, RSK 7, RSK 8, and RSK 10.

- **RSK 3**

Stock Structure Assumptions
For the purposes of this summary RSK 3 is considered to be a single management unit.

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Abundance index based on research trawl survey
Reference Points	Interim Target: B_{MSY} proxy based on arithmetic mean survey index for the period 2007 to 2018 (a period with high yield when both catch and survey index were stable) Soft Limit: 50% B_{MSY} proxy Hard Limit: 25% B_{MSY} proxy Overfishing threshold: F_{MSY} proxy based on mean relative exploitation rate for the period 2007 to 2018

Status in relation to Target	Likely (> 60%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status

RSK3: ECSI (Kaharoa) survey
Reference years: 2007-2018

RSK 3 relative biomass from ECSI _Kaharoa_ trawl survey (blue line plus vertical lines showing ± 2 s.d. (left axis)), reported QMR/MHR landings (brown dashed line), and TACC for RSK 3 (red dotted line (right axis)). Green line represents the B_{MSY} proxy of mean abundance series from 2007 to 2018. Orange line shows soft limit (50% B_{MSY} proxy), and red line shows hard limit (25% B_{MSY} proxy). Reported landings are believed to be inaccurate.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Relative biomass was stable between 2007 and 2018 and was estimated as higher than the target reference period average in 2021.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	ECSI _Kaharoa_ trawl survey core area series showed abundance increased 2–3 fold since the early 1990s (which informed the use of the reference period).
Trends in Other Relevant Indicators or Variables	ECSI mixed species inshore bottom trawl effort has declined by more than 50% since 1990, which may explain the declining catch of RSK, which is predominantly a bycatch species.

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Survey abundance index	
Assessment Dates	Latest assessment: 2022	Next assessment: 2023
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	Survey abundance index	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
- Estimate of current status is based on only the most recent survey.

Fishery Interactions
Rough skate constitute a bycatch of trawl fisheries. Skates are widely distributed and difficult for trawlers to avoid.

- **RSK 7**

Stock Structure Assumptions
For the purposes of this summary RSK 7 is considered to be a single management unit.

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Abundance index based on research trawl survey
Reference Points	Target: B_{MSY} proxy Soft Limit: 50% B_{MSY} proxy Hard Limit: 25% B_{MSY} proxy Overfishing threshold: F_{MSY} proxy
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status

RSK7: WCSI (Kaharoa) survey

RSK 7 relative biomass from WCSI *Kaharoa* trawl survey (blue line plus vertical lines showing ± 2 s.d. (left axis)), reported QMR/MHR landings (dashed line), and TACC for RSK 3 (red dotted line (right axis)). Reported landings are believed to be inaccurate.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Relative biomass was stable between 1992 and 2000. Since 2007 abundance estimates have fluctuated, however, considering the full survey series, there is no evidence of a long-term trend.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Survey abundance index	
Assessment Dates	Latest assessment: 2022	Next assessment: 2024
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	Survey abundance index	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	In the period since RSK entered the QMS abundance estimates have shown large inter-annual fluctuations. The reasons for these fluctuations are unknown.	

Qualifying Comments
- As there was no period with stable catch and abundance available, it was not possible to determine reference points, nor therefore stock status.

Fishery Interactions
Rough skate constitute a bycatch of trawl fisheries. Skates are widely distributed and difficult for trawlers to avoid.

6.   FOR FURTHER INFORMATION

Beentjes, M P (2005) Identification and reporting of commercial skate landings. *New Zealand Fisheries Assessment Report 2005/16*. 18 p.

Beentjes, M P; MacGibbon, D J (2013) Review of QMS species for inclusion in the east coast South Island winter trawl survey reports. *New Zealand Fisheries Assessment Report 2013/35*. 102 p.

Beentjes, M P; MacGibbon, D; Lyon, W S (2015) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2014 (KAH1402). *New Zealand Fisheries Assessment Report 2015/14*. 136 p.

Beentjes, M P; MacGibbon, D; Parkinson, D (2016) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2016 (KAH1605). *New Zealand Fisheries Assessment Report 2016/61*. 135 p.

Beentjes, M P; Stevenson, M L (2000) Review of the east coast South Island winter trawl survey time series, 1991–96. *NIWA Technical Report 86*. 64 p.

Beentjes, M P; Stevenson, M L (2001) Review of the east coast South Island summer trawl survey time series, 1996–97 to 1999–2000. *NIWA Technical Report 108*. 92 p.

Ford, R B; Galland, A; Clark, M R; Crozier, P; Duffy, C A J; Dunn, M R; Francis, M P; Wells, R (2015) Qualitative (Level 1) Risk Assessment of the impact of commercial fishing on New Zealand Chondrichthyans. *New Zealand Aquatic Environment and Biodiversity Report No. 157*. 111 p.

Francis, M P (1997) A summary of biology and commercial landings, and a stock assessment of rough and smooth skates (*Raja nasuta* and *R. innominata*). New Zealand Fisheries Assessment Research Document 1997/5. 27p. (Unpublished document held by NIWA library.)

ROUGH SKATE (RSK)

Francis, M P; Ó Maolagáin, C; Stevens, D (2001a) Age, growth, and sexual maturity of two New Zealand endemic skates, *Dipturus nasutus* and *D. innominatus*. *New Zealand Journal of Marine and Freshwater Research 35*: 831–842.

Francis, M P; Ó Maolagáin, C; Stevens, D (2001b) Age, growth, maturity, and mortality of rough and smooth skates (*Dipturus nasutus* and *D. innominatus*). *New Zealand Fisheries Assessment Report 2001/17*. 21 p.

Francis, M P; Ó Maolagáin, C; Stevens, D (2004) Revised growth, longevity and natural mortality of smooth skate (*Dipturus innominatus*). Final Research Report for Ministry of Fisheries Project MOF2003/01H (Dated June 2004). (Unpublished report held by Fisheries New Zealand.)

Holmes, S J; McKenzie, A; Ballara, S; MacGibbon, D J; Bian, R (in prep) Review of suitability of trawl surveys to provide abundance indices for rough skate (*Zearaja nasuta*) and smooth skate (*Dipturus innominatus*) and partial quantitative assessments of rough skate in RSK 3 and smooth skate in SSK 7. Draft New Zealand Fisheries Assessment Report.

MacGibbon, D J (2019) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2019 (KAH1902). *New Zealand Fisheries Assessment Report 2019/64*. 87 p.

MacGibbon, D J; Beentjes, M P; Lyon, W L; Ladroit, Y (2019) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2018 (KAH1803). *New Zealand Fisheries Assessment Report 2019/03*. 136 p.

Starr, P; Tornquist, M; Middleton, D; Large, K (in prep) SPO2021-01: national SPO characterisation and CPUE, Part 2A: introduction & BT CPUE. Draft New Zealand Fisheries Assessment Report.

Stevenson, M L; Hanchet, S (2000) Review of the inshore trawl survey series of the west coast South Island and Tasman and Golden Bays, 1992–97. *NIWA Technical Report 82*. 79 p.

SMOOTH SKATE (SSK)
(*Dipturus innominatus*)
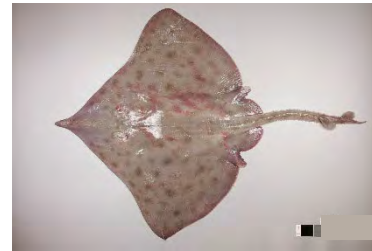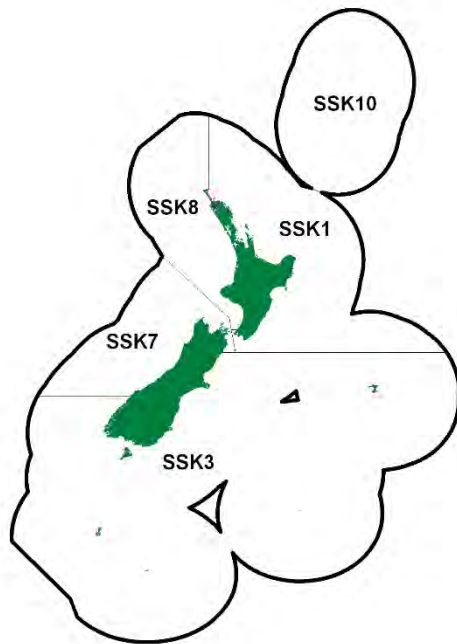
1.   FISHERY SUMMARY

1.1   Commercial fisheries

Smooth skate (*Dipturus innominatus*, SSK), which are also known as barndoor skates, are fished commercially in close association with rough skates (RSK) in New Zealand. Smooth skates grow considerably larger than rough skates, but both species are landed and processed. Two other species of deepwater skate (*Bathyraja shuntovi* and *Raja hyperborean*) are large enough to be of commercial interest but are relatively uncommon and probably comprise a negligible proportion of the landings.

Skate flesh ammoniates rapidly after death, so the wings are removed at sea, and chilled or frozen. On arrival at the shore factories, the wings are machine-skinned, graded, and packed for sale. Most of the product is exported to Europe, especially France and Italy. Skates of all sizes are processed, though some factories impose a minimum weight limit of about 1 kg (200 g per wing), and occasionally wings from very large smooth skates are difficult to market.

Smooth skates occur throughout New Zealand, but are most abundant around the South Island in depths down to 500 m. Most of the catch is taken as bycatch by bottom trawlers, but skates are also taken by longliners. Significant longline bycatch has been reported from the Bounty Plateau in QMA 6. While there is no clear separation of the depth ranges inhabited by rough and smooth skates, smooth skates tend to occur slightly deeper than rough skates (Beentjes & Stevenson 2000, 2001, Stevenson & Hanchet 2000).

Many fishers and processors did not previously distinguish rough and smooth skates in their landing returns, and coded them instead as 'skates' (SKA). Because it is impossible to determine the species composition of the catch from landings data prior to introduction of these species into the QMS, all pre-QMS data reported here consist of the sum of the three species codes RSK, SSK, and SKA. Landings have been converted from processed weight to whole weight by application of conversion factors. Further, following introduction into the QMS in 2003, the two skate species were not always correctly identified and, a considerable, but unknown catch of either species is misidentified with over-reporting of rough skate and, correspondingly, under-reporting of smooth skate (Beentjes 2005). Neither fishers nor processors were distinguishing between the two skate species or reporting catches of each species correctly at the time of the study in 2004. It is not known if reporting has improved since that time.

There have been historical changes to the conversion factors applied to skates by MAF Fisheries and Ministry of Fisheries. No record seems to have been kept of the conversion factors in use before 1987, so it is not possible to reconstruct the time series of landings data using the currently accepted factors. Consistent and appropriate conversion factors have been applied to skate landings since the end of the 1986–87 fishing year. Before that, it appears that a lower conversion factor was applied, resulting in an underestimation of landed weight by about 20%. No correction has been made for that in this report.

New Zealand annual skate landings, estimated from a variety of sources, are shown in Table 1. No FSU deepwater data were available before 1983, and it is not known whether deepwater catches, including those of foreign fishing vessels, were significant during that period. CELR and CLR data are provided by inshore and deepwater trawlers respectively. 'CELR estimated' landings were always less than 'CELR landed' landings, because the former include only the top five fish species (by weight) caught by trawlers, whereas the latter include all species landed. As a relatively minor bycatch, skates frequently do not fall into the top five species. The sum of the 'CELR landed' and CLR data provides an estimate of the total skate landings. This estimate usually agreed well with LFRR data supplied by fish processors, especially in 1993–94 and 1994–95, but in 1992–93 the difference was 467 t. The 'best estimate' of the annual historical landings comes from FSU data up to 1985–86, and LFRR data thereafter.

Table 1: New Zealand skate landings for calendar years 1974–1983, and fishing years (1 October–30 September) 1983–84 to 1995–96. Values in parentheses are based on part of the fishing year only. Landings do not include foreign catch before 1983, or unreported discards. FSU = Fisheries Statistics Unit; CELR = Catch, Effort and Landing Return; CLR = Catch Landing Return; LFRR = Licensed Fish Receivers Return; Best Estim. = best available estimate of the annual skate catch; - = no data.

| | | | FSU | | CELR | | CELR Landed | | |
Year	Inshore	Deepwater	Total	Estim.	Landed	CLR	+CLR	LFRR	Best Estim.
1974	23	–	–	–	–	–	–	–	23
1975	30	–	–	–	–	–	–	–	30
1976	28	–	–	–	–	–	–	–	28
1977	27	–	–	–	–	–	–	–	27
1978	36	–	–	–	–	–	–	–	36
1979	165	–	–	–	–	–	–	–	165
1980	441	–	–	–	–	–	–	–	441
1981	426	–	–	–	–	–	–	–	426
1982	648	–	–	–	–	–	–	–	648
1983	634	178	812	–	–	–	–	–	812
1983–84	686	298	983	–	–	–	–	–	983
1984–85	636	250	886	–	–	–	–	–	886
1985–86	613	331	944	–	–	–	–	–	944
1986–87	723	285	1 007	–	–	–	–	1 019	1 019
1987–88	1 005	421	1 426	–	–	–	–	1 725	1 725
1988–89	(530)	(136)	(665)	(252)	(265)	(28)	(293)	1 513	1 513
1989–90	–	–	–	780	1 171	410	1 581	1 769	1 769
1990–91	–	–	–	796	1 334	359	1 693	1 820	1 820
1991–92	–	–	–	1 112	1 994	703	2 698	2 620	2 620
1992–93	–	–	–	1 175	2 595	824	3 418	2 951	2 951
1993–94	–	–	–	1 247	2 236	788	3 024	2 997	2 997
1994–95	–	–	–	956	1 973	829	2 803	2 789	2 789
1995–96	–	–	–	–	–	–	–	2 789	2 789

Total skate landings (based on the 'best estimate' in Table 1) were negligible up to 1978, presumably because of a lack of suitable markets and the availability of other more abundant and desirable species. Landings then increased linearly to reach nearly 3000 t in 1992–93 and 1993–94 and remained between 2600 and 3100 t until the separation of skate species under the QMS. Reported landings of smooth skate are provided in Table 2.

Smooth skates were introduced into the QMS as a separate species from 1 October 2003 with allowances, TACCs, and TACs in Table 3. Figure 1 shows the historical landings and TACC values for the main SSK stocks. Owing to problems associated with identification of rough and smooth skates, reported catches of each species are probably not accurate (Beentjes 2005). Initiatives to improve

identification of these species begun in 2003 may have resulted in more accurate data. The largest smooth skate Fishstock is SSK 3, which on average has contributed 60% of landings since the fishing year 2003–04. SSK 3 landings have always remained below the TACC, ranging between 408 t and 473 t from 2003–04 to 2006–07, before decreasing to about 300 t in 2009–10 to 2012–13. Landings then increased again, peaking at 511 t in 2017–18. Landings in SSK 7 fluctuated around the TACC from 2010–11 to 2016–17 but have been closer to 400 t (and consistently below the TACC) since then. The SSK 8 catch has been consistently over-caught, relative to the TACC, since the fishing year 2007–08. Most recently from 2016–17 to 2020–21 an average of 53 t of landings were recorded, exceeding the TACC by 33 t. It was put on Schedule 6 on 1 October 2006. Owing to discarding and misidentification of the two skate species, RSK and SSK, catches are likely to be inaccurate.

Table 2: Reported landings (t) of SKA and SSK by QMA and fishing year, 1996–97 to present.

Fishstock FMAs Skate (SKA)*	SSK 1 1–2 Land.	TACC	SSK 3 3–6 Land.	TACC	SSK 7 7 Land.	TACC	SSK 8 8–9 Land.	TACC	SSK 10 10 Land.	TACC	Total All Total
1996–97	43	–	894	–	380	–	30	–	0	–	1 347
1997–98	44	–	855	–	156	–	31	–	0	–	1 086
1998–99	48	–	766	–	228	–	12	–	0	–	1 054
1999–00	75	–	775	–	253	–	25	–	0	–	1 128
2000–01	88	–	933	–	285	–	28	–	0	–	1 334
2001–02	132	–	770	–	311	–	35	–	0	–	1 248
2002–03	121	–	857	–	293	–	32	–	0	–	1 303
2003–04	< 1	–	< 1	–	< 1	–	< 1	–	0	–	1
Smooth skate (SSK)											
1996–97	10	–	782	–	102	–	5	–	0	–	899
1997–98	5	–	901	–	121	–	4	–	0	–	1 031
1998–99	5	–	1 011	–	100	–	15	–	0	–	1 131
1999–00	5	–	877	–	73	–	16	–	0	–	971
2000–01	9	–	859	–	104	–	7	–	0	–	979
2001–02	17	–	794	–	89	–	7	–	0	–	907
2002–03	19	–	704	–	167	–	3	–	0	–	893
2003–04	79	37	431	579	146	213	15	20	0	0	671
2004–05	82	37	408	579	125	213	15	20	0	0	630
2005–06	72	37	468	579	163	213	12	20	0	0	715
2006–07	58	37	473	579	155	213	6	20	0	0	693
2007–08	47	37	422	579	171	213	21	20	0	0	661
2008–09	38	37	332	579	168	213	22	20	0	0	560
2009–10	36	37	290	579	194	213	26	20	0	0	546
2010–11	27	37	307	579	243	213	32	20	0	0	609
2011–12	24	37	283	579	209	213	27	20	0	0	544
2012–13	36	37	292	579	231	213	39	20	0	0	598
2013–14	43	37	336	579	225	213	39	20	0	0	641
2014–15	27	37	361	579	198	213	30	20	0	0	617
2015–16	38	37	405	579	222	213	30	20	0	0	695
2016–17	56	37	481	579	244	213	46	20	0	0	827
2017–18	58	37	511	579	198	213	52	20	0	0	819
2018–19	32	37	445	579	178	213	47	20	0	0	702
2019–20	24	37	368	579	192	213	68	20	0	0	652
2020–21	24	37	388	579	212	213	54	20	0	0	678

*Use of the code SKA ceased once skates were introduced into the QMS in October 2003 and rough skates and smooth skates were recognised as a separate species. From this time all landings of skates have been reported against either the RSK or SSK code.

Table 3: Recreational and customary non-commercial allowances (t), Total Allowable Commercial Catches (TACC, t), and Total Allowable Catch (TAC, t) declared for SSK on introduction into the QMS in October 2003.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other Mortality	TACC	TAC
SSK 1 (FMAs 1–2)	1	1	1	37	40
SSK 3 (FMAs 3–6)	1	1	6	579	587
SSK 7	1	1	2	213	217
SSK 8 (FMAs 8–9)	1	1	1	20	23
SSK 10	0	0	0	0	0

SMOOTH SKATE (SSK)
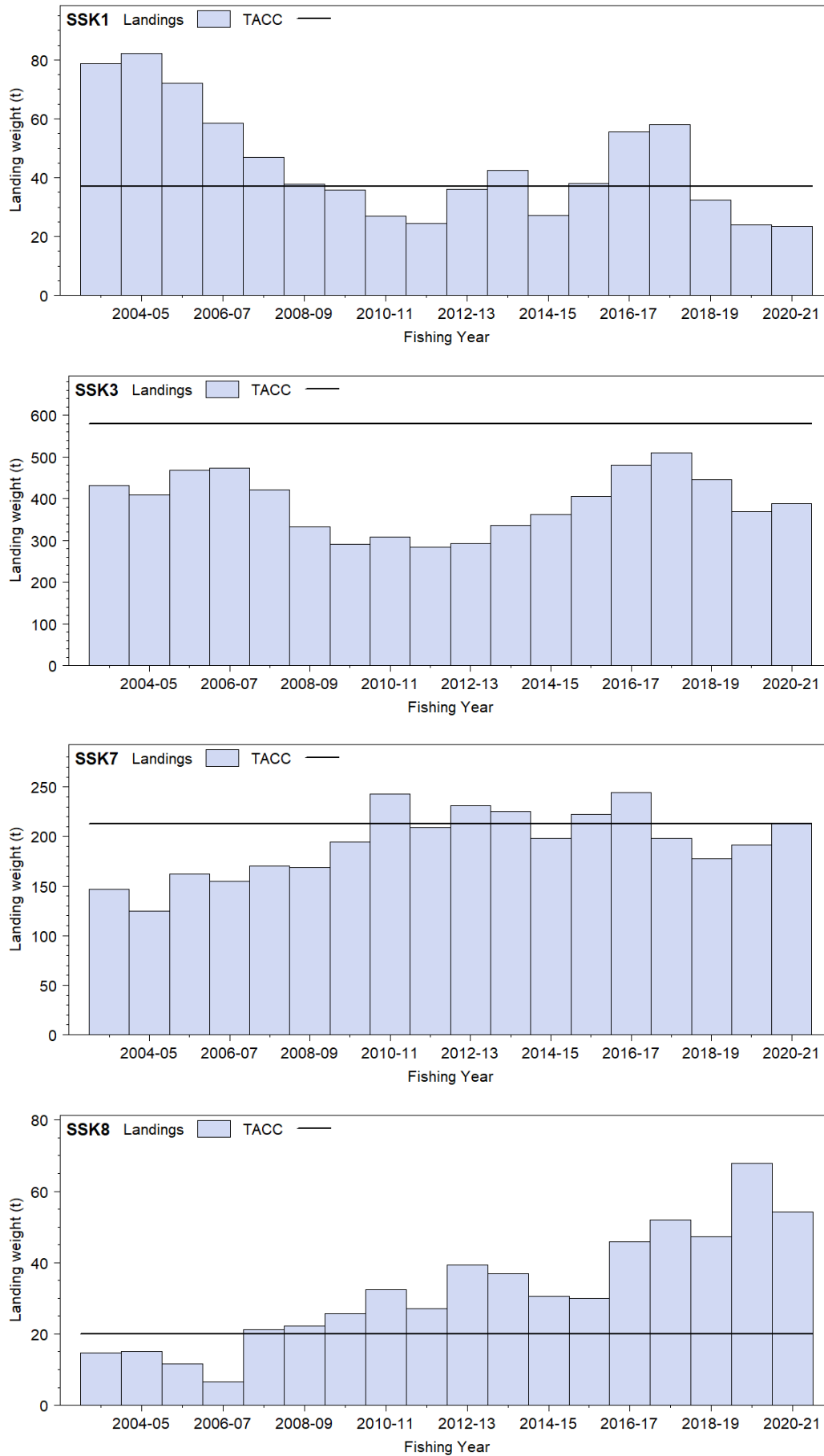
Figure 1: Reported commercial landings and TACCs for the four main SSK stocks. From top: SSK 1 (Auckland East) and SSK 3 (South East Coast, South East Chatham Rise, Sub-Antarctic, Southland), SSK 7 (Challenger), and SSK 8 (Central Egmont, Auckland West).

1.2   Recreational fisheries

Recreational fishing surveys indicate that skates are very rarely caught by recreational fishers.

1.3   Customary non-commercial fisheries

Quantitative information on the level of customary non-commercial take is not available.

1.4   Illegal catch

Quantitative information on the level of illegal catch is not available.

1.5   Other sources of mortality

Because skates are taken mainly as bycatch of bottom trawl fisheries, historical catches have probably been proportional to the amount of effort in the target trawl fisheries. Past catches were probably higher than historical landings data suggest because of unrecorded discards and unrecorded foreign catch before 1983.

2.   BIOLOGY

Little is known about the reproductive biology of smooth skates. Smooth skates reproduce by laying yolky eggs, enclosed in leathery cases, on the seabed. Two eggs are laid at a time, but the number of eggs laid annually by a female is unknown. A single embryo develops inside each egg case and the young hatch at about 10–15 cm pelvic length (body length excluding the tail) (Francis 1997).

The greatest reported age for smooth skate is 28 years for a 155 cm pelvic length female (Francis et al 2004). Females grow larger than males and also appear to live longer (Francis et al 2001a, b). There are no apparent differences in growth rate between the sexes. Males reach 50% maturity at about 93 cm and 8 years, and females at 112 cm and 13 years. However, the small sample size of mature animals, particularly females, means that the maturity ogives are poorly defined. The most plausible estimate of M is 0.10–0.20. Biological parameters relevant to stock assessment are shown in Table 4.

Table 4:   Estimates of biological parameters for skates.

Fishstock	Estimate			Source
1. Natural mortality (M)				
SSK 3	0.12–0.15			Francis et al (2004)
2. Weight $= a$ (length)^b (weight in g, length in cm pelvic length)				
	a	*b*		
SSK both sexes	0.0268	2.933		Francis (1997)
3. von Bertalanffy growth parameters				
	K	*t₀*	*L∞*	
SSK 3 (both sexes)	0.095	-1.06	150.5	Francis et al (2001b)
SSK 3 (Males)	0.117	-1.28	133.6	Francis et al (2004)

3.   STOCKS AND AREAS

Nothing is known about the stock structure or movement patterns of smooth skates. Smooth skates are distributed throughout most of New Zealand, from the Three Kings Islands to Campbell Island and the Chatham Islands, including the Challenger Plateau, Chatham Rise, and Bounty Plateau. Smooth skates have not been recorded from QMA 10.

In this report, smooth skate landings have been presented by QMA. QMAs form appropriate management units in the absence of any information on biological stocks.

4.   STOCK ASSESSMENT

4.1   Biomass estimates

4.1.1   Trawl Surveys

Relative biomass estimates are available for smooth skates from a number of trawl survey series (Table 5). In the first survey (1991) of each of two series (east coast South Island and Chatham Rise) the two skate species were not (fully) distinguished. Furthermore, there are doubts about the accuracy of species identification in some other earlier surveys (prior to 1996).

All potential surveys were reviewed to determine which might provide reliable indices for abundance (Holmes et al in prep). Surveys rejected are listed in Table 6 together with the main reasons for their exclusion. Indices taken forward for consideration for partial quantitative assessment were:
- east coast South Island (ECSI) *Kaharoa* trawl survey,
- Chatham Rise *Tangaroa* trawl survey,
- west coast South Island (WCSI) *Kaharoa* trawl survey, and
- west coast South Island (WCSI) *Tangaroa* trawl survey.

The series of biomass estimates from these four survey series are shown in Figures 2 to 5.

Chatham Rise trawl surveys

The Chatham Rise survey series using core strata starts in 1992 and data indicate this series covers an adequate depth range to track smooth skate abundance because only insignificant amounts of smooth skate have been caught from deeper strata added in more recent years (Figure 2). CVs are between 20% and 30% in most years and relative biomass estimates change without wide inter annual fluctuations. Length frequency data suggest all adult sizes are represented in the survey (as are all sizes seen in the commercial fishery), but smaller sizes caught shallower than 200 m in the Canterbury Bight and Pegasus Bay are not represented (Holmes et al in prep).

ECSI trawl surveys

The east coast South Island winter surveys from 1991 to 1996 (30–400 m) were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range; but these were discontinued after the fifth in the annual time series because of the extreme fluctuations in catchability between surveys (Beentjes & Stevenson 2001). The winter surveys were reinstated in 2007, and this time were expanded to include the 10–30 m depth range, to monitor elephantfish and red gurnard which were officially included in the list of target species in 2012. In contrast to rough skate, almost no smooth skate are caught in the 10–30 m depth range (Figure 3) indicating that in terms of biomass, only the existing core strata time series in 30–400 m should be monitored.

Smooth skate biomass estimates in the core strata (30–400 m) for the east coast South Island winter trawl surveys in recent years were higher overall than in the 1990s (Table 5, Figure 3) (MacGibbon et al 2019). There is no trend in biomass since 2007. Survey CVs are reasonable, with only two values above 25% (35% in 2012 and 28% in 2021).

The smooth skate length distributions for the east coast South Island winter trawl surveys are not consistent between surveys and comprise multiple year classes with indications of juvenile modes corresponding to 0+ fish in some years (Beentjes & MacGibbon 2013, Beentjes et al 2015, 2016, MacGibbon et al 2019). The rest of the distribution includes multiple year classes from about 1 to 25 years. The 30–100 m strata tend to have larger skates than the deeper strata (Beentjes & MacGibbon 2013). The surveys appear to be monitoring pre-recruited lengths down to 0+ age, but not the full extent of the recruited distribution (the latter was confirmed by comparison to lengths measured in commercial observer data, Holmes et al in prep). No lengths were measured before 1996.

Table 5: Doorspread biomass estimates (t) and coefficients of variation (CV %) of smooth skates.

Year	Trip Code	Biomass	CV	Year	Trip	Biomass	CV
East coast North Island (SSK 1) Autumn 20–400 m				Chatham Rise (SSK 3) Summer 200–800 m			
1993	KAH9304	23	52	1991–92	TAN9106	–	–
1994	KAH9402	144	38	1992–93	TAN9212	1 071	18
1995	KAH9502	20	59	1994	TAN9401	958	23
1996	KAH9602	85	36	1995	TAN9501	769	31
Discontinued				1996	TAN9601	1 511	30
				1997	TAN9701	1 932	22
East coast South Island (SSK 3) Winter 30–400 m				1998	TAN9801	10	26
1991	KAH9105	–	–	1999	TAN9901	1 738	20
1992	KAH9205	609	18	2000	TAN0001	1 369	23
1993	KAH9306	670	24	2001	TAN0101	2 321	19
1994	KAH9406	306	25	2002	TAN0201	2 111	17
1996	KAH9606	385	24	2003	TAN0301	1 355	21
2007	KAH0705	705	20	2004	TAN0401	2 006	21
2008	KAH0806	554	18	2005	TAN0501	1 780	24
2009	KAH0905	736	23	2006	TAN0601	1 521	29
2012	KAH1207	1 025	35	2007	TAN0701	1 922	17
2014	KAH1402	637	20	2008	TAN0801	1 376	26
2016	KAH1605	663	17	2009	TAN0901	1 162	18
2018	KAH1803	664	22	2010	TAN1001	1 576	21
2021	KAH2104	909	28	2011	TAN1101	1 009	32
				2012	TAN1201	813	22
East coast South Island (SSK 3) Summer 30–400 m				2013	TAN1301	38	20
1996–97	KAH9618	721	32	2014	TAN1401	1 309	22
1997–98	KAH9704	485	21	2016	TAN1601	1 662	22
1998–99	KAH9809	450	26	2018	TAN1801	1 529	22
1999–00	KAH9917	369	30	2020	TAN2001	847	29
2000–01	KAH0014	248	33	2022	TAN2201	1 266	28
Sub–Antarctic (SSK 3) Summer 300–800 m				Stewart–Snares shelf (SSK 3) Summer 30–600 m			
1991	TAN9105	386	23	1993	TAN9301	528	20
1992	TAN9211	119	45	1994	TAN9402	342	21
1993	TAN9310	118	43	1995	TAN9502	335	19
2000	TAN0012	435	66	1996	TAN9604	504	29
2001	TAN0118	636	43	Discontinued			
2002	TAN0219	299	65				
2003	TAN0317	475	60				
2004	TAN0414	331	52				
2005	TAN0515	34	86				
2006	TAN0617	995	43				
2007	TAN0714	483	52				
2008	TAN0813	1 406	51				
2009	TAN0911	648	76				
2011	TAN1117	1 660	79				
2012	TAN1215	680	74				
2014	TAN1412	1 012	37				
2016	TAN1614	323	50				
2018	TAN1811	141	92				
2020	TAN2014	803	60				
South Island west coast and Tasman Bay/Golden Bay (SSK 7)				West Coast South Island (*Tangaroa*) (SSK 7) 200–800m			
1992	KAH9204	339	19	2012	TAN1210	239	30
1994	KAH9404	341	18	2013	TAN1308	272	23
1995	KAH9504	315	20	2016	TAN1609	238	46
1997	KAH9701	302	26	2018	TAN1807	225	22
2000	KAH0004	140	29	2021	TAN2107	212	31
2003	KAH0304	91	79				
2005	KAH0503	80	30				
2007	KAH0704	55	44				
2009	KAH0904	67	61				
2011	KAH1104	185	33				
2013	KAH1305	188	29				
2015	KAH1503	342	25				
2017	KAH1703	62	37				
2019	KAH1902	204	28				
2021	KAH2103	123	39				

Table 6: Surveys considered but rejected for providing indices of abundance of smooth skates and main reason(s) for their rejection.

FMA	Survey	Reason(s) for rejection
SSK 1	HAGU Hauraki Gulf	Very low biomass of smooth skate present. Only very shallow strata (< 75 m) in recent surveys.
SSK 1	BPLE Bay of Plenty	Very low biomass of smooth skate present. Only very shallow strata (< 100 m) in recent surveys.
SSK 3	Sub-Antarctic Summer	Shallowest strata too deep (>300m). Relative biomass CVs always > 40% (often much higher).
SSK 3	Sub-Antarctic Autumn	Discontinued survey.
SSK 3	Stewart-Snares Shelf	Discontinued survey.
SSK 8	WCNI	Max depth only 200 m. CVs 40% or higher (for surveys of full latitudinal range).
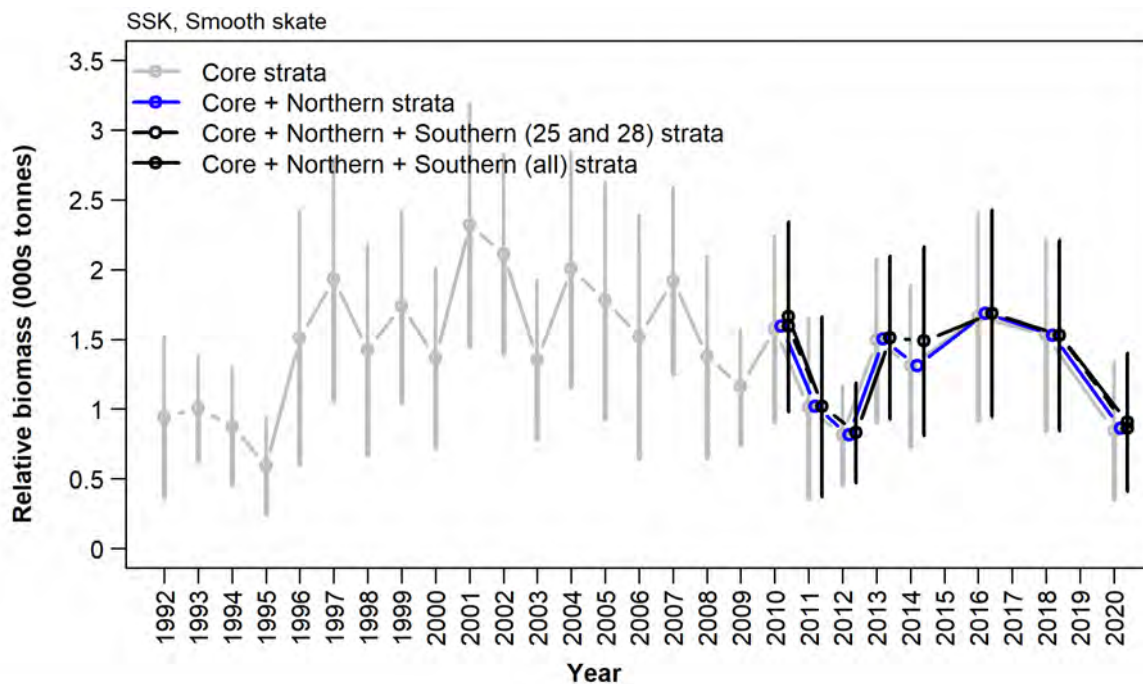
Figure 2: Smooth skate biomass for the Chatham Rise in core strata (200–800 m) and after addition of northern deep strata (1000-1300 m), two southern deep strata (800-1300 m), and further southern deep strata (800-1300 m).
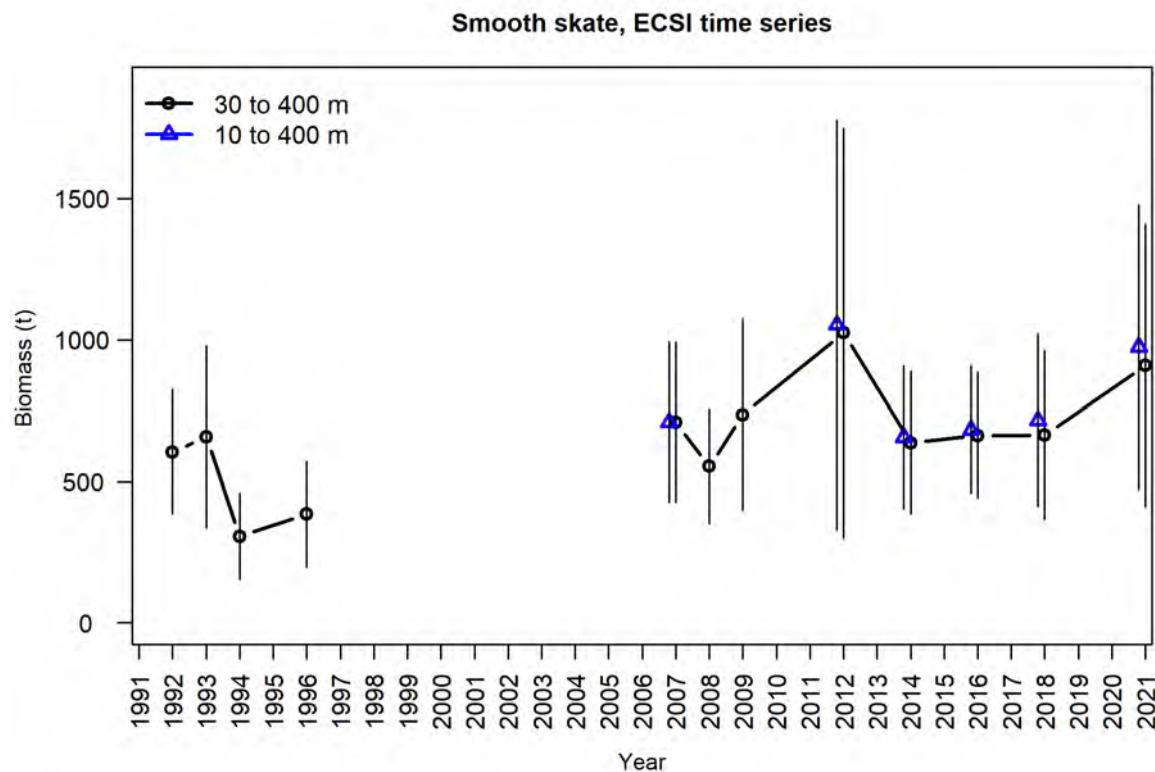
Figure 3: Smooth skate biomass for the ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m). Error bars are ± two standard deviations.

West coast South Island inshore (*Kaharoa*) trawl surveys

West coast South Island inshore trawl surveys (Figure 4) indicate that the relative biomass of smooth skate in FMA 7 declined substantially from 1997 to 2009, then recovered but with strong fluctuations in recent years. The biomass estimates have relatively high associated CVs since 2011 (25–43%).

Smooth skate are rarely caught in Tasman Bay and Golden Bay, with most of the smooth skate catch being from the west coast strata (Figure 4), particularly south of Greymouth and in depths greater than

100 m (MacGibbon 2019). Too few are caught for length frequency distribution plots to be informative. Comparison with length frequencies from the west coast South Island offshore surveys indicate the inshore surveys do not catch a representative sample of adult fish from either sex (Holmes et al in prep).

West coast South Island offshore (*Tangaroa*) trawl surveys
West coast South Island offshore trawl surveys (Figure 5) show the importance of including depths between 200 and 800 m. Addition of strata deeper than 800 m leads to almost no additional catch of smooth skate. Results from strata covering the 200–800 m depth range have reasonable CVs (20–30% except for 2016 at 46%), and length frequency data suggest the surveys are catching the full age range of smooth skates (O'Driscoll & Ballara 2019, Holmes et al in prep).
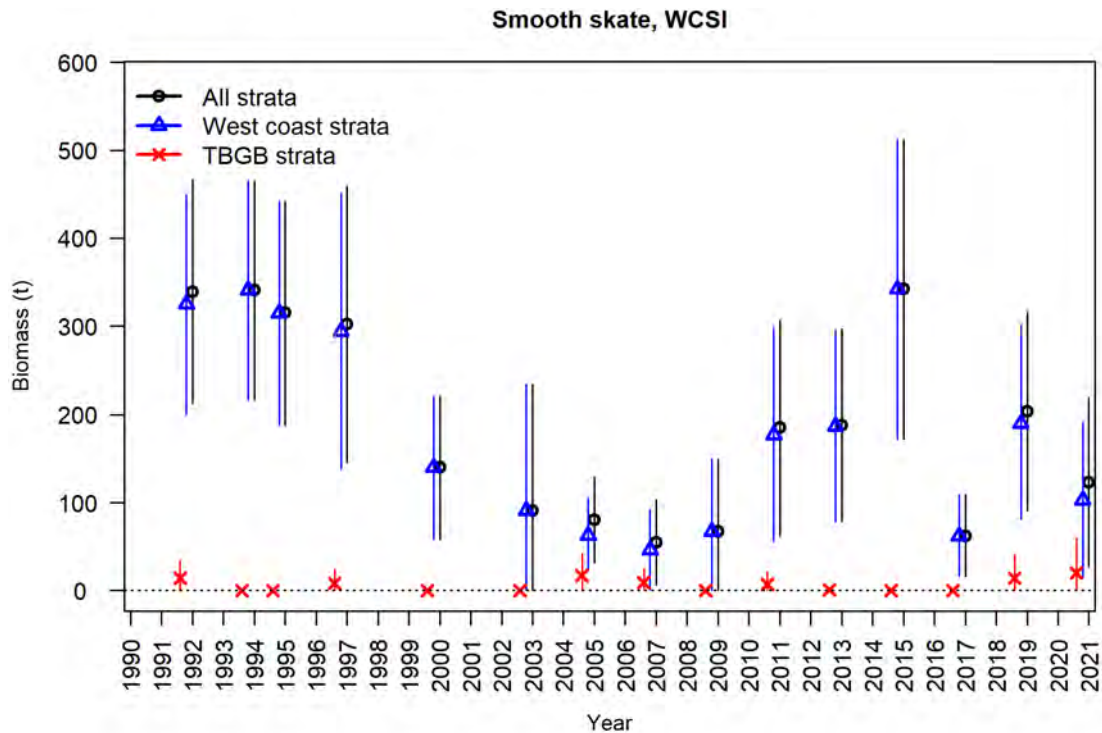
Figure 4: Smooth skate biomass for the west coast South Island (*Kaharoa*) trawl surveys. Error bars are ± two standard deviations. TBGB=Tasman Bay, Golden Bay.
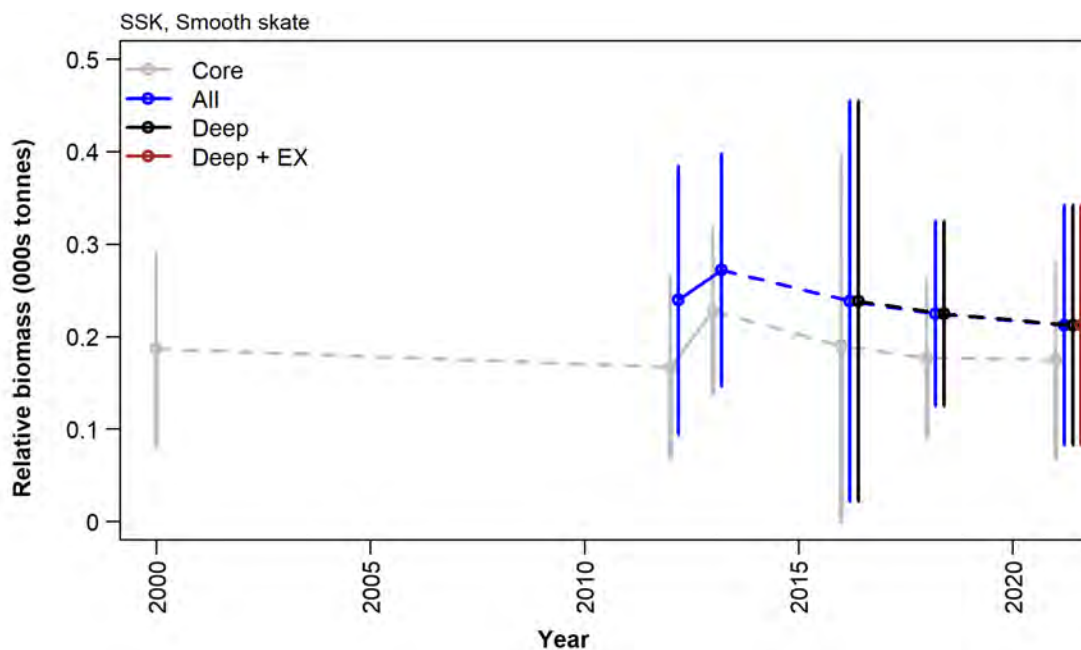
Figure 5: Smooth skate biomass for the west coast South Island (*Tangaroa*) trawl surveys for core strata (300–650 m) and 'all' strata (200–800 m). Also 'all' strata plus addition of deep strata (800–1000 m) and 'all'+deep strata plus an experimental stratum (1000–1050 m) (2021 only). Error bars are ± two standard deviations.

Establishing B$_{MSY}$ compatible reference points

In 2022 the Working Group accepted the mean of relative biomass estimates from the 'all strata' (200–800 m) WCSI *Tangaroa* survey over the years 2012–2021 to act as B_{MSY} proxy for smooth skate in SSK 7. Both catch and estimated biomass are stable over the 2012–2021 period (Figure 6A).

The WCSI *Kaharoa* survey was not considered appropriate to derive a B_{MSY} proxy because there was no period of stable and relatively high biomass and biomass estimates have seen high inter-annual variation in recent years (Figure 6B). In addition, the WCSI *Kaharoa* survey is only considered to survey juvenile smooth skate (Holmes et al in prep).

It was not possible to agree on a target for SSK 3. Catches after 2004 tended to follow the Chatham Rise survey biomass estimates and neither were stable (Figure 6C). Biomass estimates for 1997–2007 were stable, but this period only includes three years from when skate catches were first required to be reported by species. Use of the ECSI survey was also rejected. It was not possible to find a period of both stable catch and biomass estimates since the introduction of skates into the QMS (Figure 6D). In addition, only juvenile female smooth skate are considered caught in representative numbers.
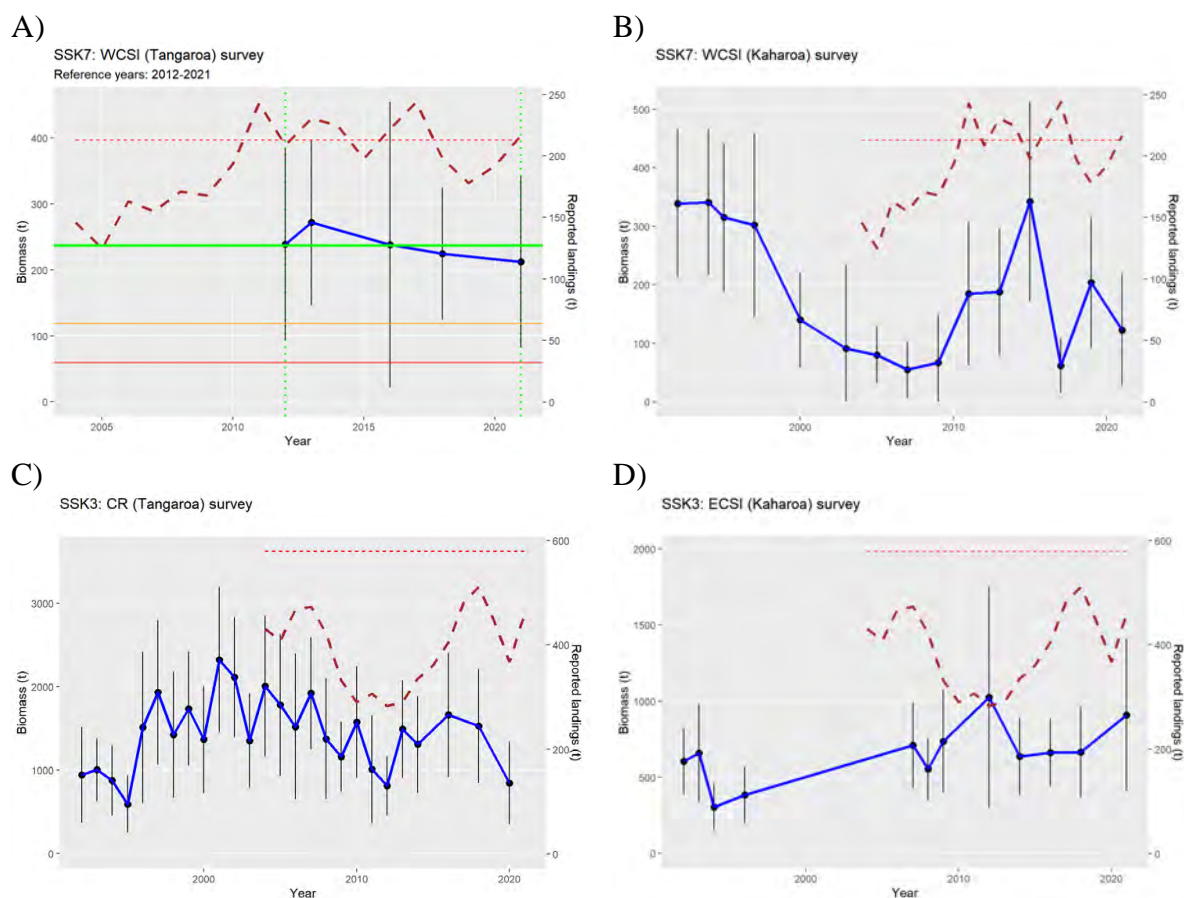
Figure 6: Relative biomass (blue line plus vertical lines showing ± 2 s.d. (left axis)) from A) WCSI *Tangaroa* trawl survey, B) WCSI *Kaharoa* trawl survey, C) Chatham Rise trawl survey, and D) ECSI *Kaharoa* trawl survey. In each plot QMR/MHR landings are shown by brown dashed line and TACC for the management area by red dotted line, with scale on right axis. For WCSI *Tangaroa* survey, the green line represents the proposed B_{MSY} proxy of mean abundance over the years indicated at the top of the figure, the orange line shows soft limit (50% B_{MSY} proxy), and the red line shows hard limit (25% B_{MSY} proxy).

4.2 Other factors

Species that constitute a minor bycatch of trawl fisheries are often difficult to manage using TACCs and ITQs. Skates are widely and thinly distributed and would be difficult for trawlers to avoid after the quota had been caught. A certain level of incidental bycatch is therefore inevitable. However, skates are relatively hardy and frequently survive being caught in trawls (although mortality would depend on the length of the tow and the weight of fish in the cod end). Skates returned to the sea alive probably have a greater chance of survival than most other fishes.

A data informed qualitative risk assessment was completed on all chondrichthyans (sharks, skates, rays, and chimaeras) at the New Zealand scale in 2014 (Ford et al 2015). Smooth skate was ranked second highest in terms of risk of the eleven QMS chondrichthyan species. Data were described as existing but poor for the purposes of the assessment and consensus over this risk score was achieved by the expert panel. This risk assessment does not replace a stock assessment for this species but may influence research priorities across species.

4.3 Future research considerations

- Work to determine the extent of current misidentification of RSK and SSK in commercial fisheries (the study of Beentjes 2005 was conducted not long after RSK and SSK were required to be reported separately under the QMS).
- Explore the potential for modelling a combined index from both the *Kaharoa* and *Tangaroa* west coast trawl surveys.
- Nothing is known about the stock structure or movement patterns of smooth skates.
- Investigate currently available maturity information (largely for males), to determine whether more information on female maturity should be collected from trawl surveys.
- Reliable catch information at species level limits our current determination of stable reference periods for SSK 3 on the Chatham Rise as well as estimates of relative exploitation rate for all SSK stocks, but trend in effort could be used to infer historical catches or relative fishing mortality to identify stable periods.
- The estimation of catches by models using species mix data from reported landings or observer data could be explored, particularly where the TACC may be limiting landings. This would be particularly useful for estimating relative exploitation rate.

5. STATUS OF THE STOCKS

No estimates of current or reference biomass are available for SSK 1, SSK 8 and SSK 10.

- **SSK 3**

Stock Structure Assumptions
For the purposes of this summary SSK 3 is considered to be a single management unit.

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Abundance index based on Chatham Rise *Tangaroa* research trawl survey
Reference Points	Target: B_{MSY} proxy Soft Limit: 50% B_{MSY} proxy Hard Limit: 25% B_{MSY} proxy Overfishing threshold: F_{MSY} proxy
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status

SSK3: CR (Tangaroa) survey

SSK 3 relative biomass from Chatham Rise *Tangaroa* trawl survey (blue line plus vertical lines showing ± 2 s.d. (left axis)) and reported QMR/MHR landings (brown dashed line) and TACC for SSK 3 (red dotted line) (right axis). Reported landings are believed to be inaccurate.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Relative biomass rose to its highest recorded level in the early 2000s before declining back to the same level seen in the early 1990s by 2012. After another rise then fall, biomass in 2020 was again at the same level as in the early 1990s.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	The ECSI *Kaharoa* survey indicated abundance has been relatively stable since 2007 and the relative biomass in 2021 is the second highest recorded value in the series. Large smooth skate are known to be under-represented in the ECSI *Kaharoa* survey.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Survey abundance index	
Assessment Dates	Latest assessment: 2022	Next assessment: 2023
Overall assessment quality rank	2 – Medium or Mixed Quality: survey catches small and highly variable	
Main data inputs (rank)	Survey abundance index	1 – High Quality
Data not used (rank)	N/A	

Changes to Model Structure and Assumptions	-
Major Sources of Uncertainty	-

Qualifying Comments

- Estimates of relative fishing mortality are likely unreliable owing to issues related to misidentification of catch between rough skates and smooth skates as well as discarding.
- Because there was no period with stable catch and abundance available, it was not possible to determine reference points.

Fishery Interactions

Smooth skate constitute a bycatch of trawl fisheries. Skates are widely distributed and difficult for trawlers to avoid.

- **SSK 7**

Stock Structure Assumptions

For the purposes of this summary SSK 7 is considered to be a single management unit.

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Abundance index based on WCSI *Tangaroa* research trawl survey
Reference Points	Interim Target: B_{MSY} proxy based on arithmetic mean survey index for the period 2012 to 2021 (a period with high yield when both catch and survey index were stable) Soft Limit: 50% B_{MSY} proxy Hard Limit: 25% B_{MSY} proxy Overfishing threshold: F_{MSY} proxy based on mean relative exploitation rate for the period 2012 to 2021
Status in relation to Target	About as Likely as Not (40–60%) to be at or above the target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status

SSK7: WCSI (Tangaroa) survey
Reference years: 2012-2021

SSK 7 relative biomass from WCSI *Tangaroa* trawl survey (blue line plus vertical lines showing ± 2 s.d. (left axis)) and reported QMR/MHR landings (brown dashed line) and TACC for SSSK 7 (red dotted line) (right axis). The green line represents the B_{MSY} proxy of mean abundance series from 2012 to 2021. The orange line shows soft limit (50% B_{MSY} proxy) and the red line shows hard limit (25% B_{MSY} proxy). Reported landings are believed to be inaccurate.

Fishery and Stock Trends

Recent Trend in Biomass or Proxy	Relative biomass was stable between 2012 and 2021.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	The core area series for the WCSI *Tangaroa* survey indicated the abundance has been relatively stable since 2000.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis

Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation

Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Survey abundance index	
Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	Survey abundance index	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments

- Estimates of relative fishing mortality are likely unreliable owing to issues related to misidentification of catch between rough skates and smooth skates as well as discarding.
- The survey series is relatively short and we do not have historical information on abundance, although the WCSI *Kaharoa* survey samples juveniles and shows a decline between 1994 and 2007 and then an increase to a biomass approximately half that of the early 1990s.

Fishery Interactions

Smooth skate constitute a bycatch of trawl fisheries. Skates are widely distributed and difficult for trawlers to avoid.
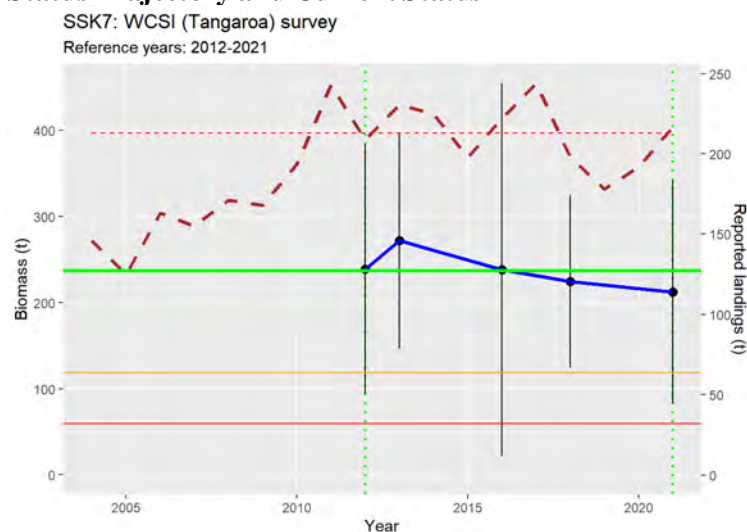
6.   FOR FURTHER INFORMATION

Beentjes, M P (2005) Identification and reporting of commercial skate landings. *New Zealand Fisheries Assessment Report 2005/16*. 18 p.

Beentjes, M P; MacGibbon, D J (2013) Review of QMS species for inclusion in the east coast South Island winter trawl survey reports. *New Zealand Fisheries Assessment Report 2013/35*. 102 p.

Beentjes, M P; MacGibbon, D; Lyon, W S (2015) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2014 (KAH1402). *New Zealand Fisheries Assessment Report 2015/14*. 136 p.

Beentjes, M P; MacGibbon, D; Parkinson, D (2016) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2016 (KAH1605). *New Zealand Fisheries Assessment Report 2016/61*. 135 p.

Beentjes, M P; Stevenson, M L (2000) Review of the east coast South Island winter trawl survey time series, 1991–96. *NIWA Technical Report 86*. 64 p.

Beentjes, M P; Stevenson, M L (2001) Review of the east coast South Island summer trawl survey time series, 1996–97 to 1999–2000. *NIWA Technical Report 108*. 92 p.

Ford, R B; Galland, A; Clark, M R; Crozier, P; Duffy, C A J; Dunn, M R; Francis, M P, Wells, R (2015) Qualitative (Level 1) Risk Assessment of the impact of commercial fishing on New Zealand Chondrichthyans. *New Zealand Aquatic Environment and Biodiversity Report No. 157*. 111 p.

Francis, M P (1997) A summary of biology and commercial landings, and a stock assessment of rough and smooth skates (*Raja nasuta* and *R. innominata*). New Zealand Fisheries Assessment Research Document 1997/5 27 p. (Unpublished document held by NIWA library, Wellington.)

Francis, M P; Ó Maolagáin, C; Stevens, D (2001a) Age, growth, and sexual maturity of two New Zealand endemic skates, *Dipturus nasutus* and *D. innominatus*. *New Zealand Journal of Marine and Freshwater Research 35*: 831–842.

Francis, M P; Ó Maolagáin, C; Stevens, D (2001b) Age, growth, maturity, and mortality of rough and smooth skates (*Dipturus nasutus* and *D. innominatus*). *New Zealand Fisheries Assessment Report 2001/17*. 21 p.

Francis, M P; Ó Maolagáin, C; Stevens, D (2004) Revised growth, longevity and natural mortality of smooth skate (*Dipturus innominatus*). Final Research Report for Ministry of Fisheries Project MOF2003/01H (Dated June 2004). (Unpublished report held by Fisheries New Zealand, Wellington.).

Holmes, S J; McKenzie, A; Ballara, S; MacGibbon, D J; Bian, R (in prep) Review of suitability of trawl surveys to provide abundance indices for rough skate (*Zearaja nasuta*) and smooth skate (*Dipturus innominatus*) and partial quantitative assessments of rough skate in RSK 3 and smooth skate in SSK 7. Draft New Zealand Fisheries Assessment Report.

MacGibbon, D J (2019) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2019 (KAH1902). *New Zealand Fisheries Assessment Report 2019/64*. 87 p.

MacGibbon, D J; Beentjes, M P; Lyon, W L; Ladroit, Y (2019) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2018 (KAH1803). *New Zealand Fisheries Assessment Report 2019/03*. 136 p.

O'Driscoll, R L: Ballara, S L (2019) Trawl and acoustic survey of hoki and middle depth fish abundance on the west coast South Island, July–August 2018 (TAN1807). *New Zealand Fisheries Assessment Report 2019/19*. 120 p.

Stevenson, M L; Hanchet, S (2000) Review of the inshore trawl survey series of the west coast South Island and Tasman and Golden Bays, 1992–97. *NIWA Technical Report 82*. 79 p.

INTRODUCTION – SNAPPER (SNA)
(*Chrysophrys auratus*)
Tamure, Kouarea
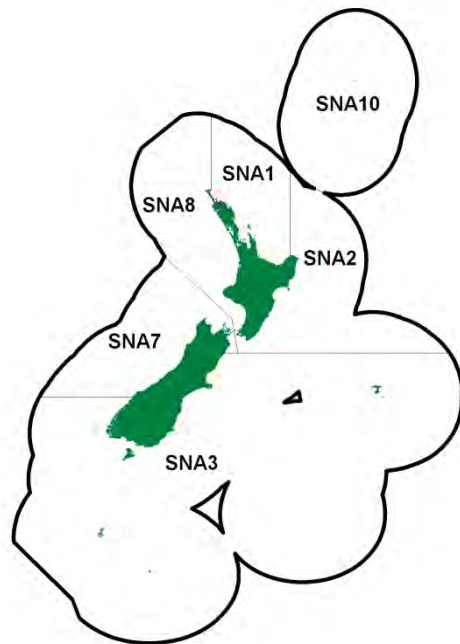
1. INTRODUCTION

Specific Working Group reports, describing/including stock assessments, are given separately for SNA 1, SNA 2, SNA 7 and SNA 8. The TACC for SNA 3 and SNA 10 are 32 t and 10 t respectively, with minimal annual landings (less than 1 t or zero t in most years) reported from these stocks.

1.1 Commercial fisheries

Snapper fisheries are one of the largest and most valuable coastal fisheries in New Zealand. The commercial fisheries, which began their development in the late 1800s, expanded in the 1970s with increased catches by trawl and Danish seine. Following the introduction of pair trawling in most areas, landings peaked in 1978 at 17 500 t (Table 1). Pair trawling was the dominant method, accounting for on average 75% of the annual SNA 8 catch from 1976 to 1989. In the 1980s an increasing proportion of the SNA 1 catch was taken by longlining as the Japanese "iki jime" market was developed. By the mid-1980s catches had declined to 8500–9000 t, and some stocks showed signs of overfishing. The fisheries had become more dependent on the recruiting year classes as stock size decreased. With the introduction of the QMS in 1986, TACCs in all Fishstocks were set at levels intended to allow for some stock rebuilding. Decisions by the Quota Appeal Authority saw TACCs increase to over 6000 t for SNA 1 by the fishing year 1990–91, and from 1330 t to 1594 t for SNA 8 by 1989–90 (Table 2).

In 1986–87, landings from the two largest Fishstocks (i.e., SNA 1 and SNA 8) were less than their respective TACCs (Table 2) but catches subsequently increased in 1987–88 to the level of the TACCs (Figure 1). Landings from SNA 7 remained below the TACC after introduction to the QMS, and in 1989–90 the TACC was reduced to 160 t. Changes to TACCs that took effect from 1 October 1992 resulted in a reduction for SNA 1 from 6010 t to 4938 t, an increase for SNA 2 from 157 t to 252 t, and a reduction for SNA 8 from 1594 t to 1500 t.

SNAPPER (SNA)

Table 1: Reported landings (t) for the main QMAs from 1931 to 1990.

Year	SNA 1	SNA 2	SNA 7	SNA 8	Year	SNA 1	SNA 2	SNA 7	SNA 8
1931–32	3 355	0	69	140	1961	5 887	589	583	1 178
1932–33	3 415	0	36	159	1962	6 502	604	582	1 352
1933–34	3 909	21	65	213	1963	6 967	636	569	1 456
1934–35	4 317	168	7	190	1964	7 269	667	574	1 276
1935–36	5 387	149	10	108	1965	7 991	605	780	1 182
1936–37	6 369	78	194	103	1966	8 762	744	1 356	1 831
1937–38	5 665	114	188	85	1967	9 244	856	1 613	1 477
1938–39	6 145	122	149	89	1968	10 328	765	1 037	1 491
1939–40	5 918	100	158	71	1969	11 318	837	549	1 344
1940–41	5 100	103	174	76	1970	12 127	804	626	1 588
1941–42	4 791	148	128	62	1971	12 709	861	640	1 852
1942–43	4 096	74	65	57	1972	11 291	878	767	1 961
1943–44	4 456	60	29	75	1973	10 450	798	1 258	3 038
1944	4 909	49	96	69	1974	8 769	716	1 026	4 340
1945	4 786	59	118	124	1975	6 774	732	789	4 217
1946	5 150	77	232	244	1976	7 743	732	1 040	5 326
1947	5 561	36	475	251	1977	7 674	374	714	3 941
1948	6 469	53	544	215	1978	9 926	454	2 720	4 340
1949	5 655	215	477	277	1979	10 273	662	1 776	3 464
1950	4 945	285	514	318	1980	7 274	636	732	3 309
1951	4 173	265	574	364	1981	7 714	283	592	3 153
1952	3 665	220	563	361	1982	7 089	160	591	2 636
1953	3 581	247	474	1 124	1983	6 539	160	544	1 814
1954	4 180	293	391	1 093	1984	6 898	227	340	1 536
1955	4 323	309	504	1 202	1985	5 876	208	270	1 866
1956	4 615	365	822	1 163	1986	5 969	255	253	959
1957	5 129	452	1 055	1 472	1987	4 016	122	210	1 072
1958	5 007	483	721	1 128	1988	5 038	165	193	1 565
1959	5 607	372	650	1 114	1989	5 754	227	292	1 571
1960	5 889	487	573	1 202	1990	5 826	429	200	1 551

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. The 'QMA totals' are approximations derived from port landing subtotals, as follows: SNA 1, Mangonui to Whakatane; SNA 2 Gisborne to Wellington/Makara; SNA 7, Marlborough Sounds ports to Greymouth; SNA 8 Paraparaumu to Hokianga.
3. Before 1946 the 'QMA' subtotals sum to less than the New Zealand total because data from the complete set of ports are not available. Subsequent minor differences result from small landings in SNA 3, not listed here.
4. Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.
5. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings.

Table 2: Reported landings (t) of snapper by Fishstock from 1983–84 to present and gazetted and actual TACCs (t) for 1986–87 to present. QMS data from 1986–present. [Continued on next page]

Fishstock FMAs	SNA 1 1		SNA 2 2		SNA 3 3, 4, 5, 6		SNA 7 7		SNA 8 8, 9	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84†	6 539	–	145	–	2	–	375	–	1 725	–
1984–85†	6 898	–	163	–	2	–	255	–	1 546	–
1985–86†	5 876	–	177	–	0	–	188	–	1 828	–
1986–87	4 016	4 710	130	130	< 1	32	257	330	893	1 331
1987–88	5 038	5 098	152	137	1	32	256	363	1 401	1 383
1988–89	5 754	5 614	210	157	< 1	32	176	372	1 527	1 508
1989–90	5 826	5 981	364	157	< 1	32	294	151	1 551	1 594
1990–91	5 273	6 002	428	157	< 1	32	160	160	1 659	1 594
1991–92	6 176	6 010	373	157	< 1	32	148	160	1 459	1 594
1992–93	5 427	4 938	324	252	< 1	32	165	160	1 543	1 500
1993–94	4 847	4 938	307	252	< 1	32	147	160	1 542	1 500
1994–95	4 857	4 938	308	252	< 1	32	150	160	1 436	1 500
1995–96	4 938	4 938	280	252	< 1	32	146	160	1 558	1 500
1996–97	5 047	4 938	351	252	< 1	32	162	160	1 613	1 500
1997–98	4 525	4 500	286	252	< 1	32	182	200	1 589	1 500
1998–99	4 412	4 500	283	252	2	32	142	200	1 636	1 500
1999–00	4 509	4 500	390	252	< 1	32	174	200	1 604	1 500
2000–01	4 347	4 500	360	252	< 1	32	156	200	1 631	1 500
2001–02	4 374	4 500	252	252	1	32	141	200	1 577	1 500
2002–03	4 487	4 500	334	315	< 1	32	187	200	1 558	1 500
2003–04	4 469	4 500	339	315	< 1	32	215	200	1 667	1 500
2004–05	4 641	4 500	399	315	< 1	32	178	200	1 663	1 500
2005–06	4 539	4 500	389	315	< 1	32	166	200	1 434	1 300
2006–07	4 429	4 500	329	315	< 1	32	248	200	1 327	1 300
2007–08	4 548	4 500	328	315	< 1	32	187	200	1 304	1 300
2008–09	4 543	4 500	307	315	< 1	32	205	200	1 345	1 300
2009–10	4 465	4 500	296	315	< 1	32	188	200	1 280	1 300
2010–11	4 516	4 500	320	315	< 1	32	206	200	1 313	1 300
2011–12	4 614	4 500	358	315	< 1	32	216	200	1 360	1 300

Table 2: [Continued]

Fishstock FMAs	SNA 1 1		SNA 2 2		SNA 3 3, 4, 5, 6		SNA 7 7		SNA 8 8, 9	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2012–13	4 457	4 500	310	315	< 1	32	211	200	1 331	1 300
2013–14	4 459	4 500	313	315	< 1	32	210	200	1 275	1 300
2014–15	4 479	4 500	271	315	< 1	32	210	200	1 272	1 300
2015–16	4 408	4 500	321	315	< 1	32	189	200	1 328	1 300
2016–17	4 620	4 500	373	315	< 1	32	263	250	1 334	1 300
2017–18	4 567	4 500	373	315	< 1	32	263	250	1 288	1 300
2018–19	4 437	4 500	364	315	< 1	32	257	250	1 293	1 300
2019–20	4 460	4 500	330	315	< 1	32	289	250	1 347	1 300
2020–21	4 579	4 500	321	315	< 1	32	337	350	1 295	1 300

Fishstock QMAs	SNA 10 10		Total	
	Landings	TACC	Landings§	TACC
1983–84†	0	–	9 153	–
1984–85†	0	–	9 228	–
1985–86†	0	–	8 653	–
1986–87	0	10	5 314	6 540
1987–88	0	10	6 900	7 021
1988–89	0	10	7 706	7 691
1989–90	0	10	8 034	7 932
1990–91	0	10	7 570	7 944
1991–92	0	10	8 176	7 962
1992–93	0	10	7 448	6 858
1993–94	0	10	6 842	6 883
1994–95	0	10	6 723	6 893
1995–96	0	10	6 924	6 893
1996–97	0	10	7 176	6 893
1997–98	0	10	6 583	6 494
1998–99	0	10	6 475	6 494
1999–00	0	10	6 669	6 494
2000–01	0	10	6 496	6 494
2001–02	0	10	6 342	6 494
2002–03	0	10	6 563	6 557
2003–04	0	10	6 686	6 557
2004–05	0	10	6 881	6 557
2005–06	0	10	6 527	6 357
2006–07	0	10	6 328	6 357
2007–08	0	10	6 367	6 357
2008–09	0	10	6 399	6 357
2009–10	0	10	6 230	6 357
2010–11	0	10	6 355	6 357
2011–12	0	10	6 547	6 357
2012–13	0	10	6 309	6 357
2013–14	0	10	6 256	6 357
2014–15	0	10	6 232	6 357
2015–16	0	10	6 247	6 357
2016–17	0	10	6 590	6 407
2017–18	0	10	6 490	6 407
2018–19	0	10	6 351	6 407
2019–20	0	10	6 425	6 407
2020–21	0	10	6 532	6 507

† FSU data. SNA 1 = Statistical Areas 001–010; SNA 2 = Statistical Areas 011–016; SNA 3 = Statistical Areas 018–032; SNA 7 = Statistical Areas 017, 033–036, 038; SNA 8 = Statistical Areas 037, 039–048.

From 1 October 1997 the TACC for SNA 1 was reduced to 4500 t, within an overall TAC of 7550 t, and the TACC for SNA 7 was increased to 200 t within an overall TAC of 306 t. In SNA 2, the bycatch of snapper in the tarakihi, red gurnard, and other fisheries resulted in overruns of the snapper TACC in all years from 1987–88 up to 2000–01. From 1 October 2002, the TACC for SNA 2 was increased from 252 t to 315 t, within a total TAC of 450 t. Nevertheless the 315 t TACC has regularly been over-caught since, except in the fishing years 2008–09 to 2009–10 and 2012–13 to 2014–15. From 1 October 2005 the TACC for SNA 8 was reduced to 1300 t within a TAC of 1785 t to ensure a faster rebuild of the stock. In 2016–17, the TAC for SNA 7 was increased from 306 t to 545 t, including an increase in the TACC from 200 t to 250 t. The SNA 7 TACC was increased again in 2020–21 to 350 t. Table 3 shows the TACs, TACCs, and allowances for each Fishstock from 1 October 2020. All commercial fisheries have a minimum legal size (MLS) for snapper of 25 cm.

Table 3:   TACs, TACCs, and allowances (t) for snapper by Fishstock from 1 October 2020.

Fishstock	TAC	TACC	Customary allowance	Recreational allowance	Other mortality
SNA 1	8 050	4 500	50	3 050	450
SNA 2	450	315	14	90	31
SNA 3	–	32	–	–	–
SNA 7	645	350	20	250	25
SNA 8	1 785	1 300	43	312	130
SNA 10	–	10	–	–	–

Foreign fishing

Japanese catch records and observations made by New Zealand naval vessels indicate that significant quantities of snapper were taken from New Zealand waters by Japanese vessels from the late 1950s until 1977. There are insufficient data to quantify historical Japanese catch tonnages for the respective snapper stocks. However, trawl catches have been reported by area from 1967 to 1977, and longline catches from 1975 to 1977 (Table 4). These data were supplied to the Fisheries Research Division of MAF in the late 1970s; however, the data series is incomplete, particularly for longline catches.

Table 4: Reported landings (t) of snapper from 1967 to 1977 by Japanese trawl and longline fisheries. These landings are included in Table 1.

Year	(a) Trawl	Trawl catch (all species)	Total snapper trawl catch	SNA 1	SNA 7	SNA 8
1967		3092	30	NA	NA	NA
1968		19 721	562	1	17	309
1969		25 997	1 289	–	251	929
1970		31 789	676	2	131	543
1971		42 212	522	5	115	403
1972		49 133	1 444	1	225	1 217
1973		45 601	616	–	117	466
1974		52 275	472	–	98	363
1975		55 288	922	26	85	735
1976		133 400	970	NA	NA	676
1977		214 900	856	NA	NA	708
Year	(b) Longline		Total Snapper	SNA 1	SNA 7	SNA 8
1975			1 510	761	–	749
1976			2 057	930	–	1 127
1977			2 208	1 104	–	1 104
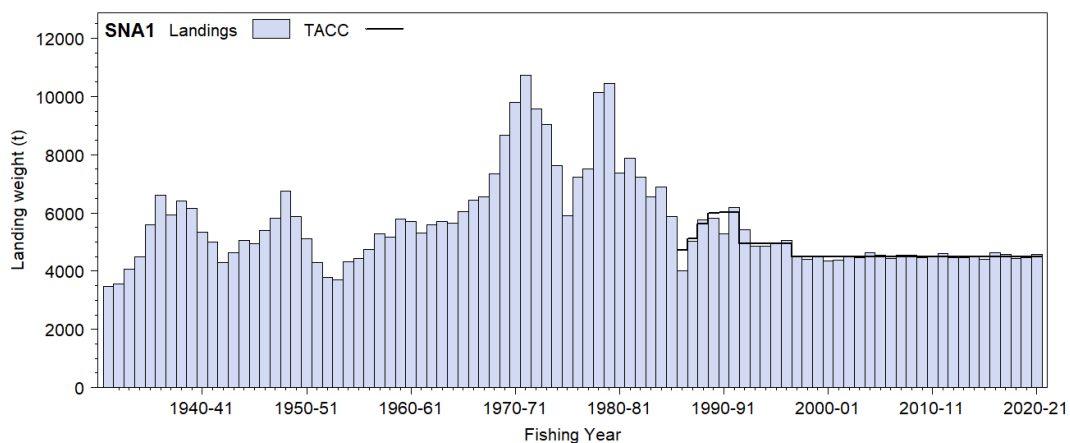
Figure 1:   Total reported landings and TACCs for the four main SNA stocks. SNA 1 (Central East). [Continued on next page]
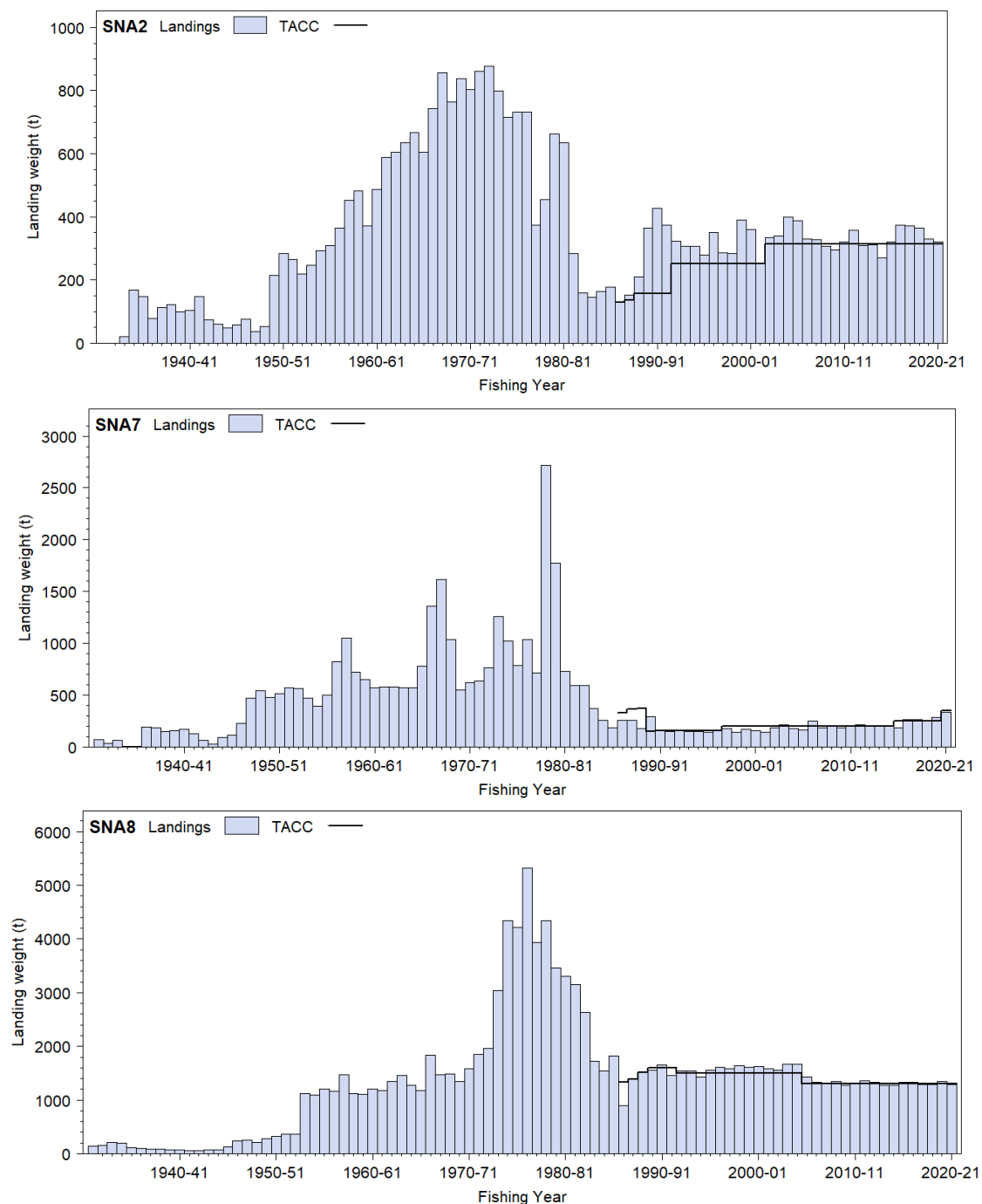
Figure 1: [Continued] Total reported landings and TACC for the four main SNA stocks. SNA 2 (Central East) and SNA 7 (Challenger) and SNA 8 (Central Egmont).

1.2   Recreational fisheries

The snapper fishery is the largest recreational fishery in New Zealand. It is the major target species on the northeast and northwest coasts of the North Island and is targeted seasonally around the rest of the North Island and the top of the South Island. The current allowances within the TAC for each Fishstock are shown in Table 3.

1.2.1   Management controls

The two main methods used to manage recreational harvests of snapper are minimum legal size limits (MLS) and daily bag limits. Both have changed over time (Table 5). The number of hooks permitted on a recreational longline was reduced from 50 to 25 in 1995.

Table 5: Changes to minimum legal size limits (MLS) and daily bag limits used to manage recreational harvesting levels in snapper stocks, 1985–2014.

Stock	MLS	Bag limit	Introduced
SNA 1	25	30	1/01/1985
SNA 1	25	20	30/09/1993
SNA 1	27	15	1/10/1994
SNA 1	27	9	13/10/1995
SNA 1	30	7	1/04/2014
SNA 2	25	30	1/01/1985
SNA 2	27	10	1/10/2005
SNA 3	25	30	1/01/1985
SNA 3	25	10	1/10/2005
SNA 7	25	30	1/01/1985
SNA 7 (excl Marlborough Sounds)	25	10	1/10/2005
SNA 7 (Marlborough Sounds)	25	3	1/10/2005
SNA 8	25	30	1/01/1985
SNA 8 (FMA 9 only)	25	20	30/09/1993
SNA 8 (FMA 9 only)	27	15	1/10/1994
SNA 8	27	10	1/10/2005

1.2.2 Estimates of recreational harvest

There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and, offsite methods where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest were calculated using an onsite approach, a tag ratio method for SNA 1, in the mid-1980s (Table 6). A tonnes per tag ratio was obtained from commercial tag return data and this tonnage was multiplied by the number of tags returned by recreational fishers to estimate recreational harvest tonnages. The tag ratio method requires that all tagged fish caught by recreational fishers are recorded, or at least that the under-reporting rate of recreational fishers is the same as that of commercial fishers. This was assumed, although no data were available to test the assumption. If the recreational under-reporting rate was greater than that of the commercial fishers a negative bias would result. In SNA 8 there was evidence that many tags recovered by commercial fishing were reported as recreational catch during the 1991 tag recapture phase, which would give a positive bias to estimates.

The next method used to generate recreational harvest estimates was the offsite regional telephone and diary survey approach: MAF Fisheries South (1991–92), Central (1992–93), and North (1993–94) regions (Teirney et al 1997). Estimates for 1996 came from a national telephone and diary survey (Bradford 1998). Another national telephone and diary survey was carried out in 2000 (Boyd & Reilly 2002) and a rolling replacement of diarists in 2001 (Boyd et al 2004) allowed estimates for a further year (population scaling ratios and mean weights were not re-estimated in 2001). Other than for the 1991–92 MAF Fisheries South survey, the diary method used mean weights of snapper obtained from fish measured at boat ramps.

The harvest estimates provided by the telephone/diary surveys are no longer considered reliable for various reasons. With the early telephone/diary method, fishers were recruited to fill in diaries by way of a telephone survey that also estimates the proportion of the population that is eligible (likely to fish). A 'soft refusal' bias in the eligibility proportion arises if interviewees who do not wish to co-operate falsely state that they never fish. The proportion of eligible fishers in the population (and, hence, the harvest) is thereby under-estimated. Pilot studies for the 2000 telephone/diary survey suggested that this effect could occur when recreational fishing was established as the subject of the interview at the outset. Another equally serious cause of bias in telephone/diary surveys was that diarists who did not immediately record their day's catch after a trip sometimes overstated their catch or the number of trips made. There is some indirect evidence that this may have occurred in all the telephone/diary surveys (Wright et al 2004).

The recreational harvest estimates provided by the 2000 and 2001 telephone/diary surveys are thought to be implausibly high for many species including snapper, which led to the development of an alternative maximum count aerial-access onsite method that provides a more direct means of estimating recreational harvests for suitable fisheries. The maximum count aerial-access approach combines data collected concurrently from two sources: a creel survey of recreational fishers returning to a subsample of ramps throughout the day; and an aerial survey count of vessels observed to be fishing at the approximate time of peak fishing effort on the same day. The ratio of the aerial count in a particular area to the number of interviewed parties who claimed to have fished in that area at the time of the overflight was used to scale up harvests observed at surveyed ramps, to estimate harvest taken by all fishers returning to all ramps. The methodology is further described by Hartill et al (2007).

This aerial-access method was first employed in the Hauraki Gulf in 2003–04 and was then extended to survey the wider SNA 1 fishery in 2004–05 and was used in 2011–12 and 2017–18 to corroborate concurrent national panel surveys. This approach has also been used to estimate recreational harvests from SNA 7 (2005–06 and 2015–16 fishing years) and SNA 8 (2006–07). The Marine Amateur Fisheries and Snapper Working Groups both concluded that this approach generally provided reliable estimates of recreational harvest for these fish stocks.

In response to the cost and scale challenges associated with onsite methods, in particular the difficulties in sampling other than trailer boat fisheries, offsite approaches to estimating recreational fisheries harvest have been revisited. This led to the implementation of a national panel survey during the 2011–12 fishing year (Wynne-Jones et al 2014). The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information was collected in computer-assisted standardised phone interviews. This national panel survey was repeated during the 2017–18 fishing year (Wynne-Jones et al 2019).

Monitoring harvest
In addition to estimating absolute harvests, a system to provide relative estimates of harvest over time for key fishstocks has been designed and implemented for some key recreational fisheries. The system uses web cameras to continuously monitor trends in trailer boat traffic at key boat ramps. This monitoring is complemented by creel surveys that provide estimates of the proportion of observed boats that were used for fishing, and of the average harvest of snapper and kahawai per boat trip. These data are combined to provide relative harvest estimates for SNA 1.

Trends inferred from this monitoring programme were initially very similar to that inferred from aerial-access harvest estimates in the Hauraki Gulf in 2004–05, 2006–07, and 2011–12, but the camera/creel snapper harvest estimate for the Hauraki Gulf in 2017–18 is substantially lower than concurrent aerial-access and national panel surveys estimates for the same year (Table 6a cf. Table 6). This difference appears to be due to a recent substantial increase in recreational fishing effort and catch around expanding mussel farms in the Firth of Thames, coinciding with a lesser increase in effort in the north-western Hauraki Gulf. Additional creel survey monitoring has been initiated to monitor changes in the recreational fishery in these areas, which had not been adequately monitored from boat ramps in the Auckland metropolitan area up until 2019–20. These estimates show that the recreational snapper harvest varies substantially more than would be expected if catches were related only to stock abundance; this suggests that changes in localised availability to recreational fishers can also have a marked effect on the recreational harvest. Web camera monitoring is continuing, and the coverage is being progressively extended to other FMAs.

1.2.2.1 SNA 1

Aerial-access surveys were conducted in FMA 1 in 2011–12 and 2017–18 (Hartill et al 2013, 2019) to independently provide harvest estimates for comparison with those generated from concurrent national panel surveys (excluding the Chatham Islands). Both surveys appear to have provided plausible results that corroborate each other and are therefore considered to be broadly reliable. Harvest estimates provided by these surveys are given in Table 6. Regional harvest estimates provided by the 2004–05 and 2011–12 aerial-access surveys were used to inform the 2013 stock assessment for SNA 1. Web

camera/creel survey monitoring (see Table 6a) suggests that the recreational harvest of snapper in SNA 1 can vary greatly between years. The overall trend across all three regions of SNA 1 suggests a decline in the recreational harvest in the years following 2011–12, that was mostly driven by declining catch rates in the Hauraki Gulf. This was followed by a period of increasing recreational harvest in recent years, from 2015–16.

1.2.2.2 SNA 2

National Panel Survey harvest estimates are available for SNA 2 from 2011–12 and 2017-18. Web camera/creel survey monitoring has been undertaken within SNA 2 since 2014–15 (monitoring at Napier and Gisborne). These data show a generally increasing trend in snapper harvest, but since the series only overlaps with one National Panel Survey (2017–18), scaled estimates of annual harvest (Table 6b) from the relative boat ramp harvest index should be considered preliminary (B. Hartill, pers. comm.).

Table 6: **Recreational catch estimates for snapper stocks. Totals for a stock are given in bold. The telephone/diary surveys ran from December to November but are denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey catch estimates). Numbers and mean weights are not calculated in the tag ratio method. Includes charter boat catch and panel survey estimates of s111 catches. [continued on next page]**

Stock	Year	Method	Number of fish (thousands)	Mean weight (g)	Total weight (t)	CV
SNA 1						
East Northland	1985	Tag ratio	–	–	370	–
Hauraki Gulf	1985	Tag ratio	–	–	830	–
Bay of Plenty	1984	Tag ratio	–	–	400	–
Total	1985[1]	Tag ratio	–	–	**1 600**	–
Total	1994	Telephone/diary	3 804	871	**2 857**	–
East Northland	1996	Telephone/diary	684	1 039	711	–
Hauraki Gulf/BoP	1996	Telephone/diary	1 852	870	1 611	–
Total	1996	Telephone/diary	2 540	915	**2 324**	–
East Northland	2000	Telephone/diary	1 457	1 154	1 681	–
Hauraki Gulf	2000	Telephone/diary	3 173	830	2 632	–
Bay of Plenty	2000	Telephone/diary	2 274	872	1 984	–
Total	2000	Telephone/diary	6 904	904	**6 242**	–
East Northland	2001	Telephone/diary	1 446	–[5]	1 669	–
Hauraki Gulf	2001	Telephone/diary	4 225	–[5]	3 507	–
Bay of Plenty	2001	Telephone/diary	1 791	–[5]	1 562	–
Total	2001	Telephone/diary	7 462	–[5]	**6 738**	–
Hauraki Gulf	2003–04	Aerial-access	–	–	1 334	0.09
East Northland	2004–05	Aerial-access	–	–	557	0.13
Hauraki Gulf	2004–05	Aerial-access	–	–	1 345	0.10
Bay of Plenty	2004–05	Aerial-access	–	–	516	0.10
Total	2004–05	Aerial-access	–	–	**2 419**	**0.06**
East Northland	2011–12	Aerial-access	–	–	718	0.14
Hauraki Gulf	2011–12	Aerial-access	–	–	2490	0.08
Bay of Plenty	2011–12	Aerial-access	–	–	546	0.12
Total	2011–12	Aerial-access	–	–	**3 754**	**0.06**
East Northland	2011–12	Panel survey	718	1 266	909	0.12
Hauraki Gulf	2011–12	Panel survey	2 350	1 022 / 987[6]	2 381	0.11
Bay of Plenty	2011–12	Panel survey	714	956 /1 003[6]	691	0.12
Total	2011–12	Panel survey	3 884	1 025	**3 981**	**0.08**
East Northland	2017–18	Aerial-access	–	–	720	0.10
Hauraki Gulf	2017–18	Aerial-access	–	–	2 068	0.07
Bay of Plenty	2017–18	Aerial-access	–	–	680	0.10
Total	2017–18	Aerial-access	–	–	**3 467**	**0.05**
East Northland	2017–18	Panel survey	587	1 351	793	**0.10**
Hauraki Gulf	2017–18	Panel survey	1 443	1 162/1 189	1 684	**0.10**
Bay of Plenty	2017–18	Panel survey	571	1 116/1 205	**650**	**0.12**
Total	2017–18	Panel survey	2 601	1 202	**3 127**	**0.07**

Table 6 [continued]: Recreational catch estimates for snapper stocks. Totals for a stock are given in bold. The telephone/diary surveys ran from December to November but are denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey catch estimates). Numbers and mean weights are not calculated in the tag ratio method. Includes charter boat catch and panel survey estimates of s111 catches.

Stock	Year	Method	Number of fish (thousands)	Mean weight (g)	Total weight (t)	CV
SNA 2						
Total	1993	Telephone/diary	28	1 282	**36**	–
Total	1996	Telephone/diary	31	1 282[2]	**40**	–
Total	2000	Telephone/diary	268	1 200[4]	**322**	–
Total	2001	Telephone/diary	144	–[5]	**173**	–
Total	2011–12	Panel survey	55	1 027	**57**	0.25
Total	2017–18	Panel survey	83	1 117	**93**	0.24
SNA 7						
Tasman Bay /Golden Bay	1987	Tag ratio	–	–	**15**	–
Total	1993	Telephone/diary	77	2 398[3]	**184**	–
Total	1996	Telephone/diary	74	2 398	**177**	–
Total	2000	Telephone/diary	63	2 148	**134**	–
Total	2001	Telephone/diary	58	–[5]	**125**	–
Total	2005–06	Aerial-access	–	–	**43**	0.17
Total	2011–12	Panel survey	110	799	**89**	0.17
Total	2015–16	Aerial-access	–	–	**83**	0.18
Total	2017–18	Panel survey	98	1 505	**147**	0.16
SNA 8						
Total	1991	Tag ratio	–	–	**250**	–
Total	1994	Telephone/diary	361	658	**238**	–
Total	1996	Telephone/diary	271	871	**236**	–
Total	2000	Telephone/diary	648	1 020	**661**	–
Total	2001	Telephone/diary	1 111	–	**1 133**	–
Total	2007	Aerial-access	–	–	**260**	0.10
Total	2011–12	Panel survey	557	770 /1 255 / 1 160[7]	**630**	0.16
Total	2017–18	Panel survey	707	–	**892**	0.12

[1] The Bay of Plenty programme was carried out in 1984 but is included in the 1985 total estimate.
[2] Mean weight obtained from 1992–93 boat ramp sampling.
[3] Mean weight obtained from 1995–96 boat ramp sampling.
[4] Mean weight obtained from 1999–2000 commercial landed catch sampling.
[5] The 2000 mean weights were used in the 2001 estimates.
[6] Separate mean weight estimates were used for summer (1 October 2011 to 30 April 2012) and for winter (1 May to 30 September 2012).
[7] Separate mean weight estimates were used for harbours (Kaipara and Manukau)/North coast (open coast fishery north of Tirua Point)/ South coast (open coast fishery south of Tirua Point).

Table 6a: Recreational catch estimates (t) for snapper in different parts of the SNA 1 stock area calculated from web camera and creel monitoring at key ramps combined with aerial-access estimates for each area in 2004–05 and 2006–07 (Hauraki Gulf only) and 2011–12 and 2018–19 (all areas within SNA 1).

Year	East Northland	CV	Hauraki Gulf	CV	Bay of Plenty	CV	Total SNA 1	CV
2004–05	730	0.14	1 216	0.13	605	0.15	2 551	0.08
2006–07	–	–	1 224	0.16	–	–	–	–
2011–12	689	0.13	2 772	0.09	596	0.18	4 057	0.07
2012–13	679	0.15	1 718	0.09	273	0.21	2 671	0.07
2013–14	540	0.12	876	0.13	216	0.19	1 632	0.08
2014–15	511	0.14	735	0.11	223	0.25	1 469	0.08
2015–16	647	0.13	657	0.15	171	0.19	1 475	0.09
2016–17	649	0.13	649	0.12	385	0.19	1 683	0.08
2017–18	751	0.13	1 037	0.11	623	0.16	2 410	0.08
2018–19	1 030	0.09	1 312	0.09	376	0.13	2 718	0.06

1.2.2.3 SNA 7

Plausible estimates for recreational catches from SNA 7 are available from the 1987 tagging programme, the aerial access surveys (in 2005–06 and 2015–16) and the national panel surveys (2011–12 and 2017–18). The estimates of recreational catch increased considerably from 2005–06 to 2017–18.

Table 6b: Preliminary recreational catch estimates for SNA 2, split by SNA 2N and SNA 2S, on basis of National Panel Survey and web camera/creel survey monitoring.

Year	SNA 2N	SNA 2S	SNA 2	source
2011–12	29.5	26.3	55.8	NPS
2012–13				
2013–14				
2014–15	10.9	25.8	36.7	Scaled creel survey
2015–16	18.4	33.6	52.0	Scaled creel survey
2016–17	13.9	36.5	50.4	Scaled creel survey
2017–18	35.2	57.9	93.1	NPS
2018–19	41.8	87.8	129.7	Scaled creel survey
2019–20	34.6	43.8	78.4	Scaled creel survey
2020–21	53.1	60.5	113.6	Scaled creel survey

Most of the recreational catch has been recorded from Tasman Bay and Golden Bay. The catch is predominantly taken by rod-and-line, although a significant proportion of the catch was taken by longline during the mid 2010s. A small proportion of the total SNA 7 recreational catch was recorded from the Marlborough Sounds.

1.2.2.4 SNA 8

In 2005, the Snapper Working Group and Plenary considered recreational catches from SNA 8. Two alternative levels were assumed for the recreational catch from 1990 to 2004, either 300 t or 600 t. The Plenary considered these values were likely to bracket the true average level of catch in this period. The estimate from the 2006–07 aerial overflight survey of the SNA 8 fishery (260 t) suggests that the assumed value of 300 t may have been the more plausible. There are potential sources of bias associated with the aerial-access estimate, both negative (a potential underestimation of the shore-based harvest, especially to the south) and positive (over-reporting of harvests by charter boat operators in a log book survey which are included in the estimate). The 2011–12 and 2017–18 national panel surveys provided plausible results and are considered to be broadly reliable and suggest that catch is increasing. Web camera/ creel survey monitoring in SNA 8 started in late 2011 and has found no general trend in fishing effort, but a gradual fluctuating increase in catch rates and hence harvest, since that time. No estimates of absolute catch have yet been developed from these data.

1.3 Customary non-commercial fisheries

Snapper form important fisheries for customary non-commercial, but the annual catch is not known. The information on Māori customary harvest under the provisions made for customary fishing is limited (Table 6c). It is likely that Māori customary fishers utilise the provisions under recreational fishing regulations. Customary reporting varies within SNA 8. Large areas of SNA 8 are gazetted under the Fisheries (Kaimoana Customary Fishing) Regulations 1998 which require reporting on authorisations. In the areas not gazetted, customary fishing authorisations issued would be under the Fisheries (Amateur Fishing) Regulations 2013, where there is no requirement to report. The numbers reported in Table 6b may be underestimated.

Table 6c: Customary approvals in SNA 8 from 2005 to 2020.

Year	Quantity approved (kg)	Reported actual quantity harvested (kg)	Number of authorisations issued
2005	130		
2006	220		3
2007	250	70	3
2008	30	30	
2009	950	651	5
2010	5 457	3 176	7
2011	4 910	2 950	15
2012	3 340	2 494	6
2013	4 887	2 965	16
2014	19 030	6 136	31
2015	16 025	5 186	19
2016	11 270	5 578	28
2017	1 510	1 133	13
2018	790	608	9
2019	18 270	912	46
2020	5 800		15

There are no estimates of customary catch available for SNA 7. Current levels of customary catch in SNA 7 are considered to be small and are assumed to be included into recreational catch estimates.

1.4 Illegal catch

No new analyses are available that provide estimates of illegal catch. For modelling SNA 1, SNA 7, and SNA 8, an assumption was made that non-reporting of catch was 20% of reported domestic commercial catch prior to 1986 and 10% of reported domestic commercial catch since the QMS was introduced. This was to account for all forms of under-reporting. These proportions were estimated in 1996, taking account of information on the black-market trade in snapper and higher levels of under-reporting (to avoid tax) that existed prior to the introduction of the QMS. The 10% under-reporting post-QMS accounts for the practice of under-recording of landed weights and the discarding of legal-size snapper. From 2016–2018 all snapper 1 trawl vessels participated in a video observation programme (Middleton & Guard 2021); the focus of that project was verification of the quantity of undersized fish returned to the sea, but significant discarding of legal-sized snapper by these vessels was unlikely during this period.

1.5 Other sources of mortality

No estimates are available regarding the amount of other sources of mortality on snapper stocks; although high-grading of longline fish and discarding of under-sized fish by all methods occurs. An at-sea study of SNA 1 commercial longline fisheries in 1997 (McKenzie 2000) found that 6–10% of snapper caught by number were under 25 cm (MLS). Results from a holding net study indicate that mortality levels amongst lip-hooked snapper caught shallower than 35 m were low.

Estimates for incidental mortality were based on other catch-at-sea data using an age-length structure model for longline, trawl, seine, and recreational fisheries. In SNA 1, estimates of incidental mortality for the year 2000 from longlines were less than 3% and for trawl, seine, and recreational fisheries between 7% and 11% (Millar et al 2001). In SNA 8, estimates of trawl and recreational incidental mortality were lower, mainly because of low numbers of 2- and 3-year old fish estimated in 2000.

With the introduction of Electronic Reporting in 2019, commercial fishers must provide comprehensive reporting of all discards and returns. All fish under the minimum legal size ("sub-MLS fish") must be returned to the sea.

In SNA 1, recreational fishers release a high proportion of their snapper catch, most of which was less than 30 cm (recreational MLS). An at-sea study in 2006–07 recorded snapper release rates of 54.2% of the catch by trailer boat fishers and 60.1% of the catch on charter boats (Holdsworth & Boyd 2008). Incidental mortality estimated from condition at release was 2.7% to 8.2% of total catch by weight depending on assumptions used.

2. BIOLOGY

Snapper are demersal fish found down to depths of about 200 m, but are most abundant in 15–60 m. They are the dominant fish in northern inshore communities and occupy a wide range of habitats, including rocky reefs and areas of sand and mud bottom. They are widely distributed in the warmer waters of New Zealand, being most abundant in the Hauraki Gulf.

Although all snapper undergo a female phase as juveniles, after maturity each individual functions as one sex (either male or female) during the rest of its life. Sexual maturity occurs at an age of 3–4 years and a length of 20–28 cm; and the sex ratio of the adult population is approximately 50:50. Snapper are serial spawners, releasing many batches of eggs over an extended season during spring and summer. The larvae have a relatively short planktonic phase which results in the spawning grounds corresponding fairly closely with the nursery grounds of young snapper. Juvenile snapper (0+) are known to reach high abundances in shallow west and east coast harbours and estuaries around the northern half of the North Island and have also been observed in catches from trawl surveys conducted in shallow coastal waters around northern New Zealand, East Cape, Hawke Bay and Tasman Bay and Golden Bay. Despite observations of spawning condition adults along the Wairarapa and Kapiti coasts,

0+ snapper have yet to be found in these areas. Young snapper disperse more widely into less sheltered coastal areas as they grow older. Large schools of snapper congregate before spawning and move on to the spawning grounds, usually in November–December. The spawning season may extend to January–March in some areas and years before the fish disperse, often inshore to feeding grounds. The winter grounds are thought to be in deeper waters where the fish are more widespread.

Water temperature appears to play an important part in the success of recruitment. Generally strong year classes in the population correspond to warm years, weak year classes correspond to cold years (Francis 1993).

Growth rate varies geographically and from year to year. Snapper from SNA 2, Tasman Bay/Golden Bay and off the west coast of the North Island grow faster and reach a larger average size than elsewhere. Snapper have a strong seasonal growth pattern, with rapid growth from November to May, and then a slowing down or cessation of growth from June to September. They may live up to 60 years or more and have very low rates of natural mortality. An estimate of $M = 0.06$ yr^{-1} was made from catch curves of commercial catches from the west coast North Island pair trawl fishery in the mid-1970s. These data were re-analysed in 1997 and the resulting estimate of 0.075 yr^{-1} has been used in the base case assessments for SNA 1, 2, 7, and 8.

Regular sampling has provided evidence that growth rates of snapper in SNA 1, SNA 7 and SNA 8 have also varied over time. For SNA 8, growth rates were considerably higher during the 1980s and 1990s compared with the 1970s and more recent period (from mid-2000s). The SNA 7 and SNA 8 growth parameters in Table 7 were derived from age-length observations from the early 1990s and, hence, represent the period of higher growth rates. The temporal variation in growth may indicate density-dependence in the growth rates of snapper, at least in SNA 1, SNA 7 and SNA 8, given the historical exploitation patterns of those stocks. Estimates of biological parameters relevant to stock assessment are shown in Table 7.

Table 7: Estimates of biological parameters.

Fishstock	Estimate			Source
1. Instantaneous rate of natural mortality (M)				
SNA 1, 2, 7, & 8	0.075			Hilborn & Starr (unpub. analysis)
2. Weight = a(length)^b (Weight in g, length in cm fork length)				
All	$a = 0.04467$	$b = 2.793$		Paul (1976)
3. von Bertalanffy growth parameters				
	Both sexes combined			
	K	t_0	L_∞	
SNA 1	0.102	-1.11	58.8	Gilbert & Sullivan (1994)
SNA 2	0.061	-5.42	68.9	NIWA (unpub. analysis)
SNA 7 (1990s)	0.122	-0.71	69.6	MPI (unpub. data)
SNA 8 (1990s)	0.16	-0.11	66.7	Gilbert & Sullivan (1994)
4. Age at recruitment (years)				
SNA 1*	4 (39%) 5 (100%)			Gilbert et al (2000)
SNA 7	3			MPI (unpub. data)
SNA 8	3			Gilbert & Sullivan (1994)

* For years when not estimated.

3.   STOCKS AND AREAS

New Zealand snapper are thought to comprise either seven or eight biological stocks based on: the location of spawning and nursery grounds; differences in growth rates, age structure, and recruitment strength; and the results of tagging studies. These stocks are assumed to comprise three in SNA 1 (East Northland, Hauraki Gulf, and Bay of Plenty (BoP)), two in SNA 2 (one of which may be associated with the BoP stock), two in SNA 7 (Marlborough Sounds and Tasman Bay/Golden Bay) and one in

SNA 8. Tagging studies reveal that limited mixing occurs between the three SNA 1 biological stocks, with greatest exchange between BoP and Hauraki Gulf.

Tagging studies in SNA 8 have shown considerable movements of fish between South Taranaki Bight and the area north of Cape Egmont. However, recent *Kaharoa* WCNI trawl surveys indicate some differences in the age structure of snapper between the two areas which may suggest a degree of spatial stratification of the SNA 8 stock.

Tagging studies in SNA 7 (1986/87) and SNA 8 (1990) revealed reciprocal movements of snapper between Tasman Bay/Golden Bay and South Taranaki Bight, although the scale of the movement was relatively low during that period.

Location-based snapper catch data from the trawl fisheries in SNA 7 and southern SNA8 has revealed an overlap of the distribution of snapper catches in western approaches to Cook Strait between Durville Island and Kapiti Island, particularly since 2014/15. Snapper age compositions are available from recent (2018-2020) *Kaharoa* trawl surveys of the South Taranaki Bight and the Tasman Bay/Golden Bay area of the WCSI trawl survey. There are strong differences in the relative strength of individual year classes from the 2019 South Taranaki Bight age composition compared to the 2018 and 2020 surveys, while the 2019 STB age composition was very similar to the age structures from the 2019 Tasman Bay/Golden Bay trawl survey and the commercial fishery in the TBGB area. These observations indicate a degree of mixing of the snapper populations between SNA 7 and the STB area (SNA8), although the extent of mixing may vary between years, potentially related to variation in the timing of the main spawning period in each area.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was last updated from the 2022 Fisheries Assessment Plenary. An issue-by-issue analysis is available in the Aquatic Environment and Biodiversity Annual Review 2021 (Fisheries New Zealand 2021), online at https://www.mpi.govt.nz/dmsdocument/51472-Aquatic-Environment-and-Biodiversity-Annual-Review-AEBAR-2021-A-summary-of-environmental-interactions-between-the-seafood-sector-and-the-aquatic-environment.

4.1 Role in the ecosystem
Snapper are one of the most abundant demersal generalist predators found in the inshore waters of northern New Zealand (Morrison & Stevenson 2001, Kendrick & Francis 2002), and as such are likely to be an important part of the coastal marine ecosystem (Salomon et al 2008). Localised depletion of snapper probably occurs within the key parts of the fisheries (Parsons et al 2009), and this has unknown consequences for ecosystem functioning in those areas.

4.1.1 Trophic interactions
Snapper are generalists, occupying nearly every coastal marine habitat less than 200 m deep. Because of this generalist nature there is a large potential for a variety of trophic interactions to involve snapper. The diet of snapper is diverse and opportunistic and largely includes crustaceans, polychaetes, echinoderms, molluscs, and other fish (Godfriaux 1969, Godfriaux 1974). As snapper increase in size, harder bodied and larger diet items increase in importance (e.g., fish, echinoids, hermit crabs, molluscs, and brachyuran crabs) (Godfriaux 1969, Usmar 2012). There is some evidence to suggest a seasonal component to snapper diet, with high proportions of pelagic items (e.g., salps and pelagic fish such as pilchards) observed during spring in one study (Powell 1937).

There is some evidence to suggest that snapper can influence the environment that they occupy in some situations. On some rocky reefs, recovery of predators inside marine reserves (including snapper and rock lobster, *Jasus edwardsii*) has led to the recovery of algal beds through predation exerted on herbivorous urchins (Babcock et al 1999, Shears & Babcock 2002). Snapper competes with other species; overlap in diet is likely with a number of other demersal predators (e.g., tarakihi, red gurnard, trevally, rig, and eagle ray). The wide range of prey consumed by these species and differences in diet preference and habitat occupied, however, is likely to reduce the amount of competition overall

(Godfriaux 1970, 1974). The importance of snapper as a food source for other predators is poorly understood.

4.1.2 Ecosystem Indicators

Tuck et al (2009) used data from the Hauraki Gulf trawl survey series (up to 2000) to derive fish-based ecosystem indicators using diversity, fish size, and trophic level. This trawl survey series covers a key component of the distribution of snapper. Tuck et al (2009) showed decreasing trends in the proportion of species with low resilience (from FishBase, Froese & Pauly 2000) and the proportion of demersal fish species in waters shallower than 50 m in the Hauraki Gulf. Several indices of fish diversity showed significant declines in muddy waters shallower than 50 m, especially in the Firth of Thames. Tuck et al (2009) did not find size-based indicators as useful as they have been overseas, but there was some indication that the maximum size of fish has decreased in the Hauraki Gulf survey area, especially over sandy bottoms. Since 2008, routine measurement of all fish species in New Zealand trawl surveys has been undertaken and this may increase the utility of size-based indicators in the future.

4.2 Bycatch (fish and invertebrates)

Most snapper taken in SNA 1 and 8, and some taken in SNA 7, is the declared target species, but some snapper is taken as a bycatch in a variety of inshore trawl and line fisheries. No summaries of observed fish and invertebrate bycatch in snapper target fisheries are currently available, so the best available information is from research fishing conducted in the areas where target fisheries take place. Although the gear used for these surveys may be different than that used in the fishery itself (e.g., smaller mesh cod ends are used in trawl surveys), they are conducted in the same areas and provide some insight as to the fish and invertebrate species likely to be caught in association with snapper.

More than 70 species have been captured in trawl surveys within SNA 1, but catches are dominated by snapper. Kendrick & Francis (2002) noted the following species in more than 30% of tows by research vessels *Ikatere* and *Kaharoa*: jack mackerels (three species), John dory, red gurnard, sand flounder, leatherjacket, rig, eagle ray, lemon sole, and trevally (see also Langley 1995a, Morrison 1997, Morrison & Francis 1997, Jones et al 2010). Smaller numbers of invertebrates are captured including green-lipped mussel, arrow squid, broad squid, octopuses, and scallop (Langley 1995a, Morrison 1997, Morrison & Francis 1997, and Jones et al 2010). For SNA 1, information on the bycatch associated with research longlining during tagging surveys is also available, although restricted to the inner and western parts of the Hauraki Gulf. The most common bycatch species in this area included: rig, school shark, hammerhead shark, eagle ray, stingrays, conger eel, trevally, red gurnard, jack mackerels, blue cod, John dory, kingfish, frostfish, and barracouta (Morrison & Parsons, NIWA, unpublished data).

Trawl surveys targeting juvenile snapper in Tasman Bay and Golden Bay have captured more than 50 finfish species. Common bycatch species (Blackwell & Stevenson 1997) were: spiny dogfish, red cod, barracouta, red gurnard, jack mackerel (three species), hake, blue warehou, tarakihi, and porcupine fish. Invertebrates captured included sponges, green-lipped mussel, octopuses, arrow squid, nesting mussel, and horse mussel. Over 80 species have been captured in trawl surveys within SNA 8. Red gurnard, jack mackerel (three species), trevally, barracouta, school shark, spiny dogfish, rig, John dory, and porcupine fish were the most abundant finfish (Langley 1995b, Morrison 1998, Morrison & Parkinson 2001). Few invertebrates other than arrow squid were caught (Morrison & Parkinson 2001).

4.3 Incidental capture of protected species (mammals, seabirds, turtles, and protected fish)

For protected species, capture estimates presented here include all animals recovered to the deck (alive, injured, or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds struck by a warp or caught on a hook but not brought onboard the vessel, Middleton & Abraham 2007, Brothers et al 2010).

4.3.1 Marine mammal captures

There were two observed captures of New Zealand fur seals in trawls targeting snapper between 2002–03 and 2019–20, but historically low observer coverage of inshore trawlers (average 6.98% in FMAs 1 and 9 between 2002–03 and 2017–18, but averaging 20.51% between 2013–14 and 2017–18) (https://psc.dragonfly.co.nz/2019v1/released/new-zealand-fur-seal/inshore-trawl/all-vessels/eez/2002-03-2017-18/) means that the frequency of captures is highly uncertain. In the same time period, there

were no observed marine mammal captures in snapper longline fisheries, when coverage has averaged 2.18% of hooks set (2.5 and 7.3% in the two most recent years) (Protected species bycatch (protectedspeciescaptures.nz)).

Observers recorded two dolphin deaths during snapper trawling in 2016–17: one common dolphin from off the North Island east coast and one bottlenose dolphin from the Northland-Hauraki Gulf area (Abraham et al 2021).

4.3.2   Seabird interactions and captures

There have been thirteen observed captures of seabirds (3 flesh-footed shearwater, 3 black petrel, 2 shearwaters that were not identified further, and 2 common diving petrel, 2 New Zealand white-faced storm petrel and an unidentified small seabird) and 26 observed deck strikes (10 common diving petrels, 10 grey-faced petrel, 2 Buller's shearwater, 1 flesh-footed shearwater, 1 cape petrel, 1 black petrel, and 1 Cook's petrel) in trawls targeting snapper between 2002–03 and 2019–20, but historically low observer coverage of inshore trawlers (average 6.98% in FMAs 1 and 9 between 2002–03 and 2017–18, but averaging 20.51% between 2013–14 and 2017–18) means that the frequency of interactions is highly uncertain. (Protected species bycatch (protectedspeciescaptures.nz))

The estimated number of total incidental captures of all seabirds in the snapper bottom longline fishery declined from 3436 in 2000–01 to 247–644 in 2003–04 (depending on the model used, Table 8, estimates from MacKenzie & Fletcher 2006, Baird & Smith 2007, 2008, Abraham & Thompson 2011a). The estimated number of captures between 2003–04 and 2006–07 appears to have been relatively stable at about 400–600 birds each year.

Table 8: **Model based estimates of seabird captures in the SNA 1 bottom longline fishery from 1998–99 to 2006–07 (from MacKenzie & Fletcher 2006 (for vessels under 28 m), Baird & Smith 2007, 2008, Abraham & Thompson 2011a). Numbers in parentheses are 95% confidence limits or estimated CVs.**

Fishing year	MacKenzie & Fletcher		Baird & Smith		Abraham & Thompson	
1998–99	1 464	(271–9 392)	–	–	–	–
1999–00	2 578	(513–13 549)	–	–	–	–
2000–01	3 436	(697–17 907)	–	–	–	–
2001–02	1 856	(353–11 260)	–	–	–	–
2002–03	1 583	(299–9 980)	–	–	739	(332–1 997)
2003–04	247	(51–1 685)	546	(CV = 34%)	644	(301–1 585)
2004–05	–	–	587	(CV = 42%)	501	(245–1 233)
2005–06	–	–	–	–	469	(222–1 234)
2006–07	–	–	–	–	457	(195–1 257)

Between 2002–03 and 2017–18, there were 156 observed captures of birds in snapper bottom longline fisheries (Table 9). Estimates of the mean total seabird captures from 2002–03 to 2017–18 vary from 713 to 325 based on a consistent capture rate. The rate of capture varied between 0.0 and 0.1 birds per 1000 hooks observed, fluctuating without obvious trend. Seabirds observed captured in snapper longline fisheries were mostly flesh-footed shearwater (53%) and black (Parkinson's) petrel (24%), and the majority were taken in the Northland-Hauraki area (88%) (Table 10). These numbers should be regarded as only a general guide on the composition of captures because the observer coverage is low, is not uniform across the area, and may not be representative.

The snapper target bottom longline fishery contributes to the total risk posed by New Zealand commercial fishing to seabirds (Table 11). The two species to which the fishery poses the most risk are black petrel and flesh-footed shearwater, with this target fishery posing 0.4421 and 0.2166 of PST, respectively (Table 11). The black petrel is assessed at very high risk from commercial fishing in New Zealand waters, and the flesh-footed shearwater is assessed at high risk from commercial fishing in New Zealand waters (Richard et al 2020).

SNAPPER (SNA)

Table 9: Number of tows by fishing year, observed, and estimated seabird captures in the snapper bottom longline fishery, 2002–03 to 2019–20. No. obs, number of observed hooks; % obs, percentage of hooks observed; Rate, number of captures per 1000 observed hooks. Estimates are based on methods described by Abraham et al (2016) and Abraham & Richard (2017, 2018) and are available via Protected species bycatch (protectedspeciescaptures.nz). Observed and estimated protected species captures in this table derive from the PSC database version PSCV6.

	Fishing effort			Observed captures		Estimated captures		
	All hooks	No. obs	% obs	Number	Rate	Mean	95% c.i.	% included
2002–03	13 728 672	0	0.0	0	–	713	522-942	93.2
2003–04	12 266 197	187 282	1.5	10	0.05	636	471-850	100.0
2004–05	11 542 491	244 692	2.1	13	0.05	573	421-766	100.0
2005–06	11 695 613	116 288	1.0	12	0.10	454	324-622	93.1
2006–07	10 348 741	62 360	0.6	0	0.00	438	319-599	93.4
2007–08	9 047 522	0	0.0	0	–	426	302-583	100.0
2008–09	8 981 466	318 274	3.5	27	0.08	441	322-594	100.0
2009–10	11 041 405	634 145	5.7	32	0.05	471	343-633	100.0
2010–11	11 343 582	0	0.0	0	–	497	356-676	100.0
2011–12	11 037 136	0	0.0	0	–	446	318-613	100.0
2012–13	10 501 460	366 120	3.5	2	0.01	418	301-567	100.0
2013–14	11 122 634	747 597	6.7	47	0.06	426	315-573	100.0
2014–15	10 845 182	0	0.0	0	–	356	250-492	100.0
2015–16	10 611 551	337 125	3.2	7	0.02	336	238-463	100.0
2016–17	10 757 586	486 700	4.5	5	0.01	338	235-469	100.0
2017–18	10 427 687	327 091	3.1	14	0.04	325	228-447	100.0
2018–19	10 811 176	269 659	2.5	3	0.01	354	245-485	100.0
2019–20	11 067 703	806 795	7.3	14	0.02	363	260-495	100.0

Table 10: Number of observed seabird captures in the snapper longline fishery, 2002–03 to 2018–19, by species or species group. The risk category is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Population Sustainability Threshold, PST (from Richard et al 2017, where full details of the risk assessment approach can be found). Observed and estimated protected species captures in this table derive from the PSC database version PSCV4, www.data.dragonfly.co.nz/psc.

Taxa	Risk category	Northland and Hauraki	Bay of Plenty	West Coast North Island	Taranaki
Black petrel	Very high	40	0	0	0
Flesh-footed shearwater	High	76	11	0	7
Northern giant petrel	Medium	1	0	0	0
Pied shag	Negligible	2	0	0	0
Fluttering shearwater	Negligible	6	0	0	0
Sooty shearwater	Negligible	2	0	0	0
Australasian gannet	Negligible	2	0	0	0
Buller's shearwater	Negligible	13	0	1	0
Southern black-backed gull	Negligible	5	0	0	0
Petrels	–	3	1	0	1
Total birds	–	163	14	1	8

Table 11: Risk ratio of seabirds predicted by the risk assessment for the snapper target bottom longline fishery and all fisheries included in the risk assessment, 2006–07 to 2016–17, showing seabird species with a risk ratio of Very High or High; estimates at a fishery-specific level were not available for other species. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Population Sustainability Threshold, PST (from Richard et al 2017, where full details of the risk assessment approach can be found). The DOC threat classifications are given by (Robertson et al 2017 at http://www.doc.govt.nz/documents/science-and-technical/nztcs19entire.pdf).

		Risk ratio			
Species name	PST (mean)	SNA target bottom longline	Total	Risk category	DOC Threat Classification
Black petrel	447	0.4421	1.23	Very high	Threatened: Nationally Vulnerable
Flesh-footed shearwater	1 450	0.2166	0.49	High	Threatened: Nationally Vulnerable

4.3.3 Sea turtle captures

Between 2002–03 and 2019–20 there was one observed capture of a green turtle in the snapper bottom longline fishery occurring in the Northland and Hauraki fishing area. Observer records documented the green turtle as captured and released alive (Fisheries New Zealand unpublished data). In the same period, there were no captures of turtles in the snapper trawl fishery.

4.3.4 Protected fish captures

White pointer sharks (*Carcharodon carcharias*, also known as great white shark) were protected in New Zealand waters in 2007 under the Wildlife Act 1953, but they are incidentally caught in commercial and recreational fisheries (Francis & Lyon 2012). Fishers have reported catching a total of 24 white pointer shark individuals in snapper trawls since 2009, 4 of which were dead upon capture, 5 were released alive but injured, and the remainder were released alive. Little is known about the survival of released individuals, but it is assumed to be low.

4.4 Benthic interactions

The spatial extent of seabed contact by trawl fishing gear in New Zealand's EEZ and Territorial Sea has been estimated and mapped for all trawl fisheries combined (Baird & Mules 2021). This most recent analysis provides an assessment of the inshore trawl footprint was for the period 2007–08 to 2018–19 (Baird & Mules 2021).

A total of almost 43 700 bottom contacting tows have targeted snapper between 2007–08 and 2018–19. Annual numbers fluctuated around 4000 tows per year up to 2012–13 but have declined to around 3000 since 2015–16 (Baird & Mules 2021). The total aggregate area fished between 2007–08 and 2018–19 was 49 250 km^2. This has mostly (67%) been within SNA 1, where annual aggregate area fished declined from around 3000 km^2 (2007–08 to 2012–13) to 2100 km^2 (2016–17), before increasing to around 3200 km^2 (2017–18 and 2018–19). Annual area fished within SNA 2 and SNA 7 has fluctuated around 350 km^2; whereas in SNA 8, the annual area fished declined from 1300 km^2 in 2007–08 to 480 km^2 by 2010–11 and has fluctuated around this level since this time (Baird & Mules 2021).

A proportion of the commercial catch of snapper is taken using bottom trawls in Benthic Optimised Marine Environment Classification (BOMEC, Leathwick et al 2012) classes A, C (northern shelf), and H (shelf break and upper-slope) (Baird & Wood 2012), and at least 90% of trawls occur shallower than 100 m depth (Baird et al 2011, tabulating data from TCEPR forms). Trawling for snapper, like trawling for other demersal species, is likely to have effects on benthic community structure and function (e.g., Thrush et al 1998, Rice 2006) and there may be consequences for benthic productivity (e.g., Jennings et al 2001, Hermsen et al 2003, Hiddink et al 2006, Reiss et al 2009). These consequences are not considered in detail here but are discussed in the Aquatic Environment and Biodiversity Annual Review 2021 (Fisheries New Zealand 2021).

4.5 Other considerations

4.5.1 Spawning disruption
Fishing within aggregations of spawning fish may have the potential to disrupt spawning behaviour and, for some fishing methods or species, may lead to reduced spawning success. No research has been conducted on disruption of snapper spawning, but aggregations of spawning snapper often receive high commercial and recreational fishing effort (Fisheries New Zealand unpublished data). Areas likely to be important for snapper spawning include the Hauraki Gulf (Cradock Channel, Coromandel Harbour to the Firth of Thames, and between the Noises, Tiritiri Matangi, and Kawau Islands (Zeldis & Francis 1998)), Rangaunu and Doubtless Bay, the Bay of Islands, eastern Bay of Plenty, and the coastal areas adjacent to the harbour mouths on the west coast such as Manukau Harbour and Kaipara Harbour (Hurst et al 2000).

4.5.2 Genetic effects
Fishing, environmental changes, including those caused by climate change or pollution, could alter the genetic composition or diversity of a species. Bernal-Ramírez et al (2003) estimated genetic diversity and confidence limits for snapper in Tasman Bay and the Hauraki Gulf. They showed a significant decline of both mean heterozygosity and mean number of alleles in Tasman Bay, but only random fluctuations in the Hauraki Gulf. In Tasman Bay, there was a decrease in genetic diversity at six of seven loci examined, compared with only one in the Hauraki Gulf. Bernal-Ramírez et al (2003) associated this decline with overfishing of the SNA 7 stock and estimated the effective population size in Tasman Bay declined to a low level between 1950 and 1998.

4.5.3 Habitat of particular significance to fisheries management

Habitat of particular significance for fisheries management (HPSFM) does not have a policy definition (Ministry for Primary Industries 2013). For juvenile snapper, it is likely that certain habitats, or locations, are critical to successful recruitment of snapper. Post settlement juvenile snapper (10–70 mm fork length) associate strongly with three-dimensional structured habitats in estuaries, harbours, and sheltered coastal areas (such as beds of seagrass and horse mussels, Thrush et al 2002, Morrison et al 2009, 2014a, b). The reason for this association is currently unclear, but the provision of food and shelter are likely explanations. Some potential nursery habitats appear to contribute disproportionately to their area. For example, the Kaipara Harbour in northern New Zealand contributed to more than 75% of the recruits to the SNA 8 fishery in 2003 (Morrison, NIWA, unpublished data, Morrison et al 2009) and a similar situation exists for snapper from Port Phillip Bay in Australia (Hamer et al 2011). These habitats are subject to land-based stressors (Morrison et al 2009, Lowe et al 2015) that may affect the survival of juvenile snapper and hence recruitment to the SNA 8 fishery. It should, however, be noted that recruitment over the last decade has been exceptionally good, suggesting that environmental factors affecting egg and larval survival in the ocean have had greater influence on the number of fertilised eggs surviving to adulthood.

5. RECRUITMENT, ENVIRONMENTAL VARIABILITY, AND CLIMATE CHANGE

This section was last updated in May 2021.

Recruitment dynamics are challenging to assess or predict because of the many underlying drivers that vary over time and space. Stock size, demographic and trait composition, condition and distribution of spawning fish, and the spatio-temporal dynamics of trophic and environmental interactions all influence recruitment processes. Annual variations in snapper recruitment have considerable impact on this fishery and improved understanding of the influence of environmental variables on recruitment patterns would be very useful for the future projection of stock size under different climate change scenarios and different environmental conditions.

New Zealand waters are becoming warmer and more acidic due to the emission of anthropogenic carbon dioxide (Law et al 2018a, 2018b). Recruitment success of New Zealand snapper has been highly correlated with warmer conditions (Francis 1993, Harley & Gilbert 2000, Zeldis et al 2005, Dunn et al 2009, Langley 2015, Garg 2020). Snapper recruitment fluctuations may significantly influence biomass where: 1) a series of weak or strong year classes occur in adjacent years, 2) a population is heavily fished and thus more easily dominated by younger year classes, or 3) a population is near the geographic limit of its range and is dominated by a few year classes due to irregular recruitment; each of which has occurred in at least one snapper stock in New Zealand (Francis 1993).

Recruitment in SNA 7 and SNA 8 has been above average in recent years (Langley 2020a, 2020b). Some spatial differences in year class strength (YCS) patterns are evident across different stocks, but appear to be reasonably well correlated, which may be a result of each stock showing similar responses to broad climatic phenomena, such as the Southern Oscillation Index (SOI) (Francis & Mackenzie 2015). Stock assessments have estimated high levels of recruitment in SNA 7 and SNA 8 between 2006 and 2019 (Langley 2015, 2020a, 2020b), which may possibly be linked to increasing water temperatures. It should nevertheless be noted that the relationship between recruitment and water temperature is unlikely to be linear, with growth and recruitment decreasing after reaching an optimum thermal maxima for Australian snapper populations (Fowler & Jennings 2003, Murphy 2013). It is unclear what the thermal maxima will be for snapper in New Zealand.

In SNA 7, recruitment has been shown to be positively correlated with air temperature (Harley & Gilbert 2000). Strong year classes have also been linked to positive SOI conditions, whereas weak year classes have been linked to negative SOI conditions (Langley 2015). More recently, Garg (2020) examined environment-recruitment relationships for SNA 1 (1970–2007) and SNA 7 (1982–2012) using generalised linear models based on annual recruitment estimates from stock assessment models that incorporated age data from otolith samples. The most variation in YCS was explained by the mean autumn (April–June) SST in SNA 1 and by mean annual SOI in SNA 7, and the Interdecadal Pacific

Oscillation accounted for the second greatest amount of variation in both SNA 1 and SNA 7. These findings were consistent with Francis (1993), who concluded that water temperature appears to play an important part in the success of recruitment, with strong year classes in the population generally corresponding to warm years, and weak year classes to cold years. As well as finding a positive correlation between YCS and SST, Dunn et al (2009) also found a positive correlation between YCS and SOI for SNA 1.

A recent study found that fishing and environmental factors initially promote individual fish growth of snapper, but regional-scale wind and temperature may also increase the sensitivity of stocks to environmental change (Morrongiello et al 2021).

Temperature-recruitment relationships are typically non-linear, and studies on snapper in South Australia have shown a reduction in recruitment after temperatures rose above 25 °C (Fowler & Jennings 2003). In Western Australia, snapper growth is greatest at mid latitudes with more moderate temperatures, and lowest at the northern limit of the geographical range for snapper, where temperatures are at their highest (Wakefield et al 2017). In South Australia, biochronology work has found an optimal temperature maximum of 18–20 °C for growth in snapper, and temperatures greater than this result in slower growth rates (Martino et al 2019), which was also in support of optimum growth conditions for juvenile snapper ascertained from aquaculture experimental studies (Fielder et al 2005). The Hauraki Gulf is currently experiencing temperatures near 20 °C, but the optimal temperature range for snapper stocks in New Zealand is unknown (Parsons et al 2020). Recent Hauraki and Bay of Plenty trawl surveys which monitored snapper recruitment and compared it to SST show that the estimated year class strength of 1+ and 2+ snapper in the Hauraki Gulf 2019 survey was well above the long-term average, whereas in the Bay of Plenty, YCSs were well above average (1+) and about average (2+) (see Parsons & Bian in prep).

Several causal mechanisms may result in the increased production of prey and a faster larval growth rate of snapper (Murphy 2013). Zeldis et al (2005) found that wind-driven upwelling caused increased flux of shelf water into the Hauraki Gulf, resulting in greater primary productivity, prey abundance, and higher larval snapper survival.

Ocean acidification (OA) has been shown to have a variable influence on snapper larvae. Although higher temperature and carbon dioxide levels may positively impact growth and survival of snapper larvae, this effect may be countered by the negative effects of elevated carbon dioxide on metabolic rates and swimming performance (McMahon et al 2020a, 2020b). Modelling the overall effect from both OA and warming on snapper populations estimated a 29% reduction to a 44% increase in fishery yield and therefore remains highly uncertain (Parsons et al 2020).

Cummings et al (2021) assessed the vulnerability of New Zealand's snapper fishery to projected environmental change as 'moderate' and outlined the following potential outcomes of increased sea temperatures: 1) southward range expansion, 2) change in distribution of predators, competitors, parasites, and disease, and 3) toxicity and decreased dissolved oxygen due to harmful algal blooms. In recent years, snapper populations appear to have been increasing, in some areas substantially, suggesting that environmental conditions are currently favourable for snapper recruitment and survival.

6.   FOR FURTHER INFORMATION

Abraham, E R; Berkenbusch, K; Richard, Y; Thompson, F (2016) Summary of the capture of seabirds, mammals, and turtles in New Zealand commercial fisheries, 2002–03 to 2012–13. *New Zealand Aquatic Environment and Biodiversity Report No. 169.* 205 p.

Abraham, E R; Richard, Y (2017) Summary of the capture of seabirds in New Zealand commercial fisheries, 2002–03 to 2013–14. *New Zealand Aquatic Environment and Biodiversity Report No. 184.* 88 p.

Abraham, E R; Richard, Y (2018) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2014–15. *New Zealand Aquatic Environment and Biodiversity Report No. 197.* 97 p.

Abraham, E R; Thompson, F N (2011a) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report No. 79.*

Abraham, E R; Thompson, F N (2011b) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report No. 80.*

Abraham, E R; Thompson, F N; Oliver, M D (2010) Summary of the capture of seabirds, mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report No. 45.* 149 p.

Abraham, E R; Tremblay-Boyer, L; Berkenbusch, K (2021) Estimated captures of New Zealand fur seal, common dolphin, and turtles in New Zealand commercial fisheries, to 2017–18. *New Zealand Aquatic Environment and Biodiversity Report No. 258*. 94 p.

Babcock, R C; Kelly, S; Shears, N T; Walker, J W; Willis, T J (1999) Changes in community structure in temperate marine reserves. *Marine Ecology Progress Series 189*: 125–134.

Baird, S J (2004a) Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1999–2000. *New Zealand Fisheries Assessment Report 2004/41*. 56 p.

Baird, S J (2004b) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2000–01. *New Zealand Fisheries Assessment Report 2004/58*. 63 p.

Baird, S J (2004c) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2001–02. *New Zealand Fisheries Assessment Report 2004/60*. 51 p.

Baird, S J (2005) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002–03. *New Zealand Fisheries Assessment Report 2005/2*. 50 p.

Baird, S J; Mules, R (2021) Extent of bottom contact by commercial trawling and dredging in New Zealand waters, 1989–90 to 2018–19. *New Zealand Aquatic Environment and Biodiversity Report No. 260*. 157 p.

Baird, S J; Smith, M H (2007) Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2003–04 to 2004–05. *New Zealand Aquatic Environment and Biodiversity Report No. 14*. 98 p.

Baird, S.J; Smith, M.H. (2008) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2005–06. *New Zealand Aquatic Environment and Biodiversity Report No. 18*. 124 p.

Baird, S J; Wood, B A (2012) Extent of coverage of 15 environmental classes within the New Zealand EEZ by commercial trawling with seafloor contact. *New Zealand Aquatic Environment and Biodiversity Report No. 89*. 43 p.

Baird, S J; Wood, B A; Bagley, N W (2011) Nature and extent of commercial fishing effort on or near the seafloor within the New Zealand 200 n. mile Exclusive Economic Zone, 1989–90 to 2004–05. *New Zealand Aquatic Environment and Biodiversity Report No. 73*. 143 p.

Baker, C S; Chilvers, B L; Constantine, R; DuFresne, S; Mattlin, R H; van Helden, A; Hitchmough, R (2010) Conservation status of New Zealand marine mammals (suborders Cetacea and Pinnipedia), 2009. *New Zealand Journal of Marine and Freshwater Research 44*: 101–115.

Ballara, S L; Anderson, O F (2009) Fish discards and non-target fish catch in the trawl fisheries for arrow squid and scampi in New Zealand waters. *New Zealand Aquatic Environment and Biodiversity Report No. 38*. 102 p.

Bernal-Ramírez, J H; Adcock, G J; Hauser, L; Carvalho, G R; Smith, P J (2003) Temporal stability of genetic population structure in the New Zealand snapper, *Pagrus auratus*, and relationship to coastal currents. *Marine Biology 142(3)*: 567–574.

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 national marine recreational fishing survey: diary results and harvest estimates. . Final Research Report for Ministry of Fisheries. (Unpublished report held by Fisheries New Zealand, Wellington.) 93 p.

Boyd, R O; Reilly, J L (2002) 1999/2000 National marine recreational fishing survey: harvest estimates. Final Research Report for Ministry of Fisheries Research Project REC9803. (Unpublished report held by Fisheries New Zealand, Wellington.)

Bradford, E (1998) Harvest estimates from the 1996 national marine fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished document held by NIWA library, Wellington.)

Brothers, N; Duckworth, A R; Safina, C; Gilman, E L (2010) Seabird bycatch in pelagic longline fisheries is grossly underestimated when using only haul data. *PloS ONE 5*: e12491. doi: 10.1371/journal.pone.001249

Cummings, V J; Lundquist, C J; Dunn, M R; Francis, M; Horn, P; Law, C; Pinkerton, M H; Sutton, P; Tracey, D; Hansen, L; Mielbrecht, E (2021) Assessment of potential effects of climate-related changes in coastal and offshore waters on New Zealand's seafood sector. *New Zealand Aquatic Environment and Biodiversity Report No. 261*. 153 p.

Dunn, M R; Hurst, R J; Renwick J; Francis, R I C C; Devine, J; McKenzie, A (2009) Fish abundance and climate trends in New Zealand. *New Zealand Aquatic Environment and Biodiversity Report No. 31*. 73 p.

Fielder, D S; Bardsley, W J; Allan, G L; Pankhurst, P M (2005) The effects of salinity and temperature on growth and survival of Australian snapper, *Pagrus auratus* larvae. *Aquaculture 250(1–2)*: 201–214.

Fisheries New Zealand (2021) Aquatic Environment and Biodiversity Annual Review 2021. Compiled by the Aquatic Environment Team, Fisheries Science and Information, Fisheries New Zealand, Wellington, New Zealand. 779 p.

Fowler, A J; Jennings, P R (2003) Dynamics in 0+ recruitment and early life history for snapper (*Pagrus auratus*, Sparidae) in South Australia. *Marine and Freshwater Research 54(8)*: 941–956.

Francis, M P (1993) Does water temperature determine year class strength in New Zealand snapper (*Pagrus auratus*, Sparidae)? *Fisheries Oceanography* 2(2): 65–72.

Francis, M P (1994) Growth of juvenile snapper, *Pagrus auratus*. *New Zealand Journal of Marine and Freshwater Research 28(2)*: 201–218.

Francis, M P; Evans, J (1992) Immigration of subtropical and tropical animals into north-eastern New Zealand. Paper presented at the Proceedings of the Second International Temperate Reef Symposium.

Francis, M P; Langley, A; Gilbert, D (1997) Prediction of snapper (*Pagrus auratus*) recruitment from sea surface temperature. *In*: Hancock, D A; Smith, D C; Grant, A; Beumer J P (Eds) *Developing and sustaining world fisheries resources: the state of science and management*, pp. 67–71. 2nd World Fisheries Congress 28 Jul–2 Aug 1996, Brisbane, Australia. CSIRO Publishing.

Francis, M P; Langley, A D; Gilbert, D J (1995) Snapper recruitment in the Hauraki Gulf. New Zealand Fisheries Assessment Research Document 1995/17. 26 p. (Unpublished document held by NIWA library, Wellington.)

Francis, M P; Lyon, W S (2012) Review of commercial fishery interactions and population information for eight New Zealand protected fish species. (Unpublished NIWA client report WLG2012-64 prepared for the Department of Conservation, Wellington.) 67 p. Available at https://www.doc.govt.nz/Documents/conservation/marine-and-coastal/marine-conservation-services/pop2011-03-protected-fish-review.pdf

Francis, M P; Paul, L J (2013) New Zealand inshore finfish and shellfish commercial landings, 1931–82. *New Zealand Fisheries Assessment Report 2013/55*. 136 p.

Froese, R; Pauly, D (2000) FishBase 2000: concepts, design and data sources. ICLARM, Los Banos, Laguna, Philippines. 344 p.

Garg, R (2020) Environment-Recruitment Relationships and Catch Data Based Analysis of Movement Patterns in New Zealand Snapper (*Chrysophrys auratus*). Unpublished master's thesis. University of Auckland, New Zealand.

Gilbert, D J (1994) A total catch history model for SNA 1. New Zealand Fisheries Assessment Research Document 1994/24. 16 p. (Unpublished document held by NIWA library, Wellington.)

Gilbert, D J; Taylor, P R (2001) The relationships between snapper (*Pagrus auratus*) year class strength and temperature for SNA 2 and SNA 7. *New Zealand Fisheries Assessment Report 2001/64*. 33 p.

Godfriaux, B L (1969) Food of predatory demersal fish in Hauraki Gulf. 1. Food and Feeding habitats of snapper. *New Zealand Journal of Marine and Freshwater Research 3*: 518–544.

Godfriaux, B L (1970) Food of predatory demersal fish in Hauraki Gulf. 3. Feeding relationships. *New Zealand Journal of Marine and Freshwater Research 4*: 325–336.

Godfriaux, B L (1974) Feeding relationships between terakihi and snapper in western Bay of Plenty, New Zealand. *New Zealand Journal of Marine and Freshwater Research 8*: 589–609.

Hamer, P A; Acevedo, S; Jenkins, G P; Newman, A (2011) Connectivity of a large embayment and coastal fishery: spawning aggregations in one bay source local and broadscale fishery replenishment. *Journal of Fish Biology 78*: 1090–1109.

Hartill, B; Bian, R; Armiger, H; Vaughan, M; Rush, N (2007) Recreational marine harvest estimates of snapper, kahawai, and kingfish in QMA 1 in 2004–05. *New Zealand Fisheries Assessment Report 2007/26*. 44 p.

Hartill, B; Bian, R; Rush, N; Armiger, H (2013) Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2011–12. *New Zealand Fisheries Assessment Report 2013/70*. 49 p.

Hartill, B; Bian, R; Rush, N; Armiger, H (2019) Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2017–18. *New Zealand Fisheries Assessment Report 2019/23*. 39 p.

Hartill, B; Sutton, C (2011) Characterisation and catch per unit effort indices for the SNA 7 fishery. *New Zealand Fisheries Assessment Report 2011/53*. 55 p.

Hartill, B; Watson, T; Cryer, M; Armiger, H (2007) Recreational marine harvest estimates of snapper and kahawai in the Hauraki Gulf in 2003–04. *New Zealand Fisheries Assessment Report 2007/25*. 55 p.

Hermsen, J M; Collie, J S; Valentine, P C (2003) Mobile fishing gear reduces benthic megafaunal production on Georges Bank. *Marine Ecology Progress Series 260*: 97–108.

Hiddink, J G; Jennings, S; Kaiser, M J; Queiros, A M; Duplisea, D E; Piet, G J (2006) Cumulative impacts of seabed trawl disturbance on benthic biomass, production, and species richness in different habitats. *Canadian Journal of Fisheries and Aquatic Sciences 63*: 721–36.

Holdsworth, J C; Boyd, R O (2008) Size, condition and estimated release mortality of snapper (*Pagrus auratus*) caught in the SNA 1 recreational fishery, 2006–07. *New Zealand Fisheries Assessment Report 2008/53*. 37 p.

Hurst, R J; Stevenson, M L; Bagley, N W; Griggs, L H; Morrison, M A; Francis, M P (2000) Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand coastal fish. Final Research Report to the Ministry of Fisheries Research Project ENV1999-03. 271 p. (Unpublished draft NIWA Technical Report available at https://fs.fish.govt.nz/Doc/22534/ENV1999-03%20Coastal%20Fish%20NZ%20Objective%201%20Final.pdf.ashx.)

Jennings, S; Dinmore, T A; Duplisea, D E; Warr, K J; Lancaster, J E (2001) Trawling disturbance can modify benthic production processes. *Journal of Animal Ecology 70*: 459–475.

Jones, E; Morrison, M; Parsons, D M; Paterson, C; Usmar, N; Bagley, N (2010) Fish communities (Chapter 13). Oceans 2020 Bay of Islands Survey report to LINZ prepared by NIWA. 98 p.

King, M R (1985) Fish and shellfish landings by domestic fishermen, 1974–82. *Fisheries Research Division Occasional Publication: Data Series 20*. 96 p.

King, M R (1986) Catch statistics for foreign and domestic commercial fishing in New Zealand waters, January–December, 1983. *Fisheries Research Division Occasional Publication: Data series 21*. 140 p.

King, M R; Jones, D M; Fisher, K A; Sanders, B M (1987) Catch statistics for foreign and domestic commercial fishing in New Zealand waters, January – December 1984. *New Zealand Fisheries Data Report No. 30*. 150 p.

Law, C S; Bell, J J; Bostock, H C; Cornwall, C E; Cummings, V J; Currie, K; ... & Tracey, D M (2018a) Ocean acidification in New Zealand waters: trends and impacts. *New Zealand Journal of Marine and Freshwater Research 52(2)*: 155–195.

Law, C S; Rickard, G J; Mikaloff-Fletcher, S E; Pinkerton, M H; Behrens, E; Chiswell, S M; Currie, K (2018b) Climate change projections for the surface ocean around New Zealand. *New Zealand Journal of Marine and Freshwater Research 52(3)*: 309–335.

Leathwick, J R; Rowden, A; Nodder, S; Gorman, R; Bardsley, S; Pinkerton, M; Baird, S J; Hadfield, M; Currie, K; Goh, A (2012) A benthic-optimised marine environment classification for New Zealand waters. *New Zealand Aquatic Environment and Biodiversity Report No. 88*. 54 p.

Lowe, M L; Morrison, M A; Taylor, R B (2015) Harmful effects of sediment-induced turbidity on juvenile fish in estuaries. *Marine Ecology Progress Series 539*: 241–254.

MacKenzie, D; Fletcher, D (2006) Characterisation of seabird captures in NZ fisheries. Final Research Report prepared for the Ministry of Fisheries, Proteus Wildlife Consultants. 99 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Martino, J C; Fowler, A; Doubleday, Z A; Grammer, G L; Gillanders, B M (2019) Using otolith chronologies to understand long-term trends and extrinsic drivers of growth in fisheries. *Ecosphere 10(1)*: e02553.

Maunder, M N; Starr, P J (1995) Validating the Hauraki Gulf snapper pre-recruit trawl surveys and temperature recruitment relationship using catch at age analysis with auxiliary information. New Zealand Fisheries Assessment Research Document 1998/15. (Unpublished document held by NIWA library, Wellington.)

McKenzie, J R (2000) Factors Affecting Mortality of small Snapper (*Pagrus auratus*) caught and released by the SNA 1 Longline Fishery. (Draft Fisheries Assessment Report held by NIWA Library, Wellington).

McMahon, S J; Parsons, D M; Donelson, J M; Pether, S M; Munday, P L (2020a) Elevated CO_2 and heatwave conditions affect the aerobic and swimming performance of juvenile Australasian snapper. *Marine Biology 167(1)*: 1–12.

McMahon, S J; Parsons, D M; Donelson, J M; Pether, S M; Munday, P L (2020b) Elevated temperature and CO_2 have positive effects on the growth and survival of larval Australasian snapper. *Marine Environmental Research 161*: 105054.

Middleton, D A J; Abraham, E R (2007) The efficacy of warp strike mitigation devices: Trials in the 2006 squid fishery. Final Research Report for research project IPA2006/02. (Unpublished report held by Fisheries New Zealand, Wellington).

Middleton, D.A.J.; Guard, D. (2021). Summary and evaluation of the electronic monitoring programmes in the SNA 1 trawl and bottom longline fisheries. *New Zealand Fisheries Assessment Report 2021/37*. 69 p

Ministry for Primary Industries (2013) Aquatic Environment and Biodiversity Annual Review 2013. Compiled by the Fisheries Management Science Team, Ministry for Primary Industries, Wellington, New Zealand. 538 p.

Ministry of Fisheries (2008). Harvest Strategy Standard for New Zealand Fisheries. 25 p. Available online at: https://fs.fish.govt.nz/Doc/16543/harveststrategyfinal.pdf.ashx

Morrison, M A; Jones, E G; Consalvey, M; Berkenbusch, K (2014a) Linking marine fisheries species to biogenic habitats in New Zealand: a review and synthesis of knowledge. *New Zealand Aquatic Environment and Biodiversity Report No. 130*. 156 p.

Morrison, M A; Lowe, M L; Parsons, D M; Usmar, N R; McLeod, I M (2009) A review of land-based effects on coastal fisheries and supporting biodiversity in New Zealand. *New Zealand Aquatic Environment and Biodiversity Report No. 37*. 100 p.

Morrison, M A; Lowe, M L; Grant, C M; Smith, P J; Carbines, G; Reed, J; Bury, S J; Brown, J (2014b) Seagrass meadows as biodiversity and productivity hotspots. *New Zealand Aquatic Environment and Biodiversity Report No. 137*. 147 p.

Morrongiello, J. R., Horn, P. L., Ó Maolagáin, C., & Sutton, P. J. (2021). Synergistic effects of harvest and climate drive synchronous somatic growth within key New Zealand fisheries. *Global Change Biology 27(7)*: 1470–1484.

Murphy, H M; Jenkins, G P; Hamer, P A; Swearer, S E (2013) Interannual variation in larval abundance and growth in snapper *Chrysophrys auratus* (Sparidae) is related to prey availability and temperature. *Marine Ecology Progress Series 487*: 151–162.

Parsons, D M; Bian, R; McKenzie, J R; McMahon, S J; Pether, S; Munday, P L (2020) An uncertain future: Effects of ocean acidification and elevated temperature on a New Zealand snapper (Chrysophrys auratus) population. *Marine Environmental Research 161*: 105089.

Parsons, D M; Morrison, M A; MacDiarmid, A B; Stirling, B; Cleaver, P; Smith, I W G; Butcher, M (2009) Risks of shifting baselines highlighted by anecdotal accounts of New Zealand's snapper (*Pagrus auratus*) fishery. *New Zealand Journal of Marine and Freshwater Research 43*: 965–983.

Paul, L J (1976) A study on age, growth and population structure of the snapper, *Chrysophrys auratus* in Hauraki Gulf. *New Zealand Fisheries Research Bulletin No. 13*. 63 p.

Paul, L J (1977) The commercial fishery for snapper *Chrysophrys (Pagrus) auratus* in the Auckland region, New Zealand, from 1900 to 1971. *Fisheries Research Division Bulletin No 15*. 84 p.

Powell, A W B (1937) Animal Communities of the Sea-bottom in Auckland and Manukau Harbours. *Transactions and Proceedings of the Royal Society of New Zealand 66*: 354–401.

Reiss, H; Greenstreet, S P; Sieben, K; Ehrich, S; Piet, G J; Quirijns, F; Robinson, L; Wolff, W J; Kröncke, I (2009) Effects of fishing disturbance on benthic communities and secondary production within an intensively fished area. *Marine Ecology Progress Series 394*: 201–213.

Rice, J (2006) Impacts of Mobile Bottom Gears on Seafloor Habitats, Species, and Communities: A Review and Synthesis of Selected International Reviews. Canadian Science Advisory Secretariat Research Document 2006/057. 35 p. (available from http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2006/RES2006_057_e.pdf).

Richard, Y; Abraham, E R (2013) Risk of commercial fisheries to New Zealand seabird populations. *New Zealand Aquatic Environment and Biodiversity Report No. 109*. 58 p.

Richard, Y; Abraham, E R (2015) Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2012–13. *New Zealand Aquatic Environment and Biodiversity Report No. 162*. 85 p.

Richard, Y; Abraham, E R; Berkenbusch, K (2017) Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2014–15. *New Zealand Aquatic Environment and Biodiversity Report No. 191*. 133 p.

Richard, Y; Abraham, E R; Berkenbusch, K (2020) Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2016–17. *New Zealand Aquatic Environment and Biodiversity Report No. 237*. 57 p

Ritchie, L; Saul, P; O'Sullivan, K. (1975) The wetfish report 1941–1970. *New Zealand Ministry of Agriculture and Fisheries Fisheries Technical Report 137*. 370 p.

Robertson, H A; Baird, K; Dowding J E; Elliott, G P; Hitchmough, R A; Miskelly, C M; McArthur, N; O'Donnell, C F J; Sagar, P M; Scofield, R P; Taylor, G A (2017) Conservation status of New Zealand birds, 2016. *New Zealand Threat Classification Series 19*. Department of Conservation, Wellington. 23 p.

Rowe, S (2009) Level 1 Risk Assessment Methodology for incidental seabird mortality associated with New Zealand fisheries in the NZ EEZ. (Unpublished report to the Seabird Stakeholder Advisory 138 Group (SSAG09.49) held by the Department of Conservation, Wellington.)

Salomon, A K; Shears, N T; Langlois, T J; Babcock, R C (2008) Cascading effects of fishing can alter carbon flow through a temperate coastal ecosystem. *Ecological Applications 18*:1874–1887.

Shears, N T; Babcock, R C (2002) Marine reserves demonstrate top-down control of community structure on temperate reefs. *Oecologia 132*: 131–142.

Stevenson, M L; MacGibbon, D J (2018) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2017 (KAH1703) *New Zealand Fisheries Assessment Report 2018/18*. 92 p.

Sullivan, K J (1985) Snapper. *In:* Colman, J A; McKoy, J L; Baird, G G (Comps. and Eds.) (1985) Background papers for the 1985 Total Allowable Catch recommendations, pp. 187–214. (Unpublished report, held in NIWA library, Wellington.)

Sullivan, K J; Hore, A J; Wilkinson, V H (1988) Snapper. *In:* Baird, G G; McKoy, J L Papers from the workshop to review fish stock assessments for the 1987–88 New Zealand fishing year, pp. 251–275. (Unpublished report, held in NIWA library, Wellington.)

Sylvester, T (1995) Initial results of the Northern boat ramp survey. *Seafood New Zealand*, February 1995. pp. 11–13.

Teirney, L D; Kilner, A R; Millar, R B; Bradford, E; Bell, J D (1997) Estimation of recreational harvests from 1991–92 to 1993–94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished document held by NIWA library, Wellington.)

Thompson, N F; Berkenbusch, K; Abraham, E R (2016) Incidental Capture of Marine mammals in New Zealand trawl fisheries, 1995–96 to 2011–12. *New Zealand Aquatic Environment and Biodiversity Report No. 167*. 78 p.

Thrush, S F; Hewitt, J E; Cummings, V J; Dayton, P K; Cryer, M; Turner, S J; Funnell, G A; Budd, R G; Milburn, C J; Wilkinson M R (1998) Disturbance of the marine benthic habitat by commercial fishing: impacts at the scale of the fishery. *Ecological Applications 8*: 866–879.

Thrush, S F; Schultz, D; Hewitt, J E; Talley, D (2002) Habitat structure in soft-sediment environments and abundance of juvenile snapper *Pagrus auratus*. *Marine Ecology Progress Series 245*: 273–280.

Tuck, I; Cole, R; Devine, J (2009) Ecosystem indicators for New Zealand fisheries. *New Zealand Aquatic Environment and Biodiversity Report No. 42*. 188 p.

Usmar, N R (2012) Ontogenetic diet shifts in snapper (*Pagrus auratus*: Sparidae) within a New Zealand estuary. *New Zealand Journal of Marine and Freshwater Research 46*: 31–46.

Wakefield, C B; Potter, I C; Hall, N G; Lenanton, R C; Hesp, S A (2017) Timing of growth zone formations in otoliths of the snapper, *Chrysophrys auratus*, in subtropical and temperate waters differ and growth follows a parabolic relationship with latitude. *ICES Journal of Marine Science 74(1)*; 180–192.

Wright, P; McClary, D; Boyd, R O (2004) 2000/2001 National Marine Recreational Fishing Survey: direct questioning of fishers compared with reported diary data. Final Research Report for Ministry of Fisheries Project REC2000-01: Objective 2. (Unpublished report held by Fisheries New Zealand, Wellington.)

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24*. 104 p.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.

Zeldis, J R; Oldman, J; Ballara, S L; Richards, L A (2005) Physical fluxes, pelagic ecosystem structure, and larval fish survival in Hauraki Gulf, New Zealand. *Canadian Journal of Fisheries and Aquatic Sciences 62(3)*: 593–610.

Zeldis, J R; Francis, R I C C (1998) A daily egg production method estimate of snapper biomass in Hauraki Gulf, New Zealand. *ICES Journal of Marine Science 55*: 522–534.

SNAPPER (SNA 1)

(*Chrysophrys auratus*)
Tāmure, Kouarea
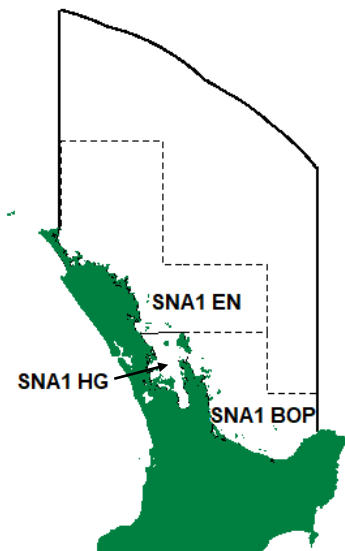
1. FISHERIES SUMMARY

1.1 Commercial fisheries

Table 1 and Table 2 provide a summary by fishing year of the reported commercial catches, TACCs, and TACs for SNA 1. Landings and TACCs are plotted in Figure 1.

Table 1: Reported landings (t) of snapper from SNA 1 from 1931 to 1990.

Year	SNA 1	Year	SNA 1
1931–32	3 355	1957	5 129
1932–33	3 415	1958	5 007
1933–34	3 909	1959	5 607
1934–35	4 317	1960	5 889
1935–36	5 387	1961	5 887
1936–37	6 369	1962	6 502
1937–38	5 665	1963	6 967
1938–39	6 145	1964	7 269
1939–40	5 918	1965	7 991
1940–41	5 100	1966	8 762
1941–42	4 791	1967	9 244
1942–43	4 096	1968	10 328
1943–44	4 456	1969	11 318
1944	4 909	1970	12 127
1945	4 786	1971	12 709
1946	5 150	1972	11 291
1947	5 561	1973	10 450
1948	6 469	1974	8 769
1949	5 655	1975	6 774
1950	4 945	1976	7 743
1951	4 173	1977	7 674
1952	3 665	1978	9 926
1953	3 581	1979	10 273
1954	4 180	1980	7 274
1955	4 323	1981	7 714
1956	4 615	1982	7 089

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. SNA 1 landings are approximations derived from port landing subtotals, as follows: SNA 1, Mangonui to Whakatane.
3. Before 1946 the 'QMA' subtotals sum to less than the New Zealand total because data from the complete set of ports are not available.
4. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings.

SNAPPER (SNA 1)

Table 2: Reported landings (t) of snapper from SNA 1 from 1983–84 to present and gazetted and actual TACCs (t) for 1986–87 to present. QMS data from 1986–present.

Fishstock FMAs	SNA 1 Landings	SNA 1 TACC	Fishstock FMAs	SNA 1 Landings	SNA 1 TACC
1983–84†	6 539	–	2002–03	4 487	4 500
1984–85†	6 898	–	2003–04	4 469	4 500
1985–86†	5 876	–	2004–05	4 641	4 500
1986–87	4 016	4 710	2005–06	4 539	4 500
1987–88	5 038	5 098	2006–07	4 429	4 500
1988–89	5 754	5 614	2007–08	4 548	4 500
1989–90	5 826	5 981	2008–09	4 543	4 500
1990–91	5 273	6 002	2009–10	4 465	4 500
1991–92	6 176	6 010	2010–11	4 516	4 500
1992–93	5 427	4 938	2011–12	4 614	4 500
1993–94	4 847	4 938	2012–13	4 457	4 500
1994–95	4 857	4 938	2013–14	4 459	4 500
1995–96	4 938	4 938	2014–15	4 479	4 500
1996–97	5 047	4 938	2015–16	4 408	4 500
1997–98	4 525	4 500	2016–17	4 620	4 500
1998–99	4 412	4 500	2017–18	4 567	4 500
1999–00	4 509	4 500	2018–19	4 437	4 500
2000–01	4 347	4 500	2019–20	4 462	4 500
2001–02	4 374	4 500	2020–21	4 579	4 500

† FSU data. SNA 1 = Statistical Areas 001–010.
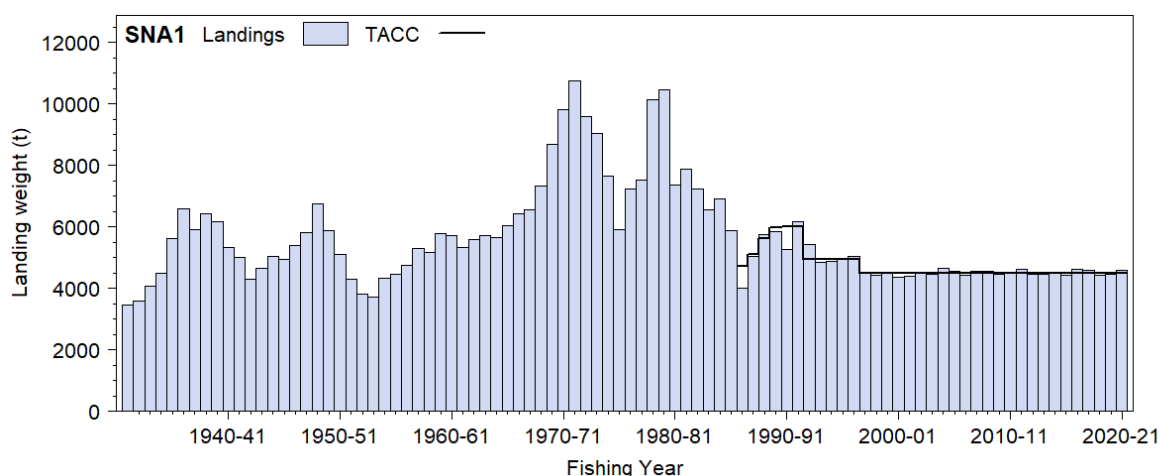
Figure 1: Total reported landings and TACCs for SNA 1.

From 1 October 1997 the TACC for SNA 1 was reduced to 4500 t, within an overall TAC of 7550 t (Table 3). All commercial fisheries have a minimum legal size (MLS) for snapper of 25 cm.

Table 3: TACs, TACCs, and allowances (t) for SNA 1 from 1 October 2021.

Fishstock	TAC	TACC	Customary allowance	Recreational allowance	Other mortality
SNA 1	8 050	4 500	50	3 050	450

Foreign fishing

Japanese catch records and observations made by New Zealand naval vessels indicate that significant quantities of snapper were taken from New Zealand waters by Japanese vessels from the late 1950s until 1977. There are insufficient data to quantify historical Japanese catch tonnages for the respective snapper stocks. However, trawl catches have been reported by area from 1967 to 1977, and longline catches from 1975 to 1977 (Table 4). These data were supplied to the Fisheries Research Division of MAF in the late 1970s; however, the data series is incomplete, particularly for longline catches.

Table 4: Reported landings (t) of snapper, and harvest within SNA 1 from 1967 to 1977 by Japanese trawl and longline fisheries.

Year	(a) Trawl	Trawl catch (all species)	Total snapper trawl catch	SNA 1
1967		3092	30	NA
1968		19 721	562	1
1969		25 997	1 289	–
1970		31 789	676	2
1971		42 212	522	5
1972		49 133	1 444	1
1973		45 601	616	–
1974		52 275	472	–
1975		55 288	922	26
1976		133 400	970	NA
1977		214 900	856	NA

Year	(b) Longline	Total Snapper	SNA 1
1975		1 510	761
1976		2 057	930
1977		2 208	1 104

1.2 Recreational fisheries

The snapper fishery is the largest recreational fishery in New Zealand. It is the major target species on the northeast and northwest coasts of the North Island and is targeted seasonally around the rest of the North Island and the top of the South Island. The current allowance within the SNA 1 TAC is shown in Table 3.

1.2.1 Management controls

The two main methods used to manage recreational harvests of snapper are minimum legal size limits (MLS) and daily bag limits. Both have changed over time (Table 5). The number of hooks permitted on a recreational longline was reduced from 50 to 25 in 1995.

Table 5: Changes to minimum legal size limits (MLS) and daily bag limits used to manage recreational harvesting levels in SNA 1.

Stock	MLS (cm)	Bag limit (no. fish)	Introduced
SNA 1	25	30	01/01/1985
SNA 1	25	20	30/09/1993
SNA 1	27	15	01/10/1994
SNA 1	27	9	13/10/1995
SNA 1	30	7	01/04/2014

1.2.2 Estimates of recreational harvest

A background to the estimation on recreational harvest of snapper is provided in the Introduction – Snapper chapter.

The recreational catch history for SNA 1 is poorly known. Aerial-access survey harvest estimates are available for the Hauraki Gulf in 2003–04 (Hartill et al 2007b) and for all three regions of SNA 1 in 2004–05 (Hartill et al 2007a), in 2011–12 (Hartill et al 2013) and in 2017–18 (Hartill et al 2019). Recreational harvest estimates for all three regions of SNA 1 are also available from national panel surveys undertaken in 2011–12 and 2017–18 (Wynne-Jones et al 2014, 2019), which were of a broadly similar magnitude to those provided by the concurrent aerial-access survey (Table 6).

1.2.3 Monitoring harvest

In addition to estimating absolute harvests, a system to provide relative estimates of harvest over time for key fishstocks has been designed and implemented for some key recreational fisheries. The system uses web cameras to continuously monitor trends in trailer boat traffic at key boat ramps. This monitoring is complemented by creel surveys that provide estimates of the proportion of observed boats that were used for fishing, and of the average harvest of snapper and kahawai per boat trip. These data are combined to provide relative harvest estimates for SNA 1.

Table 6: Recreational catch estimates for SNA 1. Totals for a stock are given in bold. The telephone/diary surveys ran from December to November but are denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey catch estimates). Numbers and mean weights are not calculated in the tag ratio method. Includes charter boat catch and panel survey estimates of s111 catches.

Stock	Year	Method	Number of fish (thousands)	Mean weight (g)	Total weight (t)	CV
East Northland	1985	Tag ratio	–	–	370	–
Hauraki Gulf	1985	Tag ratio	–	–	830	–
Bay of Plenty	1984	Tag ratio	–	–	400	–
Total	1985*	Tag ratio	–	–	**1 600**	–
Total	1994	Telephone/diary	3 804	871	**2 857**	–
East Northland	1996	Telephone/diary	684	1 039	711	–
Hauraki Gulf/BoP	1996	Telephone/diary	1 852	870	1 611	–
Total	1996	Telephone/diary	2 540	915	**2 324**	–
East Northland	2000	Telephone/diary	1 457	1 154	1 681	–
Hauraki Gulf	2000	Telephone/diary	3 173	830	2 632	–
Bay of Plenty	2000	Telephone/diary	2 274	872	1 984	–
Total	2000	Telephone/diary	6 904	904	**6 242**	–
East Northland	2001	Telephone/diary	1 446	–†	1 669	–
Hauraki Gulf	2001	Telephone/diary	4 225	–†	3 507	–
Bay of Plenty	2001	Telephone/diary	1 791	–†	1 562	–
Total	2001	Telephone/diary	7 462	–†	**6 738**	–
Hauraki Gulf	2003–04	Aerial-access	–	–	1 334	0.09
East Northland	2004–05	Aerial-access	–	–	557	0.13
Hauraki Gulf	2004–05	Aerial-access	–	–	1 345	0.10
Bay of Plenty	2004–05	Aerial-access	–	–	516	0.10
Total	2004–05	Aerial-access	–	–	**2 419**	**0.06**
East Northland	2011–12	Aerial-access	–	–	718	0.14
Hauraki Gulf	2011–12	Aerial-access	–	–	2490	0.08
Bay of Plenty	2011–12	Aerial-access	–	–	546	0.12
Total	2011–12	Aerial-access	–	–	**3 754**	**0.06**
East Northland	2011–12	Panel survey	718	1 266	909	0.12
Hauraki Gulf	2011–12	Panel survey	2 350	1 022 / 987‡	2 381	0.11
Bay of Plenty	2011–12	Panel survey	714	956 /1 003‡	691	0.12
Total	2011–12	Panel survey	3 884	1 025	**3 981**	**0.08**
East Northland	2017–18	Aerial-access	–	–	720	0.10
Hauraki Gulf	2017–18	Aerial-access	–	–	2 068	0.07
Bay of Plenty	2017–18	Aerial-access	–	–	680	0.10
Total	2017–18	Aerial-access	–	–	**3 467**	**0.05**
East Northland	2017–18	Panel survey	587	1 351	793	0.10
Hauraki Gulf	2017–18	Panel survey	1 443	1 162/1 189	1 684	0.10
Bay of Plenty	2017–18	Panel survey	571	1 116/1 205	650	0.12
Total	2017–18	Panel survey	2 601	1 202	**3 127**	**0.07**

* The Bay of Plenty programme was carried out in 1984 but is included in the 1985 total estimate.

† The 2000 mean weights were used in the 2001 estimates.

‡ Separate mean weight estimates were used for summer (1 October 2011 to 30 April 2012) and for winter (1 May to 30 September 2012).

Trends inferred from this monitoring programme were initially very similar to that inferred from aerial-access harvest estimates in the Hauraki Gulf in 2004–05, 2006–07, and 2011–12, but the camera/creel snapper harvest estimate for the Hauraki Gulf in 2017–18 is substantially lower than concurrent aerial-access and national panel surveys estimates for the same year (Table 6a cf. Table 6). This difference appears to be due to a recent substantial increase in recreational fishing effort and catch around expanding mussel farms in the Firth of Thames, coinciding with a lesser increase in effort in the north-western Hauraki Gulf. Additional creel survey monitoring has been initiated to monitor changes in the recreational fishery in these areas, which had not been adequately monitored from boat ramps in the Auckland metropolitan area up until 2019–20. These estimates show that the recreational snapper harvest varies substantially more than would be expected if catches were related only to stock abundance; this suggests that changes in localised availability to recreational fishers can also have a marked effect on the recreational harvest. Web camera monitoring is continuing, and the coverage is being progressively extended to other FMAs.

Table 6a: Recreational catch estimates (t) for snapper in different parts of the SNA 1 stock area calculated from web camera and creel monitoring at key ramps and scaled to aerial-access estimates for each area in 2004–05 and 2006–07 (Hauraki Gulf only) and 2011–12 and 2017–18 (all areas within SNA 1).

Year	East Northland	CV	Hauraki Gulf	CV	Bay of Plenty	CV	Total SNA 1	CV
2004–05	612	0.12	1 196	0.10	646	0.11	2 454	0.07
2006–07	–	–	1 272	0.16	–	–	–	–
2011–12	669	0.10	2 818	0.09	544	0.14	4 031	0.07
2012–13	525	0.11	1 232	0.11	241	0.16	1 099	0.08
2013–14	433	0.11	583	0.16	179	0.18	1 196	0.09
2014–15	414	0.12	448	0.14	182	0.25	1 044	0.09
2015–16	519	0.12	375	0.16	133	0.17	1 027	0.09
2016–17	551	0.11	398	0.15	277	0.19	1 227	0.08
2017–18	703	0.12	1 038	0.16	545	0.15	2 286	0.09
2018–19	774	0.10	1 070	0.14	280	0.13	2 125	0.08
2019–20	466	0.13	551	0.18	191	0.19	1 208	0.10
2020–21	667	0.13	498	0.17	297	0.23	1 462	0.10

The boat ramp interview data provided by this monitoring programme, and other previous boat ramp surveys, was used to model reconstructed regional catch histories for updated SNA 1 stock assessment model in 2022, which extended back as far as 1899–1900. The zero-inflated negative binomial (ZINB) generalised linear modelling approach used provides a more comprehensive reconstruction of past recreational catches because it uses data that are available from a far greater number of ramps than those surveyed as part of the web camera/creel survey monitoring programme, as far back as 2001. These ZINB models can be used to predict the number of snapper landed hourly at each surveyed ramp, including those hours when interviewing did not take place. Environmental covariates (wind speed and tidal state) and temporal factors (fishing year, month, and day type) were offered as explanatory variables to separate regional ZINB models. Hourly catch predictions from the ZINB models were then summed across the ramps surveyed in each region, to derive an index of the number of snapper landed annually at each surveyed access point. Annual mean fish weight estimates were then used to convert these annual estimates of the number of snapper landed at the surveyed ramps, into annual tonnage estimates.

Because only a subset of the access points in each region were surveyed, the resulting annual catch weight indices only provided a relative recreational snapper catch index, which was assumed would represent that landed at the other unsurveyed access points in each region. Each regional catch weight index was therefore scaled up to the corresponding geometric mean of the aerial-access estimates of the total harvest landed in each region, in 2004–05, 2011–12, and 2017–18, to account for the harvest tonnage landed throughout the region. Regional harvest back to 1900 from 1999 to 2000 was derived by interpolating from the ZINB model derived 1999–2000 point estimates to 'assumed' 1900 catch levels of 75 t for both East Northland and the Bay of Plenty, and 150 t for the Hauraki Gulf (Figure 2).

1.3 Customary non-commercial fisheries
Snapper form important fisheries for customary non-commercial, but the annual catch is not known. The information on Māori customary harvest under the provisions made for customary fishing is limited and it is likely that Māori customary fishers utilise the provisions under recreational fishing regulations.

1.4 Illegal catch
No new information is available to estimate illegal catch. For modelling SNA 1 an assumption was made that non-reporting of catch was 20% of reported domestic commercial catch prior to 1986 and 10% of reported domestic commercial catch since the QMS was introduced. This was to account for all forms of under-reporting. These proportions were based on the black-market trade in snapper and higher levels of under-reporting (to avoid tax) that existed prior to the introduction of the QMS. The 10% under-reporting post-QMS accounts for the practice of 'weighing light' and the discarding of legal-size snapper.
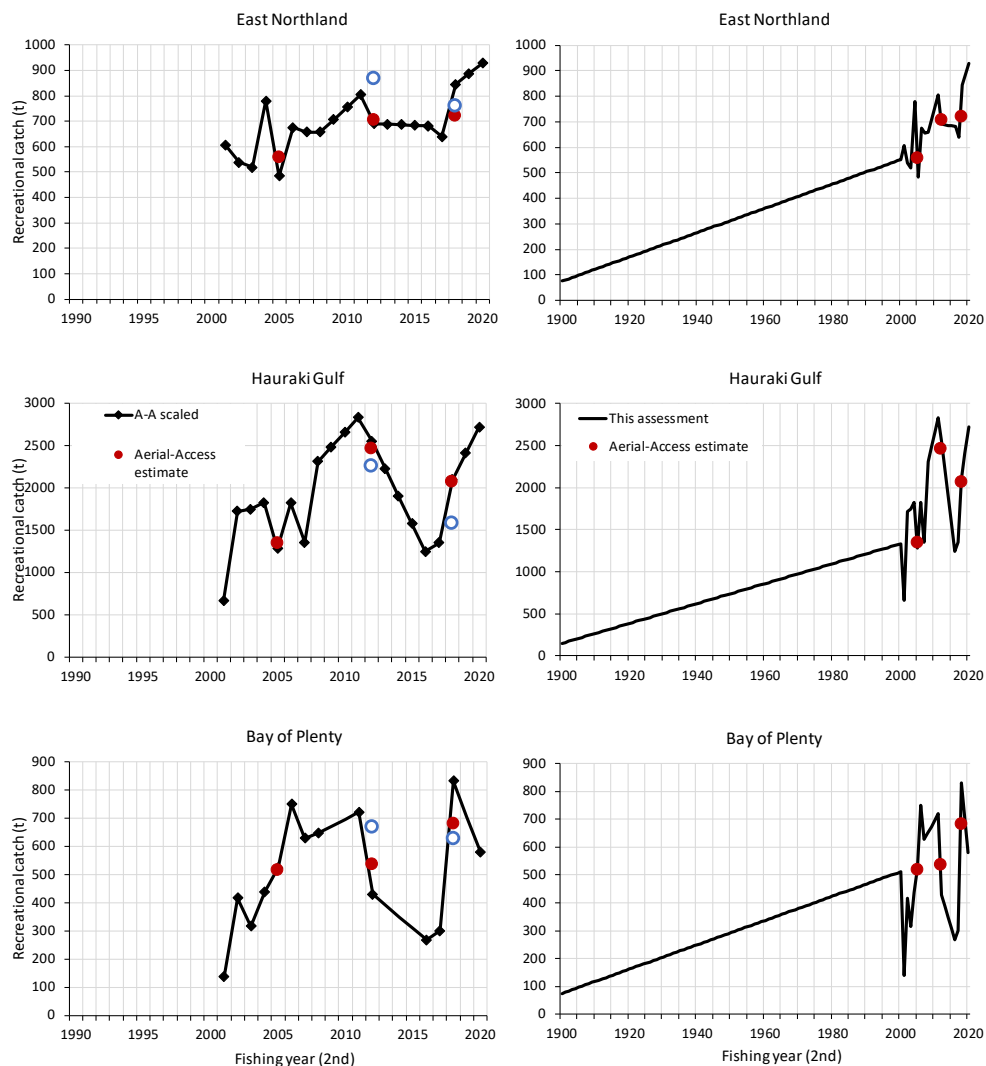
Figure 2: Regional recreational catch histories for SNA 1 based on zero inflated negative binomial modelling of creel survey landings data (snapper landed per complete creel survey hour). The relative harvest indices generated from regional model predictions were scaled up by regional harvest estimates provided by aerial-access surveys of SNA 1 in 2004–05, 2011–12, and 2017–18, to account for the catch landed by all recreational fishers at all access points including those which had not been surveyed since 2000–01 (left panels). These regional catch histories were then ramped back to nominal assumed recreational catch levels in 1900–01 (right panels).

1.5 Other sources of mortality

No estimates are available regarding the amount of other sources of mortality on snapper stocks; although high-grading of longline fish and discarding of under-sized fish by all methods occurs. An at-sea study of SNA 1 commercial longline fisheries in 1997 (McKenzie 2000) found that 6–10% of snapper caught by number were under 25 cm (MLS). Results from a holding net study indicate that mortality levels amongst lip-hooked snapper caught shallower than 35 m were low.

Estimates for incidental mortality were based on other catch-at-sea data using an age-length structure model for longline, trawl, seine, and recreational fisheries. In SNA 1, estimates of incidental mortality for the year 2000 from longlines were less than 3% and for trawl, seine, and recreational fisheries between 7% and 11% (Millar et al 2001). In SNA 8, estimates of trawl and recreational incidental mortality were lower, mainly because of low numbers of 2- and 3-year old fish estimated in 2000.

In SNA 1, recreational fishers release a high proportion of their snapper catch, most of which was less than 30 cm (recreational MLS). An at-sea study in 2006–07 recorded snapper release rates of 54.2% of the catch by trailer boat fishers and 60.1% of the catch on charter boats (Holdsworth & Boyd 2008). Incidental mortality estimated from condition at release was 2.7% to 8.2% of total catch by weight depending on assumptions used.

With the introduction of Electronic Reporting in 2019, commercial fishers must provide comprehensive reporting of all discards and returns. All fish under the minimum legal size ("sub-MLS fish") must now be returned to the sea; in SNA 1 reported quantities of sub-MLS snapper have been small (~40 t in 2020 and 2021 [i.e., < 1% of total annual commercial SNA 1 landed catch weight]).

2. BIOLOGY

For further information on snapper biology refer to the Introduction – Snapper chapter. A summary of published estimates of biological parameters for SNA 1 is presented in Table 7.

Table 7: Estimates of biological parameters.

Fishstock	Estimate		Source
1. Instantaneous rate of natural mortality (M)			
SNA 1, 2, 7, & 8	0.075		Hilborn & Starr (unpub. analysis)
2. Weight = a(length)^b (Weight in g, length in cm fork length)			
All	$a = 0.0447$	$b = 2.793$	Paul (1976)
East Northland	$a = 0.0349$	$b = 2.870$	
Hauraki Gulf	$a = 0.0494$	$b = 2.771$	Walsh et al (in press)
Bay of Plenty	$a = 0.0430$	$b = 2.813$	
3. von Bertalanffy growth parameters			

		Both sexes combined		
	K	t_0	L_∞	
SNA 1	0.102	-1.11	58.8	Gilbert & Sullivan (1994)

4. Age-at-recruitment (years)		
SNA 1*	4 (39%) 5 (100%)	Gilbert et al (2000)

* For years when not estimated.

3. STOCKS AND AREAS

New Zealand snapper are thought to comprise either seven or eight biological stocks based on: the location of spawning and nursery grounds; differences in growth rates, age structure, and recruitment strength; and the results of tagging studies. Three stocks are in SNA 1 (East Northland, Hauraki Gulf, and Bay of Plenty (BoP)), two in SNA 2 (one of which may be associated with the BoP stock), two in SNA 7 (Marlborough Sounds and Tasman Bay/Golden Bay) and one in SNA 8. Tagging studies reveal that limited mixing occurs between the three SNA 1 biological stocks, with greatest exchange between BoP and Hauraki Gulf.

4. STOCK ASSESSMENT

An assessment of SNA 1 was conducted in 2013, following a preliminary assessment undertaken in 2012. Another preliminary stock assessment carried out in 2022 was primarily focused on updating the 2013 assessment, including maintaining its basic structure and most of the assumptions. Although this preliminary assessment still required more work to provide appropriate management advice (see section 4.9 below), it was hoped that this work would provide insight on the progress of the SNA 1 stock since 2013 in terms of its status relative to current management targets.

SNA 1 (Auckland East)

4.1 Model structure
The model used for the 2013 assessment was written using CASAL (Bull et al 2012) and is a development of the three-stock, three-area model used in the 2012 assessment (Francis & McKenzie 2015a). The 2012 assessment was given a quality ranking of '2' due to lack of convergence of

MCMCs and poor estimates of the extent of depletion in 1970. These problems were largely resolved in the 2013 assessment.

The 2013 assessment model covered the time period from 1900 to 2013 (i.e., fishing years 1899–1900 to 2011–12, with two time steps in each year (Table 8).

The assessment explicitly modelled the movement of fish between areas and assumed a Home Fidelity (HF) movement dynamic. Under the HF movement, fish spawn in their home area and some move to other areas at other times of the year where they are subject to fishing. There were two sets of migrations: in time step 1, all fish returned to their home (i.e., spawning) area just before spawning; and in time step 2, some fish moved away from their home area into another area. This second migration may be characterised by a 3×3 matrix, in which the ijth element, p_{ij}, is the proportion of fish from the ith area that migrate to the jth area.

The model partitions the modelled population by age (ages 1–20, where the last age was a plus group), stock (three stocks, corresponding to the parts of the population that spawn in each of three subareas of SNA 1), area (the three subareas), and tag status (grouping fish into six categories—one for untagged fish, and one each for each of five tag release episodes). That is, at any point in time, each fish in the modelled population would be associated with one cell in a $20 \times 3 \times 3 \times 6$ array, depending on its age, the stock it belonged to, the area it was currently in, and its tag status at that time. To avoid confusion about areas and stocks, two-letter abbreviations (EN, HG, BP) are used for areas, and longer abbreviations (ENLD, HAGU, BOP) to denote stocks. As with previous snapper models (e.g., Gilbert et al 2000), this model did not distinguish fish by sex.

Table 8: Annual model time steps and the processes and observations used in each time step. Note that the home area for a fish is where it spawns (and was recruited). Each year some fish migrate away from their home ground (in step 2) and then return home in step 1 of the following year.

Time step	Model processes (in temporal order)	Observations†‡
1	age incrementation, migration to home area, recruitment, spawning, tag release	
2	migration from home area, natural and fishing mortality*	biomass, length and age compositions, tag recapture

* Fishing mortality was applied after half the natural mortality.
† The tagging biomass estimate was assumed to occur immediately before the mortality; all other observations occurred half-way through the mortality.
‡ See Table 9 for more details of all observations.

A total of 168 parameters were estimated in the base model (Table 9). The six migration parameters define the 3×3 migration matrix described above (there are only six parameters because the proportions in each row of the matrix must sum to 1). Selectivities were assumed to be age-based and double normal, and to depend on fishing method but not on area. Three selectivities were estimated for commercial fishing (for longline, single trawl, and Danish seine), one for the (single trawl) research surveys, and two for recreational fisheries (for before and after a change in recreation size limit in 1995). All priors on estimated parameters were uninformative except for the usual lognormal prior on year class strengths (with coefficient of variation (CV) of 0.6).

Table 9: Details of parameters that were estimated in the model*.

Type	Description	No. of parameters	Prior
R_0	Mean unfished recruitment for each stock	3	uniform-log
YCS	Year class strengths by year and stock	1 361	lognormal†
Migration	Proportions migrating from home grounds	6	uniform
Selectivity	Proportion selected by age by a survey or fishing method	18	uniform
q	Catchability (for relative biomass observations)	$^5/_{168}$	uniform-log

* In the MPD run, YCSs were estimated for years 1966–2007 for ENLD, 1951–2007 for HAGU, and 1971–2001 for BOP; in the MCMC run the most recent years, 2008–2012, were also estimated.
† With mean 1 and coefficient of variation 0.6.

Year class strengths were estimated as free parameters but only for years where there was at least one observation of catch-at-age. The YCS estimation period in the model was also the period over which

the R_0 parameter was also estimated. YCS estimation conformed to the Haist parameterisation in which the mean of the YCSs is constrained to 1 (Bull et al 2012). For years where YCS could not be estimated as free parameters, YCS was set to 1.

Some parameters were fixed, either because they were not able to be estimated with the available data (notably natural mortality and stock-recruit steepness were fixed at values determined by the Working Group), or because they were estimated outside the model (Table 10). As in 2012, mean length-at-age was specified by yearly values (rather than a von Bertalanffy curve) because these values showed a strong trend for the older ages. Data were available for 1994–2010 for ENLD, and for 1990–2010 for HAGU and BOP. In each stock, mean lengths for earlier years were set to the average values over these years, and for later years (including projections) to the 2006–2010 average.

Table 10: Details of parameters that were fixed in the model.

Natural mortality	0.075 y^{-1}
Stock-recruit steepness (Beverton & Holt)	0.85
Tag shedding (instantaneous rate, 1985 tagging)	0.486 y^{-1}
Tag detection (1985 and 1994 tagging)	0.85
Proportion mature	0 for ages 1–3, 0.5 for age 4, 1 for ages > 4
Length-weight [mean weight (kg) = a (length (cm))^b]	$a = 4.467 \times 10^{-5}, b = 2.793$
Mean length-at-age	provided for years 1990–2010*
Coefficients of variation for length-at-age	0.10 at age 1, 0.20 at age 20
Pair trawl selectivity	$a_1 = 6 \text{ y}, \sigma_L = 1.5 \text{ y}, \sigma_R = 30 \text{ y}$

* See text for further details.

The most important change from the model used in the 2012 assessment was that the catch history was revised and extended back to 1900, and it was assumed that each stock was at its unfished level (B_0) in 1900. Two other changes of consequence affected the tag-recapture data sets that were 'condensed' (i.e., the number of length classes in each data set was substantially decreased by combining adjacent length classes until each remaining length class contained at least 5 observed recaptures) and iteratively reweighted, together with the composition data sets (for details see Francis & McKenzie 2015b). Other minor changes included dropping small fisheries (prorating their catches over the remaining fisheries in the same area) and removing priors on recreational selectivities.

Five types of observations were used in the base stock assessment (Table 11). These were the same as in the 2012 assessment (Francis & McKenzie 2015a) except for the addition of 2012 data points for each of the CPUE time series and the recreational length compositions.

Table 11: Details of observations used in the stock assessment model. [Continued on next page]

Type	Likelihood	Area*	Source	Range of years	No. of years
Absolute biomass	Lognormal	BOP	1983 tagging	1983	1
Relative biomass	Lognormal	BOP	longline	1990–2011	22
		ENLD	longline	1990–2011	22
		HAGU	longline	1990–2011	22
		BOP	single trawl	1996–2011	16
		HAGU	research survey	1983–2001	13

Type	Likelihood	Area*	Source	Range of years	No. of years
Age composition	Multinomial	HAGU	longline	1985–2010	22
		BOP	longline	1990–2010	19
		ENLD	longline	1985–2010	18
		HAGU	Danish seine	1970–1996	11
		HAGU	research survey	1985–2001	10
		HAGU	single trawl	1975–1994	6
		BOP	single trawl	1990–1995	4
		BOP	research survey	1990–1996	3
		ENLD	research survey	1990	1
		BOP	Danish seine	1995	1
Length composition		BOP	recreational fishing	1991–2012†	14
		ENLD	recreational fishing	1991–2012†	14
		HAGU	recreational fishing	1991–2012†	14

Table 11 [continued]

Type	Likelihood	Area tagged*	Year tagged	Areas recaptured*	Years
Tag recapture	Binomials	ENLD	1983	ENLD, HAGU	1984, 1985
		HAGU	1983	ENLD, HAGU	1984, 1985
		ENLD	1993	ENLD, HAGU, BOP	1994, 1995
		HAGU	1993	ENLD, HAGU, BOP	1994, 1995
		BOP	1993	ENLD, HAGU, BOP	1994, 1995

* Areas are East Northland (ENLD), Hauraki Gulf (HAGU), and Bay of Plenty (BOP).
† All length composition data sets were split into pre-1995 (2 years) and post-1995 (11 years) because recreational selectivity was assumed to change in 1995.

Data weighting

The approach to data weighting followed the methods of Francis (2011) except that a new method was used to weight the tag-recapture data (not discussed by Francis 2011) via the dispersion parameter (for details see Francis & McKenzie 2015b). The CVs on the various abundance data sets were defined *a priori* to be consistent with the most 'plausible' fit the model was expected to achieve to the data (as agreed by the Working Group).

4.2 Catch History

Recreational catch

Direct estimates of annual recreational harvest from the three areas of SNA 1(East Northland, Hauraki Gulf, and Bay of Plenty) are available from aerial-access surveys conducted in 2004–05 and 2011–12 (Table 6) (Hartill et al 2007a, Fisheries New Zealand unpublished data).

The recreational catch history used in the previous 2012 stock assessment for SNA 1 was based on commercial longline CPUE indices (1990 to 2011) scaled to the 2004–05 aerial-access estimates for each area of SNA 1. In 2012 the Working Group decided that commercial longline CPUE indices should not be used to inform recreational catch histories because the 2011–12 aerial-access harvest estimates were well above those predicted by the longline CPUE based approach used in 2012, particularly for the Hauraki Gulf. Instead, the Working Group decided that an alternative creel survey based recreational kilogram per trip index provided a more realistic means of interpolating between the 2004–05 and 2011–12 aerial-access harvest estimates, in all three areas of SNA 1. Recreational kilogram per trip data are available for many of the years since 1991, especially since 2001, and these data explicitly take into account the 1995 changes to the recreational MLS and bag limits. These indices are based on creel survey data collected between January and April only. The geometric mean of the recreational kilogram per trip index over the period 2004–05 to 2011–12 was used to scale this index up to the level of the geometric mean of the two aerial-access harvest estimates. Exponential curves fitted to the recreational kilogram per trip index were used to provide interpolated catch estimates for years between 1990 and 2012 where no year index was available (Figure 3). The recreational harvest in 1970 was assumed to be 70% of the 1989–90 estimates in each area, with a linear increase in annual catch across the intervening years (Figure 3).

By choosing to scale recreational catch to the relative CPUE between years and scaling these estimates to the geometric mean of the two aerial surveys, the Working Group implicitly assumed that effort has remained constant throughout the period 1990–2012. Because recreational catch increased more rapidly than the BLL CPUE from 2007, the model estimated an increasing recreational exploitation rate to match the input catches. Increasing exploitation rates with fixed effort can only be resolved if recreational catchability also increased. The Working Group agreed that this was plausible even though relative recreational catchability must have increased by about 50% to account for the increased recreational catch estimates between 2005 and 2012. Projections also require the additional assumption that relative recreational catchability will remain at the values that were associated with the projected exploitation rate. The Working Group agreed to test the sensitivity of the projections to the catchability assumption by projecting forward using high and low recreational exploitation rate estimates: a) from 2013, the final model year, and b) from the average 1995–2005 exploitation rate, a period of relatively constant recreational catch incorporating the 2005 aerial catch estimate.

Recreational catch histories for each area for the period 1900 to 1970 were based on the average of two expert opinions of the harvest in 1900, provided by two regular members of the Marine Amateur

Fisheries Working Group. This averaged estimate was used to generate a linearly increasing recreational catch history for the period 1900 to 1970 (Figure 4).

The customary harvest is not known, and no additional allowance is made beyond the recreational catch.
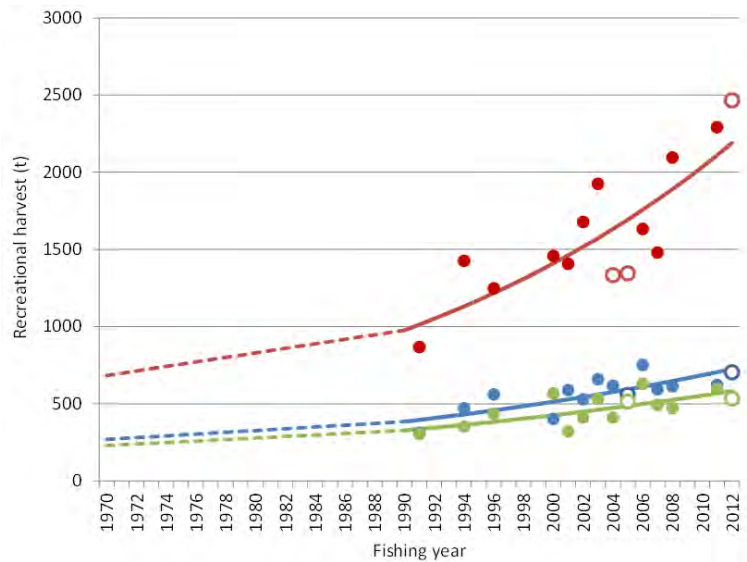
Figure 3: Recreational catch histories for the three areas of SNA 1 (Hauraki Gulf in red, East Northland in blue, and the Bay of Plenty in green). Open circles denote aerial-access survey estimates, closed circles denote recreational kilogram per trip indices scaled to the geometric mean of the aerial-access estimates, solid curved lines denote exponential fits to the scaled kilogram per trip indices which were used to predict harvests for those years for which creel survey data were not available, and dashed lines denote linear interpolations between 1990 and 1970 (when harvests were assumed to be at 70% of that predicted for 1990).
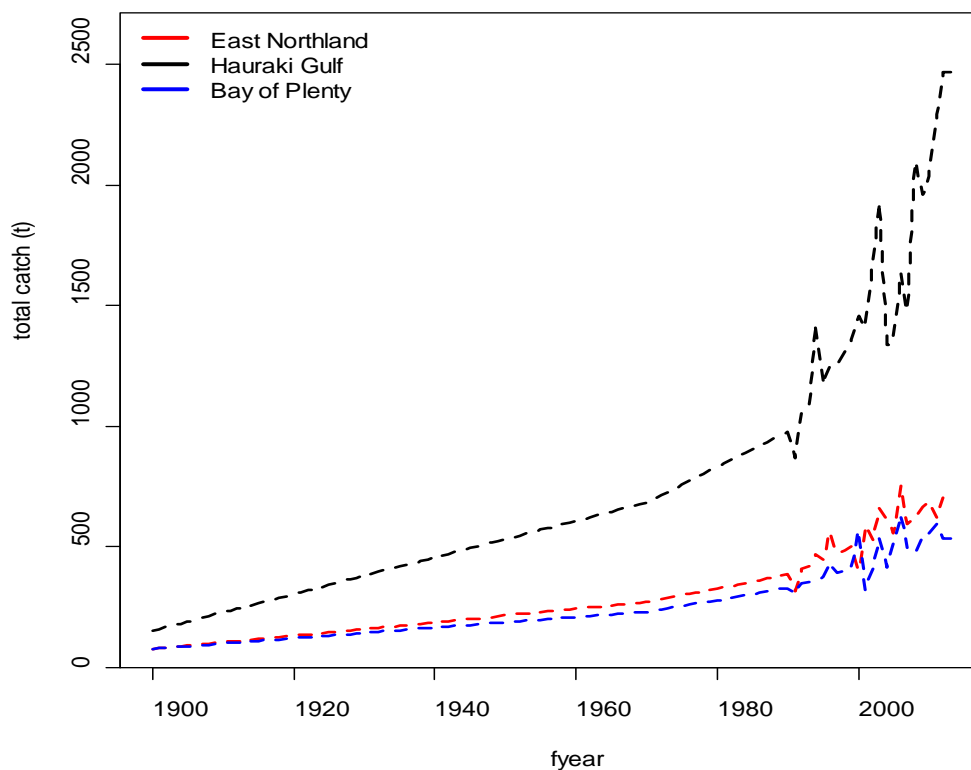
Figure 4: Assumed and derived recreational catch histories for the period 1900 to 2013 that were used in the 2013 SNA 1 assessment model.

Commercial catch

The SNA 1 commercial catch histories for the various method area fisheries after 1989–90 were derived from the catch and effort reporting database (warehou); catches for method and area between 1981–82 and 1989–90 were constructed on the basis of data contained in archived Fisheries New Zealand databases.

Commercial catch histories for the period 1915 to 1982 were derived from two sources as follows:

- 1915–73: Annual Reports on Fisheries, compiled by the Marine Department to 1971 and the Ministry of Agriculture and Fisheries to 1973 as a component of their Annual Reports to Parliament published as Appendices to the Journal of the House of Representatives. From 1931 to 1943 inclusive, data were tabulated by April–March years; these were equated with the main calendar year (e.g., 1931–32 landings are treated as being from 1931). From 1944 onwards, data were tabulated by calendar year.
- 1974–82: Ministry of Agriculture and Fisheries, Fisheries Statistics Unit (FSU) calendar year records published by King (1985). The available data grouped catches for all species comprising less than 1% of the port totals as "Minor species". An FSU hardcopy printout dated 23 March 1984 held by NIWA was used to provide species-specific catches in these cases (although this had little effect for snapper given that it is typically a major species in SNA 1 ports).

No commercial catch records are available prior to 1915; therefore, for the purposes of the current assessment the 1915 catch totals were applied back to 1900.

The only information available on the spatial distribution of SNA 1 landings before 1983 comes from "The Wetfish Report" (Ritchie et al 1975) in which snapper landings for old statistical areas were provided by year and month for the period 1960–1970. The boundaries of the old Statistical Areas 2, 3, and 4 are similar to those for the East Northland, Hauraki Gulf, and Bay of Plenty sub-stocks. However, Area 4 is smaller than the Bay of Plenty sub-stock, whereas Area 2 is larger than East Northland, and Area 3 is larger than Hauraki Gulf. Nevertheless, the match between old statistical areas and sub-stock boundaries is likely to be close enough to use the catch split from "The Wetfish Report" to apportion SNA 1 landings among sub-stocks. The percentage split by statistical area varied little over the 11-year period 1960–70:

Area 2: 17–20% (mean 19%)
Area 3: 54–59% (mean 56%)
Area 4: 22–29% (mean 25%).

The mean percentages for Areas 2, 3, and 4 were used to apportion 1960–70 SNA 1 landings among East Northland, Hauraki Gulf, and Bay of Plenty, respectively. In the absence of any information on the spatial distribution of catches before 1960, the same percentages were applied to SNA 1 landings for 1900–1959.

The historical SNA 1 commercial catch time series was divided into four method fisheries: longline (BLL), single bottom trawl (BT), pair bottom trawl (BPT), and Danish seine (DS). Catches from 'other' commercial methods (predominantly set net) were not explicitly modelled but the catch totals were prorated across the fisheries in the same area. Information on specific catching methods becomes increasing less reliable prior to 1973 so the area catch method splits from the early 1970s were applied back to 1900.

As was done for the 2000 and 2012 assessments, commercial catch totals prior to the 1986 QMS year were adjusted upwards to account for an assumed 20% level of under-reporting. Catch totals post QMS were likewise scaled assuming 10% under-reporting (Figures 5 and 6).

Estimation of foreign commercial landings

In the 1997–98 SNA 1 assessment (Davies 1999), the foreign (Japanese longline) catch was assumed to have occurred between 1960 and 1977, with cumulative total removals over the period at three alternative levels: 20 000 t, 30 000 t, and 50 000 t. The assumed pattern of catches increased linearly to a peak in 1968 then declined linearly to 1977; the catch was split evenly between East Northland

and the Hauraki Gulf/Bay of Plenty. For the 2013 assessment, the base case level of total foreign catch for the period between 1960 and 1977 was assumed to be 30 000 t, catch apportioned among the three sub-stocks in the ratio 50% East Northland, 10% Hauraki Gulf, and 40% Bay of Plenty and added to the domestic longline method totals.
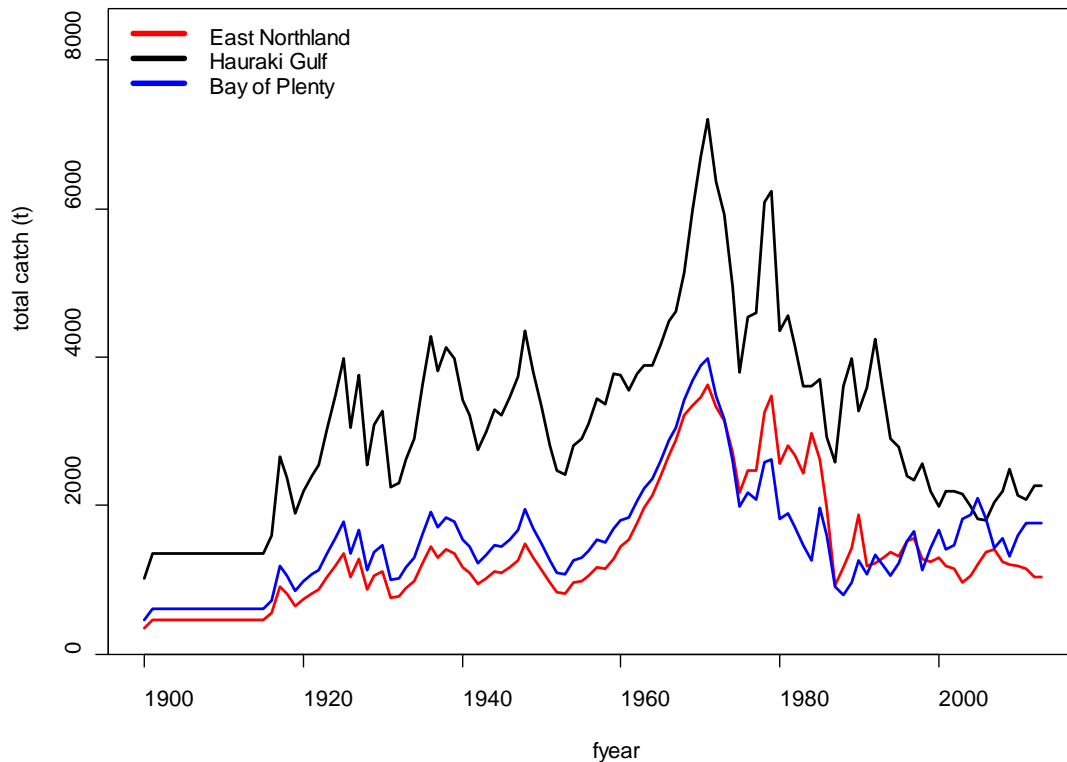

Figure 5: Commercial catch histories by area (adjusted for under-reporting) plus foreign catch used as input to the 2013 SNA 1 assessment model.
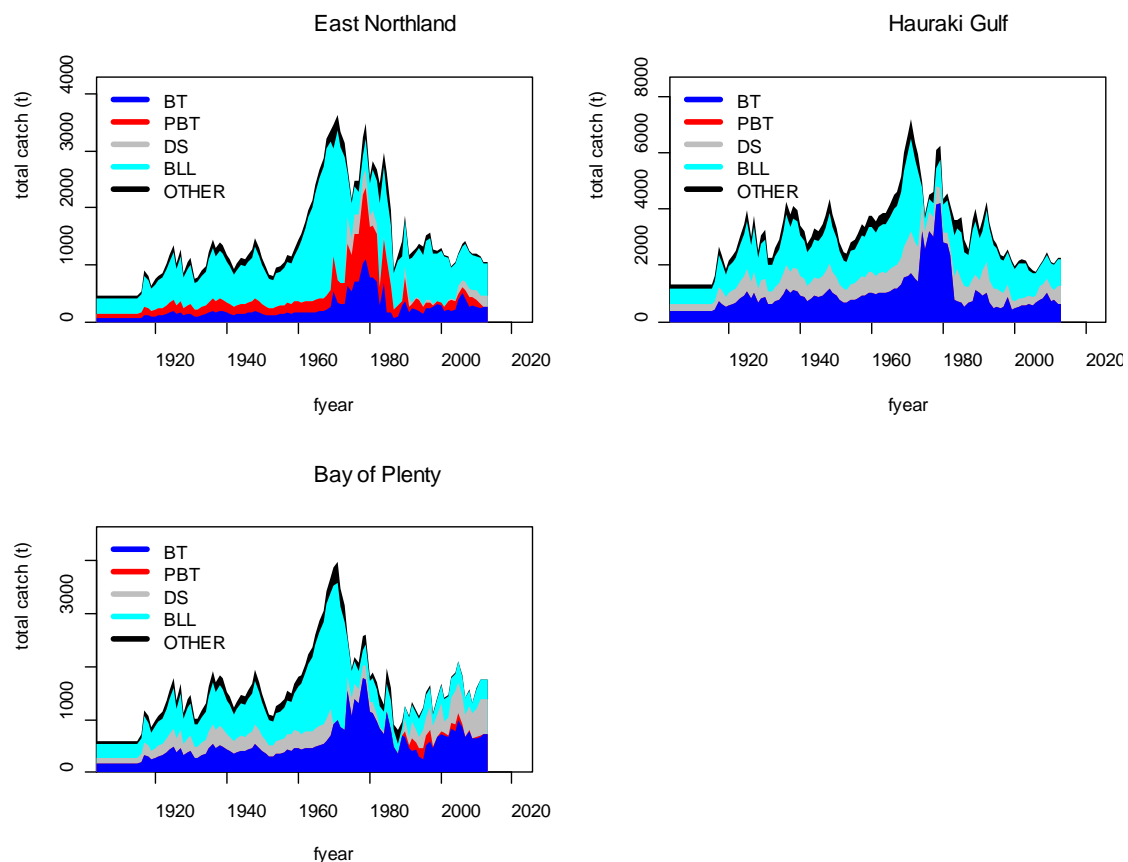

Figure 6: Commercial catch histories by method and area (adjusted for under-reporting) used as input to the 2013 SNA 1 assessment model.

4.3 Abundance indices

Trawl surveys

Trawl surveys were carried out in all three areas between the mid-1980s and 2000. Unfortunately, the only area for which a viable series of abundance estimates exists is the Hauraki Gulf. An index of relative numbers of fish surveyed from the Hauraki Gulf trawl survey series was fitted in the model and was assigned an overall CV of 0.15 (see Table 11).

Longline CPUE

CPUE indices for the fishing years 1989–90 to 2011–12 were derived using data from bottom longline fisheries operating in the East Northland, Hauraki Gulf, and Bay of Plenty areas within SNA 1 (see also McKenzie & Parsons 2012). Data for years prior to 2007–08 were fisher daily amalgamated catch totals, i.e., catch per day. After 1 October 2007 longline fishers were required to report catch and effort on a per set or event basis. To combine the data, the more detailed post 2007 data were aggregated at the daily catch level. The validity of doing this was explored by looking for discontinuities in the annual median number of hooks reported by the core vessels over the form change interval. It was concluded that combining the two data series in a single analysis was appropriate.

Analysis was restricted to a subset of 'core' vessels. The vessel selection process sought to:
- minimise the number of vessels in the analysis;
- maximise the proportion of total longline catch: threshold set at 60%;
- maximise the number of years in the fishery; and
- maximise the average number of trips per year.

Standardised CPUE indices were derived as the coefficient of the year covariate in a log-linear regression model of daily log-catch (kg). Other variables offered to the model were vessel-id, target, month, statistical area, number of hooks, and number of sets (refer McKenzie & Parsons 2012). Parameters selected by the model are given in Table 12.

Alternative analyses were undertaken, using more vessels, to include at least 80% of the total longline catch for the last five years. These analyses produced results consistent with those using fewer vessels and less of the catch suggesting that the derived standardised indices were relatively insensitive to the core vessel selection and the proportion of the total longline catch included.

The pattern in nominal (unstandardised) longline CPUE shows increasing trends in all three areas (Figure 7). Increasing trends in the standardised CPUE indices are also seen in the Hauraki Gulf and Bay of Plenty areas; however, the increase in Hauraki Gulf abundance is less steep than the unstandardised indices (Figure 7). The difference between the standardised and unstandardised longline indices is most pronounced for East Northland with the standardised indices being much flatter (Figure 7).

Table 12: Parameters (covariates) selected in the log-linear model standardisation of daily log-catch from longline (log-catch-per-day) and bottom trawl (log-catch-per-unit-tow) by area along with the proportion of variance explained (model R-squared) by the addition of each successive term (model R-squared).

	Parameter	Fyear	Number of hooks (log)	Vessel	Depth	Month	Target	Stat area
Longline								
East Northland	model R-squared	0.06	0.3	0.35	–	0.39	0.41	–
Hauraki Gulf	model R-squared	0.08	0.34	0.44	–	0.49	–	–
Bay of Plenty	model R-squared	0.07	0.53	0.43	–	–	0.57	–
Bottom Trawl								
Bay of Plenty	model R-squared	0.01	–	0.15	0.17	0.19	0.1	0.21
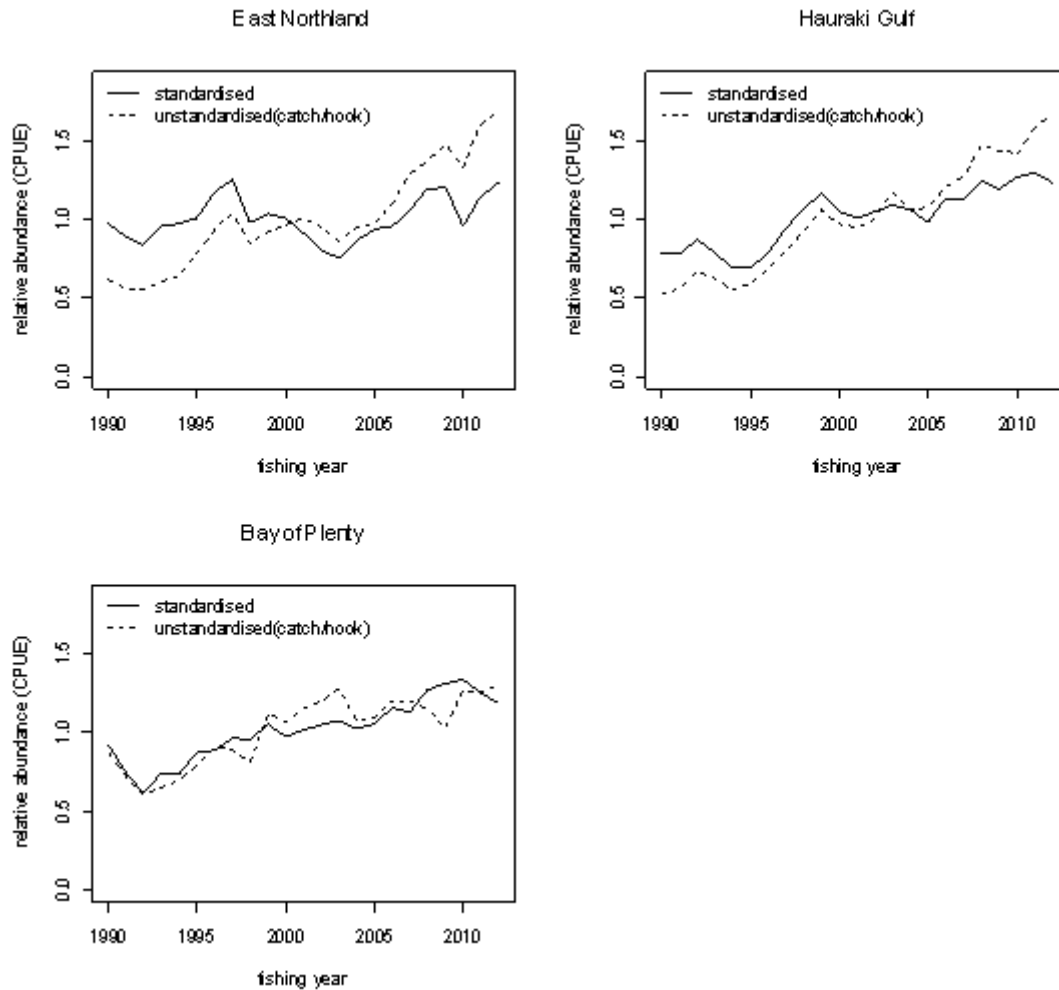
Figure 7: Longline CPUE indices of abundance (standardised and unstandardised) from 1990–2012 for the three component stocks of SNA 1.

The area specific longline CPUE indices were fitted by the 2013 model, with each series assigned an overall CV of 0.15.

Bay of Plenty single trawl CPUE
The Bay of Plenty single trawl CPUE data were available from fishing years 1989–90 to 2011–12 (a 23 year time series). However, three different catch effort form types have been in use during this period, partially limiting the temporal continuity of the series. Prior to the 1995–96 fishing year, most Bay of Plenty trawl fishers used the less detailed daily CELR reporting forms. From 1995–96, however, a significant number of Bay of Plenty trawl fishers (over 70%) were reporting on Trawl Catch Effort Processing Returns (TCEPR) that provide effort details as well as latitude and longitude information for each tow. From the 2007–08 fishing year many Bay of Plenty trawl fishers moved onto the new Trawl Catch Effort Return (TCER) forms. The TCER forms are largely identical to the TCEPR forms but require catch details of the top eight, not five, species to be recorded. It was decided not to include the CELR data in the CPUE standardisations and only to include years where a high proportion of TCEPR and TCER data were available; specifically, the 1995–96 to 2011–12 fishing years (a 17 year time series).

As with the longline analysis both standardised and unstandardised CPUE indices were derived. In the unstandardised analysis CPUE was simply catch per tow, in the standardised analysis CPUE was log catch per tow (positive catches only). The following continuous effort variables were considered in the model selection (standardisation) process: Log (fishing duration); Log (net height); Log (net width); Log (gear depth); Log (engine power); Log (vessel length*depth*breadth). Categorical variables considered were: fishing year (forced); month; season (4); vessel; and statistical area. In the Bay of Plenty trawl fishery 98% of the snapper catch is taken when targeting five main species: SNA,

1539

TRE, TAR, GUR, and JDO). Therefore 'target' was included in the standardisation as a six-level categorical variable (five target species plus an 'other' category) (refer McKenzie & Parsons 2012 for details). Parameters chosen by the standardisation procedure are given in Table 16.

The standardised CPUE indices suggest that the Bay of Plenty trawl fishery experienced a slight increase in abundance between 1996 and 2008 and more recently from 2010–11 (Figure 8).
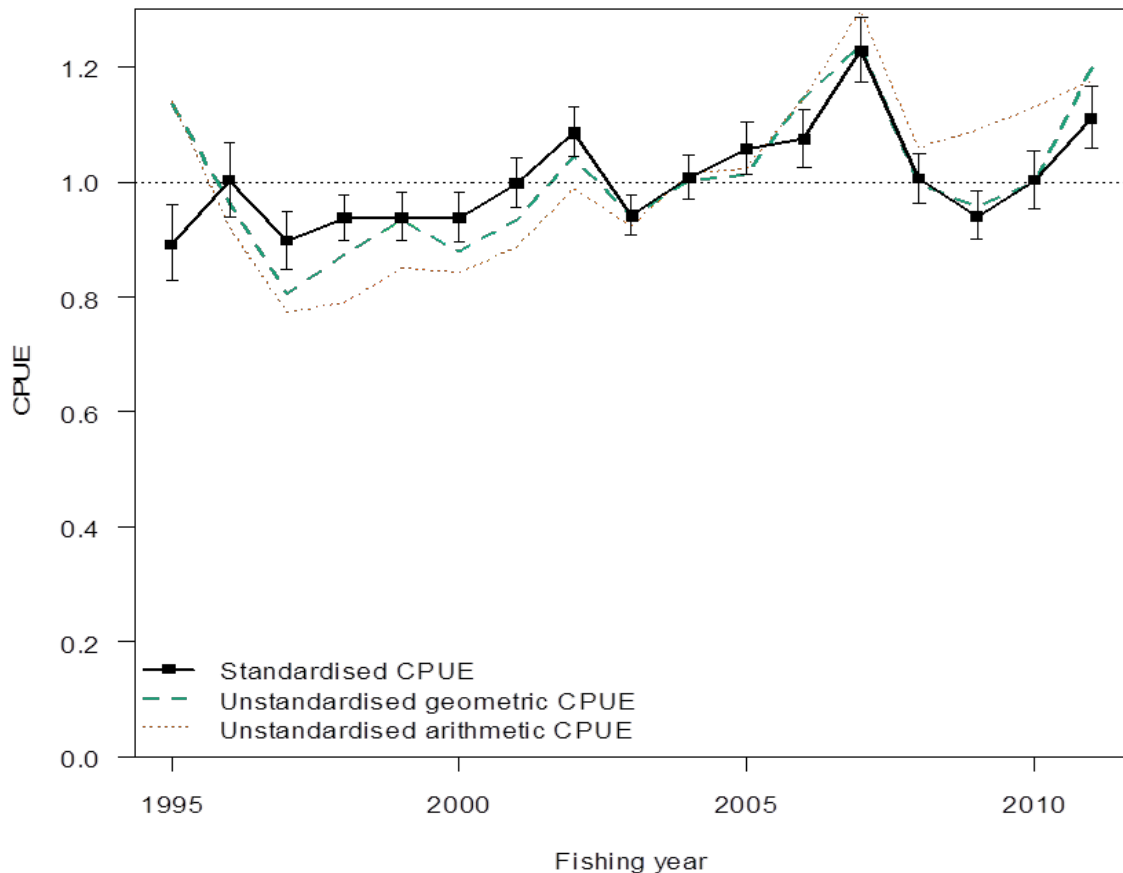
Figure 8: Single trawl CPUE indices of Bay of Plenty area abundance (standardised and unstandardised) from 1996–2012. Note: 1995 is the 1995-96 fishing year in this plot.

The single trawl Bay of Plenty CPUE was fitted with an assigned overall CV of 0.15 (see Table 11).

4.4   Catch at age and length observations

Commercial data

Catch-at-age observations from single trawl, Danish seine, and longline are available from the Bay of Plenty and Hauraki Gulf stocks; longline only for East Northland (see Table 11).

Catch-at-age sampling since 1985 in East Northland shows a greater accumulation of fish older than 20 years than observed in the Hauraki Gulf or Bay of Plenty sub-stocks (Figures 9–11). The Bay of Plenty longline age composition is similar to that for SNA 8, with the fishery largely comprising only 4–6 dominant age classes with few fish older than 20 years present in the catch samples (Figure 11).
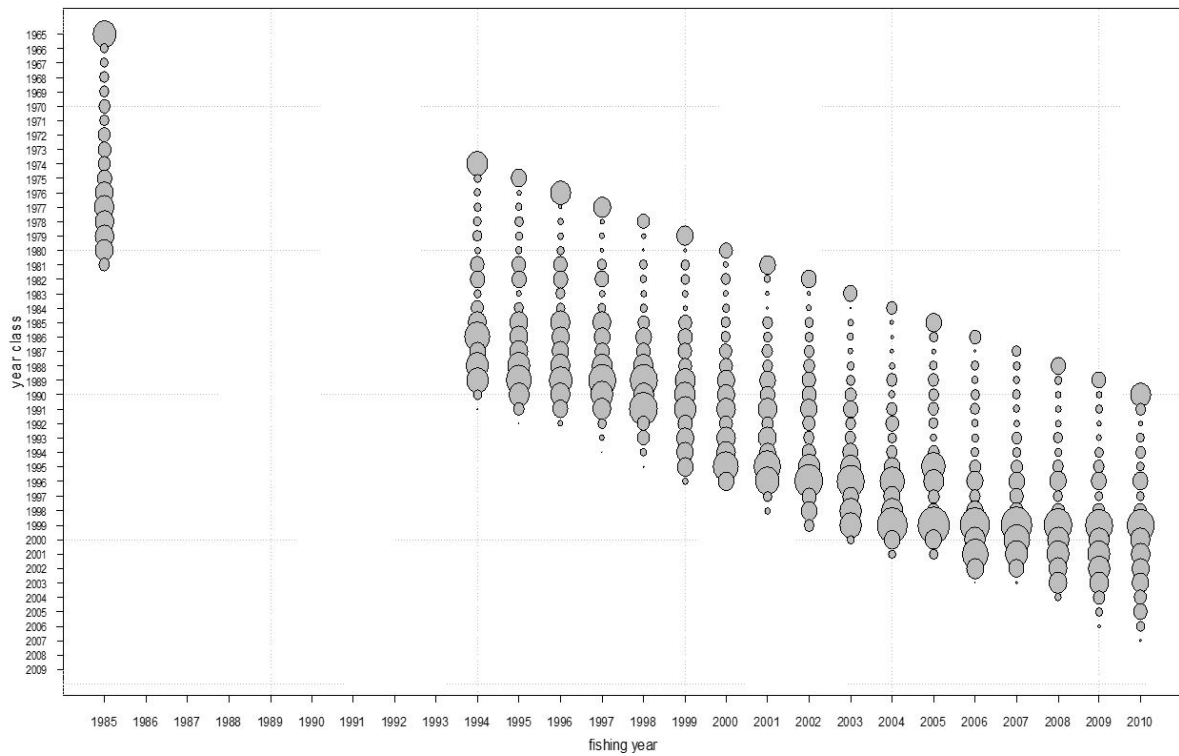
Figure 9: Relative year class strength observed in the East Northland longline fishery 1984–85 to 2009–10. Year on the x-axis refers to the second part of the fishing year. The oldest year class is a 20+ group.
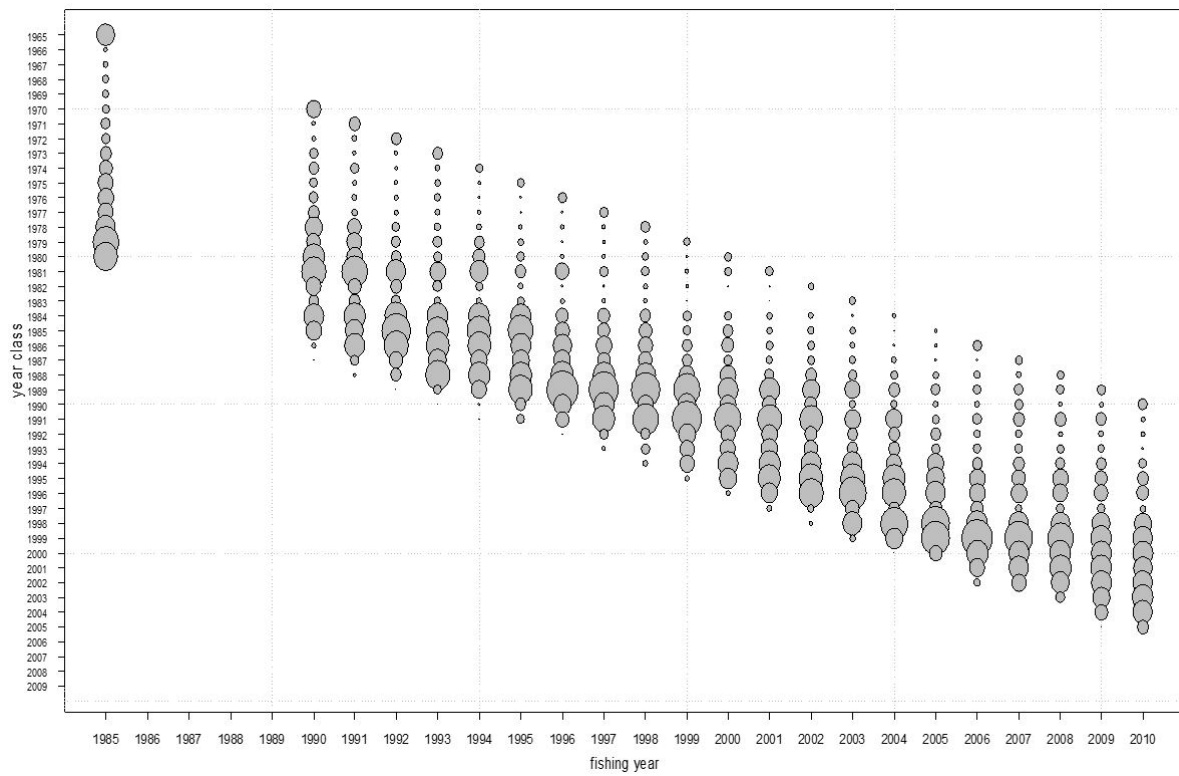
Figure 10: Relative year class strength observed in the Hauraki Gulf longline fishery 1984–85 to 2009–10. Year on the x-axis refers to the second part of the fishing year. The oldest year class is a 20+ group.

1541
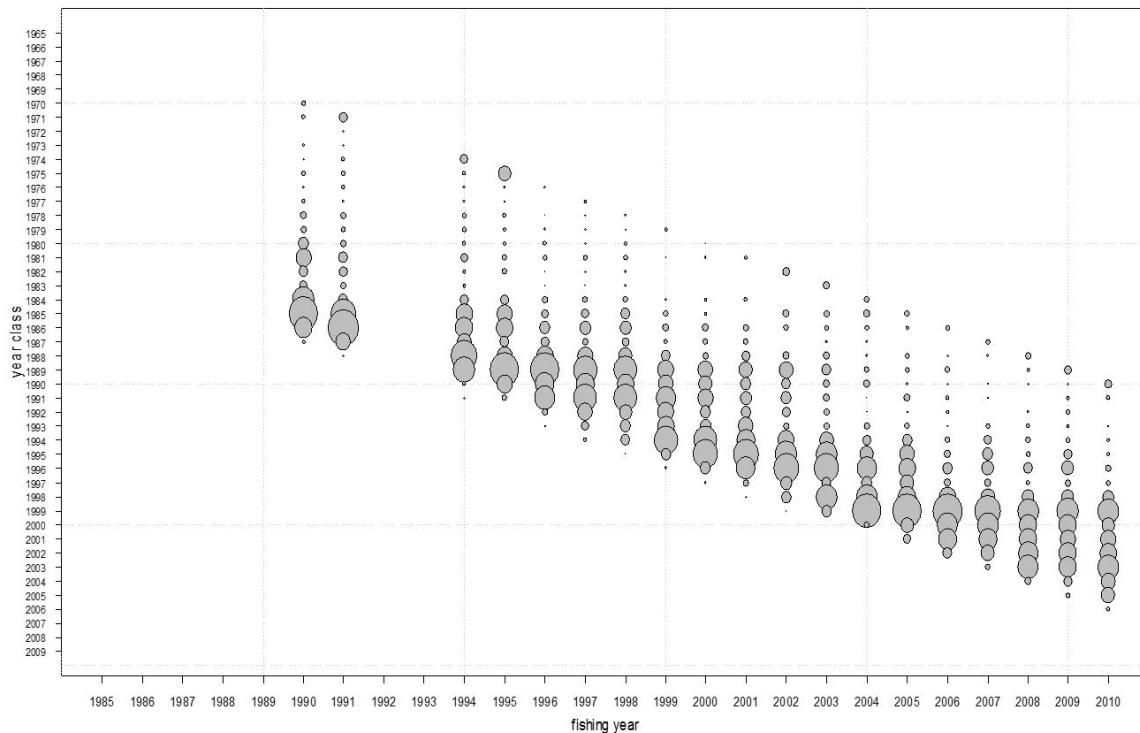
Figure 11: Relative year class strength observed in the Bay of Plenty longline fishery 1990–91 to 2009–10. Year on the x-axis refers to the second part of the fishing year. The oldest year class is a 20+ group.

Recreational data

Observations of recreational catch-at-length are available for most years after 1990, spanning the 1994 change in minimum legal size (see Table 11).

Research trawl data

Catch-at-age observations from research trawl surveys are available for most surveys and fitted in the model for all areas (see Table 11).

4.5   Snapper 1983, 1985, and 1994 tagging programmes

Analysis of past snapper tagging programmes revealed a number of sources of bias that need to be accounted for if these data are to be used for assessment purposes. Data from the 1985 and 1994 tagging programmes were corrected for bias and input directly into the assessment model. Data from the 1983 Bay of Plenty tagging programme were unavailable. The published biomass estimate (6000 t, Sullivan et al 1988) was fitted in the model as a point estimate but given a high CV (0.4) in recognition of the likely inherent but unaccountable biases in the data.

Initial mortality

The release data were adjusted for initial mortality outside the model using methods given by Gilbert & McKenzie (1999).

Tag loss

The effect of tag loss was only an issue for the 1983 and 1985 tagging programmes where external tags were used. A revised estimate of tag loss was derived from a double-tagging experiment in 1985.

Trap avoidance

Trap avoidance was found to occur for both trawl and longline tagged fish (Gilbert & McKenzie 1999); the result of this was that released fish were less likely to be recaptured using the same method. Trawl and longline methods were used to tag fish in both the 1985 and 1994 tagging programmes. The CASAL models used the scaling factors derived by Gilbert & McKenzie (1999) to adjust the tagging data for trap avoidance.

Detection of recaptured tags

Because a fisheries-independent tag recovery process was used in the 1994 programme, a reliable estimate of tag under-detection was obtained. The model was provided this estimate to adjust the 1994 tag recovery data.

The recovery of tags in 1983 and 1984 programmes relied on fishers to voluntarily return tags. Estimates of under-reporting from these programmes are less precisely known but were assumed to be 15% (1988 Snapper Plenary Report).

Differential growth of tagged fish

There is evidence that tagged fish may stop growing for 6 months after tagging (Davies et al 2006). The growth differential between tagged and untagged fish may bias results because the model will expect these fish to be larger than they are. Because it was not possible to incorporate this source of bias in the model, it was assumed that, given that the majority of tags recovered in both programmes came from the first year after release, growth bias would be minimal.

Spatial heterogeneity

A primary objective when tagging fish for biomass estimation is to ensure homogeneous mixing of tags within each spatial stratum so that the probability of recovering a tagged fish is the same in all locations. Spatial heterogeneity impedes realisation of this objective. The potential bias caused by spatial heterogeneity may be high or low because it depends largely on the spatial distribution of recapture effort (i.e., fishing) within the spatial stratum. Heterogeneity was observed in both tagging programmes because mark rates varied amongst statistical areas and methods; and was most apparent in the 1994 Hauraki Gulf Danish seine catches (Gilbert & McKenzie 1999). The results of simulation modelling using Hauraki Gulf data from the 1994 programme showed that under scenarios where the difference in the spatial mark rates was high (up to 4-fold) and catch examination tonnages were spatially disproportionate, the level of bias (positive or negative) in the biomass estimate could be as high as 35% (Davies et al 1999b). However, for scenarios where fishing was more uniform across strata, the expected level of bias was likely to be only 10%. To further investigate potential bias introduced by heterogeneity in the 1994 tagging programme, fish tagged and released by the Hauraki Gulf Danish seine fishery were excluded from the analysis. This increased the 1995 Hauraki Gulf biomass estimate by 15%, from 30 000 t to 34 000 t (Davies et al 1999a). Evidence for spatial heterogeneity in East Northland and the Bay of Plenty was much weaker than for the Hauraki Gulf (Gilbert & McKenzie 1999). For the 2013 stock assessment all tag recovery data are used, including Danish seine recoveries from the Hauraki Gulf.

4.6   Stock Assessment Results

Spawning biomass by stock and by area and for HAGUBOP

Two versions of spawning stock biomass (*SSB*) are presented in the following results. The first, labelled 'by stock', is calculated in the conventional way (in the model time step 1, when spawning occurs and all fish are in their home grounds); the second, labelled 'by area', is calculated half-way through the mortality in time step 2, when some fish are away from their home ground. The former is the usual *SSB*, but the latter is better estimated and may be more relevant for management purposes.

Some *SSB* results are also presented for the Hauraki Gulf and Bay of Plenty combined (labelled HAGUBOP by stock, or HGBP by area) because there is some doubt about the relationship between fish in these two areas.

Base model

The base model MPD achieved good fits to the abundance data and reasonably good fits to the composition data. The fit to the tag-recapture data was negatively affected by a conflict between these data and the age compositions which caused an imbalance in the fits to the tag-recapture data: the observed tag rate (the proportion of fish with tags) was greater than the expected rate in 23 of the 26 data sets. Although the expected rate lay within the 95% confidence bounds in all but three data sets, this result indicates that the model is unable to fit the tagging data well. Issues with the original tagging data and analyses have been identified elsewhere (Gilbert et al 1999, Davies et al 1999b).

All estimated spawning biomass trajectories show substantial reductions up to 1999 (for East Northland) or about 1988 (for other stocks and areas), and then some increase thereafter (Figure 12, upper panels). In terms of current biomass, both the stock BOP and area BP are estimated to be more depleted (3–10% B_0) than the other stocks and areas (15–30% B_0) (Table 13). However, for all stocks and areas, current biomass is 30–68% higher than its minimum value (Table 13). Stock HAGU and area HG are estimated to contain a much greater tonnage of fish than the other stocks and areas, both over the period of the assessment (Figure 12, upper panels) and in their unfished state (Table 13). ENLD/EN and BOP/BP are estimated to have contained broadly similar tonnages (53 000 t to 112 000 t) before the fisheries started—which was estimated to be the larger depends on whether the biomass is considered by stock or by area.
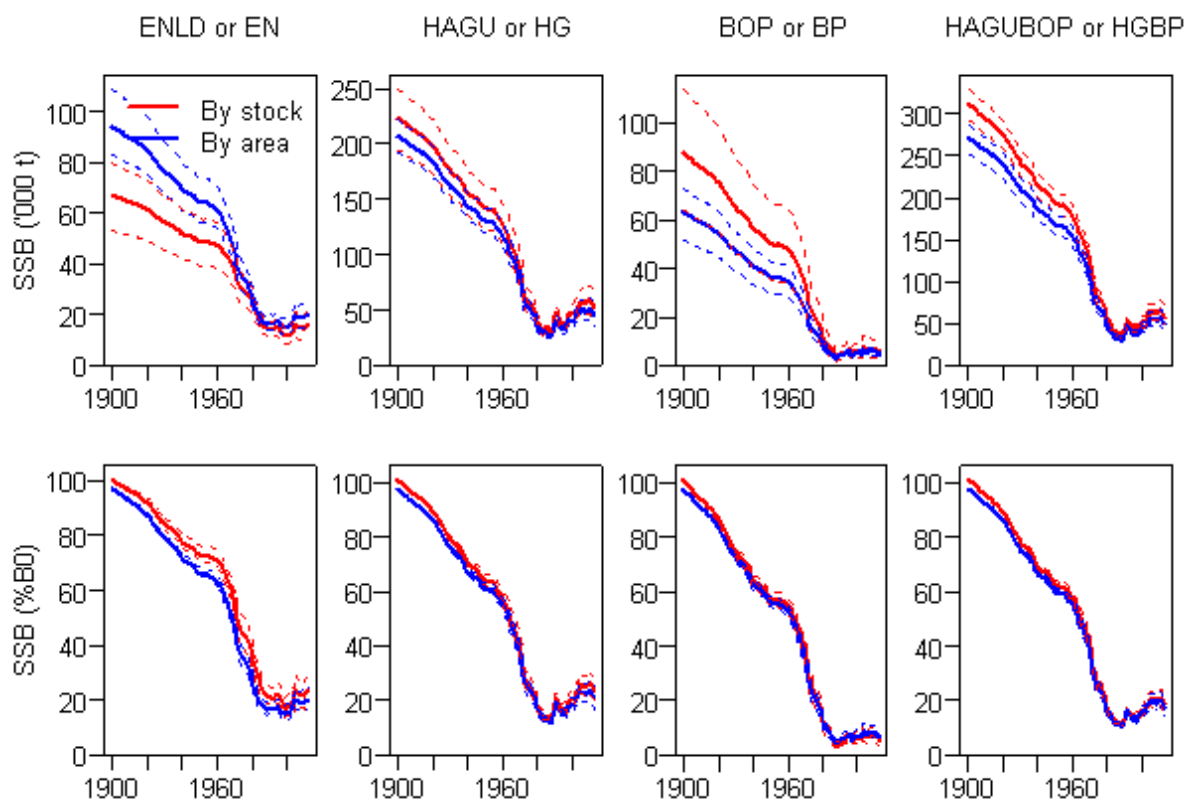
Figure 12: *SSB* trajectories by stock (red lines) and area (blue lines) from the base model. Solid lines are MCMC medians, broken lines are 95% confidence intervals.

Table 13: Base model estimates of unfished biomass (B_0) and current biomass (B_{2013} as % B_0 and % B_{min}) by stock and area. Estimates are MCMC medians with 95% confidence intervals in parentheses.

		B_0 ('000 t)	B_{2013} (% B_0)	B_{2013} (% B_{min})*
By stock	ENLD	66 (53, 79)	24 (18, 30)	137 (108, 176)
	HAGU	220 (192, 246)	24 (19, 29)	168 (137, 206)
	BOP	86 (63, 112)	6 (3, 9)	148 (104, 209)
	HAGUBOP	306 (288, 325)	19 (15, 23)	167 (139, 201)
By area	EN	96 (85, 111)	20 (16, 25)	130 (108, 159)
	HG	211 (197, 227)	21 (17, 26)	167 (136, 204)
	BP	64 (53, 74)	7 (5, 10)	145 (114, 185)
	HGBP	276 (258, 292)	18 (15, 22)	165 (136, 199)

*B_{min} was taken as B_{1999} for ENLD and EN, and as B_{1988} for other stocks and areas.

Most fish do not move away from their home grounds, with migration being most common for BOP fish and least common for ENLD fish (Table 14). Uncertainty in the proportion migrating is greatest for fish from BOP. The estimated proportion migrating from BOP to ENLD appears to be unrealistically high when compared with the observed movements of tagged fish.

Table 14: Base case migration matrix (showing proportions of each stock migrating to each area in time step 2). Estimates are MCMC medians with 95% confidence intervals in parentheses.

Stock	Area EN	Area HG	Area BP
ENLD	0.94 (0.89, 0.97)	0.05 (0.02, 0.10)	0.01 (0.00, 0.04)
HAGU	0.09 (0.05, 0.14)	0.87 (0.82, 0.91)	0.04 (0.02, 0.06)
BOP	0.17 (0.02, 0.36)	0.18 (0.07, 0.34)	0.63 (0.45, 0.83)

In all areas current exploitation rates by method are estimated to be highest for the recreational fisheries (Figure 13). Fishing intensity is estimated to be highest in BOP. For ENLD and HAGU, fishing intensity declined from peaks in the 1980s but has increased in the HAGU since 2007 (Figure 14). The fishing intensity for the HAGUBOP stock rose sharply from the early 1960s and reached a peak in the 1980s. It then declined by approximately 50% to 2007 but has since increased to 86% of the 1985 peak (Figure 14). Estimates of year class strength are precise only for a relatively narrow range of years, particularly for ENLD and BOP, where catch-at-age data are sparser (Figure 15).

No stock or area is at or above the target and none but the Bay of Plenty is below the hard limit. Probabilities of being below the soft limit range from 0.04 to 1.00 (Table 15).
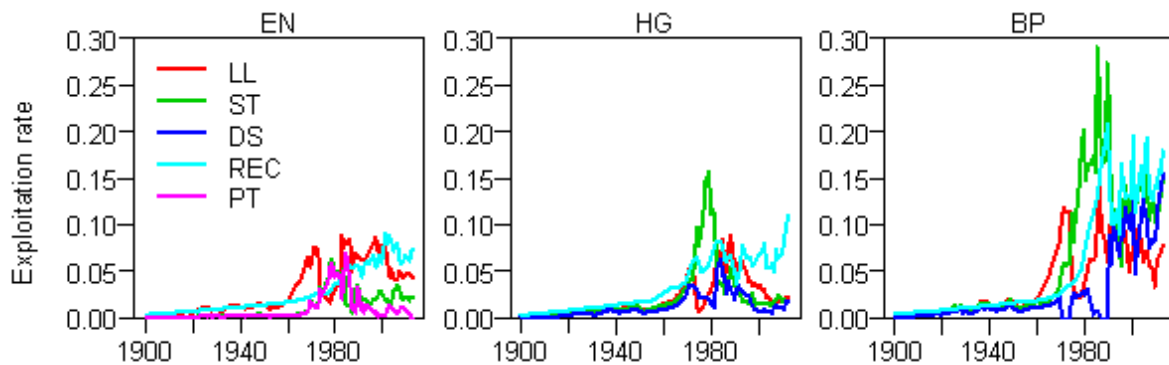
Figure 13: MPD estimates of exploitation rates by fishery and year.
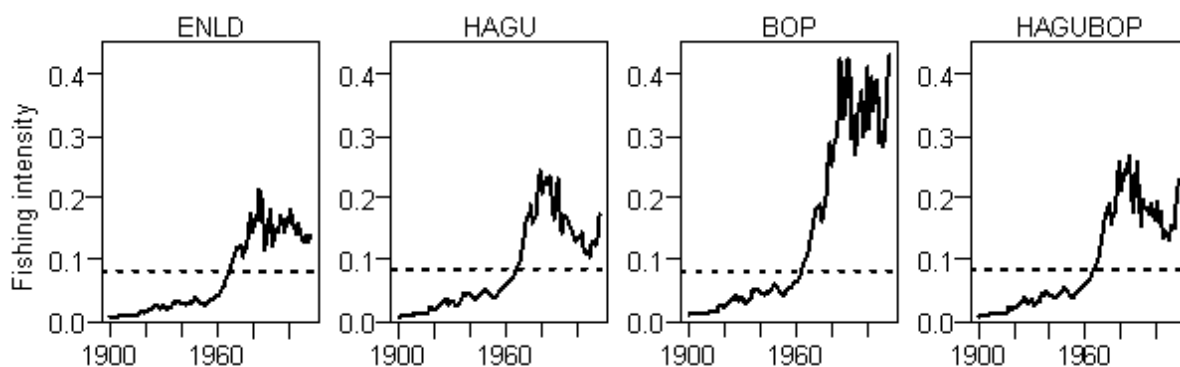
Figure 14: MPD estimates of fishing intensity by year and stock. Dotted lines show the intensity required to maintain the spawning biomass at 40% B_0 ($U_{40\%B_o}$).
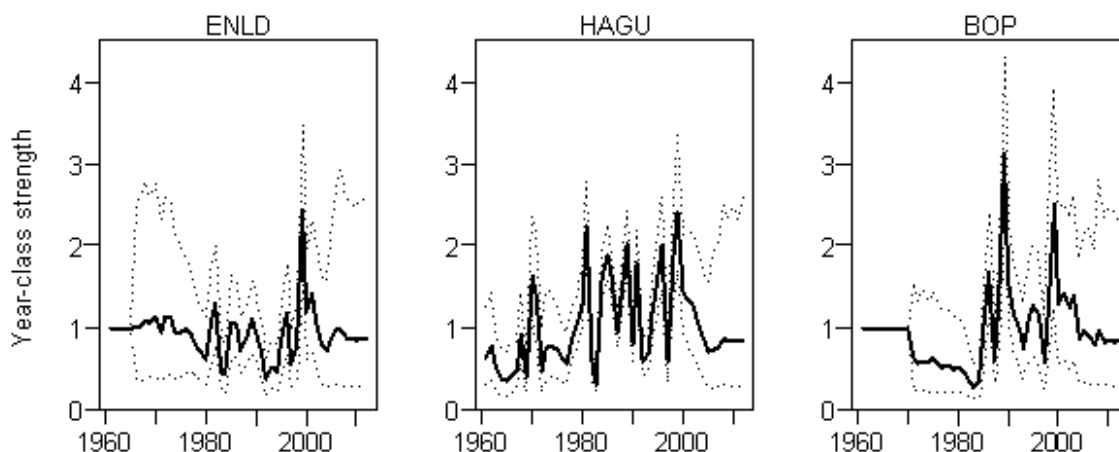
Figure 15: Estimated year class strengths by year and stock (a value of 1 indicates that the year class has the strength predicted by the stock-recruit relationship). Estimates are MCMC medians (solid lines) and 95% confidence intervals (dotted lines).

Table 15: Probabilities, by stock and area, relating current biomass to the target (40% B_0) and limits (soft 20% B_0 and hard 10% B_0).

	ENLD/EN		HAGU/HG		BOP/BP		HAGUBOP/HGBP	
Probability	**by stock**	**by area**	**by stock**	**by area**	**by stock**	**by area**	**by stock**	**by area**
At or above target	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Below soft limit	0.12	0.52	0.04	0.34	1.00	1.00	0.74	0.89
Below hard limit	0.00	0.00	0.00	0.00	0.99	0.99	0.00	0.00

Sensitivity analyses

Many alternative models were constructed and run to determine the sensitivity of the assessment to various model assumptions (Francis & McKenzie 2015b).

Some changes of assumptions had comparatively little effect on stock status. The following changes fall into this category: alternative levels of trap shyness and tag loss; allowing the initial (1900) biomass to differ from B_0; increasing the maximum age in the partition from 20 to 60; dropping tag-recapture data from Statistical Area 008 (the Bay of Plenty area closest to the Hauraki Gulf); and assuming that tagging in area BP occurred before HAGU fish in that area had returned home.

Two other alternative models were useful in demonstrating the sensitivity of the assessment to specific data sets. In one, the longline CPUE indices were replaced by their unstandardised values (which have quite different trends—see Figure 7), and, in the other, the tag-recapture data were strongly down-weighted. In both cases there was a marked change in the estimated biomass trajectories; however, neither of these runs was considered to provide useful information on current stock status.

There are nine alternative models for which some results are presented (Table 16). Most of these alternative models are easily understood, but two merit more detailed description.

Table 16: Brief descriptions of nine alternative models run to determine sensitivity to various model assumptions.

Label	Description
catch-lo/hi	Use alternative lower and higher catch histories
sel-by-area*	Assume that fishery selectivity depends on area, as well as fishing method
reweight	Age and tag-recapture data reweighted to reduce imbalance in fit to tag-recapture data
M-lo/hi	Replace the assumed value of natural mortality, $M = 0.075$ y^{-1}, with lower (0.05) and higher (0.10) values
steep-lo/hi	Replace the assumed value of stock-recruit steepness, 0.85, with lower (0.7) and higher (0.95) values
one-stock[1]	Replace the base three-stock (and three-area) model with 3 separate one-stock models: one for each area.

* MCMC runs were done for these sensitivities.

The first, sel-by-area, was motivated by the observation that, for any given fishing method and year, the mean age (or mean length for recreational fisheries) of the catch was almost always lowest in area

BP (Figure 16). In the base model this implied that the biomass was more depleted in BP than in the other areas because of the assumption that the selectivity of each fishing method is the same in all three areas. This assumption was removed in model sel-by-area (so that a separate selectivity curve was estimated for each combination of fishing method and area). Sel-by-area was considered as an alternative base case, but the overall stock status differed little from the base that was chosen when BOP and HG stock status results were combined.

The one-stock models were constructed because of uncertainty about stock structure and fish movement between areas. Although it is clear that fish spawn in all three areas and move between areas (as assumed in the base model), the complexity of this structure and movement is unlikely to be well represented in the base model. For example, the proportion of fish migrating between areas in the relatively few years of the tag-recapture data may not be representative of what happened in other years. Also, the assumptions that (a) all fish were in their home area at the time of tagging, and (b) all recaptures occurred during the period that migrating fish were away from home, are likely to be only approximately true. The one-stock models offer an alternative, and much simpler, way of analysing the available data. Each of these models may be thought of as being constructed from the base model in the obvious way, by removing the stock and area structures (and the associated migrations), and also the observations and fisheries that were associated with other areas. The only complicated part in this construction concerned the tag release and recapture observations (for details see Francis & McKenzie 2015b).

Results of the sensitivity analyses are presented in terms of their effects on current status (Figure 17). Regardless of whether current status was measured by stock or by area, all models estimated the Bay of Plenty spawning biomass to be the most depleted, and most models estimated that the Hauraki Gulf was least depleted. The greatest sensitivity was shown with model sel-by-area, which estimated much less depletion for the Bay of Plenty (current biomass was 14% B_0, compared with 6–7% B_0 in the base model), and model re-weight, which estimated more depletion for the other areas. Estimates from sel-by-area were broadly similar to those from the one-stock models. Changes in both M and steepness had predictable effects (the same for all stocks and areas): lower values, which imply lower productivity, led to more depletion, and higher values to less depletion. Current status estimates were not very sensitive to alternative catch histories. Stock status was always slightly worse by stock than by area for Bay of Plenty, with the reverse being true for East Northland and Hauraki Gulf. Due to uncertainty about the relationship between BOP and HGU, stock status is also presented for the two stocks combined.
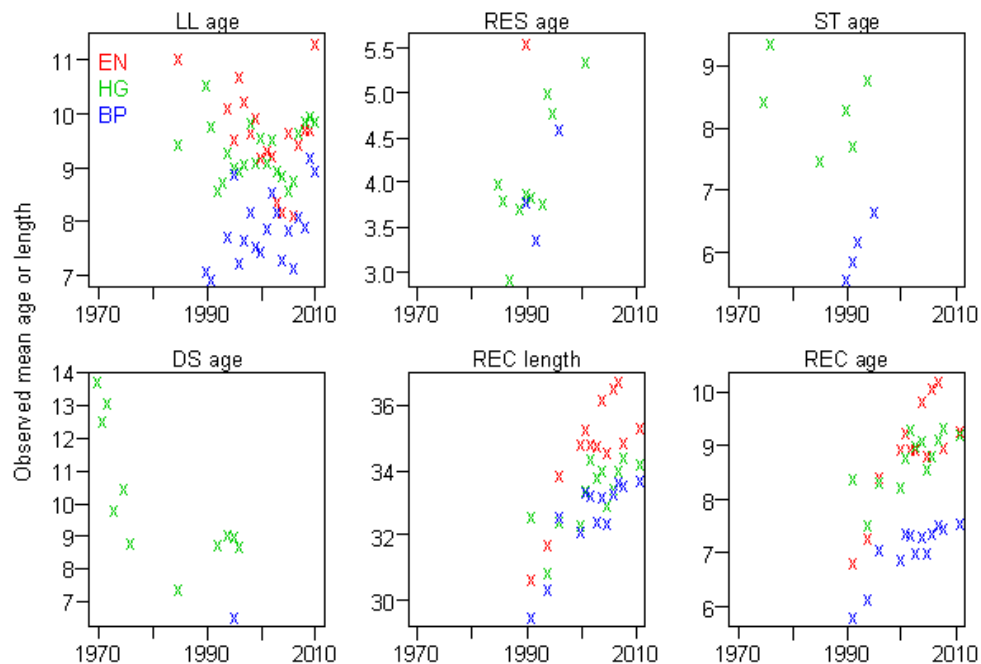
Figure 16: Observed mean age (for commercial fisheries and research surveys) or length (for recreational fisheries) by fishing method and area. In the bottom right-hand panel, the observed recreational mean lengths have been converted to ages using the mean length-at-age relationship (averaged over years 1994–2010) for each area.
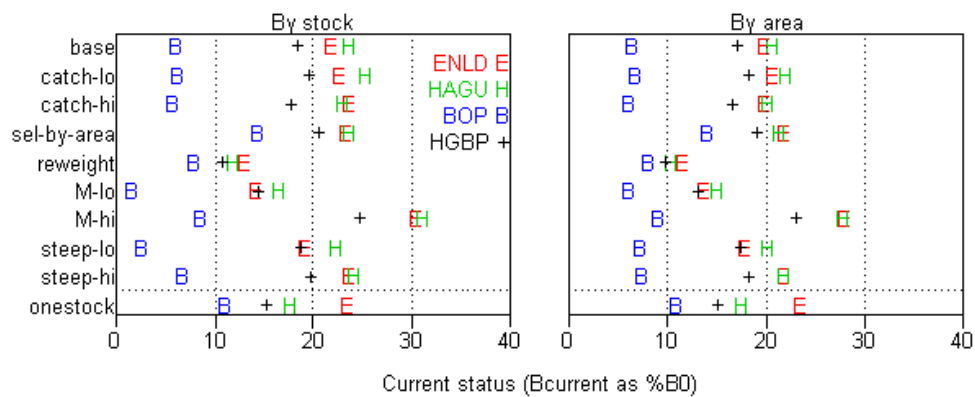
Figure 17: MPD estimates of current status (*B2013* as % *B0*), by stock and area, for the base model and some sensitivity analyses. The horizontal broken line separates the one-stock estimates from the others as a reminder that there is no distinction between spawning biomass by stock and by area for these models.

4.7 Yield estimates and projections

Five-year projections of the base case were carried out under 'status quo' conditions, which were taken to mean constant catches (equal to the 2012 and 2013 catches) for the commercial fisheries and constant exploitation rate (equal to the average of the 2008–2012 rates) for the recreational fisheries. In these projections, simulated year class strengths were resampled from the 10 most recent reliably estimated YCSs (deemed to be 1995–2004). The simulated YCSs included both the recent YCSs that were not estimated (due to the lack of recent age composition data) in the MPD (2008–2012) as well as the five 'future' YCSs (2013–2017).

With status quo catches the biomass is likely to continue to increase for all stocks and areas (Figure 18). These results changed only slightly when the future exploitation rate for the recreational fishery in HG was changed from 0.0779 (the average of the 2008–2012 rates) to 0.0648 (the average for 1995–2005) or 0.1089 (the rate for 2013). Projections from the one-stock and sel-by-area sensitivity models predicted increasing or near-stable biomass for all stocks and areas.
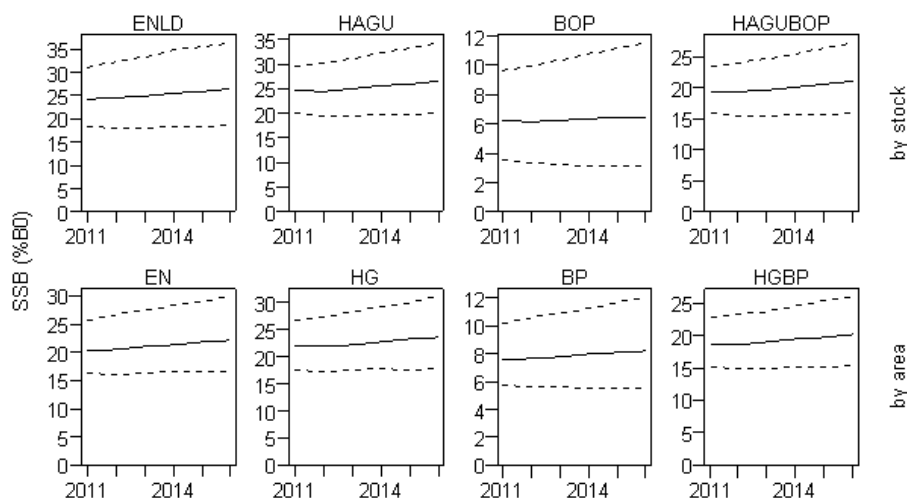
Figure 18: Projected spawning stock biomass (*SSB*) by stock and by area. Estimates are MCMC medians (solid lines) and 95% confidence intervals (broken lines).

Deterministic B_{MSY}

Deterministic B_{MSY} was calculated as 25–26% B_0 for all individual stocks and areas and 30% for the combined Hauraki Gulf/Bay of Plenty. There are several reasons why B_{MSY}, as calculated in this way, is not a suitable target for management of the SNA 1 fisheries. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge including perfect catch and biological information and perfect stock assessments (because current biomass must be known exactly in order to calculate target catch), a constant-exploitation management strategy with annual changes in TACs (which are unlikely to happen in New Zealand and not desirable for most stakeholders), and perfect management implementation of the TAC and catch splits with no under-runs or overruns. Second, it assumes

perfect knowledge of the stock-recruit relationship, which is actually very poorly known. Third, it would be very difficult with such a low biomass target to avoid the biomass occasionally falling below 20% B_0, the default soft limit according to the Harvest Strategy Standard. Thus, the actual target needs to be above this theoretical optimum; but the extent to which it needs to be above has not been determined.

Results from the deterministic B_{MSY} calculations were used to determine the level of fishing that would maintain the spawning biomass at the interim target level of 40% B_0. This ranged from 19% to 59% of the 2013 level (Table 17).

Table 17: Estimated levels of fishing—expressed as multiples of 2013 exploitation rates—that would be required to maintain spawning biomass at 40% B_0.

	ENLD	HAGU	BOP	HAGUBOP
by stock	0.59	0.50	0.19	0.38
by area	0.55	0.46	0.21	0.38

4.8 Qualifying comments

1. Uncertainty associated with some of the tagging assumptions is not explicitly incorporated into the model. Examples include confidence intervals on trap shyness, the duration of the mixing period, and clumping of recaptures (for example, higher recovery rates in 1994 Danish seine Hauraki Gulf catches).
2. A lack of recent catch-at-age data means that recent relative year class strengths were not available for projections of stock size. SNA 1 is currently only sampled for catch-at-age every three years.

4.9 Preliminary 2022 model description and results

The above described 2013 assessment model was structurally updated in 2022 in line with future research recommendations documented in the 2013 Plenary chapter, and to accommodate new abundance and compositional data series available since 2013. The key differences between the 2013 and 2022 SNA 1 stock assessment models are as follows:

- Increase in the number of age classes specifically modelled (i.e., increase from 1–20+ to 1–30+ age classes).
- Fit all recreational compositional data as catch-at-age (fitted as catch-at-length in 2013 model).
- Estimation of specific area-method selectivities rather than assuming method selectivities are the same in all areas as per the 2013 model.
- Addition of separate post 2015 Modular Harvest System (MHS) fisheries in each area in recognition that the selectivity of these new fisheries likely differs from those of standard bottom trawl gear.
- Addition of post 2015 recreational fisheries in each area also in recognition that the post 2015 recreational harvest selectivities likely changed because of 2015 MLS and bag limit changes.
- Replacement of the 1900–2021 recreational catch histories with those derived pursuant to the ZINB methods as described in section 1.2.3 above.
- Inclusion of Bay of Plenty research trawl abundance and compositional model likelihoods.
- Fitting the Hauraki Gulf and Bay of Plenty research abundance data as five separate series, i.e., one series each for ages 1 to 4 and a 5+ amalgamated abundance series expressed as relative weight, not numbers.
- Dropping the Hauraki Gulf and Bay of Plenty longline CPUE abundance series from the final 'base' model, a change based on Fishing Industry anecdotal evidence that suggests longline fishing practices had changed over the 30-year series period, meaning these series were likely to be hyper-stable.
- Changing the relative weight of the tagging data to reflect the additional data added since 2013.

The basecase and various sensitivity MPD model runs did not predict that the East Northland stock and the Hauraki Gulf/Bay of Plenty stock complex was at or above the target 40% B_0 in 2020–21.

However, most MPD model sensitivity runs predicted the two SNA 1 stock regions as being above the 20% B_0 soft limit in 2020–21 and that abundance had increased since 2013.

The basecase model MCMC generated biomass posteriors were consistent with MPD model results, with a 100% probability that the spawning stock biomass for each of the two SNA 1 stock areas was greater than 20% B_0 but less than 40% B_0 in 2021. The basecase model median posterior biomass trajectories for both SNA 1 stock areas showed increasing trends in biomass between 2012–13 to 2020–21, a prediction consistent with anecdotal stakeholder experience.

4.9.1   Qualifying Comments

The 2022 May Plenary, although acknowledging the 2022 assessment model was an improvement over the 2013 model, deemed the 2022 base model was unsuitable for providing management advice due to unresolved data conflicts and poor model diagnostics. The Plenary made further model developmental recommendations to be undertaken prior to the 2022 November Plenary when the final SNA 1 assessment is due to be presented.

4.10   Future research considerations

- Investigate options for fisheries-independent abundance estimates, such as a new tagging study or fishery independent longline surveys in areas not amenable to trawl, e.g., East Northland. This is necessary because there is uncertainty in the relationship between standardised CPUE and abundance,
- Investigate the utility of longline CPUE as an index of abundance and include possible changes in selectivity, by comparing the series used for the stock assessment with alternative series modelled using finer-scale information collected since the introduction of new statutory forms (LCER) in 2007.
- Improve the understanding of stock boundaries and movement dynamics in East Northland, Bay of Plenty, the Hauraki Gulf, and SNA 2 before these areas may be reliably modelled as separate. A new tagging study is likely to be the best option for understanding SNA 1 stock structure and mixing.
- Evaluate the optimal frequency of catch-at-age monitoring. The current three-year cycle constitutes a two thirds reduction in the number of independent observations available for any given year class over annual sampling (i.e., is a loss of precision) and also may delay, by up to three years, our first awareness of extreme recruitment events. If both SNA 1 stock assessments and catch-at-age sampling are to be conducted on a three-year cycle, it is important that the assessment be timed for the year following the latest catch-at-age study. This would provide for more reliable projections. The WG recommended changing the frequency of catch sampling to be 2 consecutive years in every 5 instead of every 3rd year.
- Develop alternative bottom trawl and or recreational CPUE indices for East Northland.
- Investigate and correct for possible adult and/or juvenile snapper catchability changes in the Hauraki Gulf and Bay of Plenty trawl survey series. This study should include an investigation of environmental covariates and spatial expansion of the stock.
- Explore utility of the trawl survey as an index of abundance for adult and juvenile snapper.
- Further develop the recreational catch model, including models with all three areas combined and an area factor and testing the addition of interaction parameters.

Recommendations for the 2022 assessment

- Investigate alternative commercial catch histories with all catches coming from bottom trawl up to 1963.
- Investigate model sensitivity to the previous recreational harvest estimate history.
- Investigate the addition of incidental mortality.
- Compare estimates of biomass and movement obtained through stock assessment with those obtained externally (e.g., Petersen analysis).
- Investigate options to simplify the model structure:
    - Stand-alone ENLD model, BPLE / HAGU model, or three separate models;
    - Explore sensitivities with alternative movement hypotheses, including no movement;
    - Fix movement parameters (at estimated values or at externally derived estimates);
    - Fit to the tag abundance estimates rather than trying to fit the individual observations.

- Reinvestigate fitting the 5+ survey abundance series as numbers not weight.
- Explore alternative selectivity ogives for fitting the 5+ survey age composition data.
- Investigate estimating q as free parameters.
- Explore sensitivities to increasing U_{max} for BPLE to avoid catch penalties,
- Further investigate models starting in the 1970s in an exploited state.
- Further investigate model YCS estimation drivers, specifically, investigate the sensitivity of the YCS pattern estimated by the model including the survey data to different YCS assumptions (e.g., 3-look rule, bounding values on YCS, etc.).
- Further investigate alternative growth hypotheses, with models in particular expanding back and forward rather than using mean weight-at-age for those time periods (including predictions).

5. STATUS OF THE STOCKS

Stock Structure Assumptions

New Zealand snapper are thought to comprise either seven or eight biological stocks based on the location of spawning and nursery grounds, differences in growth rates, age structure, and recruitment strength, and the results of tagging studies. Three stocks are assumed in SNA 1 (East Northland, Hauraki Gulf, and Bay of Plenty), two in SNA 2 (one of which may be associated with the Bay of Plenty stock), two in SNA 7 (Marlborough Sounds and Tasman Bay/Golden Bay), and one in SNA 8. Tagging studies reveal that limited mixing occurs between the three SNA 1 biological stocks, with the greatest exchange between the Bay of Plenty and Hauraki Gulf.

- **SNA 1**

Both the 2013 and 2022 assessments were based on three stocks: East Northland, Hauraki Gulf, and Bay of Plenty; however, assessment results for Hauraki Gulf and the Bay of Plenty are combined in the summaries below due to uncertainties about movement of the two stocks between the two areas.

Stock Status	
Year of Most Recent Assessment	2013; Preliminary results 2022
Assessment Runs Presented	2013; Base case models for East Northland and the Hauraki Gulf and Bay of Plenty to 2013 2022: Preliminary base case to 2021
Reference Points	Interim target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $U_{40\%B0}$
Status in relation to Target	East Northland B_{2013} was estimated to be 24% B_0; Very Unlikely ($< 10\%$) to be at or above the target Preliminary estimate of B_{2021} may have slightly increased from B_{2013}: Very Unlikely ($< 10\%$) to be at or above the target Hauraki Gulf + Bay of Plenty B_{2013} was estimated to be 19% B_0; Very Unlikely ($< 10\%$) to be at or above the target Preliminary estimate of B_{2021} may have slightly increased from B_{2013}; Very Unlikely ($< 10\%$) to be at or above the target
Status in relation to Limits	East Northland B_{2013} was About as Likely as Not (40–60%) to be below the soft limit

	B_{2013} was Very Unlikely ($< 10\%$) to be below the hard limit Preliminary estimate of B_{2021} is Unknown in relation to the soft limit Preliminary estimate of B_{2021} is Very Unlikely ($< 10\%$) to be below the hard limit Hauraki Gulf + Bay of Plenty B_{2013} was About as Likely as Not (40–60%) to be below the soft limit B_{2013} was Very Unlikely ($< 10\%$) to be below the hard limit Preliminary estimate of B_{2021} is Unknown in relation to the soft limit Preliminary estimate of B_{2021} is Very Unlikely ($< 10\%$) to be below the hard limit
Status in relation to Overfishing	East Northland 2013: Overfishing was Likely ($> 60\%$) to be occurring 2022: Unknown Hauraki Gulf+Bay of Plenty 2013: Overfishing was Likely ($> 60\%$) to be occurring 2022: Unknown

Historical Stock Status Trajectory and Current Status
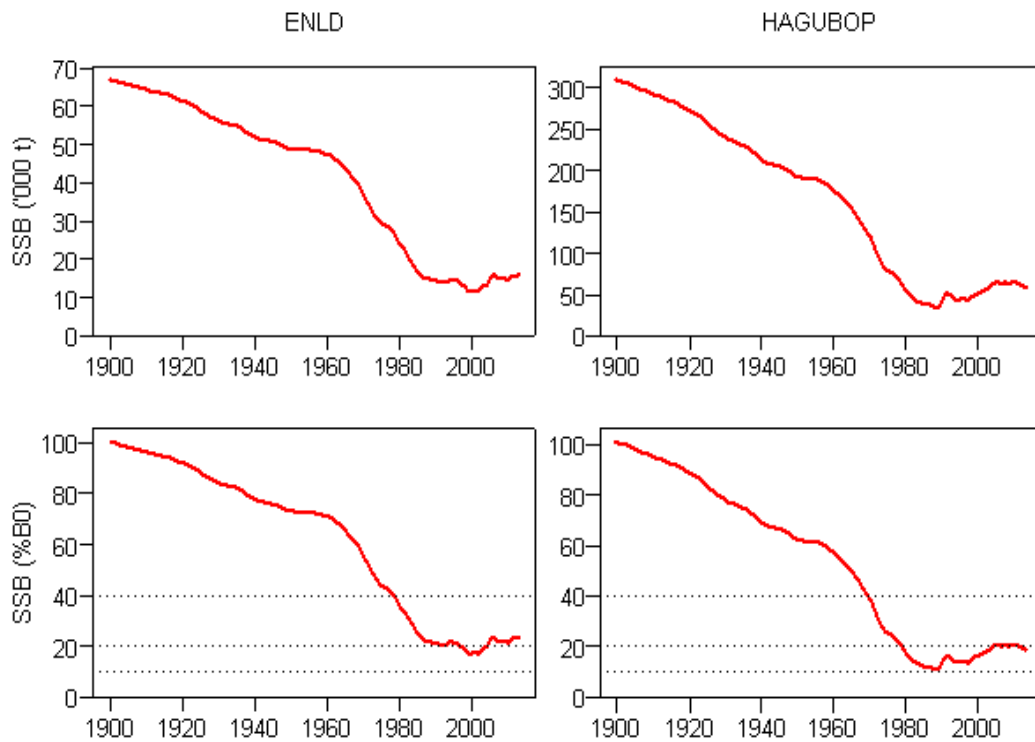
MCMC base model *SSB* and status trajectories by stock (dotted lines indicate target (40% B_0), soft limit (20% B_0), and hard limit (10% B_0)).

MCMC base model *SSB* and status trajectories by stock, for the period since 1980 (dotted lines indicate soft limit (20% *B*₀) and hard limit (10% *B*₀)).

Fisheries and Stock Trends	
Recent Trend in Biomass or Proxy	East Northland 2013: Stock biomass was estimated to have experienced a long steep decline from about 1960 to 1985 and had fluctuated without trend since then. 2022: Stock biomass may have increased slightly since 2013. Hauraki Gulf+Bay of Plenty 2013: Stock biomass was estimated to have experienced a long steep decline from about 1960 to about 1988, after which it gradually increased to 2010 and then declined slightly. 2022: Stock biomass may have increased slightly since 2013.
Recent Trend in Fishing Intensity or Proxy	 East Northland 2013: The fishing intensity for this stock rose sharply from the early 1960s, reached a peak in the early 1980s, and then since declined slightly. 2022: Unknown Hauraki Gulf + Bay of Plenty 2013: The fishing intensity for this stock rose sharply from the early 1960s and

	reached a peak in the 1980s. It then declined by approximately 50% to 2007 but then increased to 86% of the 1985 peak. 2022: Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	N/A
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits (5 years)	Unknown
Probability of Current Catch or TAC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 1 – Full Quantitative Stock Assessment	
Assessment Method	Spatially-disaggregated, 3-stock, age-structured, single-sex model undertaken in CASAL	
Assessment Dates	Latest assessment: 2013	Next assessment: November 2022
Overall assessment quality rank	1 - High Quality	
Main data inputs (rank)	- Proportions-at-age from the commercial fisheries and historic trawl surveys	1 – High Quality
	- Proportions-at-length from the recreational fishery	1 – High Quality
	- Estimates of biological parameters (e.g., growth, age-at-maturity, and length/weight)	1 – High Quality
	- Standardised longline CPUE indices	1 – High Quality
	- Standardised single trawl for the BoP	1 – High Quality
	- Estimates of recreational harvest	1 – High Quality
	- Commercial catch	1 – High Quality
	- Tag-based biomass estimates (BoP - 1983)	2 – Medium or Mixed Quality: data no longer available
	- Data from tagging experiments in 1985 (HG, EN) - Data from tagging in 1994 (all areas)	1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Catch history extended back to 1900 and stocks assumed to be at B_0 in 1900 - Tag-recapture data sets condensed and reweighted	

Major Sources of Uncertainty	- Stock structure and degree of exchange between BoP and HG - Conflict between catch-at-age and tagging data - Relationship between standardised longline CPUE and abundance, because the methodology may not account for perceived changes in fishing behaviour - Temporal trends in growth rate

Qualifying Comments

Working Group and Plenary members had difficulty reaching consensus on the reliability of the 2013 assessment (with many of the issues remaining for the 2022 assessment). Some members felt the 2013 assessment was robust to uncertainties, whereas others were concerned that alternative assumptions could affect outcomes about stock status.

Fisheries Interactions

Main QMS bycatch species are trevally, red gurnard, John dory, and tarakihi. Incidental captures of sea turtles and seabirds occur in the bottom longline fisheries, including black petrel, which are ranked very high risk in the Seabird Risk Assessment (Richard et al 2020).

6. FOR FURTHER INFORMATION

Annala, J H; Sullivan, K J (Comps) (1997) Report from the Fishery Assessment Plenary, May 1997: stock assessments and yield estimates. 381 p. (Unpublished report held by NIWA library, Wellington.)

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 national marine recreational fishing survey: diary results and harvest estimates. (Unpublished New Zealand Fisheries Assessment Research Report for the Ministry of Fisheries Project REC2000-01 held by Fisheries New Zealand, Wellington.) 92 p.

Boyd, R O; Reilly, J L (2004) 1999/2000 National Marine Recreational Fishing Survey: harvest estimates. (Unpublished New Zealand Fisheries Assessment Research Report for the Ministry of Fisheries Project REC9803 held by Fisheries New Zealand, Wellington.) 28 p.

Bradford, E (1998) Harvest estimates from the 1996 national marine fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished document held by NIWA library, Wellington.)

Bull, B; Francis, R I C C; Dunn, A; Gilbert, D J; Bian, R; Fu, D (2012) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.30.2012/03/21. *NIWA Technical Report 135.* 280 p.

Bull, B; Francis, R I C C; Dunn, A; McKenzie, A; Gilbert, D J; Smith, M H (2004) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.06-2004/09/26. *NIWA Technical Report 126.* 261 p.

Davies, N M (1999) Assessment of the SNA 1 and 8 stocks for the 1997–98 fishing year. New Zealand Fisheries Assessment Research Document 1999/19. 87 p. (Unpublished document held by NIWA library, Wellington.)

Davies, N M; Gilbert, D J; McKenzie, J R (1999a) Assessment of the SNA 1 and 8 stocks for the 1998–99 fishing year. New Zealand Fisheries Assessment Research Document 1999/28. 82 p. (Unpublished document held by NIWA library, Wellington.)

Davies, N M; McKenzie, J R; Gilbert, D J (1999b) Monte Carlo estimation of bias in Petersen mark-recapture estimates for snapper (*Pagrus auratus*). New Zealand Fisheries Assessment Research Document 1999/20. 52 p. (Unpublished document held by NIWA library, Wellington.)

Davies, N M; Walsh, C; Hartill, B (1993) Estimating catch at age of snapper from west coast and Hauraki Gulf fisheries, 1992–93. Northern Fisheries Region Internal Report No. 17. 58 p. (Unpublished report held by Fisheries New Zealand, Auckland.)

Francis, M P; Langley, A D; Gilbert, D J (1995) Snapper recruitment in the Hauraki Gulf. New Zealand Fisheries Assessment Research Document 1995/17. 26 p. (Unpublished document held by NIWA library, Wellington.)

Francis, M P; Paul, L J (2013) New Zealand inshore finfish and shellfish commercial landings, 1931–82. *New Zealand Fisheries Assessment Report 2013/55.* 136 p.

Francis, R I C C (2011) Data weighting in statistical fisheries stock assessment models *Canadian Journal of Fisheries and Aquatic Sciences. 68*: 1124–1138.

Francis, R I C C; McKenzie, J R (2015a) Assessment of the SNA 1 stocks in 2012. *New Zealand Fisheries Assessment Report 2015/75.*

Francis, R I C C; McKenzie, J R (2015b) Assessment of the SNA 1 stocks in 2013. *New Zealand Fisheries Assessment Report 2015/76.*

Froese, R; Pauly, D (2000) FishBase 2000: concepts, design and data sources. ICLARM, Los Banos, Laguna, Philippines. 344 p.

Gilbert, D J (1994) A total catch history model for SNA 1. New Zealand Fisheries Assessment Research Document 1994/24. 16 p. (Unpublished document held by NIWA library, Wellington.)

Gilbert, D J; McKenzie, J R (1999) Sources of bias in biomass estimates from tagging programmes in the SNA 1 snapper (*Pagrus auratus*) stock. New Zealand Fisheries Assessment Research Document 1999/16. 47 p. (Unpublished document held by NIWA library.)

Gilbert, D J; McKenzie, J R; Davies, N M; Field, K D (2000) Assessment of the SNA 1 stocks for the 1999–2000 fishing year. *New Zealand Fisheries Assessment Report 2000/38.* 52 p.

Gilbert, D J; Sullivan, K J (1994) Stock assessment of snapper for the 1992–93 fishing year. New Zealand Fisheries Assessment Research Document 1994/3. 37 p. (Unpublished document held by NIWA library, Wellington.)

Gilbert, D J; Sullivan, K J; Davies, N M; McKenzie, J R; Francis, M P; Stan, P J (1996) Population modelling of the SNA 1 stock for the 1995–96 fishing year. New Zealand Fisheries Assessment Research Document 96/15. 39 p. (Unpublished document held by NIWA library, Wellington.)

Hartill, B; Bian, R; Armiger, H; Vaughan, M; Rush, N (2007a) Recreational marine harvest estimates of snapper, kahawai, and kingfish in QMA 1 in 2004–05. *New Zealand Fisheries Assessment Report 2007/26.* 44 p.

Hartill, B; Bian, R; Rush, N; Armiger, H (2013) Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2011–12. *New Zealand Fisheries Assessment Report 2013/70.* 49 p.

Hartill, B; Bian, R; Rush, N; Armiger, H (2019) Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2017–18. *New Zealand Fisheries Assessment Report 2019/23.* 39 p.

Hartill, B; Watson, T; Cryer, M; Armiger, H (2007b) Recreational marine harvest estimates of snapper and kahawai in the Hauraki Gulf in 2003–04. *New Zealand Fisheries Assessment Report 2007/25*. 55 p.

Holdsworth, J C; Boyd, R O (2008) Size, condition and estimated release mortality of snapper (*Pagrus auratus*) caught in the SNA 1 recreational fishery, 2006–07. *New Zealand Fisheries Assessment Report 2008/53*. 37 p.

Jones, E; Morrison, M; Parsons, D M; Paterson, C; Usmar, N; Bagley, N (2010) Fish communities (Chapter 13). Oceans 2020 Bay of Islands Survey report to LINZ prepared by NIWA. 98 p.

Kendrick, T H; Francis, M P (2002) Fish assemblages in the Hauraki Gulf, New Zealand. *New Zealand Journal of Marine and Freshwater Research 36*: 699–717.

King, M R (1985) Fish and shellfish landings by domestic fishermen, 1974–82. *Fisheries Research Division Occasional Publication: Data Series 20*. 96 p.

King, M R (1986) Catch statistics for foreign and domestic commercial fishing in New Zealand waters, January–December, 1983. *Fisheries Research Division Occasional Publication: Data Series 21*. 140 p.

King, M R; Jones, D M; Fisher, K A; Sanders, B M (1987) Catch statistics for foreign and domestic commercial fishing in New Zealand waters, January – December 1984. *New Zealand Fisheries Data Report No. 30*. 150 p.

Langley, A D (1995a) Trawl survey of snapper and associated species in the Hauraki Gulf, October–November 1994 (KAH9411). *New Zealand Fisheries Data Report No. 61*. 35 p.

Langley, A D (2016) An update of the analysis of longline Catch-Per-Unit-Effort indices for snapper in SNA 1. *New Zealand Fisheries Assessment Report 2016/17*. 71 p.

Maunder, M N; Starr, P J (1995) Validating the Hauraki Gulf snapper pre-recruit trawl surveys and temperature recruitment relationship using catch at age analysis with auxiliary information. New Zealand Fisheries Assessment Research Document 1998/15. (Unpublished document held by NIWA library, Wellington.)

McKenzie, J R (2000) Factors Affecting Mortality of small Snapper (*Pagrus auratus*) caught and released by the SNA 1 Longline Fishery. (Draft Fisheries Assessment Report held by NIWA Library, Wellington.)

McKenzie, J R (2012) An evaluation of a fully age-structured spatially disaggregated stock assessment model for the SNA 1 QMA. *New Zealand Fisheries Assessment Report 2012/38*. 120 p.

McKenzie, J R; Diggles, B; Tubbs, L; Poortenaar, C; Parkinson, D; Webster, K; Miller, N (2006) An evaluation of a new type of plastic-coated PIT tag for tagging snapper (*Pagrus auratus*). *New Zealand Fisheries Assessment Report 2006/8*. 40 p.

McKenzie, J R; Parsons, D M (2012) Fishery characterisations and catch-per-unit-effort indices for three sub-stocks of snapper SNA 1, 1989–90 to 2009–10. *New Zealand Fisheries Assessment Report 2012/29*. 112 p.

Methot, R D (1990) Synthesis model: an adaptable framework for analysis of diverse stock assessment data. *International North Pacific Fisheries Commission Bulletin 50*: 259–275.

Methot, R D (2005) Technical description of the Stock Synthesis II assessment program. NOAA Technical Memorandum SEDAR 16-AW-04.

Methot, R D (2009) User manual for Stock Synthesis, model version 3.02C.

Methot, R D; Wetzell, C R (2013) Stock Synthesis: A biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research 142*: 86–99.

Millar, R B; Akroyd, J M; Walshe, K A R (2001) Incidental mortality of snapper in SNA 1 and SNA 8. *New Zealand Fisheries Assessment Report 2001/78*. 36 p.

Ministry of Fisheries (2008) Harvest Strategy Standard for New Zealand Fisheries. 25 p. Available online at: https://fs.fish.govt.nz/Doc/16543/harveststrategyfinal.pdf.ashx

Morrison, M (1997) Trawl survey of snapper and associated species in the Bay of Plenty, February 1996 (KAH9601). *NIWA Technical Report 2*. 33 p.

Morrison, M A; Francis, M P (1997) Trawl survey of snapper and associated species in the Hauraki Gulf, October–November 1997 (KAH9720). *NIWA Technical Report 58*. 37 p.

Parsons, D M; Bian, R (in prep) Trawl surveys of the Hauraki Gulf and Bay of Plenty in 2019, 2020 and 2021 to estimate the abundance of juvenile snapper. Draft New Zealand Fisheries Assessment Report.

Paul, L J (1976) A study on age, growth and population structure of the snapper, *Chrysophrys auratus* in Hauraki Gulf. *New Zealand Fisheries Research Bulletin No. 13*. 63 p.

Paul, L J (1977) The commercial fishery for snapper *Chrysophrys (Pagrus) auratus* in the Auckland region, New Zealand, from 1900 to 1971. *Fisheries Research Division Bulletin No 15*. 84 p.

Richard, Y; Abraham, E; Berkenbusch, K (2020) Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2016–17. *New Zealand Aquatic Environment and Biodiversity Report 237*. 57 p.

Ritchie, L; Saul, P; O'Sullivan, K. (1975) The wetfish report 1941–1970. *New Zealand Ministry of Agriculture and Fisheries Fisheries Technical Report 137*. 370 p.

Sullivan, K J (1985) Snapper. *In:* Colman, J A; McKoy, J L; Baird, G G (Comps and Eds) (1985) Background papers for the 1985 Total Allowable Catch recommendations, pp. 187–214. (Unpublished report, held in NIWA library, Wellington.)

Sullivan, K J; Hore, A J; Wilkinson, V H (1988) Snapper. *In:* Baird, G G; McKoy, J L Papers from the workshop to review fish stock assessments for the 1987–88 New Zealand fishing year, pp. 251–275. (Unpublished report, held in NIWA library, Wellington.)

Sylvester, T (1995) Initial results of the Northern boat ramp survey. *Seafood New Zealand*, February 1995. pp. 11–13.

Teirney, L D; Kilner, A R; Millar, R B; Bradford, E; Bell, J D (1997) Estimation of recreational harvests from 1991–92 to 1993–94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished document held by NIWA library, Wellington.)

Walsh, C; Davies, N M; Rush, N; Buckthought, D; Smith, M (2006b) Age composition of commercial snapper landings in SNA 1, 2004–05. *New Zealand Fisheries Assessment Report 2006/39*. 34 p.

Walsh, C; Davies, N M; Rush, N; Buckthought, D; Vaughn, M; Smith, M (2007) Length and age composition of commercial snapper landings in SNA 1, 2005–06. *New Zealand Fisheries Assessment Report 2007/01*. 30 p.

Walsh, C; Davies, N M; Rush, N; Middleton, C; Smith, M; Newmarch, G (2006c) Length and age composition of commercial snapper landings in SNA 1, 2003–04. *New Zealand Fisheries Assessment Report 2006/7*. 46 p.

Walsh, C; McKenzie, J A; Buckthought, D; Armiger, H; Ferguson, H; Smith, M; Spong, K; Miller, A (2011) Age composition of commercial snapper landings in SNA 1, 2009–10. *New Zealand Fisheries Assessment Report 2011/54*.

Walsh, C; Parsons, D; Bian, R; McKenzie, J; Armiger, H; Evans, O; Taylor, R; Buckthought, D; Smith, M; Spong, K (in press) Age composition of commercial snapper landings in SNA 1 and SNA 2, 2019–20.

Wright, P; McClary, D; Boyd, R O (2004) 2000/2001 National Marine Recreational Fishing Survey: direct questioning of fishers compared with reported diary data. Final Research Report for Ministry of Fisheries Project REC2000-01: Objective 2. (Unpublished report held by Fisheries New Zealand, Wellington.)

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24*. 104 p.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.

SNAPPER (SNA 2)

(*Chrysophrys auratus*)
Tamure, Kouarea
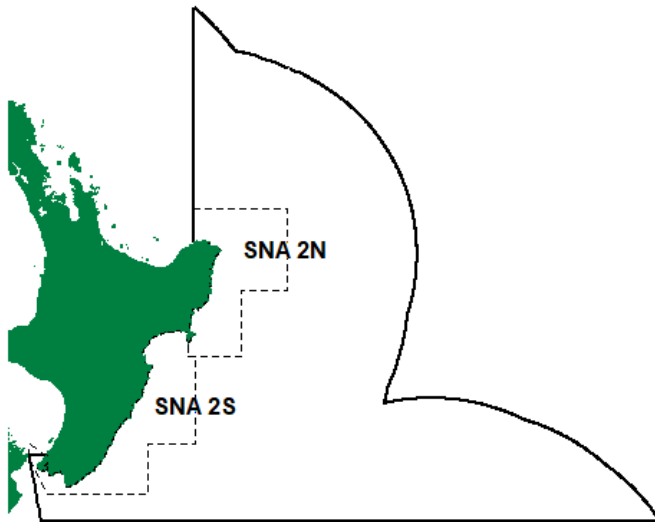
1. FISHERIES SUMMARY

1.1 Commercial fisheries

Table 1 and Table 2 provide a summary of the reported commercial catches, TACCs, and TACs for SNA 2. Landings and TACC are plotted in Figure 1.

Table 1: Reported landings (t) of snapper from SNA 2 from 1931 to 1990.

Year	Landings (t)	Year	Landings (t)	Year	Landings (t)
1931–32	0	1951	265	1971	861
1932–33	0	1952	220	1972	878
1933–34	21	1953	247	1973	798
1934–35	168	1954	293	1974	716
1935–36	149	1955	309	1975	732
1936–37	78	1956	365	1976	732
1937–38	114	1957	452	1977	374
1938–39	122	1958	483	1978	454
1939–40	100	1959	372	1979	662
1940–41	103	1960	487	1980	636
1941–42	148	1961	589	1981	283
1942–43	74	1962	604	1982	160
1943–44	60	1963	636	1983	160
1944	49	1964	667	1984	227
1945	59	1965	605	1985	208
1946	77	1966	744	1986	255
1947	36	1967	856	1987	122
1948	53	1968	765	1988	165
1949	215	1969	837	1989	227
1950	285	1970	804	1990	429

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. The 'QMA totals' are approximations derived from port landing subtotals, as follows: SNA 2 Gisborne to Wellington/Makara
3. Before 1946 the 'QMA' subtotals sum to less than the New Zealand total because data from the complete set of ports are not available.
4. Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.
5. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings.

Table 2: **Reported landings (t) of snapper from SNA 2 from 1983–84 to present and gazetted and actual TACCs (t) for 1986–87 to present. QMS data from 1986–present.**

Fishstock FMAs	SNA 2 2	
	Landings	TACC
1983–84†	145	–
1984–85†	163	–
1985–86†	177	–
1986–87	130	130
1987–88	152	137
1988–89	210	157
1989–90	364	157
1990–91	428	157
1991–92	373	157
1992–93	324	252
1993–94	307	252
1994–95	308	252
1995–96	280	252
1996–97	351	252
1997–98	286	252
1998–99	283	252
1999–00	390	252
2000–01	360	252
2001–02	252	252
2002–03	334	315
2003–04	339	315
2004–05	399	315
2005–06	389	315
2006–07	329	315
2007–08	328	315
2008–09	307	315
2009–10	296	315
2010–11	320	315
2011–12	358	315
2012–13	310	315
2013–14	313	315
2014–15	271	315
2015–16	321	315
2016–17	373	315
2017–18	373	315
2018–19	364	315
2019–20	330	315
2020–21	321	315

† FSU data. SNA 2 = Statistical Areas 011–016

In SNA 2, snapper is primarily caught as a bycatch of the tarakihi and gurnard bottom trawl fisheries and, more intermittently, in the gurnard target Danish seine fishery. From 1 October 2002, the TACC for SNA 2 was increased from 252 t to 315 t, within a total TAC of 450 t (Table 3). Nevertheless the 315 t TACC has regularly been over-caught since 1987–88, except in the fishing years 2008–09 to 2009–10 and 2012–13 to 2014–15. The minimum legal size (MLS) for snapper in SNA 2 is 25 cm.

Table 3: **TACs, TACCs, and allowances (t) for SNA 2 from 1 October 2021.**

Fishstock	TAC	TACC	Customary allowance	Recreational allowance	Other mortality
SNA 2	450	315	14	90	31
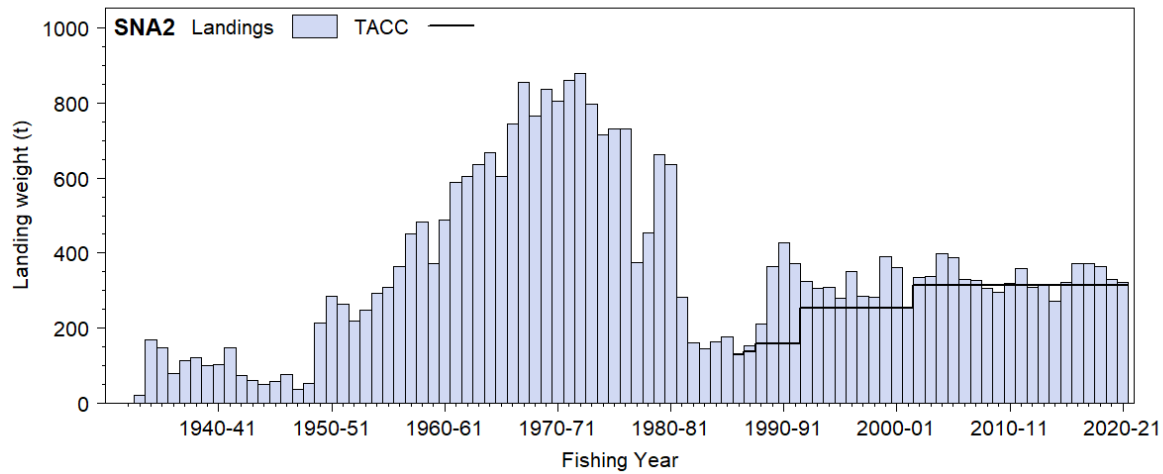
Figure 1: Total reported landings and TACCs for SNA 2.

1.2 Recreational fisheries

The snapper fishery is the largest recreational fishery in New Zealand. It is the major target species on the northeast and northwest coasts of the North Island and is targeted seasonally around the rest of the North Island and the top of the South Island. The current allowance within the SNA 2 TAC is shown in Table 3.

1.2.1 Management controls

The two main methods used to manage recreational harvests of snapper are minimum legal size limits (MLS) and daily bag limits. Both have changed over time (Table 4). The number of hooks permitted on a recreational longline was reduced from 50 to 25 in 1995.

Table 4: Changes to minimum legal size limits (MLS) and daily bag limits used to manage recreational harvesting levels in SNA 2.

Stock	MLS	Bag limit	Introduced
SNA 2	25	30	1/01/1985
SNA 2	27	10	1/10/2005

1.2.2 Estimates of recreational harvest

A background to the estimation on recreational harvest of snapper is provided in the Introduction – Snapper chapter. Recreational harvest estimates for SNA 2 are provided in Table 5a. Partitioned between the SNA 2 sub-areas, the 2017–18 panel survey provides estimates of recreational harvest from SNA 2N of 35 t and SNA 2S of 58 t (Bruce Hartill, NIWA, pers. comm.).

Table 5a: Recreational catch estimates for SNA 2. Totals for a stock are given in bold. The telephone/diary surveys ran from December to November but are denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey catch estimates). Numbers and mean weights are not calculated in the tag ratio method. Includes charter boat catch and panel survey estimates of s111 catches.

Stock	Year	Method	Number of fish (thousands)	Mean weight (g)	Total weight (t)	CV
SNA 2						
Total	1993	Telephone/diary	28	1 282	**36**	–
Total	1996	Telephone/diary	31	1 282[2]	**40**	–
Total	2000	Telephone/diary	268	1 200[4]	**322**	–
Total	2001	Telephone/diary	144	–[5]	**173**	–
Total	2011–12	Panel survey	55	1 027	**57**	0.25
Total	2017–18	Panel survey	83	1 117	**93**	0.24

[2] Mean weight obtained from 1992–93 boat ramp sampling.
[4] Mean weight obtained from 1999–2000 commercial landed catch sampling.
[5] The 2000 mean weights were used in the 2001 estimates.

Web camera/creel survey monitoring has been undertaken within SNA 2 since 2014–15 (monitoring at Napier and Gisborne). These data show a generally increasing trend in snapper harvest, but since the series only overlaps with one National Panel Survey (2017–18), scaled estimates of annual harvest (Table 5b) from the relative boat ramp harvest index should be considered preliminary (B. Hartill, pers. comm.).

Table 5b: Preliminary recreational catch estimates for SNA 2, split by SNA 2N and SNA 2S, on basis of National Panel Survey and web camera/creel survey monitoring.

Year	SNA 2N	SNA 2S	SNA 2	source
2011–12	29.5	26.3	55.8	NPS
2012–13				
2013–14				
2014–15	10.9	25.8	36.7	Scaled creel survey
2015–16	18.4	33.6	52.0	Scaled creel survey
2016–17	13.9	36.5	50.4	Scaled creel survey
2017–18	35.2	57.9	93.1	NPS
2018–19	41.8	87.8	129.7	Scaled creel survey
2019–20	34.6	43.8	78.4	Scaled creel survey
2020–21	53.1	60.5	113.6	Scaled creel survey

1.3 Customary non-commercial fisheries

Snapper form important fisheries for customary non-commercial fisheries, but the annual catch is not known. The information on Māori customary harvest under the provisions made for customary fishing is limited and it is likely that Māori customary fishers utilise the provisions under recreational fishing regulations.

1.4 Illegal catch

No new information is available to estimate illegal catch.

1.5 Other sources of mortality

With the introduction of Electronic Reporting in 2019, commercial fishers must provide comprehensive reporting of all discards and returns. All fish under the minimum legal size ("sub-MLS fish") must be returned to the sea; in SNA 2 reported quantities of sub-MLS snapper have been small (1–3 t in 2020 and 2021).

2. BIOLOGY

For further information on snapper biology refer to the Introduction – Snapper chapter. A summary of published estimates of biological parameters for SNA 2 is presented in Table 6.

Table 6: Estimates of biological parameters.

Fishstock	Estimate			Source
1. Instantaneous rate of natural mortality (M)				
SNA 1, 2, 7, & 8	0.075			Hilborn & Starr (unpub. analysis)
2. Weight $= a(\text{length})^b$ (Weight in g, length in cm fork length)				
All	$a = 0.04467$	$b = 2.793$		Paul (1976)
3. von Bertalanffy growth parameters				
	Both sexes combined			
	K	t_0	L_∞	
SNA 2N	0.027	-8.85	98.7	Walsh et al (2012)
SNA 2S	0.097	-2.02	71.7	Walsh et al (2012)

3. STOCKS AND AREAS

A review of catch at age data collected from SNA 2 in 2008 and 2009 found differences in length and age structure, year class strength and growth for snapper in northern and southern subareas of SNA 2 (Walsh et al 2012). The boundary between the areas was defined as the Mahia Peninsula, with most catch from the northern area landed and sampled in Gisborne, and from the southern area in Napier. Previous genetic sampling (Smith et al 1978) suggested snapper in Hawke Bay were genetically more similar to snapper on the west coast of the North Island than other east coast snapper, and that there was an indication of stock mixing at East Cape between the Bay of Plenty and northern SNA 2. Walsh et al (2012) concluded that there was evidence that the northern and southern areas in SNA 2 represented separate sub-stocks with minor level of mixing and migration occurring between the northern area of SNA 2 and the Bay of Plenty, similar to that seen between the sub-stocks of SNA 1.

4. STOCK ASSESSMENT

A full quantitative stock assessment was completed for SNA 2 in 2009 (Langley 2010). This assessment is not reported here because it assumed that SNA 2 comprised a single biological stock and the Plenary gave it a quality ranking of '2' at the time of review. In 2017, standardised CPUE indices for the two sub-stocks were derived using data from the mixed target bottom trawl fishery for the recent period of the fishery (2001–02 to 2015–16).

4.1 Standardised CPUE

In 2017, Schofield et al (2018a) completed a standardised CPUE analysis for the two sub-stocks of SNA 2 using commercial catch and effort data from the bottom trawl fishery. Two data series were considered: vessel-day records from TCER, TCELR, and CELR (pre-2008) forms aggregated using the Langley method (Langley 2014); and tow by tow records from TCER and TCELR forms. The analysis included tows targeting snapper, trevally, tarakihi, and red gurnard and was limited to Hawke Bay and north, because there were very limited catches of snapper in the southern and eastern areas of SNA 2.

Due to changes in regulations and reporting behaviour between 1989–90 and 2001–02, data from this period were excluded from the analysis. Throughout this period the SNA 2 TACC was consistently over-caught, in 2000 Annual Catch Entitlement was introduced, in 2001 differential deemed values were introduced, and in 2002 the SNA 2 TACC was increased to 325 t.

The boundary between the northern and southern sub-stocks was assumed to lie off the southern tip of Mahia Peninsula, splitting Statistical Area 013 into Eastern and Western sub-areas at 177.87° E. A classification partitioning model was used to allocate catch and effort reported from Statistical Area 013 on CELR forms to one of the two sub-stocks, trained using the high-resolution data available since 2007. The partition tree used landing port for the primary split and then target species as a secondary split when landing port was not Auckland, Gisborne, or Tauranga. Actual area (013W or 013E) was correctly assigned for 88.9% of records in the training dataset.

A Generalised Linear Modelling (GLM) approach was applied to model the occurrence of snapper catches (presence/absence) and the magnitude of positive snapper catches. The dependent variable of the catch magnitude CPUE models was the natural logarithm of catch. For the positive catch CPUE models, a Weibull error structure was adopted following an evaluation of alternative distributions. The presence/absence of snapper catch was modelled based on a binomial distribution. The range of potential explanatory variables included vessel, fishing year, month, location, depth, target species, trawl speed, trawl distance, and trawl duration.

The Inshore WG adopted the combined vessel day CPUE indices as indices of abundance for the SNA 2 sub-stocks (22 June 2017). These indices were updated in 2018 (Schofield et al 2018b) to include data to 30 September 2017.

The daily (pseudo-CELR) and event-based CPUE indices for SNA 2N and SNA 2S were updated in 2022, with data to 30 September 2021 and minor modifications:

- the core vessel selection required that vessels caught at least 100 kg over the course of the series rather than at least 1 kg on each trip counted in the core vessel trips/years criterion;
- interaction terms between statistical area and month were eliminated, as these caused estimation problems in the lower effort areas and did not materially change the indices;
- the error distributions were modified from Weibull to lognormal in the SNA 2S daily index and gamma in the SNA 2N event index due to slightly improved diagnostics; and
- southern statistical areas (the Wairarapa coast) were included in the SNA 2S model after observations of slightly increased catches from these areas.

The daily series for the northern sub-stock increased from 2002 to 2006, declined from 2006 to 2010 then, following a period of stability from 2010 to 2016, increased to 2020 with a small decline evident to 2021 (Figure 2). The southern sub-stock also was also at a higher level from 2002 to 2006, then declined substantially from 2006 to 2008. It showed a slower decline from 2008 to 2016, before increasing at a similar rate to SNA 2N with the increase continuing to 2021.

The event-based series, beginning in 2008, show very similar trends to the daily series for the common years (Figure 2). While the 2002 start date implies the SNA 2 CPUE series are relatively short, trends in abundance in the northern and southern areas are similar, but the variation in SNA 2S has been greater, reaching higher relative abundance in the early 2000s, and in 2021, and a lower relative abundance in 2013 -2016.

Unstandardised recreational harvest rates from creel surveys at boat ramps in Gisborne and Napier show similar trends to commercial CPUE from 2015 to 2021 (Figure 3).
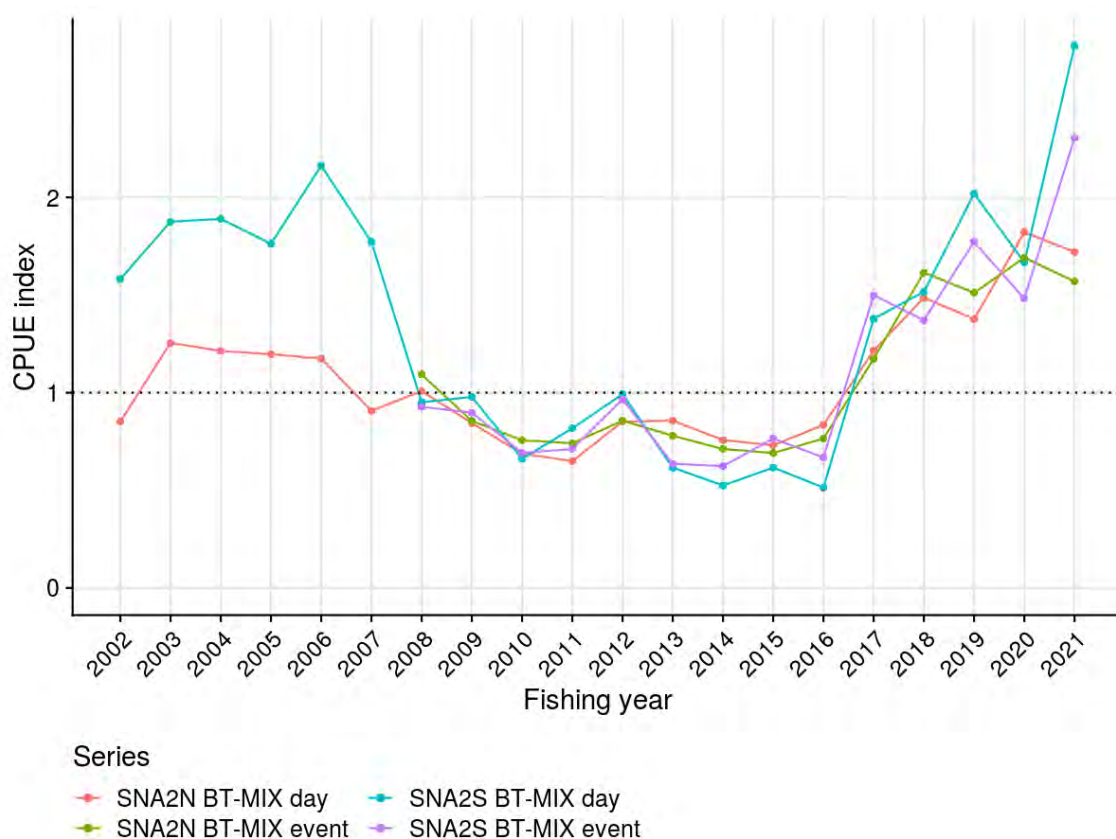
Figure 2: Comparison of standardised combined catch per unit effort (CPUE) indices for the northern and southern sub-stocks of SNA 2 from bottom trawling targeting gurnard, snapper, tarakihi, and trevally combined over all form types and aggregated to CELR resolution (BT-MIX daily), and from data reported at the event level (BT-MIX event). Series are scaled relative to the geometric mean of the years they have in common. Fishing years are labelled according to the second calendar year, e.g., 2002 = 2001–02.
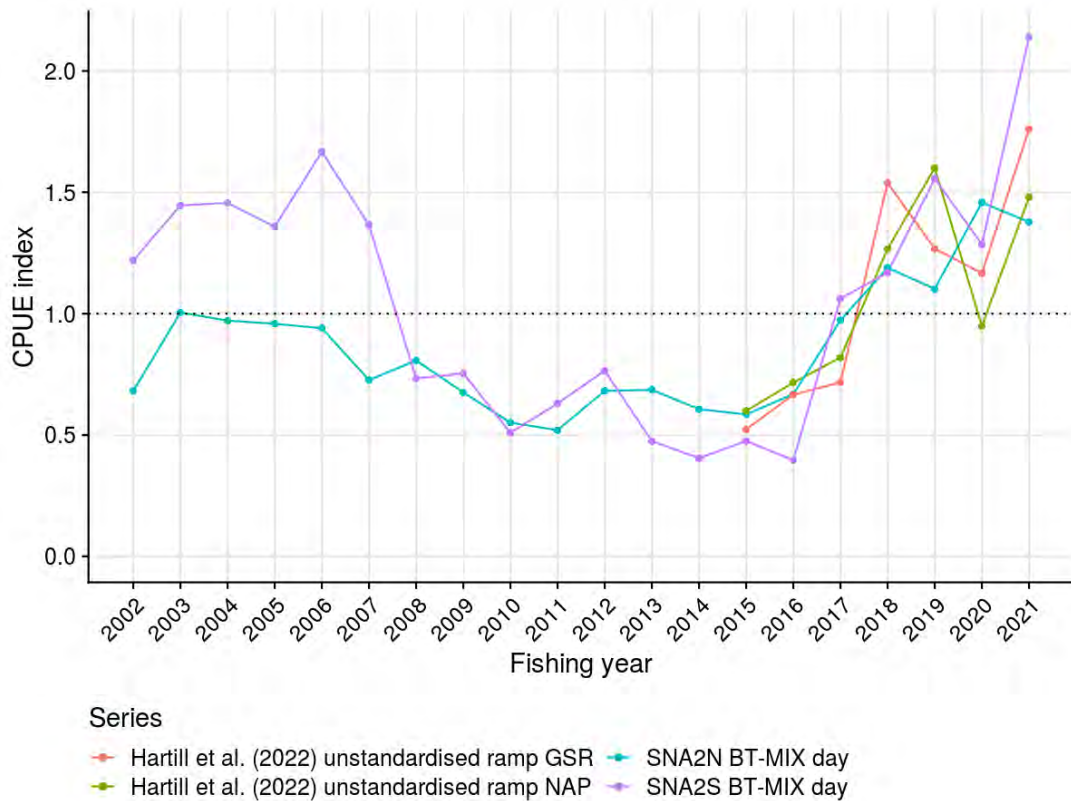
Figure 3: Comparison of standardised combined catch per unit effort (CPUE) indices for the northern and southern sub-stocks of SNA 2 from bottom trawling targeting gurnard, snapper, tarakihi, and trevally combined over all form types and aggregated to CELR resolution (BT-MIX daily) with unstandardised recreational harvest rates from monitoring of boat ramps in Gisborne (GSR) and Napier (NAP). Fishing years are labelled according to the second calendar year, e.g., 2002 = 2001–02.

Establishing B_{MSY} compatible reference points

In 2022, the Inshore Working Group adopted geometric mean standardised CPUE from the BT-MIX event-resolution model for the period 2008 to 2012 as the soft limit reference point for SNA 2S. This period had stable catch and standardised CPUE. The historical catch suggested that the stock was at a low point in the early 1980s. The longer daily resolution index (beginning in 2002) indicated that the stock was higher prior to the reference period, but it was thought that it was unlikely it had recovered to be substantially higher than the target by that time. The Working Group adopted the default Harvest Strategy Standard definitions for the target and hard limit of twice and half the soft limit, respectively. No reference point was adopted for SNA 2N, pending further work contracted as part of the SNA 1 stock assessment.

4.2   Catch at age data

Seven years of age frequency data were available from the commercial fisheries for the 2009 assessment. There was considerable variability in the age compositions among years, likely due in part to the sampling of the snapper bycatch from a number of different target fisheries. The age compositions were principally composed of younger age classes and few old fish were sampled from the catch. There are concerns regarding the representative nature of the sampling and comparability of the ageing in earlier years.

A further commercial catch sampling programme was conducted in the 2007–08 and 2008–09 fishing years (Walsh et al 2012). The study found evidence for two sub-stocks within SNA 2: a northern stock located between Mahia Peninsula and Cape Runaway, and a southern stock within Hawke Bay. Walsh et al (2012) demonstrated that, although strong year classes were consistent between stocks, a range of year classes were present in the northern area (similar to the eastern Bay of Plenty), whereas the southern area was dominated by a few strong year classes. Snapper from the southern sub-stock grew considerably faster than those from the northern sub-stock weighing 50–60% more at any given age.

Catch sampling was carried out in 2020, in the northern subarea only. Results suggest a higher proportion of 20+ fish in 2020 than in 2008 and 2009.

Future research considerations

- The pre-QMS catch history for SNA 2 requires partitioning between the northern and southern areas.
- Estimation of recreational catch histories from 2008 from the national panel survey estimates and boat ramp monitoring and other information for SNA 2N and SNA2S, based on assumption recreational catch is proportional to biomass.
- Develop fishing intensity series and reference point including recreational harvest.
- Catch sampling in both northern and southern areas is required to allow similarities and differences in year class strengths to be assessed for years other than 2008 and 2009, and to establish whether changes in growth rates observed in other snapper fisheries have also occurred in SNA 2.
- Stock assessments, including catch at age information for years prior to 2008 - which is yet to be partitioned into the two sub-stocks - and recent catch at age from SNA 2N, may be feasible.
- Further analyse information informing stock structure, including the recent genetics information for SNA stocks (VUW study).
- Explore sensitivity of the index to the composition of the core fleet.

5.   STATUS OF THE STOCKS

Stock Structure Assumptions

SNA 2 is assumed to occur in two sub-stocks. The northern sub-stock occurs between the southern tip of the Mahia Peninsula and Cape Runaway and may be associated with the SNA 1 Bay of Plenty stock. The southern sub-stock occurs within Hawke Bay and may be peripheral to the northern stock rather than entirely discrete. The majority of the SNA 2 catch is taken from the northern sub-stock, and this is assumed to be the primary stock in SNA 2.

- **SNA 2N**

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Standardised combined CPUE (positive + binomial) model based on SNA, TRE, GUR, and TAR target single trawl pseudo-CELR data
Reference Points	Target: B_{MSY}-compatible proxy based on CPUE: not determined Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: F_{MSY}
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status

(a)

(b)

(a) Annual commercial removals for SNA 2N; (b) the standardised catch per unit effort (CPUE) index for SNA 2N from trawling targeting gurnard, snapper, tarakihi and trevally.

Fisheries and Stock Trends

Recent Trend in Biomass or Proxy	The standardised CPUE index was relatively stable between 2008 and 2016 then increased 2.5 times in the period to 2020.
Recent Trend in Fishing Mortality or Proxy	Relative exploitation rate decreased steadily from 2011 to 2021.
Other Abundance Indices	Unstandardised recreational CPUE from 2015 to 2021 increased three-fold and was similar to the trend in standardised commercial CPUE.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis

Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For current (1 October 2021) catch levels: Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing overfishing to continue or to commence	Unknown

Assessment Methodology

Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Standardised single trawl CPUE index of abundance	1 – High Quality
Data not used (rank)	N/A	

SNAPPER (SNA 2)

Changes to Model Structure and Assumptions	-
Major Sources of Uncertainty	-

Qualifying Comments

Recreational harvest was 13% of removals in 2018 but the full recreational catch history is not known. The pattern in exploitation rate from commercial removals is only correct if recreational harvest is a constant proportion of removals.

Fisheries Interactions

Snapper is principally a bycatch of the tarakihi bottom trawl fishery in SNA 2N.

- **SNA 2S**

Stock Status

Year of Most Recent Assessment	2022
Assessment Runs Presented	Standardised combined CPUE (positive + binomial) models based on SNA, TRE, GUR, and TAR target single trawl event resolution and pseudo-CELR resolution data
Reference Points	Management Target: 40% B_0, interpreted as twice the geometric mean standardised CPUE from the event resolution model for the period 2008–2012 Soft Limit: geometric mean standardised CPUE in the period 2008–2012 Hard Limit: 50% of the soft limit Overfishing threshold: Half the relative exploitation rate in 2008–2012
Status in relation to Target	About as Likely as Not (40–60%) to be at or above the target in 2021
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status

(a) Annual commercial removals for SNA 2S; (b) the standardised event resolution catch per unit effort (CPUE) index (black line), relative to the agreed reference points, for SNA 2S from trawling targeting gurnard, snapper, tarakihi and trevally. Reference period by blue vertical dashed lines. Longer daily resolution standardised CPUE index shown in grey.

1566

Fisheries and Stock Trends	
Recent Trend in Biomass or Proxy	The standardised CPUE index declined slowly between 2008 and 2016 then increased three-fold to 2021.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	- Unstandardised recreational CPUE from 2015 to 2021 increased 2.5 times and was similar to the trend in standardised commercial CPUE.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing overfishing to continue or to commence	Unknown

Assessment Methodology		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Standardised single trawl CPUE index of abundance	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Reference points developed on event resolution standardised CPUE index	
Major Sources of Uncertainty	- Recreational harvest was 54% of removals in 2018 but the full recreational catch history is not known. Relative exploitation rate could not therefore be calculated.	

Qualifying Comments
The standardised CPUE index in the final year was given less weight in the assessment of stock status because it showed a large increase and was relatively poorly estimated.

Fisheries Interactions
Snapper is principally a bycatch of the red gurnard bottom trawl fishery in SNA 2S. Anecdotal feedback from fishers indicates that the operation of this fishery is constrained by the SNA 2 TACC.

6.   FOR FURTHER INFORMATION

Annala, J H; Sullivan, K J (Comps.) (1997) Report from the Fishery Assessment Plenary, May 1997: stock assessments and yield estimates. 381 p. (Unpublished report held by NIWA library, Wellington.).

Bentley, N; Kendrick, T H (2015). The inshore fisheries of the Central (East) fisheries management area (FMA2): characterisation and catch-per-unit-effort analyses, 1989–90 to 2009–10 Draft New Zealand Fisheries Assessment Report for Research Project INS2009/03. (Unpublished report held by Fisheries New Zealand, Wellington.)

Blackwell, R G; Gilbert, D J (2006) Age composition of commercial snapper landings in SNA 2, 2004–05. *New Zealand Fisheries Assessment Report 2006/46*. 18 p.

Blackwell, R G; McKenzie, J R (2013). Age composition of commercial snapper landings in SNA 2, 2007–08. *New Zealand Fisheries Assessment Report 2013/25*. 32 p.

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 national marine recreational fishing survey: diary results and harvest estimates. . Final Research Report for Ministry of Fisheries. (Unpublished report held by Fisheries New Zealand, Wellington.) 93 p.

Boyd, R O; Reilly, J L (2002) 1999/2000 National marine recreational fishing survey: harvest estimates. Final Research Report for Ministry of Fisheries Research Project REC9803. (Unpublished report held by Fisheries New Zealand, Wellington.)

Bradford, E (1998) Harvest estimates from the 1996 national marine fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished document held by NIWA library, Wellington.)

Bull, B; Francis, R I C C; Dunn, A; Gilbert, D J; Bian, R; Fu, D (2012) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.30.2012/03/21. *NIWA Technical Report 135*. 280 p.

Bull, B; Francis, R I C C; Dunn, A; McKenzie, A; Gilbert, D J; Smith, M H (2004) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.06-2004/09/26. *NIWA Technical Report 126*. 261 p.

Francis, M P; Paul, L J (2013) New Zealand inshore finfish and shellfish commercial landings, 1931–82. *New Zealand Fisheries Assessment Report 2013/55*. 136 p.

Francis, R I C C (2011) Data weighting in statistical fisheries stock assessment models *Canadian Journal of Fisheries and Aquatic Sciences*. 68: 1124–1138.

Froese, R; Pauly, D (2000) FishBase 2000: concepts, design and data sources. ICLARM, Los Banos, Laguna, Philippines. 344 p.

Gilbert, D J; Phillips, N L (2003) Assessment of the SNA 2 and Tasman and Golden Bays (SNA 7) snapper fisheries for the 2001–02 fishing year. *New Zealand Fisheries Assessment Report 2003/45*.

Gilbert, D J; Sullivan, K J (1994) Stock assessment of snapper for the 1992–93 fishing year. New Zealand Fisheries Assessment Research Document 1994/3. 37 p. (Unpublished document held by NIWA library, Wellington.)

Gilbert, D J; Taylor, P R (2001) The relationships between snapper (*Pagrus auratus*) year class strength and temperature for SNA 2 and SNA 7. *New Zealand Fisheries Assessment Report 2001/64*. 33 p.

Hartill, B; Sutton, C (2011) Characterisation and catch per unit effort indices for the SNA 7 fishery. *New Zealand Fisheries Assessment Report 2011/53*. 55 p.

King, M R (1985) Fish and shellfish landings by domestic fishermen, 1974–82. *Fisheries Research Division Occasional Publication: Data Series 20*. 96 p.

King, M R (1986) Catch statistics for foreign and domestic commercial fishing in New Zealand waters, January–December, 1983. *Fisheries Research Division Occasional Publication: Data series 21*. 140 p.

King, M R; Jones, D M; Fisher, K A; Sanders, B M (1987) Catch statistics for foreign and domestic commercial fishing in New Zealand waters, January – December 1984. *New Zealand Fisheries Data Report No. 30*. 150 p.

Langley, A D (2010) Stock assessment of SNA 2 for 2010. *New Zealand Fisheries Assessment Report 2010/26*.

Ministry of Fisheries (2008). Harvest Strategy Standard for New Zealand Fisheries. 25 p. Available online at: https://fs.fish.govt.nz/Doc/16543/harveststrategyfinal.pdf.ashx

Ritchie, L; Saul, P; O'Sullivan, K. (1975) The wetfish report 1941–1970. *New Zealand Ministry of Agriculture and Fisheries Fisheries Technical Report 137*. 370 p.

Schofield, M I; Langley, A D; Bentley, N; Middleton, D A J (2018a) Catch-per unit-effort (CPUE) analyses for SNA 2. *New Zealand Fisheries Assessment Report 2018/15*. 87 p.

Schofield, M I; Langley, A D; Middleton, D A J (2018b) Catch-per unit-effort (CPUE) update for FMA 2 snapper (SNA 2). Report for Fisheries Inshore New Zealand. https://www.inshore.co.nz/fileadmin/Documents/Science/SNA2_rapidCPUEupdate_2018.pdf

Smith, P J; Francis, R I C C; Paul, L J (1978) Genetic variation and population structure in the New Zealand snapper. *New Zealand Journal of Marine and Freshwater Research*, 12: 343-350.

Sullivan, K J (1985) Snapper. *In:* Colman, J A; McKoy, J L; Baird, G G (Comps. and Eds.) (1985) Background papers for the 1985 Total Allowable Catch recommendations, pp. 187–214. (Unpublished report, held in NIWA library, Wellington.)

Sullivan, K J; Hore, A J; Wilkinson, V H (1988) Snapper. *In:* Baird, G G; McKoy, J L Papers from the workshop to review fish stock assessments for the 1987–88 New Zealand fishing year, pp. 251–275. (Unpublished report, held in NIWA library, Wellington.)

Sylvester, T (1995) Initial results of the Northern boat ramp survey. *Seafood New Zealand*, February 1995. pp. 11–13.

Teirney, L D; Kilner, A R; Millar, R B; Bradford, E; Bell, J D (1997) Estimation of recreational harvests from 1991–92 to 1993–94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished document held by NIWA library, Wellington.)

Walsh, C; McKenzie, J M; Bian, R; Armiger, H; O'Maolagain, C; Buckthought, D; Smith, M; Ferguson, H; Miller A (2012) Snapper catch-at-length and catch-at-age heterogeneity between spatial strata in SNA 2 bottom trawl landings, 2007–08 and 2008–09. *New Zealand Fisheries Assessment Report 2012/40*. 44 p.

Wright, P; McClary, D; Boyd, R O (2004) 2000/2001 National Marine Recreational Fishing Survey: direct questioning of fishers compared with reported diary data. Final Research Report for Ministry of Fisheries Project REC2000-01: Objective 2. (Unpublished report held by Fisheries New Zealand, Wellington.)

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24*. 104 p.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.

SNAPPER (SNA 7)

(*Chrysophrys auratus*)
Tamure, Kouarea
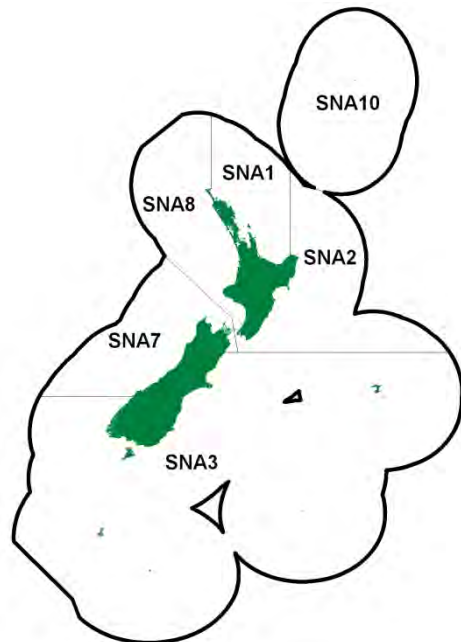
1.   FISHERIES SUMMARY

1.1   Commercial fisheries

Table 1 and Table 2 provide a summary by fishing year of the reported commercial catches, TACCs, and TACs for SNA 7. Landings and TACC are plotted in Figure 1.

Table 1: Reported landings (t) of snapper from SNA 7 from 1931 to 1990.

Year	SNA 7	Year	SNA 7
1931–32	69	1961	583
1932–33	36	1962	582
1933–34	65	1963	569
1934–35	7	1964	574
1935–36	10	1965	780
1936–37	194	1966	1 356
1937–38	188	1967	1 613
1938–39	149	1968	1 037
1939–40	158	1969	549
1940–41	174	1970	626
1941–42	128	1971	640
1942–43	65	1972	767
1943–44	29	1973	1 258
1944	96	1974	1 026
1945	118	1975	789
1946	232	1976	1 040
1947	475	1977	714
1948	544	1978	2 720
1949	477	1979	1 776
1950	514	1980	732
1951	574	1981	592
1952	563	1982	591
1953	474	1983	544
1954	391	1984	340
1955	504	1985	270
1956	822	1986	253
1957	1 055	1987	210
1958	721	1988	193
1959	650	1989	292
1960	573	1990	200

Notes:
1.   The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2.   The 'QMA totals' are approximations derived from port landing subtotals, as follows: SNA 7, Marlborough Sounds ports to Greymouth
3.   Before 1946 the 'QMA' subtotals sum to less than the New Zealand total because data from the complete set of ports are not available.
4.   Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.
5.   Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings.

Table 2: Reported landings (t) of snapper from SNA 7 from 1983–84 to present and gazetted and actual TACCs (t) for 1986–87 to present. QMS data from 1986–present.

Fishstock FMAs	SNA 7	7
	Landings	TACC
1983–84†	375	–
1984–85†	255	–
1985–86†	188	–
1986–87	257	330
1987–88	256	363
1988–89	176	372
1989–90	294	151
1990–91	160	160
1991–92	148	160
1992–93	165	160
1993–94	147	160
1994–95	150	160
1995–96	146	160
1996–97	162	160
1997–98	182	200
1998–99	142	200
1999–00	174	200
2000–01	156	200
2001–02	141	200
2002–03	187	200
2003–04	215	200
2004–05	178	200
2005–06	166	200
2006–07	248	200
2007–08	187	200
2008–09	205	200
2009–10	188	200
2010–11	206	200
2011–12	216	200
2012–13	211	200
2013–14	210	200
2014–15	210	200
2015–16	189	200
2016–17	263	250
2017–18	263	250
2018–19	257	250
2019–20	289	250
2020–21	337	350

† FSU data. SNA 7 = Statistical Areas 017, 033–036, 038

The SNA 7 TACC was increased in 2020–21 to 350 t (Table 3). All commercial fisheries have a minimum legal size (MLS) for snapper of 25 cm.

Table 3: TACs, TACCs, and allowances (t) for SNA 7 from 1 October 2020.

Fishstock	TAC	TACC	Customary allowance	Recreational allowance	Other mortality
SNA 7	645	350	20	250	25

Foreign fishing

Japanese catch records and observations made by New Zealand naval vessels indicate that significant quantities of snapper were taken from New Zealand waters by Japanese vessels from the late 1950s until 1977. There are insufficient data to quantify historical Japanese catch tonnages for the respective snapper stocks. However, trawl catches have been reported by area from 1967 to 1977, and longline catches from 1975 to 1977 (Table 4). These data were supplied to the Fisheries Research Division of MAF in the late 1970s; however, the data series is incomplete, particularly for longline catches.

Table 4: Reported landings (t) of snapper and harvest within SNA 7 from 1967 to 1977 by Japanese trawl and longline fisheries.

Year	(a) Trawl	Trawl catch (all species)	Total snapper trawl catch	SNA 7
1967		3092	30	NA
1968		19 721	562	17
1969		25 997	1 289	251
1970		31 789	676	131
1971		42 212	522	115
1972		49 133	1 444	225
1973		45 601	616	117
1974		52 275	472	98
1975		55 288	922	85
1976		133 400	970	NA
1977		214 900	856	NA

Year	(b) Longline	Total Snapper	SNA 7
1975		1 510	–
1976		2 057	–
1977		2 208	–
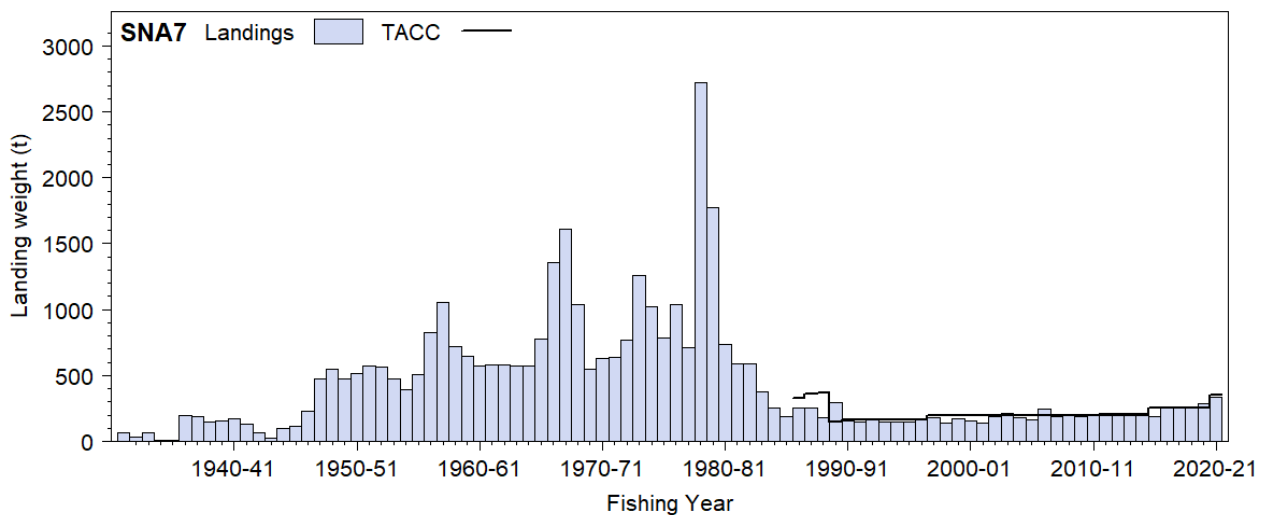
Figure 1: Total reported landings and TACCs for SNA 7.

1.2 Recreational fisheries

The snapper fishery is the largest recreational fishery in New Zealand. It is the major target species on the northeast and northwest coasts of the North Island and is targeted seasonally around the rest of the North Island and the top of the South Island. The current allowance within the SNA 7 TAC is shown in Table 3.

1.2.1 Management controls

The two main methods used to manage recreational harvests of snapper are minimum legal size limits (MLS) and daily bag limits. Both have changed over time (Table 5). The number of hooks permitted on a recreational longline was reduced from 50 to 25 in 1995.

Table 5: Changes to minimum legal size limits (MLS) and daily bag limits used to manage recreational harvesting levels in SNA 7.

Stock	MLS	Bag limit	Introduced
SNA 7	25	30	1/01/1985
SNA 7 (excl Marlborough Sounds)	25	10	1/10/2005
SNA 7 (Marlborough Sounds)	25	3	1/10/2005

1.2.2 Estimates of recreational harvest

A background to the estimation on recreational harvest of snapper is provided in the Introduction – Snapper chapter. Recreational harvest estimates for SNA 7 are provided in Table 6.

Plausible estimates for recreational catches from SNA 7 are available from the 1987 tagging programme, the aerial access surveys (in 2005–06 and 2015–16) and the national panel surveys (2011–12 and 2017–18). The estimates of recreational catch increased considerably from 2005–06 to 2017–18.

Most of the recreational catch has been recorded from Tasman Bay and Golden Bay. The catch is predominantly taken by rod-and-line, although a significant proportion of the catch was taken by longline during the mid 2010s. A small proportion of the total SNA 7 recreational catch was recorded from the Marlborough Sounds.

Table 6: **Recreational catch estimates for SNA 7. Totals for a stock are given in bold. The telephone/diary surveys ran from December to November but are denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey catch estimates). Numbers and mean weights are not calculated in the tag ratio method. Includes charter boat catch and panel survey estimates of s111 catches.**

Stock	Year	Method	Number of fish (thousands)	Mean weight (g)	Total weight (t)	CV
SNA 7						
Tasman Bay /Golden Bay	1987	Tag ratio	–	–	**15**	–
Total	1993	Telephone/diary	77	2 398[3]	**184**	–
Total	1996	Telephone/diary	74	2 398	**177**	–
Total	2000	Telephone/diary	63	2 148	**134**	–
Total	2001	Telephone/diary	58	–[5]	**125**	–
Total	2005–06	Aerial-access	–	–	**43**	0.17
Total	2011–12	Panel survey	110	799	**89**	0.17
Total	2015–16	Aerial-access	–	–	**83**	0.18
Total	2017–18	Panel survey	98	1 505	**147**	0.16

[3] Mean weight obtained from 1995–96 boat ramp sampling.
[5] The 2000 mean weights were used in the 2001 estimates.

1.3 Customary non-commercial fisheries

There are no estimates of customary catch available for SNA 7. Current levels of customary catch in SNA 7 are considered to be small and are assumed to be included into recreational catch estimates.

1.4 Illegal catch

No new information is available to estimate illegal catch. For modelling in SNA 7 an assumption was made that non-reporting of catch was 20% of reported domestic commercial catch prior to 1986 and 10% of reported domestic commercial catch since the QMS was introduced. This was to account for all forms of under-reporting. These proportions were based on the black-market trade in snapper and higher levels of under-reporting (to avoid tax) that existed prior to the introduction of the QMS. The 10% under-reporting post-QMS accounts for the practice of 'weighing light' and the discarding of legal-size snapper.

1.5 Other sources of mortality

No estimates are available regarding the amount of other sources of mortality on snapper stocks; although high-grading of longline fish and discarding of under-sized fish by all methods occurs. An at-sea study of SNA 1 commercial longline fisheries in 1997 (McKenzie 2000) found that 6–10% of snapper caught by number were under 25 cm (MLS). Results from a holding net study indicate that mortality levels amongst lip-hooked snapper caught shallower than 35 m were low.

Estimates for incidental mortality were based on other catch-at-sea data using an age-length structure model for longline, trawl, seine, and recreational fisheries. In SNA 1, estimates of incidental mortality for the year 2000 from longlines were less than 3% and for trawl, seine, and recreational fisheries between 7% and 11% (Millar et al 2001). In SNA 8, estimates of trawl and recreational incidental mortality were lower, mainly because of low numbers of 2- and 3-year old fish estimated in 2000.

In SNA 1, recreational fishers release a high proportion of their snapper catch, most of which was less than 27 cm (recreational MLS). An at-sea study in 2006–07 recorded snapper release rates of 54.2% of

the catch by trailer boat fishers and 60.1% of the catch on charter boats (Holdsworth & Boyd 2008). Incidental mortality estimated from condition at release was 2.7% to 8.2% of total catch by weight depending on assumptions used.

2.   BIOLOGY

For further information on snapper biology refer to the Introduction – Snapper chapter. A summary of published estimates of biological parameters for SNA 7 is presented in Table 7.

Table 7: Estimates of biological parameters.

Fishstock	Estimate			Source
1. Instantaneous rate of natural mortality (*M*)				
SNA 1, 2, 7, & 8	0.075			Hilborn & Starr (unpub. analysis)
2. Weight = *a*(length)^b (Weight in g, length in cm fork length)				
All	*a* = 0.04467	*b* = 2.793		Paul (1976)
3. von Bertalanffy growth parameters				
	Both sexes combined			
	K	t_0	L_∞	
SNA 7				
(1990s)	0.122	-0.71	69.6	MPI (unpub. data)
4. Age at recruitment (years)				
SNA 7	3			MPI (unpub. data)

3.   STOCKS AND AREAS

New Zealand snapper are thought to comprise either seven or eight biological stocks based on: the location of spawning and nursery grounds; differences in growth rates, age structure, and recruitment strength; and the results of tagging studies. These stocks comprise three in SNA 1 (East Northland, Hauraki Gulf, and Bay of Plenty (BoP)), two in SNA 2 (one of which may be associated with the BoP stock), two in SNA 7 (Marlborough Sounds and Tasman Bay/Golden Bay) and one in SNA 8.

Tagging studies in SNA 7 (1986/87) and SNA 8 (1990) revealed reciprocal movements of snapper between Tasman Bay/Golden Bay and South Taranaki Bight, although the scale of the movement was relatively low during that period.

Location-based snapper catch data from the trawl fisheries in SNA 7 and southern SNA8 has revealed an overlap of the distribution of snapper catches in western approaches to Cook Strait between Durville Island and Kapiti Island, particularly since 2014/15. Snapper age compositions are available from recent (2018-2020) *Kaharoa* trawl surveys of the South Taranaki Bight and the Tasman Bay/Golden Bay area of the WCSI trawl survey. There are strong differences in the relative strength of individual year classes from the 2019 South Taranaki Bight age composition compared to the 2018 and 2020 surveys, while the 2019 STB age composition was very similar to the age structures from the 2019 Tasman Bay/Golden Bay trawl survey and the commercial fishery in the TBGB area. These observations indicate a degree of mixing of the snapper populations between SNA 7 and the STB area (SNA8), although the extent of mixing may vary between years, potentially related to variation in the timing of the main spawning period in each area.

4.   STOCK ASSESSMENT

An assessment for SNA 7 was conducted in 2015 and updated in 2018, 2020 and 2021.

SNA 7 (Challenger)

The SNA 7 fishery is concentrated within Tasman Bay and Golden Bay and this area is considered to represent the main spawning area and nursery area for the stock. Most of the main data sets included in the stock assessment were derived from the Tasman/Golden Bay area. However, since the mid 2010s there has been an increase in the spatial domain of the stock, particularly for older fish, with the distribution extending into deeper areas beyond TBGB (i.e., the western approaches to Cook Strait) and southward along the west coast of the South Island. It is currently assumed that fish in these areas migrate to spawn in the shallower areas of TBGB during late October-early December and disperse during late summer.

A stock assessment of SNA 7 was conducted in 2021. The assessment updated and refined the previous stock assessments conducted during 2015–2020 (see Langley 2020a). Those assessments were primarily based on a time series of CPUE indices from the SNA 7 trawl fishery, in addition to age compositional data from the trawl fishery and a tagging biomass estimate from 1987. The current stock assessment also incorporated the snapper biomass estimates, and the associated length and age compositions, from the time-series of *Kaharoa* inshore trawl surveys of west coast South Island and Tasman Bay/Golden Bay.

The 2021 stock assessment of SNA 7 was conducted using an age-structured population model implemented in Stock Synthesis. The model incorporated data to the 2020–21 fishing year (2020 model year) including:
- Commercial catches by method, 1931–2020;
- Recreational catches, 1931–2020;
- Tag biomass estimate 1987;
- Seasonal (Oct-Dec, Jan-Apr) single trawl CPUE indices 1989–2019;
- *Kaharoa* trawl survey biomass indices (1991–2020) and length/age compositions;
- Single trawl catch age compositions 1992–2019;
- Pair trawl catch age compositions 1974–1983; and
- Recreational catch length compositions 2005–2019.

Commercial catches

Commercial catch data are available for the SNA 7 fishery from 1931 to the 2019/20 fishing year. The model data set was configured to include three commercial fisheries: two seasonal single trawl fisheries (BT) in October–December (BT1) and January–September (BT2) and a pair trawl fishery (BPT). The SNA 7 catch taken by the purse-seine method during the late 1970s and early 1980s was assigned to the pair trawl fishery, as both methods are considered to harvest the full range of adult age classes in the population.

The seasonal division of the BT catch followed the derivation of separate seasonal CPUE indices and enabled the evaluation of different assumptions regarding the seasonal availability (selectivity) of snapper to the BT fisheries.

The reported commercial catches from 1931–1986 were increased by 20% to account for an assumed level of under-reporting. Since the introduction of the Quota Management System (QMS), the accuracy of the reporting of commercial catches has improved considerably, although a degree of under-reporting may persist. For 1987–2020, reported catches were increased by 10% to account for the assumed level of under-reporting in the more recent period. These assumptions are consistent with the formulation of the commercial catch histories incorporated in other inshore finfish stock assessments (based on assumptions for SNA 1 and SNA 8 made according to quota appeals when the QMS was first introduced).

Non-Commercial catches

The recreational catch history was constructed based on estimates of recreational catch from 1987, 2005–06, 2011–12, 2015–16, and 2017–18 (Figure 2). The point estimates were used to determine estimates of recreational exploitation rates in each year based on the annual estimates of biomass from

preliminary model runs. Exploitation rates were interpolated between successive recreational catch estimates to determine annual estimates of recreational catch from 1987 to 2016. The 2018–19 recreational catch was estimated using the 2017–18 exploitation rate. For the period prior to 1987, the exploitation rate was extrapolated, declining by 10% per annum, to the early 1960s when a lower threshold of 10 t per annum was attained. Length compositions from the recreational fishery (2005, 2011, 2015–2019) were derived from sampling conducted during boat ramp interviews.

There are no estimates of customary catch available for SNA 7. Recent customary catches are likely to have been a minor component of the total catch and are not explicitly included in the model catch history.
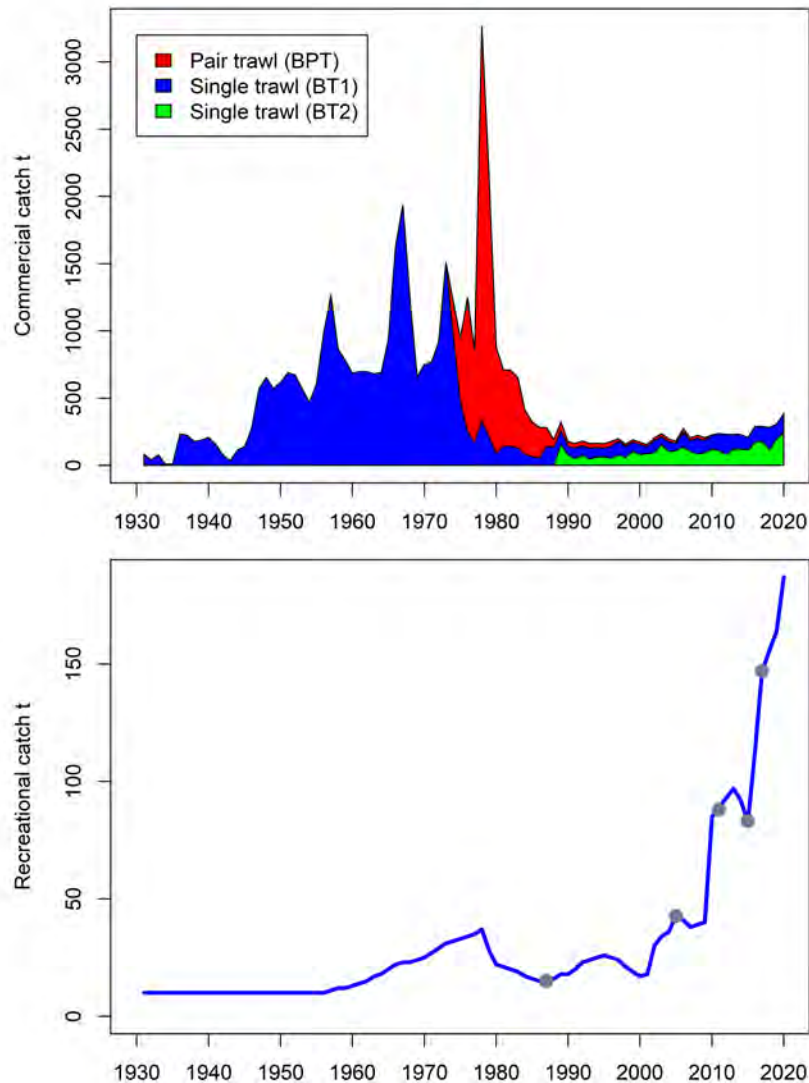
Figure 2: Commercial (top) and recreational catch histories for SNA 7 included in the stock assessment models. The commercial catch history attributes all the single trawl catch prior to 1989 to the BT1 fishery. Commercial catches include an allowance for 20% unreported catch prior to the QMS and 10% allowance in the subsequent years. The grey points represent the survey estimates of recreational catch.

Tagging biomass estimate

An estimate of 1987 stock biomass was derived from a tag release-recovery programme (Kirk et al 1988). A subsequent reanalysis of the tagging data yielded a very similar estimate of snapper biomass (1549 t) Harley & Gilbert (2000). Harley & Gilbert (2000) expressed concerns regarding the reliability of the 1987 tag biomass estimate due to spatial heterogeneity of tagged fish and the lack of tag releases in deeper water. Consequently, the tag biomass estimate was assigned a moderate level of precision (CV 30%).

CPUE indices

The previous stock assessments of SNA 7 incorporated a time series of CPUE indices as a primary index of stock abundance. The CPUE indices were based on catch and effort data from the Tasman Bay/Golden Bay trawl fishery targeting snapper, flatfish, red gurnard, and, to a lesser extent, barracouta during October–April. A detailed analysis of catch and effort data from the fishery indicated that since 2010/11 the operation of the trawl fishery had changed to increasingly avoid snapper, particularly during October–December. There was also some indication that the age composition of the snapper catch may vary between October–December and January–April. On that basis, separate sets of trawl CPUE indices were derived for the two seasons (BT1 and BT2). The analyses included catch and effort data from the 1989–90 to 2019–20 fishing years, aggregated by vessel fishing day. For each seasonal data set, a GLM approach was applied to separately model the probability of catching snapper (binomial model) and the magnitude of positive (non-zero) snapper catch (lognormal model) and the combined CPUE indices (delta-lognormal) were derived from the annual coefficients of the two models.

Due to the increase in snapper avoidance, the more recent (2010–2019) October–December (BT1) CPUE indices were not included in the assessment modelling.
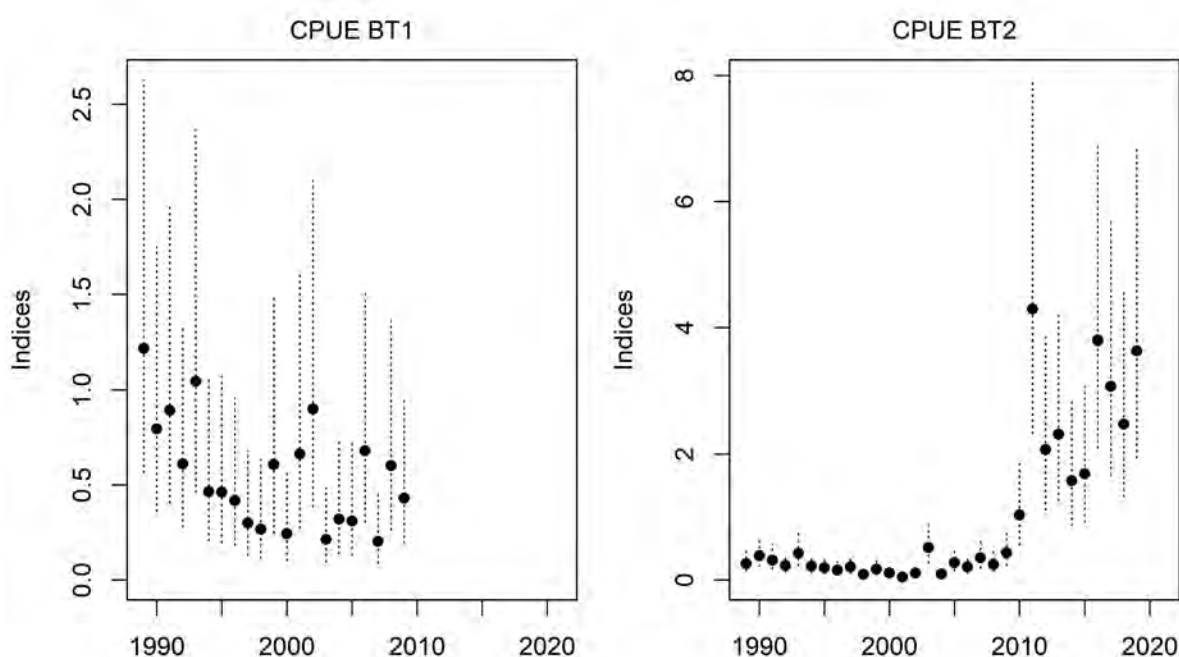
Figure 3: Relative CPUE indices derived from the delta lognormal (all years) model for the single trawl fishery during October-December (left) and January-April (right). The vertical lines represent the 95% confidence intervals. The confidence intervals were derived using a bootstrapping procedure.

The BT1 CPUE indices decline during the early 1990s and then remain at the lower level until 2010–11. The time series of BT2 CPUE indices are relatively constant during 1989–90 to 2009–10, increase initially in 2010–11 and then increased substantially in 2011–12. The indices fluctuated considerably about the higher level during the subsequent years (Figure 3). The scale of the variation in the BT2 CPUE indices may indicate a high degree of inter-annual availability of snapper within the TBGB area during summer/autumn.

Trawl survey
The West Coast South Island inshore trawl survey, including the Tasman Bay/Golden Bay area, commenced in 1992 and has been conducted biennially since 2002. The survey occurs in March–April coinciding with the period when larger, mature snapper are dispersing from TBGB following the spawning season. The survey area does not extend out into the deeper waters beyond TBGB (western approaches to Cook Strait).

Prior to 2017, the trawl survey area did not include the shallower areas (less than 20 m) of TBGB. This area has accounted for a considerable proportion of the snapper catch and also includes the main nursery areas for snapper within SNA 7. From 2017, surveys were extended to include designated "snapper" strata within the shallower area (10–20 m) of TBGB, extending the overall survey area from the original "core" strata.

Snapper biomass indices were derived for the core strata (TBGB and WCSI) for the time-series of trawl surveys. The biomass indices are very low from 1992–2011 and increase considerably in 2013 and 2015 and remain at the higher level for the three subsequent surveys. Since 2019, a larger proportion of the survey biomass was composed of snapper from the northern area of the west coast of the South Island, principally composed of older fish.

Length compositions were derived for each survey (core area) from 2009 onwards; insufficient snapper were sampled from the earlier trawl surveys to derive reliable length compositions. Age compositions are available from the three most recent trawl surveys (2017, 2019 and 2021). The 2017 and 2019 trawl surveys were dominated by two strong year classes, whereas the 2021 (core) trawl survey was dominated by younger snapper (age 2-6 yr).

The "core" survey biomass indices and length/age compositions were included in the stock assessment model. The data suggest a lower availability of older fish to the trawl survey, probably due to the dispersal of those fish into areas outside the core survey area. Consequently, the trawl survey selectivity function was parameterised to allow for the estimation of lower selectivity of the older age classes.

For the shallow TBGB snapper strata, there was a substantial increase in snapper biomass from the three recent surveys (2017, 2019 and 2021). The time-series of biomass indices was considered too short for inclusion in the stock assessment, although the age composition data from this portion of the survey are considered to provide the best available information regarding recent recruitments. The 2019 trawl survey (core + SNA) age composition was dominated by 1-year old fish, indicating strong recent recruitment (the 2017 year class). While the 2021 survey was dominated by 2- and 3-year old fish, indicating the presence of another strong year class (2018) and reaffirming the strength of the 2017 year class (age 3-yr).

The recent increase in the abundance of juvenile snapper (in the "snapper" strata) appears to have coincided with an increase in the availability of young (age 4–5 yr) snapper to the "core" trawl survey for the recent surveys, as indicated by the increased proportion of the young snapper in the area deeper than 20 m. This may indicate that the selectivity of younger snapper has increased for the core survey in recent years.

Commercial age compositions
Commercial age frequency data are available from the TBGB BPT fishery from the pre QMS era (N=5) and BT from the QMS era (N=10). The annual BPT age compositions were derived from a small number of sampled landings. The data were down-weighted in the final assessment model due to deficiencies in the initial fits that indicated that the strength of individual year classes was poorly determined from these data.

The more recent BT age compositions (2006, 2013, 2016 and 2019) were partitioned between the two seasons. In some years, a higher proportion of older fish were sampled from October–December (BT1) compared to January–April (BT2). This may indicate that older snapper are more available in TBGB during the main spawning period and subsequently disperse from the TBGB area over the following summer. The BT age compositions from the earlier years (1992, 1997-2000 and 2003) were assumed to represent the age composition of snapper from October–December (BT1), because most of the sampling took place during that period.

Model structure and assumptions

A statistical age-structured population model for SNA 7 was implemented using Stock Synthesis (Methot & Wetzell 2013). A summary of input data, fixed and estimated parameters are provided in Tables 8, 9 and 10. The main model structural assumptions for the base model are as follows:

- The initial population (1931) is in an unexploited, equilibrium state configured as a single sex comprised of 30 age classes, including a plus group. The model data period is 1931–2020 (the 2020 model year represents the 2002–21 fishing year) and includes two seasons (October-December and January-September),

- Recruitment for 1931–1974 is at the equilibrium level (with a Beverton-Holt stock-recruitment relationship, SRR, steepness of 0.95); recruitment deviates are estimated for 1975–2019. Recruitment for 2020 was assumed based on the average level of recruitment from the stock-recruitment relationship.

- Commercial fisheries selectivities are age-based and temporally invariant.

- Selectivities for the commercial BPT and BT1 fisheries have full selection for all recruited age classes (parameterised using a logistic selectivity function). The selectivity for the BT2 fishery is parameterised using a flexible, double-normal function.

- Age based selectivity for the *Kaharoa* trawl survey (core area) was parameterised using a double-normal selectivity function. Temporal variation in the age of the peak in selectivity was estimated for the three most recent trawl surveys (2016/17, 2018/19 and 2020/21) to account for an apparent increase in the availability of younger fish.

- The age compositions from the 2018 and 2020 core + SNA survey area were fitted with a separate double-normal function.

- The selectivity of the recreational fishery is length-based and parameterised using a double normal function. Selectivity is configured with three time blocks (pre-2013, 2013–2015, and 2016 onwards) to account for the increase in the catch of larger fish by the longline method in the intermediate period and increased targeting of larger fish in more recent years.

- The two sets of CPUE indices (BT1 and BT2) were assigned additional process error of 30% and 20%, respectively, based on RMSE from preliminary model runs.

- The tag biomass estimate was assumed to represent the proportion of the stock biomass that had recruited to the commercial BPT fishery in 1987. The tag biomass estimate was assigned a CV of 30% following Harley & Gilbert (2000). The moderate CV was adopted to reflect concerns regarding the reliability of the tag biomass estimate.

- The relative weightings (ESS) of the BT1, BT2 and trawl survey age compositions were determined following the approach of Francis (2011); the BT1 and BT2 age compositions were assigned an Effective Sample Size (ESS) of 20, while the two sets of trawl survey age compositions were each assigned an ESS of 50.

- The BPT age compositions were assigned a low relative weighting (ESS = 1); sufficient weight to inform the model about the fishery selectivity, while not strongly influencing the estimates of year class strength. Similarly, the recreational length compositions were also assigned an ESS of 1.0, as they may not fully represent the fishery, and the selectivity of the recreational fishery appears to have changed over time.

- Growth rates of snapper in TBGB were variable over the model period with higher growth of younger fish occurring during 1990-2009. The model was divided into three periods (pre-1990, 1990-2009 and post-2009), based on these observed differences in growth rates. The length-at-age data from each period was used to estimate time specific values of the k VB growth parameter. The time-specific growth functions were applied to the three time periods of the model.

Table 8: Summary of input data sets for the Base Case assessment model. The relative weighting includes the Effective Sample Size (ESS) of age/size composition data and the coefficient of variation (CV) associated with the abundance data. Note that model year 2020, is fishing year 2020/21, and includes the trawl survey conducted in March 2021.

Data set	Model years	Nobs	Error structure	Observation error/ESS	Process error
Tag biomass	1987	1	Lognormal	0.30	–
BT1 CPUE indices	1989–2009	21	Lognormal	0.09–0.16	0.3
BT2 CPUE indices	1989–2019	31	Lognormal	0.09–0.15	0.2
Trawl survey Core indices	1991, 1993, 1994, 1996, 1999, 2002, 2004, 2006, 2008, 2010, 2012, 2014, 2016, 2018, 2020	15	Lognormal	0.13–0.94	–
Trawl survey Core age comp	2016, 2018, 2020	3	Multinomial	ESS 50	
Trawl survey Core length comp	2008, 2010, 2012, 2014	4	Multinomial	ESS 10	
Trawl survey Core+SNA age comp	2018, 2020	2	Multinomial	ESS 50	
BT1 age comp	1992, 1997–2000, 2003, 2006, 2013, 2016, 2019	10	Multinomial	ESS 20	
BT2 age comp	2006, 2013, 2016, 2019	4	Multinomial	ESS 20	
BPT age comp	1974, 1978–1980, 1983	5	Multinomial	ESS 1	
Recreational length comp	2005, 2011, 2015–2019,	7	Multinomial	ESS 1	

Table 9: Details of parameters that were fixed in the base model.

Natural mortality	0.075 y^{-1}
Stock-recruit steepness (Beverton & Holt)	0.95
Std deviation of rec devs (sigmaR)	1.5
Proportion mature	0 for ages 1–2, 1 for ages > 2
Length-weight [mean weight (kg) = a (length (cm))^b]	$a = 3.61 \times 10\text{-}5, b = 2.8644$
Growth parameters	$L\infty = 69.6$, Length1=13.1
pre-1990 (1), 1990-2009 (2), post- 2009 (3)	$k1$=0.098, $k2$=0.122, $k3$=0.103,
Coefficients of variation for length-at-age	0.075

Table 10: Estimated parameters for the base model.

Parameter	Number of parameters	Parameterisation, priors, constraints
LnR_0	1	Uniform, uninformative
Rec devs (1975–2019)	45	SigmaR 1.5
Selectivity BPT commercial	2	Logistic
Selectivity BT1 commercial	2	Logistic
Selectivity BT2 commercial	5	Double normal
Selectivity trawl survey core	8	Double normal
Selectivity trawl survey core+SNA	5	Double normal
Selectivity tag	–	Equivalent to commercial BPT
Selectivity Recreational	8	Double normal
CPUE BT1 q	1	Uniform, uninformative
CPUE BT2 q	1	Uniform, uninformative
Trawl Survey q	1	Uniform, uninformative

For the base model option, the model biomass approximates the point estimate of the 1987 recruited biomass from the tagging programme and provides a good fit to the time-series of trawl survey biomass indices (Figure 4). The model also provides a good fit to the time series of BT2 CPUE indices to 2010. Stock biomass is predicted to have increased considerably from 2010 (2010–11 fishing year) following the overall magnitude of the increase in trawl survey biomass indices and BT2 CPUE indices. However, the fits to the individual BT2 CPUE indices from 2011–12 to 2019–20 are relatively poor (Figure 4). The fit to the BT1 CPUE indices (1989-2009) is poor (Figure 4).

The initial increases in the CPUE and trawl survey biomass indices are consistent with the recruitment of the very strong 2007 year class (Figure 5). This year class dominated the age compositions from the trawl fishery and (core) trawl survey during 2013–14 to 2018–19. More recent age compositions have been augmented by the recruitment of subsequent year classes, most notably the 2010 year class. The

SNAPPER (SNA 7)

2018/19 and 2020/21 trawl surveys (core + SNA) yielded relatively high catch rates of juvenile snapper in the shallower TBGB strata (10-20 m), which dominated the associated age compositions. Correspondingly, the model estimated exceptionally strong 2017 and 2018 year classes, although the magnitude of these recruitment estimates is uncertain.
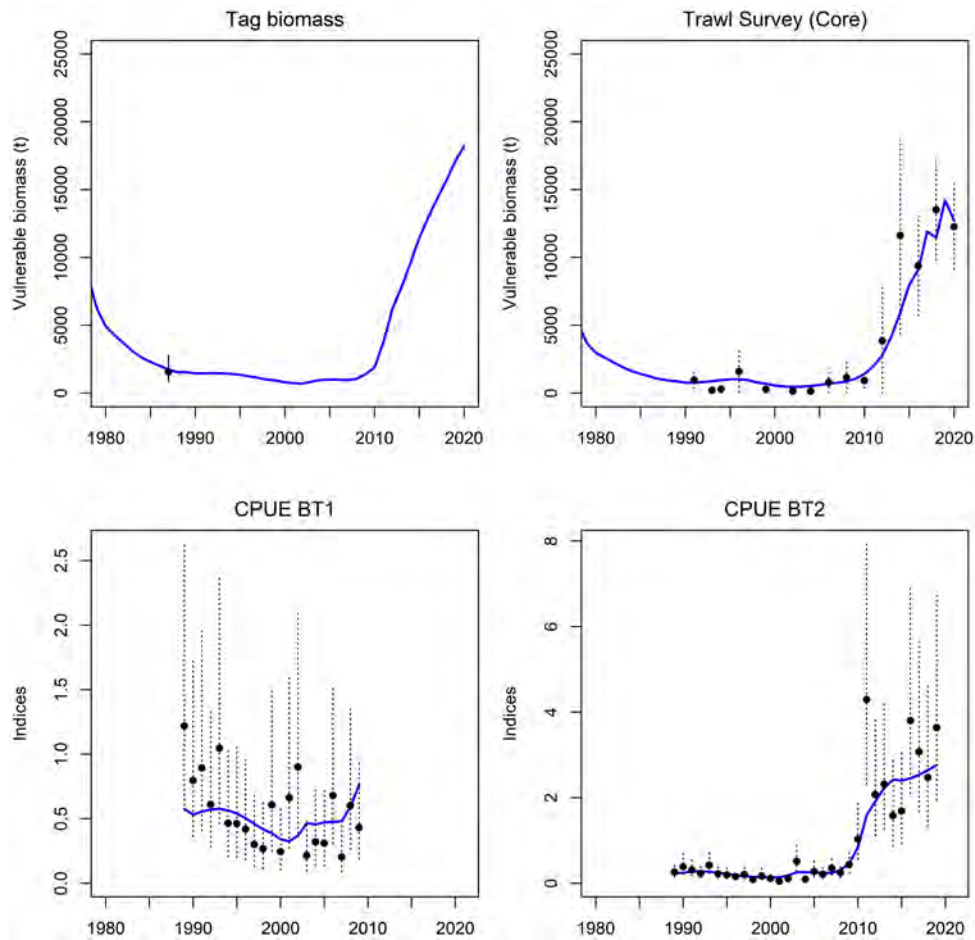
Figure 4: Biomass trajectories (MPD) for the base model option presenting the fit to the tag biomass estimate (top left panel), trawl survey (core) biomass indices (top right panel) and the CPUE indices (lower panels).
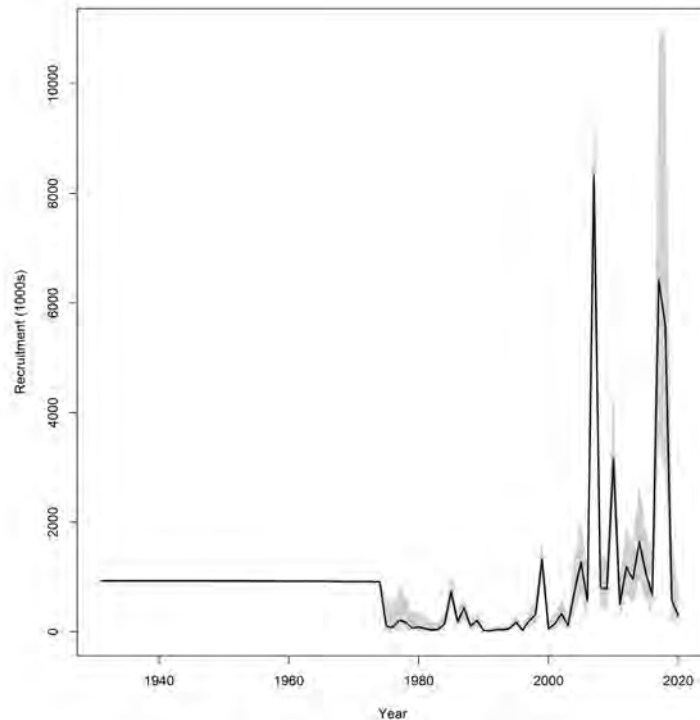
Figure 5: Annual recruitment for the base model (MCMC results). Recruitment deviates were estimated for 1975–2019. The line represents the median and the shaded area represents the 95% credible interval.

The model fits to individual age compositions from the recent years were relatively poor, indicating a degree of conflict between the 2020/21 trawl survey age composition and the trawl survey biomass and BT2 CPUE indices. A range of model trials was conducted to investigate the relative influence of the individual data sets. These trials revealed that estimates of recent biomass were relatively insensitive to the relative weighting of the CPUE indices and trawl survey biomass indices, although less emphasis on the trawl survey age compositions yielded more optimistic estimates of stock status.

The base model provides estimates of current stock status that are quite uncertain, primarily due to the uncertainty associated with the estimates of the strength of recent recruitment (2017 year class). There is also uncertainty associated with the scale of the increase in stock abundance due to differential trends in the increase of the two principal abundance indices and the associated assumptions regarding fishery/survey selectivities. A range of model sensitivities were undertaken to investigate model assumptions, these included a lower value of natural mortality (0.06 compared with 0.075), an older age of sexual maturity (5 yr compared to 3 yr), a lower value of variation in the recruitment deviates (sigmaR 1.0 compared with 1.5), no allowance for unreported catches and a suite of models contrasting the influence of the CPUE indices and the trawl survey biomass indices and the age composition data from the trawl survey (Table 11). The sensitivities were generally treated as single changes from the base model.

Table 11: Description of model sensitivities.

Sensitivity run	Description
NatMort sensitivity	$M = 0.06$
RecDev variation sensitivity	sigmaR = 1.0
Mature5yr	Knife-edge maturity at age 5 yr
CPUE indices	Exclude trawl survey biomass indices
Trawl Survey indices	Exclude CPUE indices
BPT age comp	Higher weighting on BPT age comp (ESS 10)
	Estimate rec devs 1950-2019
Trawl Survey Age down-weight	ESS = 5 for trawl survey age comps
UnreportedCatchZero	No unreport catch pre- and post QMS

Stock status (current 2020 = 2020/21 fishing year and forecast to 2025/26) for the SNA 7 spawning biomass was reported relative to the default hard limit of 10% SB_0 and the default soft limit of 20% SB_0 and interim target biomass level of 40% SB_0. Fishing mortality (2020) was reported relative to the corresponding interim target biomass level, i.e., $F_{SB40\%}$. The interim target biomass level was proposed at the SINS WG and was based on the default value for a low productivity stock as described by the Harvest Strategy Standard.

For the base model, biomass is estimated to have increased considerably from 2010 and the current (2020) biomass is well above the interim target biomass level (40% SB_0) (Figure 6, Table 12). The range of model sensitivities all estimated levels of current stock status above the interim target biomass level.

For all model options, current rates of fishing mortality are well below the corresponding fishing mortality threshold ($F_{SB40\%}$) (Figure 7, Table 12).

Table 12: Estimates of current (2020–21) and virgin spawning biomass (t) (median and the 95% confidence interval from the MCMCs) and probabilities of current biomass being above specified levels and probability of fishing mortality being below the level of fishing mortality associated with the interim target biomass level.

Model option	SB_0	SB_{2020}	SB_{2020}/SB_0	Pr(SB_{2020} > X% SB_0)		
				40%	20%	10%
Base	15 999	10 047	0.628	0.996	1.000	1.000
	(15 583-16 486)	(7 385-13 342)	(0.464-0.825)			
LowM	16 825	8 970	0.533	0.980	1.000	1.000
	(16 467-17 184)	(6 759-11 683)	(0.408-0.69)			
Mature5yr	15 719	8 800	0.561	0.983	1.000	1.000
	(15 217-16 155)	(6 511-11 774)	(0.415-0.743)			
Model_CPUE	15 994	8 014	0.502	0.895	1.000	1.000
	(15 532-16 465)	(5 659-11 172)	(0.354-0.697)			
Model_TrawlSurvey	15 868	8 710	0.551	0.973	1.000	1.000
	(15 434-16 297)	(6 237-12 434)	(0.395-0.77)			
Model_BPTage	20 242	11 150	0.548	0.935	0.982	0.986
	(18 063-22 879)	(5 516-15 711)	(0.291-0.75)			
SigmaR1.0	15 666	9 723	0.622	0.998	1.000	1.000
	(15 185-16 157)	(7 338-13 133)	(0.472-0.826)			
TrawlSurveyAgeDwt	15 846	11 042	0.698	0.998	1.000	1.000
	(15 279-16 420)	(8 025-15 027)	(0.51-0.932)			
UnreportedCatchZero	13 518	8 863	0.656	1.000	1.000	1.000
	(13 141-13 900)	(6 594-11 982)	(0.491-0.879)			

Model option	$F_{SB40\%}$	$F_{2020}/F_{SB40\%}$	Pr(F_{2020} < $F_{SB40\%}$)
Base	0.052	0.524	0.999
		(0.389-0.737)	
LowM	0.044	0.703	0.986
		(0.521-0.952)	
Mature5yr	0.050	0.562	1.000
		(0.414-0.78)	
Model_CPUE	0.051	0.660	0.985
		(0.456-0.966)	
Model_TrawlSurvey	0.054	0.573	0.997
		(0.406-0.816)	
Model_BPTage	0.052	0.474	0.976
		(0.333-0.963)	
SigmaR1.0	0.050	0.554	1.000
		(0.407-0.761)	
TrawlSurveyAgeDwt	0.052	0.491	1.000
		(0.355-0.696)	
UnreportedCatchZero	0.052	0.558	1.000
		(0.406-0.761)	

For all model options, estimates of current and equilibrium yield were derived for the stock based on the fishing mortality rate that corresponds to the interim target biomass level (Table 13). Equilibrium yields at the interim target biomass level are estimated to be about 600–700 t per annum. $F_{SB40\%}$ yields at 2020–21 biomass levels are comparable to the yields at 40% B_0. Current $F_{SB40\%}$ potential yields are at or above the level of current catch (572 t), which includes commercial catch, other sources of mortality and recreational catch.

Table 13: Estimates of equilibrium yield (t) at $F_{SB40\%}$ at the 2020–21 biomass levels and at 40% B_0, for the base model and the model sensitivities. The values represent the median and the 95% confidence interval from the MCMCs.

Model option	$F_{SB40\%}$	
	Yield at 40% B_0	Yield at current biomass
Base	696 (634-738)	1 251 (859-1 694)
LowM	616 (556-653)	950 (716-1 252)
Mature5yr	691 (630-729)	1 159 (840-1 581)
Model_CPUE	683 (608-736)	1 034 (721-1 457)
Model_TrawlSurvey	715 (651-743)	1 120 (790-1 609)
Model_BPTage	871 (758-1 000)	1 416 (800-1 989)
SigmaR1.0	661 (592-702)	1 224 (905-1 670)
TrawlSurveyAgeDwt	684 (598-728)	1 257 (881-1 766)
UnreportedCatchZero	591 (536-625)	1 093 (797-1 492)

Projections

Projections were conducted for the base model and the sensitivities. Stock projections were conducted for the 5-year period following the terminal year of the model (i.e., 2021–2025). Projections assumed future recruitments were resampled from the lognormal distribution around the geometric mean. Commercial catches in the projection period were held constant at the current TACC of 350 t with an allowance for additional mortality of 35 t. Recreational catches in the projection period assumed a constant level of fishing mortality equivalent to the fishing mortality estimated in the terminal year of the model (2020). There was no explicit allowance for customary catch.

The projections are strongly influenced by the high estimates of recent recruitment of the 2017 and 2018 year classes, resulting in an increase in total biomass during the projection period (Figure 6). These year classes are poorly estimated as they have only been observed once (2018 year class) or twice (2017 year class) in the trawl survey series and have not yet appeared in the commercial fishery. There is concern that the strength of these year classes may be over-estimated in the assessment models resulting in overly optimistic stock projections. A more precautionary metric of projected stock status was derived from the lower 25% quantile of the distribution of projected stock biomass, reflecting the lower range of biomass from the lower range of the estimates of the recent recruitments.

For the base case (and all other model options), stock abundance is predicted to continue to increase in the projection period and biomass is well above the target biomass ($SB_{40\%}$ level) in 2025 (Table 14). Recreational catches are projected to increase in proportion to the overall increase in stock biomass. The median of the lower 25% quantile (0.731) of the projected biomass is also higher than the estimate of current stock status (0.628) indicating that biomass increases at the lower range of values estimated for the recent recruitments.

Table 14: Estimates of projected (2025–26) spawning biomass (t) (median and the 95% confidence interval from the MCMCs) and probability of the spawning biomass being above default biomass limits and the interim target level in 2025 from the base model projections and the lower 25% quantile of the projections.

Model option	SB_{2025}/SB_0	$Pr(SB\ 2025 > X\%\ SB_0)$		
		10%	20%	40%
Base	0.895 (0.631-1.279)	1.00	1.00	1.00
Lower 25% Quantile	0.731 (0.561-0.797)	1.00	1.00	1.00
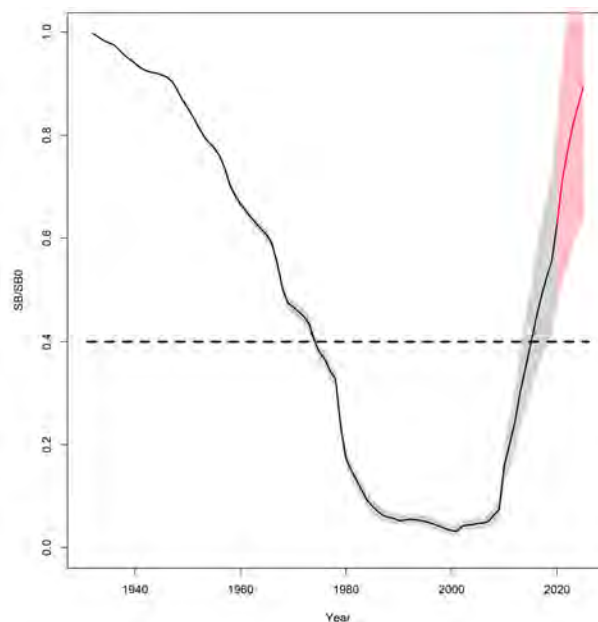
Figure 6: Annual trend in spawning biomass relative to the 40% SB_0 interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% confidence interval. The projection period (2021–2025) is in red. The dashed line represents the interim target level.
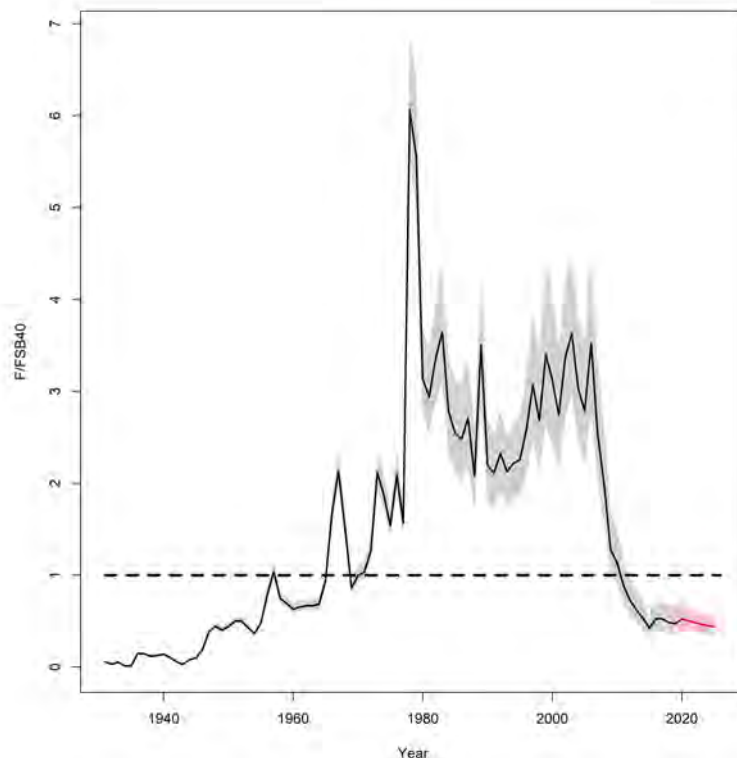
Figure 7: Annual trend in fishing mortality relative to the $F_{SB40\%}$ interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% credible interval. The projection period (2021−2025) is in red. The dashed line represents the interim target level.

Qualifying comments

The 1987 tag biomass estimate is considered to be an underestimate of the total recruited biomass due to the relatively small proportion of older fish estimated to be in the tagged fish population. However, model testing, either excluding or increasing the tag biomass estimate, has indicated that the assessment is relatively insensitive to the tag biomass estimate, especially with the assumed level of precision (CV 30%).

The level of stock depletion in the mid-1980s is strongly determined by the large catches taken during the late 1970s and early 1980s. There is an assumed level of unreported catch taken throughout the period based on assumed levels of under-reporting from the SNA 1 and SNA 8 fisheries (i.e., 20% of the reported catch). Several participants in the SNA 7 trawl fishery during that period were interviewed. The interviewees considered that unreported catches (including discards) of snapper were minor and that the assumed 20% overrun was unrealistically high. A model sensitivity revealed that stock status was not sensitive to the assumptions regarding unreported catch, although the level of assumed catch does influence the estimates of long-term yield.

During the earlier period of the fishery (prior to 1970) the trawl method may have had lower selectivity for larger (older) snapper than is currently estimated by the assessment model. Model trials have indicated that the estimates of current stock status are not sensitive to the assumptions regarding the selectivity of the trawl fishery in the early period.

For the previous assessment, the main abundance indices were CPUE indices derived for the entire fishing season (October-April). Subsequent analyses revealed increasing avoidance of snapper by the trawl fleet since 2010, especially during the spawning season (October-December). For the current assessment, the main set of CPUE indices was derived for January-April. The degree of avoidance of snapper is likely to be considerably less during this period. Nonetheless, it is considered that the main CPUE indices are also likely to under-estimate the extent of the increase in snapper abundance from 2010 onwards. There is, however, a general correspondence between the increase in the CPUE indices and the abundance indices from the *Kaharoa* trawl survey.

The increased avoidance of snapper has included changes in the configuration of the trawl gear over the last 3-5 years, including a reduction in the headline height to reduce the catch of snapper, particularly larger fish. The overall effect of this change in gear configuration has not been quantified but it may have resulted in a change in the selectivity of the trawl fishery, particularly for older fish. This effect has not been incorporated in the assessment modelling.

The time-series of core area trawl survey biomass indices was included in the stock assessment. This component of the survey does not adequately monitor the younger (1-4 yr) snapper which are predominantly found within the shallower areas (<20m) of Tasman Bay and Golden Bay not included in the core survey area.

The older fish in the population (greater than 10 years) do not appear to be fully available to the trawl survey. The trawl survey occurs during late summer and older fish may have already dispersed to areas outside the survey area, following spawning in November-December. There are significant catches of snapper taken within SNA 7 outside of the trawl survey area, i.e., in the deeper areas in the western approaches to Cook Strait. The distribution of older snapper may also extend into the southern areas of SNA 8 (South Taranaki Bight and Kapiti coast). The proportion of the older fish within the survey area may vary between years depending on the timing of the dispersal of larger snapper from Tasman Bay/Golden Bay. The most recent survey age composition was poorly fitted in the assessment models and, correspondingly, the selectivity function for the trawl survey is not well estimated, particularly for the older age classes.

Recent (2017) modifications of the trawl survey design to include the shallower areas of Tasman Bay/Golden Bay (SNA strata) have improved the utility of the survey for monitoring of SNA 7, particularly for younger (1-4 yr) fish. However, the limited number of observations (3 surveys) meant there were insufficient data to reliably estimate the selectivity for snapper within the shallower area separately from the core area. Therefore, the inclusion of two sets of age compositions (core and core+SNA strata) in the assessment model duplicated the age composition data from the core survey area, effectively doubling the influence of these data in the assessment model. Down-weighting these two data sets in the model likelihood resulted in an overall improvement in stock status. The trawl survey age composition data were informative due to the lower proportion of older snapper from the 2020/21 survey, particularly relative to the age composition from the October-December trawl fishery.

The most recent trawl survey has reaffirmed the presence of a (very) strong 2017 year class and indicated that the 2018 year class is also likely to be strong. However, there is only a single observation of the 2018 year class from the trawl survey which is not sufficient to precisely quantify the magnitude of this year class.

Future research considerations

Trawl surveys
- The modified WCSI RV *Kaharoa* survey (extra snapper strata in Tasman and Golden Bays) is monitoring the abundance and age composition of younger (1-4 yr) snapper enabling recent recruitments to be estimated in the stock assessment model and should be continued on the current biennial basis.
- The potential to utilise the surveys to derive numbers at age indices for younger (1-4 yr) age classes should be explored.
- Explore alternative approaches to incorporating data from the new strata into the assessment, including accounting for selectivity differences.

Age sampling of commercial catches
- A cycle for two consecutive years in five is recommended for SNA 7 shed sampling. Sampling should be stratified by season (and possibly target species) to enable a comparison between the age structure of catches from the spawning and post spawning periods and potential differences in age structure related to fishing depth.
- Concurrent sampling of SNA 7 and SNA 8 (particularly the south Taranaki region) would enable an evaluation of the connectivity between the two QMAs.

Recreational harvest estimates
- The recreational catches from the period prior to 2005 have been assumed and are highly uncertain. Future modelling should include an evaluation of alternative levels of recreational catch from this period.
- Recreational fishing has accounted for significant proportion of the total catch from SNA 7. In addition to the NPS, there should be ongoing sampling of the recreational catch of snapper from boat ramps; such data also need to be analysed in more detail. Boat ramp data may also provide the opportunity to collect additional size composition data from the recreational fishery, which could be used to derive age compositions.

Assessment model structure
- Changes in stock abundance and age composition over the last decade appear to have expanded the stock distribution, with older fish now extending down the west coast of the South Island and probably into South Taranaki Bight. These changes may be influencing seasonal availability to the fishery and trawl survey, and more complex assessment model structure should be considered to model seasonal availability and selectivity (potentially interacting with density).

Dynamic B_0
- Recent recruitment is estimated to be at an historically high level suggesting the stock is currently in a phase of higher productivity and that there is a degree of non-stationarity in the assumed nature of the relationship between spawning biomass and recruitment that is likely to violate the assumptions of equilibrium conditions. Further consideration is required to develop stock status indicators that account for an increase in the productivity of the SNA 7 stock.

Environmental drivers of recruitment
- Further investigation should be conducted to identify correlations between snapper recruitment and key environmental variables to improve our understanding of snapper recruitment dynamics.

Fisher behaviour impacts on CPUE
- Explore changes in fishing operations related to increased avoidance or preferential targeting of snapper to qualify the utility of CPUE indices for the monitoring of trends in snapper abundance.

Mean age at length
- Evaluate fit of VB functions to age data and if there are issues consider alternative means of representing mean age at length.

5. STATUS OF THE STOCKS

Stock Structure Assumptions

New Zealand snapper are thought to comprise either seven or eight biological stocks based on the location of spawning and nursery grounds, differences in growth rates, age structure, and recruitment strength, and the results of tagging studies. These stocks are assumed to comprise three in SNA 1 (East Northland, Hauraki Gulf, and Bay of Plenty), two in SNA 2 (one of which may be associated with the Bay of Plenty stock), two in SNA 7 (Marlborough Sounds and Tasman/Golden Bay), and one in SNA 8. Tagging studies reveal that limited mixing occurs between the three SNA 1 biological stocks, with the greatest exchange between the Bay of Plenty and Hauraki Gulf.

- **SNA 7**

The assessment is for the Tasman Bay, Golden Bay, and west coast South Island stock unit of SNA 7. The Marlborough Sounds is excluded as it is considered to support a separate stock of snapper within SNA 7.
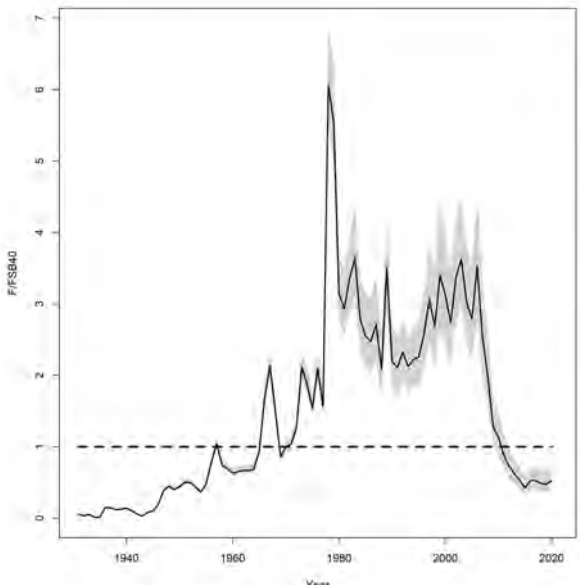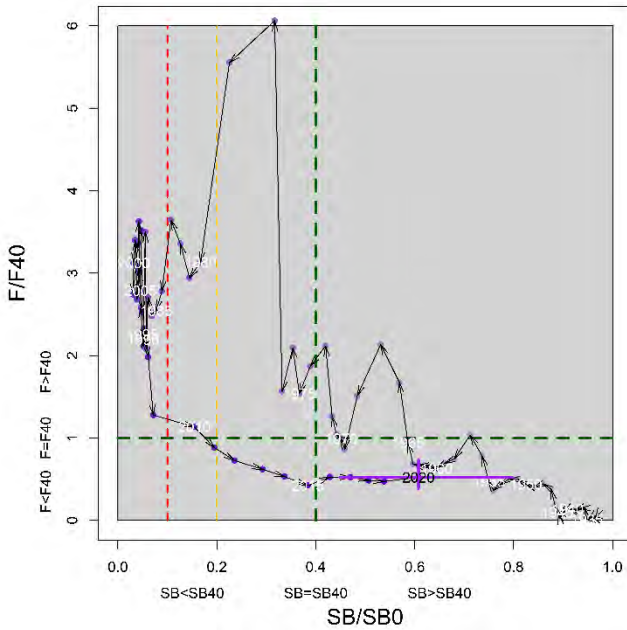
Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Base case model
Reference Points	Interim target: 40% SB_0 Soft Limit: 20% SB_0 Hard Limit: 10% SB_0 Interim overfishing threshold: $F_{SB40\%}$
Status in relation to Target	$B_{2020–21}$ was estimated to be 63% B_0; Very Likely ($> 90\%$) to be at or above the target
Status in relation to Limits	Soft Limit: Exceptionally Unlikely ($< 1\%$) to be below Hard Limit: Exceptionally Unlikely ($< 1\%$) to be below
Status in relation to Overfishing	F was estimated to be 0.52 $F_{SB40\%}$; overfishing is Very Unlikely ($< 10\%$) to be occurring
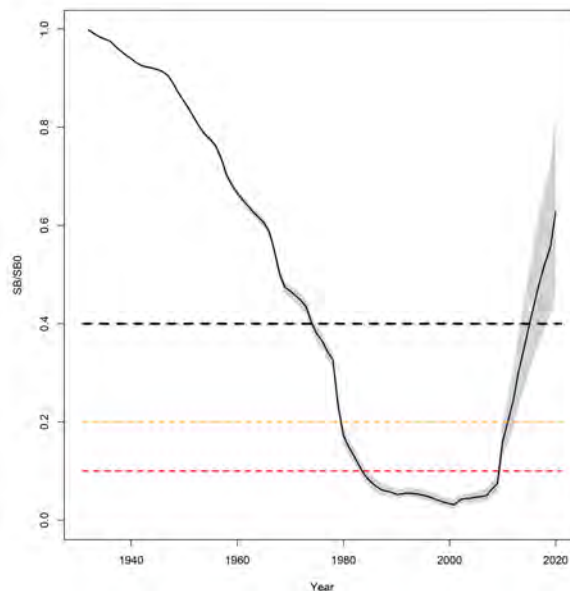
Historical Stock Status Trajectory and Current Status
 Annual trend in spawning biomass relative to the 40% SB_0 interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% credible interval. The black dashed line represents the interim target level. The red and orange dashed lines represent the hard and soft limits, respectively.

Fisheries and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass was at an historical low level in the early 2000s and increased substantially from 2009, initially due to the recruitment of several strong year classes. More recent recruitments have also been well above average.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality declined steadily from 2006 to 2015, and has remained well below the overfishing threshold since then.

Annual trend in fishing mortality relative to the $F_{SB40\%}$ interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% credible interval. The dashed line represents the interim target level.

Annual spawning biomass and fishing mortality compared to the $SB_{40\%}$ interim target biomass level and corresponding fishing mortality reference for the base model (median values from MCMCs and 95% confidence intervals for the terminal year). The green dashed lines represent the biomass and fishing mortality target levels. The red and orange dashed lines represent the hard and soft biomass limits, respectively.

Other Abundance Indices	- The BT1 CPUE index post 2010 although assumed to be biased low also shows a substantial increase.
Trends in Other Relevant Indicators or Variables	- The increase in recreational catch estimates from 2005 onwards suggests that abundance has increased.

Projections and Prognosis	
Stock Projections or Prognosis	Projections (5 yr) are provided based on long-term average recruitment, using both the median and 25th percentiles. Biomass is projected to continue to increase at the level of the current TACC and increasing recreational catch.

Probability of Current Catch or TAC causing Biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)	
Probability of Current Catch or TAC causing Overfishing to continue or to commence	Exceptionally Unlikely (< 1%)	

Assessment Methodology and Evaluation		
Assessment Type	Level 1 – Full Quantitative Stock Assessment	
Assessment Method	Age-structured Stock Synthesis model with MCMC estimation	
Assessment Dates	Latest assessment: 2022	Next assessment: 2024
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Commercial catch history (1983 onwards)	1 – High Quality
	- Commercial catch history (pre-1983)	2 – Medium or Mixed Quality: catches are considered to be less reliable
	Tagging biomass estimate	2 – Medium or Mixed Quality: whether the older ages are indexed by the tagging study is uncertain
	- CPUE indices	1 – High Quality
	- Historical commercial age frequency	2 – Medium or Mixed Quality: needs to be better characterised by method of capture
	- Recent commercial age frequency	1 – High Quality
	- Recreational catch history (2005 onwards)	1 – High quality
	- Recreational catch history (preceding period)	2 – Medium or Mixed Quality: historical levels of recreational catch are assumed
	- *Kaharoa* WCSI trawl survey biomass indices (core area)	1 – High Quality
	-Trawl survey age compositions (2016, 2018, 2020)	1 – High Quality
	-Trawl survey length compositions (2008–2016)	1– High Quality
Data not used (rank)	BT1 (October to December) CPUE index post 2010	3 – Low Quality: biased low due to avoidance behaviour
Changes to Model Structure and Assumptions	- Inclusion of Kaharoa trawl survey biomass indices (Core area TBGB+WCSI) - Seasonal stratification of fishery catches, CPUE indices, and age composition - Parameterisation of trawl fishery selectivity (Jan-Apr) - Parameterisation of trawl survey selectivity - CPUE data (October to December) post 2010 excluded - Recruitment estimated from 1975, previously from 1950	
Major Sources of Uncertainty	- Strength of recent recruitment (2017 and 2018 year classes) - Historical commercial catches - Historical and projected levels of recreational catch	

	- Availability of older (10+ yr) snapper to the trawl survey and summer commercial trawl fishery - Connectivity between SNA 7 and southern SNA 8

Qualifying Comments

It was recognised that if the increases in abundance represent a regime shift, or a significant change in productivity levels, with an associated increase in B_0, then the use of historical levels of relative abundance to establish target and limit reference points may not be appropriate.

Fisheries Interactions

Snapper target fisheries have a bycatch of flatfish, red cod, gurnard, tarakihi, and small amounts of barracouta and blue warehou. Snapper is taken as a bycatch of the inshore trawl fisheries operating within FMA 7, particularly within Tasman Bay and Golden Bay. Since 2013/14, most (> 80%) of the snapper catch has been taken as a bycatch of those fisheries.

6. FOR FURTHER INFORMATION

Annala, J H; Sullivan, K J (Comps.) (1997) Report from the Fishery Assessment Plenary, May 1997: stock assessments and yield estimates. 381 p. (Unpublished report held by NIWA library, Wellington.).

Bentley, N; Kendrick, T H (2015). The inshore fisheries of the Central (East) fisheries management area (FMA2): characterisation and catch-per-unit-effort analyses, 1989–90 to 2009–10 Draft New Zealand Fisheries Assessment Report for Research Project INS2009/03. (Unpublished report held by Fisheries New Zealand, Wellington.)

Bernal-Ramírez, J H; Adcock, G J; Hauser, L; Carvalho, G R; Smith, P J (2003) Temporal stability of genetic population structure in the New Zealand snapper, *Pagrus auratus*, and relationship to coastal currents. *Marine Biology 142(3)*: 567–574.

Bian, R; McKenzie, J R; Davies, N M (2009) Determination of optimum frequency for SNA 8 snapper market sampling based on retrospective analysis. *New Zealand Fisheries Assessment Report 2009/50*. 15 p.

Blackwell, R G; Gilbert, D J (2006) Age composition of commercial snapper landings in SNA 2, 2004–05. *New Zealand Fisheries Assessment Report 2006/46*. 18 p.

Blackwell, R G; McKenzie, J R (2013). Age composition of commercial snapper landings in SNA 2, 2007–08. *New Zealand Fisheries Assessment Report 2013/25*. 32 p.

Blackwell, R G; Stevenson, M L (1997) Trawl survey of juvenile snapper in Tasman and Golden Bays, July 1996 (KAH9608). *New Zealand Fisheries Data Report No. 87*.12 p.

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 national marine recreational fishing survey: diary results and harvest estimates. . Final Research Report for Ministry of Fisheries. (Unpublished report held by Fisheries New Zealand, Wellington.) 93 p.

Boyd, R O; Reilly, J L (2002) 1999/2000 National marine recreational fishing survey: harvest estimates. Final Research Report for Ministry of Fisheries Research Project REC9803. (Unpublished report held by Fisheries New Zealand, Wellington.)

Bradford, E (1998) Harvest estimates from the 1996 national marine fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished document held by NIWA library, Wellington.)

Brothers, N; Duckworth, A R; Safina, C; Gilman, E L (2010) Seabird bycatch in pelagic longline fisheries is grossly underestimated when using only haul data. *PloS ONE 5*: e12491. doi: 10.1371/journal.pone.001249

Bull, B; Francis, R I C C; Dunn, A; Gilbert, D J; Bian, R; Fu, D (2012) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.30.2012/03/21. *NIWA Technical Report 135*. 280 p.

Bull, B; Francis, R I C C; Dunn, A; McKenzie, A; Gilbert, D J; Smith, M H (2004) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.06-2004/09/26. *NIWA Technical Report 126*. 261 p.

Davies, N M (1997) Assessment of the west coast snapper (*Pagrus auratus*) stock (SNA 8) for the 1996–97 fishing year. New Zealand Fisheries Assessment Research Document 1997/12. 47 p. (Unpublished document held by NIWA library, Wellington.)

Davies, N M (1999) Assessment of the SNA 1 and 8 stocks for the 1997–98 fishing year. New Zealand Fisheries Assessment Research Document 1999/19. 87 p. (Unpublished document held by NIWA library, Wellington.)

Davies, N M; Gilbert, D J; McKenzie, J R (1999a) Assessment of the SNA 1 and 8 stocks for the 1998–99 fishing year. New Zealand Fisheries Assessment Research Document 1999/28. 82 p. (Unpublished document held by NIWA library, Wellington.)

Davies, N M; McKenzie, J R; Gilbert, D J (2006) Assessment of the SNA 8 stock for the 2003–04 fishing year. *New Zealand Fisheries Assessment Report 2006/9*. 32 p.

Davies, N M; McKenzie, J R; Gilbert, D J (2013) Assessment of the SNA 8 stock for the 2004–05 fishing year. *New Zealand Fisheries Assessment Report 2013/28*. 73 p.

Davies, N M; McKenzie, J R; Gilbert, D J (1999b) Monte Carlo estimation of bias in Petersen mark-recapture estimates for snapper (*Pagrus auratus*). New Zealand Fisheries Assessment Research Document 1999/20. 52 p. (Unpublished document held by NIWA library, Wellington.)

Davies, N M; Walsh, C; Hartill, B (1993) Estimating catch at age of snapper from west coast and Hauraki Gulf fisheries, 1992–93. Northern Fisheries Region Internal Report No. 17. 58 p. (Unpublished report held by Fisheries New Zealand, Auckland.)

Dunn, M R; Hurst, R J; Renwick J; Francis, R I C C; Devine, J; McKenzie, A (2009) Fish abundance and climate trends in New Zealand. *New Zealand Aquatic Environment and Biodiversity Report No. 31*. 73 p.

Fielder, D S; Bardsley, W J; Allan, G L; Pankhurst, P M (2005) The effects of salinity and temperature on growth and survival of Australian snapper, *Pagrus auratus* larvae. *Aquaculture 250(1–2)*: 201–214.

Fowler, A J; Jennings, P R (2003) Dynamics in 0+ recruitment and early life history for snapper (*Pagrus auratus*, Sparidae) in South Australia. *Marine and Freshwater Research 54(8)*: 941–956.

Francis, M P (1993) Does water temperature determine year class strength in New Zealand snapper (*Pagrus auratus*, Sparidae)? *Fisheries Oceanography* 2(2): 65–72.

Francis, M P (1994) Growth of juvenile snapper, *Pagrus auratus. New Zealand Journal of Marine and Freshwater Research 28(2)*: 201–218.

Francis, M P; Evans, J (1992) Immigration of subtropical and tropical animals into north-eastern New Zealand. Paper presented at the Proceedings of the Second International Temperate Reef Symposium.

Francis, M P; Langley, A; Gilbert, D (1997) Prediction of snapper (*Pagrus auratus*) recruitment from sea surface temperature. *In*: Hancock, D A; Smith, D C; Grant, A; Beumer J P (Eds) *Developing and sustaining world fisheries resources: the state of science and management*, pp. 67–71. 2nd World Fisheries Congress 28 Jul–2 Aug 1996, Brisbane, Australia. CSIRO Publishing.

Francis, M P; Langley, A D; Gilbert, D J (1995) Snapper recruitment in the Hauraki Gulf. New Zealand Fisheries Assessment Research Document 1995/17. 26 p. (Unpublished document held by NIWA library, Wellington.)

Francis, M P; Lyon, W S (2012) Review of commercial fishery interactions and population information for eight New Zealand protected fish species. (Unpublished NIWA client report WLG2012-64 prepared for the Department of Conservation, Wellington.) 67 p. Available at https://www.doc.govt.nz/Documents/conservation/marine-and-coastal/marine-conservation-services/pop2011-03-protected-fish-review.pdf

Francis, M P; Paul, L J (2013) New Zealand inshore finfish and shellfish commercial landings, 1931–82. *New Zealand Fisheries Assessment Report 2013/55*. 136 p.

Francis, R I C C (2011) Data weighting in statistical fisheries stock assessment models *Canadian Journal of Fisheries and Aquatic Sciences*. 68: 1124–1138.

Francis, R I C C; McKenzie, J R (2015a) Assessment of the SNA 1 stocks in 2012. *New Zealand Fisheries Assessment Report 2015/75*.

Francis, R I C C; McKenzie, J R (2015b) Assessment of the SNA 1 stocks in 2013. *New Zealand Fisheries Assessment Report 2015/76*.

Froese, R; Pauly, D (2000) FishBase 2000: concepts, design and data sources. ICLARM, Los Banos, Laguna, Philippines. 344 p.

Gilbert, D J (1994) A total catch history model for SNA 1. New Zealand Fisheries Assessment Research Document 1994/24. 16 p. (Unpublished document held by NIWA library, Wellington.)

Gilbert, D J; McKenzie, J R (1999) Sources of bias in biomass estimates from tagging programmes in the SNA 1 snapper (*Pagrus auratus*) stock. New Zealand Fisheries Assessment Research Document 1999/16. 47 p. (Unpublished document held by NIWA library.)

Gilbert, D J; McKenzie, J R; Davies, N M; Field, K D (2000) Assessment of the SNA 1 stocks for the 1999–2000 fishing year. *New Zealand Fisheries Assessment Report 2000/38*. 52 p.

Gilbert, D J; Phillips, N L (2003) Assessment of the SNA 2 and Tasman and Golden Bays (SNA 7) snapper fisheries for the 2001–02 fishing year. *New Zealand Fisheries Assessment Report 2003/45*.

Gilbert, D J; Sullivan, K J (1994) Stock assessment of snapper for the 1992–93 fishing year. New Zealand Fisheries Assessment Research Document 1994/3. 37 p. (Unpublished document held by NIWA library, Wellington.)

Gilbert, D J; Sullivan, K J; Davies, N M; McKenzie, J R; Francis, M P; Stan, P J (1996) Population modelling of the SNA 1 stock for the 1995–96 fishing year. New Zealand Fisheries Assessment Research Document 96/15. 39 p. (Unpublished document held by NIWA library, Wellington.)

Gilbert, D J; Taylor, P R (2001) The relationships between snapper (*Pagrus auratus*) year class strength and temperature for SNA 2 and SNA 7. *New Zealand Fisheries Assessment Report 2001/64*. 33 p.

Godfriaux, B L (1969) Food of predatory demersal fish in Hauraki Gulf. 1. Food and Feeding habitats of snapper. *New Zealand Journal of Marine and Freshwater Research 3*: 518–544.

Godfriaux, B L (1970) Food of predatory demersal fish in Hauraki Gulf. 3. Feeding relationships. *New Zealand Journal of Marine and Freshwater Research 4*: 325–336.

Godfriaux, B L (1974) Feeding relationships between terakihi and snapper in western Bay of Plenty, New Zealand. *New Zealand Journal of Marine and Freshwater Research 8*: 589–609.

Hamer, P A; Acevedo, S; Jenkins, G P; Newman, A (2011) Connectivity of a large embayment and coastal fishery: spawning aggregations in one bay source local and broadscale fishery replenishment. *Journal of Fish Biology 78*: 1090–1109.

Harley, S J; Gilbert, D J (2000) Assessment of the Tasman and Golden Bays snapper fishery for the 1999–2000 fishing year. *New Zealand Fisheries Assessment Report 2000/28*. 42 p.

Hartill, B; Bian, R; Armiger, H; Vaughan, M; Rush, N (2007) Recreational marine harvest estimates of snapper, kahawai, and kingfish in QMA 1 in 2004–05. *New Zealand Fisheries Assessment Report 2007/26*. 44 p.

Hartill, B; Bian, R; Rush, N; Armiger, H (2013) Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2011–12. *New Zealand Fisheries Assessment Report 2013/70*. 49 p.

Hartill, B; Bian, R; Rush, N; Armiger, H (2019) Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2017–18. *New Zealand Fisheries Assessment Report 2019/23*. 39 p.

Hartill, B; Sutton, C (2011) Characterisation and catch per unit effort indices for the SNA 7 fishery. *New Zealand Fisheries Assessment Report 2011/53*. 55 p.

Hartill, B; Watson, T; Cryer, M; Armiger, H (2007) Recreational marine harvest estimates of snapper and kahawai in the Hauraki Gulf in 2003–04. *New Zealand Fisheries Assessment Report 2007/25*. 55 p.

Holdsworth, J C; Boyd, R O (2008) Size, condition and estimated release mortality of snapper (*Pagrus auratus*) caught in the SNA 1 recreational fishery, 2006–07. *New Zealand Fisheries Assessment Report 2008/53*. 37 p.

Hurst, R J; Stevenson, M L; Bagley, N W; Griggs, L H; Morrison, M A; Francis, M P (2000) Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand coastal fish. Final Research Report to the Ministry of Fisheries Research Project ENV1999-03. 271 p. (Unpublished draft NIWA Technical Report available at https://fs.fish.govt.nz/Doc/22534/ENV1999-03%20Coastal%20Fish%20NZ%20Objective%201%20Final.pdf.ashx.)

Jones, E; Morrison, M; Parsons, D M; Paterson, C; Usmar, N; Bagley, N (2010) Fish communities (Chapter 13). Oceans 2020 Bay of Islands Survey report to LINZ prepared by NIWA. 98 p.

Kendrick, T H; Bentley, N (2010) Fishery characterisation and catch-per-unit-effort indices for snapper in SNA 8, 1989–90 to 2007–08. *New Zealand Fisheries Assessment Report 2010/42*.

Kendrick, T H; Francis, M P (2002) Fish assemblages in the Hauraki Gulf, New Zealand. *New Zealand Journal of Marine and Freshwater Research 36*: 699–717.

King, M R (1985) Fish and shellfish landings by domestic fishermen, 1974–82. *Fisheries Research Division Occasional Publication: Data Series 20*. 96 p.

King, M R (1986) Catch statistics for foreign and domestic commercial fishing in New Zealand waters, January–December, 1983. *Fisheries Research Division Occasional Publication: Data series 21*. 140 p.

King, M R; Jones, D M; Fisher, K A; Sanders, B M (1987) Catch statistics for foreign and domestic commercial fishing in New Zealand waters, January – December 1984. *New Zealand Fisheries Data Report No. 30*. 150 p.

Kirk, P D; Drummond, K L; Ryan, M (1988) Preliminary stock size analysis: Tasman/Golden Bay snapper tagging programme. New Zealand Fisheries Assessment Research Document 88/44. (Unpublished report held by Fisheries New Zealand, Wellington.)

Langley, A D (1995a) Trawl survey of snapper and associated species in the Hauraki Gulf, October–November 1994 (KAH9411). *New Zealand Fisheries Data Report No. 61*. 35 p.

Langley, A D (1995b) Trawl survey of snapper and associated species off the west coast of the North Island, October 1994 (KAH9410). *New Zealand Fisheries Data Report No. 65*. 35 p.

Langley, A D (2010) Stock assessment of SNA 2 for 2010. *New Zealand Fisheries Assessment Report 2010/26*.

Langley, A D (2013) An update of the analysis of SNA 7 trawl CPUE indices and other recent data from the SNA 7 fishery. *New Zealand Fisheries Assessment Report 2013/17*. 46 p.

Langley, A D (2014). Updated CPUE analyses for selected South Island inshore finfish. *New Zealand Fisheries Assessment Report 2014/40.* 116 p.

Langley, A D (2015) Stock assessment of SNA 7 for 2015. *New Zealand Fisheries Assessment Report 2015/42.* 67 p.

Langley, A D (2016) An update of the analysis of longline Catch-Per-Unit-Effort indices for snapper in SNA 1. *New Zealand Fisheries Assessment Report 2016/17.* 71 p.

Langley, A D (2017) Catch-Per-Unit-Effort indices for snapper in SNA 8. *New Zealand Fisheries Assessment Report 2017/45.* 40 p.

Langley, A D (2018) Stock assessment of snapper in SNA 7. *New Zealand Fisheries Assessment Report 2018/25.* 67 p.

Langley, A D (2020a) An update of the stock assessment of snapper in SNA 7. *New Zealand Fisheries Assessment Report 2020/09.* 67 p.

Langley, A D (2020b) Stock assessment of snapper in SNA 8 for 2020. *New Zealand Fisheries Assessment Report 2020/20.* 87 p

Langley, A D (2021) Stock assessment of snapper in SNA 8 for 2021. *New Zealand Fisheries Assessment Report 2021/38.* 86 p

Martino, J C; Fowler, A; Doubleday, Z A; Grammer, G L; Gillanders, B M (2019) Using otolith chronologies to understand long-term trends and extrinsic drivers of growth in fisheries. *Ecosphere 10(1)*: e02553.

Maunder, M N; Starr, P J (1995) Validating the Hauraki Gulf snapper pre-recruit trawl surveys and temperature recruitment relationship using catch at age analysis with auxiliary information. New Zealand Fisheries Assessment Research Document 1998/15. (Unpublished document held by NIWA library, Wellington.)

McKenzie, J R (2000) Factors Affecting Mortality of small Snapper (*Pagrus auratus*) caught and released by the SNA 1 Longline Fishery. (Draft Fisheries Assessment Report held by NIWA Library, Wellington).

McKenzie, J R (2012) An evaluation of a fully age-structured spatially disaggregated stock assessment model for the SNA 1 QMA. *New Zealand Fisheries Assessment Report 2012/38.* 120 p.

McKenzie, J R; Diggles, B; Tubbs, L; Poortenaar, C; Parkinson, D; Webster, K; Miller, N (2006) An evaluation of a new type of plastic-coated PIT tag for tagging snapper (*Pagrus auratus*). *New Zealand Fisheries Assessment Report 2006/8.* 40 p.

McKenzie, J R; Parsons, D M (2012) Fishery characterisations and catch-per-unit-effort indices for three sub-stocks of snapper SNA 1, 1989–90 to 2009–10. *New Zealand Fisheries Assessment Report 2012/29.* 112 p.

McMahon, S J; Parsons, D M; Donelson, J M; Pether, S M; Munday, P L (2020a) Elevated CO 2 and heatwave conditions affect the aerobic and swimming performance of juvenile Australasian snapper. *Marine Biology 167(1)*: 1–12.

McMahon, S J; Parsons, D M; Donelson, J M; Pether, S M; Munday, P L (2020b) Elevated temperature and CO2 have positive effects on the growth and survival of larval Australasian snapper. *Marine Environmental Research 161*: 105054.

Methot, R D (1990) Synthesis model: an adaptable framework for analysis of diverse stock assessment data. *International North Pacific Fisheries Commission Bulletin 50*: 259–275.

Methot, R D (2005) Technical description of the Stock Synthesis II assessment program. NOAA Technical Memorandum SEDAR 16-AW-04.

Methot, R D (2009) User manual for Stock Synthesis, model version 3.02C.

Methot, R D; Wetzell, C R (2013) Stock Synthesis: A biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research 142*: 86–99.

Middleton, D A J; Abraham, E R (2007) The efficacy of warp strike mitigation devices: Trials in the 2006 squid fishery. Final Research Report for research project IPA2006/02. (Unpublished report held by Fisheries New Zealand, Wellington).

Millar, R B; Akroyd, J M; Walshe, K A R (2001) Incidental mortality of snapper in SNA 1 and SNA 8. *New Zealand Fisheries Assessment Report 2001/78.* 36 p.

Ministry of Fisheries (2008). Harvest Strategy Standard for New Zealand Fisheries. 25 p. Available online at: https://fs.fish.govt.nz/Doc/16543/harveststrategyfinal.pdf.ashx

Morrison, M (1997) Trawl survey of snapper and associated species in the Bay of Plenty, February 1996 (KAH9601). *NIWA Technical Report 2.* 33 p.

Morrison, M A (1998) Trawl survey of snapper and associated species off the west coast of the North Island, November 1996 (KAH9615). *NIWA Technical Report 33.* 48 p.

Morrison, M A; Francis, M P (1997) Trawl survey of snapper and associated species in the Hauraki Gulf, October–November 1997 (KAH9720). *NIWA Technical Report 58.* 37 p.

Morrison, M A; Jones, E G; Consalvey, M; Berkenbusch, K (2014a) Linking marine fisheries species to biogenic habitats in New Zealand: a review and synthesis of knowledge. *New Zealand Aquatic Environment and Biodiversity Report No. 130.* 156 p.

Morrison, M A; Parkinson, D M (2001) Trawl survey of snapper and associated species off the west coast of the North Island, November 1999 (KAH9915). *NIWA Technical Report 100.* 51 p.

Morrison, M A; Lowe, M L; Parsons, D M; Usmar, N R; McLeod, I M (2009) A review of land-based effects on coastal fisheries and supporting biodiversity in New Zealand. *New Zealand Aquatic Environment and Biodiversity Report No. 37.* 100 p.

Morrison, M A; Lowe, M L; Grant, C M; Smith, P J; Carbines, G; Reed, J; Bury, S J; Brown, J (2014b) Seagrass meadows as biodiversity and productivity hotspots. *New Zealand Aquatic Environment and Biodiversity Report No. 137.* 147 p.

Morrison, M A; Stevenson, M L (2001) Review of west coast North Island trawl survey time series, 1986–96. *NIWA Technical Report 107.* 55 p.

Murphy, H M; Jenkins, G P; Hamer, P A; Swearer, S E (2013) Interannual variation in larval abundance and growth in snapper *Chrysophrys auratus* (Sparidae) is related to prey availability and temperature. *Marine Ecology Progress Series 487*: 151–162.

Parker, S J; Parsons, D; Stevenson, M; Sutton, C; Walsh, C (2015) Landed catch sampling of snapper in SNA 7 in the 2013–14 fishing year. *New Zealand Fisheries Assessment Report 2015/61.* 21 p.

Parsons, D M; Bian, R (in prep) Trawl surveys of the Hauraki Gulf and Bay of Plenty in 2019, 2020 and 2021 to estimate the abundance of juvenile snapper. Draft New Zealand Fisheries Assessment Report.

Parsons, D M; Bian, R; McKenzie, J R; McMahon, S J; Pether, S; Munday, P L (2020) An uncertain future: Effects of ocean acidification and elevated temperature on a New Zealand snapper (Chrysophrys auratus) population. *Marine Environmental Research 161*: 105089.

Parsons, D M; Morrison, M A; MacDiarmid, A B; Stirling, B; Cleaver, P; Smith, I W G; Butcher, M (2009) Risks of shifting baselines highlighted by anecdotal accounts of New Zealand's snapper (*Pagrus auratus*) fishery. *New Zealand Journal of Marine and Freshwater Research 43*: 965–983.

Parsons, D M ; Parker, S J ; Stevenson, M; Sutton, C; Buckthought, D; Bian, R; McKenzie, J; Walsh, C (2018) Catch at-age of snapper in SNA 7 in the 2016–17 fishing year. *New Zealand Fisheries Assessment Report 2018/03.* 23 p.

Paul, L J (1976) A study on age, growth and population structure of the snapper, *Chrysophrys auratus* in Hauraki Gulf. *New Zealand Fisheries Research Bulletin No. 13.* 63 p.

Paul, L J (1977) The commercial fishery for snapper *Chrysophrys (Pagrus) auratus* in the Auckland region, New Zealand, from 1900 to 1971. *Fisheries Research Division Bulletin No 15.* 84 p.

Powell, A W B (1937) Animal Communities of the Sea-bottom in Auckland and Manukau Harbours. *Transactions and Proceedings of the Royal Society of New Zealand 66*: 354–401.

Ritchie, L; Saul, P; O'Sullivan, K. (1975) The wetfish report 1941–1970. *New Zealand Ministry of Agriculture and Fisheries Fisheries Technical Report 137.* 370 p.

Schofield, M I; Langley, A D; Bentley, N; Middleton, D A J (2018a) Catch-per unit-effort (CPUE) analyses for SNA 2. *New Zealand Fisheries Assessment Report 2018/15.* 87 p.

Schofield, M I; Langley, A D; Middleton, D A J (2018b) Catch-per unit-effort (CPUE) update for FMA 2 snapper (SNA 2). Report for Fisheries Inshore New Zealand. https://www.inshore.co.nz/fileadmin/Documents/Science/SNA2_rapidCPUEupdate_2018.pdf

Stevenson, M L; MacGibbon, D J (2018) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2017 (KAH1703) *New Zealand Fisheries Assessment Report 2018/18.* 92 p.

Sullivan, K J (1985) Snapper. *In:* Colman, J A; McKoy, J L; Baird, G G (Comps. and Eds.) (1985) Background papers for the 1985 Total Allowable Catch recommendations, pp. 187–214. (Unpublished report, held in NIWA library, Wellington.)

Sullivan, K J; Hore, A J; Wilkinson, V H (1988) Snapper. *In:* Baird, G G; McKoy, J L Papers from the workshop to review fish stock assessments for the 1987–88 New Zealand fishing year, pp. 251–275. (Unpublished report, held in NIWA library, Wellington.)

Sylvester, T (1995) Initial results of the Northern boat ramp survey. *Seafood New Zealand,* February 1995. pp. 11–13.

Teirney, L D; Kilner, A R; Millar, R B; Bradford, E; Bell, J D (1997) Estimation of recreational harvests from 1991–92 to 1993–94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished document held by NIWA library, Wellington.)

Vignaux, M (1993) Catch per unit of effort (CPUE) analysis of the SNA 8 snapper fishery. New Zealand Fisheries Assessment Research Document 1993/2. 12 p. (Unpublished document held by NIWA library, Wellington.)

Wakefield, C B; Potter, I C; Hall, N G; Lenanton, R C; Hesp, S A (2017) Timing of growth zone formations in otoliths of the snapper, *Chrysophrys auratus,* in subtropical and temperate waters differ and growth follows a parabolic relationship with latitude. *ICES Journal of Marine Science 74(1);* 180–192.

Walsh, C; Armiger, H; Bian, R; Buckthought, D; McKenzie, J (2017) Length and age composition of commercial snapper landings in SNA 8, 2015–16. *New Zealand Fisheries Assessment Report 2017/02.* 40 p.

Walsh, C; Davies, N M (2004) Length and age composition of commercial landings in SNA 8, 2003–04. *New Zealand Fisheries Assessment Report 2004/56.* 18 p.

Walsh, C; Davies, N M; Buckthought, D (2006a) Length and age composition of commercial snapper landings in SNA 8, 2005–06. *New Zealand Fisheries Assessment Report 2006/54.* 21 p.

Walsh, C; Davies, N M; Rush, N; Buckthought, D; Smith, M (2006b) Age composition of commercial snapper landings in SNA 1, 2004–05. *New Zealand Fisheries Assessment Report 2006/39.* 34 p.

Walsh, C; Davies, N M; Rush, N; Buckthought, D; Vaughn, M; Smith, M (2007) Length and age composition of commercial snapper landings in SNA 1, 2005–06. *New Zealand Fisheries Assessment Report 2007/01.* 30 p.

Walsh, C; Davies, N M; Rush, N; Middleton, C; Smith, M; Newmarch, G (2006c) Length and age composition of commercial snapper landings in SNA 1, 2003–04. *New Zealand Fisheries Assessment Report 2006/7.* 46 p.

Walsh, C; McKenzie, J; Armiger, H (2006d) Spatial and temporal patterns in snapper length and age composition and movement, west coast North Island, New Zealand. *New Zealand Fisheries Assessment Report 2006/6.* 59 p.

Walsh, C; McKenzie, J M; Bian, R; Armiger, H; O'Maolagain, C; Buckthought, D; Smith, M; Ferguson, H; Miller A (2012) Snapper catch-at-length and catch-at-age heterogeneity between spatial strata in SNA 2 bottom trawl landings, 2007–08 and 2008–09. *New Zealand Fisheries Assessment Report 2012/40.* 44 p.

Walsh, C; McKenzie, J A; Buckthought, D; Armiger, H; Ferguson, H; Smith, M; Spong, K; Miller, A (2011) Age composition of commercial snapper landings in SNA 1, 2009–10. *New Zealand Fisheries Assessment Report 2011/54.*

Wright, P; McClary, D; Boyd, R O (2004) 2000/2001 National Marine Recreational Fishing Survey: direct questioning of fishers compared with reported diary data. Final Research Report for Ministry of Fisheries Project REC2000-01: Objective 2. (Unpublished report held by Fisheries New Zealand, Wellington.)

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24.* 104 p.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67.* 139 p.

Zeldis, J R; Oldman, J; Ballara, S L; Richards, L A (2005) Physical fluxes, pelagic ecosystem structure, and larval fish survival in Hauraki Gulf, New Zealand. *Canadian Journal of Fisheries and Aquatic Sciences 62(3)*: 593–610.

Zeldis, J R; Francis, R I C C (1998) A daily egg production method estimate of snapper biomass in Hauraki Gulf, New Zealand. *ICES Journal of Marine Science 55*: 522–534.

SNAPPER (SNA 8)

(*Chrysophrys auratus*)
Tamure, Kouarea
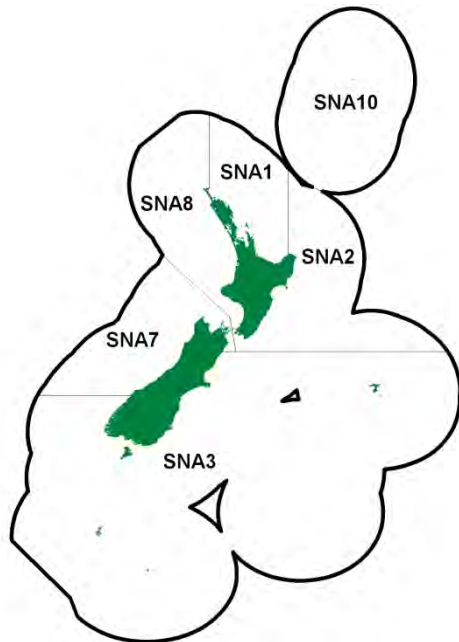
1. FISHERIES SUMMARY

1.1 Commercial fisheries

Table 1 and Table 2 provide a summary by fishing year of the reported commercial catches, TACCs, and TACs for SNA 8. Landings and TACC are plotted in Figure 1.

Table 1: Reported landings (t) of snapper from SNA 8 from 1931 to 1990.

Year	SNA 8	Year	SNA 8
1931–32	140	1961	1 178
1932–33	159	1962	1 352
1933–34	213	1963	1 456
1934–35	190	1964	1 276
1935–36	108	1965	1 182
1936–37	103	1966	1 831
1937–38	85	1967	1 477
1938–39	89	1968	1 491
1939–40	71	1969	1 344
1940–41	76	1970	1 588
1941–42	62	1971	1 852
1942–43	57	1972	1 961
1943–44	75	1973	3 038
1944	69	1974	4 340
1945	124	1975	4 217
1946	244	1976	5 326
1947	251	1977	3 941
1948	215	1978	4 340
1949	277	1979	3 464
1950	318	1980	3 309
1951	364	1981	3 153
1952	361	1982	2 636
1953	1 124	1983	1 814
1954	1 093	1984	1 536
1955	1 202	1985	1 866
1956	1 163	1986	959
1957	1 472	1987	1 072
1958	1 128	1988	1 565
1959	1 114	1989	1 571
1960	1 202	1990	1 551

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. The 'QMA totals' are approximations derived from port landing subtotals, as follows: SNA 8 Paraparaumu to Hokianga.
3. Before 1946 the 'QMA' subtotals sum to less than the New Zealand total because data from the complete set of ports are not available.
4. Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.
5. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings.

Table 2: Reported landings (t) of snapper from SNA 8 from 1983–84 to present and gazetted and actual TACCs (t) for 1986–87 to present. QMS data from 1986–present.

Fishstock FMAs	SNA 8 8, 9	
	Landings	TACC
1983–84†	1 725	–
1984–85†	1 546	–
1985–86†	1 828	–
1986–87	893	1 331
1987–88	1 401	1 383
1988–89	1 527	1 508
1989–90	1 551	1 594
1990–91	1 659	1 594
1991–92	1 459	1 594
1992–93	1 543	1 500
1993–94	1 542	1 500
1994–95	1 436	1 500
1995–96	1 558	1 500
1996–97	1 613	1 500
1997–98	1 589	1 500
1998–99	1 636	1 500
1999–00	1 604	1 500
2000–01	1 631	1 500
2001–02	1 577	1 500
2002–03	1 558	1 500
2003–04	1 667	1 500
2004–05	1 663	1 500
2005–06	1 434	1 300
2006–07	1 327	1 300
2007–08	1 304	1 300
2008–09	1 345	1 300
2009–10	1 280	1 300
2010–11	1 313	1 300
2011–12	1 360	1 300
2012–13	1 331	1 300
2013–14	1 275	1 300
2014–15	1 272	1 300
2015–16	1 328	1 300
2016–17	1 334	1 300
2017–18	1 288	1 300
2018–19	1 293	1 300
2019–20	1 347	1 300
2020–21	1 295	1 300

† FSU data. SNA 8 = Statistical Areas 037, 039–048. § Includes landings from unknown areas before 1986–87.

From 1 October 2005 the TACC for SNA 8 was reduced to 1300 t within a TAC of 1785 t to ensure a faster rebuild of the stock (Table 3). All commercial fisheries have a minimum legal size (MLS) for snapper of 25 cm.

Table 3: TACs, TACCs, and allowances (t) for SNA 8 from 1 October 2020.

Fishstock	TAC	TACC	Customary allowance	Recreational allowance	Other mortality
SNA 8	1 785	1 300	43	312	130

Foreign fishing

Japanese catch records and observations made by New Zealand naval vessels indicate that significant quantities of snapper were taken from New Zealand waters by Japanese vessels from the late 1950s until 1977. There are insufficient data to quantify historical Japanese catch tonnages for the respective snapper stocks. However, trawl catches have been reported by area from 1967 to 1977, and longline catches from 1975 to 1977 (Table 4). These data were supplied to the Fisheries Research Division of MAF in the late 1970s; however, the data series is incomplete, particularly for longline catches.

Table 4: Reported landings (t) of snapper from 1967 to 1977 by Japanese trawl and longline fisheries.

Year	(a) Trawl	Trawl catch (all species)	Total snapper trawl catch	SNA 8
1967		3092	30	NA
1968		19 721	562	309
1969		25 997	1 289	929
1970		31 789	676	543
1971		42 212	522	403
1972		49 133	1 444	1 217
1973		45 601	616	466
1974		52 275	472	363
1975		55 288	922	735
1976		133 400	970	676
1977		214 900	856	708

Year	(b) Longline	Total Snapper	SNA 8
1975		1 510	749
1976		2 057	1 127
1977		2 208	1 104
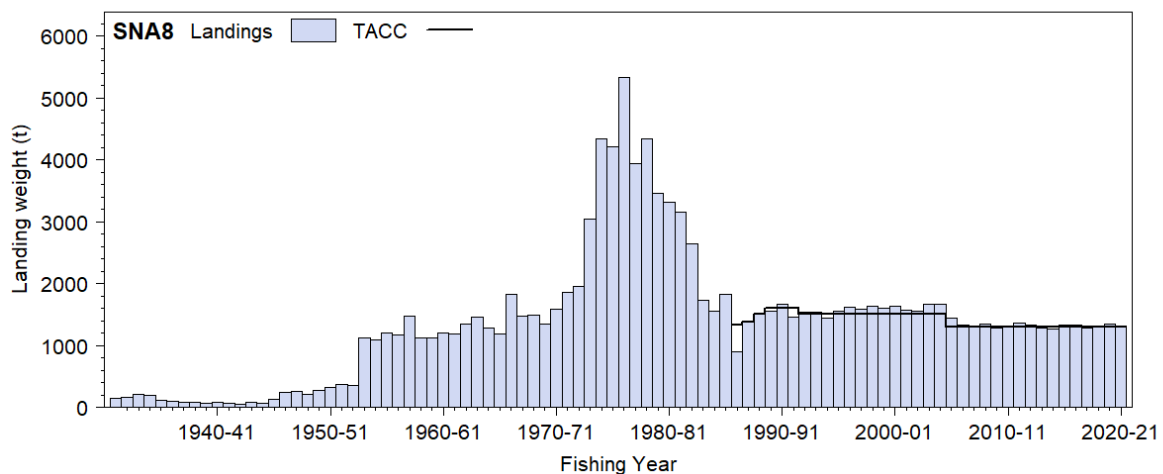
Figure 1: Total reported landings and TACC for the SNA 8.

1.2 Recreational fisheries

The snapper fishery is the largest recreational fishery in New Zealand. It is the major target species on the northeast and northwest coasts of the North Island and is targeted seasonally around the rest of the North Island and the top of the South Island. The current allowance within the SNA 8 TAC is shown in Table 3.

1.2.1 Management controls

The two main methods used to manage recreational harvests of snapper are minimum legal size limits (MLS) and daily bag limits. Both have changed over time (Table 5). The number of hooks permitted on a recreational longline was reduced from 50 to 25 in 1995.

Table 5: Changes to minimum legal size limits (MLS) and daily bag limits used to manage recreational harvesting levels in SNA 8.

Stock	MLS	Bag limit	Introduced
SNA 8	25	30	1/01/1985
SNA 8 (FMA 9 only)	25	20	30/09/1993
SNA 8 (FMA 9 only)	27	15	1/10/1994
SNA 8	27	10	1/10/2005

1.2.2 Estimates of recreational harvest

A background to the estimation on recreational harvest of snapper is provided in the Introduction – Snapper chapter. Recreational harvest estimates for SNA 8 are provided in Table 6.

In 2005, the Snapper Working Group and Plenary considered recreational catches from SNA 8. Two alternative levels were assumed for the recreational catch from 1990 to 2004, either 300 t or 600 t. The Plenary considered these values were likely to bracket the true average level of catch in this period. The estimate from the 2006–07 aerial overflight survey of the SNA 8 fishery (260 t) suggests that the assumed value of 300 t may have been the more plausible. There are potential sources of bias associated with the aerial-access estimate, both negative (a potential underestimation of the shore-based harvest, especially to the south) and positive (over-reporting of harvests by charter boat operators in a log book survey which are included in the estimate). The 2011–12 and 2017–18 national panel surveys provided plausible results and are considered to be broadly reliable and suggest that catch is increasing. Web camera/ creel survey monitoring in SNA 8 started in late 2011 and has found no general trend in fishing effort, but a gradual fluctuating increase in catch rates and hence harvest, since that time. No estimates of absolute catch have yet been developed from these data.

Table 6: Recreational catch estimates for snapper stocks. Totals for a stock are given in bold. The telephone/diary surveys ran from December to November but are denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey catch estimates). Numbers and mean weights are not calculated in the tag ratio method. Includes charter boat catch and panel survey estimates of s111 catches.

Stock	Year	Method	Number of fish (thousands)	Mean weight (g)	Total weight (t)	CV
SNA 8						
Total	1991	Tag ratio	–	–	**250**	–
Total	1994	Telephone/diary	361	658	**238**	–
Total	1996	Telephone/diary	271	871	**236**	–
Total	2000	Telephone/diary	648	1 020	**661**	–
Total	2001	Telephone/diary	1 111	–	**1 133**	–
Total	2007	Aerial-access	–	–	**260**	0.10
Total	2011–12	Panel survey	557	770 /1 255 / 1 160[7]	**630**	0.16
Total	2017–18	Panel survey	707	–	**892**	0.12

[7] Separate mean weight estimates were used for harbours (Kaipara and Manukau)/North coast (open coast fishery north of Tirua Point)/ South coast (open coast fishery south of Tirua Point).

1.3 Customary non-commercial fisheries

Snapper form important fisheries for customary non-commercial, but the annual catch is not known. The information on Māori customary harvest under the provisions made for customary fishing is limited (Table 7). It is likely that Māori customary fishers utilise the provisions under recreational fishing regulations. Customary reporting varies within SNA 8. Large areas of SNA 8 are gazetted under the Fisheries (Kaimoana Customary Fishing) Regulations 1998 which require reporting on authorisations. In the areas not gazetted, customary fishing authorisations issued would be under the Fisheries (Amateur Fishing) Regulations 2013, where there is no requirement to report. The numbers reported in Table 7 may be underestimated.

Table 7: Customary approvals in SNA 8 from 2005 to 2020.

Year	Quantity approved (kg)	Reported actual quantity harvested (kg)	Number of authorisations issued
2005	130		
2006	220		3
2007	250	70	3
2008	30	30	
2009	950	651	5
2010	5 457	3 176	7
2011	4 910	2 950	15
2012	3 340	2 494	6
2013	4 887	2 965	16
2014	19 030	6 136	31
2015	16 025	5 186	19
2016	11 270	5 578	28
2017	1 510	1 133	13
2018	790	608	9
2019	18 270	912	46
2020	5 800	Current year	15

1.4   Illegal catch

No new information is available to estimate illegal catch. For modelling SNA 8 an assumption was made that non-reporting of catch was 20% of reported domestic commercial catch prior to 1986 and 10% of reported domestic commercial catch since the QMS was introduced. This was to account for all forms of under-reporting. These proportions were based on the black-market trade in snapper and higher levels of under-reporting (to avoid tax) that existed prior to the introduction of the QMS. The 10% under-reporting post-QMS accounts for the practice of 'weighing light' and the discarding of legal-size snapper.

1.5   Other sources of mortality

No estimates are available regarding the amount of other sources of mortality on snapper stocks; although high-grading of longline fish and discarding of under-sized fish by all methods occurs. An at-sea study of SNA 1 commercial longline fisheries in 1997 (McKenzie 2000) found that 6–10% of snapper caught by number were under 25 cm (MLS). Results from a holding net study indicate that mortality levels amongst lip-hooked snapper caught shallower than 35 m were low.

Estimates for incidental mortality were based on other catch-at-sea data using an age-length structure model for longline, trawl, seine, and recreational fisheries. In SNA 1, estimates of incidental mortality for the year 2000 from longlines were less than 3% and for trawl, seine, and recreational fisheries between 7% and 11% (Millar et al 2001). In SNA 8, estimates of trawl and recreational incidental mortality were lower, mainly because of low numbers of 2- and 3-year old fish estimated in 2000.

In SNA 1, recreational fishers release a high proportion of their snapper catch, most of which was less than 27 cm (recreational MLS). An at-sea study in 2006–07 recorded snapper release rates of 54.2% of the catch by trailer boat fishers and 60.1% of the catch on charter boats (Holdsworth & Boyd 2008). Incidental mortality estimated from condition at release was 2.7% to 8.2% of total catch by weight depending on assumptions used.

2.   BIOLOGY

For further information on snapper biology refer to the Introduction – Snapper chapter. A summary of published estimates of biological parameters for SNA 8 is presented in Table 8.

Table 8: Estimates of biological parameters.

Fishstock	Estimate			Source
1. Instantaneous rate of natural mortality (M)				
SNA 1, 2, 7, & 8	0.075			Hilborn & Starr (unpub. analysis)
2. Weight = a(length)^b (Weight in g, length in cm fork length)				
All	$a = 0.04467$	$b = 2.793$		Paul (1976)
3. von Bertalanffy growth parameters	Both sexes combined			
	K	t_0	L_∞	
SNA 8 (1990s)	0.16	-0.11	66.7	Gilbert & Sullivan (1994)
4. Age at recruitment (years)				
SNA 8	3			Gilbert & Sullivan (1994)

3. STOCKS AND AREAS

New Zealand snapper are thought to comprise either seven or eight biological stocks based on: the location of spawning and nursery grounds; differences in growth rates, age structure, and recruitment strength; and the results of tagging studies. These stocks comprise three in SNA 1 (East Northland, Hauraki Gulf, and Bay of Plenty (BoP)), two in SNA 2 (one of which may be associated with the BoP stock), two in SNA 7 (Marlborough Sounds and Tasman Bay/Golden Bay) and one in SNA 8. Tagging studies reveal that limited mixing occurs between the three SNA 1 biological stocks, with greatest exchange between BoP and Hauraki Gulf.

Tagging studies in SNA 8 have shown considerable movements of fish between South Taranaki Bight and the area north of Cape Egmont. However, recent *Kaharoa* WCNI trawl surveys indicate some differences in the age structure of snapper between the two areas which may suggest a degree of spatial stratification of the SNA 8 stock.

Tagging studies in SNA 7 (1986/87) and SNA 8 (1990) revealed reciprocal movements of snapper between Tasman Bay/Golden Bay and South Taranaki Bight, although the scale of the movement was relatively low during that period.

Location-based snapper catch data from the trawl fisheries in SNA 7 and southern SNA8 has revealed an overlap of the distribution of snapper catches in western approaches to Cook Strait between Durville Island and Kapiti Island, particularly since 2014/15. Snapper age compositions are available from recent (2018-2020) *Kaharoa* trawl surveys of the South Taranaki Bight and the Tasman Bay/Golden Bay area of the WCSI trawl survey. There are strong differences in the relative strength of individual year classes from the 2019 South Taranaki Bight age composition compared to the 2018 and 2020 surveys, while the 2019 STB age composition was very similar to the age structures from the 2019 Tasman Bay/Golden Bay trawl survey and the commercial fishery in the TBGB area. These observations indicate a degree of mixing of the snapper populations between SNA 7 and the STB area (SNA8), although the extent of mixing may vary between years, potentially related to variation in the timing of the main spawning period in each area.

4. STOCK ASSESSMENT

An assessment for SNA 8 was conducted in 2020 and finalised in 2021.

SNA 8 (Auckland West/Central West)

A stock assessment for SNA 8 was conducted in 2020 (Langley 2020b) and updated and finalised in 2021 (Langley 2021). The assessment superseded the assessment conducted in 2005 (Davies et al 2013) and incorporated data from the intervening period, including recent trawl survey recruitment indices, commercial age composition data, and trawl CPUE indices.

4.1. Stock assessment model
The 2021 stock assessment of SNA 8 was conducted using an age-structured population model implemented in Stock Synthesis. The model incorporated data to the 2020–21 fishing year (2021 model year) including:
- Commercial catches by method, 1931–2021;
- Recreational catches, 1931–2021;
- Tag biomass estimates and population length compositions 1990, 2002;
- Estimates of numbers at age 2, 3, 4, and 5 year from *Kaharoa* inshore trawl surveys;
- Single trawl CPUE indices 1997–2020;
- Pair trawl CPUE indices 1974–1991;
- Single trawl catch age compositions (26 observations) 1975–2019;
- Pair trawl catch age compositions (18 observations) 1975–2006;
- Recreational catch length compositions; and
- Average length-at-age derived from otolith samples.

Commercial catches

Reported commercial catches from 1931–1990 were compiled by Gilbert & Sullivan (1994). These catches include estimates of reported foreign catches for 1968 to 1979 (Gilbert & Sullivan 1994). Annual commercial catches from 1986–87 to 2019–20 fishing years were available from catch reporting under the Quota Management System (Figure 2).

Previous snapper assessments have included an additional component of catch to account for unreported commercial catches (Davies et al 2006). Annual unreported catches were assumed to represent an additional 20% of the reported catch in the period prior to the introduction of the QMS and 10% of the reported catch in the subsequent years.

The commercial catch was dominated by two main fishing methods: single trawl and pair trawl. The pair trawl fishery developed in the mid-1970s and was the dominant method during 1976–1989 accounting for an average of 75% of the annual catch. The proportion of the catch taken by each trawl method during 1989–90 to 2019–20 was determined from the catch and effort data from the fisheries.

The compiled commercial catch history includes estimates of foreign catch; i.e., trawl catches from 1967 to 1977 and longline catch from 1975 to 1977 were included at the reported levels (Davies 1999). However, catch reports from the Japanese longline fleet were not available for 1965–1974 (Davies et al 2006). Following previous assessments (e.g., Davies et al 2006), an additional catch of 2000 t per annum was assumed for the Japanese fleet for that period.
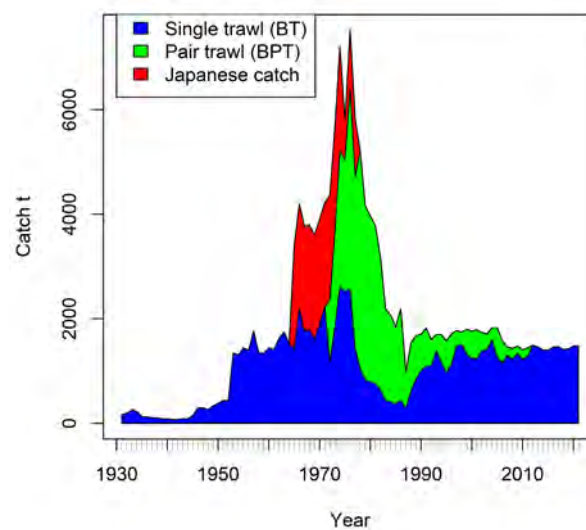
Figure 2: Annual commercial catches included in the base model, assuming unreported Japanese longline catches of 2000 t.

Recreational catches

A time series of recreational catch for 1931–2021 was configured, informed by recreational catch estimates available from 1990 (Figure 3). There is no information available regarding earlier (pre-1990) levels of recreational catch. Previous assessments formulated annual catches for this period based on an assumed initial (1931) level of recreational catch of 60 t and a linear increase in catch over subsequent years to the level of the 1990 recreational catch estimate (239 t). Annual catches were assumed to remain at the same level during 1990–1996.

Recreational catches in 2007, 2012, and 2018 were assumed to be equivalent to the point estimates from the respective recreational surveys, assumed known without error. A preliminary catch history was configured that assumed recreational catches increased linearly between each successive survey. The resultant catch history was incorporated in a preliminary configuration of the assessment model to generate a biomass trajectory that provided estimates of the exploitation rate for the recreational fishery corresponding to each survey estimate. The resultant estimates of exploitation rate were then used to iteratively regenerate the recreational catches in the years between the survey estimates (for 1997 to

2019). Exploitation rates were assumed to change linearly between successive surveys and the interpolated exploitation rate was applied to the annual biomass estimates to determine the recreational catches for the intervening years. The recreational catch in 2019 was derived based on the exploitation rate corresponding to the recreational catch estimate from 2018. This approach allows the recreational catch to vary annually in response to variations in stock abundance (as opposed to linear interpolation of catches between successive surveys). For the base model, recreational catches in 2020 and 2021 were held constant at the 2019 level. An alternative series of recent (2019–2021) recreational catches was derived using the recreational harvest rate from 2018 (*RecF* model).

Length composition data from the SNA 8 recreational fishery reveal that smaller fish are typically caught inside the west coast harbours (Hokianga, Kaipara, Manukau, Raglan, Kawhia) rather than the coastal area outside the harbours. On that basis, the annual recreational catches were partitioned into two fisheries based on these definitions, apportioned based on the recent distribution of catch (approximately 25% within harbours).

Customary Catch

There were no reliable estimates of annual customary catches from SNA 8 available for inclusion in the assessment model, although recent information indicates that the level of customary catch was relatively low (less than 6 t per annum, Table 7). A component of the customary catch is probably included within the time series of recreational catch estimates and no additional estimate for customary catch was included in the assessment model.
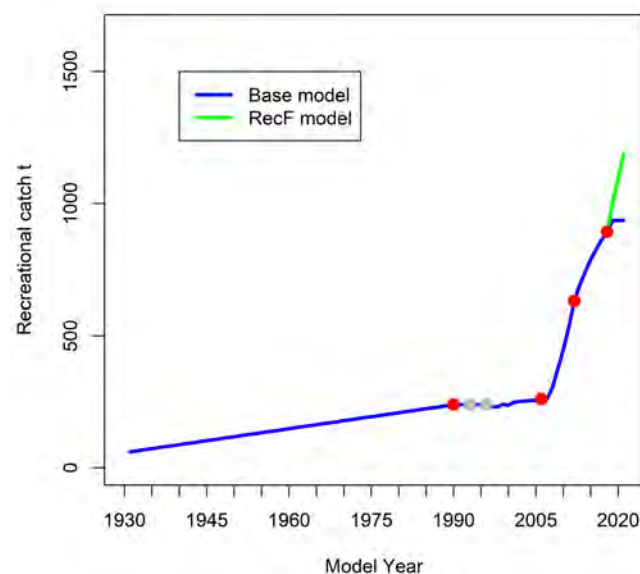
Figure 3: Recreational catch estimates from SNA 8 (red points) used in the derivation of the recreational catch history (blue line). The green line represents an alternative series of recent recreational catches assuming a constant recreational harvest rate from 2018. The grey points are additional recreational catch estimates from the 1993–94 and 1995–96 telephone diary surveys (presented for comparison only).

Tagging biomass

Two estimates of absolute biomass are available from tagging programmes conducted in 1990 and 2002. The current assessment used the equivalent biomass estimates included in a previous assessment; i.e., 1990, 9505 t (CV = 0.18) and 2002, 10 442 t (CV = 0.12) (Davies et al 2013). The biomass estimates were derived to represent all fish in the population 3 years and older, corresponding to fish above 25 cm fork length (FL).

The two tagging programmes also provided estimates of the population length composition for fish above 25 cm FL. The current assessment used the population proportions-at-length included in the previous assessment (Davies et al 2013). These length compositions represented fish aged 3 years and older and, accordingly, were truncated at a lower bound of 25 cm which approximates the lower length range of 3-year old fish.

Trawl survey indices

Trawl surveys of inshore finfish species, including snapper, off the west coast of the North Island were first conducted by RV *Kaharoa* in October–November 1986 and 1987. The spatial extent of these initial surveys was relatively limited and did not encompass the broader distribution of snapper. The survey area was extended for the subsequent series of trawl surveys that were conducted in 1989, 1991, 1994, 1996, and 1999. The *Kaharoa* trawl surveys were reinstated in 2018 and additional surveys were conducted in 2019 and 2020.

Since 1989, all surveys have encompassed a core area (from Ninety Mile Beach to North Taranaki Bight extending to the 100 m depth contour) and applied a similar spatial stratification. The spatial domain of the core area was refined to account for the removal of the Māui dolphin trawl exclusion area which was not sampled by the 2018–2020 trawl surveys.

The core area was applied to derive a comparable time series of survey biomass indices and scaled length compositions. The length compositions were converted to age compositions using an age-length key derived from otoliths collected from the core area of the survey.

The surveys were conducted at the beginning of the fishing year (October–November) and have been assigned to the corresponding model year following the calendar year of the survey. For example, the trawl survey in November 2018 was assigned to the 2019 model year (and denoted the 2018–19 survey). Correspondingly, the ages of the sampled fish were incremented to the age at 1 January following the survey (e.g., fish aged 1+ at the time of the survey were assigned an age of 2 years).

The five biomass indices from the earlier surveys are substantially lower than the biomass estimates from the three recent surveys, although there is also a considerable difference in the magnitude of these three recent indices (Figure 4). The corresponding age compositions from the surveys reveal that the earlier surveys were dominated by 2- to 5-year old fish. For the recent surveys, the age compositions comprised a higher proportion of fish older than 6 years, particularly for the two most recent surveys (2019–20 and 2020–21).
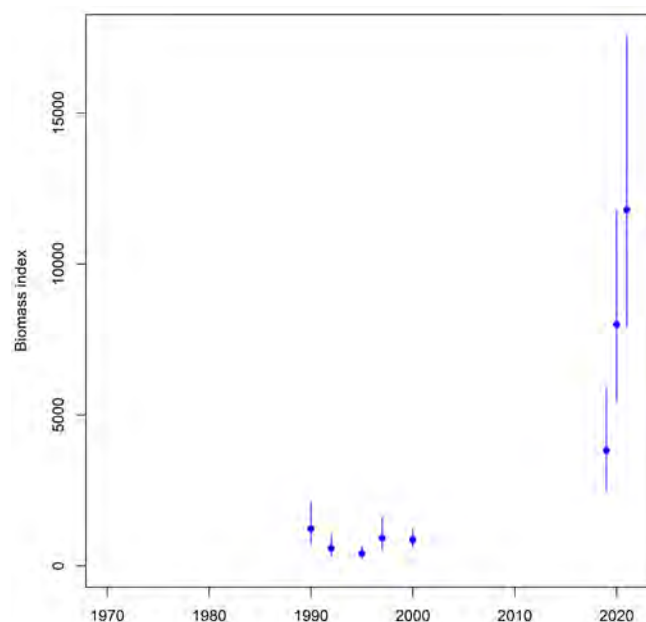
Figure 4: Snapper total biomass indices (and 95% confidence intervals) from the core area of the WCNI trawl survey area.

Most of the large increase in the biomass indices between the 2018–19 and 2019–20 trawl surveys was attributable to an increase in the abundance of fish surveyed in the 8- to 12-year old age range fish. The comparison of successive estimates of the individual year classes indicates that the catchability of these older fish was greater for the 2019–20 survey than for the 2018–19 survey. There is some concern regarding the timing of the 2018–19 trawl survey which was later than the other surveys in the series. The distribution of snapper catches and the gonadal maturation data suggested that the 2018–19 survey

may have coincided with the main spawning period. Consequently, a significant proportion of the adult biomass may have been concentrated in areas not adequately sampled by the survey, in particular the shallower areas in the vicinity of harbour entrances.

Similarly, there was a considerable increase in the snapper biomass indices between the 2019–20 and 2020–21 trawl surveys (Figure 4), including an increase in the abundance of older fish (> 10 years). Most of the increase in biomass was in the 50–100 m depth range in the vicinity of Kaipara Harbour and Manukau Harbour. This may indicate an expansion of the main distribution of mature snapper, from the shallower areas not fully sampled by the current trawl survey, thereby increasing the overall availability of snapper to the trawl survey.

The survey age compositions were partitioned to derive estimates of numbers of fish in each age class. Survey estimates of 1-year old fish (0+) are relatively imprecise compared with estimates of numbers of fish in the older age classes. There are a limited number of year classes for which successive estimates of relative abundance (numbers of fish) are available from across a range of age classes from successive surveys. However, estimates of the numbers of 1-year old fish are generally substantially lower than subsequent estimates of the same year class at older ages and the individual estimates are poorly correlated. This indicates that the survey estimates of 1-year old fish probably do not provide a reliable index of the relative abundance of an individual year class. Probably because a large proportion resides in shallow water and harbours, which are not surveyed.

In contrast, there is a reasonable correspondence between successive trawl survey estimates of the number of fish in a specific year class over the 2- to 5-year age classes (Figure 5). For example, the estimates of abundance of the 2016 year class from the three successive trawl surveys (at ages 3, 4, and 5 years) indicated that the year class was one of the strongest indices from the respective series. This suggests that the trawl surveys are consistently sampling fish within those age classes.

Commercial age compositions

There is a considerable time series of age compositions available from the single trawl (26 years) and pair trawl fisheries (18 years), including samples from the mid-late 1970s. Those samples are characterised by a high proportion of fish in the oldest, aggregated age group (20+ 'plus group'). Fish older than 20 years represented a trivial proportion of the sampled catch from 1990 onwards. The more recent age compositions tended to be dominated by relatively strong year classes that are evident in successive samples.
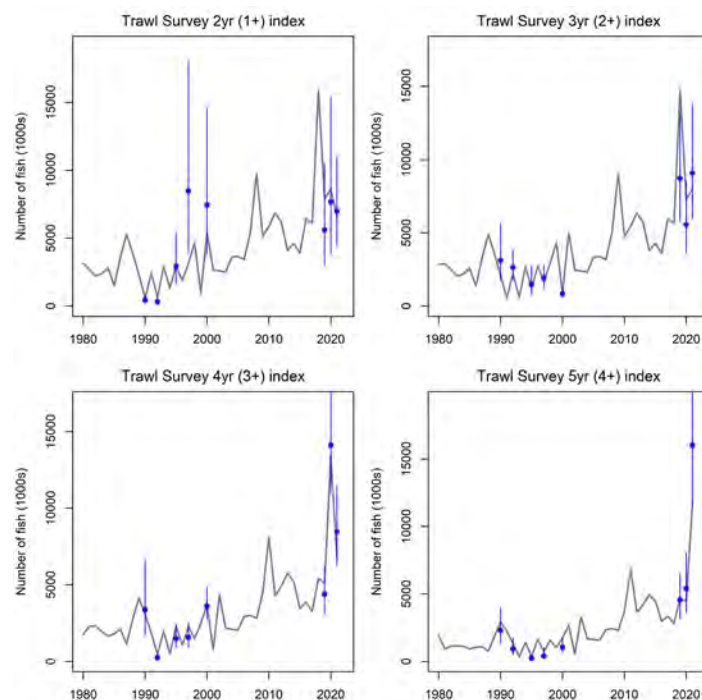
Figure 5: The four sets of age-specific trawl survey abundance indices (blue points and associated 95% confidence intervals) and the model fit to each set of indices (grey lines).

CPUE indices

Vignaux (1993) derived CPUE indices for the pair trawl fishery for 1974–1991 and the CPUE indices have been incorporated in the stock assessments of SNA 8 conducted since Gilbert & Sullivan (1994). The CPUE indices decline considerably during 1974–1986 and then recover somewhat over the subsequent years (Figure 6). The CPUE indices have an associated CV of 0.13–0.30 (Vignaux 1993) and the most recent assessment (Davies et al 2013) assumed an additional process error of 0.20.

A standardised CPUE analysis of the SNA 8 single trawl fishery catch and effort data was updated, including data from 1996–97 to 2019–20 (following Langley 2017). The data set comprised individual trawl records (fishing event-based data) from trawls targeting snapper, trevally, and red gurnard during January–April. The annual CPUE indices were relatively constant during 1996–97 to 2003–04. The indices increased over the subsequent years, initially increasing by approximately 70% during 2003–04 to 2007–08, and then increasing considerably during 2007–08 to 2014–15 (Figure 6). The indices remained at the higher level during 2015–16 to 2018–19 but were considerably lower in 2019–20. In recent years, there have been a limited number of vessels operating in the inshore trawl fishery and the operation of the vessels has changed in response to the increase in the abundance of snapper (increased avoidance). The standardised CPUE analysis has not adequately accounted for the change in fishing operation, particularly in the most recent year, as indicated by a divergence in the CPUE trends from the two main vessels in the fishery.

The recent trawl CPUE indices have an associated CV of 0.12–0.18. From the results of preliminary modelling, the CPUE indices were assigned a process error of 0.1.
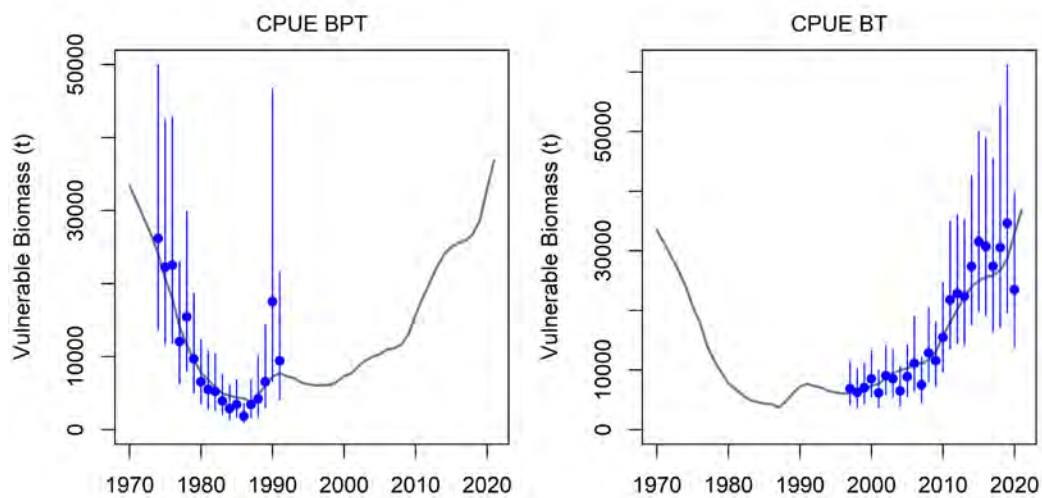
Figure 6: BPT CPUE indices (left) and recent BT CPUE indices (right). The grey line represents the model fit to the indices.

Model structure

The assessment model included the entire SNA 8 catch history (from 1932) and assumed that the initial population age structure was in an equilibrium, unexploited state. The population structure included 30 age classes (both sexes combined), the oldest age class representing an aggregated 'plus' group (30 years and older). The model data period extended to the 2021 year (2020–21 fishing year).

The key biological parameters for the SNA 8 stock assessment are presented in Table 9. Natural mortality (M) was specified as a constant value of 0.075 based on the analysis of Hilborn & Starr (given in Langley 2020).

There is no evidence of sexual dimorphism in snapper growth and the growth parameters have been determined for both sexes combined. There is a large data set of age-length observations from snapper sampled from the mid-1970s to recent years. These data indicate the growth of snapper has varied over time characterised by three periods: slower growth rates of fish sampled during the 1970s, higher growth rates during the 1980s, 1990s, and early 2000s, and slower growth rates since the mid-2000s. Separate

growth parameters (k and *Linf*) of the von Bertalanffy function were estimated for these three time blocks (1931–1979, 1980–2005, and 2006–2021) during the preliminary modelling phase. The model was informed by the time series of age-length data aggregated as annual mean length-at-age observations. The resultant growth parameters were fixed in the final set of model options (and the mean length-at-age observations were not included in the input data sets). The estimated growth parameters were very similar for the early and recent periods, and the growth parameters for the intervening period were comparable with the published growth parameters derived from the same period.

The parameterisation of growth in Stock Synthesis constrains annual growth increments to be greater than or equal to zero. Thus, the decline in growth rates between 2005 and 2006 resulted in a transition in the growth of individual cohorts with the length of the older cohorts remaining constant for several years.

Maturity was assumed to be age-specific with all fish reaching sexual maturity at age 3 years. The age of maturity was constant for the entire model period.

Table 9: Biological parameters and priors for the interim base case model.

Component	Parameters	Value, Priors	
Biology	*M*	0.075	Fixed
	VB Growth	*Len1* = 13.1 cm	Fixed
	1931–1979	$k = 0.146$, *Linf* = 54.5 cm	Fixed
	1980–2005	$k = 0.112$, *Linf* = 69.6 cm	Fixed
	2006–2021	$k = 0.150$, *Linf* = 54.4 cm	Fixed
	CV length-at-age	0.08	Fixed
	Length-wt	$a = 4.467e-5$, $b = 2.793$	Fixed
	Maturity	$0.0 \leq 2$ yr, $1.0 \geq 3$ yr	Fixed
Recruitment	LnR_0		Estimated (1)
	B-H SRR steepness h	0.95	Fixed
	SigmaR σR	0.6	Fixed
	Recruitment deviates	Lognormal deviates (1960–2019)	Estimated (60)

The model was structured with an annual time step comprising two seasons (October–January and February–September). The seasonal structure partitions the main spawning period and commercial catch (season 1). Spawning is assumed to occur instantaneously at the start of the year and recruitment is a function of the spawning biomass at the start of the year. A Beverton-Holt spawning stock-recruitment relationship was assumed with a fixed value of steepness (h). Recruitment deviates (1960–2019) from the SRR were estimated assuming a standard deviation of the natural logarithm of recruitment (σ_R) of 0.6.

Initially, a value of steepness of 0.85 was assumed for the SRR, equivalent to the default value of steepness used in the SNA 1 stock assessment. However, an evaluation of initial model options revealed that a significant proportion of MCMCs samples were crashing the population during the 2000s due to very low recruitments resulting from the combination of very low spawning biomass and the value of steepness assumed for the SRR. Subsequent model options specified a higher value of steepness of 0.95.

The model was configured to encompass three commercial fisheries: single trawl (BT), pair trawl (BPT), and Japanese longline. In addition, there were two recreational fisheries (inside and outside harbours). Age composition data are available from the single trawl fishery (23 observations) and the pair trawl fishery (18 observations). For all age compositions there was assumed to be no error associated with the age determination.

A comparison between the age compositions from the single and pair trawl fisheries revealed no appreciable difference in the age structure of the catch from the two methods. A common age-specific selectivity function was assumed for the two fisheries, and the associated sets of CPUE indices parameterised using a flexible, double normal selectivity function enabling the estimation of the age of peak selectivity, the widths of the ascending and descending limbs, and the selectivity of the terminal (oldest) age class.

There are no data from the Japanese longline fishery and the level of catch was assumed. The selectivity function for the fishery was defined to approximate the selectivity of a generalised snapper longline fishery with a knife-edge selectivity at age 5 years and full selection of the older age classes.

The two recreational fisheries are characterised by differences in length composition. The length composition data were included in a preliminary model option and the selectivity of each fishery was estimated using a length-based, double normal selectivity function. The resultant estimate of selectivity for the harbour fishery was tightly constrained around a mode of 28–32 cm, whereas the recreational fishery outside the harbours was estimated to have a broader selectivity for larger fish. The selectivity parameters were fixed in the final model options and the recreational fishery length frequency observations were excluded from the estimation procedure.

The tagging biomass estimates and associated population length observations were derived for all fish aged 3 years and older (Davies et al 2006. Accordingly, an age-specific, knife-edged selectivity function was assumed with an associated catchability of 1.0.

Initially, the time series of *Kaharoa* trawl survey biomass indices and associated age compositions were included in preliminary modelling and the selectivity of the survey was estimated using an age-specific double normal selectivity function. However, there was a persistent lack of fit to the two recent (2019–20 and 2020–21) trawl survey biomass indices related to a difference in the catchability of older fish between recent surveys (see Trawl Survey Biomass Indices - above).

For the final model options, the trawl survey data were reconfigured to determine estimates of the relative abundance of the individual age classes which appear to be consistently sampled by the trawl survey; i.e., fish aged 2 (1+), 3 (2+), 4 (3+), and 5 (4+) years. Thus, four separate sets of indices were derived from the trawl survey data, expressed as the number of fish at age from each survey (with an associated coefficient of variation). The indices were incorporated in the model with a corresponding age-specific selectivity and separate catchability coefficients. The abundance indices and age compositions used in the model are summarised in Table 10. Estimated parameters and structural assumptions are summarised in Table 11.

Fishing mortality was modelled using a hybrid method that calculates the harvest rate using Pope's approximation and then converts it to an approximation of the corresponding fishery specific F. The timing of the fisheries and CPUE indices within the year was specified so that annual catches were taken instantaneously halfway through the first season (October–January). This is generally consistent with the period of the main commercial catch.

The main data inputs were assigned relative weightings based on the approach of Francis (2011). The two sets of trawl CPUE indices (BPT and BT) were assumed to have a lognormal distribution with observation error specified as the standard error of the individual CPUE indices. Based on initial model fits the indices were assigned an additional process error of 0.1 for the BT CPUE indices and 0.2 for the BPT CPUE indices. The tagging biomass indices and age-specific trawl survey indices were assigned the native coefficient of variation from each index with no additional process error. For the two sets of fisheries age compositions, the individual age compositions were each assigned an Effective Sample Size approximating the value derived from Method TA1.8 of Francis (2011).

Model uncertainty was determined using Markov chain Monte Carlo (MCMC) implemented using the Metropolis-Hastings algorithm. For each model option, 1000 MCMC samples were drawn at 1000 intervals from a chain of 1.1 million following an initial burn-in of 100 000. The performance of the MCMC sample was evaluated using a range of diagnostics.

Stock status was determined relative to the equilibrium, unexploited spawning (mature) biomass of female fish (SB_0). Current biomass was defined as the biomass in the 2021 model year (2020–21 fishing year) ($SB_{CURRENT}$ or SB_{2020}).

Following the Harvest Strategy Standard (HSS), current biomass was assessed relative to the default soft limit of 20% SB_0 and hard limit of 10% SB_0 (Ministry of Fisheries 2008). The HSS includes a default target biomass level of 40% SB_0 for stocks with low productivity where an operational ('real world') SB_{MSY} has not been fully evaluated. The Inshore Fisheries Assessment Working Group accepted 40% SB_0 as an appropriate SB_{MSY} proxy for SNA 8. Current stock biomass is reported relative to the default target biomass level ($SB_{40\%}$) and current levels of fishing mortality are reported relative to the level of fishing mortality that result in $SB_{40\%}$ under equilibrium conditions (i.e., $F_{SB40\%}$). The reference level of age specific fishing mortality is determined from the composite age-specific fishing mortality from the last year of the model data period (2020–21). Estimates of equilibrium yield are determined from the level of fishing mortality that produces the target biomass level ($F_{SB40\%}$).

Table 10: **Summary of input data sets for the Base Case assessment model. The relative weighting includes the Effective Sample Size (ESS) of age/size composition data and the coefficient of variation (CV) associated with the abundance data.**

Data set	Model years	Nobs	Error structure	Observation error/ESS	Process error
			Lognormal		
Tag biomass	1990, 2002	2	Lognormal	0.18, 0.12	–
BT CPUE indices	1997–2020	23	Lognormal	0.12–0.18	0.1
BPT CPUE indices	1974–1991	18	Lognormal	0.12–0.30	0.2
Trawl survey age 2yr	1990, 1992, 1995, 1997, 2000, 2019, 2020, 2021	7	Lognormal	0.26–0.48	–
Trawl survey age 3yr	1990, 1992, 1995, 1997, 2000, 2019, 2020, 2021	7	Lognormal	0.16–0.38	–
Trawl survey age 4yr	1990, 1992, 1995, 1997, 2000, 2019, 2020, 2021	7	Lognormal	0.12–0.38	–
Trawl survey age 5yr	1990, 1992, 1995, 1997, 2000, 2019, 2020, 2021	7	Lognormal	0.18–0.45	–
BT age comp	1975, 1976, 1990–2010, 2013, 2016, 2019	26	Multinomial	ESS 20	
BPT age comp	1975, 1976, 1978–1980, 1986, 1987, 1989–1992, 2000–2006	18	Multinomial	ESS 10	
Tag length comp	1990, 2002	2	Multinomial	ESS 10	

Table 11: **Estimated parameters and structural assumptions for the interim base model.**

Parameter	Number of parameters	Parameterisation, priors, constraints
LnR_0	1	Uniform, uninformative
Rec devs (1960–2019)	60	SigmaR 0.6
Selectivity BPT and BT commercial	4	Double normal
Selectivity JP	–	Knife edged 5 yr
Selectivity trawl survey age indices	–	Fixed, age specific (4)
Catchability trawl survey age indices	4	Uniform, uninformative
Selectivity tag	–	Knife edged 3 yr
Selectivity Recreational (2)	–	Fixed
CPUE q	2	Uniform, uninformative

Results

The model provided a coherent fit to all the main datasets. The trend in stock biomass is consistent with the previous stock assessments (Davies et al 2013, Langley 2020); i.e., the stock is estimated to have been heavily depleted during the 1960s and 1970s, reaching a nadir in 1987 at about 6% of the virgin biomass level. The spawning biomass increased slightly in the late 1980s, following the recruitment of the strong 1985 and 1986 year classes, and then remained at about 9% of the virgin biomass level throughout the 1990s. The more recent data sets, specifically the recent CPUE indices and age compositions, provided a coherent signal that stock abundance has increased considerably from 2009, primarily due to an increase in recruitment from the mid-2000s.

Annual recruitment remained relatively constant during the 1960s and 1970s (Figure 7), although recruitment was generally lower during the 1980s and 1990s when spawning biomass was at the lowest level (below 10% SB_0). However, relatively large recruitments were estimated during the mid-2000s when the stock was still at a relatively low level (10–20% SB_0). Recruitment was well above average during 2005–2018, with exceptionally high recruitments estimated for 2006 and 2016–2018. The estimates of recent recruitment are informed by the age-specific trawl survey indices.
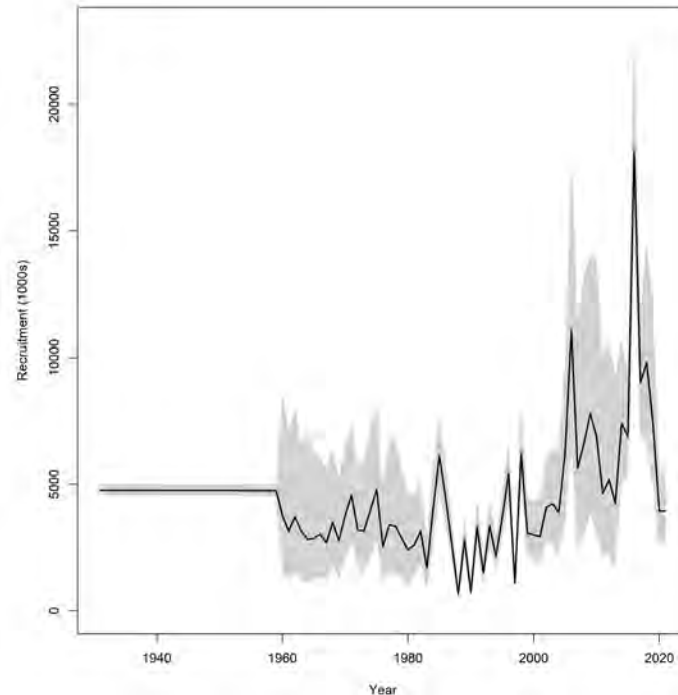
Figure 7: Annual estimates of recruitment (numbers of fish, thousands) from the Base Case model (MCMCs). The black line represents the median of the MCMC estimates and the shaded error represents the 95% confidence interval.

Current (2021 = 2020–21 fishing year) stock status was determined relative to equilibrium, unexploited spawning biomass. Spawning biomass has increased considerably over the last 10 years and current biomass was estimated to exceed the default target (40% SB_0) biomass level, and the probability of the stock being below the hard (10% SB_0) and soft (20% SB_0) limits is negligible (Table 31). There has been a corresponding decline in fishing mortality over the last 10 years and current (2021) fishing mortality is estimated to be below the rate that equates to the target biomass level (under equilibrium conditions i.e., $F_{SB40\%}$).

Sensitivities

A number of key assumptions of the model were investigated as (single change) sensitivities to the Base Case model (Table 12). The historical level of Japanese catch is unknown and in previous assessments (Davies et al, 2006, 2013, Langley 2020), the base level of catch (2000 t) was bracketed by alternative catch levels of 1000 t (*JPcatch1000*) and 3000 t (*JPcatch3000*). The resulting estimates of stock status was insensitive to the level of Japanese catch and the two sensitivities were not repeated for the current assessment.

The influence of key stock productivity parameters were also investigated, specifically a lower value of natural mortality of 0.06 (*NatMort06*), a higher variability (sigmaR 0.8) in the deviations of recruitment deviations (*SigmaR08*), and a lower value of steepness (0.85) of the SRR (*Steep085*). For the *Steep085* sensitivity, a significant proportion of MCMC chains resulted in the stock crashing at low levels of stock biomass due to the lower value of steepness of the SRR. On that basis, the *Steep085* was not included in the final set of model sensitivities.

The lower natural mortality option (*NatMort06*) estimated lower levels of current biomass (relative to virgin spawning biomass) compared with the Base Case, although the level of biomass approaches the default target level and there was a very low probability of the stock being below the hard and soft

limits, while current fishing mortality rates were above the reference level. The *SigmaR08* model provided very similar estimates of current stock status to the Base Case and is not included in the final suite of sensitivities.

The influence of key data sets was also investigated. The trawl CPUE indices from the last five years (2016–2020) were excluded due to concerns regarding the reliability of the indices (*CPUEex5yr*). The selectivity of the commercial fisheries was alternatively configured to fully select the older age classes (*BTlogistic*) The alternative series of recreational catches from 2019–2021 derived from a constant recreational harvest rate (*RecF*) was also included. These model sensitivities yield estimates of current stock status that are very similar to the Base Case.

Table 12: Estimates of current (2021 = FY 2020–21) and virgin spawning biomass (t) (median and the 95% confidence interval from the MCMCs) and probabilities of current biomass being above specified levels and probability of fishing mortality being below the level of fishing mortality associated with the interim target biomass level. The potential yield in 2021 was derived by applying the $F_{SB40\%}$ fishing mortality rate to the current (2021) biomass.

Model option	SB_0	SB_{2021}	SB_{2021}/SB_0	$\Pr(SB_{2021} > X\% \, SB_0)$		
				40%	20%	10%
Base	99 319 (95 129–104 419)	53 689 (37 876–68 059)	0.541 (0.39–0.663)	0.967	1.000	1.000
NatMort06	111 315 (106 790–116 147)	47 244 (29 475–60 641)	0.423 (0.267–0.53)	0.664	0.990	0.998
BTlogistic	93 724 (90 592–96 961)	46 153 (25 223–58218)	0.493 (0.275–0.61)	0.845	0.991	1.000
CPUEex5yr	99 063 (94 668–103 793)	52 097 (34 866–67 410)	0.528 (0.358–0.658)	0.942	0.999	1.000
RecF	99 497 (94 786–104 014)	5 656 (35 840–67 824)	0.54 (0.36–0.661)	0.959	0.998	1.000

	$F_{SB40\%}$	$F_{2021}/F_{SB40\%}$	$\Pr(F_{2021} < F_{SB40\%})$	Yield 2021
Base	0.054 (0.053–0.056)	0.81 (0.643–1.136)	0.916	3 951 (2 977–4 881)
NatMort06	0.043 (0.041–0.045)	1.167 (0.909–1.843)	0.121	3 046 (2 112–3 714)
BTlogistic	0.058 (0.057–0.059)	0.882 (0.705–1.557)	0.761	3 367 (2 039–4 144)
CPUEex5yr	0.054 (0.052–0.056)	0.831 (0.647–1.226)	0.873	3 876 (2 818–4 813)
RecF	0.054 (0.053–0.056)	0.901 (0.721–1.336)	0.787	3 922 (2 871–4 793)

Projections

Five-year stock projections (to the 2025–26 fishing year) were conducted using the Base Case model assuming annual catches equivalent to the 2019–2020 catch; i.e., a commercial catch of 1346 t (approximating the current TACC of 1300 t) and an allowance of 10% for unreported catches (total 1481 t). Annual recreational catches were either assumed to be constant at 935 t (the 2019 catch level, representing a total annual catch of 2416 t) or were projected forward based on the recreational fishery mortality rate from the terminal year of the *RecF* model (2021). An additional 5-year projection was conducted assuming total annual catches in the projection period at the level equivalent to the current (2021) potential yield at $F_{SB40\%}$ (3951 t, commercial and recreational catch combined).

Annual recruitment deviates for the 5-year projection period were resampled from the long-term average level with the standard deviation equivalent in sigmaR (0.6). The average level of estimated recruitment in the recent (10 year) period was considerably higher (~65% higher) than the long-term average level of recruitment.

The projections indicate that the stock biomass will continue to increase during the 5-year projection period due, in part, to the contribution of the exceptionally large 2016 year class. At current levels of

catch, the biomass at the end of the period (2026) is projected to be 21% higher than current (2020–21) biomass ($SB_{2026}/SB_0 = 0.653$, C.I. 0.49–0.77) (Figure 8, Table 13). The higher catch scenario (3951 t) results in a smaller (8%) increase in biomass during the projection period.
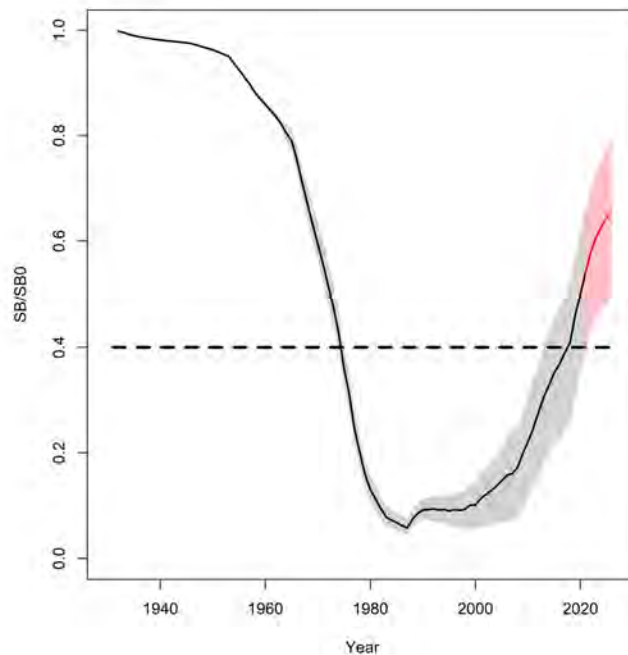
Figure 8: Annual spawning biomass relative to virgin biomass (equilibrium, unexploited) estimated from the Base Case model (black) and the five-year projection (red) assuming annual catches equivalent to the 2021 catch. The solid line represents the median of the MCMCs and the shaded area represents the 95% confidence interval. The horizontal dashed line represents the default target biomass level.

Table 13: Projected spawning biomass relative to virgin biomass (and 95% confidence interval) and the probability of the spawning biomass being above default biomass limits and interim target level in 2026 (fishing year 2025–26) for the base case at the current level of catch and the potential yield corresponding to $F_{SB40\%}$. The $RecF$ model assumes current commercial catch and a constant harvest rate for the recreational fishery.

Model	Catch (t)	SB_{2026}/SB_0	SB_{2026}/SB_{2021}	Pr ($SB_{2026} > X\%SB_0$)		
				10%	**20%**	**40%**
Base	2 416 (1 481+935)	0.653 (0.493–0.789)	1.207 (1.119–1.349)	1.00	1.00	1.00
RecF	1 481 + Rec (Rec ~ 1250)	0.635 (0.478–0.759)	1.175 (1.090–1.340)	1.00	1.00	1.00
Base	3 951 ($F_{SB40\%}$)	0.587 (0.421–0.723)	1.081 (0.998–1.188)	1.00	1.00	0.98

Qualifying comments

For the current assessment, recent trends in stock abundance are strongly informed by the recent CPUE indices from the trawl fishery. The overall trend in these indices is generally consistent with other recent observations from the fisheries. However, it is apparent that the operation of the commercial fisheries has changed considerably in response to the increase in the abundance of snapper over the last decade. These changes are unlikely to have been fully accounted for in the derivation of the standardised CPUE indices.

Since 1989–90, the area north of Cape Egmont has accounted for 90–95% of the SNA 8 commercial catch. Most observational data included in the model are also derived from the northern area of the fisheries including the CPUE indices, trawl survey indices, and the commercial age composition data. Consequently, the dynamics of the assessment model will be strongly influenced by the data from the northern area of the fisheries.

Prior to the mid-1980s, the southern area of the fisheries accounted for approximately 30% of the commercial catch. The 2002 tagging programme estimated that 21% of the SNA 8 biomass resided in the southern area (Gilbert et al 2005) and while most movements of tagged fish were relatively limited, there were northward movements of tagged fish from the South Taranaki Bight and reciprocal movements of fish from the areas north of Cape Egmont.

Similar patterns in the age structure of snapper from South Taranaki Bight and northern areas of the SNA 8 fisheries were apparent from commercial catch-at-age data (Walsh et al 2006). However, the results of the recent *Kaharoa* trawl surveys have identified some differences in the age structure of the snapper population between the two areas, including differences in the relative strength of individual year classes. This may indicate some degree of spatial structure in the SNA 8 population and possible linkages between the southern area of SNA 8 and the SNA 7 (Tasman Bay/Golden Bay) stock.

Estimates of stock status have been provided principally based on the assumption of long-term, equilibrium conditions. Productivity of the SNA 8 stock appears to have varied considerably over the history of the fisheries, with variable levels of recruitment and variation in growth rates (that appear to be related to stock abundance). Recent recruitment is estimated to be at an historically high level suggesting the stock is currently in a phase of higher productivity and that there is a degree of non-stationarity in the assumed nature of the relationship between spawning biomass and recruitment that may violate the assumptions of equilibrium conditions. Further consideration is required to develop stock status indicators that account for variation in the productivity of the SNA 8 stock.

The higher potential yields estimated for the stock are attributable to the higher recruitment estimated for the recent period (10 years). These recruitments have the potential to support higher catches over the short term (5 years), although future catch levels would need to be determined based on ongoing monitoring and assessment.

Future research considerations

Abundance indices

Trawl surveys: The variability in the catchability of adult snapper in the recent west coast North Island (WCNI) trawl surveys has limited the utility of the trawl surveys to monitor the overall magnitude of the increase in the abundance of snapper. The limitations of the trawl survey are partly attributable to variability in the timing of the survey relative to the main spawning period and the restriction from sampling within the Māui dolphin trawl exclusion zone. Further, the distribution of snapper appears to have expanded (into deeper water) as the abundance of snapper has increased over recent years. A longer time series of trawl surveys may enable a more thorough evaluation of the factors influencing the variability in catchability of adults (> 5 y) and, thereby, increase the utility of the trawl surveys to monitor stock abundance. In the interim, subsequent trawl surveys would continue to provide additional estimates of the abundance of recent year classes (surveyed as 2- to 5-year old fish). A current project to review the utility of the WCNI trawl survey series will further investigate the potential for including adult biomass indices in the stock assessment modelling framework.

CPUE indices: The trawl CPUE indices represent an important index of abundance within the current assessment model. However, there have been considerable recent changes in the operation of the inshore trawl fishery to minimise snapper catches. These changes in fishing operation are not fully accounted for in the standardised CPUE analysis and, consequently, the CPUE indices are likely to under-estimate the extent of the increase in snapper abundance, especially in recent (3–5) years. This limits the utility of the CPUE indices to monitor current and future trends in stock abundance.

Changes in fishing behaviour: A project to document past and ongoing changes in gear and fishing behaviour should also be undertaken to help interpret CPUE data. This should be considered as two phases: (i) developing ongoing relationships with fishers, and (ii) working together to ensure relevant information is identified and provided. (This is generic across snapper and other fisheries.)

Given the breakdown of the bottom trawl CPUE series in recent years, and difficulties encountered with including the estimates of adult biomass from the trawl survey in the stock assessment, a review of future monitoring of SNA8 biomass is recommended.

Other methods for developing abundance indices: Such a review should also consider other potential methods for monitoring abundance such as another traditional mark-recapture experiment or a genetics-based estimate of stock size.

Stock structure and biological parameters

Stock structure: Age compositions from recent inshore trawl surveys should be examined to further investigate stock relationships between SNA 8 and SNA 7 and the spatial structure of the snapper population within sub areas of SNA 8.

Biological parameters: The current assumption that maturity is knife-edged at 3 years needs to be reviewed. Trawl survey data should be analysed to test this assumption and to determine whether it is preferable to represent the age of maturity as an ogive. Estimates of several other biological parameters also rely on old analyses and should also be revisited and revised if necessary. In particular, estimates of growth by eras should be evaluated.

Catch and age

Catch sampling: The current assessment highlights the utility of regular (currently triennial) sampling of the age composition of the commercial catch, particularly to provide information regarding the relative strength of recruited year classes. The current assessment estimates an exceptionally strong 2016 year class based on observations of the year class from the three recent trawl surveys (at ages 3, 4, and 5 years). This year class is likely to have recruited to the commercial fisheries over the last few years and age composition data from the fisheries will refine model estimates of the relative strength of the year class. The next catch sampling programme for the SNA 8 is scheduled for 2021–22. A review of the frequency, seasonal coverage, and gear types included (e.g., add PRB - Precision Seafood Harvesting Bottom Trawl) of future sampling should be conducted following an evaluation of the efficacy of the trawl survey sampling of the snapper population.

Age composition data: Age composition data from the 1970s are being regenerated following a re-ageing of the older (> 20 year) fish in the samples. This will improve the utility of the age composition data particularly in the estimation of recruitment variation in the period prior to 1960. The revised age composition data should be included in the next iteration of the SNA 8 stock assessment.

Recreational fisheries

The recent increase in the catch from the recreational fishery highlights the importance of this component of the fishery, which currently accounts for approximately 40% of the total catch. Consequently, it is important to routinely monitor the level of recreational catch to determine total removals from the stock. The next national panel survey to estimate recreational catch is scheduled for 2022–23, depending on budgets and priorities. Indices of recreational fishing activity have also been developed from web cam observations at key boat ramps within SNA 8. These observations should be evaluated in conjunction with the overall recreational harvest survey data. There is potential for the web cam indices to provide more regular monitoring of recreational fishing activity and catch.

Consideration should also be given to including a sensitivity for recreational catches prior to the 1970s.

Other

Model assumptions: A simulation approach to evaluate current model assumptions is currently underway and outputs should be used to inform the next assessment. This project is focusing on the potential biases associated with key structural assumptions of the assessment, particularly those related to the spatial structure of the snapper population within SNA 8, non-stationarity in recruitment, and the potential for variation in growth rates to be related to stock abundance (i.e., density dependence).

Environmental considerations: Recruitment variation is undoubtedly linked to variation in the prevailing environmental conditions associated with the spawning period and/or larval phase. Further investigation should be conducted to identify correlations between snapper recruitment estimates and key environmental variables to improve understanding of snapper recruitment dynamics. Consideration should be given to examining SNA 7 and SNA 8 together with a view to understanding the drivers of productivity changes.

Density-dependent processes: Projections indicate a continued increase in population biomass at current catch levels. The potential for density-dependent processes to curb such large increases should be considered and possibly modelled.

Other sources of fishing-related mortality: The default assumption is that Other Sources of Fishing Related Mortality) added 20% to catches prior to the introduction of snapper into the QMS in 1986 and 10% thereafter. The basis for this assumption should be revisited, particularly for the latter period. In particular, it is important to identify whether there are any regulations or changes in fishing behaviour that could have resulted in step changes.

Commercial trawl selectivities: Prior to about 1980 when the fleet of bottom trawl vessels was upgraded to more powerful vessels, the ability of this fleet to catch large snapper is likely to have been considerably lower than it currently is. A sensitivity investigating a reduced selectivity for single bottom trawl pre-1980 by moving the right-hand limb of the selectivity curve down to reduce the vulnerability of the largest fish should be considered for the next assessment update. (One such run was conducted post-Plenary and resulted in a small increase in SB_0 and a small decrease in the current stock status. However, the differences were not sufficient to alter current conclusions about the relative magnitude of the increase in stock size.)

5.   STATUS OF THE STOCKS

Stock Structure Assumptions

New Zealand snapper are thought to comprise either seven or eight biological stocks based on the location of spawning and nursery grounds, differences in growth rates, age structure, and recruitment strength, and the results of tagging studies. These stocks are assumed to comprise three in SNA 1 (East Northland, Hauraki Gulf, and Bay of Plenty), two in SNA 2 (one of which may be associated with the Bay of Plenty stock), two in SNA 7 (Marlborough Sounds and Tasman/Golden Bay), and one in SNA 8. Tagging studies reveal that limited mixing occurs between the three SNA 1 biological stocks, with the greatest exchange between the Bay of Plenty and Hauraki Gulf.

- **SNA 8**

Stock Structure Assumptions

Tagging, genetic, and morphological studies have revealed that snapper off the west coast of the North Island (i.e., SNA 8) are likely to comprise a separate biological unit.

Stock Status	
Year of Most Recent Assessment	2021
Assessment Runs Presented	Base Case model
Reference Points	Interim Target: 40% B_0 (HSS default) Soft Limit: 20% B_0 (HSS default) Hard Limit: 10% B_0 (HSS default) Overfishing threshold: $F_{SB40\%}$
Status in relation to Target	$B_{2020-21}$ was estimated to be 54% B_0; Likely ($> 60\%$) to be at or above the target
Status in relation to Limits	Soft Limit: Very Unlikely ($< 10\%$) to be below Hard Limit: Exceptionally Unlikely ($< 1\%$) to be below

Status in relation to Overfishing	$F_{2020-21}$ was estimated to be 81% $F_{SB40\%}$. Overfishing is Unlikely ($< 40\%$) to be occurring.

Historical Stock Status Trajectory and Current Status

Annual trend in spawning biomass relative to the 40% SB_0 interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% credible interval. The dashed line represents the interim target level. The red and orange dashed lines represent the hard and soft biomass limits, respectively.

Fisheries and Stock Trends
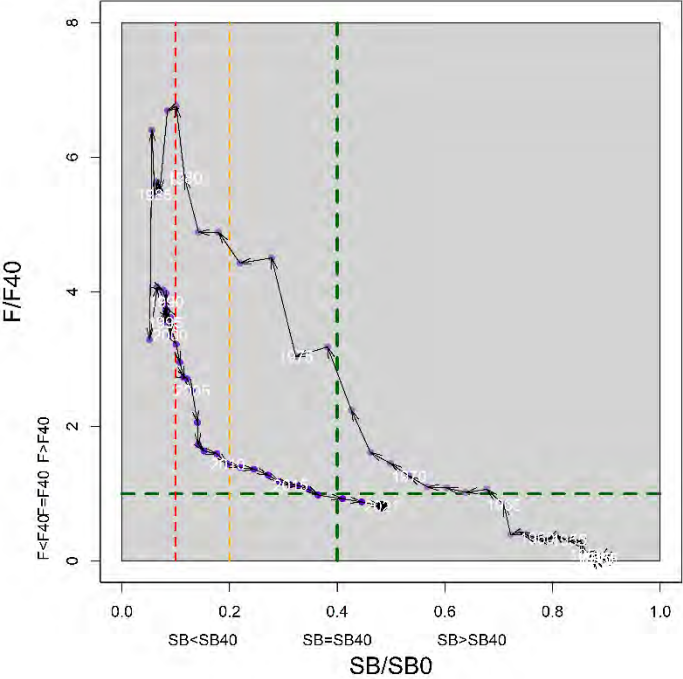
Recent Trend in Biomass or Proxy	Spawning biomass was estimated to have increased gradually during the 2000s followed by a more rapid increase in biomass from 2009 (in response to the recruitment of the strong 2006 and 2016 year classes).
Recent Trend in Fishing Mortality or Proxy	Fishing mortality is estimated to have declined by around 75% since 2000.
	Annual fishing mortality compared to the $SB_{40\%}$ interim target fishing mortality level (dashed line) for the interim base case model (median values from MCMCs).

Annual spawning biomass and fishing mortality compared to the *SB40%* interim target biomass level and corresponding fishing mortality reference for the interim base case model (median values from MCMCs). The green dashed lines represent the biomass and fishing mortality target levels. The red and orange dashed lines represent the hard and soft biomass limits, respectively.

Other Abundance Indices	The increase in the trawl survey adult (> 6 y) biomass indices between 1989–1999 and 2018–2020 corroborates the recent increase in biomass.
Trends in Other Relevant Indicators or Variables	Estimates of recreational catch have increased 3-fold since 2006. The increase in catch is likely to be related to an increase in stock abundance.

Projections and Prognosis	
Stock Projections or Prognosis	Abundance is Very Likely (> 90%) to increase over the next five years at current levels of catch (2,416 t compared to a TAC of 1785 t and a TACC of 1300 t) and Likely (> 60%) to increase at higher levels of catch (corresponding to $F_{SB40\%}$ in 2021 = 3951 t).
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Level 1 – Full Quantitative Stock Assessment	
Assessment Method	Age-structured Bayesian stock assessment implemented with Stock Synthesis software and uncertainty estimated by MCMC	
Assessment Dates	Latest assessment: 2021	Next assessment: 2024
Overall assessment quality rank	1 – High Quality	
Main data inputs	- Proportions at age data from the commercial fisheries - Estimates of biological parameters (e.g., growth, age-	1 – High Quality

	at-maturity and length/ weight), including temporal variation in growth	1 – High Quality
	- Standardised single trawl CPUE index of abundance	1 – High Quality (less reliable CPUE indices for the last 2-3 years)
	- Estimates of recreational harvest (recent levels)	1 – High Quality
	- Estimates of recreational harvest (pre-1990)	2 – Medium or Mixed Quality: level of catch is assumed
	- Commercial catch (from 1983 onwards)	1 – High Quality
	- Commercial catch (prior to 1983)	2 – Medium or Mixed Quality: less reliable reporting of catches prior to 1983
	- Two tag-based biomass estimates	1 – High Quality (second estimate)
	- Trawl survey age specific indices	1 – High Quality
Data not used (rank)	- Trawl survey total biomass indices	2 – Medium or Mixed Quality: variable catchability of older age classes for the three most recent trawl surveys
Changes to Model Structure and Assumptions	Relative to the 2005 assessment: - parameterising fisheries selectivities as age-specific functions - BH SRR with an assumed value of steepness and recruitment deviates estimated (from 1960) - Natural mortality fixed rather than estimated - revised recreational catch history incorporating recent recreational catch estimates (2006/07, 2011/12, and 2017/18) - partitioning of the recreational catch by fisheries areas - incorporating additional age specific indices (2, 3, 4, and 5 year old fish) from the trawl survey - parameterisation of time varying growth - updated single trawl CPUE time series for 1997–2020	

Major Sources of Uncertainty	- There have been considerable changes in the operation of the trawl fisheries during the assessment period related to the extent of targeting/avoidance of snapper. The CPUE analysis has endeavoured to account for some of these changes; however, the CPUE indices are considered to under-estimate the increase in abundance during the more recent years. - The precision of the estimates of the recent (2014 onwards) year class strengths from the trawl survey have yet to be fully supported by sufficient additional observations from the commercial catch-at-age. - The shift in the overall level of recruitment is likely to be related to environmental conditions. Non-stationarity of the relationship between spawning biomass and recruitment is not represented by SRR and the assumed value of steepness.

Qualifying Comments

The stock structure relationship between the northern and southern areas of SNA 8 is unclear. The current assessment is primarily based on data from the northern area of the fisheries and the population dynamics may differ in the southern area.

It was recognised that if the increases in abundance represented a regime shift, or a significant change in productivity levels, with an associated increase in B_0, then the use of historical levels of relative abundance to establish a soft limit may not be appropriate.

Fisheries Interactions

The primary species caught in association with snapper in bottom trawl fisheries are trevally, red gurnard, John dory, and tarakihi. Since 2010–11, most (> 80%) of commercial catch of snapper has been taken as a bycatch of trawls targeting trevally and red gurnard.

6.   FOR FURTHER INFORMATION

Annala, J H; Sullivan, K J (Comps.) (1997) Report from the Fishery Assessment Plenary, May 1997: stock assessments and yield estimates. 381 p. (Unpublished report held by NIWA library, Wellington.).

Bian, R; McKenzie, J R; Davies, N M (2009) Determination of optimum frequency for SNA 8 snapper market sampling based on retrospective analysis. *New Zealand Fisheries Assessment Report 2009/50*. 15 p.

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 national marine recreational fishing survey: diary results and harvest estimates. Final Research Report for Ministry of Fisheries. (Unpublished report held by Fisheries New Zealand, Wellington.) 93 p.

Boyd, R O; Reilly, J L (2002) 1999/2000 National marine recreational fishing survey: harvest estimates. Final Research Report for Ministry of Fisheries Research Project REC9803. (Unpublished report held by Fisheries New Zealand, Wellington.)

Bradford, E (1998) Harvest estimates from the 1996 national marine fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished document held by NIWA library, Wellington.)

Bull, B; Francis, R I C C; Dunn, A; Gilbert, D J; Bian, R; Fu, D (2012) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.30.2012/03/21. *NIWA Technical Report 135*. 280 p.

Bull, B; Francis, R I C C; Dunn, A; McKenzie, A; Gilbert, D J; Smith, M H (2004) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.06-2004/09/26. *NIWA Technical Report 126*. 261 p.

Davies, N M (1997) Assessment of the west coast snapper (*Pagrus auratus*) stock (SNA 8) for the 1996–97 fishing year. New Zealand Fisheries Assessment Research Document 1997/12. 47 p. (Unpublished document held by NIWA library, Wellington.)

Davies, N M (1999) Assessment of the SNA 1 and 8 stocks for the 1997–98 fishing year. New Zealand Fisheries Assessment Research Document 1999/19. 87 p. (Unpublished document held by NIWA library, Wellington.)

Davies, N M; Gilbert, D J; McKenzie, J R (1999a) Assessment of the SNA 1 and 8 stocks for the 1998–99 fishing year. New Zealand Fisheries Assessment Research Document 1999/28. 82 p. (Unpublished document held by NIWA library, Wellington.)

Davies, N M; McKenzie, J R; Gilbert, D J (1999b) Monte Carlo estimation of bias in Petersen mark-recapture estimates for snapper (*Pagrus auratus*). New Zealand Fisheries Assessment Research Document 1999/20. 52 p. (Unpublished document held by NIWA library, Wellington.)

Davies, N M; McKenzie, J R; Gilbert, D J (2006) Assessment of the SNA 8 stock for the 2003–04 fishing year. *New Zealand Fisheries Assessment Report 2006/9*. 32 p.

Davies, N M; McKenzie, J R; Gilbert, D J (2013) Assessment of the SNA 8 stock for the 2004–05 fishing year. *New Zealand Fisheries Assessment Report 2013/28*. 73 p.

Francis, M P; Paul, L J (2013) New Zealand inshore finfish and shellfish commercial landings, 1931–82. *New Zealand Fisheries Assessment Report 2013/55*. 136 p.

Francis, R I C C (2011) Data weighting in statistical fisheries stock assessment models *Canadian Journal of Fisheries and Aquatic Sciences*. 68: 1124–1138.

Francis, R I C C; McKenzie, J R (2015a) Assessment of the SNA 1 stocks in 2012. *New Zealand Fisheries Assessment Report 2015/75*.

Francis, R I C C; McKenzie, J R (2015b) Assessment of the SNA 1 stocks in 2013. *New Zealand Fisheries Assessment Report 2015/76*.

Froese, R; Pauly, D (2000) FishBase 2000: concepts, design and data sources. ICLARM, Los Banos, Laguna, Philippines. 344 p.

Gilbert, D J; Sullivan, K J (1994) Stock assessment of snapper for the 1992–93 fishing year. New Zealand Fisheries Assessment Research Document 1994/3. 37 p. (Unpublished document held by NIWA library, Wellington.)

Kendrick, T H; Bentley, N (2010) Fishery characterisation and catch-per-unit-effort indices for snapper in SNA 8, 1989–90 to 2007–08. *New Zealand Fisheries Assessment Report 2010/42*.

King, M R (1985) Fish and shellfish landings by domestic fishermen, 1974–82. *Fisheries Research Division Occasional Publication: Data Series 20*. 96 p.

King, M R (1986) Catch statistics for foreign and domestic commercial fishing in New Zealand waters, January–December, 1983. *Fisheries Research Division Occasional Publication: Data series 21*. 140 p.

King, M R; Jones, D M; Fisher, K A; Sanders, B M (1987) Catch statistics for foreign and domestic commercial fishing in New Zealand waters, January – December 1984. *New Zealand Fisheries Data Report No. 30*. 150 p.

Langley, A D (1995b) Trawl survey of snapper and associated species off the west coast of the North Island, October 1994 (KAH9410). *New Zealand Fisheries Data Report No. 65*. 35 p.

Langley, A D (2017) Catch-Per-Unit-Effort indices for snapper in SNA 8. *New Zealand Fisheries Assessment Report 2017/45*. 40 p.

Langley, A D (2020b) Stock assessment of snapper in SNA 8 for 2020. *New Zealand Fisheries Assessment Report 2020/20*. 87 p

Langley, A D (2021) Stock assessment of snapper in SNA 8 for 2021. *New Zealand Fisheries Assessment Report 2021/38*. 86 p

McKenzie, J R; Diggles, B; Tubbs, L; Poortenaar, C; Parkinson, D; Webster, K; Miller, N (2006) An evaluation of a new type of plastic-coated PIT tag for tagging snapper (*Pagrus auratus*). *New Zealand Fisheries Assessment Report 2006/8*. 40 p.

Methot, R D (1990) Synthesis model: an adaptable framework for analysis of diverse stock assessment data. *International North Pacific Fisheries Commission Bulletin 50*: 259–275.

Methot, R D (2005) Technical description of the Stock Synthesis II assessment program. NOAA Technical Memorandum SEDAR 16-AW-04.

Methot, R D (2009) User manual for Stock Synthesis, model version 3.02C.

Methot, R D; Wetzell, C R (2013) Stock Synthesis: A biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research 142*: 86–99.

Millar, R B; Akroyd, J M; Walshe, K A R (2001) Incidental mortality of snapper in SNA 1 and SNA 8. *New Zealand Fisheries Assessment Report 2001/78*. 36 p.

Ministry of Fisheries (2008). Harvest Strategy Standard for New Zealand Fisheries. 25 p. Available online at: https://fs.fish.govt.nz/Doc/16543/harveststrategyfinal.pdf.ashx

Morrison, M A (1998) Trawl survey of snapper and associated species off the west coast of the North Island, November 1996 (KAH9615). *NIWA Technical Report 33*. 48 p.

Morrison, M A; Parkinson, D M (2001) Trawl survey of snapper and associated species off the west coast of the North Island, November 1999 (KAH9915). *NIWA Technical Report 100*. 51 p.

Morrison, M A; Stevenson, M L (2001) Review of west coast North Island trawl survey time series, 1986–96. *NIWA Technical Report 107*. 55 p.

Paul, L J (1977) The commercial fishery for snapper *Chrysophrys (Pagrus) auratus* in the Auckland region, New Zealand, from 1900 to 1971. *Fisheries Research Division Bulletin No 15*. 84 p.

Ritchie, L; Saul, P; O'Sullivan, K. (1975) The wetfish report 1941–1970. *New Zealand Ministry of Agriculture and Fisheries Fisheries Technical Report 137*. 370 p.

Sullivan, K J (1985) Snapper. *In:* Colman, J A; McKoy, J L; Baird, G G (Comps. and Eds.) (1985) Background papers for the 1985 Total Allowable Catch recommendations, pp. 187–214. (Unpublished report, held in NIWA library, Wellington.)

Sullivan, K J; Hore, A J; Wilkinson, V H (1988) Snapper. *In:* Baird, G G; McKoy, J L Papers from the workshop to review fish stock assessments for the 1987–88 New Zealand fishing year, pp. 251–275. (Unpublished report, held in NIWA library, Wellington.)

Sylvester, T (1995) Initial results of the Northern boat ramp survey. *Seafood New Zealand*, February 1995. pp. 11–13.

Teirney, L D; Kilner, A R; Millar, R B; Bradford, E; Bell, J D (1997) Estimation of recreational harvests from 1991–92 to 1993–94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished document held by NIWA library, Wellington.)

Vignaux, M (1993) Catch per unit of effort (CPUE) analysis of the SNA 8 snapper fishery. New Zealand Fisheries Assessment Research Document 1993/2. 12 p. (Unpublished document held by NIWA library, Wellington.)

Walsh, C; Armiger, H; Bian, R; Buckthought, D; McKenzie, J (2017) Length and age composition of commercial snapper landings in SNA 8, 2015–16. *New Zealand Fisheries Assessment Report 2017/02*. 40 p.

Walsh, C; Davies, N M (2004) Length and age composition of commercial landings in SNA 8, 2003–04. *New Zealand Fisheries Assessment Report 2004/56*. 18 p.

Walsh, C; Davies, N M; Buckthought, D (2006a) Length and age composition of commercial snapper landings in SNA 8, 2005–06. *New Zealand Fisheries Assessment Report 2006/54*. 21 p.

Walsh, C; McKenzie, J; Arminger, H (2006d) Spatial and temporal patterns in snapper length and age composition and movement, west coast North Island, New Zealand. *New Zealand Fisheries Assessment Report 2006/6*. 59 p.

Wright, P; McClary, D; Boyd, R O (2004) 2000/2001 National Marine Recreational Fishing Survey: direct questioning of fishers compared with reported diary data. Final Research Report for Ministry of Fisheries Project REC2000-01: Objective 2. (Unpublished report held by Fisheries New Zealand, Wellington.)

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24*. 104 p.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.

SOUTHERN BLUE WHITING (SBW)
(*Micromesistius australis*)
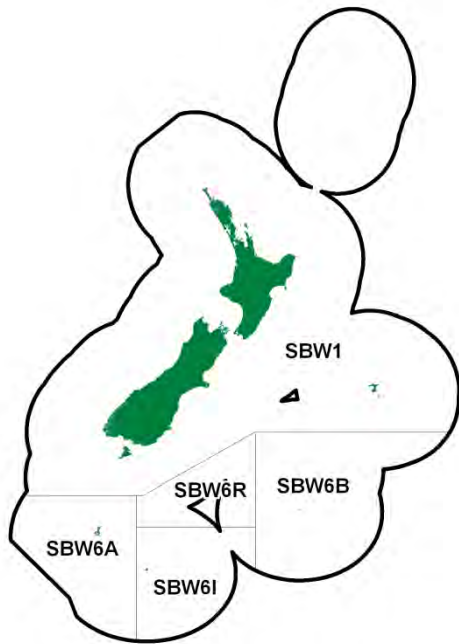
1.   FISHERY SUMMARY

1.1   Commercial fisheries

Southern blue whiting are almost entirely restricted in distribution to Sub-Antarctic waters. They are dispersed throughout the Campbell Plateau and Bounty Plateau for much of the year, but during August and September they aggregate to spawn near the Campbell Islands (Campbell Rise), on Pukaki Rise, on Bounty Plateau, and near the Auckland Islands in depths of 250–600 m. During most years, fish in the spawning fishery range between 35 and 50 cm fork length (FL), although occasionally a smaller size class of males (29–32 cm FL) is also present.

Reported landings for the period 1971 to 1977 are shown in Table 1. Estimated landings by area from the trawl catch and effort logbooks and QMRs are given from 1978 to the present in Table 2, and Figure 1 shows the historical landings and TACC values for the main southern blue whiting stocks. Landings were chiefly taken by the Soviet foreign licensed fleet during the 1970s and early 1980s, and the fishery fluctuated considerably peaking at almost 50 000 t in 1973 and again at almost 30 000 t in 1979. The Japanese surimi vessels first entered the fishery in 1986 and catches gradually increased to a peak of 76 000 t in 1991–92. A catch limit of 32 000 t, was introduced for the first time in the 1992–93 fishing year with area sub-limits of 15 000 t in 6B, 11,000 t in 6I and 6 000 t in 6R (Table 2). The total catch limit increased to 58 000 t in 1996–97 for three years. The southern stocks of southern blue whiting were introduced to the Quota Management System on 1 November 1999, with the TACCs given in Table 2. The fishing year was also changed to 1 April to 31 March to reflect the timing of the main fishing season. TACC changes since 2000–01 are shown in Table 2. A nominal TACC of 8 t (SBW 1) was set for the rest of the EEZ, and typically less than 10 t per year were reported from SBW 1 most years from 2000–01 to 2012–13 (Table 2). However, landings ranged between 21 t and 86 t from 2013–14 to 2016–17 and the TACC for SBW 1 was increased to 98 t for the 2017–18 season. Landings were 38 t in 2019–20 and 35 t in 2020–21.

Table 1: Reported annual landings (t) of southern blue whiting for all areas, 1971 to 1977.

Fishing year	Landings	Fishing year	Landings
1971	10 400	1975	2 378
1972	25 800	1976	17 089
1973	48 500	1977	26 435
1974	42 200		

Landings for other stocks have been between 20 000 t and 40 000 t since 2000, with the majority of the catch currently taken by foreign owned vessels (predominantly large factory trawlers) producing headed

and gutted or dressed frozen product and waste to fishmeal. On the Bounty Plateau, the TACC has been almost fully caught in each year since 2002–03, but effort and landings have been decreasing in recent years with only 788 t of the 3145 t TACC landed in 2019–20 and 1100 t of the 2180 t TACC landed in 2020–21. The TACC on the Campbell Rise has been increasingly under-caught since 2014–15, most recently by 12 683 t in 2019–20 and 27 218 t in 2020–21. On the other grounds, the catch limits have been under-caught in most years since their introduction. This reflects the economic value of these fish, the availability of alternative fishing opportunities, and difficulties experienced by operators in both timing their arrival on the grounds and locating the aggregations of fish. On the Pukaki Rise and Auckland Islands Shelf, operators have generally found it difficult to justify expending time to locate fishable aggregations, given the small allocation available in these areas, the small fish size and relatively low value of the product, and the more certain option available to fish southern blue whiting near Campbell Island where aggregations are concurrent.

Table 2: Estimated catches (t) and actual TACCs (or catch limits) of southern blue whiting by area from vessel logbooks and QMRs. – no catch limit in place. Before 1997–98 there was no separate catch limit for Auckland Islands Shelf.

Fish. year	SBW6B Bounty Plateau Catch	Limit	SBW6I Campbell Rise Catch	Limit	SBW6R Pukaki Rise Catch	Limit	SBW6A Auckland Is. Catch	Limit	SBW1 Rest of NZ Catch	Limit	Total Catch	Limit
1978 *f*	0	–	6 403	–	79	–	15	–	–	–	6 497	–
1978–79+	1 211	–	25 305	–	601	–	1 019	–	–	–	28 136	–
1979–80+	16	–	12 828	–	5 602	–	187	–	–	–	18 633	–
1980–81+	8	–	5 989	–	2 380	–	89	–	–	–	8 466	–
1981–82+	8 325	–	7 915	–	1 250	–	105	–	–	–	17 595	–
1982–83+	3 864	–	12 803	–	7 388	–	184	–	–	–	24 239	–
1983–84+	348	–	10 777	–	2 150	–	99	–	–	–	13 374	–
1984–85+	0	–	7 490	–	1 724	–	121	–	–	–	9 335	–
1985–86+	0	–	15 252	–	552	–	15	–	–	–	15 819	–
1986–87+	0	–	12 804	–	845	–	61	–	–	–	13 710	–
1987–88+	18	–	17 422	–	157	–	4	–	–	–	17 601	–
1988–89+	8	–	26 611	–	1 219	–	1	–	–	–	27 839	–
1989–90+	4 430	–	16 542	–	1 393	–	2	–	–	–	22 367	–
1990–91+	10 897	–	21 314	–	4 652	–	7	–	–	–	36 870	–
1991–92+	58 928	–	14 208	–	3 046	–	73	–	–	–	76 255	–
1992–93+	11 908	15 000	9 316	11 000	5 341	6 000	1 143	–	–	–	27 708	32 000
1993–94+	3 877	15 000	11 668	11 000	2 306	6 000	709	–	–	–	18 560	32 000
1994–95+	6 386	15 000	9 492	11 000	1 158	6 000	441	–	–	–	17 477	32 000
1995–96+	6 508	8 000	14 959	21 000	772	3 000	40	–	–	–	22 279	32 000
1996–97+	1 761	20 200	15 685	30 100	1 806	7 700	895	–	–	–	20 147	58 000
1997–98+	5 647	15 400	24 273	35 460	1 245	5 500	0	1 640	–	–	31 165	58 000
1998–00†	8 741	15 400	30 386	35 460	1 049	5 500	750	1 640	–	–	40 926	58 000
2000–01#	3 997	8 000	18 049	20 000	2 864	5 500	19	1 640	9	8	24 938	35 148
2001–02#	2 262	8 000	29 999	30 000	230	5 500	10	1 640	1	8	32 502	45 148
2002–03#	7 564	8 000	33 445	30 000	508	5 500	262	1 640	16	8	41 795	45 148
2003–04#	3 812	3 500	23 718	25 000	163	5 500	116	1 640	3	8	27 812	35 648
2004–05#	1 477	3 500	19 799	25 000	240	5 500	95	1 640	9	8	21 620	35 648
2005–06#	3 962	3 500	26 190	25 000	58	5 500	66	1 640	2	8	30 278	35 648
2006–07#	4 395	3 500	19 763	20 000	1 115	5 500	84	1 640	7	8	25 364	30 648
2007–08#	3 799	3 500	20 996	20 000	513	5 500	278	1 640	1	8	25 587	30 648
2008–09#	9 863	9 800	20 483	20 000	1 377	5 500	143	1 640	21	8	31 887	36 948
2009–10#	15 468*	14 700	19 040	20 000	4 853	5 500	174	1 640	5	8	39 540	41 848
2010–11#	13 913	14 700	20 224	23 000	4 433	5 500	131	1 640	8	8	38 709	44 848
2011–12#	6 660	6 860	30 971	29 400	686	5 500	92	1 640	2	8	38 411	43 408
2012–13#	6 827	6 860	21 321	29 400	1 702	5 500	49	1 640	8	8	29 907	43 408
2013–14#	4 278˜	4 028	28 607	29 400	14	5 500	47	1 640	21	8	32 967	40 576
2014–15#	7 054	6 860	24 592	39 200	34	5 500	156	1 640	29	8	31 865	53 208
2015–16#	2 405	2 940	22 100	39 200	12	5 500	181	1 640	35	8	24 733	49 288
2016–17#	2 569	2 940	19 875	39 200	11	5 500	46	1 640	86	8	22 587	49 288
2017–18#	2 423	2 377	18 334	39 200	36	5 500	202	1 640	51	98	21 046	48 815
2018–19#	1 101	3 145	15 147	39 200	36	5 500	218	1 640	33	98	16 535	49 583
2019–20#	788	3 145	26 517	39 200	3 631	5 500	182	1 640	39	98	31 157	49 583
2020–21#	1 100	2 830	11 982	39 200	71	5 500	211	1 640	71	98	13 436	49 268

f   1 April–30 September.   +   1 October–30 September.
†   1 October 1998–31 March 2000.   #   1 April–31 March.
*   Reported catch total for 2009–10 does not include fish lost when FV *Oyang 70* sank on 18 August 2010.
˜   In 2013, although the TACC remained at 6860 t, the ACE available to balance against catch was limited to 4028 t because 2832 t was shelved under a voluntary agreement with industry.

The TACC for the Bounty Plateau stock was increased to 9800 t for the 2008–09 season and further increased to 14 700 t for the 2009–10 and 2010–11 seasons but decreased to 6860 t for the 2011–12 season. In 2013–14, 2832 t were shelved, leaving the effective catch limit at 4028 t. The TACC for the Bounty Plateau stock was reduced to 2940 t for the 2015–16 and 2016–17 seasons, further reduced to 2377 t for the 2017–18 season, and then increased to 3145 t for the 2018–19 and 2019–20 seasons, before a reduction to 2830 t for the 2020–21 season. The TACC for the Campbell Rise stock was reduced from 25 000 t to 20 000 t in 2006–07, where it remained until 2009–10. For the 2010–11 season the catch limit for the Campbell Rise stock was raised to 23 000 t, in 2011–12 to 29 400 t, and in 2014–15 it was raised to 39 200 t. Catch limits for Pukaki Rise and Auckland Islands Shelf have remained unchanged since 1997.
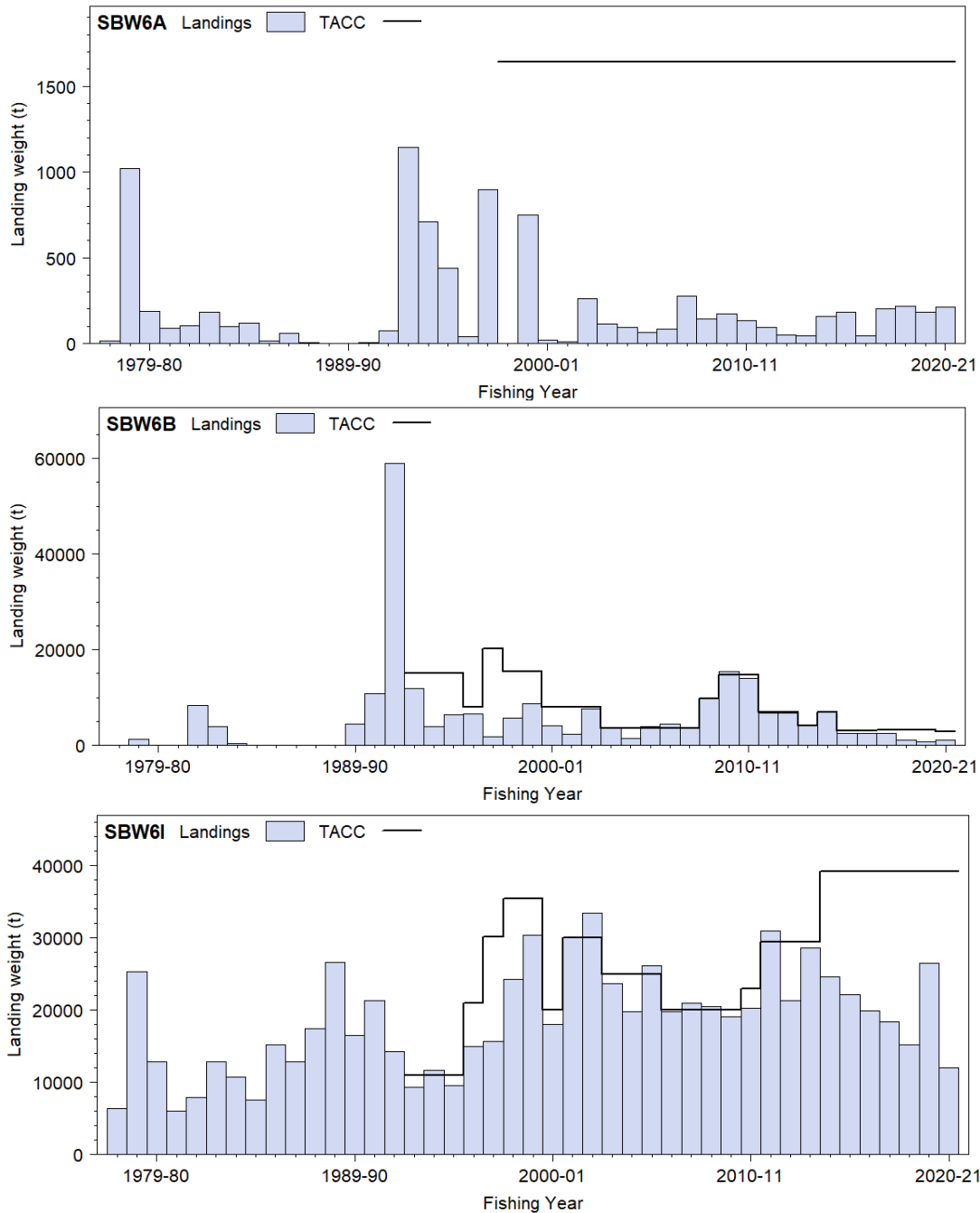
Figure 1: Reported commercial landings and TACC for the main SBW stocks. From top: SBW 6A (Auckland Islands Shelf), SBW 6B (Bounty Plateau), and SBW 6I (Campbell Rise). [Continued on next page]
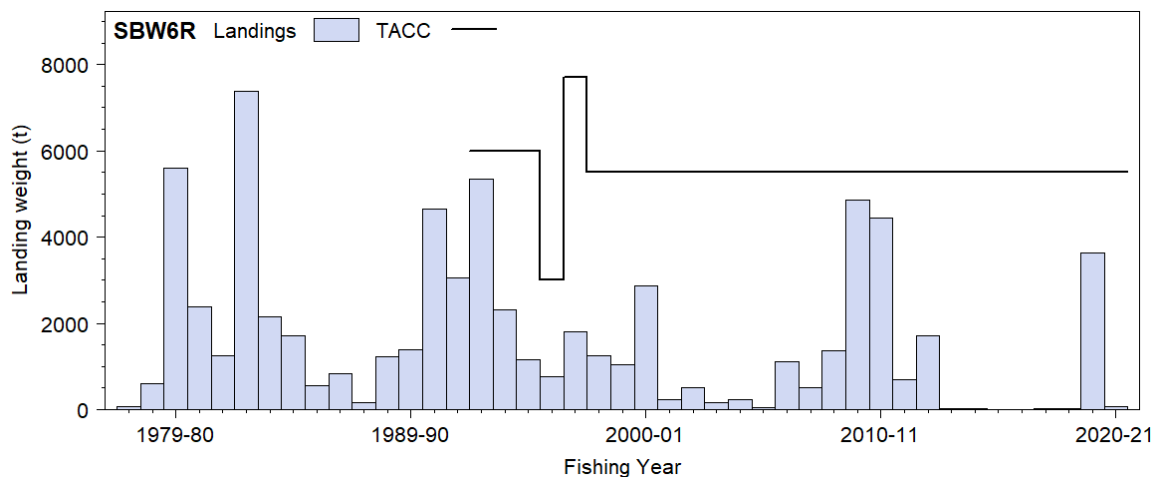
Figure 1:[continued] Reported commercial landings and TACC for the main SBW stocks. SBW 6R (Pukaki Rise).

1.2   Recreational fisheries
There is no recreational fishery for southern blue whiting.

1.3   Customary non-commercial fisheries
Customary non-commercial take does not occur for southern blue whiting.

1.4   Illegal catches
The level of illegal and unreported catch is thought to be low. However, in 2005 the master and operator of a vessel, fishing for southern blue whiting (SBW), were convicted for area misreporting 700 t. The SBW was caught in SBW 6I but was falsely reported as having been caught in SBW 6A and 6R during two trips in August and September 2002. Following on from this, the operators of a vessel were convicted for dumping quota management species. Crew estimated that between 40 and 310 t of SBW6I were illegally discarded during the trip. Where catch returns have been revised, the corrected totals by area are given in Table 2.

1.5   Other sources of mortality
Scientific observers have occasionally reported discards of undersize fish and accidental loss from torn or burst cod-ends. The amount of possible discarding was estimated by Clark et al (2000) and Anderson (2004, 2009). Anderson (2004) quantified total annual discard estimates (including estimates of fish lost from the net at the surface) as ranging between 0.4% and 2.0% of the estimated southern blue whiting catch over all the southern blue whiting fisheries. Anderson (2009) reviewed fish and invertebrate bycatch and discards in the southern blue whiting fishery based on observer data from 2002 to 2007; an estimated 0.23% of the catch was discarded from observed vessels. The low levels of discarding occur primarily because most catch came from vessels that targeted spawning aggregations.

In August 2010, the FV *Oyang 70* sank while fishing for SBW on the Bounty Plateau. It was fishing an area between 48°00' S and 48°20' S, and 179°20' E and 180° between 15 and 17 August 2010, before sinking on 18 August 2010. The Ministry of Fisheries estimated that it had taken a catch of between 120 t and 190 t that was lost with the vessel.

2.   BIOLOGY

Southern blue whiting is a schooling species that is confined to Sub-Antarctic waters. Early growth has been well documented with fish reaching a length of about 20 cm FL after one year and 30 cm FL after two years. Growth slows down after five years and virtually ceases after ten years. Ages have been validated up to at least 15 years by following strong year classes, but ring counts from otoliths suggest a maximum age of 25 years.

The age and length of maturity, and recruitment to the fishery, varies between areas and between years. In some years a small proportion of males mature at age 2, but the majority do not mature until age 3

or 4, usually at a length of 33–40 cm FL. Most females also mature at age 3 or 4, at 35–42 cm FL. Ageing studies have shown that this species has very high recruitment variability.

Southern blue whiting are highly synchronised batch spawners. Four spawning areas have been identified: on Bounty Plateau, Pukaki Rise, Auckland Islands Shelf, and Campbell Rise. The Campbell Rise has two separate spawning grounds, to the north and south respectively. Fish appear to recruit first to the southern ground but thereafter spawn on the northern ground. Spawning on Bounty Plateau begins in mid-August and finishes by mid-September. Spawning begins 3–4 weeks later in the other areas, finishing in late September/early October. Spawning appears to occur at night, in midwater, over depths of 400–500 m on Campbell Rise but shallower elsewhere.

Natural mortality (M) was estimated using the equation $\log_e(100)/$maximum age, where maximum age is the age to which 1% of the population survives in an unexploited stock. Using a maximum age of 22 years, M was estimated to equal 0.21. The value of 0.2 is assumed to reflect the imprecision of this value. Campbell Rise stock assessments estimated M within the model in 2016 and 2020, using an informed prior with a mean of 0.2 (see Table 3 and Roberts & Dunn 2017).

Table 3: Estimates of biological parameters for the Campbell Rise southern blue whiting stock.

Fishstock			Estimate		Source
1. Natural mortality (M)					
		Males	Females		
Campbell Rise		0.2	0.2		Hanchet (1991)
		0.17	0.18		Roberts & Hanchet (2019)
		0.16	0.17		Doonan (2020)
2. Weight = a (length)^b (Weight in g, length in cm fork length)					
		Males		Females	
	a	b	a	b	
Campbell Rise	0.00515	3.092	0.00407	3.152	Hanchet (1991)

Note: Estimates of natural mortality and the length-weight coefficients are assumed to be the same for the other stocks. Observed length-at-age data are used for all stocks.

3. STOCKS AND AREAS

Hanchet (1999) reviewed the stock structure of southern blue whiting. He examined historical data on southern blue whiting distribution and abundance, reproduction, growth, and morphometrics. There appear to be four main spawning grounds of southern blue whiting; on the Bounty Plateau, Pukaki Rise, Auckland Islands Shelf, and Campbell Rise. There are also consistent differences in the size and age distributions of fish, in the recruitment strength, and in the timing of spawning between these four areas. Multiple discriminant analysis of data collected in October 1989 and 1990 showed that fish from Bounty Plateau, Pukaki Rise, and Campbell Rise could be distinguished on the basis of their morphometric measurements. The Plenary concluded that this constitutes strong evidence that fish in these areas return to spawn on the grounds to which they first recruit. No genetic studies have been carried out, but given their proximity, it is unlikely that there would be detectable genetic differences in the fish between these four areas.

For the purposes of stock assessment, it is assumed that there are four stocks of southern blue whiting with fidelity within stocks: the Bounty Plateau stock, the Pukaki Rise stock, the Auckland Islands Shelf stock, and the Campbell Rise stock.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

Tables and accompanying text in this section were updated for the southern blue whiting fishery 2022 Fishery Assessment Plenary (Fisheries New Zealand 2020). A more detailed summary from an issue-by-issue perspective is available in the Aquatic Environment and Biodiversity Annual Review 2021 (Fisheries New Zealand 2021), online at https://www.mpi.govt.nz/dmsdocument/51472-Aquatic-Environment-and-Biodiversity-Annual-Review-AEBAR-2021-A-summary-of-environmental-interactions-between-the-seafood-sector-and-the-aquatic-environment.

4.1   Role in the ecosystem

Southern blue whiting is one of the dominant (in terms of biomass) middle depth fish species found on the Campbell Plateau and Bounty Plateau at depths between 250–600 m. Francis et al (2002) categorised southern blue whiting as part of an upper slope assemblage and estimated its distribution to be centred on about 500 m depth and latitude 51° S. During August and September, southern blue whiting form large dense spawning aggregations on the Campbell Rise and Bounty Plateau and, to a lesser extent, on the Pukaki Rise and near the Auckland Islands. The species is also found in much lower numbers on the Stewart-Snares shelf and Chatham Rise.

These stocks are characterised by highly variable year class strengths, with the strong year classes growing at a significantly lower rate than others (i.e., showing signs of density dependent growth). Their substantial abundance suggests that southern blue whiting are probably an important part of the Campbell Rise and Bounty Plateau ecosystems, but their variability suggests that these systems may function differently at different times. For instance, very large changes have been observed in the abundance of southern blue whiting on the Bounty Plateau, with a 7-fold increase between 2005 and 2007 followed by a 4-fold decrease to 2009 (Dunn & Hanchet 2011). The large increase was due to the very strong 2002 year class recruiting to the fishery, but the rapid decline is not easily explained. Whatever the reason, there are likely to be implications for the role of the southern blue whiting population in the ecosystem during such events.

4.1.1   Trophic interactions

Crustaceans and teleosts are the dominant prey groups for southern blue whiting. Stevens et al (2011) showed that in the Sub-Antarctic (and similarly from the Chatham Rise), crustaceans occurred in 70% of stomachs, mainly euphausiids (37%), natant decapods (24%), and amphipods (11%). Teleosts occurred in 32% of stomachs, mainly myctophids (10%). Salps (7%) and cephalopods (2%) were of lesser importance.

Predation by marine mammals and large teleosts is probably the main source of mortality for adults, and juveniles are frequently taken by seabirds (MPI 2013). Large hake and ling taken as bycatch in the fishery have usually been feeding on southern blue whiting, and large hoki caught during Sub-Antarctic trawl surveys have occasionally been feeding on juvenile southern blue whiting. Juvenile (90–130 mm FL) southern blue whiting were found to be the main prey item of black-browed albatross at Campbell Island during the chick rearing period in January 1997 (Cherel et al 1999) and are also regularly taken by grey-headed albatross and rockhopper penguins breeding at Campbell Island (Cherel et al 1999).

4.1.2 Ecosystem Indicators

Tuck et al (2009) used data from the Sub-Antarctic trawl survey series to derive fish-based ecosystem indicators using diversity, fish size, and trophic level. This trawl survey has run regularly using the same vessel since 1991 and covers much of the area inhabited by southern blue whiting. Tuck et al (2009) showed generally increasing trends in the proportion of threatened fish species and those with low resilience (from FishBase, Froese & Pauly 2000) and indices of fish diversity often showed positive trends. The proportion of piscivorous and demersal species and the mean trophic level generally declined over the time period, especially in areas where southern blue whiting are more common. Highly variable recruitment of dominant species like southern blue whiting may strongly influence such trends. Changes in fish size were less consistent, and Tuck et al (2009) and Tuck et al (2014) did not find size-based indicators as useful as they have been overseas. Routine measurement of all fish species in New Zealand trawl surveys since 2008 may increase the utility of size-based indicators in the future.

4.2   Bycatch (fish and invertebrates)

4.2.1   Fish

The southern blue whiting fishery is characterised by large, 'clean' catches of the target species with minimal fish bycatch. Anderson (2009) estimated that, for southern blue whiting target tows, southern blue whiting accounted for more than 99% of the total estimated catch recorded by observers and more than 99% of the total reported catch from the fishery based on catch-effort forms.

A total of 120 bycatch species have been recorded by observers (Anderson 2009), of which the main bycatch species have been ling, hake, and hoki, with smaller amounts of porbeagle shark, opah, silverside, and pale ghost shark (Finucci et al 2019), with a decreasing trend in hake bycatch.

Given the high proportion of target species catch, discards in this fishery are correspondingly low, composed mainly by target catch and mostly related to loss of catch during the haul (Anderson 2009).

4.2.2 Invertebrates

There is little invertebrate bycatch in this fishery even though most trawls are on or close to the seabed for at least part of the time (Cole et al 2007). Protected coral bycatch has been negligible in this fishery (Weaver 2021).

4.3 Incidental capture of protected species (seabirds, mammals, and protected fish)

Southern blue whiting trawlers occasionally capture marine mammals (pinnipeds), including New Zealand sea lions and New Zealand fur seals (which were classified as 'Nationally Critical' and 'Not Threatened', respectively, under the New Zealand Threat Classification System in 2010, Baker et al 2016). Vessels in the southern blue whiting fishery also interact with, and incidentally capture, seabirds and, at least in one occasion, have captured a protected shark species.

Observer data for bottom trawl fisheries bycatch of seabirds, mammals, and coral are summarised on an annual basis by the Department of Conservation Conservation Services Programme (CSP) (Weaver 2021). Coral impacts are discussed under Invertebrates (section 4.2.2).

4.3.1 Marine mammal captures

The New Zealand sea lion (rāpoka), *Phocarctos hookeri*, is the rarest sea lion in the world. The estimated total population of around 11 800 sea lions in 2015 is classified by the Department of Conservation as 'Nationally Vulnerable' under the New Zealand Threat Classification System (Baker et al 2019). Pup production at the main Auckland Island rookeries showed a steady decline between 1998 and 2009 and has subsequently stabilised (details can be found in the Aquatic Environment and Biodiversity Annual Review 2021, Fisheries New Zealand 2021).

Sea lions forage in depths down to 600 m and overlap with trawling down to 500 m depth for arrow squid. Sea lions interact with some trawl fisheries which can result in incidental capture and subsequent drowning (Smith & Baird 2005, 2007a & b, Thompson & Abraham 2010a, Thompson & Abraham 2012, Abraham & Thompson 2011, Abraham et al 2016). Since 1988, incidental captures of sea lions have been monitored by government observers on-board an increasing proportion of the fishing fleet.

Annual sea lion pup counts at breeding sites are used to index trends in the total sea lion population. The Auckland Islands is the largest breeding site for sea lions: 68% of all sea lion pups are born there; 30% are born at Campbell Island/Motu Ihupuku, and the remaining 2% at Stewart Island/Rakiura and the South Island/Te Waipounamu (currently restricted to the Otago and Catlins coasts). Between 1998 and 2009 the number of sea lion pups born annually at the Auckland Islands declined by 50%. In 2014, the Minister of Conservation and the Minister for Primary Industries asked officials to develop a New Zealand sea lion/rāpoka Threat Management Plan (NZSL TMP) which is available online: https://www.fisheries.govt.nz/protection-and-response/sustainable-fisheries/managing-our-impact-on-marine-life/new-zealand-sea-lion/.

Captures of New Zealand sea lions in the Campbell Rise southern blue whiting trawl fishery have been variable between years (Table 4). The sea lion captures occur close to Campbell Island in SBW 6I and are mostly males (91%). There were 21 captures in 2012–13, mostly early in the season, which led to the development of an operational plan that includes observers being placed on all trips and compulsory use of sea lion exclusion devices (SLEDs) on all tows in SBW 6I (MPI 2015).

The New Zealand fur seal was classified as 'Least Concern' by IUCN in 2008 and as 'Not Threatened' under the New Zealand Threat Classification System in 2010 (Baker et al 2016).

SOUTHERN BLUE WHITING (SBW)

Southern blue whiting has one of the highest observed capture rates of New Zealand fur seals for any observed fishery. The observed capture rate of fur seals in the southern blue whiting fishery has varied considerably between years, ranging without trend from a high of 23.96 fur seals per 100 tows in 2005–06 to a low of 2.05 fur seals per 100 tows in 2016–17 (Abraham et al 2016, Table 5). Almost all fur seals captured in this fishery have been caught at the Bounty Plateau in August and September when the southern blue whiting are in dense spawning aggregations.

Table 4: Number of tows by fishing year and observed New Zealand sea lion captures in the Campbell Island southern blue whiting trawl fisheries, 2002–03 to 2019–20. Annual fishing effort (tows), number of observed tows and observer coverage (%) in Campbell Island southern blue whiting trawl fisheries; number of observed captures and observed capture rate (captures per hundred tows) of New Zealand sea lion; estimated captures and capture rate of New Zealand sea lion (mean and 95% credible interval). Estimates are based on methods described by Abraham et al (2021), available online at https://protectedspeciescaptures.nz/PSCv6/released/. Observed and estimated protected species captures in this table derive from the PSC database version PSCV6.. * denotes the year that standardised SLED designs were introduced.

	Fishing effort			Obs. captures		Est. captures		Est. capture rate	
Fishing year	Tows	No. Obs	% obs	Captures	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	638	275	43.1	0	0.00	1	0-3	0.09	0-0.47
2003–04	740	241	32.6	1	0.41	3	1-9	0.41	0.14-1.22
2004–05	870	335	38.5	2	0.60	5	2-13	0.60	0.23-1.49
2005–06	624	217	34.8	3	1.38	10	3-22	1.59	0.48-3.53
2006–07*	630	224	35.6	3	1.34	15	6-30	2.36	0.95-4.76
2007–08	818	331	40.5	5	1.51	8	5-14	0.95	0.61-1.71
2008–09	1 188	300	25.3	0	0.00	1	0-7	0.10	0-0.59
2009–10	1 113	396	35.6	11	2.78	24	15-37	2.19	1.35-3.32
2010–11	1 171	433	37.0	6	1.39	15	8-25	1.25	0.68-2.13
2011–12	951	669	70.3	0	0.00	1	0-4	0.10	0-0.42
2012–13	791	791	100.0	21	2.65	21	21-21	2.65	2.65-2.65
2013–14	804	803	99.9	2	0.25	2	2-2	0.25	0.25-0.25
2014–15	673	669	99.4	6	0.90	6	6-6	0.89	0.89-0.89
2015–16	442	443	100.2	3	0.68				
2016–17	537	537	100.0	0	0.00				
2017–18	455	455	100.0	2	0.44				
2018–19	749	748	99.9	0	0.00				
2019–20	348	348	100.0	1	0.29				

Table 5: Number of tows (commercial and observed) by fishing year, observed and estimated New Zealand fur seal captures and capture rate in southern blue whiting trawl fisheries, 2002–03 to 2019–20 (Abraham et al 2021). Estimates are available online at https://protectedspeciescaptures.nz/PSCv6/released/. Observed and estimated protected species captures in this table derive from the PSC database version PSCV6.

	Fishing effort			Obs. captures		Est. captures		Est. capture rate	
Fishing year	Tows	No. Obs	% obs	Captures	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	638	275	43.1	8	2.91	22	8–78	3.47	1.25–12.23
2003–04	740	241	32.6	13	5.39	36	13–122	4.88	1.76–16.49
2004–05	870	335	38.5	33	9.85	103	35–472	11.8	4.02–54.25
2005–06	624	217	34.8	52	23.96	67	52–122	10.77	8.33–19.55
2006–07	630	224	35.6	13	5.80	25	13–76	3.96	2.06–12.06
2007–08	818	331	40.5	24	7.25	110	25–600	13.41	3.06–73.35
2008–09	1 188	300	25.3	17	5.67	129	25–488	10.88	2.10–41.08
2009–10	1 113	396	35.6	16	4.04	114	20–460	10.2	1.80–41.29
2010–11	1 171	433	37.0	36	8.31	76	38–251	6.5	3.25–21.43
2011–12	951	669	70.3	25	3.74	69	25–289	7.3	2.63–30.39
2012–13	791	791	100.0	27	3.41	27	27–27	3.42	3.42–3.42
2013–14	804	803	99.9	95	11.83	97	95–116	11.98	11.74–14.34
2014–15	673	669	99.4	41	6.13	41	41–42	6.07	6.06–6.20
2015–16	442	443	100.2	51	11.51				
2016–17	537	537	100.0	11	2.05				
2017–18	455	455	100.0	17	3.74				
2018–19	749	748	99.9	11	1.47				
2019–20	348	348	100.0	8	2.30				

4.3.2 Seabird captures

Vessels are legally required to use seabird mitigation devices and also to adhere to industry Operating Procedures with regards to managing risk of environmental interactions. For protected species, capture estimates presented include all animals recovered to the deck (alive, injured, or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds struck by a warp or caught on a hook but not brought on board the vessel; Middleton & Abraham 2007, Brothers et al 2010).

Mitigation methods such as streamer (tori) lines, Brady bird bafflers, and offal management are used in the southern blue whiting trawl fishery. Warp mitigation was voluntarily introduced from about 2004 and made mandatory in April 2006 (Department of Internal Affairs 2006). The 2006 notice mandated that all trawlers over 28 m in length use a seabird scaring device while trawling (being 'paired streamer lines', 'bird baffler' or 'warp deflector' as defined in the Notice).

In each of the 2018–19 fishing year there were 37 observed captures of birds in southern blue whiting trawl fisheries, while in 2019–20 there were only 3, at rates of 4.9 and 0.9 birds per 100 observed tows respectively (Table 6). The average capture rate in southern blue whiting trawl fisheries for the period from 2002–03 to 2019–20 is about 1.5 birds per 100 tows, a low rate relative to some other New Zealand trawl fisheries, e.g., for scampi (3.8 birds per 100 tows) and squid (12.9 birds per 100 tows) over the same years.

Overall, the impact that the southern blue whiting fisheries have on seabirds is relatively small. This can be seen in the proportions of the overall fisheries Population Sustainability Threshold (PST) that are attributable to the southern blue whiting fisheries for each species (Table 7). Observed seabird captures since 2002–03 have been dominated by grey petrels (88 of the 138 observed seabird captures since 2002–03), a negligible risk species where the southern blue whiting fisheries are estimated to be responsible for about 20% of the risk ratio (Table 7).

Table 6: **Number of tows by fishing year and observed seabird captures in southern blue whiting trawl fisheries, 2002–03 to 2019–20. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described by Abraham & Richard (2020) and are available online at https://protectedspeciescaptures.nz/PSCv6/released/. Observed and estimated protected species captures in this table derive from the PSC database version PSCV6..**

Fishing year	Fishing effort			Obs. captures		Est. captures		Est. capture rate	
	Tows	No. Obs	% obs	Captures	Rate	Mean	95% c.i.	Mean	95% c.i.
2002–03	638	275	43.1	0	0.00	4	0-13	0.69	0-2.04
2003–04	740	241	32.6	1	0.41	8	2-19	1.03	0.27-2.57
2004–05	870	335	38.5	2	0.60	11	4-24	1.28	0.46-2.76
2005–06	624	217	34.8	1	0.46	7	1-17	1.06	0.16-2.72
2006–07	630	224	35.6	3	1.34	9	3-19	1.39	0.48-3.02
2007–08	818	331	40.5	3	0.91	10	4-21	1.19	0.49-2.57
2008–09	1 188	300	25.3	0	0.00	12	3-27	1.02	0.25-2.27
2009–10	1 113	396	35.6	11	2.78	25	14-40	2.21	1.26-3.59
2010–11	1 171	433	37.0	13	3.00	26	16-41	2.18	1.37-3.5
2011–12	951	669	70.3	3	0.45	7	3-14	0.69	0.32-1.47
2012–13	791	791	100.0	19	2.40	19	19-19	2.40	2.4-2.4
2013–14	804	803	99.9	17	2.12	17	17-17	2.12	2.11-2.11
2014–15	673	669	99.4	7	1.05	7	7-9	1.07	1.04-1.34
2015–16	442	443	100.2	6	1.35	6	6-6	1.36	1.36-1.36
2016–17	537	537	100.0	6	1.12	6	6-7	1.13	1.12-1.3
2017–18	455	455	100.0	6	1.32	6	6-6	1.32	1.32-1.32
2018–19	749	748	99.9	37	4.95	37	37-37	4.94	4.94-4.94
2019–20	348	348	100.0	3	0.86	3	3-3	0.86	0.86-0.86

Table 7: Risk ratio for seabirds predicted by the level two risk assessment for the target southern blue whiting (SBW) fishery and all fisheries included in the level two risk assessment, 2006–07 to 2016–17, showing seabird species with a risk ratio of at least 0.001 of PST. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Population Sustainability Threshold, PST (from Richard et al 2017 and Richard et al 2020, where full details of the risk assessment approach can be found). 2018-19 and 2019-20 data were unavailable at time of publication. The DOC threat classifications are shown (Robertson et al 2017 at http://www.doc.govt.nz/documents/science-and-technical/nztcs19entire.pdf).

| | | Risk ratio | | | |
Species	PST (mean)	SBW trawl*	Total	Risk category	DOC Threat Classification
Salvin's albatross	3 460	0.009	0.765	High	Threatened: Nationally Critical
Grey petrel	5 460	0.006	0.03	Negligible	At Risk: Naturally Uncommon
Campbell black-browed albatross	2 000	0.002	0.06	Low	At Risk: Naturally Uncommon

* SWB trawl from Richard et al (2017).

4.3.3 Protected fish species captures

The basking shark (*Cetorhinus maximus*) was classified as 'Endangered' by IUCN in 2013 and as 'Threatened – Nationally Vulnerable' in 2016, under the New Zealand Threat Classification System (Duffy et al 2018). Basking shark has been a protected species in New Zealand since 2010, under the Wildlife Act 1953, and is also listed in Appendix II of the CITES convention. Observer reported records include the incidental capture of one basking shark in 2016 by the southern blue whiting fishery.

4.4 Benthic interactions

The spatial extent of seabed contact by trawl fishing gear in New Zealand's EEZ and Territorial Sea has been estimated and mapped in numerous studies for trawl fisheries targeting deepwater species (Baird et al 2011, Black et al 2013, Black & Tilney 2015, Black & Tilney 2017, Baird & Wood 2018, and Baird & Mules 2019, 2021a, 2021b), species in waters shallower than 250 m (Baird et al. 2015, Baird & Mules 2020a), and all trawl fisheries combined (Baird & Mules 2021a, 2021b). The most recent assessment of the deepwater trawl footprint was for the period 1989–90 to 2018–19 (Baird & Mules 2021b).

During 1989–90 to 2018–19, about 17 400 southern blue whiting bottom-contacting trawls were reported on TCEPRs and ERS (Baird & Mules 2021b): about 1000–2000 tows were reported annually during 1989–90 to 1991–92; 300–500 in most other years, except in 1997–98, 1998–99, 2009–10, and 2010–11 when about 700 tows were reported each year. The total footprint generated from these tows was estimated at about 23 350 km². This footprint represented coverage of 0.5% of the seafloor of the combined EEZ and the Territorial Sea areas, and 1.7% of the 'fishable area', that is, the seafloor area open to trawling, in depths of less than 1600 m. For the 2018–19 fishing year, 398 southern blue whiting bottom tows had an estimated footprint of 757 km² which represented coverage of < 0.1% of the EEZ and Territorial Sea and < 0.1% of the fishable area (Baird & Mules 2021b).

The overall trawl footprint for southern blue whiting (1989–90 to 2018–19) covered 4.0% of seafloor in 200–400 m, 7.5% in 400–600 m, and 0.2% of 600–1600 m seafloor (Baird & Mules 2021b). In 2018–19, the southern blue whiting footprint contacted 0.1%, 0.3%, and < 0.1% of those depth ranges, respectively (Baird & Mules 2021b), and no effort was reported deeper than 800 m. The BOMEC areas with the highest proportion of area covered by the southern blue whiting footprint were classes F (Sub-Antarctic island shelves), I (Chatham Rise slope and shelf edge of the east coast South Island), and L (deeper waters off the Stewart-Snares shelf and around the main Sub-Antarctic islands). The 2018–19 southern blue whiting footprint covered 0.25% of the 38 608 km² of class F, 0.02% of the 52 224 km² of class I, and almost 1% of the 198 577 km² of class L (Baird & Mules 2021b).

Where trawls for southern blue whiting are fished on the bottom, they are likely to have effects on benthic community structure and function (e.g., Cole et al 2007, Rice 2006) and there may be consequences for benthic productivity (e.g., Jennings 2001, Hermsen et al 2003, Hiddink et al 2006, Reiss et al 2009). However, any consequences from southern blue whiting fishing, due to the gear type and scale of the fishery (typically less than 600 tows fished on the bottom per year), are likely to be relatively minor. A more general review of habitat interactions can be found in the Aquatic Environment and Biodiversity Annual Review 2021 (Fisheries New Zealand 2021).

4.5 Other considerations

4.5.1 Spawning disruption

Fishing during spawning may disrupt spawning activity or success. Canadian research carried out on Atlantic cod (*Gadus morhua*) concluded that "Cod exposed to a chronic stressor are able to spawn successfully, but there appears to be a negative impact of this stress on their reproductive output, particularly through the production of abnormal larvae" (Morgan et al 1999). Morgan et al (1997) also reported disruption of a spawning shoal of Atlantic cod: "Following passage of the trawl, a 300-m-wide "hole" in the aggregation spanned the trawl track. Disturbance was detected for 77 min after passage of the trawl." There has been no research carried out on the disruption of spawning southern blue whiting by fishing in New Zealand, where fishing occurs almost entirely on spawning aggregations.

4.5.2 Genetic effects

Fishing, environmental changes such as altered average sea temperatures (climate change), or pollution could alter the genetic composition or diversity of a species. There are no known studies of the genetic diversity of southern blue whiting from New Zealand. Genetic studies for stock discrimination are reported above under 'Stocks and Areas' (section 3).

4.5.3 Habitat of particular significance to fisheries management

Habitat of particular significance for fisheries management does not have a policy definition (MPI 2013). Studies have identified areas of importance for spawning and juvenile southern blue whiting where distribution plots highlight hotspot areas for the 0+, 1+, immature, and adult fish (O'Driscoll & Bagley 2003). These are the Campbell Plateau and Bounty Plateau, with minimal numbers recorded on the Chatham Rise.

5. STOCK ASSESSMENT

An updated assessment of the Campbell Island Rise stock was completed in 2020, using research time series of abundance indices from wide-area acoustic surveys from 1993 to 2019 and proportion-at-age data from the commercial fishery. New information included a wide-area acoustic survey of the Campbell Rise carried out in August–September 2019, which produced a biomass estimate of 91 000 t (Ladroit et al 2020). The general purpose stock assessment program, CASAL (Bull et al 2012), was used and the approach, which used Bayesian estimation, was the same as that adopted by Roberts & Hanchet (2019). Roberts & Hanchet (2019) introduced an initial equilibrium age structure in 1960 rather than using a non-equilibrium age structure in 1979 which was used in previous assessments (e.g., Dunn & Hanchet 2017). Therefore, year class strengths were estimated from 1958 (instead of 1977), the catch history was extended back to 1971, the first year of reported catches (1979 previously, see Table 1). The new 2020 model produced similar estimates of status to the old model, but it also produced stable estimates of natural mortality when using Markov chain Monte Carlo (MCMC) methods.

A stock assessment was also completed for the Bounty Plateau stock in 2014 using data up to 2013 from local area acoustic surveys of aggregations. The general purpose stock assessment program, CASAL (Bull et al 2012) with Bayesian estimation was used. Preliminary model runs did not provide a satisfactory fit to both the high local area aggregation acoustic biomass estimates observed in 2007–2008 and the lower local area aggregation biomass estimates observed since 2009. Development of the assessment then focused on evaluating models with different assumptions that allowed a comparison of the extent to which the high biomass and subsequent decline were fitted. However, these have not proven successful, and the stock assessment has now been rejected by the Working Group in favour of developing a harvest control rule (HCR). An HCR that would lead to a low risk of the stock falling below the soft limit reference point was developed and used the most recent acoustic index of abundance as an absolute measure of abundance. Four further acoustic surveys were completed at the Bounty Plateau from 2014 to 2017, but surveys in 2018, 2019, and 2020 were unsuccessful.

No new assessment is available for the Pukaki Rise stock due to the paucity of useful abundance data. No assessment has been made of the Auckland Islands Shelf stock. The years given in the biomass and yield sections of this report refer to the August–September spawning/fishing season.

5.1 Estimates of fishery parameters and abundance indices

(i) Bounty Plateau

Between 1993 and 2001, a series of wide-area acoustic surveys for southern blue whiting were carried out by the RV *Tangaroa*. From 2004 to 2017, a series of local area aggregation surveys were carried out from industry vessels (O'Driscoll 2015, O'Driscoll & Dunford 2017, O'Driscoll & Ladroit 2017, O'Driscoll 2018). The fishing vessels opportunistically collected acoustic data from the Bounty Plateau fishing grounds using a random survey design over an ad hoc area that encompassed an aggregation of southern blue whiting (O'Driscoll 2015). The local area aggregation surveys have had mixed levels of success (Table 8).

Table 8: **Estimates of biomass (t) for immature and mature fish from wide-area acoustic surveys of the Bounty Plateau from 1993–2001 (from Fu et al 2013); and mature fish from local aggregation surveys in 2004–2016 (O'Driscoll 2015, O'Driscoll & Dunford 2017, O'Driscoll & Ladroit 2017); and the proportion of catch that occurred before the biomass estimate in each year (based on catch effort data, and sample dates for the acoustic snapshots). Sampling CVs for the surveys are given in parentheses.**

Year	Wide-area survey estimates		Local aggregation survey estimates	
	Immature	Mature	Mature	Proportion
1993	15 269 (33%)	43 338 (58%)	–	–
1994	7 263 (27%)	17 991 (25%)	–	–
1995	0 (–)	17 945 (24%)	–	–
1997	3 265 (54%)	27 594 (37%)	–	–
1999	344 (37%)	21 956 (75%)	–	–
2001	668 (28%)	11 784 (35%)	–	–
2004	–	–	8 572 (69%)	0.73
2005	–	–	–	–
2006	–	–	11 949 (12%)	0.78
2007	–	–	79 285 (19%)	0.93
2008	–	–	75 889 (34%)	0.68
2009	–	–	16 640 (21%)	0.29
2010	–	–	18 074 (36%)	0.35
2011	–	–	20 990 (28%)	0.89
2012	–	–	16 333 (7%)	0.84
2013	–	–	28 533 (27%)	0.76
2014	–	–	11 852 (31%)	0.75
2015	–	–	6 726 (42%)	0.44
2016	–	–	6 201 (35%)	0.93
2017	–	–	7 719 (24%)	0.61

Acoustic data collected in 2005 could not be used because of inadequate survey design and acoustic interference from the scanning sonar used by the vessel for searching for fish marks. There was some concern that the surveys in 2006 and 2009 may not have sampled the entire aggregation because fish marks extended beyond the area being surveyed on some transects. However, the surveys in 2010–2012 appeared to have sampled the entire aggregation and gave a similar estimate of biomass to that in 2009. The 2013 aggregation survey was higher than the preceding four surveys, but since then biomass estimates have progressively declined, supporting the view that biomass has declined in this stock. Surveys in 2018, 2019, and 2020 were unsuccessful and did not produce estimates of abundance principally because surveyable aggregations of fish were not observed during the survey periods. It is possible that the first spawning in 2018 and 2019 was earlier than in 2016 and 2017, and therefore that the acoustic data collection was too late (e.g., Large 2021, in press).

A standardised CPUE analysis was carried out for the Bounty Plateau for data up to 2002. However, the results of this analysis were not consistent with the acoustic survey estimates, and the model structure and assumptions were inadequate to reliably determine the indices or associated variance. The indices were therefore rejected by the Working Group as indices of abundance and have not been used in assessments.

(ii) Campbell Rise

Wide-area acoustic surveys of the Campbell Rise have been carried out from RV *Tangaroa* since 1995, with the most recent survey in August–September 2019 (Ladroit et al 2020). The estimate of mature biomass in 2019 was similar to that in 2016, and the 4th highest in the time series (Table 9).

A standardised CPUE analysis of the Campbell Rise stock was completed up until the 2005 fishing season. In the past there has been concern that because of the highly aggregated nature of the fishery, and the associated difficulty in finding and maintaining contact with the highly mobile schools in some years, the CPUE series may not be monitoring abundance. The indices have therefore not been used in the stock assessment since 1998.

Table 9: Estimates of biomass (t) for immature and mature fish from wide-area acoustic surveys of the Campbell Rise 1993–2019 (from Ladroit et al 2020). Sampling CVs for the surveys are given in parentheses.

	Wide-area surveys	
Year	Immature	Mature
1993	35 208 (25%)	16 060 (24%)
1994	8 018 (38%)	72 168 (34%)
1995	15 507 (29%)	53 608 (30%)
1998	6 759 (20%)	91 639 (14%)
2000	1 864 (24%)	71 749 (17%)
2002	247 (76%)	66 034 (68%)
2004	5 617 (16%)	42 236 (35%)
2006	3 423 (24%)	43 843 (32%)
2009	24 479 (26%)	99 521 (27%)
2011	14 454 (17%)	53 299 (22%)
2013	8 004 (55%)	65 801 (25%)
2016	4 456 (19%)	97 117 (16%)
2019	4 020 (18%)	91 145 (27%)

(iii) Pukaki Rise

Wide-area surveys of the Pukaki Rise were carried out between 1993 and 2000 (Fu et al. 2013) from RV *Tangaroa*, and more recently (2009 to 2012) local area aggregation estimates were obtained by industry vessels (Table 10). The biomass estimates from the last two surveys (2010, 2012) were considered too small to be plausible (Table 10).

Table 10: Estimates of biomass (t) for immature and mature fish from wide-area acoustic surveys of the Pukaki Rise 1993–2000 (from Fu et al 2013 and O'Driscoll 2013) and local area aggregation surveys from 2009–2012. Sampling CVs for the surveys are given in parentheses.

	Wide-area survey estimates				Local aggregation survey estimates		
Year	Immature		Mature	Vessel	Transects	Area(km^2)	Biomass (%cv)
1993	9 558 (25%)		26 298 (32%)				–
1994	125 (100%)	3 591 (48%)	21 506 (44%)				–
1995	0 (–)		6 552 (18%)				–
1997	1 866 (12%)		16 862 (34%)				–
2000	1 868 (62%)	8 363 (74%)	6 960 (37%)				–
2009				–	*Meridian 1*	4	50	188 (29%)
				–		5	283	9 459 (30%)
				–		5	71	6 272 (41%)
				–	*Aleksandr Buryachenko*	6	60	2 361 (12%)
				–		7	117	7 903 (26%)
				–		6	19	11 321 (38%)
2010				–	*Meridian 1*	10	364	1 085 (17%)
2012				–	*San Waitaki*	–	–	3 272 (21%)

5.2 Biomass estimates

(i) Campbell Rise stock (2020 stock assessment)

The stock assessment model

An updated stock assessment for the Campbell Rise stock was completed for the 2019–20 year (Doonan 2020).

A two-sex, single stock and area Bayesian statistical catch-at-age model for the Campbell Rise southern blue whiting stock was implemented in CASAL (Bull et al 2012). The model partitioned the stock into immature and mature fish with two sexes and age groups 2–15, with a plus group at age 15. The model was run for the years 1960–2019. Five year projections were run for the years 2020–2025. The annual cycle was partitioned into two time steps (Table 11). In the first time step (nominally the non-spawning season), 90% of natural mortality was assumed to have taken place. In the second time step (spawning

season), fish matured and were migrated to a spawning area where fish ages were incremented; the 2-year-olds were recruited to the population, and mature fish were subjected to fishing mortality. The remaining 10% of natural mortality was then applied to the entire population following fishing. A two sex model was used because there are significant differences observed between males and females in both the proportions at age in the commercial catch for fished aged 2–4 (see later) and their mean size at age (Hanchet & Dunn 2010). The stock recruitment relationship was assumed to be Beverton-Holt with a steepness of 0.9, with the proportion of males at recruitment (at age 2) assumed to be 0.5 of all recruits.

Southern blue whiting exhibit large interannual differences in growth, presumably caused by local environmental factors but also closely correlated with the occurrence of strong and weak year classes. Hence, an empirical size-at-age matrix was used which was derived by qualitatively reviewing the empirically estimated mean sizes-at-age from the commercial catch-at-length and -age data (Hanchet & Dunn 2010). Missing mean sizes in the matrix were inferred from the relative size of their cohort and the mean growth of similar ages in other years; and cohorts with unusually small or large increments were similarly adjusted. For projections, the mean sizes-at-age were assumed to be equal to the average of the estimated sizes-at-age from 2015 to 2019 (5 years).

In general, southern blue whiting on the Campbell Rise are assumed to be mature when on the fishing ground, because they are spawning when they are fished. Hence, it was assumed that all mature fish were equally selected by fishing, and that no immature fish were selected. The maximum exploitation rate (U_{max}) was assumed to be 0.8. The proportion of immature fish that mature in each year was estimated for ages 2–5, with fish aged 6 and above assumed to be fully mature.

The updated model was started in 1960 and assumed an equilibrium age distribution. The model estimated year class strengths back to 1958, which allowed the flexibility to fit to strongly non-equilibrium age composition observed in the commercial trawl catches since 1979. Catches for the Campbell Rise in years 1971–1977 were estimated by assuming the proportion of the catch from all areas taken at the Campbell Rise was equal to the proportion across the period since 1978, following Roberts & Hanchet (2019) (see Table 12).

Table 11: Annual cycle of the stock model, showing the processes taking place at each step, and the available observations. Fishing mortality (F) and natural mortality (M) that occur within a time step occur after all other processes. M, proportion of M occurring in that time step.

Period	Process	M	Length at age	Observations
1. Nov–Aug	Natural mortality	0.9	–	–
2. Sep–Oct	Age, recruitment, F, M	0.1	Matrix applies here	Proportion at age, acoustic indices

Table 12: Estimated catches for Campbell Rise from 1971 to 1977 (see Roberts & Hanchet 2019).

Fishing year	Estimated catch (t)
1971	7 260
1972	18 010
1973	33 856
1974	29 458
1975	1 660
1976	11 929
1977	18 453

Observations

The model was fitted to a single time series of acoustic biomass estimates and the catch-at-age data from the fishery; the time series of acoustic biomass estimates came from a wide-area survey series conducted by the research vessel *Tangaroa* for immature and for mature fish. The acoustic survey estimates were used as relative estimates of mid-season biomass (i.e., after half the catch has been removed), with associated CVs estimated from the survey analysis (Table 9).

Catch-at-age observations by sex were available for most years from the commercial fishery for the period 1979 to 2019. These catch-at-age data were fitted to the model as proportions-at-age, where estimates of the proportions-at-age by age were estimated by bootstrap using the NIWA catch-at-age software (Bull & Dunn 2002).

Estimation

Model parameters were estimated using Bayesian methods implemented using the NIWA stock assessment program CASAL v2.30 (Bull et al 2012). For initial runs only the mode of the joint posterior distribution was estimated. For the final runs presented here, the full posterior distribution was sampled using MCMC methods, based on the Metropolis-Hastings algorithm.

An initial MCMC chain was estimated using a burn-in length of 1 million iterations, with every 10 000th sample taken from the next 10 million iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior). To improve mixing at MCMC (following the approach of Roberts & Doonan 2016) the covariance matrix was recalculated empirically from the 1000 samples obtained from the initial MCMC chain and the chain started afresh with the new covariance matrix out to a length 3.3×10^6 iterations (no burn-in). The initial chain was discarded.

Equilibrium 'virgin' biomass is equal to the population that there would have been if all the year class strengths (YCSs) were equal to one and there was no fishing. Year class strengths were estimated for all years from 1958 to 2016, under the assumption that the estimates from the model should average one.

Prior distributions and penalty functions

In general, the assumed prior distributions used in the assessment were intended to be non-informative with wide bounds (Table 13). The exceptions to this were the priors and penalties on the mature biomass catchability coefficient and on relative year class strengths. The prior assumed for the relative year class strengths was lognormal, with mean 1.0 and CV 1.3.

Before the 2016 assessment, the log-normal prior for the wide-area acoustic survey catchability coefficient was revised following the adoption of a new target-strength and length relationship for SBW (O'Driscoll et al 2013). The revised prior had a mean of 0.54 and CV of 0.44. The old prior had a mean of 0.87 and a CV of 0.30.

Natural mortality was parameterised by the average of male and female, with the difference estimated with an associated normal prior with mean zero and standard deviation 0.05. Penalty functions were used to constrain the model so that any combinations of parameters that did not allow the historical catch to be taken were strongly penalised. A small penalty was applied to encourage the estimates of year class strengths to average to 1.

Table 13: The distributions, priors, and bounds assumed for the various parameters being estimated for the Campbell Rise stock assessment.

Parameter	N	Distribution	Values Mean	CV	Bounds Lower	Upper
B_0	1	Uniform-log	–	–	30 000	800 000
Male maturity	4	Uniform	–	–	0.001	0.999
Female maturity	4	Uniform	–	–	0.001	0.999
Year class strength	56	Lognormal	1.0	1.3	0.001	100
Wide-area catchability mature q	1	Lognormal	0.54	0.44	0.1	1.5
Wide-area catchability immature q	1	Uniform	–	–	0.01	1.5
*Natural mortality (average)	1	Lognormal	0.2	0.2	0.075	0.325
*Natural mortality (difference)	1	Normal	0.0	0.05	-0.05	0.05

*Natural mortality was estimated for a sensitivity run

Model runs

The Working Group considered a base case and 4 sensitivities (Table 14). The base case assumed a fixed natural mortality of 0.2 and an equilibrium age distribution in 1960. The sensitivities included an update of the 2015–16 base case model (with non-equilibrium age estimated in the model start year of 1979) and models with alternative assumptions of natural mortality (M), including estimating M. Model outputs were relatively insensitive to alternative catch histories for the period 1971–1977.

Lognormal errors, with known CVs, were assumed for the relative biomass indices, and multinomial errors were assumed for the proportions-at-age data. However, the error terms allowed for sampling error only and additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance. This additional variance, termed process error, was estimated in the initial MPD runs using all the available data and fixed at these values for the MCMCs. Process errors were estimated separately for the proportion-at-age data using the method of Francis (2011) and for the acoustic estimates from the wide-area surveys (but was estimated to be nil for mature biomass at MPD).

Table 14: MCMC model runs, labels, and descriptions.

Model type	Model label	Description
Base case	Base	Model with equilibrium age distribution for the year 1960, YCSs estimated for years 1958–2013, catch history for years 1971–2019, natural mortality equal to 0.20.
Sensitivity	Mfree	Model Bass, but with natural mortality estimated.
Sensitivity	Tvary	Model Base, but with time varying adjustment to maturity from 1990 to 2019.

Results

The estimated MCMC marginal posterior distributions for spawning stock biomass trajectories are shown for the base case model run in Figure 2, and the results are summarised in Tables 15 and 16. The run suggests that the stock biomass increased above B_0 in the mid-1970s, due to strong year classes in the mid-1960s. This was followed by 20 years of below average recruitment which led to a steep decline in stock biomass. There was a large increase from 1994 to 1996 in response to the very strong 1991 year class. The population then declined until stronger 2006, 2009, and 2011 year classes recruited to the fishery. From 2012 to 2016 (last estimated YCS), recruitment has fluctuated about the average. Exploitation rates and relative year class strengths are shown in Figure 3. Estimates of the adult acoustic q and M are given in Table 16.
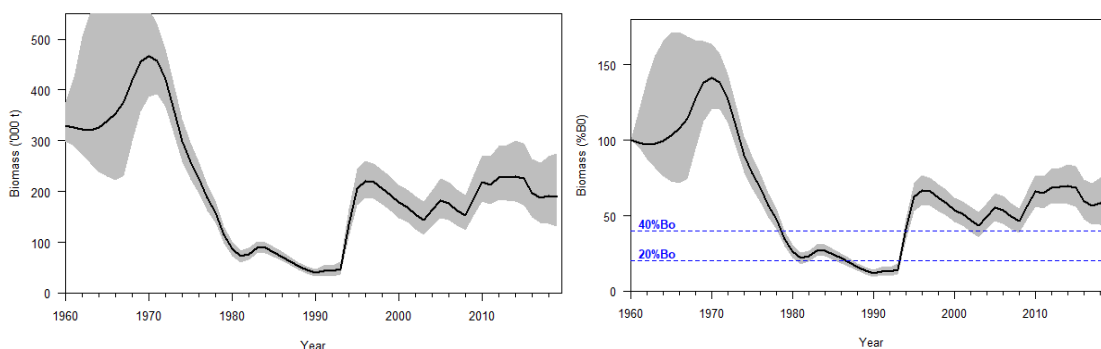
Figure 2: MCMC posterior plots of the trajectories of biomass (left) and current stock status (% B_{2013}/B_0) (right) for the Campbell Rise stock for the base case model. The shaded regions are the 95% credible intervals.

Table 15: Bayesian median and 95% credible intervals of equilibrium (B_0) and current biomass (% B_0) for the base and sensitivities.

Model	B_0 (`000 t)	B_{2019} (% B_0)
Base	329 (299–372)	58 (42–76)
Mfree	321 (294–360)	51 (35–71)
Tvary	331 (300–373)	54 (40–72)

Table 16: Bayesian median and 95% credible intervals of the catchability coefficients (q) and natural mortality parameters for the wide-area acoustic biomass indices for the base case model run and the sensitivity cases.

	Catchability		Natural mortality	
Model	Immature	Mature	Male	Female
Base	0.26 (0.22–0.32)	0.40 (0.33–0.48)	–	–
Mfree	0.35 (0.24–0.49)	0.49 (0.35–0.62)	0.164 (0.126–0.208)	0.170 (0.135–0.213)
Tvary	0.26 (0.21–0.31)	0.42 (0.35–0.50)	–	–
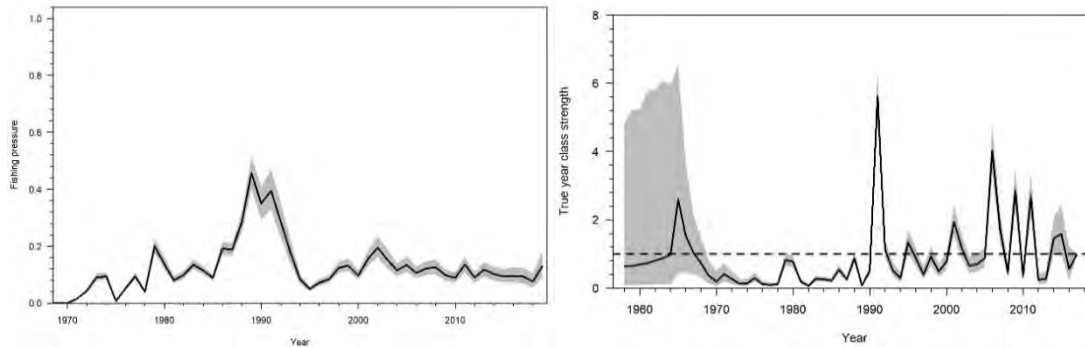
Figure 3: Estimated posterior distributions of exploitation rates (left) and relative year class strength (right) for the Campbell Rise stock for the base case model.

Projections were made assuming fixed catch levels of 21 059 t (average of catches in 2015–16 to 2019–20) and 39 200 t (TACC) for the years 2021 to 2025. Projections were made using the MCMC samples, with recruitments drawn randomly from the distribution of year class strengths for the period 1958–2016 estimated by the model and applied from year 2017 onwards. An alternative recruitment distribution used estimated YCS from 2007 to 2016 (last 10 years). For projections, the mean sizes-at-age were assumed to be equal to the average sizes-at-age from 2015 to 2019 (five year average). This gave four scenarios.

For each scenario, the probability that the mid-season biomass for the specified year will be less than the soft limit (20% B_0) is given in Table 17. The probability of dropping below the soft limit at annual catch levels of 21 059 t is between 2 and 7% depending on recruitment distribution. Under both recruitment conditions the biomass is expected to decline over the next 5 years but remain above the soft limit. However, if catches are at 39 200 t (TACC), then there is a 24 to 48% chance that the biomass is below the soft limit depending on recruitment conditions.

Table 17: Probability that the projected mid-season vulnerable biomass for 2020–2025 will be greater or equal to 40% B_0, less than 20% B_0, less than 10% B_0, and the median projected biomass (% B_0), at a projected catch of 21 059 t or 39 200 t, for the base case model assuming average recruitment over the period 1958–2016 for 2017+, and assuming recruitment from 2007–2016.

						Fishing year
	2019–20	**2020–21**	**2021–22**	**2022–23**	**2023–24**	**2024–25**
Catch 39 200 t + YCS 1958– 2016						
Median *SSB* (% *Bo*)	55	49	40	33	26	20
%[*SSB* >= 40% *Bo*]	95	78	51	35	26	22
%[*SSB* < 20% Bo]	0	0	3	18	37	49
%[*SSB* < 10% *Bo*]	0	0	0	3	13	29
Catch 39 200 t + YCS 2007– 2016						
Median *SSB* (% *Bo*)	57	54	48	43	38	35
%[*SSB* >= 40% *Bo*]	96	85	70	57	47	40
%[*SSB* < 20% Bo]	0	0	2	8	16	24
%[*SSB* < 10% *Bo*]	0	0	0	2	5	10
Catch 21 059 t + YCS 1958– 2016						
Median *SSB* (% *Bo*)	55	51	48	45	43	41
%[*SSB* >= 40% *Bo*]	95	85	73	62	56	52
%[*SSB* < 20% Bo]	0	0	0	1	4	7
%[*SSB* < 10% *Bo*]	0	0	0	0	0	1
Catch 21 059 t + YCS 2007– 2016						
Median *SSB* (% *Bo*)	57	57	56	55	55	55
%[*SSB* >= 40% *Bo*]	96	90	85	82	80	78
%[*SSB* < 20% Bo]	0	0	0	1	2	2
%[*SSB* < 10% *Bo*]	0	0	0	0	0	0

(ii) Bounty Plateau stock

A stock assessment for the Bounty Plateau stock was completed for 2014 (Dunn et al 2015). Preliminary model runs did not provide a satisfactory fit to both the high local area aggregation acoustic biomass estimates observed in 2007–2008 and the lower local area aggregation biomass estimates observed since 2009. Development of the assessment then focused on evaluating models with different assumptions that allowed a comparison of the extent to which the high biomass and subsequent decline were fitted. However, these have not proven successful, and the stock assessment was rejected by the Working Group and a harvest control rule was developed.

Development of a harvest control rule (HCR)

An HCR that would lead to a low risk of the stock falling below the soft limit reference point was developed and used the most recent acoustic index of abundance as an absolute measure of abundance. In the HCR, risk was defined as the probability of the SSB being below 20% SSB_0 (the soft limit). The HCR is given by TACC $t+1 = $ HCR-p $(B_t – C_t/2)$, where B_t is acoustic abundance, C_t is catch, and HCR-p is a fixed proportion in year t.

Results of simulations for different levels of harvest (HCR-p) and assumptions of natural mortality are given in Table 18 (Doonan 2017).

For 2017, the currently accepted HCR for SBW 6B, Bounty Plateau, was applied using the abundance estimate from the industry acoustic survey completed in the 2017 fishing season (O'Driscoll 2018). The HCR depends on the values of natural mortality and steepness and these were specified by Fisheries New Zealand to be 0.2 y^{-1} and 0.9, respectively. The HCR gave a yield for the 2018 fishing season of 3209 t (Doonan 2018). This yield assumes that there will not be a very large cohort entering the mature population. No further work was conducted to develop or explore assumptions underlying the current HCR, e.g., what procedures should be undertaken to detect and respond to another very large recruitment event (which is excluded from the current HCR), or, whether the HCR is more robust if it is based on the end-of-year biomass rather than that at the start of the fishing season.

Table 18: Case-2: Risk for a combination of M and HCR-p values with steepness set to 0.90 and survey process CV at 0% (probability of SSB_0 being below 0.20 B_0 over a 120-year projection). Risk is the probability of SSB_0 being below 0.2 B_0 over a 120-year projection. Mean over 2 runs. Standard simulation error was about 0.0025. Acceptable risks are below the thick black border.

			HCR-p		
M	0.1	0.15	0.2	0.25	0.3
0.1	0.037	0.151	0.305	0.460	0.589
0.15	0.010	0.053	0.131	0.229	0.332
0.2	0.003	0.021	0.058	0.113	0.180
0.25	0.002	0.012	0.035	0.070	0.117
0.3	0.001	0.007	0.020	0.042	0.071

The HCR has not been updated since 2018 because acoustic indices were not available from the 2018, 2019, or 2020 acoustic surveys.

(ii) Pukaki Rise stock

An assessment of the Pukaki Rise stock was carried out in 2002. The age structured separable Sequential Population Analysis (sSPA) model was used to estimate the numbers-at-age in the initial population in 1989 and subsequent recruitment. The model estimates selectivity for ages 2, 3, and 4 and assumes that the selectivity after age 4 is 1.0. No stock-recruitment relationship is assumed in the sSPA.

Table 19: RV *Tangaroa* age 2, 3, and 4+ acoustic biomass estimates (t) for the Pukaki Rise used in the 2002 assessment. Estimates differ from those in Table 10 because they were calculated with old estimates of target strength and sound absorption.

Year	Age 1	Age 2	Age 3	Age 4+
1993	578	26 848	9 315	31 152
1994	13	1 193	6 364	35 969
1995	0	102	775	11 743
1997	22	2 838	864	34 086
2000	58	7 268	5 577	24 931

Table 20: Values for the input parameters to the separable Sequential Population Analysis for the initial run and sensitivity runs for the Pukaki Rise stock.

Parameter	Initial run	Sensitivity runs
M	0.2	0.15, 0.25
Acoustic age 3 and 4+ indices CV	0.3	0.1, 0.5
Acoustic age 1, 2 indices CV	0.7	0.5, 1.0
Weighting on proportion-at-age data	50	5, 100
Years used in analysis	1989–2000	1979–2000
Acoustic q	estimated	0.68, 1.4, 2.8

Preliminary runs of the model were fitted to proportion-at-age data from 1989 to 2000 and the acoustic indices given in Table 19, which differ from those in Table 10 because they were calculated with an older estimate of target strength and sound absorption. The indices were fitted in the model as relative estimates of mid-season biomass (i.e., after half the catch has been removed), with the CVs as shown in Table 20. The proportion-at-age data are assumed to be multinomially distributed with a median sample size of 50 (equivalent to a CV of about 0.3). Details of the input parameters for the initial and sensitivity runs are given in Table 20.

Biomass estimates in the initial run, and in the sensitivity runs, all appeared to be over-pessimistic because the adult (4+) acoustic q was very high. For example, for the initial run the 4+ acoustic q was estimated to be 2.7. The Working Group did not accept this initial run as a base case assessment but agreed to present a range of possible biomass estimates. The Plenary agreed to present a range, based on assumptions concerning the likely range of the value for the acoustic q.

Bounds for the adult (4+) acoustic q were obtained using the approach of Cordue (1996). Uncertainty over various factors including mean target strength, acoustic system calibration, target identification, shadow or dead zone correction, and areal availability were all taken into account. In addition to obtaining the bounds, a 'best estimate' for each factor was also calculated. The factors were then multiplied together. This independent evaluation of the bounds on the acoustic q suggested a range of 0.65–2.8, with a best estimate of 1.4. Clearly the q from the initial run is almost at the upper bound and probably outside the credible range. When the model was run fixing the acoustic q at 0.65 and 2.8, estimates of B_0 were 18 000 t and 54 000 t, and estimates of B_{2000} were 8000 t and 48 000 t, respectively (Table 21, Figure 4). Within these bounds current biomass is greater than B_{MAY}. Assuming the 'best estimate' of q of 1.4 gave B_0 equal to 22 000 t and B_{2000} equal to 13 000 t.

Based on the range of stock biomass modelled in the assessment, the average catch level since 2002 (380 t) is unlikely to have made much impact on stock size. A more intensive fishery or more consistent catches from year to year would seem to be required to provide any contrast in the biomass indices. This stock has been only lightly exploited since 1993, when over 5000 t was taken in the spawning season.

An assessment was planned for the Pukaki Rise stock in 2014 but the Working Group did not accept that the 2012 acoustic survey provided an acceptably realistic biomass estimate for the stock, so an assessment was not possible.

Table 21: Parameter estimates for the Pukaki stock as a result of fixing the adult 4+ acoustic q at various values. B_{mid}, mid-season spawning stock biomass; $N_{2,1992}$ size of the 1990 year class (millions). All values in t x 10^3.

Fixing the acoustic q value	B_0	$B_{mid\ 89}$	$B_{mid\ 00}$	$N_{2,1992}$	$B_{mid\ 00}$ (%B_0)	$B_{mid\ 00}$ (%B_{may})
$q = 0.65$	54	36	48	63	88	246
$q = 1.4$	22	22	13	28	58	161
$q = 2.8$	18	19	8	23	44	123
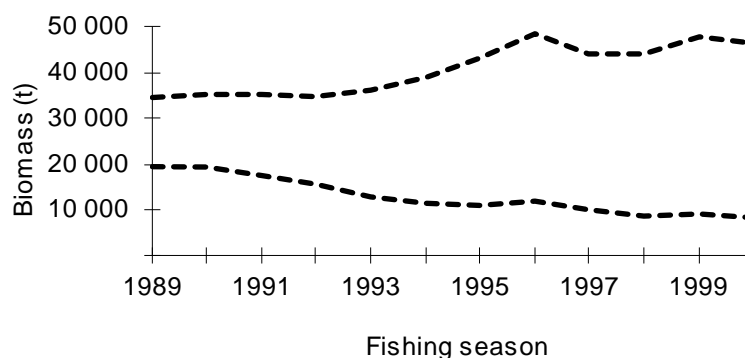
Figure 4: Mid-season spawning stock biomass trajectory bounds for the Pukaki Rise stock. Bounds based on acoustic *q* of 0.65 and 2.8.

(iv) Auckland Islands Shelf stock

No estimate of current biomass is available for the Auckland Islands Shelf stock. The acoustic estimate of the adult biomass in 1995 was 7800 t.

5. FUTURE RESEARCH CONSIDERATIONS

- For Campbell Rise southern blue whiting, a candidate for further research or investigation would be to determine how to best represent mean weights-at-age in the projections given the negative relationship between year class strength and growth.
- For the Pukaki Rise, the Sub-Antarctic trawl surveys may provide an index of abundance for this stock, but this has yet to be determined.
- Revise biological parameters.
- Review stock monitoring and management options for the Bounty Plateau.

6. STATUS OF THE STOCKS

Stock Structure Assumptions

Southern blue whiting are assessed as four independent biological stocks, based on the presence of four main spawning areas and some differences in biological parameters and morphometrics between these areas (Hanchet 1999).

The four main stocks SBW 6A (Auckland Islands Shelf), SBW 6B (Bounty Plateau), SBW 6I (Campbell Rise), and SBW 6R (Pukaki Rise) cover the four main bathymetric features in the Sub-Antarctic QMA6. SBW 1 is a nominal stock covering the rest of the New Zealand EEZ where small numbers of fish may occasionally be taken as bycatch.

- **Auckland Islands Shelf (SBW 6A)**

Stock Status	
Year of Most Recent Assessment	-
Assessment Runs Presented	-
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends

Recent Trend in Biomass or Proxy	Catches have fluctuated without trend
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	No reliable indices of abundance
Trends in Other Relevant Indicators or Variables	Catch in 2007 and 2008 was dominated by large (40–50 cm long) fish - no sign of recent strong year classes.

Projections and Prognosis

Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	-

Assessment Methodology

Assessment Type	Level 4: Low information	
Assessment Method	None	
Assessment Dates	-	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs	- Catch history - erratic catches with no trend Limited catch-at-age data (1993–1998) and 2008	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- No reliable time series of data available. - Catches have been erratic for the past 10 years and have been taken as bycatch in other middle depth fisheries so unlikely to provide reliable CPUE indices.	

Qualifying Comments

There were several years of high catches (700–1100 t) during the mid-1990s but since then annual catches have averaged about 100 t. Good recruitment in southern blue whiting tends to be episodic and it is likely that the period of high catches was due to the presence of the strong year 1991 year class. Catches will probably remain low until another strong year class enters the fishery.

Fishery Interactions

Fish bycatch is low in the SBW target fishery. There are some interactions with New Zealand sea lions and seabirds.

- **Bounty Plateau (SBW 6B)**

Stock Status

Year of Most Recent Assessment	2018
Assessment Runs Presented	Harvest control rule simulations
Reference Points	Management Target: A fishing mortality rate calculated from the harvest control rule Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: A fishing mortality rate calculated from the harvest control rule
Status in relation to Target	Likely (> 60%) to be below the target F

Status in relation to Limits	Unknown
Status in relation to Overfishing	Overfishing is Unlikely ($< 40\%$) to be occurring

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends

Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Intensity or Proxy	Fishing mortality is likely to have fluctuated around the target F in recent years.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Recruitment was estimated to be low from 1995 to 2001 but was extremely high in 2002 and has been low since then. The 2007 year class appears to be above average.

Projections and Prognosis

Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation

Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Harvest Control Rule based on simulations of an age structured model	
Assessment Dates	Latest assessment: 2018	Next assessment: 2022
Overall assessment quality rank	2 – Medium Quality	
Main data inputs (rank)	- Wide-area acoustic abundance indices - Acoustic abundance indices from local area aggregation surveys - Proportions-at-age data from the commercial fisheries and trawl surveys - Estimates of biological parameters - Estimates of acoustic target strength	1 – High Quality 2 – Medium Quality (uncertainty in the proportion of the spawning aggregation covered by the surveys) 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	- Commercial CPUE	3 – Low Quality: does not track stock biomass
Changes to Model Structure and Assumptions	- Previous (2014) assessment rejected and replaced with a harvest control rule	
Major Sources of Uncertainty	- The proportion of the spawning biomass that is indexed by the local area aggregation survey in each year is variable and uncertain. - Estimates of fishing mortality assume the catchability coefficient of the acoustic biomass estimates is known.	

Qualifying Comments

Three surveys from 2014 to 2016 showed a progressive decline in stock biomass to low levels but a slight increase in 2017. Acoustic surveys in 2018, 2019, and 2020 were unsuccessful and did not produce indices of abundance.

Fishery Interactions
There is relatively low non-target catch in this fishery. Protected species interactions have been recorded for New Zealand fur seals and seabirds. Southern blue whiting is caught using midwater trawl gear, which sometimes interact with benthic habitats.

Campbell Rise (SBW 6I)

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Base case stock assessment model
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	B_{2020} was estimated at 56% B_0 and is Very Likely ($>90\%$) to be at or above the target
Status in relation to Limits	B_{2020} is Exceptionally Unlikely ($<1\%$) to be below soft or hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely ($<10\%$) to be occurring
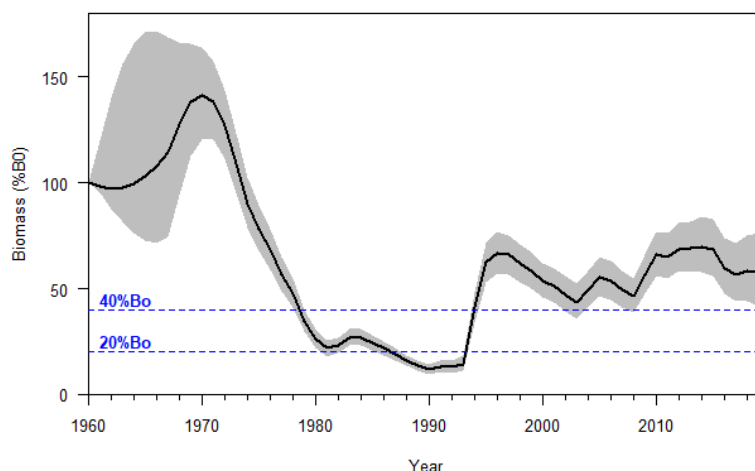
Historical Stock Status Trajectory and Current Status
 Trajectory over time of spawning biomass (%B_0) for the Campbell Rise southern blue whiting stock from the start of the assessment period in 1960 to 2019. The blue horizontal lines show the management target (40% B_0) and the soft limit (20% B_0). Biomass estimates are based on Base case MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	With strong recent recruitment the biomass has increased well above the management target.
Recent Trend in Fishing Intensity or Proxy	Fishing pressure has declined with the increase in stock size.

Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	The 2006, 2009, and 2011 year classes appear to be very strong, but not as strong as the 1991 year class.

Projections and Prognosis	
Stock Projections or Prognosis	The biomass of the Campbell Rise stock would be expected to decrease over the next 1–5 years if catches are at the TACC (39 200 t). At current catches (21 059 t), the biomass will remain above the target (40% B_0) until 2022–23 or 2023–24 depending on recruitment.

Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits	At the current catch: Soft Limit: Exceptionally Unlikely ($< 1\%$) over next 3 years Hard Limit: Exceptionally Unlikely ($< 1\%$) over next 4–5 years At the TACC: Soft Limit: Exceptionally Unlikely ($< 1\%$) over next 2 years Hard Limit: Exceptionally Unlikely ($< 1\%$) over next 3 years
Probability of Current Catch or TACC causing Overfishing to continue or commence	At the current catch: Very Unlikely ($< 10\%$) At the TACC: As likely as not (40-60%)

Assessment Methodology		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2020	Next assessment: 2023
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Research time series based on acoustic indices	1 – High Quality
	- Proportions-at-age data from the commercial fisheries and trawl surveys	1 – High Quality
	- Estimates of biological parameters	1 – High Quality
Data not used (rank)	- Commercial CPUE	3 – Low Quality: does not track stock biomass
Changes to Model Structure and Assumptions	- None	
Major Sources of Uncertainty	- Uncertainty about the size of future age classes affects the reliability of stock projections - Future mean weight at age in the projections	

Qualifying Comments
Recent catches have been consistently less than the TACC and there are no indications that the fishery is likely to change in the next few years.

Fishery Interactions
There is relatively low non-target catch in this fishery. Protected species interactions have been recorded for New Zealand sea lions, New Zealand fur seals, and seabirds. Southern blue whiting is caught using midwater trawl gear, which sometimes interacts with benthic habitats.

- **Pukaki Rise (SBW 6R)**

Stock Status	
Year of Most Recent Assessment	2002
Assessment Runs Presented	The results of three runs were presented assuming different values for the adult acoustic q.
Reference Points	Interim Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Current status unknown. Believed to be only lightly exploited between 1993 and 2002
Status in relation to Limits	Current status unknown. Believed to be only lightly exploited between 1993 and 2002
Status in relation to Overfishing	-

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Catches over the last 10 years have fluctuated without trend.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	No current reliable indices of abundance (wide-area surveys were discontinued in 2000)
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2002)	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	-

Assessment Methodology		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age structured separable Sequential Population Analysis (sSPA) with maximum likelihood estimation	
Assessment Dates	Last assessment: 2002	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	- Abundance indices from wide-area acoustic surveys - Catch-at-age data	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	The adult acoustic q was estimated in the model to be 2.7 which the Working Group thought was unrealistically high. A run based on a more plausible value for q suggested the 2000 biomass was above 50% B_0.	

Qualifying Comments
The Sub-Antarctic trawl surveys may provide an index of abundance for this stock, but this has yet to be determined.

Fishery Interactions
There is relatively low non-target catch in this fishery. Protected species interactions and interactions with benthic habitats are negligible.

7.   FOR FURTHER INFORMATION

Abraham, E R; Richard, Y; Berkenbusch, K; Thompson, F (2016) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 2002–03 to 2012–13. *New Zealand Aquatic Environment and Biodiversity Report* No. 169. 205 p.

Abraham, E R; Richard, Y (2017) Summary of the capture of seabirds in New Zealand commercial fisheries, 2002–03 to 2013–14. *New Zealand Aquatic Environment and Biodiversity Report* No. 184. 88 p.

Abraham, E R; Richard, Y (2018) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2014–15. *New Zealand Aquatic Environment and Biodiversity Report* No. 197. 97 p.

Abraham, E.R.; Richard, Y. (2020). Estimated capture of seabirds in New Zealand trawl and longline fisheries, to 2017–18. *New Zealand Aquatic Environment and Biodiversity Report* No. 249. 86 p

Abraham, E R; Thompson, F N (2011) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report No. 80*. 172 p.

SOUTHERN BLUE WHITING (SBW)

Abraham, E R; Tremblay-Boyer, L. Birkenbusch, K. (2021) Estimated captures of New Zealand fur seal, common dolphin, and turtles in New Zealand commercial fisheries, to 2017–18. *New Zealand Aquatic Environment and Biodiversity Report No. 258*. 94 p.

Anderson, O F (2004) Fish discards and non-target fish catch in the fisheries for southern blue whiting and oreos. *New Zealand Fisheries Assessment Report 2004/9*. 40 p.

Anderson, O F (2009) Fish and Invertebrate Bycatch and Discards in Southern Blue Whiting Fisheries, 2002–07. *New Zealand Aquatic Environment and Biodiversity Report No. 43*. 42 p.

Baird, S J (2004a) Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1999–2000. *New Zealand Fisheries Assessment Report 2004/41*. 56 p.

Baird, S J (2004b) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2000–01. *New Zealand Fisheries Assessment Report 2004/58*. 63 p.

Baird, S J (2004c) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2001–02. *New Zealand Fisheries Assessment Report 2004/60*. 51 p.

Baird, S J (2005) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002–03. *New Zealand Fisheries Assessment Report 2005/2*. 50 p.

Baird, S J; Mules, R (2019) Extent of bottom contact by New Zealand commercial trawl fishing for deepwater Tier 1 and Tier 2 target species determined using CatchMapper software, fishing years 2008–17. *New Zealand Aquatic Environment and Biodiversity Report No. 229*. 106 p.

Baird, S J; Mules, R (2021a) Extent of bottom contact by commercial fishing activity in New Zealand waters, for 1989–90 to 2017–18**.** *New Zealand Aquatic Environment and Biodiversity Report No. 259*. 143 p.

Baird, S J; Mules, R (2021b) Extent of bottom contact by commercial trawling and dredging in New Zealand waters, 1989–90 to 2018–19. *New Zealand Aquatic Environment and Biodiversity Report No. 260*. 157 p.

Baird, S J; Smith, M H (2007) Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2003–04 to 2004–05. *New Zealand Aquatic Environment and Biodiversity Report No. 14*. 98 p.

Baird, S J; Wood, B A (2012) Extent of coverage of 15 environmental classes within the New Zealand EEZ by commercial trawling with seafloor contact. *New Zealand Aquatic Environment and Biodiversity Report No. 89*. 43 p.

Baird, S J; Wood, B A (2018) Extent of bottom contact by New Zealand commercial trawl fishing for deepwater Tier 1 and Tier 2 target fishstocks, 1989–90 to 2015–16. *New Zealand Aquatic Environment and Biodiversity Report No. 193*. 102 p.

Baird, S J; Wood, B A; Bagley, N. W. (2011) Nature and extent of commercial fishing effort on or near the seafloor within the New Zealand 200 n. mile Exclusive Economic Zone, 1989–90 to 2004–05. *New Zealand Aquatic Environment and Biodiversity Report No. 73*. 143 p.

Baker, C S; Chilvers, B L; Childerhouse, S; Constantine, R; Currey, R; Mattlin, R; van Helden, A; Hitchmough, R; Rolfe, J (2016) Conservation status of New Zealand marine mammals, 2013. *New Zealand Threat Classification Series 14*. Department of Conservation, Wellington. 18 p.

Baker, C S; Boren, L; Childerhouse, S; Constantine, R; van Helden, A; Lundquist, D.; Rayment, W; Rolfe, J R (2019) Conservation status of New Zealand marine mammals, 2019. *New Zealand Threat Classification Series 29*. Department of Conservation, Wellington. 18 p.

Black, J; Tilney, R (2015) Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989–1990 to 2010–2011. *New Zealand Aquatic Environment and Biodiversity Report No. 142*. 56 p.

Black, J; Tilney, R (2017) Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989/90 to 2011/12 and 1989/90 to 2012/13. *New Zealand Aquatic Environment and Biodiversity Report No. 176*. 65 p.

Black, J; Wood, R; Berthelsen, T; Tilney, R (2013) Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989–1990 to 2009–2010. *New Zealand Aquatic Environment and Biodiversity Report No. 110*. 57 p.

Brothers, N; Duckworth, A R; Safina, C; Gilman, E L (2010) Seabird bycatch in pelagic longline fisheries is grossly underestimated when using only haul data. *PLoS One 5(8)*: e12491.

Bull, B; Dunn, A (2002) Catch-at-age: User manual v1.06.2002/09/12. *NIWA Internal Report 114*. 23 p.

Bull, B; Francis, R I C C; Dunn, A; Gilbert, D J; Bian, R; Fu, D (2012) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.30.2012/03/21. *NIWA Technical Report 135*. 280 p.

Cherel, Y; Waugh, S; Hanchet, S (1999) Albatross predation of juvenile southern blue whiting (*Micromesistius australis*) on the Campbell Plateau. *New Zealand Journal of Marine and Freshwater Research Vol. 33*: 437–441.

Childerhouse, S; Burns, T; French, R; Michael, S; Muller, C (2017). Report for CSP Project New Zealand sea lion monitoring at the Auckland Islands 2016/17. (Unpublished BPM-17-FINAL-Report for CSP Project NZSL Auckland Island monitoring 2016-17 v1.1 available at https://www.doc.govt.nz.) 24 p.

Clark, M R; Anderson, O F; Gilbert, D J (2000) Discards in trawl fisheries for southern blue whiting, orange roughy, hoki, and oreos in New Zealand waters. *NIWA Technical Report 71*. 73 p.

Cole, R; Stevenson, M G; Hanchet, S; Gorman, R M; Rickard, G J; Morrisey, D; Handley, S (2007) Information on benthic impacts in support of the Southern Blue Whiting Fishery Plan. National Institute of Water and Atmospheric Research. (Unpublished Final Research Report for Ministry of Fisheries Research Project ZBD2005-16 Objectives 1-6 held by Fisheries New Zealand, Wellington.) 33 p.

Cordue, P L (1996) A model-based method for bounding virgin biomass using a catch history, relative biomass indices, and ancillary information. New Zealand Fisheries Assessment Research Document 1996/8. 48 p. (Unpublished report held by NIWA library, Wellington.)

Department of Internal Affairs (2006) Seabird Scaring Devices – Circular Issued Under Authority of the Fisheries (Commercial Fishing) Amendment Regulations 2006 (No. F361). *New Zealand Gazette 6 April 2006*: 842–846.

Doonan, I J (2017) Evaluation of a simple harvest control rule for the Bounty southern blue whiting management area (SBW6B*). New Zealand Fisheries Assessment Report 2017/52*. 14 p.

Doonan, I J (2018) Objective 2: To apply the agreed harvest control rule to SBW6B, 2018. (Unpublished Final Research Report held by Fisheries New Zealand, Wellington.) 2 p.

Doonan, I J (2020) Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for data up to 2018–19. *New Zealand Fisheries Assessment Report 2020/43*. 20 p.

Duffy, C; Francis, M; Dunn, M; Finucci, B; Ford, R; Hitchmough, R; Rolfe, J (2018) Conservation status of New Zealand chondrichthyans (chimaeras, sharks and rays), 2016. *New Zealand Threat Classification Series 23*. Department of Conservation, Wellington. 13 p.

Dunford, A (2003) Review and revision of southern blue whiting (*Micromesistius australis*) target strength. (Unpublished Final Research Report for Ministry of Fisheries Research Project SBW2001/02 Objective 2 held by Fisheries New Zealand, Wellington.) 16 p.

Dunford, A J; Macaulay, G J (2006) Progress in determining southern blue whiting (*Micromesistius australis*) target strength: results of swimbladder modelling. *ICES Journal of Marine Science 63*: 952–955.

Dunn, A; Grimes, P J; Hanchet, S M (2001) Comparative evaluation of two-phase and adaptive cluster sampling designs for acoustic surveys of southern blue whiting (*M. australis*) on the Campbell Rise. Final Research Report for Ministry of Fisheries Research Project SBW1999/01. Objective 1. 15 p. (Unpublished report held by FNZ, Wellington.)

Dunn, A; Hanchet, S M (2011) Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform for 2009–10. *New Zealand Fisheries Assessment Report 2011/26*. 30 p.

Dunn, A; Hanchet, S M (2015) Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2013 with revised target strength acoustic biomass estimates. *New Zealand Fisheries Assessment Report 2015/80*. 23 p.

Dunn, A; Hanchet, S M (2017) Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2016. *New Zealand Fisheries Assessment Report 2017/38*. 20 p.

Dunn, A; Hanchet, S M; Dunford, A. (2015). Southern blue whiting (Micromesistius australis) stock assessment for the Bounty Platform up to and including the 2014 season. Final Research Report for Ministry of Fisheries Research Project DEE201002SBWD. 20 p. (Unpublished report held by FNZ, Wellington.)

Finucci, B; Edwards, C T T; Anderson, O F (2019). Fish and invertebrate bycatch in New Zealand deepwater fisheries from 1990–91 until 2016–17. *New Zealand Aquatic Environment and Biodiversity Report No. 210*. 77 p.

Fisheries New Zealand (2020) Fisheries Assessment Plenary, May 2020: stock assessments and stock status. Compiled by the Fisheries Science and Information Group, Fisheries New Zealand, Wellington, New Zealand. 1746 p.

Fisheries New Zealand (2021) Aquatic Environment and Biodiversity Annual Review 2021. Compiled by the Aquatic Environment Team, Fisheries Science and Information, Fisheries New Zealand, Wellington, New Zealand. 779 p.

Francis, R I C C (1992) Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 27 p. (Unpublished document held at NIWA library, Wellington.)

Francis, R I C C (2011) Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences 68*: 1124–1138.

Francis, M P; Hurst, R J; McArdle, B H; Bagley, N W; Anderson, O F (2002) New Zealand demersal fish assemblages. *Environmental Biology of Fishes 65(2)*: 215–234.

Froese, R; Pauly, D (Eds.) (2000) FishBase 2000: concepts, design and data sources. *ICLARM Contribution No.1594*. International Center for Living Aquatic Resources Management (ICLARM). Los Banos, Laguna, Philippines. 344 p.

Fu, D; Hanchet, S; O'Driscoll, R L (2013) Estimates of biomass and c.v.s of southern blue whiting from previous acoustic surveys from 1993 to 2012 using a new target strength – fish length relationship. (Unpublished Final Research Report for Ministry of Fisheries Research Project DEE201002SBWB held by Fisheries New Zealand, Wellington.) 52 p.

Gauthier, S; Fu, D; O'Driscoll, R L; Dunford, A (2011) Acoustic estimates of southern blue whiting from the Campbell Island Rise, August–September 2009. *New Zealand Fisheries Assessment Report 2011/09*. 40 p.

Grimes, P; Fu, D; Hanchet, S M (2007) Estimates of biomass and CVs of decomposed age classes of southern blue whiting from previous acoustic surveys from 1993 to 2004 using a new target strength - fish length relationship. (Unpublished Final Research Report for Ministry of Fisheries Research Project SBW2005-01 held by Fisheries New Zealand, Wellington.) 34 p.

Hanchet, S M (1991) Southern blue whiting fishery assessment for the 1991–92 fishing year. New Zealand Fisheries Assessment Research Document 1991/7. 48 p. (Unpublished document held by NIWA library, Wellington.)

Hanchet, S M (1999) Stock structure of southern blue whiting (*Micromesistius australis*) in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research 33(4)*: 599–610.

Hanchet, S M (2002) Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform for 2002 and 2003. *New Zealand Fisheries Assessment Report 2002/53*. 23 p.

Hanchet, S M (2005a) Southern blue whiting (*Micromesistius australis*) stock assessment update for the Campbell Island Rise for 2005. *New Zealand Fisheries Assessment Report 2005/40*. 40 p.

Hanchet, S M (2005b) Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform for 2004–05. *New Zealand Fisheries Assessment Report 2005/45*. 36 p.

Hanchet, S M; Blackwell, R G (2005) Development and evaluation of catch-per-unit-effort indices for southern blue whiting (*Micromesistius australis*) on the Campbell Island Rise (1986–2002) and the Bounty Platform (1990–2002). *New Zealand Fisheries Assessment Report 2005/55*. 60 p.

Hanchet, S M; Blackwell, R G; Dunn, A (2005) Development and evaluation of catch-per-unit-effort indices for southern blue whiting (*Micromesistius australis*) on the Campbell Island Rise New Zealand. *ICES Journal of Marine Sciences 62*: 1131–1138.

Hanchet, S M; Blackwell, R G; Stevenson, M L (2006) Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2006. *New Zealand Fisheries Assessment Report 2006/41*. 45 p.

Hanchet, S M; Dunn, A (2010) Review and summary of the time series of input data available for the assessment of southern blue whiting (*Micromesistius australis*) stocks. *New Zealand Fisheries Assessment Report 2010/32*. 37 p.

Hanchet, S M; Dunn, A; Stevenson, M L (2003a) Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2003. *New Zealand Fisheries Assessment Report 2003/59*. 42 p.

Hanchet, S M; Grimes, P J; Coombs, R F (2002a) Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, August 2001. *New Zealand Fisheries Assessment Report 2002/58*. 35 p.

Hanchet, S M; Grimes, P J; Coombs, R F; Dunford, A (2003b) Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) for the Campbell Island Rise, August–September 2002. *New Zealand Fisheries Assessment Report 2003/44*. 38 p.

Hanchet, S M; Grimes, P J; Dunford, A; Ricnik, A (2002b) Classification of fish marks from southern blue whiting acoustic surveys. (Unpublished Final Research Report for Ministry of Fisheries Research Project SBW2000/02 Objective 2 held by Fisheries New Zealand, Wellington.) 55 p.

Hanchet, S M; Haist, V; Fournier, D (1998) An integrated assessment of southern blue whiting (*Micromesistius australis*) from New Zealand waters using separable Sequential Population Analysis. *In* Funk, F et al (Eds.). Alaska Sea Grant College Program Report No. AK-SG-98-01. University of Alaska, Fairbanks, 1998.

Hanchet, S M; Renwick, J A (1999) Prediction of southern blue whiting (*Micromesistius australis*) year class strength in New Zealand waters. New Zealand Fisheries Assessment Research Document 1999/51. 24 p. (Unpublished document held in NIWA library, Wellington.)

Hermsen, J M; Collie, J S; Valentine, P C (2003) Mobile fishing gear reduces benthic megafaunal production on Georges Bank. *Marine Ecology Progress Series 260*: 97–108.

Hiddink, J G; Jennings, S; Kaiser, M J; Queiros, A M; Duplisea, D E; Piet, G J (2006) Cumulative impacts of seabed trawl disturbance on benthic biomass, production, and species richness in different habitats. *Canadian Journal of Fisheries and Aquatic Sciences 63*:721–36.

Jennings, S; Dinmore, T A; Duplisea, D E; Warr, K J; Lancaster, J E (2001) Trawling disturbance can modify benthic production processes. *Journal of Animal Ecology 70*: 459–475.

Ladroit, Y; O'Driscoll, R L; Large, K (2020) Acoustic estimates of southern blue whiting from the Campbell Island Rise, August-September 2019. *New Zealand Fisheries Assessment Report 2020/26*. 56 p.

Large, K. (2021a) Review and summary of the time series of input data available for the assessment of southern blue whiting (*Micromesistius australis*) stocks up to and including the 2017 season. *New Zealand Fisheries Assessment Report 2021/11*. 41 p.

Large, K (2021b) Review and summary of the time series of input data available for the assessment of southern blue whiting (*Micromesistius australis*) stocks up to and including the 2019 season. *New Zealand Fisheries Assessment Report 2021/14*. 77 p.

Large, K; O'Driscoll, R L; Schimel, A (2021) Review and summary of the time series of input data available for the assessment of southern blue whiting (*Micromesistius australis*) stocks up to and including the 2018 season. *New Zealand Fisheries Assessment Report 2021/13*. 56 p.

Large, K; Hanchet, S M (2017) Review and summary of the time series of input data available for the assessment of southern blue whiting (*Micromesistius australis*) stocks up to and including the 2016 season. *New Zealand Fisheries Assessment Report 2017/35*. 44 p.

SOUTHERN BLUE WHITING (SBW)

Large, K; O'Driscoll, R L; Datta, S (in press). Review and summary of the time series of input data available for the assessment of southern blue whiting (*Micromesistius australis*) stocks up to and including the 2020 season. New Zealand Fisheries Assessment Report.

Leathwick, J R; Rowden, A; Nodder, S; Gorman, R; Bardsley, S; Pinkerton, M; Baird, S J; Hadfield, M; Currie, K; Goh, A (2012) A Benthic-optimised Marine Environment Classification (BOMEC) for New Zealand waters. *New Zealand Aquatic Environment and Biodiversity Report No. 88*. 54 p.

MacKenzie, D; Fletcher, D (2006) Characterisation of seabird captures in commercial trawl and longline fisheries in New Zealand 1997/98 to 2003/04. (Unpublished Final Research Report for Ministry of Fisheries project ENV2004/04 held by Fisheries New Zealand, Wellington.) 102 p.

McClatchie, S; Macaulay, G; Hanchet, S; Coombs, R F (1998) Target strength of southern blue whiting (*Micromesistius australis*) using swimbladder modelling, split beam and deconvolution. *ICES Journal of Marine Science 55*: 482–493.

McClatchie, S; Thorne, R; Grimes, P J; Hanchet, S (2000) Ground truth and target identification for fisheries acoustics. *Fisheries Research 47*: 173–191.

Middleton, D A; Abraham, E R (2007) The efficacy of warp strike mitigation devices: trials in the 2006 squid fishery. (Unpublished Final Research Report for Ministry of Fisheries research project IPA2006/02 held by Fisheries New Zealand, Wellington.)

Monstad, T; Borkin, I; Ermolchev, V (1992) Report of the joint Norwegian-Russian acoustic survey on blue whiting, spring 1992. *ICES C.M. 1992/H:6*, Pelagic Fish Committee. 26 p.

Morgan, M J; DeBlois, E M; Rose, G A (1997) An observation on the reaction of Atlantic cod (*Gadus morhua*) in a spawning shoal to bottom trawling. *Canadian Journal of Fisheries and Aquatic Sciences, 54(S1)*, 217–223.

Morgan, M J; Wilson, C E; Crim, L W (1999) The effect of stress on reproduction in Atlantic cod. *Journal of Fish Biology 54(3)*: 477–488.

MPI (2013) Aquatic Environment and Biodiversity Annual Review 2013. Compiled by the Fisheries Management Science. Ministry for Primary Industries, Wellington, New Zealand. 538 p.

MPI (2015) Aquatic Environment and Biodiversity Annual Review 2015. Compiled by the Fisheries Management Science. Ministry for Primary Industries, Wellington, New Zealand. 682 p.

MPI (2017) Aquatic Environment and Biodiversity Annual Review 2015. Compiled by the Fisheries Management Science. Ministry for Primary Industries, Wellington, New Zealand.

O'Driscoll, R L (2011a) Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2010. NIWA Client Report WLG2011-01 for The Deepwater Group Ltd, January 2011. 28 p. (Unpublished report held by NIWA, Wellington).

O'Driscoll, R L (2011b) Industry acoustic surveys of spawning southern blue whiting on the Bounty Platform and Pukaki Rise 2004–09. *New Zealand Fisheries Assessment Report 2011/17*. 53 p.

O'Driscoll, R L (2012) Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2011. *New Zealand Fisheries Assessment Report 2012/16*. 29 p.

O'Driscoll, R L (2013) Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2012. *New Zealand Fisheries Assessment Report 2013/4*. 26 p.

O'Driscoll, R L (2015) Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2014. *New Zealand Fisheries Assessment Report 2015/02*. 28 p

O'Driscoll, R.L. (2018). Acoustic biomass estimates of southern blue whiting on the Bounty Plateau in 2017. *New Zealand Fisheries Assessment Report 2018/11*. 28 p.

O'Driscoll, R L; Bagley, N W (2003) Trawl survey of middle depth species in the Southland and Sub-Antarctic areas, November–December 2002 (TAN0219). *New Zealand Fisheries Assessment Report 2003/1*, 53 p.

O'Driscoll, R L; Dunford, A J (2017) Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2015. *New Zealand Fisheries Assessment Report 2017/19*. 29 p.

O'Driscoll, R L; Dunford, A J; Ladroit, Y (2014). Acoustic estimates of southern blue whiting from the Campbell Island Rise, August–September 2013 (TAN1309). *New Zealand Fisheries Assessment Report 2014/22*. 46 p.

O'Driscoll, R L; Grimes, P J; Dunford, A (2005) Acoustic estimates of southern blue whiting from the Campbell Island Rise, August–September 2004. *New Zealand Fisheries Assessment Report 2005/41*. 29 p.

O'Driscoll, R L; Hanchet, S M (2004) Acoustic survey of spawning southern blue whiting on the Campbell Island Rise from FV *Aoraki* in September 2003. *New Zealand Fisheries Assessment Report 2004/27*. 31 p.

O'Driscoll, R L; Hanchet, S M; Gauthier, S; Grimes, P J (2007) Acoustic estimates of southern blue whiting from the Campbell Island Rise, August–September 2006. New Zealand Fisheries Assessment Report 2007/20. 34 p.

O'Driscoll, R L; Ladroit, Y (2017) Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2016. *New Zealand Fisheries Assessment Report 2017/20*. 24 p.

O'Driscoll, R L; Large, K; Marriott, P (2018) Acoustic estimates of southern blue whiting from the Campbell Island Rise, August–September 2016. *New Zealand Fisheries Assessment Report 2018/56*. 60 p.

O'Driscoll, R L; Macaulay, G J; Gauthier, S (2006) Biomass estimation of spawning southern blue whiting from industry vessels in 2006. (Unpublished NIWA Client Report WLG2006-xx for the Deepwater Stakeholders' Group held by NIWA, Wellington.) 39 p.

O'Driscoll, R L; Oeffner, J; Dunford, A J (2013) *In situ* target strength estimates of optically verified southern blue whiting (*Micromesistius australis*). *ICES Journal of Marine Science 70*: 431–439.

O'Driscoll, R L; Oeffner, J; Dunford, A J (2015) Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2013. *New Zealand Fisheries Assessment Report 2015/01*. 28 p.

Reiss, H; Greenstreet, S P R; Seibe, K; Ehrich, S; Piet, G J; Quirijns, F; Robinson, L; Wolff, W K; Kronke, I (2009) Effects of fishing disturbance on benthic communities and secondary production within an intensively fished area. *Marine Ecology Progress Series 394*: 201–213.

Rice, J (2006) Impacts of Mobile Bottom Gears on Seafloor Habitats, Species, and Communities: A Review and Synthesis of Selected International Reviews. *Canadian Science Advisory Secretariat Research Document 2006/057*. 35 p. (Available from http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2006/RES2006_057_e.pdf.)

Richard, Y; Abraham, E R (2015) Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2012–13. *New Zealand Aquatic Environment and Biodiversity Report No. 162*. 85 p

Richard, Y; Abraham, E R; Berkenbusch, K (2017) Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2014–15. *New Zealand Aquatic Environment and Biodiversity Report No. 191*. 133 p.

Richard, Y; Abraham, E R; Berkenbusch, K (2020) Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2016–17. *New Zealand Aquatic Environment and Biodiversity Report No. 237*. 57 p.

Roberts, J; Doonan, I (2016) Quantitative Risk Assessment of Threats to New Zealand Sea Lions. *New Zealand Aquatic Environment and Biodiversity Report No. 166*. 111 p.

Roberts, J; Dunn, A (2017) Investigation of alternative model structures for the estimation of natural mortality in the Campbell Island Rise southern blue whiting (*Micromesistius australis*) stock assessment (SBW 6I). *New Zealand Fisheries Assessment Report 2017/26*. 14 p.

Roberts, J; Hanchet, S M (2019) Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2017. *New Zealand Fisheries Assessment Report 2019/44*. 21 p.

Roberts, J; Lalas, C (2015) Diet of New Zealand sea lions (*Phocarctos hookeri*) at their southern breeding limits. *Polar Biology 38*: 1483–1491.

Robertson, H A; Baird, K; Dowding J E; Elliott, G P; Hitchmough, R A; Miskelly, C M; McArthur, N; O'Donnell, C F J; Sagar, P M; Scofield, R P; Taylor, G A (2017) Conservation status of New Zealand birds, 2016. *New Zealand Threat Classification Series 19*. Department of Conservation, Wellington. 23 p.

Shpak, V M (1978) The results of biological investigations of the southern putassu *Micromesistius australis* (Norman, 1937) on the New Zealand plateau and perspectives of its fishery. Unpublished TINRO manuscript. (Translation held in NIWA library, Wellington.)

Smith, M H; Baird, S J (2005) Factors that may influence the level of mortality of New Zealand sea lions (*Phocarctos hookeri*) in the squid (*Nototodarus* spp.) trawl fishery in SQU 6T. *New Zealand Fisheries Assessment Report 2005/20*. 35 p.

Smith, M H; Baird, S J (2007a) Estimation of the incidental captures of New Zealand sea lions (*Phocarctos hookeri*) in New Zealand fisheries in 2003–04, with particular reference to the SQU 6T squid (*Nototodarus* spp.) trawl fishery. *New Zealand Fisheries Assessment Report 2007/7*. 32 p.

Smith, M H; Baird, S J (2007b) Estimation of the incidental captures of New Zealand sea lions (*Phocarctos hookeri*) in New Zealand fisheries in 2004–05, with particular reference to the SQU 6T squid (*Nototodarus* spp.) trawl fishery. *New Zealand Aquatic Environment and Biodiversity Report No. 12*. 31 p

Smith, M H; Baird, S J (2009) Model-based estimation of New Zealand fur seal (*Arctocephalus forsteri*) incidental captures and strike rates for trawl fishing in New Zealand waters for the years 1994–95 to 2005–06. *New Zealand Aquatic Environment and Biodiversity Report No. 40*. 92 p.

Stevens, D W; O'Driscoll, R L; Dunn, M R; MacGibbon, D; Horn, P L; Gauthier, S (2011) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2010 (TAN1001). *New Zealand Fisheries Assessment Report 2011/10*. 112 p.

Thompson, F N; Abraham, E R (2010a) Estimation of the capture of New Zealand sea lions (*Phocarctos hookeri*) in trawl fisheries, from 1995–96 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report 66*.

Thompson, F N; Abraham, E R (2010b) Estimation of fur seal (*Arctocephalus forsteri*) bycatch in New Zealand trawl fisheries, 2002–03 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report No. 61*. 37 p.

Thompson, F N; Abraham, E R; Oliver, M D (2010a) Estimation of fur seal bycatch in New Zealand trawl fisheries, 2002–03 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report No. 56*. 29 p.

Thompson, F N; Oliver, M D; Abraham, E R (2010b) Estimation of the capture of New Zealand sea lions (*Phocarctos hookeri*) in trawl fisheries, from 1995–96 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report No. 52*. 25 p.

Thompson, F N; Abraham, E R; Berkenbusch, K (2012) Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11. (Unpublished Final Research Report for Ministry for Primary Industries project PRO2010-01 held by Fisheries New Zealand, Wellington.) 90 p.

Thompson, F N; Berkenbusch, K; Abraham, E R (2013) Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11. New Zealand Aquatic Environment and Biodiversity Report No. 105. 73 p.

Thompson, F N; Berkenbusch, K; Abraham, E R (2016) Incidental capture of marine mammals in New Zealand trawl fisheries, 1995–96 to 2011–12. New Zealand Aquatic Environment and Biodiversity Report No. 167. 78 p.

Tuck, I D; Cole, R; Devine, J A (2009) Ecosystem indicators for New Zealand fisheries. *New Zealand Aquatic Environment and Biodiversity Report No. 42*. 188 p.

Tuck, I D; Pinkerton, M H; Tracey, D M; Anderson, O A; Chiswell, S M (2014) Ecosystem and environmental indicators for deepwater fisheries. *New Zealand Aquatic Environment and Biodiversity Report No. 127*. 143 p.

Weaver, S. (2021) Conservation Services Programme Annual Summary 2019-20. New Zealand Department of Conservation, Wellington, New Zealand. 106 p.

SPINY DOGFISH (SPD)

(*Squalus acanthias*)
Makohuarau, Pioke, Kāraerae
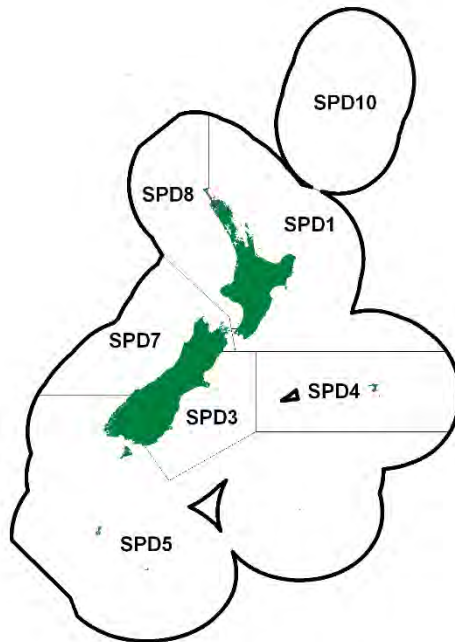
1.   FISHERY SUMMARY

1.1   Commercial fisheries

Spiny dogfish are found throughout the southern half of New Zealand, extending to East Cape and Manakau Harbour on the east and west coasts of the North Island respectively. A related species, the northern spiny dogfish (*Squalus mitsukurii*), is mainly restricted to North Island waters, overlapping with its conspecific in the central west coast area and around the Chatham Islands. Although they have different species codes for reporting purposes it is probable that some misidentification and misreporting occurs—particularly in FMAs 1, 8, and 9.

The best estimate of reported catch from the fishery is shown in the final column in Table 1. For the period 1980–81 to 1986–87 the best estimate of landings is the sum of the FSU data. For the period 1987–88 to 1996–97 it is the sum of the LFRR and the discards from the CELR and CLR. It has been assumed here that all the fish which have been caught and discarded will die, and that all the discarded fish have been recorded. Although neither assumption is likely to be true, and the biases they produce will at least partially cancel each other out, it is likely that the true level of discards is considerably higher. However, these figures are currently the best estimates of total removals from the fishery from 1980–81 to 1996–97.

Before 1980–81 landings of rig and both *Squalus* species were included together and catches of the latter were probably small. Since then the reported landings of spiny dogfish has fluctuated between about 3000 and 7000 t in most years, averaging about 5600 t from 2010–11 to 2018–19. The reported catch by the deepwater fleet has remained fairly constant during most of the period, averaging 2000–4000 t, with a slight decrease in recent years. The reported catch by the inshore fleet has shown a steady increase throughout the period and is now at a similar level to the catch from the deepwater fleet.

Most of the spiny dogfish caught by the deepwater fleet are taken as a bycatch in the jack mackerel, barracouta, hoki, red cod, and arrow squid fisheries, in depths from 100 to 500 m. Some are packed whole but most are trunked and exported to markets in Asia and Europe.

Table 1: Reported catches of spiny dogfish (t) by fishing year. FSU (Fisheries Statistics Unit), LFRR (Licensed Fish Receiver Return). Discards reported from CELR (Catch Effort Landing Return), and CLR (Catch Landing Return). Numbers in brackets are probably underestimates. (no data).

	FSU		LFRR	Discards	Best Estimate
	Inshore	Deepwater			
1980–81	–	(196)	–	–	196
1981–82	–	1 881	–	–	1 881
1982–83	(107)	2 568	–	–	2 675
1983–84	309	2 949	–	–	3 258
1984–85	303	3 266	–	–	3 569
1985–86	311	2 802	–	–	3 113
1986–87	870	2 277	2 608	–	3 147
1987–88	834	3 877	4 823	–	4 823
1988–89	(351)	(500)	3 573	(16)	3 589
1989–90	(14)	0	2 952	321	3 273
1990–91	–	–	5 983	333	6 316
1991–92	–	–	3 274	521	3 795
1992–93	–	–	4 157	616	4 773
1993–94	–	–	6 150	1 063	7 213
1994–95	–	–	4 793	628	5 421
1995–96	–	–	6 230	1 920	8 150
1996–97	–	–	4 887	2 572	7 459

Spiny dogfish are also taken as bycatch by inshore trawlers, setnetters, and longliners targeting flatfish, snapper, tarakihi, and gurnard. Because of processing problems due to their spines, sandpaper-like skin, and short shelf life, and their low economic value, many inshore fishers are not interested in processing and landing them. Furthermore, because of their sheer abundance they can at times severely hamper fishing operations for other commercial species and they are regarded by many fishers as a major nuisance. Trawlers working off Otago during the summer months often reduce towing times and headline heights, and at times leave the area altogether to avoid having to spend hours pulling hundreds of meshed dogfish out of trawl nets. Setnetters and longliners off the Otago coast, and in Tasman Bay and the south Taranaki Bight, have also complained about spiny dogfish taking longline baits, attacking commercial fish caught in the nets or lines, and rolling up nets.

Table 2 gives available historical landings data for 1978 to 1982. The catch by FMA from the FSU, CELR, and CLR databases is shown in Table 3. Substantial landings have been reported from FMAs 3, 5, 6, and 7 since 1982–83; landings from FMA 4 have increased substantially since the mid-1990s. In the early 1980s landings were highest in FMAs 5 and 6, with 1000–2000 t taken annually by factory trawlers. By the 1990s landings from FMA 3 and, to a lesser extent, FMA 7 became more important. The catch in both these areas was taken equally by factory trawlers and inshore fleets. Since the fishing year 2013–14 the highest landings have been reported from SPD 3, 4, and 5, which together contributed 82% of total spiny dogfish landings in 2019–20. The catch in FMA 1 is unlikely to be spiny dogfish which is considered to be virtually absent from the area, and so these catches should probably be attributed to *S. mitsukurii*.

Table 2: Reported landings (t) for the main QMAs from 1978 to 1982. For SPD, there are no data available for 1931 to 1977 years.

Year	SPD 1	SPD 3	SPD 4	SPD 5	SPD 7	SPD 8
1978	1	20	0	38	124	41
1979	2	130	67	74	128	40
1980	0	39	13	149	11	31
1981	2	123	92	203	73	150
1982	20	291	31	2 228	113	84

Note: Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Competitive quotas of 4075 t for FMA 3, and of 3600 t for FMAs 5 and 6, were introduced for the first time in the 1992–93 fishing year. These quotas were based on yields derived from trawl surveys using a method that is now considered obsolete, and harvest levels which are now considered unreliable. The reported catches exceeded the FMA 3 quota in 1997–98, 2000–01, and 2001–02 and the FMAs 5 and 6 quota in 2001–02.

Spiny dogfish was introduced into the QMS in October 2004. Catches and TACCs are shown in Table 4, and Figure 1 depicts historical landings and TACC values for the main SPD stocks. Landings for all Fishstocks have generally remained well below the TACC limits.

Prior to their introduction into the QMS, spiny dogfish were legally discarded at sea (provided that total catch was reported). Although discard rates increased dramatically through the 1990s (Table 5), this is believed to reflect a change in reporting practice rather than an increase in the proportion of catch discarded. Spiny dogfish were placed on Schedule 6 when they were introduced to the QMS.

Table 3: Reported landings (t) of spiny dogfish by FMA. Proportions by area have been taken from CELR and CLR and prorated to the best estimate from Table 1. Competitive quotas of 4075 t for FMA 3, and of 3600 t for FMAs 5 and 6, were introduced for the first time in the 1992–93 fishing year.

Year	FMA 1	FMA 2	FMA 3	FMA 4	FMA 5	FMA 6	FMA 7	FMA 8	FMA 9	FMA 10	Other	Total
1982–83	4	0	151	131	2 089	81	145	66	7			2 675
1983–84	22	18	409	347	565	1 700	119	63	16			3 258
1984–85	21	12	557	481	451	1 899	90	48	10			3 569
1985–86	13	11	892	411	537	1 017	120	92	20			3 113
1986–87	64	18	1 048	162	1 002	29	501	296	27			3 147
1987–88	50	9	1 664	172	642	16	1 402	841	27			4 823
1988–89	341	16	1 510	168	771	7	633	132	11			3 589
1989–90	36	14	2 243	136	241	2	521	80	0			3 273
1990–91	129	14	2 987	513	1 708	14	883	67	0			6 316
1991–92	54	23	1 801	66	538	33	1 031	249	0			3 795
1992–93	50	9	2 128	218	817	22	1 163	366	0			4 773
1993–94	51	34	3 165	358	1 158	21	2 212	214	0			7 213
1994–95	84	47	2 883	363	606	37	1 205	196	0			5 421
1995–96	68	177	2 558	969	1 147	152	1 205	186	15			7 052
1996–97	30	159	2 428	1 287	764	120	1 517	235	7	1	1	6 555
1997–98	52	165	5 042	917	428	223	2 389	1 172	34	0	11	10 433
1998–99	45	488	3 148	1 048	1 996	154	1 902	74	< 1	0	< 1	8 424
1999–00	15	328	3 309	994	1 163	189	1 505	25	7	0	5	7 540
2000–01	38	336	4 355	1 075	1 389	212	1 310	54	16	0	28	8 811
2001–02	12	222	4 249	1 788	3 734	487	961	71	12	0	–	11 530
2002–03	10	245	3 553	1 010	2 621	413	772	85	19	0	0	8 727
2003–04	12	91	2 077	516	1 032	302	423	20	5	0	0	4 477

Table 4: Reported domestic landings (t) of spiny dogfish by Fishstock and TACC from 2004–05. [Continued on next page]

Fishstock FMA	SPD 1 1&2		SPD 3 3		SPD 4 4		SPD 5 5&6		SPD 7 7	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2004–05	234	331	2 707	4 794	839	1 626	2 479	3 700	842	1 902
2005–06	186	331	3 831	4 794	1 055	1 626	2 298	3 700	832	1 902
2006–07	239	331	2 712	4 794	822	1 626	2 165	3 700	1 125	1 902
2007–08	156	331	2 082	4 794	1 397	1 626	1 501	3 700	928	1 902
2008–09	229	331	1 981	4 794	866	1 626	2 071	3 700	929	1 902
2009–10	128	331	1 855	4 794	667	1 626	2 205	3 700	1 116	1 902
2010–11	176	331	1 976	4 794	825	1 626	1 443	3 700	1 436	1 902
2011–12	187	331	1 607	4 794	740	1 626	1 390	3 700	1 704	1 902
2012–13	193	331	1 302	4 794	442	1 626	1 547	3 700	1 298	1 902
2013–14	226	331	1 411	4 794	1 090	1 626	2 068	3 700	914	1 902
2014–15	212	331	1 860	4 794	1 380	1 626	1 715	3 700	1 022	1 902
2015–16	178	331	1 284	4 794	1 002	1 626	1 092	3 700	858	1 902
2016–17	225	331	1 725	4 794	1 377	1 626	1 604	3 700	897	1 902
2017–18	163	331	2 007	4 794	1 756	1 626	1 534	3 700	920	1 902
2018–19	183	331	1 970	4 794	1 149	1 626	1 268	3 700	610	1 902
2019–20	158	331	1 750	4 794	907	1 626	1 062	3 700	645	1 902
2020–21	147	331	2 169	4 794	854	1 626	1 602	3 700	636	1 902

Fishstock FMA	SPD 8 8&9		Total	
	Landings	TACC	Landings	TACC
2004–05	121	307	7 222	12 660
2005–06	108	307	8 311	12 660
2006–07	118	307	7 181	12 660
2007–08	124	307	6 188	12 660
2008–09	150	307	6 226	12 660
2009–10	194	307	6 166	12 660

SPINY DOGFISH (SPD)

Table 4: [Continued]

Fishstock FMA	SPD 8 8&9 Landings	TACC	Total Landings	TACC
2010–11	221	307	6 077	12 660
2011–12	252	307	5 880	12 660
2012–13	182	307	4 965	12 660
2013–14	122	307	5 831	12 660
2014–15	123	307	6 312	12 660
2015–16	148	307	4 525	12 660
2016–17	181	307	5 112	12 660
2017–18	149	307	6 528	12 660
2018–19	162	307	5 342	12 660
2019–20	149	307	4 671	12 660
2020–21	145	307	5 552	12 660
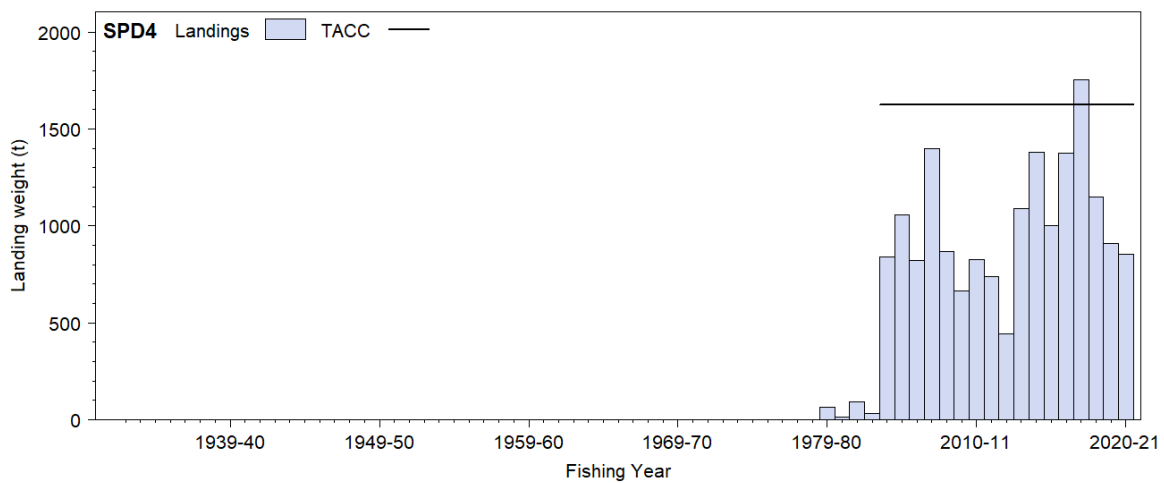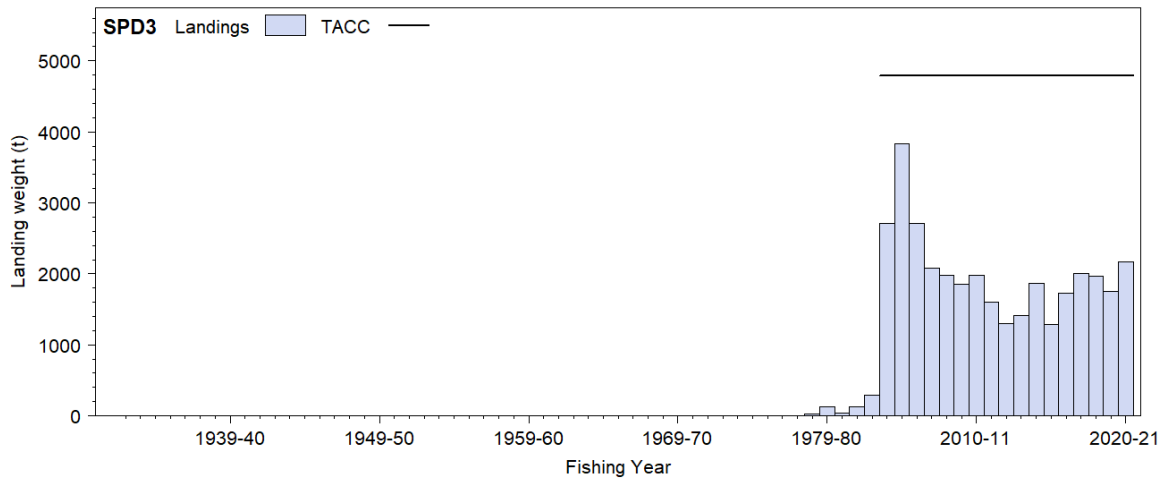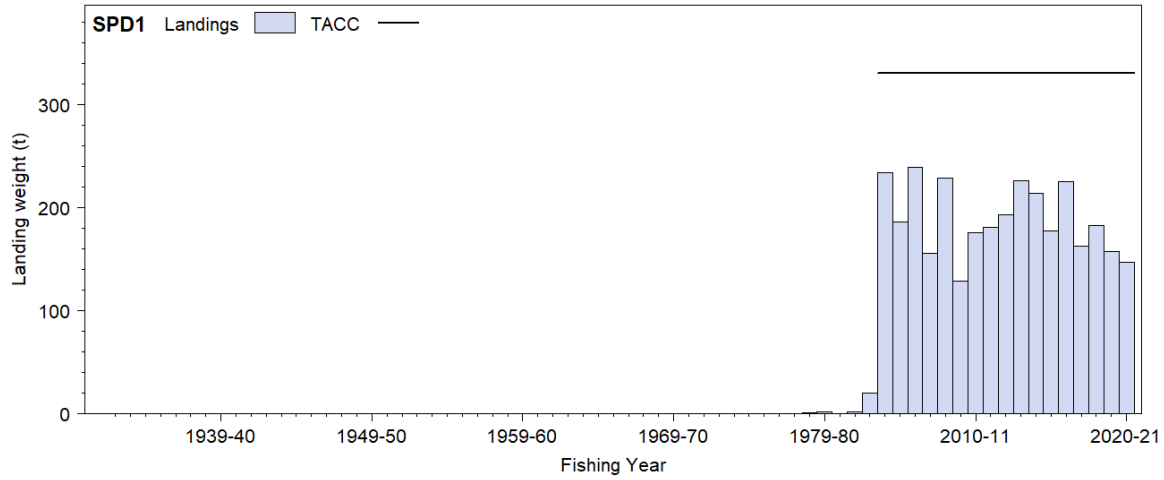
Figure 1: Reported commercial landings and TACCs for the six main SPD stocks SPD 1 (Auckland East, Central East), SPD 3 (South East Coast), and SPD 4 (South East Chatham Rise). [Continued on next page]
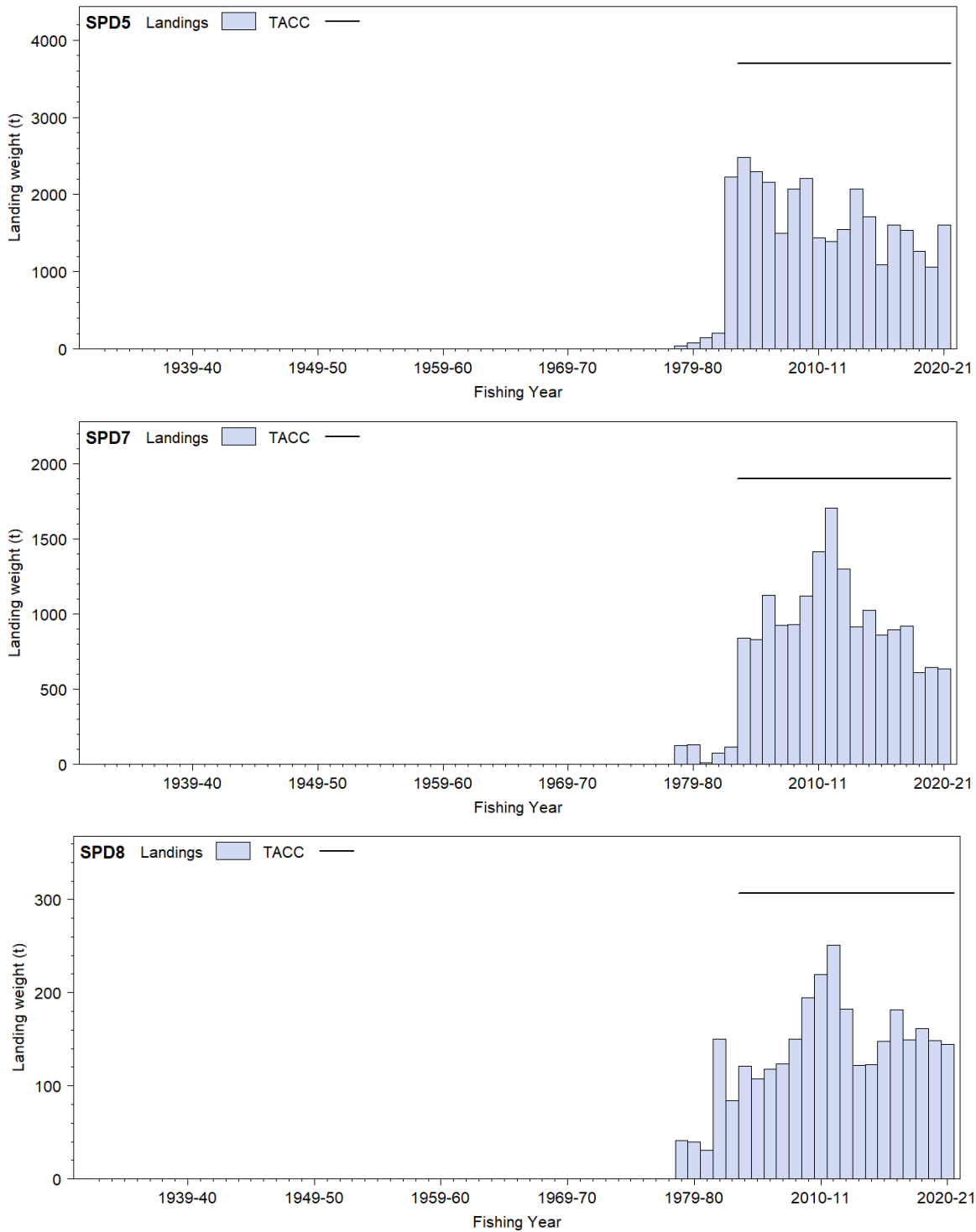
Figure 1 [Continued]: Reported commercial landings and TACCs for the six main SPD stocks SPD 5 (Sub-Antarctic, Southland), SPD 7 (Challenger), and SPD 8 (Central Egmont, Auckland West).

Table 5: Discard rates (% of catch) by FMA and fishing year (after Manning et al 2004). [Continued on next page]

FMA	1	2	3	4	5	6	7	8	9	10	Other	Average
Fishing year												
1989–90	11	17	18	4	46	100	13	34	0	0	0	18
1990–91	7	0	6	2	29	11	21	24	0	0	0	11
1991–92	9	3	8	13	34	90	42	18	0	0	0	20
1992–93	13	47	5	51	39	43	20	80	0	0	0	21
1993–94	5	65	13	42	21	34	29	66	0	0	0	23
1994–95	2	52	8	31	20	74	29	64	98	0	5	19
1995–96	7	39	18	55	39	94	45	72	100	0	11	36

Table 5 [Continued]

FMA Fishing year	1	2	3	4	5	6	7	8	9	10	Other	Average
1996–97	15	61	26	40	70	68	59	89	93	0	16	44
1997–98	53	83	51	53	72	86	81	92	100	0	16	64
1998–99	20	92	57	60	29	78	82	63	0	0	16	58
1999–00	9	86	60	55	39	68	81	84	35	0	0	62
2000–01	37	70	60	77	57	77	72	56	29	0	87	64
Average	15	74	35	53	42	78	54	68	78	0	16	45

1.2 Recreational fisheries

Spiny dogfish are caught by recreational fishers throughout their geographical range in New Zealand. They are mainly taken as bycatch when targeting other more valued species using rod and line and setnet. In many parts of New Zealand, spiny dogfish are regarded by recreational anglers as a pest, often clogging nets and taking baits from hooks. Estimates of recreational landings obtained from telephone-diary surveys in 1991–92 to 1993–94, 1996, and 1999–00 are given in Table 6.

Table 6: Number and weight of spiny dogfish harvested by recreational fishers by Fishstock from telephone-diary surveys. Surveys were carried out in different years in the MAF Fisheries regions: South in 1991–92, Central in 1992–93, North in 1993–94 (Teirney et al 1997), and nationally in 1996 (Bradford 1998) and 1999–00 (Boyd & Reilly 2004). Survey harvests are presented as a range to reflect the uncertainty in the estimates.

Fishstock	Survey	Number	CV%	Harvest Range (t)	Point estimate (t)
1991–92					
FMA 3	South		23		120
FMA 5	South		–		2
FMA 7	South		92		11
1992–93					
FMA 2	Central		42		133
FMA 7	Central		35		46
FMA 8	Central		45		143
1993–94					
FMA 1,9	North		–		< 10
1996					
FMA 1	National	1 000	–	–	–
FMA 2	National	5 000	–	–	–
FMA 3	National	21 000	17	25–40	33
FMA 5	National	9 000	–	–	–
FMA 7	National	24 000	21	30–45	37
FMA 9	National	15 000	–	–	–
1999–00					
FMA 1	National	9 000	61	4.4–17.9	11
FMA 2	National	22 000	37	17.3–37.8	28
FMA 3	National	93 000	27	83.2–145.9	115
FMA 5	National	7 000	47	4.4–12.3	8
FMA 7	National	25 000	35	20.4–41.9	31
FMA 8	National	21 000	52	12.7–40.3	27
FMA 9	National	12 000	82	2.7–26.2	14

The harvest estimates provided by telephone-diary surveys between 1991 and 2001 are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a national panel survey was conducted for the first time throughout the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year (Wynne-Jones et al 2014). The panel members were contacted regularly about their fishing activities and harvest information in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 7. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 7: Recreational harvest estimates for spiny dogfish stocks from national panel surveys (Wynne-Jones et al 2014, 2019). Mean fish weights were obtained from boat ramp surveys (Hartill & Davey 2015, Davey et al 2019).

Stock	Year	Method	Number of fish	Total weight (t)	CV
SPD 1	2011–12	Panel survey	5 211	5.3	0.29
	2017–18	Panel survey	2 759	4.2	0.43
SPD 3	2011–12	Panel survey	4 130	4.2	0.29
	2017–18	Panel survey	2 912	4.5	0.46
SPD 5	2011–12	Panel survey	466	0.5	0.81
	2017–18	Panel survey	1 504	2.3	0.70
SPD 7	2011–12	Panel survey	6 035	6.1	0.54
	2017–18	Panel survey	5 019	7.7	0.34
SPD 8	2011–12	Panel survey	6 358	6.5	0.26
	2017–18	Panel survey	1 791	2.7	0.43

1.3   Customary non-commercial fisheries

Māori fishers traditionally caught large numbers of 'dogfish' and this included rig, school shark, and spiny dogfish. Quantitative information on the current level of customary non-commercial fisheries take is not available.

1.4   Illegal catch

It is unlikely that there is an illegal catch of spiny dogfish because the quota for this species has never been reached, and it has low commercial value.

1.5   Other sources of mortality

It is likely that a large amount of spiny dogfish is discarded by fishers and never reported. The level of mortality and any temporal trends from non-reported discards have not been estimated. The introduction of cost recovery charges in 1994–95 may account for the decline in reported discards in that year.

2.   BIOLOGY

Spiny dogfish are widely distributed around the South Island and extend as far north as Manukau Harbour and East Cape on the west and east coasts of the North Island, respectively. They are most abundant off the east coast of the South Island and the Stewart-Snares shelf. They are found on the continental shelf and upper slope down to a depth of at least 500 m but are most common in depths of 50–150 m. Schools are strongly segregated by size and sex. The size of fish in the commercial fishery is not known but will depend to a large extent on the method of capture and the area fished.

Spiny dogfish are born at a size of 18–30 cm total length (TL). They have been aged using fin spines, and early growth has been validated by following modes in length frequency and eye lens weight frequency data. Males mature at 58 cm TL at age 6, and females mature at 73 cm TL at age 10. The maximum ages and lengths in a study of east coast South Island dogfish were 21 years and 90 cm TL for males, and 26 years and 111 cm TL for females.

M was estimated using the equation $\log_e 100$/maximum age, where maximum age is the age to which 1% of the population survive in an unexploited stock. Using a maximum age of 26 gave an estimate of M of 0.18. This has been revised up to 0.2 to reflect the imprecision with which this estimate is known. A similar estimate of M was obtained using a survivorship table approach (Hanchet 1986). At an instantaneous mortality rate of 0.2 y^{-1} an initial population of 1000 females would replace themselves over their lifespan (given their length-at-age, length-at-maturity, and fecundity-length relationships).

Female spiny dogfish give birth to young over an extended period between April and September, mainly on the shelf edge in depths of 200–300 m. Mating also occurs in deeper water (coincident with a movement of mature males offshore), after which females with young 'candled' embryos move into shallower waters

of 100 m or less. They remain there for 12 months until the embryos are 15 cm long after which they return to deeper water. Parturition occurs after a gestation period approaching 24 months, and this is closely followed by mating and ovulation and the biennial cycle is repeated. Both the number and the size of the young increase linearly with the length of the mother. The number of young per litter ranges from 1 to 19.

Young of the year move inshore into shallower waters shortly after birth. Over the next few years they move steadily into deeper water but remain in size segregated schools comprising up to 2 or 3 age classes. Once maturity is reached both males and females undergo inshore/offshore migrations associated with reproductive activity. A north/south migration along the east coast South Island during autumn/spring has also been postulated, but the full extent of this migration is unknown.

Spiny dogfish are found both on the bottom and in midwater and feed on a very wide range of species, including *Munida*, krill, fish, squid, and crabs.

Biological parameters relevant to the stock assessment are shown in Table 8.

Table 8: Estimates of biological parameters of spiny dogfish for QMA 3 (Hanchet 1986).

1. Natural mortality (*M*)

0.2

2. Weight = a (length)^b (Weight in g, length in cm fork length)

	Males			Females	
	a	b		a	b
	0.00275	3.05		0.00139	3.25

3. von Bertalanffy growth parameters

	Males			Females	
K	t_0	L_∞	K	t_0	L_∞
0.116	-2.88	89.5	0.069	-3.45	120.1

4. Maturity ogive

Age (years)	3	4	5	6	7	8	9	10	11	12	> 12
Males	0.00	0.02	0.21	0.68	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Females	0.00	0.00	0.00	0.00	0.04	0.04	0.23	0.52	0.75	1.00	1.00

3. STOCKS AND AREAS

No specific research on the stock structure of spiny dogfish has been carried out. Limited tagging has been conducted, so the only available data come from seasonal trawl surveys and fisheries landings data.

The analysis of *W.J. Scott* and *James Cook* surveys carried out from 1978 to 1983 clearly showed seasonal migrations of spiny dogfish along the east coast of South Island (ECSI). Spiny dogfish were most abundant in the southern part of the coast from October to April, and more abundant to the north in May to September. It is also clear from summer trawl surveys of the area that there is a resident part of the population of spiny dogfish on the Stewart-Snares shelf over the summer months. However, there have been no comparable series of seasonal surveys there and so it is presently unclear whether the east coast South Island fish migrate south as far as the Stewart-Snares shelf. Until more data become available fish from the two areas should be treated as separate stocks.

Seasonal trawl surveys were also carried out off west coast South Island (WCSI) between June 1981 and April 1983 using the *W.J. Scott*. The catches showed a strong seasonal component being highest in summer and autumn and lowest in winter and spring. It is likely that some fish migrate north in winter, perhaps to the northern and southern Taranaki Bights, and Tasman Bay and Golden Bay. However, it is also clear from summer trawl surveys of the areas that there is a resident part of the population of spiny dogfish in the Taranaki Bights over the summer months. It may therefore be appropriate to treat fish from FMAs 7 and 8 as a single stock.

There is little commercial catch in FMAs 1, 2, 4, and 9, and little data on movement in or between the areas. Until more data have been obtained it would seem appropriate to manage spiny dogfish with the following five fishstocks:

- SPD 1: FMAs 1 & 2
- SPD 3: FMA 3
- SPD 4: FMA 4
- SPD 5: FMAs 5 & 6
- SPD 7 and SPD 8: FMAs 7, 8, & 9

4.   STOCK ASSESSMENT

There are no estimates of current or virgin biomass.

4.1   Estimates of fishery parameters and abundance

Biomass indices of spiny dogfish from recent trawl surveys using *Tangaroa* and *Kaharoa* are summarised in Figures 2–5 and Table 9. Based on a combination of CVs, variability in biomass indices, and the time span of each series, it is concluded that surveys provide reliable indices of dogfish abundance off the west coast of the South Island, the east coast of the South Island, and on the Chatham Rise. Relative biomass indices suggest that spiny dogfish became more abundant on the Chatham Rise during the early to mid-1990s. Apart from a temporary increase during the mid-1990s, the abundance of spiny dogfish off the west coast South Island appears to have been fairly stable. Off the east coast of the South Island spiny dogfish biomass increased in the early 1990s and has fluctuated without trend since then.

West coast South Island inshore trawl survey

Biomass fluctuated between 3919 and 10 270 t from 1992 to 2011 (Figure 2). Biomass in 2013 was the highest in the series, but this was influenced by a single large catch, reflected in the large CV. Biomass has generally declined since then to the lowest estimate of the series in 2021. The decrease has come almost entirely from the west coast strata; biomass from Tasman Bay and Golden Bay has been relatively stable, but low (MacGibbon et al 2022). The decrease in biomass, though most pronounced in adult females, is seen in juveniles and adults of both sexes. Most of the biomass is found off the west coast within the 100–200 m strata. Adults usually comprise slightly more of the biomass than juveniles and females usually contribute more of the biomass than males.

Despite a trend of declining biomass in recent years there appears to be no change to the size range of spiny dogfish captured on the survey. The size distribution of spiny dogfish has been similar and generally bimodal throughout the time series. For males, there is usually a mode from around 30–50 cm and a larger second mode from around 50–75 cm. The female distribution is often bimodal but less well defined than males with modes from around 30–60 cm and 60–90 cm. Within Tasman Bay and Golden Bay, almost all spiny dogfish are males, and unimodal from 50–70 cm.
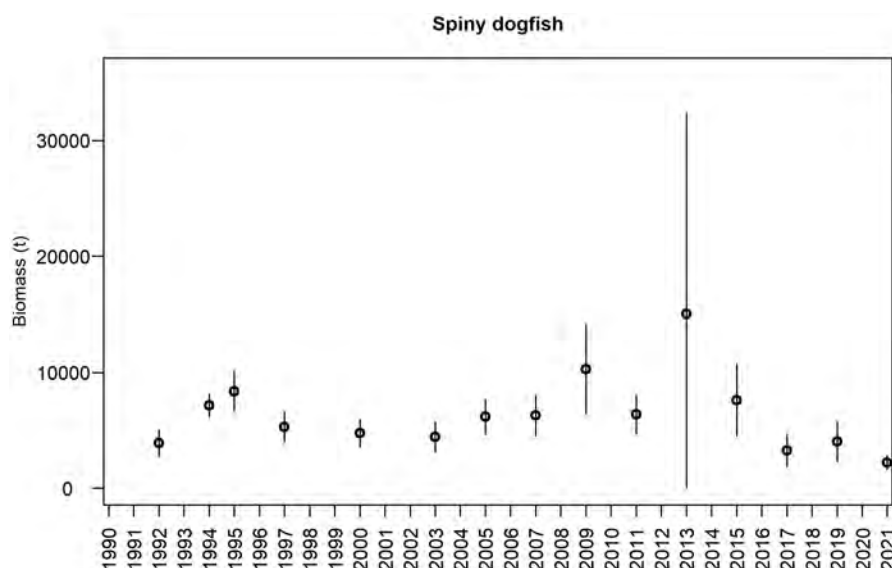
Figure 2: Spiny dogfish biomass for the west coast South Island inshore trawl survey time series (error bars are ± two standard deviations).

Chatham Rise trawl survey

The Chatham Rise trawl survey was designed primarily for hoki and, for spiny dogfish, covers the relevant depth range 200–400 m. It therefore excludes a small portion of SPD habitat at depths less than 200 m around the Mernoo Bank and Chatham Islands. The survey biomass estimates for SPD increased from 1992 to 1997 and have cycled around the series mean since then (Figure 3). The Chatham Rise SPD survey catch is dominated by mature females (60–100 cm), whereas that of the ECSI survey consists mostly of males and females < 60 cm (Beentjes et al 2016, Stevens et al 2015).
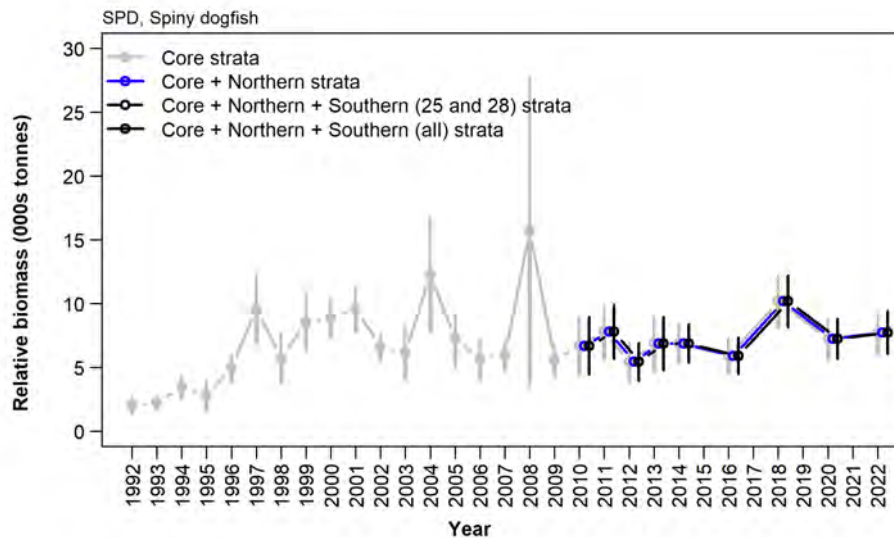
Figure 3: Spiny dogfish biomass for the Chatham Rise inshore trawl survey time series (error bars are ± two standard deviations).

East coast South Island inshore trawl survey

The east coast South Island winter surveys from 1991 to 1996 (30–400 m) were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range; but these were discontinued after the fifth in the annual time series because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007, and this time were expanded to include the 10–30 m depth range, to monitor elephantfish and red gurnard which were officially included in the list of target species in 2012. Six surveys (2007, 2012, 2014, 2016, 2018, and 2021) surveys provide full coverage of the 10–30 m depth range.

Spiny dogfish biomass in the core survey area increased markedly in 1996 and has fluctuated over the last eight surveys with a clear declining trend, most marked in 2021 when biomass dropped by 68% (Table 9, Figure 4) (Beentjes et al in prep). Pre-recruited biomass was a small component of the total biomass estimate in the 1992 to 1994 surveys at 1–3% of total biomass, but since 1996 it has ranged from 7 to 52%, and in 2021 it was 52%, the highest in the time series (Table 9, Figure 4). This is also reflected in the biomass of juvenile spiny dogfish (based on the length-at-50% maturity), which increased markedly from about 14% of total biomass before 1996, to between 32 and 57% in the last nine surveys, and it was 55% and 63% of the biomass in 2018 and 2021, respectively (Figure 5).

The additional spiny dogfish biomass captured in the 10–30 m depth range accounted for 5%, 8%, 10%, 5%, 5%, and 13% of the biomass in the core plus shallow strata (10–400 m) for 2007, 2012, 2014, 2016, 2018, and 2021, respectively, indicating that it is useful to monitor the shallow strata for spiny dogfish biomass (Table 9, Figure 4). Further, the addition of the 10–30 m depth range may be important for monitoring the small fish. The spatial distribution of spiny dogfish hotspots varies, but overall this species is consistently well represented over the entire survey area, most commonly from 30 m to about 350 m. Spiny dogfish are consistently the most commonly caught species on the ECSI trawl survey and occurred in 94–100% of core strata tows (94% in 2021). Spiny dogfish comprised 10–46% of the total catch on the surveys with a downward trend and the lowest value in the time series was in 2021.
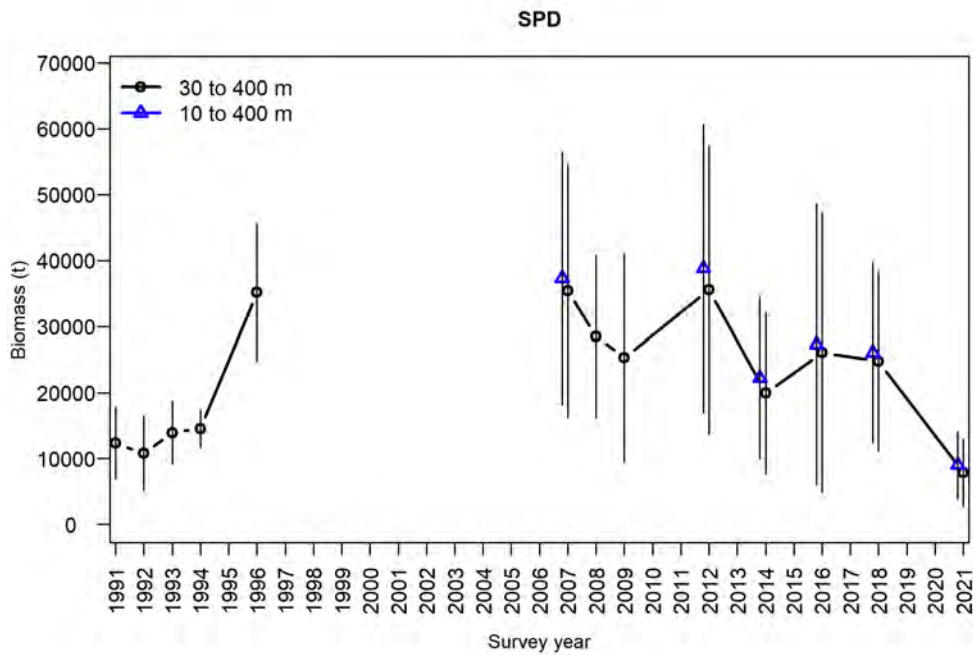
Figure 4: Spiny dogfish total biomass for ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m). Error bars are ± two standard deviations.
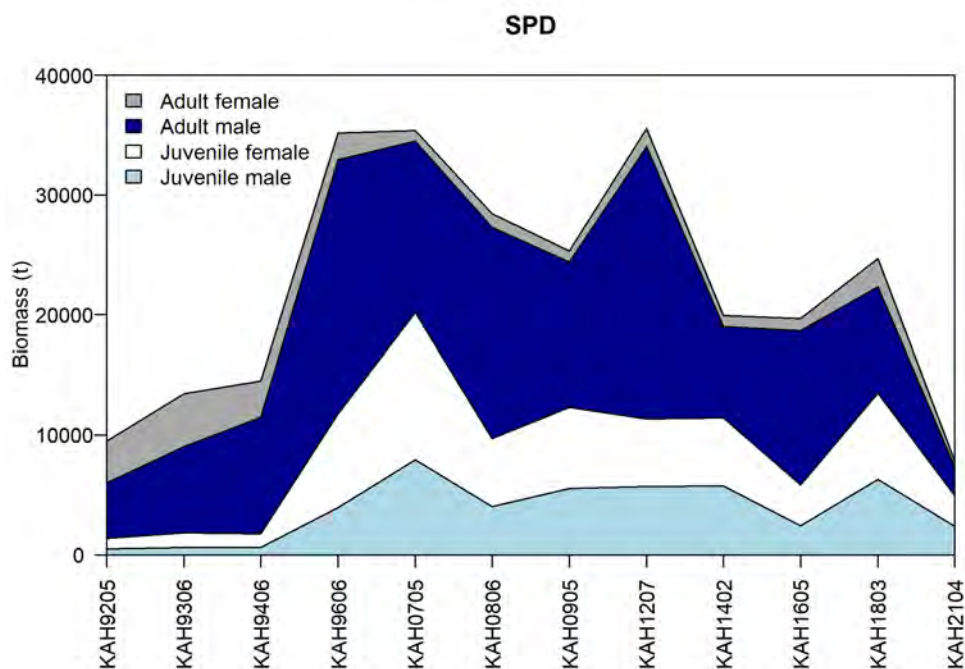
Figure 5: Spiny dogfish juvenile and adult biomass for ECSI winter surveys in core strata (30–400 m), where juvenile is below and adult is equal to or above length at which 50% of fish are mature.

The size distributions of spiny dogfish in the 1992 to 1994 surveys were similar and generally bimodal for males, but less defined for females which are less numerous than males throughout the core strata time series. From 1996 onwards, smaller fish were more abundant, and there were many more larger fish in the population. The large increase in biomass observed post-1996 is in part a result of the change in the population size composition. In contrast, in 2021 the time series biomass low is associated with a marked drop off in numbers of larger fish over about 50 cm. Spiny dogfish on the ECSI sampled on these surveys were considerably smaller than those from the Chatham Rise, Southland, and the sub-Antarctic surveys (Bagley & Hurst 1996, O'Driscoll & Bagley 2001, Livingston et al 2002, Stevens et al 2017), suggesting that this area may be an important nursery ground for juvenile spiny dogfish and there may be movement in and out of the ECSI survey area.

SPINY DOGFISH (SPD)

Table 9: Relative biomass indices (t) and coefficients of variation (CV) for spiny dogfish for east coast North Island (ECNI), east coast South Island (ECSI) - summer and winter, Chatham Rise, Stewart-Snares shelf, Sub-Antarctic, west coast South Island (WCSI) and west coast North Island (WCNI) survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16, and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (50 cm). [Continued on next two pages]

Region	Fishstock	Year	Trip number	Biomass estimate	CV (%)	Biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
ECNI	SPD 2	1993	KAH9304	963	78	–	–	–	–	–	–	–	–	–	–
		1994	KAH9402	988	47	–	–	–	–	–	–	–	–	–	–
		1995	KAH9502	658	25	–	–	–	–	–	–	–	–	–	–
		1996	KAH9602	1 026	51	–	–	–	–	–	–	–	–	–	–
ECSI (winter)	SPD 3			30–400 m		10–400 m		30–400 m		10–400 m		30–400 m		10–400 m	
		1991	KAH9105	12 873	22	–	–	–	–	–	–	–	–	–	–
		1992	KAH9205	10 787	26	–	–	266	27	–	–	9 212	31	–	–
		1993	KAH9306	13 949	17	–	–	343	72	–	–	13 122	17	–	–
		1994	KAH9406	14 530	10	–	–	205	49	–	–	14 325	10	–	–
		1996	KAH9606	35 169	15	–	–	3 412	23	–	–	31 757	16	–	–
		2007	KAH0705	35 386	24	37 299	26	5 831	46	–	–	29 554	27	–	–
		2008	KAH0806	28 476	22	–	–	1 886	50	–	–	26 590	22	–	–
		2009	KAH0905	25 311	31	–	–	2 398	30	–	–	22 913	32	–	–
		2012	KAH1207	35 546	31	38 821	28	3 804	58	–	–	31 742	34	–	–
		2014	KAH1402	19 949	31	22 188	28	5 683	34	–	–	14 266	36	–	–
		2016	KAH1605	26 063	41	27 300	39	2 639	34			18 299	50		
		2018	KAH1803	24 758	28	26 049	26	7 423	55	–	–	17 336	29	–	–
		2021	KAH2104	7 857	32	9 010	29	4 099	54			3 758	33		
ECSI (summer)	SPD 3	1996–97	KAH9618	35 776	28	–	–	–	–	–	–	–	–	–	–
		1997–98	KAH9704	29 765	25	–	–	–	–	–	–	–	–	–	–
		1998–99	KAH9809	22 842	16	–	–	–	–	–	–	–	–	–	–
		1999–00	KAH9917	49 832	37	–	–	–	–	–	–	–	–	–	–
		2000–01	KAH0014	30 508	34	–	–	–	–	–	–	–	–	–	–
Chatham Rise	SPD 4	1991	TAN9106	2 390	14	–	–	–	–	–	–	–	–	–	–
		1992	TAN9212	2 220	11	–	–	–	–	–	–	–	–	–	–
		1994	TAN9401	3 449	13	–	–	–	–	–	–	–	–	–	–
		1995	TAN9501	2 841	21	–	–	–	–	–	–	–	–	–	–
		1996	TAN9601	4 969	11	–	–	–	–	–	–	–	–	–	–
		1997	TAN9701	8 905	9	–	–	–	–	–	–	–	–	–	–
		1998	TAN9801	9 586	9	–	–	–	–	–	–	–	–	–	–
		1999	TAN9901	6 334	8										
		1999–00	TAN0001	6 191	17	–	–	–	–	–	–	–	–	–	–
		2000–01	TAN0101	12 289	18	–	–	–	–	–	–	–	–	–	–
		2001–02	TAN0201	2 390	14	–	–	–	–	–	–	–	–	–	–

Table 9 [Continued]: Relative biomass indices (t) and coefficients of variation (CV) for spiny dogfish for east coast North Island (ECNI), east coast South Island (ECSI) - summer and winter, Chatham Rise, Stewart-Snares shelf, Sub-Antarctic, west coast South Island (WCSI) and west coast North Island (WCNI) survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16, and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (50 cm).

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
Chatham Rise	SPD 4	2002–03	TAN0301	2 220	11	–	–	–	–	–	–	–	–	–	–
		2004	TAN0401	3 449	13	–	–	–	–	–	–	–	–	–	–
		2005	TAN0501	7 227	15	–	–	–	–	–	–	–	–	–	–
		2006	TAN0601	5 650	14	–	–	–	–	–	–	–	–	–	–
		2007	TAN0701	5 906	10	–	–	–	–	–	–	–	–	–	–
		2008	TAN0801	15 674	38	–	–	–	–	–	–	–	–	–	–
		2009	TAN0901	5 548	11	–	–	–	–	–	–	–	–	–	–
		2010	TAN1001	6 698	17	–	–	–	–	–	–	–	–	–	–
		2011	TAN1101	7 794	14	–	–	–	–	–	–	–	–	–	–
		2012	TAN1201	5 438	14	–	–	–	–	–	–	–	–	–	–
		2013	TAN1301	6 884	15	–	–	–	–	–	–	–	–	–	–
		2014	TAN1401	6 886	11	–	–	–	–	–	–	–	–	–	–
		2016	TAN1601	5 908	12	–	–	–	–	–	–	–	–	–	–
		2018	TAN1801	10 175	10	–	–	–	–	–	–	–	–	–	–
		2020	TAN2001	7 238	11	–	–	–	–	–	–	–	–	–	–
		2022	TAN2201	7 740	11	–	–	–	–	–	–	–	–	–	–
Stewart-Snares shelf	SPD 5	1993	TAN9301	35 776	28	–	–	–	–	–	–	–	–	–	–
		1994	TAN9402	29 765	25	–	–	–	–	–	–	–	–	–	–
		1995	TAN9502	22 842	16	–	–	–	–	–	–	–	–	–	–
		1996	TAN9604	49 832	37	–	–	–	–	–	–	–	–	–	–
Sub-Antarctic (*Spring*)	SPD 5	1991	TAN9105	8 502	55	–	–	–	–	–	–	–	–	–	–
		1992	TAN9211	1 150	15	–	–	–	–	–	–	–	–	–	–
		1993	TAN9310	1 585	21	–	–	–	–	–	–	–	–	–	–
		2000	TAN0012	4 173	12	–	–	–	–	–	–	–	–	–	–
		2001	TAN0118	8 528	31	–	–	–	–	–	–	–	–	–	–
		2002	TAN0219	3 505	19	–	–	–	–	–	–	–	–	–	–
		2003	TAN0317	2 317	17	–	–	–	–	–	–	–	–	–	–
		2004	TAN0414	3 378	27										
		2005	TAN0515	4 344	19	–	–	–	–	–	–	–	–	–	–
		2006	TAN0617	3 039	19	–	–	–	–	–	–	–	–	–	–
Sub-Antarctic (*Autumn*)	SPD 5	1992	TAN9204	926	30	–	–	–	–	–	–	–	–	–	–
		1993	TAN9304	440	38	–	–	–	–	–	–	–	–	–	–
		1996	TAN9605	207	56	–	–	–	–	–	–	–	–	–	–
		1998	TAN9805	1 532	36	–	–	–	–	–	–	–	–	–	–

SPINY DOGFISH (SPD)

Table 9 [Continued]: Relative biomass indices (t) and coefficients of variation (CV) for spiny dogfish for east coast North Island (ECNI), east coast South Island (ECSI) - summer and winter, Chatham Rise, Stewart-Snares shelf, Sub-Antarctic, west coast South Island (WCSI) and west coast North Island (WCNI) survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16, and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (50 cm).

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
WCSI	SPD 7	1992	KAH9204	3 919	15	–	–	–	–	–	–	–	–	–	–
		1994	KAH9404	7 145	7	–	–	–	–	–	–	–	–	–	–
		1995	KAH9504	8 370	10	–	–	–	–	–	–	–	–	–	–
		1997	KAH9701	5 275	13	–	–	–	–	–	–	–	–	–	–
		2000	KAH0004	4 777	12	–	–	–	–	–	–	–	–	–	–
		2003	KAH0304	4 446	15	–	–	–	–	–	–	–	–	–	–
		2005	KAH0503	6 175	12	–	–	–	–	–	–	–	–	–	–
		2007	KAH0704	6 219	14	–	–	–	–	–	–	–	–	–	–
		2009	KAH0904	10 270	19	–	–	–	–	–	–	–	–	–	–
		2011	KAH1104	6 402	13	–	–	–	–	–	–	–	–	–	–
		2013	KAH1305	15 087	57	–	–	–	–	–	–	–	–	–	–
		2015	KAH1503	7 613	21	–	–	–	–	–	–	–	–	–	–
		2017	KAH1703	3 255	22	–	–	–	–	–	–	–	–	–	–
		2019	KAH1902	4 031	22	–	–	–	–	–	–	–	–	–	–
		2021	KAH2103	2 226	14	–	–	–	–	–	–	–	–	–	–
WCNI	SPD 9	1991	KAH9111	443*	34	–	–	–	–	–	–	–	–	–	–
		1994	KAH9410	381*	30	–	–	–	–	–	–	–	–	–	–
		1996	KAH9615	634*	68	–	–	–	–	–	–	–	–	–	–
		1999	KAH9915	106*	15	–	–	–	–	–	–	–	–	–	–

*Assuming areal availability, vertical availability, and vulnerability equal 1.0. Biomass is only estimated outside 10 m depth except for COM9901 and CMP0001. Note: because trawl survey biomass estimates are indices, comparisons between different seasons (e.g., summer and winter ECSI) are not strictly valid.

Manning et al (2004) evaluated the usefulness of commercial CPUE, commercial length composition, trawl survey relative biomass estimates and trawl-survey-catch length composition for monitoring all major SPD stocks (Table 10).

Table 10: Catch and effort data sets and analyses evaluated as monitoring tools for major SPD stocks.

QMA	Data set and analysis
SPD 3 - East coast South Island	1. Standardised setnet CPUE for core vessels targeting SPD.
	2. Standardised setnet CPUE for core vessels targeting all species.
	3. Standardised bottom trawl CPUE for core vessels targeting all species.
	4. Relative abundance indices from east coast South Island trawl surveys (discontinued after 2001)
SPD 4 - Chatham Rise	5. Standardised bottom trawl CPUE for core Korean vessels
	6. Standardised bottom trawl CPUE for core domestic vessels
	7. Standardised bottom longline CPUE for core domestic vessels
	8. Relative abundance indices from Chatham Rise trawl surveys.
SPD 5 - Stewart-Snares shelf	9. Standardised bottom trawl CPUE.
	10. Relative abundance indices from Stewart-Snares shelf surveys (discontinued after 1996)
SPD 7 - West coast South Island	11. Standardised bottom trawl CPUE for core vessels
	12. Relative abundance indices from west coast South Island trawl surveys.

Based on the results of the analyses listed in Table 10, the following methods were recommended for monitoring SPD:

QMA	Recommended Monitoring Tools
SPD 3 - East coast South Island	Standardised setnet CPUE using model 2 (core vessels targeting all species)
SPD 4 - Chatham Rise	Chatham Rise trawl survey and length composition of commercial catch
SPD 5 – Stewart-Snares shelf	*Standardised bottom trawl CPUE and length composition of commercial catch.
SPD 7 - West coast South Island	West coast South Island trawl survey and length composition of commercial catch

* Information on historical changes in reporting rates is required before this index can be used.

4.2   Biomass estimates

Lack of suitable information has precluded estimation of virgin and current biomass for spiny dogfish. Although most of the necessary biological parameters (Hanchet 1986, 1988, Hanchet & Ingerson 1997), relative indices of abundance and data required to estimate fishing selectivity for most important fisheries (with the exception of FMA 4 bottom longline and FMA 3 setnet fisheries) are now available, robust stock assessments will also require estimates of historical, unreported discarding and discard mortality so that an accurate history of fishery related removals can be constructed.

4.3   Yield estimates and projections

MCY cannot be estimated.

CAY cannot be determined.

4.4   Other factors

The ability to withstand harvesting depends on the strength of a number of compensatory mechanisms. For example, under exploitation individuals may grow faster, show increased fecundity, or suffer reduced natural mortality. In elasmobranchs the number of young born is related directly to the number of adult females, and, because of the relatively large size and hence good survival of the young at birth, it is presumed that there is a strong stock recruit relationship for these species.

Several methods of estimating *MCY* involve the multiplication of a harvest level by an estimate of B_0 or B_{av}. Francis & Francis (1992) used Monte Carlo simulation to estimate harvest levels for calculating *MCY* for a rig stock. No stock-recruitment data were available for elasmobranchs at the time and so they used values for the Beverton & Holt steepness parameter ranging from 0.35 to 0.50, and recruitment variability of 0.4. These values were all at the low range of values used for teleost species and which they considered appropriate for rig. The results of their simulation studies showed that the estimates of *MCY* obtained using the harvest levels given in the equations in the Guide to Biological Reference Points were overly optimistic for rig. Given that spiny dogfish have a slower growth rate and are less fecund than rig, it seems reasonable to assume that those harvest levels are also unsuitable for spiny dogfish.

A data informed qualitative risk assessment was completed on all chondrichthyans (sharks, skates, rays and chimaeras) at the New Zealand scale in 2014 (Ford et al 2015). Spiny dogfish was ranked seventh

highest in terms of risk of the eleven QMS chondrichthyan species. Data were described as existing and sound for the purposes of the assessment and consensus over this risk score was achieved by the expert panel. This risk assessment does not replace a stock assessment for this species but may influence research priorities across species.

5.   STATUS OF THE STOCKS

No estimates of current or reference biomass are available, but trawl survey estimates of abundance have been calculated for a number of years (Table 9).

Although reported commercial catches of spiny dogfish were observed to increase in all major FMAs during the 1990s, the extent to which these increases can be attributed to changes in reporting practice (i.e., more accurate reporting of discards in recent times) is uncertain. Trawl surveys, on the other hand, indicate that there was a general increase in the abundance of spiny dogfish, particularly around the South Island, in the mid-1990s.

6.   FOR FURTHER INFORMATION

Bagley, N W; Hurst, R J (1996) Trawl survey of middle depth and inshore bottom species off Southland, February-March 1995 (TAN9502). *New Zealand Fisheries Data Report No. 73.* 48 p.

Beentjes, M P; MacGibbon, D J; Ladroit, Y (in prep) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2021 (KAH2104). Draft New Zealand Fisheries Assessment Report.

Beentjes, M P; MacGibbon, D; Parkinson, D (2016) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2016 (KAH1605). *New Zealand Fisheries Assessment Report 2016/61.* 135 p.

Boyd, R O; Reilly, J L (2004) 1999/2000 National Marine Recreational Fishing Survey: harvest estimates. (Unpublished New Zealand Fisheries Assessment Research Report for the Ministry of Fisheries Project REC9803 held by Fisheries New Zealand, Wellington.) 28 p.

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished document held in NIWA library, Wellington.)

Da Silva, H M (1993) The causes of variability in the stock-recruitment relationship of spiny dogfish, *Squalus acanthias*, in the NW Atlantic. *ICES CM 1993/G:52.* 17 p.

Davey, N; Hartill, B; Carter, M (2019) Mean weight estimates for recreational fisheries in 2017–18. *New Zealand Fisheries Assessment Report 2019/25.* 36 p.

Ford, R B; Galland, A; Clark, M R; Crozier, P; Duffy, C A J; Dunn, M R; Francis, M P; Wells, R (2015) Qualitative (Level 1) Risk Assessment of the impact of commercial fishing on New Zealand Chondrichthyans. *New Zealand Aquatic Environment and Biodiversity Report No. 157.* 111 p.

Francis, M P; Francis, R I C C (1992) Growth, mortality, and yield estimates for rig (*Mustelus lenticulatus*). New Zealand Fisheries Assessment Research Document 1992/5. 32 p. (Unpublished document held in NIWA library, Wellington.)

Francis, M P; Paul, L J (2013) New Zealand inshore finfish and shellfish commercial landings, 1931–82. *New Zealand Fisheries Assessment Report 2013/55.* 136 p.

Francis, R I C C; Hurst, R J; Renwick, J A (2001) An evaluation of catchability assumptions in New Zealand stock assessments. *New Zealand Fisheries Assessment Report 2001/1.* 37 p.

Hanchet, S M (1986) The distribution and abundance, reproduction, growth and life history characteristics of the spiny dogfish (*Squalus acanthias* Linnaeus) in New Zealand. PhD Thesis, University of Otago, New Zealand.

Hanchet, S M (1988) Reproductive biology of *Squalus acanthias* from the east coast, South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research 22:* 537–549.

Hanchet, S M (1991) Diet of spiny dogfish, *Squalus acanthias* Linnaeus, on the east coast, South Island, New Zealand. *Journal of Fish Biology 39:* 313–323.

Hanchet, S M; Ingerson, J K V (1997) A summary of biology and commercial landings, and a stock assessment of spiny dogfish (*Squalus acanthias*). New Zealand Fisheries Assessment Research Document 1997/6. 32 p. (Unpublished document held by NIWA library, Wellington.)

Hartill, B; Davey, N (2015) Mean weight estimates for recreational fisheries in 2011–12. *New Zealand Fisheries Assessment Report 2015/25.* 37 p.

Livingston, M E; Bull, B; Stevens, D W; Bagley, N W (2002) A review of hoki and middle depths trawl surveys of the Chatham Rise, January 1992–2001. *NIWA Technical Report 113.* 146 p.

MacGibbon, D J (2019) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2019 (KAH1902) *New Zealand Fisheries Assessment Report 2019/64.* 87 p.

MacGibbon, D J; Beentjes, M P; Lyon, W L; Ladroit, Y (2019) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2018 (KAH1803). *New Zealand Fisheries Assessment Report 2019/03.* 136 p.

MacGibbon, D J; Walsh, C; Buckthought, D; Bian, R (2022) Inshore trawl survey off the west coast South Island and in Tasman Bay and Golden Bay, March–April 2021 (KAH2103). *New Zealand Fisheries Assessment Report 2022/11.* 97 p.

Manning, M J; Hanchet, S M; Stevenson, M L (2004) A description and analysis of New Zealand's spiny dogfish (*Squalus acanthias*) fisheries and recommendations on appropriate methods to monitor the status of the stocks. *New Zealand Fisheries Assessment Report 2004/61.* 135 p.

O'Driscoll, R L; Bagley, N W (2001) Review of summer and autumn trawl survey time series from the Southland and Sub-Antarctic areas, 1991–98. *NIWA Technical Report 102.* 115 p.

Palmer, G (1994) Spiny dogfish - pest or potential. *Seafood New Zealand,* March 1994. Pp 31–36.

Phillips, N L (2004) Length frequency distributions of spiny dogfish from the Chatham Rise, Sub-Antarctic, and the west coast South Island fisheries. *New Zealand Fisheries Assessment Report 2004/53.*

Stevens, D W; O'Driscoll, R L; Ballara, S L; Ladroit, Y (2017) Trawl survey of hoki and middle-depth species on the Chatham Rise, January 2016 (TAN1601). *New Zealand Fisheries Assessment Report 2017/08*. 131 p.

Stevens, D W; O'Driscoll, R L; Dunn, M R; Ballara, S L; Horn, P L (2012) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2011 (TAN1101). *New Zealand Fisheries Assessment Report 2012/10*. 98 p

Stevens, D W; O'Driscoll, R L; Ladroit, Y; Ballara, S L; MacGibbon, D J; Horn, P L (2015). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2014 (TAN1401). *New Zealand Fisheries Assessment Report 2015/19*. 119 p.

Stevens, D W; O'Driscoll, R L; Oeffner, J; Ballara, S L; Horn, P L (2014) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2013 (TAN1301). *New Zealand Fisheries Assessment Report 2014/02*. 110 p.

Stevenson, M L (2007) Inshore trawl survey of the west coast of the South Island and Tasman and Golden Bays, March–April 2007 (KAH0704). *New Zealand Fisheries Assessment Report 2007/41*.

Stevenson, M L; MacGibbon, D J (2018) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2017 (KAH1703) *New Zealand Fisheries Assessment Report 2018/18*. 92 p.

Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94 New Zealand. Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished document held by NIWA library, Wellington.)

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019) National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24*. 104 p.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.

SPRAT (SPR)

(*Sprattus antipodum, S. muelleri*)
Kupae

1. FISHERY SUMMARY

There are two species of sprats in New Zealand, *Sprattus antipodum* (slender sprat) and *S. muelleri* (stout sprat). They can be distinguished by body shape, colour, and some morphological features, but since they are very similar it is impractical to separate them in large catches.

Sprats were introduced into the QMS on 1 October 2002, with the allowances, TACCs and TACs shown in Table 1, which have not been changed since.

Table 1: Recreational and customary non-commercial allowances, TACCs and TACs for sprats by Fishstock.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other mortality	TACC	TAC
SPR 1	20	10	0	70	100
SPR 3	10	5	0	285	300
SPR 4	3	2	0	10	15
SPR 7	10	5	0	85	100
SPR 10	0	0	0	0	0

1.1 Commercial fisheries

The sprat "fishery" is minor and intermittent. There is no information on catches or landings of sprats prior to 1990, although occasional catches were made during exploratory fishing projects on small pelagic species, mainly in the 1960s and 1970s. Sprats have undoubtedly been caught in most years, but were either not reported, reported as "bait", or included in the category "mixed species". The name "sprat" is used in a general sense for several unrelated small fishes, and the juveniles of some larger species. This may have introduced errors into catch records. Reported landings since 1990 have ranged from less than 1 t to 7 t (Table 2); no landings were reported in 2017–18 and 2019-20, and < 1 t has been landed annually since 2004–05. The most consistent (but small) catches have been by bottom trawl. Reported landings by setnet and beach seine could be of true sprats, but may also be of yellow-eyed mullet (*Aldrichetta forsteri*), known colloquially as sprats. This is particularly likely in the upper North Island where the presence of sprats is considerably reduced or non-existent.

SPRAT (SPR)

Table 2: Reported landings (t) of sprat by Fishstock and fishing year. No catches reported for SPR 10, which has a TACC of 0.

FMA	SPR 1 1, 2, 8 & 9		SPR 3 3, 5 & 6		SPR 4 4		SPR 7 7		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1990–91†	3	-	< 1	-	0	-	< 1	-	3	-
1991–92†	1	-	0	-	0	-	0	-	1	-
1992–93†	< 1	-	< 1	-	0	-	0	-	< 1	-
1993–94†	< 1	-	< 1	-	0	-	< 1	-	1	-
1994–95†	< 1	-	< 1	-	0	-	< 1	-	1	-
1995–96†	< 1	-	6	-	0	-	< 1	-	7	-
1996–97†	< 1	-	1	-	0	-	< 1	-	1	-
1997–98†	< 1	-	< 1	-	0	-	< 1	-	< 1	-
1998–99†	2	-	< 1	-	0	-	< 1	-	4	-
1999–00†	< 1	-	< 1	-	0	-	1	-	2	-
2000–01†	< 1	-	< 1	-	0	-	< 1	-	< 1	-
2001–02	< 1	-	< 1	-	0	-	< 1	-	< 1	-
2002–03	< 1	70	< 1	285	0	10	0	85	< 1	450
2003–04	< 1	70	3	285	0	10	0	85	3	450
2004–05	< 1	70	0	285	0	10	0	85	< 1	450
2005–06	< 1	70	0	285	0	10	0	85	< 1	450
2006–07	< 1	70	< 1	285	0	10	0	85	< 1	450
2007–08	< 1	70	0	285	0	10	0	85	< 1	450
2008–09	< 1	70	< 1	285	0	10	< 1	85	1	450
2009–10	< 1	70	0	285	0	10	0	85	0	450
2010–11	< 1	70	0	285	0	10	0	85	< 1	450
2011–12	< 1	70	0	285	0	10	0	85	< 1	450
2012–13	< 1	70	< 1	285	0	10	< 1	85	< 1	450
2013–14	< 1	70	0	285	< 1	10	0	85	< 1	450
2014–15	< 1	70	< 1	285	0	10	< 1	85	< 1	450
2015–16	< 1	70	0	285	0	10	0	85	< 1	450
2016–17	0	70	< 1	285	0	10	< 1	85	< 1	450
2017–18	0	70	0	285	0	10	0	85	0	450
2018–19	< 1	70	0	285	0	10	0	85	< 1	450
2019–20	0	70	0	285	0	10	0	85	0	450
2020–21	0	70	< 1	285	0	10	0	85	< 1	450

† CELR

1.2 Recreational fisheries
There is no known recreational fishery, but small numbers are caught in small-mesh setnets and beach seines.

1.3 Customary non-commercial fisheries
Quantitative information on the current level of customary non-commercial take is not available.

1.4 Illegal catch
Estimates of illegal catch are not available, but are probably insignificant or nil.

1.5 Other sources of mortality
Some accidental captures of sprats by vessels purse seining for other small pelagic species may be discarded if no market is available.

2. BIOLOGY

Sprats occur in coastal waters from the Bay of Islands to Stewart Island, and are present at the Auckland Islands. It is not known whether the two species have different distributions. Sprats appear to be most abundant off the southeastern coast of the South Island, where anchovies are absent. Their vertical distribution within the water column is not known.

Spawning occurs in areas of reduced salinity when water temperatures are coolest 9–10.5 °C; there are consequently regional differences in spawning season with spawning peaks occurring between June and November (Taylor & Marriott 2004). The eggs are pelagic.

No reliable ageing work has been undertaken. Sprats are assumed to feed on zooplankton, and are preyed upon by larger fishes, seabirds, and marine mammals.

There have been no biological studies that are directly relevant to the recognition of separate stocks, or to yield estimates. Consequently no estimates of biological parameters are available. There is an extensive international literature base on sprats, mainly *Sprattus sprattus*, but the relevance of this to the New Zealand species is unknown.

3.   STOCKS AND AREAS

There is no biological information on which to make an assessment on whether separate stocks exist. However, there are two species, and their relative distributions are unknown. As presently understood, both species are more common around southern New Zealand. If their distributions do differ, and the biomass of each species fluctuates independently, there are unknown implications for localised stock depletion.

4.   STOCK ASSESSMENT

There have been no previous stock assessments of sprats. There have been two very general estimates of biomass in the Canterbury Bight region: 50 000 t (Robertson 1978), and 60 000 t (Colman 1979), with a possible yield of 10 000 t. No information on biomass variability is available.

4.1   Estimates of fishery parameters and abundance
No fishery parameters are available.

4.2   Biomass estimates
No estimates of biomass (B_0, B_{MSY}, or $B_{CURRENT}$) are available.

4.3   Yield estimates and projections

Estimation of Maximum Constant Yield (*MCY*)
MCY cannot be determined.

Estimation of Current Annual Yield (*CAY*)
Current biomass cannot be estimated, so *CAY* cannot be determined.

Other yield estimates and stock assessment results
No information is available.

4.4   Other factors
Data from some ichthyoplankton surveys show one or both sprat species to be locally abundant. However, it is unlikely that the biomass is comparable to the very large stocks in the northern hemisphere where there are large sprat fisheries.

It is not known whether the biomass of sprats is stable or variable, but the latter is considered more likely.

In some localities around the South Island, sprats are a major food source for many fishes, seabirds, and marine mammals. Excessive localised harvesting may disrupt ecosystems.

5.   STATUS OF THE STOCKS

No estimates of current biomass are available. At the present level of minimal catches, stocks are at or close to their natural level. This is nominally a virgin biomass, but not necessarily a stable one.

6.   FOR FURTHER INFORMATION

Baker, A N (1973) Spawning and development of the New Zealand sprat, *Sprattus antipodum* (Hector). Zoology Publications from Victoria University of Wellington No. 62. 12 p.

Colman, J A (1979) Spawning of the sprat, *Sprattus antipodum* (Hector), round the South Island of New Zealand. *New Zealand Journal of Marine and Freshwater Research* 13(2): 263–272.

Fenaughty, J M; Bagley, N W (1981) *W.J. Scott* New Zealand trawling survey: South Island east coast. *Fisheries Technical Report* No. 157. 224 p.

Morgans, J F C (1966) Possibilities raised by a study of the size distribution in a sample of a shoal of sprats, *Sprattus antipodum* (Hector). *Transactions of the Royal Society of New Zealand, Zoology* 8(13): 141–147.

Robertson, D A (1978) Blue mackerel, pilchard, anchovy, sprat, saury, and lanternfish. In Habib, G; Roberts, P E (Comps.) Proceedings of the Pelagic Fisheries Conference July 1977. pp. 85–89. Fisheries Research Division Occasional Publication No. 15.

Smith, P J; Robertson, D A (1981) Genetic evidence for two species of sprat (*Sprattus*) in New Zealand waters. *Marine Biology* 62(4): 227–233.

Taylor, P.R., Marriot, P.M. (2004) A summary of information on spawning of the small inshore pelagic species, anchovy (*Engraulis australis*), garfish (*Hyporhamphus ihi*), pilchard (*Sardinops sagax*), and sprat (*Sprattus antipodum* and *S. muelleri*), with a series of stock boundaries proposed for future testing. Draft New Zealand Fisheries Assessment Report 2004/xx. 33 p.

Whitehead, P J P; Smith, P J; Robertson, D A (1985) The two species of sprat in New Zealand waters (*Sprattus antipodum* and *S. muelleri*). *New Zealand Journal of Marine and Freshwater Research* 19(2): 261–271.

(*Kathetostoma giganteum*)
Pūwhara

1. FISHERY SUMMARY

1.1 Commercial fisheries

The code STA includes all species of the genus *Kathetostoma* (Uranoscopidae). Although giant (*K. giganteum*) and banded (*K. binigrasella*) stargazer are found off New Zealand, catches of banded stargazer are rarely found on trawl surveys around the country (D. MacGibbon, NIWA, pers. comm.), suggesting that > 99% of the commercial STA catch is giant stargazer.

Giant stargazer is a moderate-sized benthic teleost distributed widely in New Zealand waters. It is found on muddy and sandy substrates to depths of 500 m, but is most common between 50–300 m on the continental shelf around the South Island (Anderson et al 1998), where it supports a moderate-value commercial trawl fishery. It was incorporated into the QMS on 1 October 1997 and is managed as eight separate Quota Management Areas (QMAs) or Fishstocks: STA 1–5, 7–8, and 10.

It is caught by both directed fishing and as bycatch of fisheries targeting other species. The main target fishery is on the Stewart-Snares shelf west of Stewart Island (Statistical Areas 029–030). Other target fisheries exist off the west coast of the South Island (WCSI) and off Cape Campbell on the east coast of the South Island (ECSI). It is also caught by small domestic trawl vessels targeting red cod (*Pseudophycis bachus*), tarakihi (*Nemadactylus macropterus*), flatfishes (*Colistium* spp., *Peltorhamphus* spp., and *Rhombosolea* spp.), and scampi (*Metanephrops challengeri*) on the continental shelf throughout its range and by larger, foreign-licensed and New Zealand-chartered foreign vessels targeting barracouta (*Thyrsites atun*), jack mackerels (*Trachurus* spp.), and squid (*Nototodarus* spp.) in deeper waters, in particular on the western Chatham Rise and on the continental slope surrounding the Stewart-Snares shelf. Giant stargazer is an important bycatch of scampi fishing in STA 2–4. Catches by methods other than bottom trawling are minimal. Reported landings from 1979 to 1987–88 are given in Table 1. Reported landings for the main QMAs for 1931 to 1982 are given in Table 2.

STARGAZER (STA)

Table 1: Reported landings (t) of giant stargazer by vessel flag from 1979 to 1987–88.

Year	New Zealand		Foreign-licensed	Total	Year	New Zealand		Foreign-licensed	Total
	Domestic	Chartered				Domestic	Chartered		
1979*	387	155	159	701	1983–84†	1 463	525	360	2 348
1980*	723	–	–	723	1984–85†	1 027	321	178	1 526
1981*	1 010	314	84	1 408	1985–86†	1 304	386	142	1 832
1982*	902	340	283	1 526	1986–87†	1 126	379	63	1 568
1983*	1 189	329	465	1 983	1987–88†	839	331	26	1 196

*MAF data.   †FSU data.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	STA 1	STA 2	STA 3	STA 4	STA 5	STA 6	STA 7
1931–32	0	0	0	0	0	0	0
1932–33	0	0	0	0	0	0	0
1933–34	0	0	0	0	0	0	0
1934–35	0	0	0	0	0	0	0
1935–36	0	0	0	0	0	0	0
1936–37	0	0	0	0	0	0	0
1937–38	0	0	0	0	0	0	0
1938–39	0	0	0	0	0	0	0
1939–40	0	0	0	0	0	0	0
1940–41	0	0	0	0	0	0	0
1941–42	0	0	0	0	0	0	0
1942–43	0	0	0	0	0	0	0
1943–44	0	0	0	0	0	0	0
1944	0	0	0	0	0	0	0
1945	0	0	0	0	0	0	0
1946	0	0	0	0	0	0	0
1947	0	0	0	0	0	0	0
1948	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0
1950	0	1	0	0	0	0	0
1951	0	1	0	0	0	0	0
1952	0	8	0	0	0	1	1
1953	0	2	0	0	0	0	0
1954	0	7	0	0	0	1	1
1955	0	2	3	0	0	0	0
1956	0	12	4	0	0	2	2
1957	0	15	5	0	0	2	2
1958	0	25	11	0	0	4	3
1959	0	23	13	0	0	4	3
1960	0	18	17	0	0	4	2
1961	0	7	16	0	0	2	1
1962	0	6	22	0	5	2	1
1963	0	10	15	0	1	3	1
1964	0	9	22	0	0	3	1
1965	0	12	17	0	2	4	1
1966	0	12	31	0	27	4	2
1967	0	24	32	0	6	38	2
1968	0	28	32	0	7	24	3
1969	0	40	25	0	21	14	3
1970	0	42	80	0	124	78	2
1971	0	37	72	0	87	50	3
1972	0	30	71	0	70	41	2
1973	0	36	78	0	38	36	2
1974	0	31	73	7	128	29	3
1975	0	10	75	3	92	34	1
1976	0	26	99	10	348	54	2
1977	0	17	70	0	293	53	1
1978	0	29	72	8	268	61	2
1979	1	23	230	104	245	86	1
1980	3	28	331	57	467	132	1
1981	15	25	487	95	557	322	2
1982	4	22	565	89	500	270	3

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

The total landings between 1979 and 1986–87 were variable, ranging between 701 and 2348 t and averaging 1481 t per year. Different trends are apparent for domestic and foreign vessels. The domestic and chartered catch was relatively stable throughout the middle and later half of the series, which probably reflects the stability of effort in the red cod, tarakihi, flatfish, and barracouta fisheries at this time as well as better reporting compliance. However, landings by foreign-licensed vessels declined steadily from a high of 465 t in 1983 to a low of 26 t in 1986–87, probably reflecting the declining importance of foreign-licensed vessels in New Zealand's deepwater fisheries following the phasing-in of the QMS, which began in 1983 and which was fully implemented by 1986–87. Reported landings since 1983 by Fishstock are given in Table 3 and Figure 1 graphs the historical landings and TACC values for the main STA stocks. The total catches for 1986–87 and 1987–88 in Table 1 are less than those in Table 3 because of under-reporting to the FSU during those years.

After 1983, the catch began to increase rapidly, reaching 3426 t in 1990–91, and averaging about 3000 t thereafter. The increase in catch is due to a number of factors, including: (a) increased target fishing in Southland (STA 5); (b) the availability of more quota through the decisions of the Quota Appeal Authority; (c) better management of quotas by quota owners; (d) quota trading in STA 3, 4, 5, and 7; (e) changes in fishing patterns in the Canterbury Bight (STA 3) and the west coast of the South Island (STA 7); (f) a possible increase in abundance of stargazer in STA 7; and (g) increases in STA 3, 5, and 7 TACCs introduced under the Adaptive Management Programme (AMP) in the 1991–92 fishing year.

The Adaptive Management Programme (AMP) was a management regime within the QMS for data-poor New Zealand Fishstocks that were considered able to sustain increased exploitation. Under the AMP, quota owners collected additional data from the fishery (typically fine-scale catch and effort data and rudimentary, but necessary, biological data such as fish length and sex) in return for an increased TACC. Under the AMP, TACCs for five giant stargazer Fishstocks (STA 1–3, 5, and 7) were increased at the start of the 1991–92 fishing year, and a sixth (STA 8) was increased in 1993–94. However, the TACCs for Fishstocks STA 1–3, 5, and 8 reverted to their pre-AMP levels in 1997–98 following the removal of these Fishstocks from the AMP in July 1997 because of the failure of quota owners to meet the data-collection requirements of the AMP. Subsequently, landings in three of these Fishstocks (STA 1, 2, and 5) exceeded their reduced, post-AMP TACCs; although of these, STA 5 was the only one with a TACC greater than 40 t at this time. STA 3 and STA 7 were reviewed in 1998 and retained in the AMP until the end of the 2002–03 fishing year. The TACC in STA 7 was further increased to 997 t at the start of the 2002–03 fishing year with a TAC of 1000 t (which included a 2 t recreational and a 1 t customary allowance). STA 7 was reviewed again in 2007 (Starr et al 2007b) and retained in the AMP. In October 2010 the TACC was increased to 1042 t, increasing the TAC to 1072 t, and in October 2015 the TACC was further increased to 1122 t. STA 3 was reviewed in 2008 (Starr et al 2008) and retained at the existing TACC of 902 t, with customary and recreational allocations of 1 t and 2 t respectively, giving a total TAC of 905 t. All AMP programmes ended on 30 September 2009.

STA 5, STA 7, and STA 3 are the most important Fishstocks, in terms of the recorded landed catch, among the eight Fishstocks, with smaller contributions from STA 2 and STA 4. The STA 4 TACC is set at 2158 t, the highest among the eight STA Fishstocks, although landings are only a tenth of this level in most years and the TACC has never been approached or exceeded. Most of the STA 4 catch is caught as bycatch of fishing directed at other target species. A relatively high recorded landed catch in 1990–91 (790 t) was due to exploratory fishing for these target species which has since ceased. Landings exceeded 100 t in STA 2 from 1990–91 to 1992–93 due to the development of the scampi fishery in this FMA. Landings subsequently decreased and averaged just 16 t in 2010–11 to 2020–21. Landings in STA 8 have also been lower than the TACC throughout the time series.

Although the TACC in STA 7 was increased to 700 t in 1991–92 under the terms of the AMP, it was over-caught in nearly every subsequent fishing year up to 2002–03, when the TACC was further increased to 997 t. Landings reached a high of 1440 t in 2000–01, before dropping back to 800 t in 2001–02. These high recorded landings resulted mainly from the use of bycatch trades with barracouta and flatfish. With the removal of the bycatch trade system in October 2001, fishers faced the penalty of high deemed values for any over-catch, and this may have reduced the over-catch in

this Fishstock in the short term, although landings exceeded the TACC from 2004–05 until 2009–10. The TACC was increased in 2009 and again in 2015, and landings have increased with the TACC. With the exception of STA 1, landings in recent years have generally not exceeded TACCs.

Table 3: Reported landings (t) of giant stargazer by QMS Fishstock (QMA) from 1983 to present. TACCs from 1986–87 to present are also provided. * MAF data. [Continued on next page]

Fishstock FMA(s)	STA 1 1 & 9		STA 2 2		STA 3 3		STA 4 4		STA 5 5 & 6	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983*	8	–	34	–	540	–	168	–	843	–
1984*	5	–	24	–	588	–	143	–	1023	–
1985*	9	–	15	–	438	–	82	–	695	–
1986*	12	–	24	–	415	–	95	–	566	–
1986–87	10	20	31	30	644	560	72	2 000	738	1 060
1987–88	3	20	46	33	783	581	110	2 005	886	1 144
1988–89	3	20	41	37	675	591	134	2 005	1 215	1 173
1989–90	9	21	53	37	747	703	218	2 009	1 150	1 175
1990–91	8	21	125	37	674	734	790	2 014	1 061	1 239
1991–92	18	50	105	100	756	900	366	2 014	1 056	1 500
1992–93	19	50	115	101	811	901	231	2 014	1 247	1 500
1993–94	8	50	73	101	871	902	113	2 014	1 327	1 500
1994–95	10	50	74	101	829	902	223	2 014	1 216	1 525
1995–96	17	50	69	101	876	902	259	2 014	1 159	1 525
1996–97	22	50	77	101	817	902	149	2 014	977	1 525
1997–98	29	21	54	38	667	902	263	2 014	544	1 264
1998–99	27	21	46	38	641	902	137	2 014	1 145	1 264
1999–00	36	21	42	38	719	902	161	2 014	1 327	1 264
2000–01	26	21	45	38	960	902	233	2 014	1 439	1 264
2001–02	34	21	58	38	816	902	391	2 158	1 137	1 264
2002–03	31	21	41	38	863	902	308	2 158	967	1 264
2003–04	23	21	27	38	578	902	186	2 158	1 193	1 264
2004–05	27	21	28	38	646	902	366	2 158	1 282	1 264
2005–06	34	21	30	38	824	902	359	2 158	1 347	1 264
2006–07	22	21	31	38	719	902	292	2 158	1 359	1 264
2007–08	36	21	26	38	572	902	436	2 158	1 171	1 264
2008–09	35	21	22	38	574	902	139	2 158	1 137	1 264
2009–10	17	21	26	38	576	902	198	2 158	1 339	1 264
2010–11	21	21	19	38	570	902	134	2 158	1 235	1 264
2011–12	21	28	17	38	397	902	213	2 158	1 288	1 264
2012–13	19	21	13	38	439	902	133	2 158	1 140	1 264
2013–14	20	21	14	38	499	902	133	2 158	1 274	1 264
2014–15	12	21	10	38	497	902	172	2 158	1 144	1 264
2015–16	10	21	11	38	490	902	115	2 158	1 264	1 264
2016–17	19	21	12	38	543	902	99	2 158	992	1 264
2017–18	25	21	18	38	669	902	108	2 158	1 151	1 264
2018–19	26	21	17	38	601	902	122	2 158	938	1 264
2019–20	27	21	14	38	559	902	108	2 158	939	1 264
2020–21	18	21	31	38	578	902	116	2 158	1 007	1 264

Fishstock FMA(s)	STA 7 7		STA 8 8		STA 10 10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983*	323	–	3	–	0	–	1 919	–
1984*	444	–	3	–	0	–	2 230	–
1985*	328	–	4	–	0	–	1 571	–
1986*	362	–	3	–	0	–	1 477	–
1986–87	487	450	7	20	0	10	1 990	4 150
1987–88	505	493	5	20	0	10	2 338	4 306
1988–89	520	499	5	20	0	10	2 593	4 355
1989–90	585	525	1	22	0	10	2 763	4 502
1990–91	762	528	6	22	0	10	3 426	4 605
1991–92	920	700	18	22	0	10	3 239	5 296
1992–93	861	702	5	22	0	10	3 289	5 300
1993–94	715	702	4	50	0	10	3 111	5 329
1994–95	730	702	7	50	0	10	3 089	5 354
1995–96	877	702	4	50	0	10	3 261	5 354
1996–97	983	702	10	50	0	10	3 034	5 354
1997–98	564	702	10	22	0	10	2 132	4 973
1998–99	949	702	2	22	0	10	2 946	4 973
1999–00	1 184	702	3	22	0	10	3 472	4 973
2000–01	1 440	702	4	22	0	10	4 146	4 973
2001–02	802	702	4	22	0	10	3 238	5 117
2002–03	957	997	4	22	0	10	3 171	5 412
2003–04	934	997	6	22	0	10	2 947	5 412
2004–05	1 028	997	5	22	0	10	3 381	5 412
2005–06	1 010	997	3	22	0	10	3 606	5 412
2006–07	1 051	997	4	22	0	10	3 478	5 412

Table 3 [Continued]

Fishstock FMA(s)	STA 7 7		STA 8 8		STA 10 10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2007–08	1 014	997	3	22	0	10	3 258	5 412
2008–09	1 001	997	5	22	0	10	2 913	5 412
2009–10	1 093	997	6	22	0	10	3 247	5 456
2010–11	1 037	1 042	7	22	0	10	3 023	5 456
2011–12	1 056	1 042	7	22	0	10	3 006	5 456
2012–13	1 097	1 042	7	22	0	10	2 849	5 456
2013–14	1 062	1 042	6	22	0	10	3 007	5 456
2014–15	1 093	1 042	5	22	0	10	2 933	5 456
2015–16	1 132	1 122	5	22	0	10	3 027	5 536
2016–17	1 114	1 122	3	22	0	10	2 782	5 536
2017–18	1 030	1 122	4	22	0	10	3 004	5 536
2018–19	1 131	1 122	5	22	0	10	2 840	5 536
2019–20	1 088	1 122	3	22	0	10	2 738	5 536
2020–21	1 093	1 208	3	22	0	10	2 846	5 622
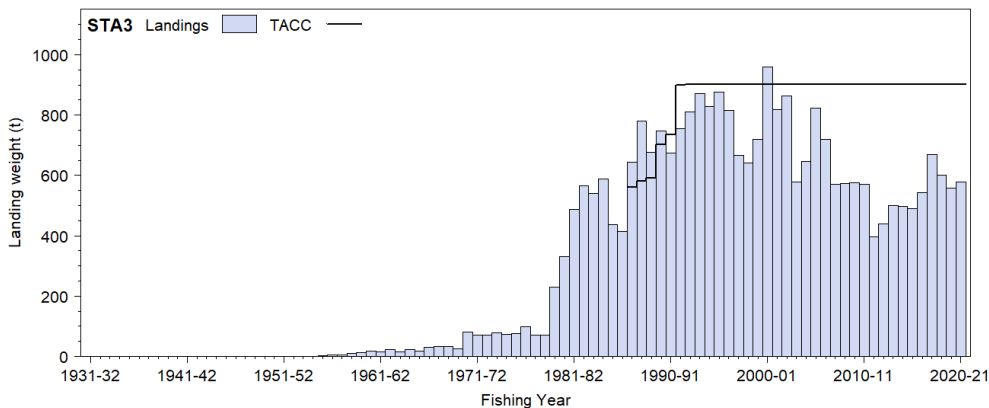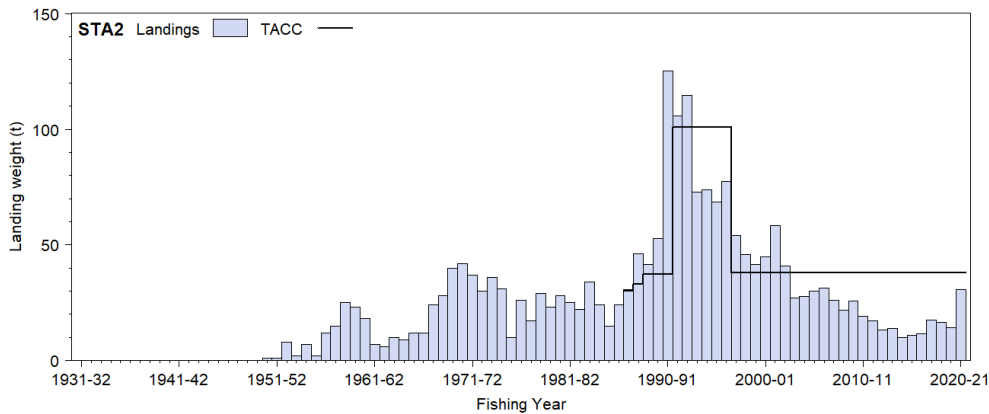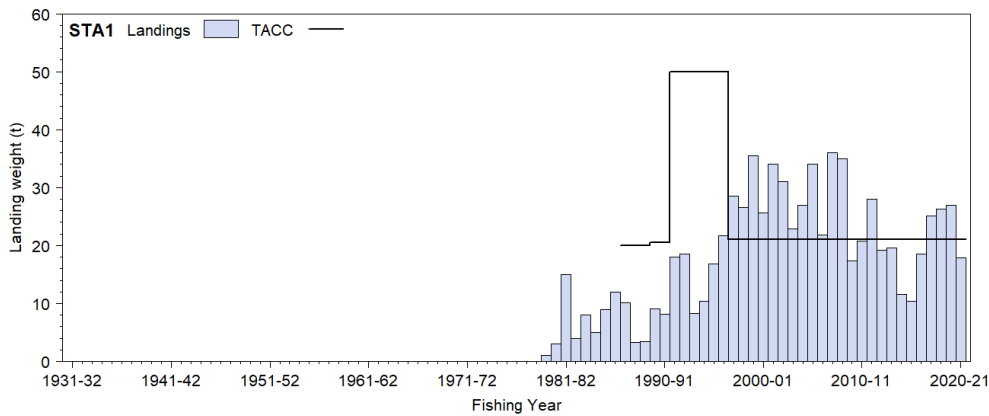
Figure 1: Reported commercial landings and TACC for the seven main STA stocks. From top to bottom: STA 1 (Auckland East), STA 2 (Central East), and STA 3 (South East Coast). [Continued on next page]
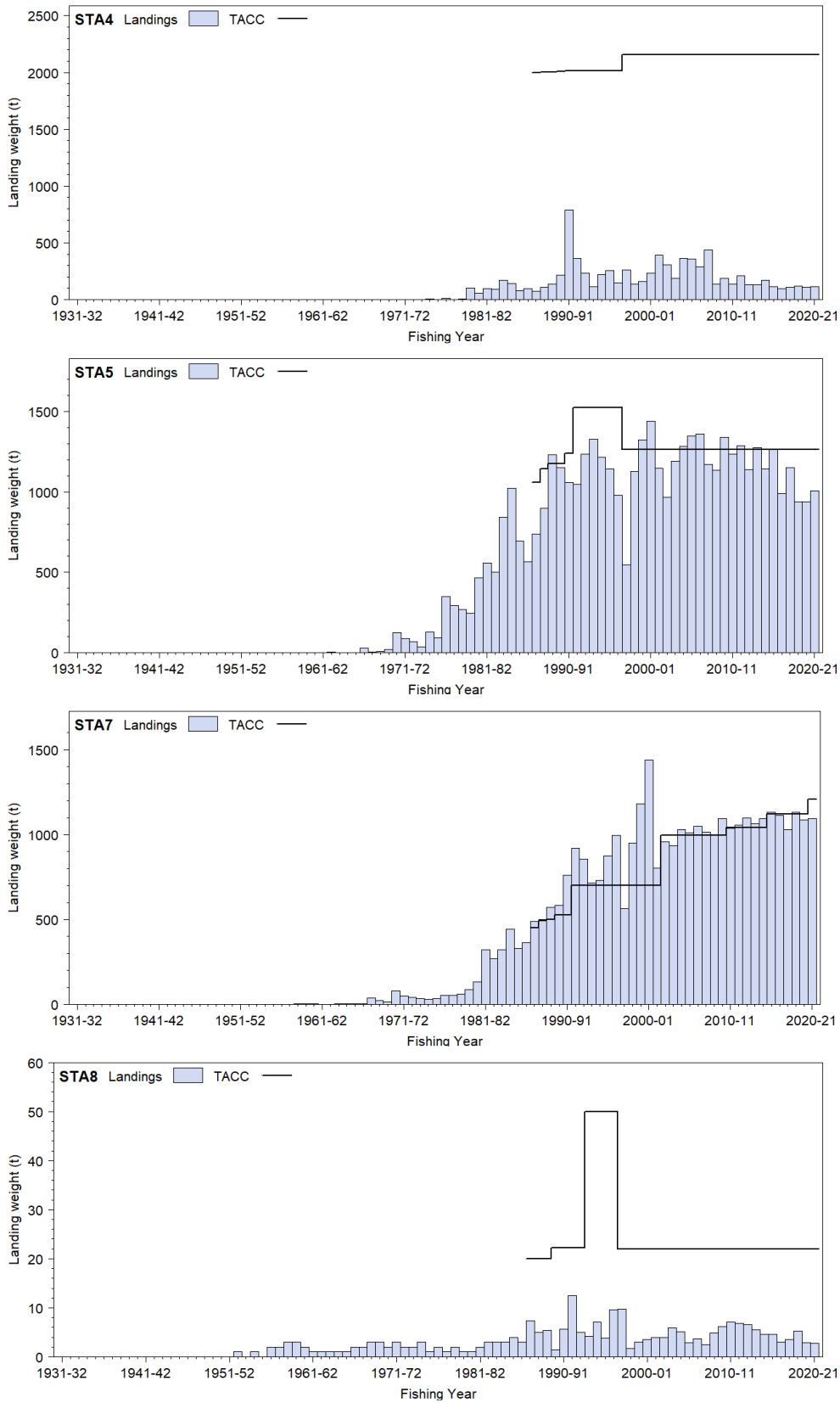
Figure 1 [Continued]: Reported commercial landings and TACC for the seven main STA stocks. From top to bottom: STA 4 (Chatham Rise), STA 5 (Southland), STA 7 (Challenger), and STA 8 (Central Egmont).

Most of the stargazer catch is landed in a processed state. The conversion factors for giant stargazer were revised during the early 1990s to determine a conversion factor that was consistent with the main processed state (DVC). Recent analyses of catch and effort data from the STA 5 and STA 7 fisheries have taken these changes in the conversion factors into account in determining the landed catch (in greenweight). For STA 5, the correction for the changes in the conversion factors resulted in an increase (9–34%) in the annual landed catch from 1989–90 to 1996–97 (Langley & Bentley 2014). Similarly, for STA 7 the correction resulted in an increase (17–37%) in the annual landed catches from 1989–90 to 1996–97 (Langley 2015). These changes in conversion factor have not been applied to the total reported landings from the stargazer Fishstocks in Tables 1 and 2 and Figure 1.

The landings data (Tables 1–3) probably include an unknown quantity of catch from other uranoscopid species misidentified as *K. giganteum*. Fishers in STA 1–3 and 8 have been known to report brown (*Gnathagnus innotabilis*) and spotted stargazer (*Genyagnus monopterygius*) as *K. giganteum* in the past. Landings in STA 4 and 5 probably include an unknown amount of banded stargazer (*Kathetostoma binigrazella*). Although the true extent of misreporting due to misidentification is unknown, it is likely to be small.

1.2   Recreational fisheries

Stargazer were not reported as being caught by recreational fishers in surveys conducted in the MAF Fisheries South region in 1991–92, Central region in 1992–93, and North region in 1993–94. In a national survey in 1996, a few giant stargazer were reported in STA 1 and 3, with an estimated take of 1000 fish in STA 1 and less than 500 fish taken in STA 3 (Bradford 1998). No giant stargazer catch was recorded for the recreational fishers during the 1999–2000 national diary survey (Boyd & Reilly 2004). In the 2011–12 national panel survey (Wynne-Jones et al 2014), only four fishers reported catching stargazer and the estimated catches were 53 fish in STA 1 (CV = 100%) and 481 fish in STA 7 (CV = 71%). In the 2017–18 national panel survey (Wynne-Jones et al 2019), again only four fishers reported catching stargazer and the estimated catches were 156 fish in STA 1 (CV = 58%) and 399 fish in STA 7 (CV = 100%). Recreational catch thus appears to be negligible.

1.3   Customary non-commercial fisheries

No quantitative information is available on the level of customary non-commercial take.

1.4   Illegal catch

No quantitative information is available on the level of illegal catch.

1.5   Other sources of mortality

No quantitative information is available on the level of other sources of mortality.

2.   BIOLOGY

Giant stargazer is found throughout the New Zealand EEZ. It is most plentiful around the South Island (STA 3, 5, & 7) and on the Mernoo Bank on the Chatham Rise (STA 4).

Using data collected from the West Coast South Island trawl survey series (Drummond & Stevenson 1995a, 1995b, 1996, Stevenson 1998, Stevenson & Hanchet 2000, Stevenson 2002, 2004), Manning (2008) found that giant stargazer reach sexual maturity at a length of about 40–55 cm in total length (TL), depending on sex, at an age of between 5–7 years. Age and growth studies suggest that some individuals reach a maximum age of at least 25 years (Sutton 1999, Manning & Sutton 2004, Sutton 2004, Manning & Sutton 2007a, 2007b). Otolith growth zones have not been validated. A number of attempts at growth zone validation have been undertaken unsuccessfully. A tag and release programme was initiated with all released fish being injected with oxytetracycline as part of the East Coast South Island trawl survey. A single fish has been recaptured but the otoliths were not recovered. Andrews (2009) investigated the feasibility of using lead-radium dating of otoliths as a means of validating age. However, the levels of radium-226 in stargazer otoliths were too low (nearly 10 times lower than expected) to generate meaningful results. Using maximum-likelihood methods, Manning & Sutton (2004) found that giant stargazer growth differs significantly between the east, south, and

west coasts of the South Island. They suggested that these differences represented different biological stock units in these areas, although the true stock structure is unclear (Tate 1987). Manning (2005) investigated the effect of assuming alternative growth models with different functional forms on the data and conclusions presented by Manning & Sutton (2004). His results were consistent with the earlier results.

M was estimated using the equation $M = \ln 100 / t_{max}$, where t_{max} is the maximum age to which 1% of the population survives in an unexploited stock. Using an unvalidated maximum age of 26 years, yields $M = 0.18$. Preliminary results of the STA 7 quantitative stock assessment (Manning 2008) suggested 0.18 was an underestimate of the unknown true value. A revised estimate based on applying Hoenig's (1983) regression to the age composition data from the West Coast South Island survey series suggested that a value of 0.23 is more reasonable (Manning 2008). Although the West Coast South Island age composition data were collected from an exploited stock, 0.23 is considered to be closer to the true value than 0.18.

Stargazer have an annual reproductive cycle with a winter spawning season. Spawning probably occurs in mid and outer shelf waters all around New Zealand. The generalised spawning date assumed in the age and growth studies cited above is 1 July in any given calendar year.

Biological parameters relevant to the stock assessment are given in Table 4.

Table 4: Estimates of giant stargazer biological parameters

Fishstock					Estimate		Source
1. Natural mortality (*M*).							
STA 5					0.20		Sutton (2004)
STA 7					0.18		Manning & Sutton (2007a)

2. Weight = a(length)^b (Weight in g, length in cm fork length).

	Females		Males		All fish		
	a	*b*	*a*	*b*	*a*	*b*	
STA 3	-	-	-	-	0.015	3.01	McClatchie (uppub.data)
STA 5	-	-	-	-	0.024	2.92	McGregor (unpub. data)
STA 7	0.018	2.97	0.013	3.07	-	-	Manning & Sutton (2007a)

3. Length at maturity (cm total length).

	Females		Males		
	L_{50}	L_{95}	L_{50}	L_{95}	
STA 7	54.37	11.24	40.98	14.90	Manning (2008)

4. Age at maturity (years).

	Females		Males		
	A_{50}	A_{95}	A_{50}	A_{95}	
STA 7	7.23	4.34	5.53	4.38	Manning (2008)

5. von Bertalanffy length-at-age model parameter estimates.

	Females			Males			
	L_∞	K (yr^{-1})	t_0 (yr)	L_∞	K (yr^{-1})	t_0 (yr)	
STA 3	78.11	0.14	-1.25	61.49	0.2	-0.97	Sutton (1999)
STA 5	73.92	0.18	-0.22	59.12	0.19	-1.19	Sutton (1999)
STA 5	72.61	0.17	-0.02	60.76	0.18	-1.16	Sutton (2004)
STA 7	85.74	0.13	-0.666	71.00	0.15	-0.664	Manning & Sutton (2007a); a revision of earlier results presented by Manning & Sutton (2004)

3.   STOCKS AND AREAS

There are no new data that would alter the stock boundaries given in previous assessment documents. It is not known if there is more than one giant stargazer stock in New Zealand. The present QMAs were used as a basis for Fishstocks, except for QMAs 5 and 6, which were combined (STA 5). The basis for choosing these boundaries was a general review of the distribution and relative abundance of stargazer within the fishery.

As noted, length-at-age differs significantly between the east, south, and west coasts of the South Island (Manning & Sutton 2004, Manning 2005). This is consistent with the Fishstock boundaries.

4.   STOCK ASSESSMENT

An integrated assessment for STA 7 was updated in 2008 with data that included the commercial catch, trawl survey biomass and proportions-at-age estimates, and commercial catch proportions-at-age.

4.1   Trawl surveys

4.1.1   Relative biomass
Indices of relative biomass are available from recent *Tangaroa* and *Kaharoa* trawl surveys of the Chatham Rise, east coast South Island, and west coast South Island (Table 5, Figures 2–3).

Chatham Rise Trawl Survey
The Chatham Rise Trawl Survey was designed primarily for hoki and covers the depth range 200–400 m. It therefore excludes stargazer habitat around the Mernoo Bank in less than 200 m and is not considered a reliable index of abundance for STA 4.

West Coast South Island (WCSI) Inshore Trawl Survey
Biomass estimates for the WCSI Inshore Trawl Survey time series are presented in Figure 2. The biomass time series was fairly constant for the first four surveys but declined in 2000 and again in 2003 to a low of 834 t. The biomass steadily increased after that with the highest estimate (2118 t) in 2013. From 2005, the biomass remained between 1500 and 2000 t until 2021, when it declined to the second lowest estimate in the time series at 985 t. Most biomass has come from the west coast South Island region, with little contribution from Tasman Bay and Golden Bay. In 2021, no giant stargazer were caught in Tasman Bay and Golden Bay, a first in the time series.

Most trawl stations capture stargazer, but strata in 100–200 m and south of Cape Foulwind contribute most of the total biomass. Throughout the time series, most of the biomass has comprised adult fish with females contributing the majority of the adult biomass. Most of the juvenile biomass consists of male fish.

Most fish are between 40 and 70 cm, and virtually all are between 10 and 70 cm. Few fish under 45 cm were caught on the 2021 survey compared with previous surveys. Only three surveys have caught fewer fish under 45 cm: 1992, 1994, and 2003. In Tasman Bay and Golden Bay, fish typically have been small, under 45 cm, and adults were rarely caught, but no fish were caught in 2021. There are often what appear to be small modes at 20–25 cm and 25–30 cm, but these are not thought to contain discrete year classes, rather they include fish aged 1–2 and 1–3 years, respectively (Manning & Sutton 2007a). Few fish over 40 cm are caught in Tasman Bay and Golden Bay.

East Coast South Island (ECSI) Trawl Survey (STA 3)
The ECSI winter surveys from 1991 to 1996 in 30–400 m were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range, but these were discontinued after the fifth in the annual time series because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007 and this time included additional 10–30 m strata in an attempt to index elephantfish and red gurnard which were officially included in the list of target species in 2012. Only six surveys (2007, 2012, 2014, 2016, 2018, and 2021) provide full coverage of the 10–30 m depth range.

Giant stargazer biomass showed peaks in 2007 and 2014, but no overall trend. The 2021 biomass estimate was the highest in the time series and 48% higher than the previous estimate in 2018 (Table 5, Figure 3) (Beentjes et al in prep.). Pre-recruited biomass (< 30 cm) has been a small but consistent component of the total biomass estimate on all surveys (range 2–9% of total biomass) and was 9% in 2021, the highest of the time series. The juvenile to adult biomass ratio (based on length-at-50% maturity) was relatively constant over the time series at about 1 to 1, and in 2021 biomass was 44% juvenile fish.

The distribution of giant stargazer hotspots varies between years, but overall this species is consistently well represented over the entire survey area (occurs in 71–92% of core strata tows), most

commonly from 30 m to about 200 m. None were caught in 10–30 m on any of the six surveys and hence the addition of the shallow strata (10–30 m) is of no importance for monitoring giant stargazer.

The size distributions of giant stargazer in each of the 13 core strata surveys were similar and generally had one large mode comprising multiple age classes and, in some years, a small juvenile mode. The 2016 survey appeared to have a relatively abundant mode from 15 to 25 cm which tracked through to 2018. The 2021 survey showed good representation of both juvenile and adult fish, commensurate with the high biomass estimate. Giant stargazer sampled on these ECSI surveys are generally smaller than those from the Chatham Rise, Southland, and WCSI inshore surveys (Bagley & Hurst 1996a, Stevenson & Hanchet 2000, Livingston et al 2002, Stevens et al 2015, Stevenson & MacGibbon 2018), suggesting that this area may be an important nursery ground for juvenile giant stargazer.
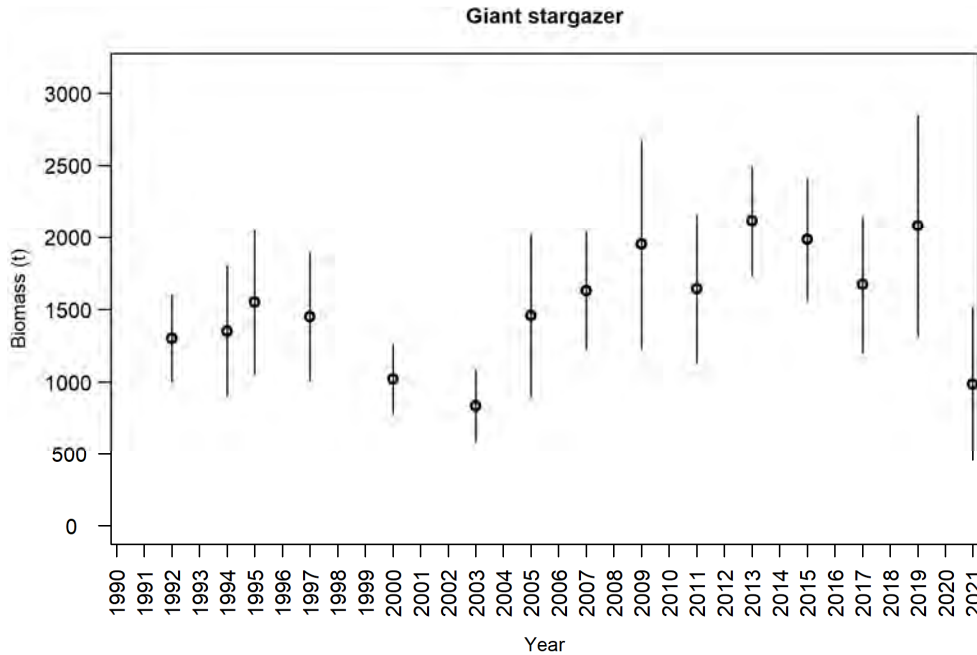
Figure 2: Giant stargazer biomass estimates for the West Coast South Island Inshore Trawl Survey time series. Error bars are ± two standard deviations.
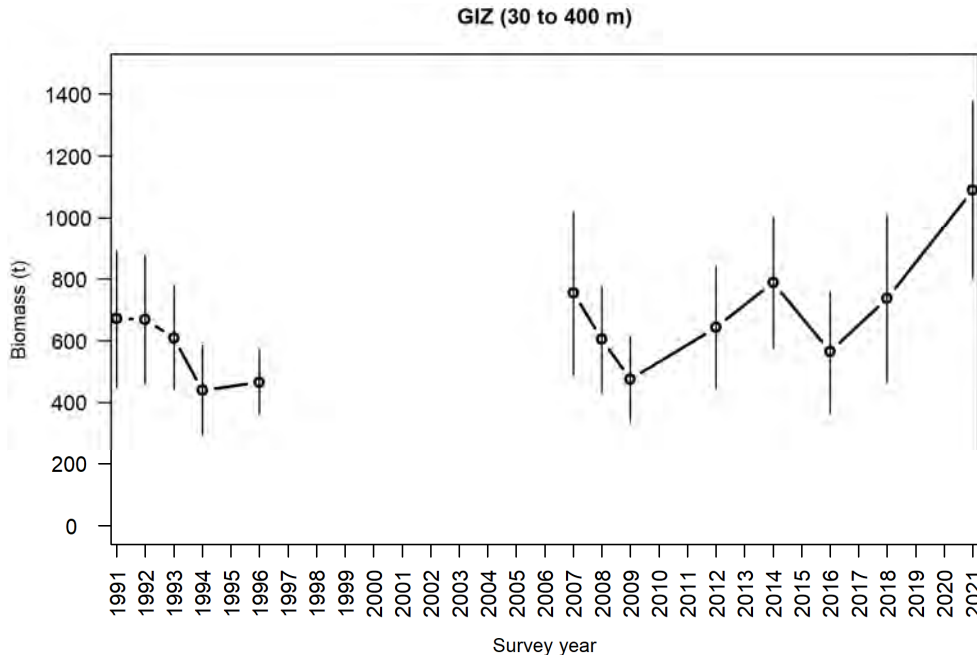
Figure 3:   Giant stargazer (GIZ) total biomass for all ECSI winter surveys in core strata (30–400 m). Error bars are ± two standard deviations.

Table 5: Relative biomass indices (t) and coefficients of variation (CV) for giant stargazer for the East Coast North Island (ECNI), East Coast South Island (ECSI) — summer and winter, Chatham Rise, West Coast South Island (WCSI), and the Stewart Island-Snares Island survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16, & 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. –, not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (30 cm).

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
ECNI (inshore)	STA 2	1993	KAH9304	184	22	–	–	–	–	–	–	–	–	–	–
		1994	KAH9402	58	47	–	–	–	–	–	–	–	–	–	–
		1995	KAH9502	44	35	–	–	–	–	–	–	–	–	–	–
		1996	KAH9602	57	17	–	–	–	–	–	–	–	–	–	–
ECNI (scampi)	STA 2	1993	KAH9301	250	16	–	–	–	–	–	–	–	–	–	–
		1994	KAH9401	215	20	–	–	–	–	–	–	–	–	–	–
		1995	KAH9501	122	17	–	–	–	–	–	–	–	–	–	–
				30–400m		10–400m		30–400m		10–400m		30–400m		10–400m	
ECSI (winter)	STA 3	1991	KAH9105	672	17	–	–	26	22	–	–	646	17	–	–
		1992	KAH9205	669	16	–	–	35	14	–	–	634	16	–	–
		1993	KAH9306	609	14	–	–	19	16	–	–	591	14	–	–
		1994	KAH9406	439	17	–	–	10	25	–	–	429	17	–	–
		1996	KAH9606	466	11	–	–	13	34	–	–	452	11	–	–
		2007	KAH0705	755	18	–	–	33	24	–	–	722	18	–	–
		2008	KAH0806	606	14	–	–	13	28	–	–	592	14	–	–
		2009	KAH0905	475	14	–	–	10	34	–	–	464	15	–	–
		2012	KAH1207	643	16	–	–	26	22	–	–	617	16	–	–
		2014	KAH1402	790	14	–	–	39	17	–	–	751	14	–	–
		2016	KAH1605	565	17	–	–	22	24	–	–	543	18	–	–
		2018	KAH1803	738	18	–	–	53	33	–	–	685	18	–	–
		2021	KAH2104	1 090	13			95	20			996	14		
ECSI (summer)	STA 3	1996	KAH9618	897	12	–	–	–	–	–	–	–	–	–	–
		1997	KAH9704	543	11	–	–	–	–	–	–	–	–	–	–
		1998	KAH9809	999	10	–	–	–	–	–	–	–	–	–	–
		1999	KAH9917	472	14	–	–	–	–	–	–	–	–	–	–
		2000	KAH0014	214	16	–	–	–	–	–	–	–	–	–	–
Chatham Rise	STA 4	1992	TAN9106	2 570	11	–	–	–	–	–	–	–	–	–	–
		1993	TAN9212	2 560	13	–	–	–	–	–	–	–	–	–	–
		1994	TAN9401	2 853	12	–	–	–	–	–	–	–	–	–	–
		1995	TAN9501	1 429	13	–	–	–	–	–	–	–	–	–	–
		1996	TAN9601	3 039	16	–	–	–	–	–	–	–	–	–	–
		1997	TAN9701	2 328	15	–	–	–	–	–	–	–	–	–	–
		1998	TAN9801	1 702	14	–	–	–	–	–	–	–	–	–	–
		1999	TAN9901	1 903	13	–	–	–	–	–	–	–	–	–	–
		2000	TAN0001	2 148	13	–	–	–	–	–	–	–	–	–	–
		2001	TAN0101	1 772	16	–	–	–	–	–	–	–	–	–	–

*Assuming areal availability, vertical availability and vulnerability equal 1.0. Biomass is only estimated outside 10 m depth. Note: because trawl survey biomass estimates are indices, comparisons between different seasons (e.g., summer and winter ECSI) are not strictly valid.

Table 5 **[continued]: Relative biomass indices (t) and coefficients of variation (CV) for giant stargazer for the East Coast North Island (ECNI), East Coast South Island (ECSI) - summer and winter, Chatham Rise, West Coast South Island (WCSI), and the Stewart Island-Snares Island survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16, & 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. –, not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (30 cm). Note: WCSI total biomass estimates are updated (P. Starr pers. comm.) to match the values given for GIZ in table 4, MacGibbon (2019).**

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)
Chatham Rise	STA 4	2002	TAN0201	2 195	16	–	–	–	–	–	–
		2003	TAN0301	1 380	15	–	–	–	–	–	–
		2005	TAN0501	3 045	13	–	–	–	–	–	–
		2006	TAN0601	2 007	19	–	–	–	–	–	–
		2007	TAN0701	1 684	12	–	–	–	–	–	–
		2008	TAN0801	4 677	40	–	–	–	–	–	–
		2009	TAN0901	3 154	24	–	–	–	–	–	–
		2010	TAN1001	1 140	17	–	–	–	–	–	–
		2011	TAN1101	3 169	28	–	–	–	–	–	–
		2012	TAN1201	1 751	13	–	–	–	–	–	–
		2013	TAN1301	2 108	34	–	–	–	–	–	–
		2014	TAN1401	1 601	17						
		2016	TAN1601	2 228	17						
WCSI	STA 7	1992	KAH9204	1 450	14			–	–	–	–
		1994	KAH9404	1 358	17			–	–	–	–
		1995	KAH9504	1 556	16			–	–	–	–
		1997	KAH9701	1 450	15			–	–	–	–
		2000	KAH0004	1 023	12			–	–	–	–
		2003	KAH0304	834	15			–	–	–	–
		2005	KAH0503	1 458	19			–	–	–	–
		2007	KAH0704	1 630	13			–	–	–	–
		2009	KAH0904	1 952	19			–	–	–	–
		2011	KAH1104	1 620	16			–	–	–	–
		2013	KAH1305	2 118	9			–	–	–	–
		2015	KAH1503	1 984	11			–	–	–	–
		2017	KAH1703	1 674	14			–	–	–	–
		2019	KAH1902	2 081	18			–	–	–	–
		2021	KAH2103	985	27			–	–	–	–
Stewart & Snares	STA 5	1993	TAN9301	2 650	20	–	–	–	–	–	–
		1994	TAN9402	3 755	11	–	–	–	–	–	–
		1995	TAN9502	2 452	11	–	–	–	–	–	–
		1996	TAN9604	1 733	11						
Stewart & Snares	Banded Stargazer BGZ 5	1993	TAN9301	409	27	–	–	–	–	–	–
		1994	TAN9402	250	21	–	–	–	–	–	–
		1995	TAN9502	316	29	–	–	–	–	–	–
		1996	TAN9604	232	34	–	–	–	–	–	–

4.2   CPUE analysis

STA 2 and 3

CPUE indices have been calculated for STA 2 (Vignaux 1997) and STA 3 (SEFMC 2002, SeaFIC 2005a, Starr et al 2008). The currently accepted CPUE series for STA 3 (Figure 4) is based on a mixed target species fishery including red cod, barracouta, tarakihi, and stargazer and shows no trend from about 2000–01 to the most recent year in 2006–07 (Starr et al 2008).
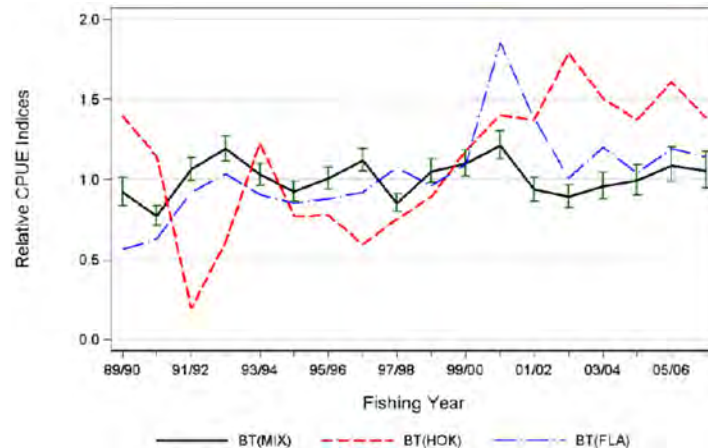
Figure 4: Comparison of the lognormal indices from the three bottom trawl CPUE series for STA 3; a) BT(MIX): mixed species target trawl fishery; b) BT(HOK): hoki target trawl fishery; c) BT(FLA): target flatfish trawl fishery. Each series is scaled to the geometric mean = 1 (Starr et al 2008).

STA 5

About 80% of the STA 5 catch is caught by small (< 43 m) inshore bottom trawl vessels targeting giant stargazer. The remainder of the catch is caught mostly by large ($\geq$ 43 m) deepwater bottom trawl vessels targeting other species such as barracouta, jack mackerels, and squids. Catches by methods other than bottom trawling are very small.

Standardised CPUE indices currently represent the only available information for monitoring STA 5 abundance. There have been previous analyses of the CPUE data from this fishery by Vignaux (1997), Phillips (2001), and Manning (2007). In 2014, a new CPUE analysis was conducted that included catch and effort data from the inshore target stargazer trawl fleet operating in Statistical Areas 030, 029, and 025 during 1989–90 to 2012–13.

Data processing was similar to the approach of Manning (2007), whereby the declared landed catches were corrected for changes in the conversion factor of giant stargazer during the early 1990s. Landed catches from individual fishing trips were apportioned to the associated fishing effort records in proportion to the reported estimated catch of giant stargazer. An attempt to replicate the analysis of Manning (2007) yielded comparable CPUE indices for the 1989–90 to 2003–04 period.

Changes in statutory reporting in 2007–08 (from CELR to TCER forms) required that the more recent, location based TCER trawl effort data be aggregated into a format consistent with the CELR data format to configure a comparable times series. The aggregation procedure is described in detail by Langley & Bentley (2014). The final CPUE data set was limited to a core set of 14 vessels that accounted for 80% of the total target stargazer catch. One of the main vessels changed fishing gear from single trawl to a twin rig trawl in the mid-2000s and, on that basis, was assigned to a different vessel category depending on the fishing gear deployed.

The final CPUE data set included a trivial number of zero stargazer catches and those records were ignored in the final analysis. A generalised linear model, based on positive catch and effort targeted at stargazer, was formulated using an AIC based step-wise fitting procedure and investigated a number of alternative distributional assumptions. The final model included the natural logarithm of catch as the dependent variable; fishing year, vessel, and month as categorical predictor variables; and the effort variables: natural log of the number of trawls and fishing duration, included as third order

polynomial functions. The Weibull error distribution was accepted as the most suitable of those which were investigated (Langley & Bentley 2014).

In 2017, the CPUE model was updated to include three additional years: 2013–14 to 2015–16 (Langley 2017). The updated CPUE indices were virtually identical to the previous CPUE indices for the corresponding period, i.e., 1989–90 to 2012–13. The CPUE indices from the model have fluctuated without trend with peaks in 1991–92 to 1993–94 and 2006–07 to 2009–08 (Figure 5). The 2013–14 to 2015–16 indices are slightly below the average for the series. CPUE indices were also derived from the short time series of high resolution TCER data from 2007–08 to 2015–16. These indices had a similar trend to the corresponding annual indices from the primary CPUE model (Figure 5).
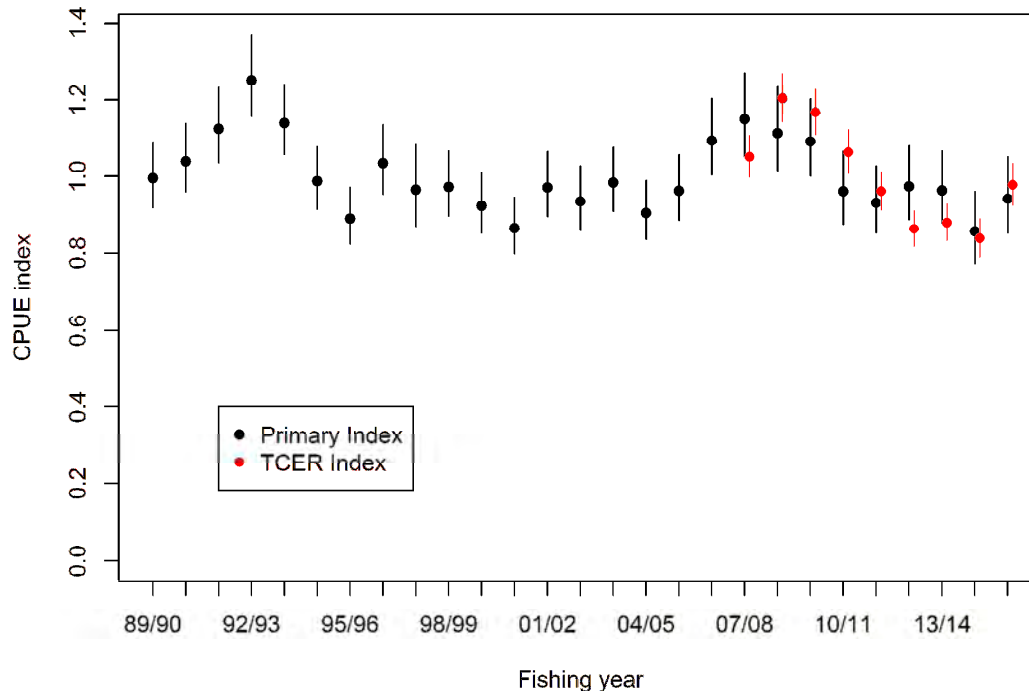
Figure 5: A comparison of STA 5 CPUE indices from the base model and indices derived from the high resolution, location based TCER data and the associated 95% confidence intervals.

Establishing B_{MSY} compatible reference points
In 2014, the Southern Inshore Working Group (SINSWG) accepted mean standardised CPUE for the period 1989–90 to 2012–13 as a B_{MSY}-compatible proxy for STA 5. The working group accepted the default Harvest Strategy Standard definitions that the Soft and Hard Limits would be one half and one quarter the target, respectively.

STA 7
A CPUE series calculated for STA 7 (SeaFIC 2002, 2003b, 2005b, Starr et al 2007b), based on a mixed west coast South Island target species fishery (stargazer, barracouta, red cod, and tarakihi), was not accepted by the AMP WG as an indicator of STA 7 abundance. The Southern Inshore and AMP Fishery Assessment Working Groups had concerns about using bycatch fisheries to monitor stargazer abundance in these areas due to possible changes in recording and fishing practices. A characterisation of the STA 7 fishery, including detailed trawl location data, identified a number of areas of higher stargazer abundance along the WCSI and it was speculated that the previous trends in STA 7 CPUE could have been influenced by the extent of fishing in these localised areas (Langley 2015). The SINSWG reaffirmed the previous conclusions regarding the utility of the aggregated (CELR based) CPUE time series.

An additional time series of CPUE indices was derived from the detailed trawl location data set. The data set included trawl records from bottom trawl fishing effort targeting barracouta, tarakihi, blue

warehou, stargazer, or red cod in the WCSI inshore trawl fishery (Langley 2015) from 2007–08 to 2012–13. The standardised CPUE analysis included both positive catch and presence/absence models that incorporated fishing location and fishing depth variables. The resulting Combined indices were relatively stable, increasing slightly (5–8%) over the 6 year period (Table 6). The trawl survey biomass indices were also relatively stable over that period. The SINSWG concluded that the trawl location based CPUE indices have potential to monitor the relative abundance of STA 7; however, the utility of the CPUE indices can only be evaluated once a longer time series of CPUE indices are available for comparison with the relative abundance indices from the WCSI trawl survey.

Table 6: Annual combined STA 7 trawl location based CPUE indices, including the lower and upper bounds of the confidence intervals.

Fishing year	Index	LCI	UCI
2007–08	0.969	0.909	1.025
2008–09	0.956	0.905	1.010
2009–10	1.029	0.975	1.087
2010–11	0.982	0.926	1.037
2011–12	1.052	0.995	1.110
2012–13	1.013	0.954	1.069

4.3 Stock Assessment Models

STA 3

Establishing B_{MSY} compatible reference points
In 2017, the working group accepted the geometric average ECSI trawl survey recruited (> 30 cm) biomass estimates for the period 1991 to 2016 as the B_{MSY}-compatible proxy for STA 3, with the rationale that catches had been somewhat stable over that period while abundance remained high. The working group accepted the default Harvest Strategy Standard definitions that the Soft and Hard Limits would be one half and one quarter the target, respectively.

STA 7
An age-structured model partitioned by age (0–25 years) and sex was fitted to the WCSI trawl survey relative abundance indices (1992–2005), WCSI survey proportions-at-age data (1992–2005), and WCSI fishery catch-at-age data (Manning 2008). This assessment has not been updated and the WCSI trawl survey is currently used to monitor the status of STA 7.

Establishing B_{MSY} compatible reference points
In 2018, the working group accepted the geometric average WCSI trawl survey total biomass estimates for the period 2005 to 2017 as the B_{MSY}-compatible proxy for STA 7, with the rationale that catches had been stable over that period while abundance remained high. The 2003 index was excluded because of extreme catchability values among a range of species (Stevenson & MacGibbon 2018). The working group accepted the default Harvest Strategy Standard definitions that the Soft and Hard Limits would be one half and one quarter the target, respectively.

4.4 Other factors
The use of a single conversion factor for deepwater and inshore vessels has resulted in about a 5–10% under-estimate pre 1990–91 of the reported greenweight landings. In 1990–91, separate deepwater and inshore conversion factors were introduced.

Stargazer landings have been influenced by changes in fishing patterns and fishing methods in the target species fisheries and indirectly by the abundance of those target species. Landings have also been influenced by changes in reporting behaviour for the different species. Stargazer were also taken historically in substantial quantities by foreign-licensed and chartered trawlers fishing offshore grounds for other species (see Table 1). Because stargazer was mainly a bycatch in these early fisheries, there may be under-reporting in these data. Therefore, any estimate of *MCY* based on catch data is likely to be conservative.

5.   STATUS OF THE STOCKS

No estimates of current and reference biomass are available.

- **STA 1**

The TACC for STA 1 was increased from 21 t to 50 t in the 1991–92 fishing year under an AMP. In 1997, the TACC was reduced to 21 t upon its removal from the programme. Recent catches have exceeded this level. It is not known if recent catch levels and current TACC are sustainable. The status of STA 1 relative to B_{MSY} is unknown.

- **STA 2**

The TACC for STA 2 was increased from 37 t to 100 t in the 1991–92 fishing year under an AMP. Landings in the early 1990s peaked in the range of 105–125 t but have subsequently declined.

The TACC was reduced to 38 t in the 1997–98 fishing year, upon the removal of STA 2 from the AMP. Landings have been below the TACC since 2003–04. It is not known whether recent catches and the current TACC will cause the STA 2 stock size to decline. The status of STA 2 relative to B_{MSY} is unknown.

- **STA 3**

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Series of biomass indices from the East Coast South Island trawl survey
Reference Points	Target: B_{MSY}-compatible proxy based on mean recruited biomass from the East Coast South Island trawl survey for the period 1991 to 2016 Soft Limit: 50% of target Hard Limit: 25% of target Overfishing Threshold: Mean relative exploitation rate for the period 1991 to 2016
Status in relation to Target	Likely (> 60%) to be at or above the target
Status in relation to Limits	Very Unlikely (< 10%) to be below both soft and hard limits
Status in relation to Overfishing	Unlikely (< 40%) to be overfishing

Historical Stock Status Trajectory and Current Status

Comparison of the GIZ ECSI recruited trawl survey indices with the QMR/MHR landings and TACC for STA 3. Error bars are ± two standard deviations, assuming a lognormal distribution. The agreed B_{MSY} proxy (geometric average: 1991–2016 ECSI recruited winter survey biomass estimates=577 t) is shown as a green dashed line; the calculated Soft Limit (=50% B_{MSY} proxy) is shown as a purple dashed line; the calculated Hard Limit (=25% B_{MSY} proxy) is shown as a grey dashed line.
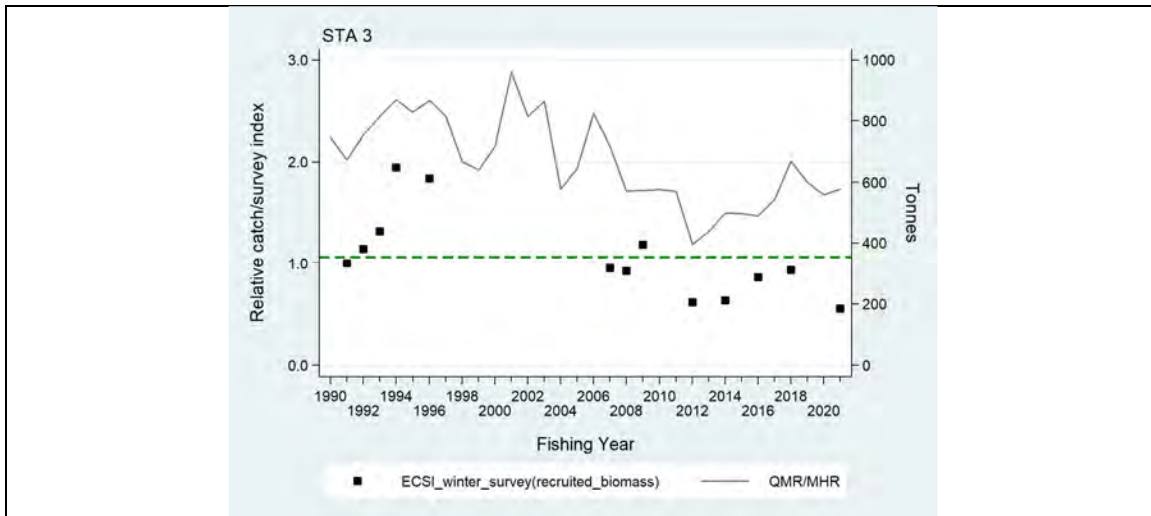
Relative fishing pressure for STA 3 based on the ratio of QMR/MHR landings to the corresponding ECSI recruited winter trawl survey recruited biomass index which has been normalised so that the geometric mean=1.0 overall index values. Horizontal green dashed line is the relative geometric mean fishing pressure from 1991 to 2016 (1.061).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass appears to be fluctuating around the long-term mean, with the 2021 ECSI survey estimate the highest in the time series.
Recent Trend in Fishing Intensity or Proxy	Relative exploitation rate increased steadily from 2012 to 2018, but dropped 40% in 2021 relative to 2018.
Other Abundance Indices	A standardised CPUE series from 1989–90 to 2006–07 showed no trend, suggesting that there was little change during the period when no surveys were conducted.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	STA 3 remains primarily a bycatch in the mixed-species inshore trawl fishery. STA 3 stock size is Likely (> 60%) to remain near current levels at current catch levels. It is Unknown if catches near the TACC would cause the stock to decline.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Current catch: Soft Limit: Unlikely (< 40%) Hard Limit: Unlikely (< 40%) TACC: Unknown
Probability of Current Catch or TACC causing overfishing to continue or to commence	Current Catch: Unlikely (< 40%) TACC: Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Trawl survey biomass and standardised CPUE based on lognormal error distribution and positive catches	
Assessment Dates	Latest assessment: 2022	Next assessment: 2023
Overall assessment quality (rank)	1 – High Quality	
Main data inputs (rank)	- ECSI trawl survey series	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and	-	

Assumptions	
Major Sources of Uncertainty	-

Qualifying Comments
-

Fishery Interactions
STA 3 are caught in fisheries for flatfish, barracouta, hoki, red cod, and tarakihi. Target STA only accounted for about 4% of total landings from 1989–90 to 2007–08.

- **STA 4**

Stargazer in this Fishstock occur mainly on the Chatham Rise on the shelf around the Chatham Islands but are sparsely distributed over the rest of the Chatham Rise. In most of this Fishstock they may not be economic to target. However, if fishing is overly concentrated in those areas where stargazer can be targeted, such as close to the Chatham Islands, there are concerns that local depletion may occur.

The 2011 estimate of biomass from the Chatham Rise trawl survey was above the long-term mean (1991–2011). The original TACC of 2014 t for STA 4 was based on a yield estimate from a single trawl survey in 1983. This method is now considered obsolete. The TACC was increased in 2000–01 to 2158 t. Catches have always been substantially less than the TACC. The average catch since the TACC increase has been 300 t. It is not known if catches at the level of the current TACC would be sustainable.

- **STA 5**

Stock Structure Assumptions

For the purpose of this summary STA 5 is considered to be a single stock.

Stock Status	
Year of Most Recent Assessment	2017
Assessment Runs Presented	Standardised CPUE based on bottom trawl positive catches and effort targeting STA 5
Reference Points	Target: B_{MSY}-compatible proxy based on mean CPUE for the period 1989–90 to 2012–13 Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: Mean relative exploitation rate for the period 1989–90 to 2012–13
Status in relation to Target	About as Likely as Not (40–60%) to be at or above the target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing is About as Likely as Not (40–60%) to be occurring

Historical Stock Status Trajectory and Current Status

A comparison of the CPUE indices and the annual catch and TACC. The horizontal grey line represents the average
of the CPUE indices from 1989–90 to 2012–13 (target reference point).

Fishery and Stock Trends

Recent Trend in Biomass or Proxy	CPUE has fluctuated without trend (1989–90 to 2012–13) with peaks in 1991–92 to 1993–94 and 2006–07 to 2009–08. The 2015–16 value is at 94% of the target reference level.
Recent Trend in Fishing Intensity or Proxy	**Fishing mortality proxy is Standardised Fishing Effort = Total catch/CPUE (normalised). The dashed line represents the average of the series from 1989–90 to 2012–13 (corresponding to the target reference point).** Fishing mortality has fluctuated about the long-term average and recent levels of fishing mortality were slightly higher than the target level.

Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Catches have been maintained near the current level for the last 28 years and there has been no indication of a decline in CPUE over that period, indicating that the current level of catch is probably sustainable, at least in a 3–5 year period.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) for both catch and TACC Hard Limit: Very Unlikely (< 10%) for both catch and TACC
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Current Catch: About as Likely as Not (40–60%) TACC: About as Likely as Not (40–60%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE indices	
Assessment Dates	Latest assessment: 2017	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	No change from previous (2014) assessment	

Qualifying Comments
-

Fishery Interactions
Most (70–80%) of the STA 5 catch is taken by the target trawl fishery with a smaller component of the catch taken by a flatfish trawl fishery. The species composition of the landed catch from the target fishery is dominated by stargazer with a small associated catch of ling, tarakihi, and spiny dogfish. Vessels participating in the target fishery may also conduct trawls in shallower water with associated catches of flatfish, red gurnard, and elephantfish.

- **STA 7**

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Biomass estimates from the WCSI trawl survey to 2021
Reference Points	Target: Geometric mean of WCSI total trawl survey biomass estimates for the reference period 2005–2017 Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: Mean fishing intensity during the reference period (above)
Status in relation to Target	Unlikely (< 40%) to be at or above target
Status in relation to Limits	Soft Limit: About as Likely as Not (40–60%) to be below Hard limit: Unlikely (< 40%) to be below
Status in relation to Overfishing	Overfishing is Likely (> 60%) to be occurring

Historical Stock Status Trajectory and Current Status

Comparison of the STA WCSI total trawl survey indices with the QMR/MHR landings and TACC for STA 7. Error bars are ± two standard deviations, assuming a lognormal distribution. The agreed B_{MSY} proxy (geometric average: 2005–2017 WCSI survey biomass estimates=1761 t) is shown as a green dashed line; the calculated Soft Limit (= 50% B_{MSY} proxy) is shown as a purple dashed line; the calculated Hard Limit (= 25% B_{MSY} proxy) is shown as a grey dashed line.
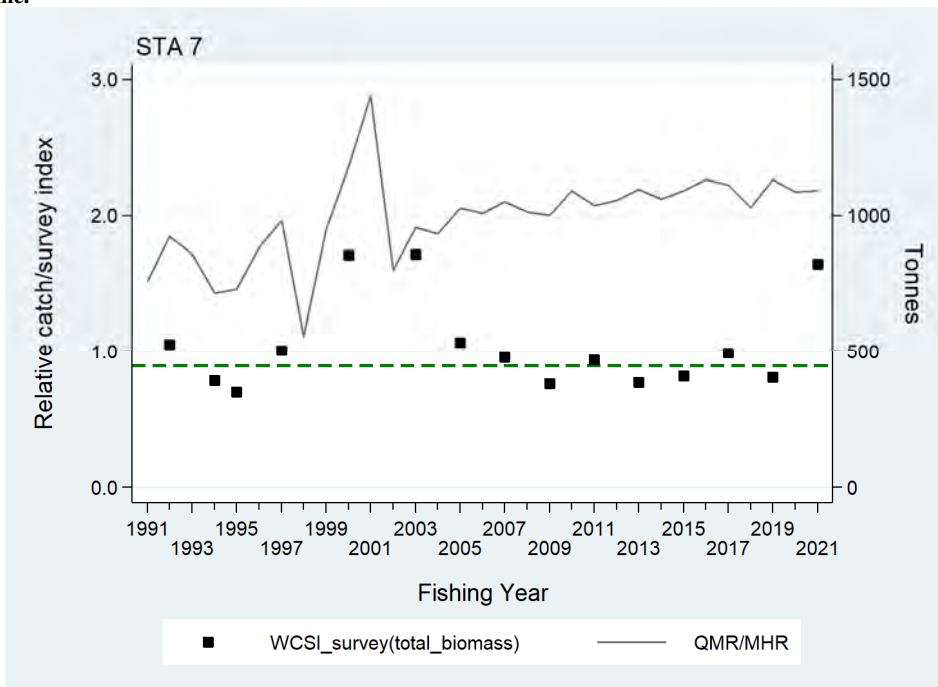
Relative fishing pressure for STA 7 based on the ratio of QMR/MHR landings to the corresponding WCSI total biomass trawl survey index which has been normalised so that the geometric mean=1.0 overall index values. Horizontal green dashed line is the geometric mean fishing pressure from 2005 to 2017 (0.891).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The WCSI trawl survey indices have been high since 2009, compared with those in the early 1990s, although the most recent (2021) estimate is below the target and the second lowest in the time series.
Recent Trend in Fishing Intensity or Proxy	Relative fishing intensity fluctuated around the threshold from 2005 until 2019, and then rose above the threshold in 2021.
Other Abundance Indices	CPUE indices from the WCSI mixed trawl fishery derived from individual trawl data (from 2007–08 to 2012–13) were relatively stable.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	It is Unknown whether the STA 7 stock will continue to decline, or remain below the target at current catch level. However, the low numbers of juveniles in the 2021 survey suggest biomass will not increase.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Likely (> 60%)

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Evaluation of recent trawl survey indices (up to 2021)	
Assessment Dates	Latest assessment: 2022	Next assessment: 2024
Overall assessment quality (rank)	1 – High Quality	
Main data inputs (rank)	- Biomass estimates from the biennial WCSI trawl survey up to 2021	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Fishery Interactions
-

- **STA 8**

The TACC for STA 8 increased from 22 t to 50 t in the 1993–94 fishing year under an AMP. Landings increased to 18 t in 1991–92 but have since declined to less than 5 t. The TACC was reduced back to 22 t in 1997, upon the removal of STA 8 from the programme. It is not known if recent catch levels and current TACC are sustainable. The status of STA 8 relative to B_{MSY} is unknown.

6.   FOR FURTHER INFORMATION

Anderson O F; Bagley, N W; Hurst, J; Francis, M P; Clark, M R; McMillan, P J (1998) Atlas of New Zealand fish and squid distributions from research bottom trawls. *NIWA Technical Report* 42. 303 p.

Andrews, A H (2009) Feasibility of lead-radium dating giant stargazer (*Kathetostoma giganteum*). Final Research Report for Ministry of Fisheries Project STA2004-03, 6 p. (Unpublished report held by Fisheries New Zealand.)

Bagley, N W; Hurst, R J (1995) Trawl survey of middle depth and inshore bottom species off Southland, February-March 1994 (TAN9402). *New Zealand Fisheries Data Report No. 57.* 50 p. (Report held by NIWA library, Wellington.)

Bagley, N W; Hurst, R J (1996a) Trawl survey of middle depth and inshore bottom species off Southland, February-March 1995 (TAN9502). *New Zealand Fisheries Data Report No. 73*. 47 p. (Report held by NIWA library, Wellington.)

Bagley, N W; Hurst, R J (1996b) Trawl survey of middle depth and inshore bottom species off Southland, February-March 1996 (TAN9604). *New Zealand Fisheries Data Report No. 77*. 51 p. (Report held by NIWA library, Wellington.)

Beentjes, M P; MacGibbon, D J; Ladroit, Y (in prep) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2021 (KAH2104). Draft New Zealand Fisheries Assessment Report.

Beentjes, M P; MacGibbon, D J; Parkinson, D (2016) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2016 (KAH1605). *New Zealand Fisheries Assessment Report 2016/61*. 135 p.

Beentjes, M.P.; MacGibbon, D.J.; Ladroit, Y. (in prep). Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2021 (KAH2104). *New Zealand Fisheries Assessment Report 2022/XX*. XXX p.

Boyd, R O; Reilly, J L (2004) 1999–2000 National Marine Recreational Fishing Survey: harvest estimates. (Unpublished draft New Zealand Fisheries Assessment Report for the Ministry of Fisheries Project REC9803 held by Fisheries New Zealand.) 28 p.

Bradford, E (1998) Harvest estimates from the 1996 national marine recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27p. (Unpublished report held by NIWA library, Wellington.)

Drummond, K L; Stevenson, M L (1995a) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 1992 (KAH9204). *New Zealand Fisheries Data Report No. 63*. 58 p. (Report held by NIWA library, Wellington.)

Drummond, K L; Stevenson, M L (1995b) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 1994 (KAH9404). *New Zealand Fisheries Data Report No. 64*. 55 p. (Report held by NIWA library, Wellington.)

Drummond, K L; Stevenson, M L (1996) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 1995 (KAH9504). *New Zealand Fisheries Data Report No. 74*. 60 p. (Report held by NIWA library, Wellington.)

Francis, M P; Paul, L J (2013) New Zealand inshore finfish and shellfish commercial landings, 1931–82. *New Zealand Fisheries Assessment Report 2013/55*. 136 p.

Francis, R I C C; Hurst, R J; Renwick, J A (2001) An evaluation of catchability assumptions in New Zealand stock assessments. *New Zealand Fisheries Assessment Report 2001/1*. 37 p.

Hoenig, J M (1983) Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin 81*: 898–903.

Hurst, R J; Bagley, N W (1987) Results of a trawl survey of barracouta and associated finfish near the Chatham Islands, New Zealand, December 1984. *New Zealand Fisheries Technical Report No. 3*. 44 p.

Hurst, R J; Bagley, N W (1994) Trawl survey of middle depth and inshore bottom species off Southland, February-March 1993 (TAN9301). *New Zealand Fisheries Data Report No. 52*. 58 p. (Report held by NIWA library, Wellington.)

Hurst, R J; Bagley, N W (1997) Trends in Southland trawl surveys of inshore and middle depth species, 1993–96. *New Zealand Fisheries Technical Report No. 50*. 66 p.

Hurst, R J; Bagley, N W; Uozumi, Y (1990) New Zealand-Japan trawl survey of shelf and upper slope species off southern New Zealand, June 1986. *New Zealand Fisheries Technical Report No. 18*. 50 p.

Hurst, R J; Fenaughty, J M (1986) Report on biomass surveys 1980–84; summaries and additional information. *Fisheries Research Division Internal Report No. 21*. 53 p.

Langley, A D (2002) The analysis of STA 3 catch and effort data from the RCO 3 target trawl fishery, 1989–90 to 2000–01. Report to the Inshore Fisheries Stock Assessment Working Group. (Unpublished report held by Fisheries New Zealand.)

Langley, A D (2015). Fishery characterisation and Catch-Per-Unit-Effort indices for giant stargazer in STA 7. *New Zealand Fisheries Assessment Report 2015/33*. 58 p.

Langley, A D (2017) STA 5 fishery characterisation and Catch-Per-Unit-Effort analysis. (Unpublished report presented to the Southern Inshore Fishery Assessment Working Group on 14 March 2017 as document SINS-WG-2017-12, held by Fisheries New Zealand, Wellington.)

Langley, A D; Bentley, N (2014) Fishery characterisation and Catch-Per-Unit-Effort indices for giant stargazer in STA 5. *New Zealand Fisheries Assessment Report 2014/64*. 45 p.

Livingston, M E; Bull, B; Stevens, D W; Bagley, N W (2002) A review of hoki and middle depths trawl surveys of the Chatham Rise, January 1992–2001. *NIWA Technical Report 113*. 146 p.

Lydon, G J; Middleton, D A J; Starr, P J (2006) Performance of the STA 3 Logbook Programmes. AMP-WG-06/21. (Unpublished manuscript available from the New Zealand Seafood Industry Council, Wellington.)

MacGibbon, D J (2019) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2019 (KAH1902) *New Zealand Fisheries Assessment Report 2019/64*. 87 p.

MacGibbon, D J; Beentjes, M P; Lyon, W L; Ladroit, Y (2019) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2018 (KAH1803). *New Zealand Fisheries Assessment Report 2019/03*. 136 p.

MacGibbon, D J; Walsh, C; Buckthought, D; Bian, R (2022). Inshore trawl survey of the west coast South Island and Tasman Bay and Golden Bay, March–April 2021 (KAH2103). *New Zealand Fisheries Assessment Report 2022/11*. 97 p.

Manning, M J (2005) On fitting and comparing selected statistical models of fish growth. Unpublished MSc thesis, University of Auckland, Auckland, New Zealand. 162 p.

Manning, M J (2007) Relative abundance of giant stargazer (*Kathetostoma giganteum*) in STA 5 based on commercial catch-per-unit-effort data. *New Zealand Fisheries Assessment Report 2007/14*. 42 p.

Manning, M J (2008) The first quantitative stock assessment of giant stargazer (*Kathetostoma giganteum*) in STA 7. *New Zealand Fisheries Assessment Report 2008/33*. 82 p.

Manning, M J; Sutton, C P (2004) Age and growth of giant stargazer, *Kathetostoma giganteum*, from the West Coast of the South Island (STA 7). *New Zealand Fisheries Assessment Report 2004/17*. 60 p.

Manning, M J; Sutton, C P (2007a) Further study on the age and growth of giant stargazer, *Kathetostoma giganteum*, from the west coast of the South Island (STA 7). *New Zealand Fisheries Assessment Report 2007/12*. 68 p.

Manning, M J; Sutton, C P (2007b) The composition of the commercial and research stargazer (*Kathetostoma giganteum*) catch off the west coast of the South Island (STA 7) during the 2004–05 fishing year. *New Zealand Fisheries Assessment Report 2007/36*. 43 p.

Phillips, N L (2001) Descriptive and CPUE analysis of catch and effort data for the giant stargazer (*Kathetostoma giganteum*) in the STA 5 fishery from the 1989–90 to the 1999–00 fishing year. Draft New Zealand Fisheries Assessment Report.

Seafood Industry Council (SeaFIC) (2002) Performance of the STA 7 Adaptive Management Programme. Unpublished report presented to the Adaptive Management Programme Fishery Assessment Working Group on 4 March 2002. p. (Unpublished report available from Fisheries New Zealand, Wellington.)

Seafood Industry Council (SeaFIC) (2003a) Performance of the STA 3 Adaptive Management Programme. Unpublished report presented to the Adaptive Management Programme Fishery Assessment Working Group as document AMP-WG-2003/02. 43 p. (Unpublished report available from Fisheries New Zealand, Wellington.)

Seafood Industry Council (SeaFIC) (2003b) Performance of the STA 7 Adaptive Management Programme. Unpublished report presented to the Adaptive Management Programme Fishery Assessment Working Group as document AMP-WG-2003/14. 42 p. (Unpublished report available from Fisheries New Zealand, Wellington.)

Seafood Industry Council (SeaFIC) (2005a) Performance of the STA 3 Adaptive Management Programme. Unpublished report presented to the Adaptive Management Programme Fishery Assessment Working Group as document AMP-WG-2005/19. p. (Unpublished report available from Fisheries New Zealand, Wellington.)

Seafood Industry Council (SeaFIC) (2005b) Performance of the STA 7 Adaptive Management Programme. Unpublished report presented to the Adaptive Management Programme Fishery Assessment Working Group as document AMP-WG-2005/09. p. (Unpublished report available from Fisheries New Zealand, Wellington.)

SEFMC (2002) 2002 report to the Adaptive Management Programme Fishery Assessment Working Group: review of the STA 3 Adaptive Management Programme. Unpublished report presented to the Adaptive Management Programme Fishery Assessment Working Group on 1 March 2002. p. (Unpublished report available from Fisheries New Zealand, Wellington.)

Starr, P J; Kendrick, T H; Lydon, G J; Bentley, N (2007a) Report to the Adaptive Management Programme Fishery Assessment Working Group: STA 3 Adaptive Management Programme. AMP-WG-07/27. (Unpublished manuscript available from the New Zealand Seafood Industry Council, Wellington.) 6 p.

Starr, P J; Kendrick, T H; Lydon, G J; Bentley, N (2007b) Report to the Adaptive Management Programme Fishery Assessment Working Group: Full-term review of the STA 7 Adaptive Management Programme. AMP-WG-07/14. (Unpublished manuscript available from the New Zealand Seafood Industry Council, Wellington). 65 p.

Starr, P J; Kendrick, T H; Lydon, G J; Bentley, N (2008) Report to the Adaptive Management Programme Fishery Assessment Working Group: Full-term review of the STA 3 Adaptive Management Programme. AMP-WG-08/07-rev.2 (Unpublished manuscript available from the New Zealand Seafood Industry Council, Wellington.) 102 p.

Stevens, D W; O'Driscoll, R L; Ballara, S L; Ladroit, Y (2017) Trawl survey of hoki and middle-depth species on the Chatham Rise, January 2016 (TAN1601). *New Zealand Fisheries Assessment Report 2017/08*. 131 p.

Stevens, D W; O'Driscoll, R L; Dunn, M R; Ballara, S L; Horn, P L (2012) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2011 (TAN1101). *New Zealand Fisheries Assessment Report 2012/10*. 98 p.

Stevens, D W; O'Driscoll, R L; Ladroit, Y; Ballara, S L; MacGibbon, D J; Horn, P L (2015) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2014 (TAN1401). *New Zealand Fisheries Assessment Report 2015/19*. 119 p.

Stevens, D W; O'Driscoll, R L; Oeffner, J; Ballara, S L; Horn, P L (2014) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2013 (TAN1301). *New Zealand Fisheries Assessment Report 2014/02*. 110 p.

Stevenson, M L (1998) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 1997 (KAH9701). *NIWA Technical Report* 12. 70 p.

Stevenson, M L (2002) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2000 (KAH0004). *NIWA Technical Report* 115. 71 p.

Stevenson, M L (2004) Trawl survey of the west coast of the South Island and Tasman and Golden Bays, March-April 2003 (KAH0304). *New Zealand Fisheries Assessment Report 2004/4*. 69 p.

Stevenson, M L (2007) Inshore trawl surveys of the west coast of the South Island and Tasman and Golden Bays, March-April 2007 (KAH0704). *New Zealand Fisheries Assessment Report 2007/41*. 64 p

Stevenson, M L (2012) Inshore trawl survey of the west coast of the South Island and Tasman and Golden Bays, March-April 2011. *New Zealand Fisheries Assessment Report 2012/50*. 77 p.

Stevenson, M L; Hanchet, S M (2000) Review of the inshore trawl survey series of the west coast South Island and Tasman and Golden Bays, 1992–1997. *NIWA Technical Report 82*. 79 p.

Stevenson, M L, MacGibbon D J (2018) Inshore trawl survey of the west coast of the South Island and Tasman and Golden Bays, March-April 2017. *New Zealand Fisheries Assessment Report 2018/18*. 92 p.

Sutton, C P (1999) Ageing methodology, growth parameters, and estimates of mortality for giant stargazer (*Kathetostoma giganteum*) from the east and south coasts of the South Island. New Zealand Fisheries Assessment Research Document 1999/15. 19 p. (Unpublished document held by NIWA library, Wellington.)

Sutton, C P (2004) Estimation of age, growth, and mortality of giant stargazer (*Kathetostoma giganteum*) from Southland trawl surveys between 1993 and 1996. *New Zealand Fisheries Assessment Report 2004/38*. 14 p.

Tate, M L (1987) The species and stock structure of the New Zealand inshore fishery for giant stargazer. MSc thesis lodged at University of Otago, Dunedin. 134 p.

Vignaux, M (1997) CPUE analyses for fishstocks in the adaptive management programme. New Zealand Fisheries Assessment Research Document 1997/24. 68 p. (Unpublished document held by NIWA library, Wellington.)

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019) National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24*. 104 p.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.

INTRODUCTION - SURF CLAMS

Surf clam is a generic term used here to cover the following seven species:

Deepwater tuatua	*Paphies donacina*	(PDO)
Fine (silky) dosinia	*Dosinia subrosea*	(DSU)
Frilled venus shell	*Bassina yatei*	(BYA)
Large trough shell	*Mactra murchisoni*	(MMI)
Ringed dosinia	*Dosinia anus*	(DAN)
Triangle shell	*Crassula aequilatera*	(SAE)
Trough shell	*Mactra discors*	(MDI)

The same FMAs apply to all these species and this introduction will cover issues common to all of these species. Each species has its own chapter.
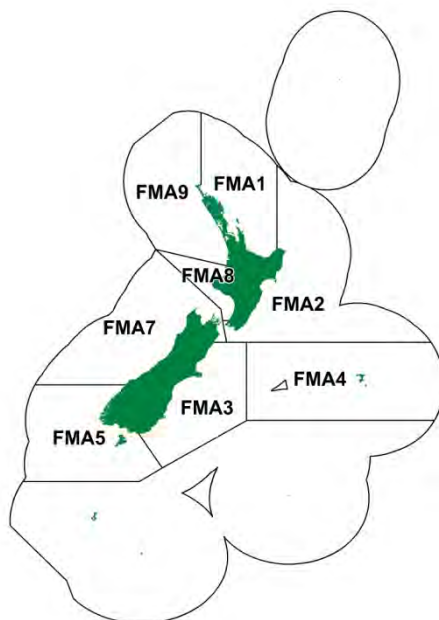
1.   INTRODUCTION

All surf clams were introduced into the Quota Management System on 1 April 2004. The fishing year is from 1 April to 31 March and commercial catches are measured in greenweight. There is no minimum legal size (MLS) for surf clams. Surf clams are managed under Schedule 6 of the Fisheries Act 1996. This allows them to be returned to the sea soon after they are taken, provided they are likely to survive.

The development of hydraulic dredges, facilitated by the New Zealand Fishing Industry Board in 1985, enabled the potential for surf clam fisheries on exposed surf beaches to be investigated. Exploratory surveys between 1988 and 1992 found high densities of surf clams off beaches in Poverty Bay, the Kapiti and Manawatu coasts, Marlborough, Pegasus Bay, and Oreti Beach in Southland.

Before surf clams were introduced into the Quota Management System, commercial surf clam fisheries were managed using special permits (sections 63, 64 (1) (c), and 66 of the Fisheries Act 1983). Four special permits for exploratory fishing were issued between 1986 and 1992. Permit holders had a sole right to fish a defined length of coastline and had an annual quota for each surf clam species. A moratorium was placed on the issue of new permits in 1993 to allow structured and informed development of surf clam fisheries. A special permit to fish for surf clams in Southland was granted in 2000. Commercial fishing trials began in FMA 8 in 1986, and FMAs 3 and 7 in 1987.

New Zealand operates a mandatory shellfish quality assurance programme for all bivalve shellfish grown and harvested in areas for human consumption. Shellfish caught outside this programme can only be sold for bait. This programme is based on international best practice and is managed by New Zealand Food Safety, in cooperation with the District Health Board Public Health Units and the shellfish industry [1]. This involves surveying the water catchment area for pollution, sampling water and shellfish microbiologically over at least 12 months, classifying and listing areas for harvest, regular monitoring of the water and shellfish, biotoxin testing, and closure after rainfall and when biotoxins are detected. Products are traceable by source and time of harvest in case of contamination.

2.   BIOLOGY

Three families of surf clams dominate the biomass in different regions of New Zealand. At the northern locations, the venerids *D. anus* and *D. subrosea* make up the major proportion of the surf clam biomass, and *D. anus* is abundant at all other North Island locations. The mactrids and mesodesmatid become increasingly abundant south of Ohope (Bay of Plenty). The mesodesmatid *P. donacina* is most abundant around central New Zealand from Nuhaka on the east coast south to the Kapiti Coast, Cloudy Bay, and as far south as Pegasus Bay. The mactrids *M. murchisoni* and *M. discors* dominate in southern New Zealand (Blueskin Bay, Te Waewae, and Oreti), where they account for more than 80% of the total biomass (Cranfield et al. 1994, Cranfield & Michael 2001).

Each species grows to a larger size in the South Island than in the North Island (Cranfield & Michael 2002). Growth parameters are available for several surf clam species from two locations, Cloudy Bay (FMA 7) and the Kapiti Coast (FMA 8). Length frequencies of sequential population samples were analysed by Cranfield et al. (1993) using MULTIFAN to estimate the von Bertalanffy growth parameters (Table 1). MULTIFAN simultaneously analyses multiple sets of length frequency samples using a maximum likelihood method to estimate the proportion of clams in each age class and the von Bertalanffy growth parameters (see Fournier et al. 1990). Less confidence should be placed in the estimates from MULTIFAN for Cloudy Bay relative to the Kapiti Coast because length sample sizes were smaller from Cloudy Bay, and there was a lack of juvenile surf clams in samples.

Incremental growth of recaptured marked clams at Cloudy Bay was analysed using GROTAG to corroborate the MULTIFAN estimates (Cranfield et al. 1993). GROTAG uses a maximum-likelihood method to estimate growth rate (Francis 1988). The estimates and annual mean growth estimates at lengths α and β are shown in Table 2. Low numbers of marked clams were recaptured from the Kapiti Coast, indicative estimates are given in Cranfield & Michael (2001).

Table 1: Von Bertalanffy growth parameter estimates from Cranfield et al. (1993) for surf clams estimated using MULTIFAN (SE in parentheses). – Indicates where estimates were not generated.

Stock	Site	L_∞ (mm)	K
BYA 7	Cloudy Bay	–	–
BYA 8	Kapiti Coast	–	–
DAN 7	Cloudy Bay	0.10 (0.03)	77.5 (0.71)
DAN 8	Kapiti Coast	0.13 (0.02)	58.7 (0.28)
DSU 7	Cloudy Bay	–	–
DSU 8	Kapiti Coast	–	–
MDI 7	Cloudy Bay	0.41 (0.03)	68.0 (0.35)
MDI 8	Kapiti Coast	0.42 (0.02)	56.0 (0.95)
MMI 7	Cloudy Bay	0.57 (0.01)	88.0 (0.44)
MMI 8	Kapiti Coast	0.35 (0.01)	75.2 (0.30)
PDO 7	Cloudy Bay	0.33 (0.01)	94.1 (0.29)
PDO 8	Kapiti Coast	–	–
SAE 7	Cloudy Bay	1.01 (0.02)	60.3 (0.92)
SAE 8	Kapiti Coast	0.80 (0.03)	52.1 (0.25)

---

[1] For full details of this programme, refer to the Animal Products (Regulated Control Scheme-Bivalve Molluscan Shellfish) Regulations 2006 and the Animal Products (Specifications for Bivalve Molluscan Shellfish) Notice 2006 (both referred to as the BMSRCS) at: http://www.nzfsa.govt.nz/industry/sectors/seafood/bms/page-01.htm

Table 2: **Mean annual growth estimates (mm/year) at lengths α and β (95% confidence intervals in parentheses for mean growth values) from Cloudy Bay (Cranfield et al. 1996). *L** is the transitional length, at which point the model allows an asymptotic reduction in growth rate and values of *L*∞ are included for reference.**

Species	α (mm)	g_α (mm year^{-1})	β (mm)	g_β (mm year^{-1})	*L** (mm)	*L*∞ (mm)	Residual error (mm)
Paphies donacina	50.0	10.26 (9.7 – 10.8)	80.0	1.41 (1.1 – 1.7)	80.0	84.8	1.25
Crassula aequilatera	30.0	22.71 (22.2 – 23.0)	50.0	6.23 (6.0 – 6.4)	55.0	57.6	2.04
Mactra murchisoni	40.0	17.83 (17.4 – 18.2)	70.0	4.65 (4.3 – 4.9)	80.0	80.6	1.42
Mactra discors	35.0	11.01 (10.5 – 11.7)	55.0	2.69 (2.4 – 2.9)	62.0	61.5	0.63
Dosinia anus	20.0	12.5 (12.0 – 13.2)	55.0	1.99 (1.8 – 2.2)	63.0	61.6	0.44

The maximum ages for these species were estimated from the number of age classes indicated in MULTIFAN analyses, and from shell sections. Estimates of natural mortality come from age estimates (Table 3). Higher mortality is seen where the surf clams are subject to higher wave energies, e.g., *C. aequilatera* and *M. murchisoni* are distributed within the primary wave break and hence show higher mortality (Cranfield et al. 1993). The maximum age of Kapiti coast shells suggests higher mortality than Cloudy Bay, perhaps because the Kapiti Coast is more exposed and surf clams there have a higher chance of being eroded out of the seabed by storms (Cranfield et al. 1993). Surf clam populations are subject to catastrophic mortality from being dislodged from within the seabed and being washed ashore during storms, high nearshore seawater temperatures and low oxygen levels during calm summer periods, blooms of toxic algae, and long periods of reduced salinity from high freshwater outflow (Eggleston & Hickman 1972, Cranfield & Michael 2001).

Table 3: **Estimates of the instantaneous natural mortality rate, *M*. A = minimum number of year classes indicated by MULTIFAN; B = maximum age indicated by shell sections; M1 = mortality range estimated from using two equations: $lnM = 1.23-0.832\ln(t_{max})$ and $1nM = 1.44-0.982 1n(t_{max})$, (Hoenig 1983); M2 mortality estimated from $M = \ln100/(t_{max})$; t_{max} is the estimate of maximum age.**

	A	B	M1	M2
Cloudy Bay				
Mactra murchisoni	8	11	0.40–0.46	0.42
Mactra discors	7	14	0.32–0.38	0.33
Crassula aequilatera	5	7	0.63–0.68	0.66
Paphies donacina	10	17	0.26–0.32	0.27
Dosinia anus	16	22	0.20–0.26	0.21
Kapiti Coast				
Mactra murchisoni	8	11*	0.40–0.46	0.42
Mactra discors	8	16*	0.28–0.34	0.29
Crassula aequilatera	3	5*	0.87–0.89	0.92
Paphies donacina[†]				
Dosinia anus	19	26*	0.17–0.23	0.18

*Shell sections not yet examined. Ages are inferred from Cloudy Bay data.
[†]Growth data could not be analysed.

3. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was first introduced to the May 2011 Plenary after review by the Aquatic Environment Working Group and is updated as relevant research is undertaken and published. It was last updated in 2021. This summary is from the perspective of the surf clam fisheries; a more detailed summary from an issue-by-issue perspective is available in the Aquatic Environment and Biodiversity Annual Review 2021 (Fisheries New Zealand 2021), online at https://www.mpi.govt.nz/dmsdocument/51472-Aquatic-Environment-and-Biodiversity-Annual-Review-AEBAR-2021-A-summary-of-environmental-interactions-between-the-seafood-sector-and-the-aquatic-environment.

3.1 Ecosystem role

Worldwide, the ecosystem roles of subtidal communities on expose surf beaches are difficult to study. The physical environments of surf beaches are defined by their sand, wave, and tidal regimes. Surf beaches range from narrow and steep (reflective) beaches with no surf zone and coarse sediments (e.g., Cloudy Bay, FMA 7) to wide and flat (dissipative) beaches with extensive surf zones, finer sand and larger waves and tides (e.g., Pegasus Bay, (FMA 3), after Defo et al. 2009). The surf zone systems of New Zealand dissipative beaches are similar to those describe in California (Morin et al. 1985) and South Africa (McLachlan et al. 1984). There is distinct zonation of subtidal, beach communities driven by an environmental gradient: the nearshore swash zone characterized by almost continual sweeping and shifting sands churned up by strong, fluctuating wave surge at one extreme, to a relatively benign environment with reduced surge, and finer sediments with almost no sand movement at the other extreme (Morin et al. 1985). As common on most exposed surf beaches, suspension feeding bivalves dominate the nearshore biomass. Beyond the primary wave break where the bottom becomes more stable and finer, there is a rapid rise in species diversity, but in New Zealand, generally a decreased in overall biomass.

Only three published papers examine aspects of the role of surf clams in the ecosystem in New Zealand. Juvenile surf clams, mainly *Paphies spp.*, are important prey for the paddle crab *Ovalipes catharus* in central New Zealand (Wear & Haddon 1987). Predation of *Dosinia* spp. by rock lobsters has been documented from the reef/soft sediment interface zones (Langlois et al. 2005, Langlois et al. 2006), notably surf clams are usually harvested from exposed beaches, not reef/soft sediment interface zones.

Surf clams are filter-feeders; recent research suggests that most of their food is obtained from microalgae from the top 2 cm of the sediment and the bottom 2–3 cm of the water column (Sasaki et al. 2004). The effects of predation are difficult to study on exposed sandy beaches and it is believed internationally that there are no keystone species in this environment and predation is not important in structuring the community (McLachlan & Brown 2006).

3.2 Fishery captures (fish and invertebrates)

The only bycatch caught in large quantities associated with surf clam dredging in New Zealand is *Fellaster zelandiae* — the sand dollar or sea biscuit (Haddon et al. 1996, Triantafillos 2008a, Triantafillos 2008b, White et al. 2012). Other species caught in association with surf clams include paddle crabs (*Ovalipes catharus*), a number of bivalves including the lance shell (*Resania lanceolata*), otter clams (*Zenatia acinaces*), battle axe (*Myadora striata*), olive tellinid (*Hiatula nitidia*), the wedge shell (*Peronaea gairmadi*), and the gastropods the olive shell (*Baryspira australis*) and ostrich foot shell (*Struthiolaria papulosa*). Fish are rarely caught but include juvenile common soles (*Peltorhamphus novaezeelandiae*) and stargazers (*Kathetostoma* spp.) (NIWA, unpublished data).

3.3 Fishery captures (seabirds and mammals)

Not relevant to surf clam fisheries.

3.4 Benthic impacts

Surf clams mainly inhabit the surf zone, a high-energy environment characterised by high sand mobility (Michael et al. 1990). Divers observed that the survey dredge (used for surf clam surveys) formed a well-defined track in the substrate, but within 24 hours (probably much less time) the track could not be distinguished, indicating that physical recovery of the substrate was rapid (Michael et al. 1990). A different dredge is used for commercial fishing, and the impacts of this dredge have not been tested. Shallow water environments such as the surf zone or those subjected to frequent natural disturbance tend to recover faster from the effects of mobile fishing gears compared with those in deeper water (Kaiser et al. 1996, Collie et al. 2000, Hiddink et al. 2006, Kaiser et al. 2006).

Incidental effects of hydraulic dredging on the target species within New Zealand fisheries have not been studied. Any effects will be species, size, dredge, and location specific. For the Italian surf clam (*Chamelea gallina*), laboratory experiments found that 50% of the surf cams had reburied after 4 hours (95% CI 3.6–4.4) and 90% after 8 hours (95% CI 7.7–8.2) (Bargione et al 2021). There are no data on

reburial times of New Zealand surf clams encountering hydraulic dredges. Given the time it takes for *Chamelea gallina* to rebury, and New Zealand surf conditions, surf clams may be washed ashore. In the same research Bargione et al (2021) found survival of disturbed clams in both laboratory experiments and caged sea trials was high. A laboratory study by Cranfield and Michael (1995) found that surf clams (PDO, SAE, and MMI) float on liquified sand, and based on laboratory observations suggest that some surf clams that encounter hydraulic dredges may suffer some damage or stress. The survival of New Zealand surf clams encountering hydraulic dredges and the return of surf clams to sea is currently unknown.

Surf clam species show zonation by sediment type and mobility which is generally, although not always, correlated with depth and wave exposure. Species with good burrowing ability are generally found in shallow, mobile sediment zones (for example, *Paphies donacina*), and those species less able to burrow (for example, *Dosinia subrosea* and *Bassina yatei*) are generally found in softer, more stable sediments. The present high-value species (*Crassula aequilatera, Mactra murchisoni, Paphies donacina* and *Mactra discors*) generally occur in transition zones from highly mobile sediments to mostly stable sediment. Mobile fishing gear effects will be primarily determined by the characteristics of the beach and target species. Little fishing presently takes place in the most vulnerable areas characterised by stable, soft fine sediment communities because of the lower densities of surf clams and the presently lower value of species there.

An Italian study showed that widespread intensive hydraulic dredging can adversely modify habitat at depths of 4–6 m within the surf zone environment, although recovery in this study occurred within six months (Morello et al. 2006). Scottish (Tuck et al. 2000; Hauton et al. 2003a, 2003b) and American (Mercaldo-Allen et al. 2017) studies detected benthic community and physical impacts, but survival of discarded bycatch was generally high. The applicability of these studies' finding to New Zealand is unknown, given the relatively sheltered nature of some of the habitats examined compared to surf beaches. In New Zealand, the effects of hydraulic dredging are likely to vary with site specific environmental conditions and depending on whether beaches have reflective or dissipative beach profiles.

3.5   Other considerations
None.

3.6   Key information gaps
The distribution of hydraulic dredging in New Zealand is localised at fishery scale, and generally not widespread geographically. The impacts of hydraulic dredging at the intensities fished are unknown. Key information gaps include population connectivity and stock structure, and spatial and temporal variability in key population parameters, e.g., recruitment patterns varied on Wellington west coast beaches with juveniles of *Mactra discors* and *M. murchisoni* dominating in alternate years (Conroy et al. 1996).

A key information gap is the survival of surf calms encountered by the hydraulic dredge and that pass under or through the dredge on the seabed, and of those landed onboard and returned to sea.

4.   FOR FURTHER INFORMATION

Bargione, G., Petetta, A., Vasapollo, C. et al. Reburial potential and survivability of the striped venus clam (Chamelea gallina) in hydraulic dredge fisheries. Sci Rep 11, 9109 (2021). https://doi.org/10.1038/s41598-021-88542-8

Brierley, P.J.; Cranfield, J.; Knedler, K.; Bauckham, A.; Town, J.; Stevens, P.; Sullivan, M.; Blank, F.; Martin, N. (1990). Management and development of the New Zealand sub-tidal clam fishery. Report of the Surf Clam Working Group. (Unpunished report held by MAF Fisheries. New Zealand). 57 p.

Collie, J; Escanero, G; Valentine, P (2000) Photographic evaluation of the impacts of bottom fishing on benthic epifauna. *ICES Journal of Marine Science* 57, 987–1001.

Conroy, A.M.; Smith, P.J.; Michael, K.P.; Stotter, D.R. (1993). Identification and recruitment patterns of juvenile surf clams, *Mactra discors* and *M. murchisoni* from central New Zealand. *New Zealand Journal of Marine and Freshwater Research 27(3))*: 279-285.

Constantino, R; Caspar, M B; Tata-Regala, J; Carvalho, S; Curdia, J; Drago, T; Taborda, R; Monteiro, C C (2009) Clam dredging effects and subsequent recovery of benthic communities at different depth ranges. *Marine Environmental Research* 67(2): 89–99.

Cranfield, H.J.; Michael, K.P. (1950). A laboratory study of the behaviour of surf clams (*Paphies donacina, Spisula aequilatera, Mactra murchisoni*). (Unpublished report to Kai Moana (Pacific) Ltd., held by NIWA).

Cranfield, H.J.; Michael, K.P. (2001). Growth rates of five species of surf clams on a southern North Island beach, New Zealand. *New Zealand Journal of Marine and Freshwater Research 35*: 909-924.

Cranfield, H; Michael, K (2001) The surf clam fishery in New Zealand: description of the fishery, its management, and the biology of surf clams. *New Zealand Fisheries Assessment Report 2001/62*. 24 p.

Cranfield, H; Michael, K (2002) Potential area boundaries and indicative TACs for the seven species of surf clam. (Unpublished report to the Ministry of Fisheries, held by Fisheries New Zealand).

Cranfield, H; Michael, K; Francis, R (1996) Growth Rates of Five Species of Subtidal Clam on a Beach in the South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research 47*: 773–784.

Cranfield, H J; Michael, K P; Stotter, D R (1993) Estimates of growth, mortality, and yield per recruit for New Zealand surf clams. New Zealand Fisheries Assessment Research Document 1993/20. 26 p. (Unpublished document held by NIWA library, Wellington).

Cranfield, H J; Michael, K P; Stotter, D R; Doonan, I J (1994) Distribution, biomass and yield estimates of surf clams off New Zealand beaches. New Zealand Fisheries Assessment Research Document 94/11. 17p. (Unpublished document held in NIWA library, Wellington).

Defeo, O.; McLachlan, A.; Schoeman, D.S.; Schlacher, T.A.; Dugan, J.; Jones, A.; Lastra, M.; Scapini, F. (2009). Threats to sandy beach ecosystems: a review. *Estuarine, Coastal and Shelf Science 81(1)*: 1-12.

Eggleston, D.; Hickman, R.W. (1972). Mass Strandings of Molluscs at Te Waewae Bay, Southland, New Zealand. *New Zealand Journal of Marine and Freshwater Research 6(3)*: 379-382.

Fisheries New Zealand (2021) Aquatic Environment and Biodiversity Annual Review 2021. Compiled by the Aquatic Environment Team, Fisheries Science and Information, Fisheries New Zealand, Wellington, New Zealand. 779 p.

Fournier, D A; Sibert, J R; Majkowski, J; Hampton, J (1990) MULTIFAN a likelihood-based method for estimating growth parameters and age composition from multiple length frequency data sets illustrated using data for southern bluefin tuna (*Thunnus maccoyii*). *Canadian Journal of Fisheries and Aquatic Science*s 47: 301–317.

Francis, R I C C (1988) Maximum likelihood estimation of growth and growth variability from tagging data. *New Zealand Journal of Marine and Freshwater Research* 22: 42–51.

Haddon, M; Willis, T J; Wear, R G; Anderlini, V C (1996) Biomass and distribution of five species of surf clam off an exposed west coast North Island beach, New Zealand. *Journal of Shellfish Research* 15(2): 331–339.

Hauton, C.; Atkinson, R.J.A.; Moore, P.G. (2003a) The impact of hydraulic blade dredging on a benthic megafaunal community in the Clyde Sea area, Scotland. *Journal of Sea Research* 50, 45–56.

Hauton, C.; Hall-Spencer, J.M.; Moore, P.G. (2003b) An experimental study of the ecological impacts of hydraulic bivalve dredging on maerl. *ICES Journal of Marine Science* 60(2), 381–392.

Hiddink, J; Jennings, S; Kaiser, M; Queiros, A; Duplisea, D; Piet, G (2006) Cumulative impacts of seabed trawl disturbance on benthic biomass, production, and species richness in different habitats. *Canadian Journal of Fisheries and Aquatic Sciences* 63, 721–736.

Hoenig, J M (1983) Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin* 82: 898–903.

Kaiser, M; Clarke, K; Hinz, H; Austen, M; Somerfield, P; Karakassis, I (2006) Global analysis of response and recovery of benthic biota to fishing. *Marine Ecology-Progress Series* 311: 1–14.

Kaiser, M; Hill, A; Ramsay, K; Spencer, B; Brand, A; Veale, L; Prudden, K; Rees, E; Munday, B; Ball, B; Hawkins, S (1996) Benthic disturbance by fishing gear in the Irish Sea: a comparison of beam trawling and scallop dredging. *Aquatic Conservation: Marine and Freshwater Ecosystems* 6: 269–285.

Langlois, T; Anderson, M J; Babcock, R; Kato, S (2005) Marine reserves demonstrate trophic interactions across habitats. *Oecologia* 147(1): 134–140.

Langlois, T J; Anderson, M J; Brock, M; Murman, G (2006) Importance of rock lobster size-structure for trophic interactions: choice of soft-sediment bivalve prey. *Marine Biology* 149(3): 447–454.

McLachlan, A; Brown, A (2006) *The Ecology of Sandy Shores*. Academic Press.

McLachlan, A.; Cockcroft, A.; Malan, D. (1984). Benthic faunal response to a high energy gradient. *Marine Ecology Progress Series. 16(1)*: 51-63.

Mercaldo-Allen, R.; Meseck, S.; Goldberg, R.; Clark, P.; Kuropat, C.; Rose, J.M. (2017) Effects of clam dredging on benthic ecology of two cultivated northern quahog beds with different harvest histories and sediment grain sizes. *Aquaculture International* 25: 1971–1985.

Michael, K; Olsen, G; Hvid, B; Cranfield, H (1990) Design and performance of two hydraulic subtidal clam dredges in New Zealand. *New Zealand Fisheries Technical Report* No. 21. 16 p.

Minami, T; Sasaki, K; Ito, K (2009) Recent research topics in biological production processes of marine bio-resources in the coastal waters and estuaries. *Tohoku Journal of Agricultural Research 59(3–4)*: 67–70.

Morello, E B; Froglia, C; Atkinson, R G A; Moore, P G (2005) Impacts of hydraulic dredging on a macrobenthic community of the Adriatic Sea, Italy. *Canadian Journal of Fisheries and Aquatic Sciences* 62(9): 2076–2087.

Morello, E B; Froglia, C; Atkinson, R G A; Moore, P G (2006) Medium-term impacts of hydraulic clam dredgers on a macrobenthic community of the Adriatic Sea (Italy). *Marine Biology* 149(2): 401–413.

Morin, J.; Kastendiek, J.; Harrington, A.; Davis, N. (1985). Organization and patterns of interactions in a subtidal sand community on an exposed coast. *Marine Ecology Progress Series* 27: 163-185.

Reise, K (1984) *Tidal flat ecology*. Berlin, Springer-Verlag.

Sasaki, K; Sanematsu, A; Kato Y.; Ito K. (2004) Dependence of the Surf Clam *Pseudocardium sachalinense* (Bivalvia: Mactridae) On the Near-Bottom Layer for Food Supply. *Journal of Molluscan Studies* 70(3): 207–212.

Triantafillos, L (2008a) Survey of subtidal surf clams in Pegasus Bay, November–December 2007. Prepared by NIWA for Seafood Innovations Limited and SurfCo. Limited. 43 p. (Unpublished document held by Fisheries New Zealand.).

Triantafillos, L (2008b) Survey of subtidal surf clams in Quota Management Area 2, June–August 2008. Prepared by NIWA for Seafood Innovations Limited and SurfCo. Limited. 40 p. (Unpublished document held by Fisheries New Zealand).

Tuck, I.D.; Bailey, N.; Harding, M.; Sangster, G.; Howell, T.; Graham, N.; Breen, M. (2000) The impact of water jet dredging for razor clams, *Ensis* spp., in a shallow sandy subtidal environment. *Journal of Sea Research* 43, 65–81.

White, W. L., Millar, R. B., Breen, B. and Farrington, G. (2012) Survey of subtidal surf clams from the Manawatu Coast (FMA8), October-November 2012. Report for the Shellfish Working Group Meeting 19th November 2012, 35 p.+ Addendum.

Wear, R.; Haddon, M. (1987). Natural diet of the crab *Ovalipes catharus* (Crustacea, Portunidae) around central and northern New Zealand. *Marine Ecology Progress Series*: 39-49.

DEEPWATER TUATUA (PDO)

(*Paphies donacina*)
Tuatua
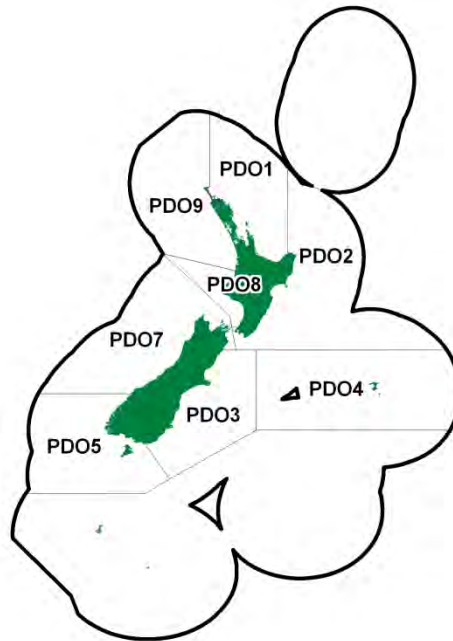
1. FISHERY SUMMARY

This species is part of the surf clam fishery and the reader is guided to the Introduction – surf clams chapter for information common to all relevant species.

1.1 Commercial fisheries

Deepwater tuatua (*Paphies donacina*) were introduced into the Quota Management System on 1 April 2004 with a total TACC of 168 t. Biomass surveys in QMA 2 supported a TAC increase from April 2010. This increased the TAC for PDO from 2 t to 509 t. In April 2013 a biomass survey in QMA 8 supported a further increase. This increased the TAC in PDO 8 from 19 t to 296 t and the total PDO TAC from 791 t to 1215 t. An additional biomass survey supported an increase in the TAC of PDO 7 in April 2016 to 200 t and the national TAC of PDO to 1215 t (Table 1).

Table 1: Current TAC, TACC, and allowances for other sources of mortality for *Paphies donacina*.

QMA	TAC (t)	TACC (t)	Recreational catch	Customary catch	Other sources of mortality (t)
1	1	1	0	0	0
2	509	466	9	9	25
3	150	108	21	21	0
4	3	1	1	1	0
5	3	1	1	1	0
7	200	184	1	5	10
8	296	262	9	10	15
9	53	1	26	26	0

Reported landings and TACCs are shown for Fishstocks with historical landings in Table 2 and in Figure 1 for PDO 3 and PDO 7. Landings have been reported from PDO 3, PDO 5, PDO 7, and PDO 8. Between the years 1992–93 and 1995–96, reported landings ranged from a few kilograms to about 6 t; no further landings were reported until 2002–03. Reported total landings subsequently varied, with recent years showing a marked upward trend in PDO 3, PDO 7, and PDO 8. Landings in PDO 3 ranged from 0.0 t to 11.21 t between 2006–07 and 2012–13 and increased to about 90 t in 2018–19 and 2019–20. Since 2002–03, landings in PDO 7 have ranged between 2.2 t and 182 t (in 2016–17), but dropped to 125 t in 2019–20. Landings in PDO 8 increased from 2 t in 2015–16 to 30 t in 2018–19 and 66 t in 2019–20. Total PDO landings peaked at 282 t in 2018–19, with over 50% of catches originating in PDO 7.

DEEPWATER TUATUA (PDO)

Table 2: TACCs and reported landings (t) of deepwater tuatua by Fishstock from 1992–93 to the present from CELR and CLR data. PDO areas where catch has never been reported are not tabulated. See Table 1 for TACC of stocks not landed.

Fishstock	PDO 3		PDO 5		PDO 7		PDO 8		Total	
	Landing	TACC	Landing	TACC	Landing	TACC	Landing	TACC	Landing	TACC
1992–93	0	–	0	–	0.29	–	0	–	0.29	–
1993–94	0	–	0.005	–	3.38	–	0	–	3.38	–
1994–95	0	–	0	–	5.04	–	0	–	5.04	–
1995–96	4.44	–	0	–	1.67	–	0	–	6.11	–
1996–97	0	–	0	–	0	–	0	–	0	–
1997–98	0	–	0	–	0	–	0	–	0	–
1998–99	0	–	0	–	0	–	0	–	0	–
1999–00	0	–	0	–	0	–	0	–	0	–
2000–01	0	–	0	–	0	–	0	–	0	–
2001–02	0	–	0	–	0	–	0	–	0	–
2002–03	0	–	0	–	2.25	–	0	–	2.25	–
2003–04	0	108	0	1	10.14	50	0	1	10.14	168
2004–05	0	108	0	1	12.53	50	0	1	12.69	168
2005–06	0	108	0	1	10.63	50	0.148	1	13.73	168
2006–07	1.17	108	0	1	20.00	50	0	1	21.16	168
2007–08	3.17	108	0	1	21.15	50	0	1	24.32	168
2008–09	4.09	108	0	1	4.32	50	0	1	8.41	168
2009–10	11.21	108	0	1	1.50	50	0	1	12.71	168
2010–11	3.93	108	0	1	38.80	50	0	1	42.73	629
2011–12	0	108	0	1	17.10	50	0	1	17.05	629
2012–13	6.95	108	0	1	30.13	50	0	1	37.08	629
2013–14	24.16	108	0	1	39.12	50	0	262	63.28	890
2014–15	46.22	108	0	1	54.01	184	0	262	112.91	890
2015–16	59.49	108	0	1	98.03	184	2.22	262	207.44	890
2016–17	25.61	108	0	1	182.12	184	8.61	262	214.34	890
2017–18	70.48	108	0	1	180.40	184	8.42	262	259.30	890
2018–19	92.12	108	0	1	159.20	184	30.79	262	282.11	890
2019–20	89.57	108	0	1	125.41	184	66.47	262	281.45	890
2020–21	85.26	108	0	1	86.86	184	33.55	262	205.67	890
2021–22	85.47	108	0	1	15.89	184	70.43	262	171.79	890

*In 2004–05 and 2005–06, 0.16 and 2.953 t respectively were reportedly landed, but the QMA was not recorded. These amounts are included in the total landings for those years.
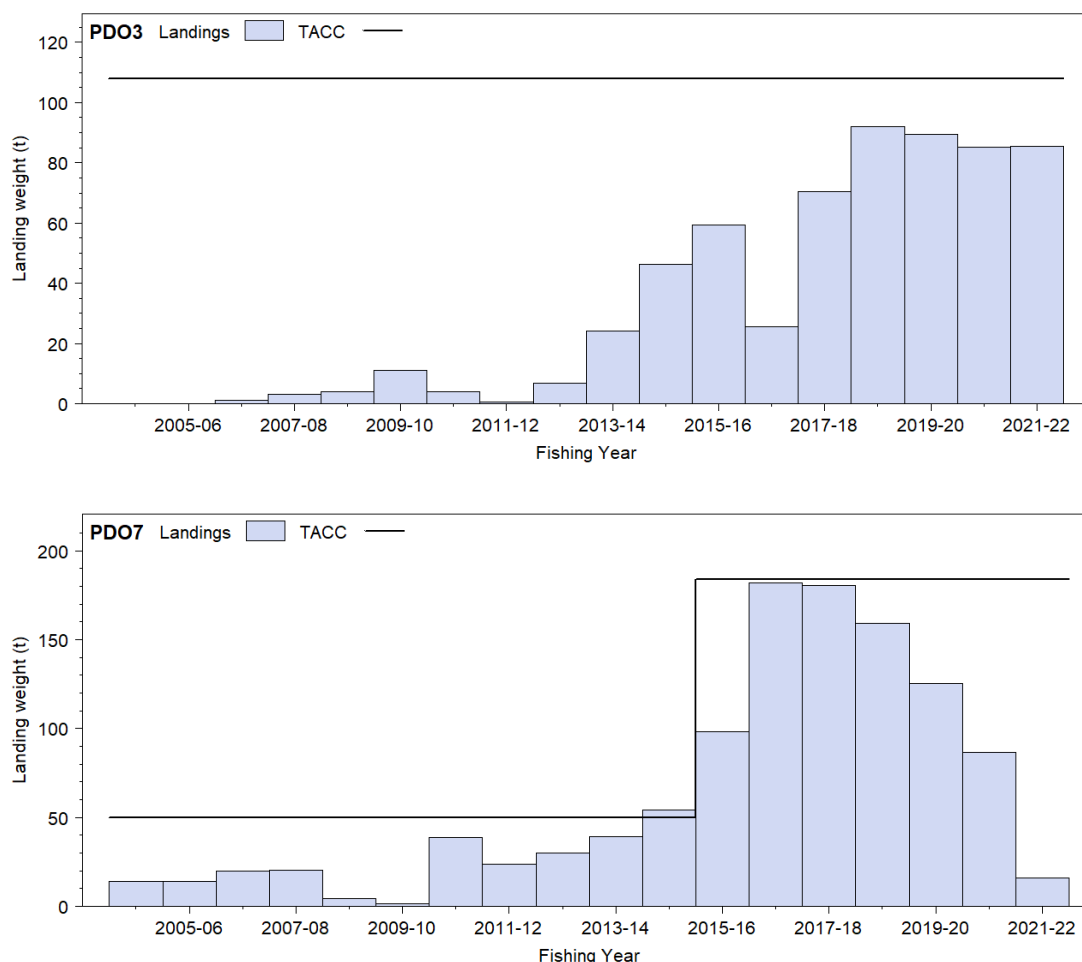
Figure 1: Reported commercial catch and TACC for the two main PDO stocks since when the TACC was introduced in the 2004–05 fishing year: PDO3 (South-East Coast) and PDO7 (Challenger).

1.2   Recreational fisheries

Deepwater tuatua inhabit the shallowest part of the subtidal zone compared with other surf clams, and therefore are potentially the most vulnerable to shore-based harvesting. However, neither the telephone-diary surveys in the 1990s nor the two national panel surveys in 2011–12 (Wynne-Jones et al 2014) and in 2017–18 (Wynne-Jones et al 2019) differentiated species of tuatua, and the harvest is thought to comprise mostly intertidal tuatua *P. subtriangulata* (Cranfield & Michael 2001). On beaches where *P. donacina* extends to just below low water, some recreational catch of this species may occur during spring low tides.

1.3   Customary fisheries

P. donacina is an important handpicked resource of local iwi, especially in Pegasus Bay, Canterbury. Deepwater tuatua form an important fishery for customary non-commercial, but the total annual catch is not known.

Māori customary fishers utilise the provisions under both the recreational fishing regulations and the various customary regulations. Many tangata whenua harvest deepwater tuatua under their recreational allowance and these are not included in records of customary catch. Customary reporting requirements vary around the country. Customary fishing authorisations issued in the South Island and Stewart Island would be under the Fisheries (South Island Customary Fishing) Regulations 1999. Many rohe moana / areas of the coastline in the North Island and Chatham Islands are gazetted under the Fisheries (Kaimoana Customary Fishing) Regulations 1998 which require reporting on authorisations. In the areas not gazetted, customary fishing permits would be issued would be under the Fisheries (Amateur Fishing) Regulations 2013, where there is no requirement to report catch.

The information on Māori customary harvest under the provisions made for customary fishing can be limited (Table 3). These numbers are likely to be an underestimate of customary harvest as only the catch approved and harvested in numbers are reported in the table.

Table 3: Fisheries New Zealand records of customary harvest of deepwater tuatua in PDO 2 (approved and reported in numbers), between 2011–12 and 2013–14. No records since. – no data.

Fishing year	PDO 2 Numbers	
	Approved	Harvested
2011–12	2 000	500
2012–13	–	–
2013–14	1 000	390

1.4   Illegal catch

There is no documented illegal catch of this clam.

1.5   Other sources of mortality

There is no quantitative information on other sources of mortality, although this clam is subject to localised catastrophic mortality from erosion during storms, high temperatures and low oxygen levels during calm summer periods, blooms of toxic algae, and excessive freshwater outflow (Cranfield & Michael 2001).

2.   BIOLOGY

P. donacina occurs mainly around the lower half of the North Island, the South Island, and Stewart Island. It is found from low tide to about 4 m depth, although juveniles may extend to the mid-tide mark. Maximum length is variable between areas, ranging from 73 mm to 109 mm (Cranfield et al 1993). The sexes are separate and they are broadcast spawners; the larvae are thought to be planktonic for between 18 and 21 days (Cranfield et al 1993). Settlement and early juveniles occur in the intertidal zone; these animals are mobile and migrate offshore as they grow. The deepwater tuatua (*Paphies donacina*) showed seasonal adjustment in its oxygen uptake and filtration rates to compensate for seasonal temperature variation in the habitat (Marsden 1999).

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, the boundaries of stocks of surf clams are likely to be the continuous lengths of exposed sandy beaches between geographical features (rivers, headlands, etc.). Circulation patterns may isolate surf clams genetically as well as ecologically.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

For further information on environmental and ecosystem considerations refer to the Introduction – surf clams chapter.

5. STOCK ASSESSMENT

MCY is estimated from the survey biomass estimates. All stocks were considered as an effectively virgin state in 1993–94 when the initial biomass estimates were made (Cranfield et al 1993).

5.1 Estimates of fishery parameters and abundance

No fisheries parameters or abundance estimates are available for any deepwater tuatua stocks.

5.2 Biomass estimates

Biomass has been estimated for PDO 2, 3, 7, and 8 at various times during 1994 to 2015. A stratified random survey using a hydraulic dredge was employed for all these surveys. Survey size has been expressed either as length of beach (Table 4), or as area (Table 5), which makes comparisons difficult.

In both 2012 (FMA 8) and 2015 (Cloudy Bay, FMA 7), White et al (2012, 2015) have conducted a 2-phase stratified random sampling survey. The survey area was stratified by 4 depth strata (0–2 m, 2–4 m, 4–6 m, and 6–8 m, each with respect to Chart Datum). Each station comprised a ~50 m tow, sampling ~80 m^2 of seabed. All commercial species of subtidal surf clams caught were sorted by species. The total weight of each of these species was measured on board. Individuals from each species were collected and measured for shell length along the anterior-posterior axis (to the nearest millimetre). For tows with less than ~500 individuals, the maximum of either 20 individuals or 20% of the total was measured. For tows with higher than ~500 individuals, 10% with an upper limit of ~200 individuals per tow were measured. To subsample large catches and to avoid issues of size sorting inside the dredge, each of the bins was subsampled by tipping one bin into two bins and repeating until the requisite sub sample size was reached. The number and weight of the main bycatch species were also recorded. Both the biomass densities and biomass estimates were calculated for all the commercial species of subtidal surf clams caught.

Table 4: A summary of biomass estimates in tonnes green weight (with standard deviation in parentheses) from exploratory surveys of Cloudy Bay, Marlborough (Cranfield et al 1994b, White et al 2015, respectively); Clifford Bay, Marlborough (Michael et al 1994); Foxton Beach, Manawatu coast (White et al 2012); and Rabbit Island, Nelson (Michael & Olsen 1988).

Area	Cloudy Bay (PDO 7)	Clifford Bay (PDO 7)	Foxton Beach (PDO 8)	Rabbit Island (PDO 7)
Length of beach (km)	11	21	46	8
Biomass (t)	154 (60), 1 541 (247)	284 (123)	3 289 (546)	108

Table 5: A summary of biomass estimates in tonnes green weight from the surveys in PDO 2 and 3 (Triantafillos 2008a, 2008b). Note: unless otherwise stated the CV is less than 20%.

Location	Five sites (PDO 2)	Ashley River to 6 nm south of the Waimakariri River (PDO 3)
Area surveyed (km^2)	28.0	13.4
Biomass (t)	5 651.8	320.8

5.3   Yield estimates and projections

Estimation of Maximum Constant Yield (*MCY*)

Growth and mortality data from Cloudy Bay, Marlborough and the Kapiti Coast, Manawatu (Cranfield et al 1993) have been used in a yield per recruit model to estimate the reference fishing mortality $F_{0.1}$ (Cranfield et al 1994b). The Shellfish Working Group (SFWG) did not accept these estimates of $F_{0.1}$ because there was considerable uncertainty in both the estimates and the method used to generate them. The *MCY* estimates of Triantafillos (2008a, 2008b) and White et al (2012, 2015) used the full range of $F_{0.1}$ estimates from Cranfield et al (1993) and are shown in Table 6. Estimates of *MCY* are available from numerous locations and were calculated using Method 1 for a virgin fishery (Ministry for Primary Industries 2015) with an estimate of virgin biomass B_0, where:

$$MCY = 0.25 \times F_{0.1}\, B_0$$

The SFWG recommended that *MCY* estimates are adequate to use to inform management decisions relevant to all surf clam fisheries, with the following caveats: 1) due to the uncertainty in $F_{0.1}$ values, for all species other than SAE, the *MCY* estimates should use the $F_{0.1}$ values toward the higher end of the range, and 2) there is a need to account for any substantial catch that has already come out of any surf clam fishery when estimating *MCY*; however there was no consensus on the best way to do this.

Table 6: Mean *MCY* estimates (t) for *P. donacina* from virgin biomass at locations sampled around New Zealand (Triantafillos 2008a, 2008b; White et al 2012, 2015). The two $F_{0.1}$ values, which are subsequently used to estimate *MCY*, are the minimum and maximum estimates from Cranfield et al. (1993).

Location	$F_{0.1}$	MCY
Five sites (PDO 2)	0.36/0.52	508.7/734.7
Ashley River to 6 n. mile south of the Waimakariri River (PDO 3)	0.36/0.52	28.9/41.7
Foxton Beach (PDO 8)	0.36/0.52	296.1/427.6
Cloudy Bay (PDO 7)	0.36/0.52	138.7/200.3

Estimation of Current Annual Yield (*CAY*)

CAY has not been estimated for *P. donacina*.

The SFWG recommended moving all surf clam fisheries away from an *MCY* management strategy and towards an exploitation rate management strategy. The SFWG recognised that an exploitation rate approach is more survey intensive, but better allows for the variable nature of biomass for surf clams because it allows greater flexibility in catch (to take greater landings from available biomass) whilst keeping catches sustainable.

6.   STATUS OF THE STOCKS

- **PDO 2**

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	-
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2008	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review the fishery parameters for this species.

Fishery Interactions
PDO can be caught together with other surf clam species and non-QMS bivalves.

- **PDO 3**

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown

Recent Trend in Fishing Mortality or Proxy	Catches in PDO 3 have ranged from 0 to 11.21 t between 2006–07 and 2012–13 and overall increased since to reach 92.12 t in 2018–19.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2008	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review the fishery parameters for this species.

Fishery Interactions
PDO can be caught together with other surf clam species and non-QMS bivalves.

- **PDO 7**

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Very Likely (> 90%) to be at or above the target
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Intensity or Proxy	Fishing has increased from 17.10 t in 2011–12 to 182.12 t in 2016–17 and reduced to 159.2 t in 2018–19.

Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below limits	Current catches at the TACC are Very Unlikely ($< 10\%$) to cause declines below soft or hard limits.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely ($< 10\%$)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2015	Next assessment: Unknown
Overall assessment quality rank		
Main data inputs (rank)	- Abundance and length frequency information	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review the fishery parameters for this species.

Fishery Interactions
PDO can be caught together with other surf clam species and non-QMS bivalves.

- **PDO 8**

Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Fishing has increased since 2018-19 but it remains at a relatively low level
Other Abundance Indices	-

Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2012	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review the fishery parameters for this species.

Fishery Interactions
PDO can be caught together with other surf clam species and non-QMS bivalves.

7.   FOR FURTHER INFORMATION

Annala, J H; Sullivan, K J; O'Brien, C J; Smith, N W M (compilers.) (2001) Report from the fishery assessment plenary, May 2001: stock assessments and yield estimates. 515 p. (Unpublished report held in NIWA library, Wellington).

Bradford, E (1998) Harvest estimates from the 1996 national marine recreational fishing surveys. New Zealand Fisheries Assessment Research Document 98/16 27p. (Unpublished report held in NIWA library, Wellington).

Brierley, P (Convenor) (1990) Management and development of the New Zealand sub-tidal clam fishery. Report of the surf clam working group, MAF Fisheries (Unpublished report held in NIWA library, Wellington). 57 p.

Cranfield, H J; Doonan, I J; Michael, K P (1994b) Dredge survey of surf clams in Cloudy Bay, Marlborough. *New Zealand Fisheries Technical Report* No. 39. 18 p.

Cranfield, H J; Michael, K P (2001) The surf clam fishery in New Zealand: description of the fishery, its management, and the biology of surf clams. *New Zealand Fisheries Assessment Report 2001/62*. 24 p.

Cranfield, H J; Michael, K P; Stotter, D R (1993) Estimates of growth, mortality, and yield per recruit for New Zealand surf clams. New Zealand Fisheries Assessment Research Document 1993/20. 26p. (Unpublished report held in NIWA library, Wellington).

Cranfield, H J; Michael, K P; Stotter, D R; Doonan, I J (1994a) Distribution, biomass and yield estimates of surf clams off New Zealand beaches. New Zealand Fisheries Assessment Research Document 94/1. 17 p. (Unpublished report held in NIWA library, Wellington.)

Haddon, M; Willis, T J; Wear, R G; Anderlini, V C (1996) Biomass and distribution of five species of surf clam off an exposed west coast North Island beach, New Zealand. *Journal of Shellfish Research 15*: 331–339.

Marsden, I D (1999) Respiration and feeding of the surf clam *Paphies donacina* from New Zealand. *Hydrobiologia 405*: 179–188.

Marsden, I D (2000) Variability in low tide populations of tuatua, *Paphies donacina*, in Pegasus Bay, Canterbury, New Zealand. *New Zealand Journal of Marine and Freshwater Research 34*: 359–370.

Michael, K; Cranfield, H; Doonan, I; Hadfield, J (1994) Dredge survey of surf clams in Clifford Bay, Marlborough, New Zealand Fisheries Data Report. No. 54. (Unpublished report held at NIWA library, Wellington.)

Michael, K P; Olsen, G P (1988) Surf clam resource, Rabbit Island, Nelson. Fisheries Research Centre Internal Report No. 84. 17 p. (Unpublished report held in NIWA library, Greta Point, Wellington.)

Ministry for Primary Industries (2015). Fisheries Assessment Plenary, May 2015: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1475 p.

Triantafillos, L (2008a) Survey of subtidal surf clams in Pegasus Bay, November–December 2007. 43 p. Prepared by NIWA for Seafood Innovations Limited and SurfCo. Limited. (Unpublished report held at Fisheries New Zealand.)

Triantafillos, L (2008b) Survey of subtidal surf clams in Quota Management Area 2, June - August 2008. 40 p. Prepared by NIWA for Seafood Innovations Limited and SurfCo. Limited. (Unpublished report held at Fisheries New Zealand.)

White, W; Millar, R; Breen, B; Farrington, G (2012) Survey of subtidal surf clams from the Manawatu Coast (FMA 8), October–November 2012. (Unpublished Report held by Fisheries New Zealand Wellington.) 35 p.+ Addendum.

DEEPWATER TUATUA (PDO)

White, W; Millar, R; Farrington, G; Breen, D; Selveraj, S (2015). Stock assessment of surf clams from Cloudy Bay, NZ. *Institute for Applied Ecology New Zealand Report 15/01*. Published by Applied Ecology New Zealand, an Institute of Auckland University of Technology. 34 p.

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24*. 104 p.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.

FINE (SILKY) DOSINIA (DSU)

(*Dosinia subrosea*)
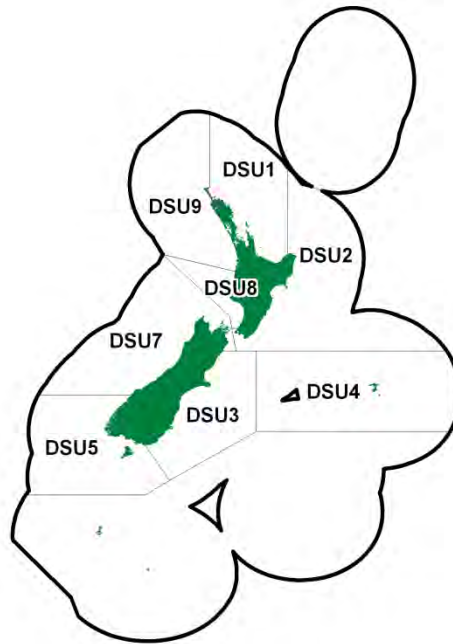
1.   FISHERY SUMMARY

This species is part of the surf clam fishery and the reader is guided to the Introduction – surf clam chapter for information common to all relevant species.

Fine Dosinia (*Dosinia subrosea*) were introduced into the Quota Management System on 1 April 2004 with a TAC and a TACC of 1 t in each QMA, leading to an overall TAC of 8 t and an overall TACC of 8 t for the country (Table 1). There were no allowances for customary, recreational, or other sources of mortality and no changes to any of these values have occurred since.

Table 1: Current TAC and TACC for *Dosinia subrosea*.

QMA	TAC (t)	TACC (t)
1	1	1
2	1	1
3	1	1
4	1	1
5	1	1
7	1	1
8	1	1
9	1	1
Total	8	8

1.1   Commercial fisheries

Landings have only ever been reported from DSU 1 and DSU 7. In 1993–94 total landings were 235 kg, with half originating in DSU 1, and half originating in DSU 7. In 1994–95 and 1995–96 reported landings came entirely from DSU 7, with 26 kg and 38 kg recorded respectively. No further landings were reported until after 2002–03. In 2003–04 total landings of 89 kg were recorded, which increased to 110 kg in 2004–05, and 169 kg in 2005–06. By the 2006–07 fishing year, only 3 kg of landings were reported, and after the 2008–09 fishing year landings ceased until 2019–20 (Table 2).

1.2   Recreational fisheries

There are no known records of recreational use of this surf clam.

Table 2: TACCs and reported landings (t) of *Dosinia subrosea* by Fishstock from 1993–94 to the present day from CELR and CLR data for Fishstocks where landings have been reported. See Table 1 for TACC of stocks not landed.

Fishing year	DSU 1 Landings	DSU 1 TACC	DSU 7 Landings	DSU 7 TACC	Total Landings	Total TACC
1993–94	0.123	-	0.112	-	0.235	-
1994–95	0	-	0.026	-	0.026	-
1995–96	0	-	0.011	-	0.038	-
1996–97	0	-	0	-	0	-
1997–98	0	-	0	-	0	-
1998–99	0	-	0	-	0	-
1999–00	0	-	0	-	0	-
2000–01	0	-	0	-	0	-
2001–02	0	-	0	-	0	-
2002–03	0	-	0	-	0	-
2003–04	0	1.0	0.089	1.0	0.089	-
2004–05	0	1.0	0.078	1.0	0.110*	8.0
2005–06	0	1.0	0.061	1.0	0.169*	8.0
2006–07	0	1.0	0.003	1.0	0.003	8.0
2007–08	0	1.0	0	1.0	0	8.0
2008–09	0	1.0	0.001	1.0	0.001	8.0
2009–10	0	1.0	0	1.0	0	8.0
2010–11	0	1.0	0	1.0	0	8.0
2011–12	0	1.0	0	1.0	0	8.0
2012–13	0	1.0	0	1.0	0	8.0
2013–14	0	1.0	0	1.0	0	8.0
2014–15	0	1.0	0	1.0	0	8.0
2015–16	0	1.0	0	1.0	0	8.0
2016–17	0	1.0	0	1.0	0	8.0
2017–18	0	1.0	0	1.0	0	8.0
2018–19	0	1.0	0	1.0	0	8.0
2019–20	0	1.0	0	1.0	0.003	8.0
2020–21	0	1.0	0	1.0	0	8.0
2021–22	0	1.0	0	1.0	0	8.0

*In 2004–05 and 2005–06 32.4 and 90 kg were reported but the QMA was not recorded. This amount is included in the total landings for these years.

1.3 Customary fisheries

Offshore clams such as *D. subrosea* are likely to have been harvested for customary use only when washed ashore after storms (Carkeek 1966). There are no estimates of current customary use of this clam.

1.4 Illegal catch

There is no known illegal catch of this clam.

1.5 Other sources of mortality

There is no quantitative information on other sources of mortality, although this clam is probably sometimes taken as a bycatch in inshore trawling. Surf clam populations are also subject to localised catastrophic mortality from erosion during storms, high temperatures and low oxygen levels during calm summer periods, blooms of toxic algae, and excessive freshwater outflow (Cranfield & Michael 2001).

2. BIOLOGY

D. subrosea has not been found in high densities in any survey work. It is found around the New Zealand coast in deeper softer sediment habitats. Around the North Island it is found between 6 m and 10 m in depth, and around the South Island between 5 m and 8 m (Cranfield & Michael 2002). It is smaller and smoother than *D. anus* and is usually found in more stable habitats. Maximum length is variable between areas, ranging from 41 mm to 68 mm (Cranfield et al 1993). The sexes are believed to be separate, and they are likely to be broadcast spawners with planktonic larvae (Cranfield & Michael 2001). Anecdotal evidence suggests that spawning is likely to occur in the summer months. Recruitment of surf clams is thought to be highly variable between years.

For information on growth, age, and natural mortality of this species and general statements about relative biomass of all surf clam species around the country (excluding *Bassinia yatei)* see the Introduction – surf clam chapter.

3.   STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, the boundaries of stocks of surf clams are likely to be the continuous lengths of exposed sandy beaches between geographical features (such as rivers and headlands). Circulation patterns may isolate surf clams genetically as well as ecologically.

4.   ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

See the Introduction – surf clam chapter.

5.   STOCK ASSESSMENT

All stocks are considered in effectively virgin state and an *MCY* is estimated from the survey biomass estimates. All stocks were considered in an effectively virgin state in 1993–94 when the initial biomass estimates were made (Cranfield et al 1993). Total catches of DSU have not exceeded 1 t in any Fishstock since then.

5.1   Estimates of fishery parameters and abundance

No fisheries parameters or abundance estimates are available for any DSU stocks.

5.2   Biomass estimates

Biomass has been estimated from 11 km of beach at Cloudy Bay (DSU 7) with a stratified random survey using a hydraulic dredge (Cranfield et al 1994b). The virgin biomass for this area was estimated to be 21 t. Subsequent surveys estimated biomass from one site in DSU 3 and a number of sites in DSU 2 (Table 3).

Table 3: A summary of biomass estimates greenweight (t) from the surveys in DSU 2 and 3 (Triantifillos 2008a, Triantifillos 2008b). Note: unless otherwise stated the CV is less than 0.2.

Location	Five sites (PDO 2)	Ashley River to 6 n mile south of the Waimakariri River (PDO 3)
Area surveyed (km^2)	28.0	13.4
Biomass (t)	5.9	12.2*

* CV is 0.29.

5.3   Yield estimates and projections

Estimation of Maximum Constant Yield (*MCY*)

Growth and mortality data from Cloudy Bay in Marlborough and the Kapiti Coast in Manawatu (Cranfield et al 1993) have been used in a yield per recruit model to estimate the reference fishing mortality $F_{0.1}$ (Cranfield et al 1994b, Triantifillos 2008a, 2008b). The Shellfish Working Group (SFWG) did not accept these estimates of $F_{0.1}$ because there was considerable uncertainty in both the estimates and the method used to generate them. The *MCY* estimates of Triantifillos (2008b) that use the full range of $F_{0.1}$ estimates from Cranfield et al (1993) are shown in Table 4, but should be interpreted with caution.

Estimates of *MCY* were calculated using Method 1 for a virgin fishery (Annala et al 2001) with an estimate of virgin biomass B_0, where:

$$MCY = 0.25* F_{0.1} B_0$$

Table 4: Mean *MCY* estimates (t) for *D. subrosea* from virgin biomass at DSU 2 (Triantifillos 2008a, 2008b). The two $F_{0.1}$ values, which are subsequently used to estimate MCY, are the minimum and maximum estimates from Cranfield et al. (1993).

Location	$F_{0.1}$	MCY
Five sites (DSU 2)	0.27/0.54	0.4/0.8

Estimation of Current Annual Yield (*CAY*)

CAY has not been estimated for *D. subrosea*.

The SFWG recommended moving all surf clam fisheries away from an *MCY* management strategy and towards an exploitation rate management strategy. The SFWG recognised that an exploitation rate approach is more survey intensive, but better allows for the variable nature of biomass for surf clams because it allows greater flexibility in catch (to take greater landings from available biomass) whilst keeping catches sustainable.

6. STATUS OF THE STOCKS

- DSU-*Dosinia subrosea*

There is no evidence of appreciable biomass of this species in any area.

7. FOR FURTHER INFORMATION

Annala, J H; Sullivan, K J; O'Brien, C J; Smith, N W McL (compilers.) (2001) Report from the fishery assessment plenary, May 2001: stock assessments and yield estimates. 515 p. (Unpublished report held in NIWA library, Wellington).

Brierley, P (Convenor) (1990) Management and development of the New Zealand sub-tidal clam fishery. Report of the surf clam working group, MAF Fisheries (Unpublished report held in NIWA library, Wellington). 57 p.

Carkeek, W C (1966) *The Kapiti coast*. Reed, Wellington. 187 p.

Cranfield, H J; Michael, K P (2001) The surf clam fishery in New Zealand: description of the fishery, its management, and the biology of surf clams. *New Zealand Fisheries Assessment Report 2001/62*. 24 p.

Cranfield, H; Michael, K (2002) Potential area boundaries and indicative TACs for the seven species of surf clam. NIWA report to the Ministry of Fisheries. (Unpublished report held by Fisheries New Zealand.)

Cranfield, H J; Michael, K P; Stotter, D R (1993) Estimates of growth, mortality, and yield per recruit for New Zealand surf clams. New Zealand Fisheries Assessment Research Document 1993/20. 26 p. (Unpublished document held by NIWA library.)

Cranfield, H J; Michael, K P; Stotter, D R; Doonan, I J (1994a) Distribution, biomass and yield estimates of surf clams off New Zealand beaches. New Zealand Fisheries Assessment Research Document 1994/1 17 p. (Unpublished document held by NIWA library.)

Cranfield, H J; Doonan, I J; Michael, K P (1994b) Dredge survey of surf clams in Cloudy Bay, Marlborough. *New Zealand Fisheries Technical Report* 39: 18 p.

Haddon, M; Willis, T J; Wear, R G; Anderlini, V C (1996) Biomass and distribution of five species of surf clam off an exposed west coast North Island beach, New Zealand. *Journal of Shellfish Research* 15: 331–339.

Triantifillos, L (2008a) Survey of subtidal surf clams in Pegasus Bay, November–December 2007. 43 p. Report prepared by NIWA for Seafood Innovations Limited and SurfCo. Limited. (Unpublished document held by Fisheries New Zealand.)

Triantifillos, L (2008b) Survey of subtidal surf clams in Quota Management Area 2, June – August 2008. 40 p. Report prepared by NIWA for Seafood Innovations Limited and SurfCo. Limited. (Unpublished document held by Fisheries New Zealand.)

FRILLED VENUS SHELL (BYA)

(*Bassina yatei*)
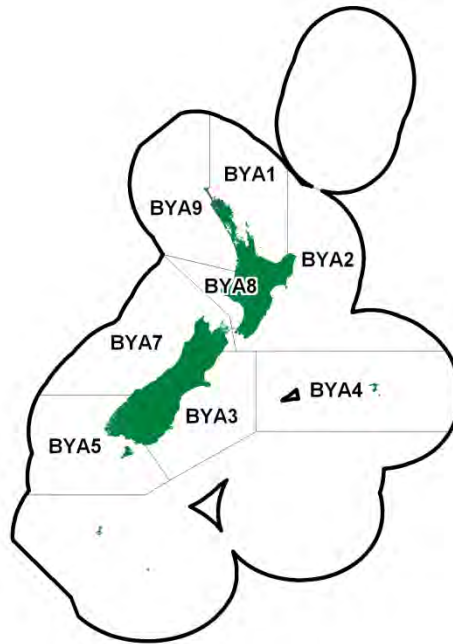
1. FISHERY SUMMARY

This species is part of the surf clam fishery and the reader is guided to the Introduction – surf clam chapter for information common to all relevant species.

1.1 Commercial fisheries

The frilled venus shell (*Bassina yatei*) was introduced into the Quota Management System on 1 April 2004 with a combined TAC of 16 t and a TACC of 16 t. There were no allowances for customary, recreational, or other sources of mortality. These limits have not been changed (Table 1).

Table 1: Current TAC and TACC for *Bassina yatei*.

QMA	TAC (t)	TACC (t)
1	1	1
2	1	1
3	1	1
4	1	1
5	1	1
7	9	9
8	1	1
9	1	1
Total	16	16

Small BYA 7 landings (all around 1 t or less) were reported from 1992–93 to 1994–95, 2001–02 to 2004–05, 2008–09, and 2011–12 to 2015–16, and landings of over 7 t were reported from BYA 1 in 2002–03 (Table 2). No frilled venus shell landings have been recorded since the fishing year 2015–16.

1.2 Recreational fisheries

There are no known records of recreational use of this surf clam.

1.3 Customary fisheries

Offshore clams such as *B. yatei* are likely to have been harvested for customary use only when washed ashore after storms. Shells of this clam have been found irregularly and in small numbers in a few middens. There are no estimates of current customary use of this clam.

Table 2: TACCs and reported landings (t) of frilled venus shell by Fishstock from 1992–93 to present from CELR and CLR data. See Table 1 for TACC of stocks not landed.

Year	BYA 1 Landings	BYA 1 TACC	BYA 7 Landings	BYA 7 TACC	Total Landings	Total TACC
1992–93	0	–	0.026	–	0.026	–
1993–94	0	–	0.007	–	0.007	–
1994–95	0	–	0.001	–	0.001	–
1995–96	0	–	0	–	0	–
1996–97	0	–	0	–	0	–
1997–98	0	–	0	–	0	–
1998–99	0	–	0	–	0	–
1999–00	0	–	0	–	0	–
2000–01	0	–	0	–	0	–
2001–02	7.473	–	0.049	–	7.522	–
2002–03	0	–	1.132	9	1.132	–
2003–04	0	1	1.295	9	1.296	–
2004–05	0	1	0.207	9	0.207	16
2005–06	0	1	0	9	0.036*	16
2006–07	0	1	0	9	0	16
2007–08	0	1	0	9	0	16
2008–09	0	1	0.003	9	0.003	16
2009–10	0	1	0	9	0	16
2010–11	0	1	0	9	0	16
2011–12	0	1	0.350	9	0.350	16
2012–13	0	1	1.174	9	1.174	16
2013–14	0	1	1.106	9	1.106	16
2014–15	0	1	0.931	9	0.931	16
2015–16	0	1	0.998	9	0.998	16
2016–17	0	1	0	9	0	16
2017–18	0	1	0	9	0	16
2018–19	0	1	0	9	0	16
2019–20	0	1	0	9	0	16
2020–21	0	1	0	9	0	16
2021–22	0	1	0	9	0	16

* In 2005–06 36.4 kg were reportedly landed, but the QMA was not recorded. This amount is included in the total landings for that year.

1.4 Illegal catch

There is no documented illegal catch of this clam.

1.5 Other sources of mortality

There is no quantitative information on other sources of mortality, although this clam is subject to localised catastrophic mortality from erosion during storms, high temperatures and low oxygen levels during calm summer periods, blooms of toxic algae, and excessive freshwater outflow (Cranfield & Michael 2001).

2. BIOLOGY

Bassina yatei is endemic to New Zealand and is found around the coast in sediments at depths between 6 m and 9 m. Maximum length is variable between areas, ranging from 48 mm to 88 mm (Cranfield & Michael 2002). The sexes are likely to be separate, and they are likely to be broadcast spawners with planktonic larvae. Anecdotal evidence suggests spawning is likely to occur in the summer months. Recruitment of surf clams is thought to be highly variable between years.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, the boundaries of stocks of surf clams are likely to be the continuous lengths of exposed sandy beaches between geographical features (rivers, headlands, etc). Circulation patterns may isolate surf clams genetically as well as ecologically.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

See the Introduction – surf clam chapter.

5. STOCK ASSESSMENT

5.1 Estimates of fishery parameters and abundance
No estimates of fisheries parameters or abundance are available for this species.

5.2 Biomass estimates
Biomass has been estimated for two sites in the Marlborough Sounds (Cloudy Bay by Cranfield et al 1994b and White et al 2015) and Clifford Bay (by Michael et al 1994)) with a stratified random survey using a hydraulic dredge. Estimates are shown in Table 3.

In 2015, White et al (2015) conducted a 2-phase stratified random sampling survey. The survey area was stratified by 4 depth strata (0–2 m, 2–4 m, 4–6 m, and 6–8 m, each with respect to Chart Datum). Each station comprised a ~50 m tow, sampling ~80 m^2 of seabed. All commercial species of subtidal surf clams caught were sorted by species. The total weight of each species was measured on board. Individuals from each species were collected and measured for shell length along the anterior-posterior axis (to the nearest millimetre). For tows with less than ~500 individuals, the maximum of either 20 individuals or 20% of the total was measured. For tows with higher than ~500 individuals, 10% with an upper limit of ~200 individuals per tow were measured. To subsample large catches and to avoid issues of size sorting inside the dredge, each of the bins was subsampled by tipping one bin into two bins and repeating until the requisite sub sample size was reached. The number and weight of the main bycatch species was also recorded. Both the biomass densities and biomass estimates were calculated for all the commercial species of subtidal surf clams caught.

Table 3: A summary of biomass estimates in tonnes greenweight (with standard deviation in parentheses) from exploratory surveys of Cloudy Bay (Cranfield et al 1994b and White et al 2015) and Clifford Bay (Michael et al 1994), both in Marlborough.

Area	Cloudy Bay (BYA 7)	Clifford Bay (BYA 7)
Length of beach (km)	11, 11	21
Biomass (t)	123 (50), 193 (72)	0.2 (0.8)

5.3 Yield estimates and projections
Growth and mortality data from Cloudy Bay in Marlborough and the Kapiti Coast in Manawatu (Cranfield et al 1993) have been used in a yield per recruit model to estimate the reference fishing mortality $F_{0.1}$ (Cranfield et al 1994b). The Shellfish Working Group (SFWG) did not accept these estimates of $F_{0.1}$ because there was considerable uncertainty in both the estimates and the method used to generate them. The MCY estimates of White et al (2015) used the full range of $F_{0.1}$ estimates from Cranfield et al (1993) and are shown in Table 4. Estimates of MCY were calculated using Method 1 for a virgin fishery (Ministry for Primary Industries 2015) with an estimate of virgin biomass B_0, where:

$$MCY = 0.25 * F_{0.1} B_0$$

The SFWG recommended that MCY estimates are adequate to use to inform management decisions relevant to all surf clam fisheries, with the following caveats: 1) due to the uncertainty in $F_{0.1}$ values, for all species other than SAE, the MCY estimates should use the $F_{0.1}$ values toward the higher end of the range, and 2) there is a need to account for any substantial catch that has already come out of any surf clam fishery when estimating MCY; however there was no consensus on the best way to do this.

Table 4: Mean MCY estimates (t) for B. yatei from virgin biomass at Cloudy Bay (BYA 7) from White et al (2015). The two $F_{0.1}$ values, which are subsequently used to inform MCY, are the minimum and maximum estimates from Cranfield et al (1993).

Location	$F_{0.1}$	MCY
Cloudy Bay (BYA 7)	0.25/0.42	12.1/20.3

CAY has not been estimated for B. yatei.

The SFWG recommended moving all surf clam fisheries away from an MCY management strategy and towards an exploitation rate management strategy. The SFWG recognised that an exploitation rate

approach is more survey intensive, but better allows for the variable nature of biomass for surf clams because it allows greater flexibility in catch (to take greater landings from available biomass) whilst keeping catches sustainable.


6.   STATUS OF THE STOCKS

- BYA 7 - *Bassina yatei*

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold:-
Status in relation to Target	Because of the relatively low levels of exploitation of *B. yatei*, it is likely that the stock is still effectively in a virgin state, therefore it is Very Likely (> 90%) to be at or above the target.
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Landings have averaged 0.51 t between the 2001–02 and 2015–16 fishing years. No landings since 2016-17.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Fishing is Very Unlikely (< 10%) to cause declines below soft or hard limits in the short to medium term.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2015	Next assessment: Unknown
Overall assessment quality rank		
Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments

Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review fishery parameters for this species.

Virgin stock size in areas sampled has been small. It is not known if peak abundances may be outside the surveyed areas.

Fishery Interactions

BYA can be caught together with other surf clam species and non-QMS bivalves.

For all other BYA stocks there is no current evidence of appreciable biomass.

7. FOR FURTHER INFORMATION

Beentjes, M P; Baird, S J (2004) Review of dredge fishing technologies and practice for application in New Zealand. *New Zealand Fisheries Assessment Report 2004/37*. 40 p.

Brierley, P (Convenor) (1990) Management and development of the New Zealand sub-tidal clam fishery. Report of the surf clam working group, MAF Fisheries (Unpublished report held in NIWA library, Wellington). 57 p.

Cranfield, H J; Michael, K P (2001) The surf clam fishery in New Zealand: description of the fishery, its management, and the biology of surf clams. *New Zealand Fisheries Assessment Report 2001/62*. 24 p.

Cranfield, H; Michael, K (2002) Potential area boundaries and indicative TACs for the seven species of surf clam. NIWA report to the Ministry of Fisheries. (Unpublished report held by Fisheries New Zealand).

Cranfield, H J; Michael, K P; Stotter, D R (1993) Estimates of growth, mortality, and yield per recruit for New Zealand surf clams. New Zealand Fisheries Assessment Research Document 1993/20. 26 p. (Unpublished report held in NIWA library, Wellington).

Cranfield, H J; Michael, K P; Stotter, D R; Doonan, I J (1994a) Distribution, biomass and yield estimates of surf clams off New Zealand beaches. New Zealand Fisheries Assessment Research Document 1994/1. 17 p. (Unpublished report held in NIWA library, Wellington).

Cranfield, H J; Doonan I J; Michael, K P (1994b) Dredge survey of surf clams in Cloudy Bay, Marlborough. *New Zealand Fisheries Technical Report 39*. 18 p.

Haddon, M; Willis, T J; Wear, R G; Anderlini, V C (1996) Biomass and distribution of five species of surf clam off an exposed west coast North Island beach, New Zealand. *Journal of Shellfish Research 15*: 331–339.

Michael, K; Cranfield, H; Doonan, I; Hadfield, J (1994) Dredge survey of surf clams in Clifford Bay, Marlborough. New Zealand Fisheries Data Report No. 54. (Unpublished report held in NIWA library, Wellington).

Ministry for Primary Industries (2015) Fisheries Assessment Plenary, May 2015: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1475 p.

White, W; Millar, R; Farrington, G; Breen, D; Selveraj, S (2015) Stock assessment of surf clams from Cloudy Bay, NZ. *Institute for Applied Ecology New Zealand Report 15/01*. Published by Applied Ecology New Zealand, an Institute of Auckland University of Technology. 34 p.

LARGE TROUGH SHELL (MMI)

(*Mactra murchisoni*)
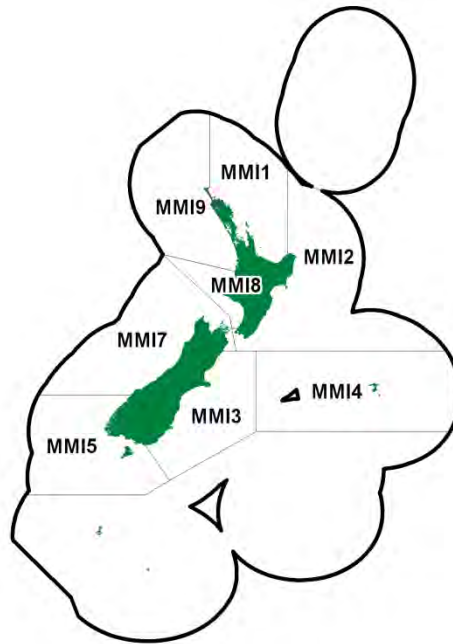
1.   FISHERY SUMMARY

This species is part of the surf clam fishery and the reader is guided to the Introduction – surf clams chapter for information common to all relevant species.

1.1   Commercial fisheries

Large trough shells (*Mactra murchisoni*) were introduced into the Quota Management System on 1 April 2004 with a total TACC of 162 t. No allowances were initially made for customary, recreational, or other sources of mortality; some allowances were introduced for MMI 8 and 7 in 2013 and 2016, respectively. Biomass surveys in QMA 3 supported a TACC increase from April 2010. This increased the TACC for MMI 3 from 3 t to 62 t. A subsequent biomass survey in 2012 supported a TAC increase in MMI 8 from 25 t to 631 t in April 2013. Another biomass survey supported a TAC increase in MMI 7 from 61 t to 144 t in April 2016. The current total TAC is 872 t (Table 1).

Table 1: Current TAC, TACC, and allowances for other sources of mortality for *Mactra murchisoni.*

Fishstock	TAC (t)	TACC (t)	Recreational Allowance (t)	Customary Allowance (t)	Other sources of mortality (t)
MMI 1	2	2	0	0	0
MMI 2	3	3	0	0	0
MMI 3	65	62	0	0	3
MMI 4	1	1	0	0	0
MMI 5	1	1	0	0	0
MMI 7	144	131	1	5	7
MMI 8	631	589	0	10	32
MMI 9	25	25	0	0	0
Total	872	814	1	15	42

All reported landings have been from MMI 3 and MMI 7. Between the 1991–92 and 1995–96 fishing years landings were small and confined to MMI 7. No further landings were reported until 2002–03. Since then the reported total landings have ranged between about 23 t and 77 t, with an equal amount of landings recorded from 2002–03 to 2018–19 coming from each of the two stocks (Table 2).

MMI 3 landings reached the TACC in 2013–14, and again in 2019–20, but decreased to levels well below the TACC in the intervening years. MMI 7 landings were close to the TACC from 2004–05 to 2006–07 but have fluctuated around a lower level since this time; the TACC was increased in 2015. Figure 1 shows the historical landings and TACCs for the two main MMI stocks.

Table 2: TACCs and reported landings (t) of large trough shell by Fishstock from 1991–92 to present from CELR and CLR data. Fishstocks where no catch has been reported are not tabulated. See Table 1 for TACC of stocks not landed.

	MMI 3		MMI 7		Total	
Year	Landings	TACC	Landings	TACC	Landings	TACC
1991–92	0	0	0.35	–	0.35	–
1992–93	0	0	1.54	–	1.54	–
1993–94	0	0	8.33	–	8.33	–
1994–95	0	0	10.43	–	10.43	–
1995–96	0	0	0.14	–	0.14	–
1996–97	0	0	0	–	0	–
1997–98	0	0	0	–	0	–
1998–99	0	0	0	–	0	–
1999–00	0	0	0	–	0	–
2000–01	0	0	0	–	0	–
2001–02	0	0	0	–	0	–
2002–03	0	0	22.62	–	22.62	–
2003–04	0	44	29.68	61	29.68	162
2004–05	0	44	60.02	61	60.86*	162
2005–06	0	44	53.96	61	57.92*	162
2006–07	7.48	44	54.09	61	61.57	162
2007–08	36.90	44	15.04	61	51.94	162
2008–09	32.15	44	6.66	61	38.81	162
2009–10	25.76	44	3.42	61	29.18	162
2010–11	12.60	62	17.43	61	30.03	180
2011–12	0	62	47.34	61	47.34	180
2012–13	44.45	62	32.81	61	77.27	180
2013–14	63.87	62	4.89	61	68.75	744
2014–15	59.00	62	9.69	61	68.64	744
2015–16	46.72	62	23.98	131	71.77	814
2016–17	35.79	62	25.62	131	62.59	814
2017–18	40.39	62	29.43	131	71.87	814
2018–19	29.92	62	32.43	131	62.92	814
2019–20	62.91	62	36.12	131	99.62	814
2020–21	63.10	62	16.53	131	79.96	814
2021–22	62.07	62	17.98	131	85.07	814

*In 2004–05 and 2005–06, 0.84 and 3.9554 t respectively were reportedly landed, but the QMA was not recorded. These amounts are included in the total landings for these years.

1.2   Recreational fisheries

Offshore clams such as *M. murchisoni* are likely to have been harvested for recreational use only when washed ashore after storms. There are no estimates of recreational take for this surf clam.

1.3   Customary fisheries

Offshore clams such as *M. murchisoni* are likely to have been harvested for customary use only when washed ashore after storms. Shells of this clam have been found irregularly, and in small numbers, in a few middens (Conroy et al 1993). There are no estimates of current customary catch of this clam.

1.4   Illegal catch

There is no documented illegal catch of this clam.

1.5   Other sources of mortality

There is no quantitative information on other sources of mortality, although this clam is subject to localised catastrophic mortality from erosion during storms, high temperatures and low oxygen levels during calm summer periods, blooms of toxic algae, and excessive freshwater outflow (Cranfield & Michael 2001).
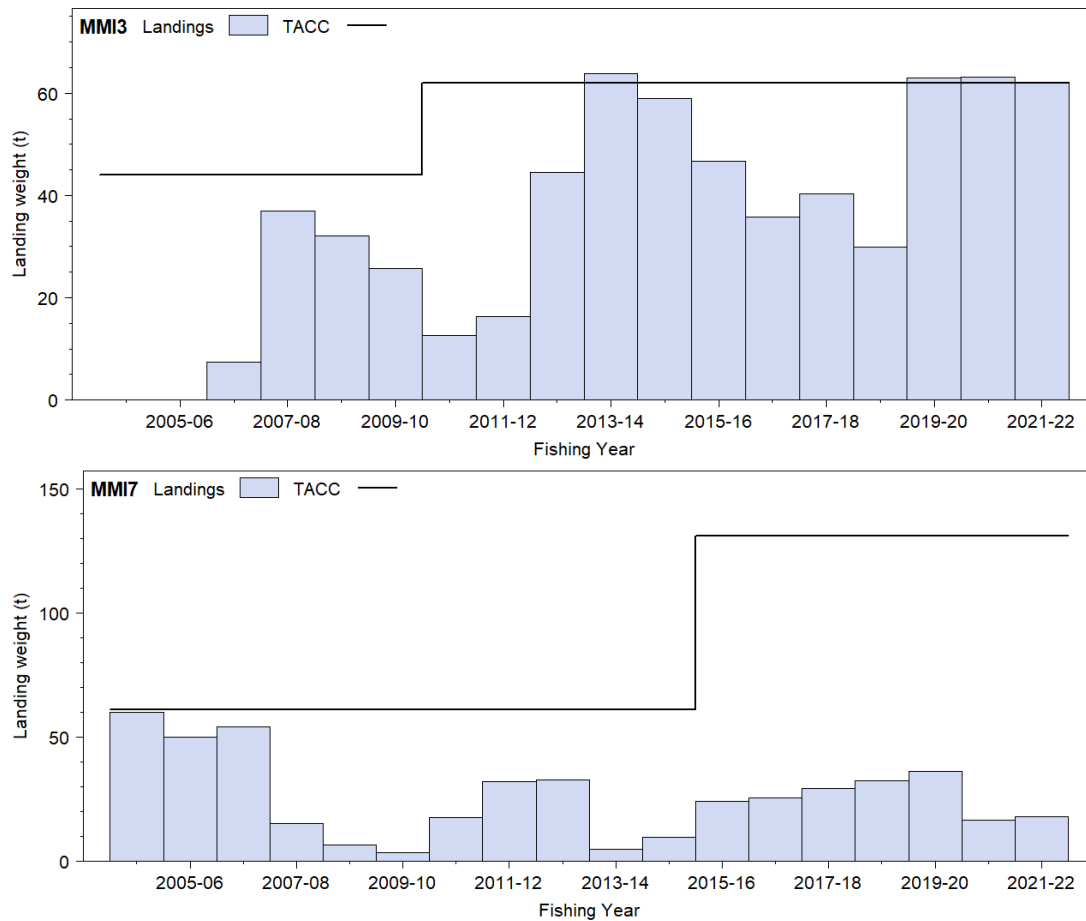
Figure 1: Reported commercial landings and TACC for MMI 3 (South East Coast) (top) and MMI 7 (Challenger) (bottom). Note that these figures do not show data prior to entry into the QMS.

2. BIOLOGY

M. murchisoni is most abundant around the lower half of the North Island and the South Island. It is found most commonly between about 4 m and 8 m in depth. Maximum length is variable between areas, ranging from 63 mm to 102 mm (Cranfield et al 1993). The sexes are separate, they are broadcast spawners, and the larvae are thought to be planktonic for between 20 and 30 days (Cranfield & Michael 2001). Recruitment of spat is to the same depth zone that adults occur in, although recruitment between years is highly variable (Conroy et al 1993).

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however the boundaries of stocks of surf clams are likely to be the continuous lengths of exposed sandy beaches between geographical features (rivers, headlands, etc). Circulation patterns may isolate surf clams genetically as well as ecologically.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

See the Introduction – surf clams chapter.

5. STOCK ASSESSMENT

5.1 Estimates of fishery parameters and abundance

No estimates of fisheries parameters or abundance are available for this species.

5.2 Biomass estimates

Biomass has been estimated from MMI 2, 3, 7, and 8 at various times between 1994 and 2015 with stratified random surveying using a hydraulic dredge. Survey size has been expressed either as length of beach (Table 3), or as area (Table 4), which makes comparisons difficult.

In both 2012 (FMA 8) and 2015 (Cloudy Bay, FMA 7), White et al (2012, 2015) have conducted a 2-phase stratified random sampling survey. The survey area was stratified by 4 depth strata (0–2 m, 2–4 m, 4–6 m, and 6–8 m, each with respect to Chart Datum). Each station comprised a ~50 m tow, sampling ~80 m^2 of seabed. All commercial species of subtidal surf clams caught were sorted by species. The total weight of each of these species was measured on board. Individuals from each species were collected and measured for shell length along the anterior-posterior axis (to the nearest millimetre). For tows with less than ~500 individuals, the maximum of either 20 individuals or 20% of the total was measured. For tows with higher than ~500 individuals, 10% with an upper limit of ~200 individuals per tow were measured. To subsample large catches and to avoid issues of size sorting inside the dredge, each of the bins was subsampled by tipping one bin into two bins and repeating until the requisite sub sample size was reached. The number and weight of the main bycatch species was also recorded. Both the biomass densities and biomass estimates were calculated for all the commercial species of subtidal surf clams caught.

Table 3: A summary of biomass estimates in tonnes greenweight (with standard deviation in parentheses) from exploratory surveys of Cloudy Bay (Cranfield et al 1994a) and Clifford Bay in Marlborough (Michael et al 1994), and Foxton beach on the Manawatu coast (White et al 2012).

Area	Cloudy Bay (MMI 7)	Clifford Bay (MMI 7)	Foxton Beach (MMI 8)
Length of beach (km)	11	21	46[#]
Biomass (t)	248 (96)	192 (79)	3 603 (342)[#]

[#] Biomass was estimated at Foxton Beach from a mix of a systematic survey to the north and a stratified survey to the south of this location.

Table 4: A summary of biomass estimates in greenweight (t) from the surveys in MMI 2 (Triantifillos 2008b), MMI 3 (Triantifillos 2008a), and MMI 7 (White et al 2015). Note: unless otherwise stated the CV is less than 20%.

Location	Five sites (MMI 2)	Ashley River to 6 nm south of the Waimakariri River (MMI 3)	Cloudy Bay (MMI 7)
Area surveyed (km^2)	28.0	13.4	5.7
Biomass (t)	33.8	444.1	1 008.8

5.3 Yield estimates and projections

Growth and mortality data from Cloudy Bay in Marlborough and the Kapiti Coast in Manawatu (Cranfield et al 1993) have been used in a yield per recruit model to estimate the reference fishing mortality $F_{0.1}$ (Cranfield et al 1994a, Triantifillos 2008a, 2008b). The Shellfish Working Group (SFWG) did not accept these estimates of $F_{0.1}$ because there was considerable uncertainty in both the estimates and the method used to generate them. The MCY estimates of Triantafillos (2008a, 2008b) and White et al (2012) using the full range of $F_{0.1}$ estimates from Cranfield et al (1993) are shown in Table 5. The SFWG recommended that MCY estimates are adequate to use to inform management decisions relevant to all surf clam fisheries, with the following caveats: 1) due to the uncertainty in $F_{0.1}$ values, for all species other than SAE, the MCY estimates should use the $F_{0.1}$ values toward the higher end of the range, and 2) there is a need to account for any substantial catch that has already come out of any surf clam fishery when estimating MCY; however there was no consensus on the best way to do this.

Estimates of MCY are available from numerous locations (Table 5) and were calculated using Method 1 for a virgin fishery (MPI 2015) with an estimate of virgin biomass B_0, where:

$$MCY = 0.25 * F_{0.1} B_0$$

Table 5: *MCY* estimates (t) for *M. murchisoni* from virgin biomass at locations sampled around New Zealand (Triantifillos 2008a, 2008b, White et al 2012). The two *F0.1* values, which are subsequently used to estimate *MCY*, are the minimum and maximum estimates from Cranfield et al (1993).

Location	$F_{0.1}$	MCY
Five sites (MMI 2)	0.43/0.57	47.7/63.3
Ashley River to 6 nm south of the Waimakariri River (MMI 3)	0.70/0.89	5.9/7.5
Cloudy Bay (MMI 7)	0.43/0.57	108.4/143.7
46 km of coast north and south of the Manawatu River (MMI 8)	0.70/0.89	630.6/801.7

Estimation of Current Annual Yield (*CAY*)

CAY has not been estimated for *M. murchisoni*.

The SFWG recommended moving all surf clam fisheries away from an *MCY* management strategy and towards an exploitation rate management strategy. The SFWG recognised that an exploitation rate approach is more survey intensive, but better allows for the variable nature of biomass for surf clams because it allows greater flexibility in catch (to take greater landings from available biomass) whilst keeping catches sustainable.

6.   STATUS OF THE STOCKS

- **MMI 3- *Mactra murchisoni***

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Landings have been decreasing from 63.87 t in 2013–14 to 29.23 t in 2018–19 and reached the TACC in 2019–20.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology	
Assessment Type	Level 2 - Partial Quantitative Stock Assessment

Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Last assessment: 2008	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)		
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review fishery parameters for this species.

Fishery Interactions
MMI can be caught together with other surf clam species and non-QMS bivalves.

- **MMI 7**

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Very Likely ($> 90\%$) to be at or above the target.
Status in relation to Limits	Very Unlikely ($< 10\%$) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely ($< 10\%$) to be occurring

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Landings have been variable but averaged 28.1 t since 2002.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Current catches are Very Unlikely ($< 10\%$) to cause declines below soft or hard limits in the short to medium term.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely ($< 10\%$)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Last assessment: 2015	Next assessment: Unknown
Overall assessment quality rank		

Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments

Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review fishery parameters for this species.

Fishery Interactions

MMI can be caught together with other surf clam species and non-QMS bivalves.

- **MMI 8**

Stock Status

Year of Most Recent Assessment	2012
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status

Unknown

Fishery and Stock Trends

Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Fishing is light in MMI 8.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis

Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation

Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2012	Next assessment: Unknown
Overall assessment quality rank		
Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)		

Changes to Model Structure and Assumptions	-
Major Sources of Uncertainty	-

Qualifying Comments

Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review fishery parameters for this species.

Fishery Interactions

MMI can be caught together with other surf clam species and non-QMS bivalves.

For all other MMI stocks there is no current evidence of appreciable biomass.

7. FOR FURTHER INFORMATION

Beentjes, M P; Baird, S J (2004) Review of dredge fishing technologies and practice for application in New Zealand. *New Zealand Fisheries Assessment Report 2004/37*. 40 p.

Brierley, P (Convenor) (1990) Management and development of the New Zealand sub-tidal clam fishery. Report of the surf clam working group, MAF Fisheries. (Unpublished report held in NIWA library, Wellington). 57 p.

Conroy, A; Smith, P; Michael, K; Stotter, D (1993) Identification and recruitment patterns of juvenile surf clams, *Mactra discors* and *M. murchisoni* from central New Zealand. *New Zealand Journal of Marine and Freshwater Research 27*: 279–285.

Cranfield, H J; Doonan, I J; Michael, K P (1994a) Dredge survey of surf clams in Cloudy Bay, Marlborough. *New Zealand Fisheries Technical Report 39*. 18 p.

Cranfield, H J; Michael, K P (2001) The surf clam fishery in New Zealand: description of the fishery, its management, and the biology of surf clams. *New Zealand Fisheries Assessment Report 2001/62*. 24 p.

Cranfield, H J; Michael, K P; Stotter, D R (1993) Estimates of growth, mortality, and yield per recruit for New Zealand surf clams. New Zealand Fisheries Assessment Research Document 1993/20. 26 p. (Unpublished report held by NIWA library, Wellington).

Cranfield, H J; Michael, K P; Stotter, D R; Doonan, I J (1994b) Distribution, biomass and yield estimates of surf clams off New Zealand beaches. New Zealand Fisheries Assessment Research Document 1994/1. 17 p. (Unpublished document held by NIWA library, Wellington).

Haddon, M; Willis, T J; Wear, R G; Anderlini, V C (1996) Biomass and distribution of five species of surf clam off an exposed west coast North Island beach, New Zealand. *Journal of Shellfish Research 15*: 331–339.

Michael, K; Cranfield, H; Doonan, I; Hadfield, J (1994) Dredge survey of surf clams in Clifford Bay, Marlborough. *New Zealand Fisheries Data Report No. 54*.

Ministry for Primary Industries (2015). Fisheries Assessment Plenary, May 2015: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1475 p.

Triantifillos, L (2008a) Survey of subtidal surf clams in Pegasus Bay, November–December 2007. Prepared by NIWA for Seafood Innovations Limited and SurfCo. Limited. 43 p.

Triantifillos, L (2008b) Survey of subtidal surf clams in Quota Management Area 2, June–August 2008. Prepared by NIWA for Seafood Innovations Limited and SurfCo. Limited. 40 p.

White, W; Millar, R; Breen, B; Farrington, G (2012) Survey of subtidal surf clams from the Manawatu Coast (FMA 8), October–November 2012. (Unpublished Report held by Fisheries New Zealand Wellington.) 35 p. + Addendum.

White, W; Millar, R; Farrington, G; Breen, D; Selveraj, S (2015) Stock assessment of surf clams from Cloudy Bay, NZ. I*nstitute for Applied Ecology New Zealand Report 15/01*. Published by Applied Ecology New Zealand, an Institute of Auckland University of Technology. 34 p.

RINGED DOSINIA (DAN)

(*Dosinia anus*)
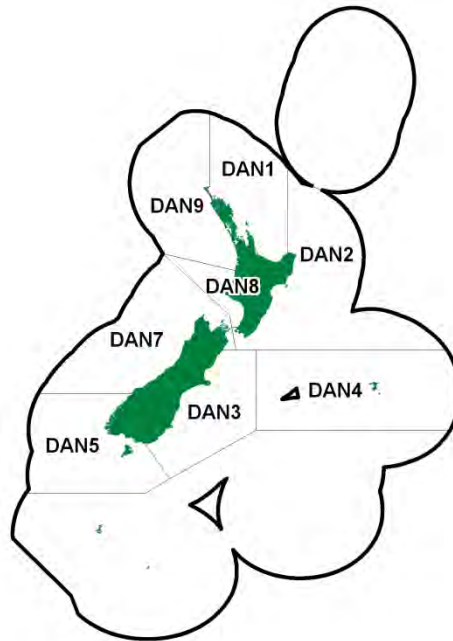
1.   FISHERY SUMMARY

This species is part of the surf clam fishery and the reader is guided to the Introduction – surf clams chapter for information common to all relevant species.

1.1   Commercial fisheries

Ringed dosinia (*Dosinia anus*) were introduced into the Quota Management System on 1 April 2004 with a combined TAC of 112 t, with catches measured in greenweight. Biomass surveys in QMA 2 and 3 supported a TACC increase from April 2010. This increased the TACC for DAN 2 from 18 t to 61 t and DAN 3 from 4 t to 52 t. A subsequent biomass survey in DAN 8 resulted in a TACC increase in DAN 8 from 33 t to 214 t in April 2013. At the same time, allowances for customary, recreational, or other sources of mortality were introduced for DAN 8, increasing the TAC from 33 t to 236 t. Another biomass survey increased the DAN 7 TACC from 15 t to 120 t in April 2016, and allowances for customary, recreational, or other sources of mortality were introduced in 2016 increasing the TAC from 15 t to 133 t. The overall TAC is now 530 t (Table 1). There are no allowances for customary, recreational, or other sources of mortality for the other stocks.

Table 1: Current TAC, TACC and allowances for other sources of mortality for *Dosinia anus*.

Fishstock	TAC (t)	TACC (t)	Recreational Allowance (t)	Customary Allowance (t)	Other sources of mortality (t)
DAN 1	7	7	0	0	0
DAN 2	64	61	0	0	3
DAN 3	55	52	0	0	3
DAN 4	1	1	0	0	0
DAN 5	1	1	0	0	0
DAN 7	133	120	1	5	7
DAN 8	236	214	0	10	12
DAN 9	33	33	0	0	0
Total	530	489	1	15	25

Prior to 2006–07 landings had only been reported in DAN 7 and ranged from about 10 kg to 2000 kg. Small amounts of landings (less than 1 t) were reported in DAN 3 before 2008–09 but increased to 7 t in 2014–15 and 2015–16. Since then DAN 3 landings have declined again, with only 50 kg recorded in 2019–20. From 2002–03 until 2014–15, landings in DAN 7 fluctuated between 100 kg and 5000 kg. Since 2015–16 landings increased sharply to 25 t in 2018–19 and 2019–20 (Table 2). Landings have remained well below the allocated TACCs in all years.

Table 2: TACCs and reported landings (t) of ringed dosinia by Fishstock from 1991–92 to the present day from CELR and CLR data. Fishstocks where no catch has been reported are not tabulated. See Table 1 for TACCs of stocks that are not landed.

Year	DAN 3 Landings	DAN 3 TACC	DAN 7 Landings	DAN 7 TACC	DAN 8 Landings	DAN 8 TACC	Total Landings	Total TACC
1991–92	0	–	0	–	–	–	0	
1992–93	0	–	0.16	–	–	–	0.16	–
1993–94	0	–	0.29	–	–	–	0.29	–
1994–95	0	–	0.07	–	–	–	0.07	–
1995–96	0	–	0.01	–	–	–	0.01	–
1996–97	0	–	0	–	–	–	0	–
1997–98	0	–	0	–	–	–	0	–
1998–99	0	–	0	–	–	–	0	–
1999–00	0	–	0	–	–	–	0	–
2000–01	0	–	0	–	–	–	0	–
2001–02	0	–	0	–	–	–	0	–
2002–03	0	–	0.11	–	–	–	0.11	–
2003–04	0	4	0.90	15	0	33	0.90	–
2004–05	0	4	1.98	15	0	33	2.02*	112
2005–06	0	4	1.10	15	0	33	1.02*	112
2006–07	0.09	4	2.46	15	0	33	2.55	112
2007–08	0.77	4	0.82	15	0	33	1.59	112
2008–09	1.40	4	0.16	15	0	33	1.56	112
2009–10	0.84	4	0.21	15	0	33	1.05	112
2010–11	0.77	52	2.20	15	0	33	3.02	203
2011–12	0	52	5.30	15	0	33	5.30	203
2012–13	0.55	52	3.53	15	0	33	4.08	203
2013–14	5.48	52	0.73	15	0	214	6.21	384
2014–15	7.12	52	0.31	15	0	214	7.43	384
2015–16	7.01	52	9.51	120	0.23	214	16.74	489
2016–17	2.11	52	8.80	120	0.88	214	11.79	489
2017–18	1.77	52	17.00	120	0.11	214	18.88	489
2018–19	0.06	52	25.55	120	0.64	214	26.25	489
2019–20	0.05	52	25.29	120	0.12	214	25.46	489
2020–21	1.13	52	11.35	120	0	214	12.48	489
2021–22	0	52	10.83	120	1.28	214	12.11	489

*In 2004–05 and 2005–06, 32.4 and 90 kg were reported but the QMA was not recorded. This amount is included in the total landings for these years.

1.2 Recreational fisheries

There are no known records of recreational use of this surf clam.

1.3 Customary fisheries

Offshore clams such as *D. anus* are likely to have been harvested for customary use only when washed ashore after storms. Shells of this clam have been found irregularly, and in small numbers in a few middens (Carkeek 1966). There are no estimates of current customary use of this clam.

1.4 Illegal catch

There is no known illegal catch of this clam.

1.5 Other sources of mortality

There is no quantitative information on other sources of mortality, although this clam is probably sometimes taken as a bycatch in inshore trawling. Harvesters claim that the hydraulic clam rake does not damage surf clams and minimises damage to the few species of other macrofauna captured. Surf clam populations also are subject to localised catastrophic mortality from erosion during storms, high temperatures and low oxygen levels during calm summer periods, blooms of toxic algae, and excessive freshwater outflow (Cranfield & Michael 2001).

2. BIOLOGY

Dosinia anus is found around the New Zealand coast in sediments at depths between 5 m and 8 m around the North Island, and between 6 m and 10 m around the South Island. It is larger and rougher than *D. subrosea* and is usually found on more exposed beaches shallower in the substrate. Maximum length is variable between areas, ranging from 58 mm to 82 mm (Cranfield et al 1993). The sexes are likely to be separate, and they are likely to be broadcast spawners with planktonic larvae. Anecdotal evidence suggests that spawning is likely to occur in the summer months and spat probably recruit to the deeper water of the outer region of the surf zone. Recruitment of surf clams is thought to be highly variable between years.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, the boundaries of stocks of surf clams are likely to be the continuous lengths of exposed sandy beaches between geographical features (such as rivers and headlands). Circulation patterns may isolate surf clams genetically as well as ecologically.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

See the Introduction – surf clams chapter.

5. STOCK ASSESSMENT

5.1 Estimates of fishery parameters and abundance
No estimates of fisheries parameters or abundance are available for this species.

5.2 Biomass estimates
Biomass has been estimated at Cloudy Bay and Clifford Bay in DAN 7 and Foxton Beach in DAN 8 with a stratified random survey using a hydraulic dredge (Table 3). Survey size has been recorded as either length of beach or area, which makes comparison difficult.

In both 2012 (FMA 8) and 2015 (Cloudy Bay, FMA 7), White et al (2012, 2015) conducted a 2-phase stratified random sampling survey. The survey area was stratified by 4 depth strata (0–2 m, 2–4 m, 4–6 m, and 6–8 m, each with respect to Chart Datum). Each station comprised a ~50 m tow, sampling ~80 m^2 of seabed. All commercial species of subtidal surf clams caught were sorted by species. The total weight of each of these species was measured on board. Individuals from each species were collected and measured for shell length along the anterior-posterior axis (to the nearest millimetre). For tows with less than ~500 individuals, the maximum of either 20 individuals or 20% of the total was measured. For tows with higher than ~500 individuals, 10% with an upper limit of ~200 individuals per tow were measured. To subsample large catches and to avoid issues of size sorting inside the dredge, each of the bins was subsampled by tipping one bin into two bins and repeating until the requisite sub sample size was reached. The number and weight of the main bycatch species was also recorded. Both the biomass densities and biomass estimates were calculated for all the commercial species of subtidal surf clams caught.

Table 3: A summary of biomass estimates for *D. anus* in tonnes green weight (with standard deviation in parentheses) from exploratory surveys of Cloudy Bay (Cranfield et al 1994b[1], White et al 2015[2]), and Clifford Bay, both in Marlborough (Michael et al 1994) as well as on the Manawatu coastline (White et al 2012).

Area	Cloudy Bay[1] (DAN 7)	Cloudy Bay[2] (DAN 7)	Clifford Bay (DAN 7)	Foxton Beach (DAN 8)
Length of beach (km)	11		21	46
Area (km^2)		5.7		
Biomass (t)	72 (30)	1 270 (156)	5 (3)	3 498 (329)

5.3 Yield estimates and projections

Growth and mortality data from Cloudy Bay in Marlborough and the Kapiti Coast in Manawatu (Cranfield et al 1993) have been used in a yield-per-recruit model to estimate the reference fishing mortality $F_{0.1}$ (Cranfield et al 1994b, Triantifillos 2008a, 2008b). The Shellfish Working Group (SFWG) did not accept these estimates of $F_{0.1}$ because there was considerable uncertainty in both the estimates and the method used to generate them. The MCY estimates of Triantifillos (2008a, 2008b) and White et al (2012, 2015) that use the full range of $F_{0.1}$ estimates from Cranfield et al (1993) are shown in Table 4. The SFWG recommended that MCY estimates are adequate to use to inform management decisions relevant to all surf clam fisheries, with the following caveats: 1) due to the uncertainty in $F_{0.1}$ values, for all species other than SAE, the MCY estimates should use the $F_{0.1}$ values toward the higher end of the range, and 2) there is a need to account for any substantial catch that has already come out of any surf clam fishery when estimating MCY; however there was no consensus on the best method.

Estimates of MCY were calculated using Method 1 for a virgin fishery (MPI 2015) with an estimate of virgin biomass B_0, where:

$$MCY = 0.25* F_{0.1} B_0$$

CAY has not been estimated for $D. anus$.

The SFWG recommended moving all surf clam fisheries away from an MCY management strategy and towards an exploitation rate management strategy. The SFWG recognised that an exploitation rate approach is more survey intensive, but better allows for the variable nature of biomass for surf clams because it allows greater flexibility in catch (to take greater landings from available biomass) whilst keeping catches sustainable.

Table 4: Mean MCY estimates (t) for $D. anus$ from virgin biomass from DAN 2 (Triantifillos 2008b), DAN 3 (Triantifillos 2008a), DAN 7 (White et al 2015), and DAN 8 (White et al 2012). The two $F_{0.1}$ values, which are subsequently used to estimate MCY, are the minimum and maximum estimates from Cranfield et al. (1993).

Location	$F_{0.1}$	MCY
Five sites (DAN 2)	0.25/0.42	52.8/88.7
Ashley River to 6 nm south of the Waimakariri River (DAN 3)	0.27/0.54	63.8/127.7
Cloudy Bay (DAN 7)	0.25/0.42	79.4/133.4
Foxton Beach (DAN 8)	0.27/0.54	236.1/472.2

6. STATUS OF THE STOCKS

- **DAN 2 & 3**

Stock Status	
Year of Most Recent Assessment	2008 for DAN 2 and 3
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Intensity or Proxy	Fishing is minimal in DAN 2 and 3.
Other Abundance Indices	-

Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis

Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology

Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Main data inputs	Abundance and length frequency information	
Period of Assessment	Latest assessment: 2008	Next assessment: Unknown
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments

Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review fishery parameters for this species

Fishery Interactions

DAN can be caught together with other surf clam species and non-QMS bivalves.

- **DAN 7**

Stock Status

Year of Most Recent Assessment	2015
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Despite an increase in the landings since 2015-16, the exploitation levels of *D. anus* remain relatively low. It is likely that the stock is still effectively in a virgin state, therefore they are Very Likely (> 90%) to be at or above the target.
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status

Unknown

Fishery and Stock Trends

Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Intensity or Proxy	Fishing has been light with landings averaging 1.5 t from 2002–03 to 2014–15 but increasing since, reaching 25.55 in 2018–19.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing decline below Limits	Current catches are Very Unlikely (< 10%) to cause declines below soft or hard limits in the short to medium term.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Main data inputs	Abundance and length frequency information	
Period of Assessment	Latest assessment: 2015	Next assessment: Unknown
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review fishery parameters for this species

Fishery Interactions
DAN can be caught together with other surf clam species and non-QMS bivalves.

- **DAN 8**

Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Intensity or Proxy	Fishing is minimal
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing decline below Limits	Unknown

Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology

Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Main data inputs	Abundance and length frequency information	
Period of Assessment	Latest assessment: 2012	Next assessment: Unknown
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments

Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review fishery parameters for this species

Fishery Interactions

DAN can be caught together with other surf clam species and non-QMS bivalves.

For all other DAN stocks there is no current evidence of appreciable biomass.

7.   FOR FURTHER INFORMATION

Brierley, P (Convenor) (1990) Management and development of the New Zealand sub-tidal clam fishery. Report of the surf clam working group, MAF Fisheries. (Unpublished report held in NIWA library, Wellington). 57 p.

Carkeek, W (1966) *The Kapiti Coast*. Reed, Wellington. 187 p.

Cranfield, H J; Doonan, I J; Michael, K P (1994b) Dredge survey of surf clams in Cloudy Bay, Marlborough. *New Zealand Fisheries Technical Report No. 39*. 18 p.

Cranfield, H J; Michael, K P (2001) The surf clam fishery in New Zealand: description of the fishery, its management, and the biology of surf clams. *New Zealand Fisheries Assessment Report 2001/62*. 24 p.

Cranfield, H J; Michael, K P; Stotter, D R (1993) Estimates of growth, mortality, and yield per recruit for New Zealand surf clams. New Zealand Fisheries Assessment Research Document 1993/20. 26 p. (Unpublished document held in NIWA library, Wellington).

Cranfield, H J; Michael, K P; Stotter, D R; Doonan, I J (1994a) Distribution, biomass and yield estimates of surf clams off New Zealand beaches. New Zealand Fisheries Assessment Research Document 1994/1. 17 p. (Unpublished document held in NIWA library, Wellington.).

Haddon, M; Willis, T J; Wear, R G; Anderlini, V C (1996) Biomass and distribution of five species of surf clam off an exposed west coast North Island beach, New Zealand. *Journal of Shellfish Research 15*: 331–339.

Michael, K; Cranfield, H; Doonan, I J; Hadfield, J D (1994) Dredge survey of surf clams in Clifford Bay, Marlborough. New Zealand Fisheries Data Report 54. 15 p. (Unpublished document held in NIWA library, Wellington).

Ministry for Primary Industries (2015). Fisheries Assessment Plenary, May 2015: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1475 p.

Triantifillos, L (2008a) Survey of subtidal surf clams in Pegasus Bay, November–December 2007. Prepared by NIWA for Seafood Innovations Limited and SurfCo. Limited. 43 p. (Unpublished report available from Fisheries New Zealand).

Triantifillos, L (2008b) Survey of subtidal surf clams in Quota Management Area 2, June – August 2008. Prepared by NIWA for Seafood Innovations Limited and SurfCo. Limited. 40 p. (Unpublished Report available from Fisheries New Zealand).

White, W; Millar, R; Breen, B; Farrington, G (2012) Survey of subtidal surf clams from the Manawatu Coast (FMA 8), October–November 2012. (Unpublished Report held by Fisheries New Zealand Wellington.) 35 p.+ Addendum.

White, W; Millar, R; Farrington, G; Breen, D; Selveraj, S (2015). Stock assessment of surf clams from Cloudy Bay, NZ. *Institute for Applied Ecology New Zealand Report 15/01*. Published by Applied Ecology New Zealand, an Institute of Auckland University of Technology. 34 p.

TRIANGLE SHELL (SAE)

(*Crassula aequilatera*)
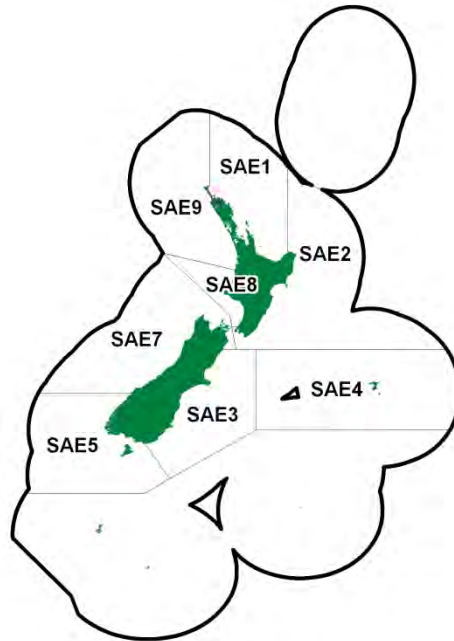
1. FISHERY SUMMARY

This species is part of the surf clam fishery and the reader is guided to the Introduction – surf clams chapter for information common to all relevant species.

1.1 Commercial fisheries

Triangle shells (*Crassula aequilatera*, also known as *Spisula aequilatera*) were introduced into the QMS on 1 April 2004 with a total TACC of 406 t. No allowances were initially set for customary, non-commercial, recreational, or other sources of mortality, but some allowances were introduced to SAE 8 and 7 in 2013 and 2016, respectively. Biomass surveys supported an increase in TAC in SAE 2 and SAE 3 from 1 April 2010 from 1 t and 264 t respectively to 132 t and 483 t, respectively. A subsequent biomass survey in SAE 8 resulted in a TAC increase from 8 t to 1821 t in April 2013. Another biomass survey resulted in an increase in the SAE 7 TAC from 112 t to 235 t in April 2016, with a current total national TAC of 2692 t (Table 1).

Table 1: Current TAC, TACC, and allowances for other sources of mortality for *Crassula aequilatera*.

Fishstock	TAC (t)	TACC (t)	Recreational allowance (t)	Customary Allowance (t)	Other sources of mortality (t)
SAE 1	9	9	0	0	0
SAE 2	132	125	0	0	7
SAE 3	483	459	0	0	24
SAE 4	1	1	0	0	0
SAE 5	3	3	0	0	0
SAE 7	235	217	1	5	12
SAE 8	1821	1720	0	10	91
SAE 9	8	8	0	0	0
Total	2692	2542	1	15	134

Apart from 200 kg in SAE 2 in 2003–04 and landings up to 25 t in SAE 8 since 2014–15, all reported landings have been from SAE 3 and SAE 7. For SAE 3, there were no landings until 2006–07. Between 2006–07 and 2014–15, landings in SAE 3 fluctuated between 0.6 t and 11 t, with no landings reported in 2011–12. From 2014–15 onwards, landings increased to 203 t in 2018–19, declining to 187 t in 2019–20. For SAE 7, there were minimal landings from 1991–92 to 1995–96; no further landings were reported

until 2002–03 (52 t). SAE 7 landings fluctuated between 1t and 45 t until 2010–11, and then increased to a peak of 319 t in 2015–16, before declining again; in 2019–20 109 t were recorded. Reported landings and TACCs are shown for the Fishstocks with historical landings in Table 2. Figure 1 shows historical landings and TACCs for the two main SAE stocks. Landings are market-driven and have not been constrained by the TACCs.

Table 2: TACCs and reported landings (t) of triangle shell by Fishstock from 1990–91 to present from CELR and CLR data. See Table 1 for TACCs of stocks not landed.

Fishstock	SAE 2		SAE 3		SAE 7		SAE 8		Total	
	Landing	TACC	Landing	TACC	Landing	TACC	Landing	TACC	Landing	TACC
1991–92	0	–	0	–	0.18	–	0	–	0.18	–
1992–93	0	–	0	–	0.40	–	0	–	0.40	–
1993–94	0	–	0	–	2.85	–	0	–	2.85	–
1994–95	0	–	0	–	2.10	–	0	–	2.10	–
1995–96	0	–	0	–	0.12	–	0	–	0.12	–
1996–97	0	–	0	–	0	–	0	–	0	–
1997–98	0	–	0	–	0	–	0	–	0	–
1998–99	0	–	0	–	0	–	0	–	0	–
1999–00	0	–	0	–	0	–	0	–	0	–
2000–01	0	–	0	–	0	–	0	–	0	–
2001–02	0	–	0	–	0	–	0	–	0	–
2002–03	0	–	0	–	52.15	–	0	–	52.15	–
2003–04	0.20	1	0	264	9.58	112	0	8	9.78	406
2004–05	0	1	0	264	18.53	112	0	8	19.36*	406
2005–06	0	1	0	264	28.07	112	0	8	31.02*	406
2006–07	0	1	0.61	264	45.96	112	0	8	46.56	406
2007–08	0	1	3.91	264	5.02	112	0	8	8.93	406
2008–09	0	1	10.91	264	2.51	112	0	8	13.42	406
2009–10	0	1	8.62	264	1.46	112	0	8	10.08	406
2010–11	0	125	4.04	459	16.92	112	0	8	20.96	725
2011–12	0	125	0	459	82.27	112	0	8	82.27	725
2012–13	0	125	9.83	459	161.20	112	0	1 720	171.03	2 437
2013–14	0	125	3.61	459	191.07	112	0	1 720	195.32	2 437
2014–15	0	125	5.92	459	241.04	112	0.45	1 720	246.96	2 437
2015–16	0	125	34.97	459	319.09	217	21.02	1 720	375.09	2 867
2016–17	0	125	150.40	459	186.47	217	9.51	1 720	346.38	2 867
2017–18	0	125	133.98	459	157.49	217	5.05	1 720	296.52	2 867
2018–19	0	125	202.88	459	86.34	217	3.84	1 720	293.06	2 867
2019–20	0	125	187.45	459	109.10	217	24.92	1 720	321.47	2 867
2020–21	0	125	196.39	459	19.33	217	10.69	1 720	226.41	2 867
2021–22	0	125	185.88	459	33.05	217	31.95	1 720	250.88	2 867

*In 2004–05 and 2005–06, 0.837 t and 2.952 t respectively were reported landed, but the QMA was not recorded. These amounts are included in the total landings for these years.

1.2   Recreational fisheries

There are no estimates of recreational take for this surf clam.

1.3   Customary fisheries

Shells of this species have been found irregularly, and in small numbers in a few middens (Carkeek 1966). There are no estimates of current customary catch of this species.

1.4   Illegal catch

There is no documented illegal catch of this species.

1.5   Other sources of mortality

There is no quantitative information on other sources of mortality, although this clam is subject to localised catastrophic mortality from erosion during storms, high temperatures and low oxygen levels during calm summer periods, blooms of toxic algae, and excessive freshwater outflow (Cranfield & Michael 2001).
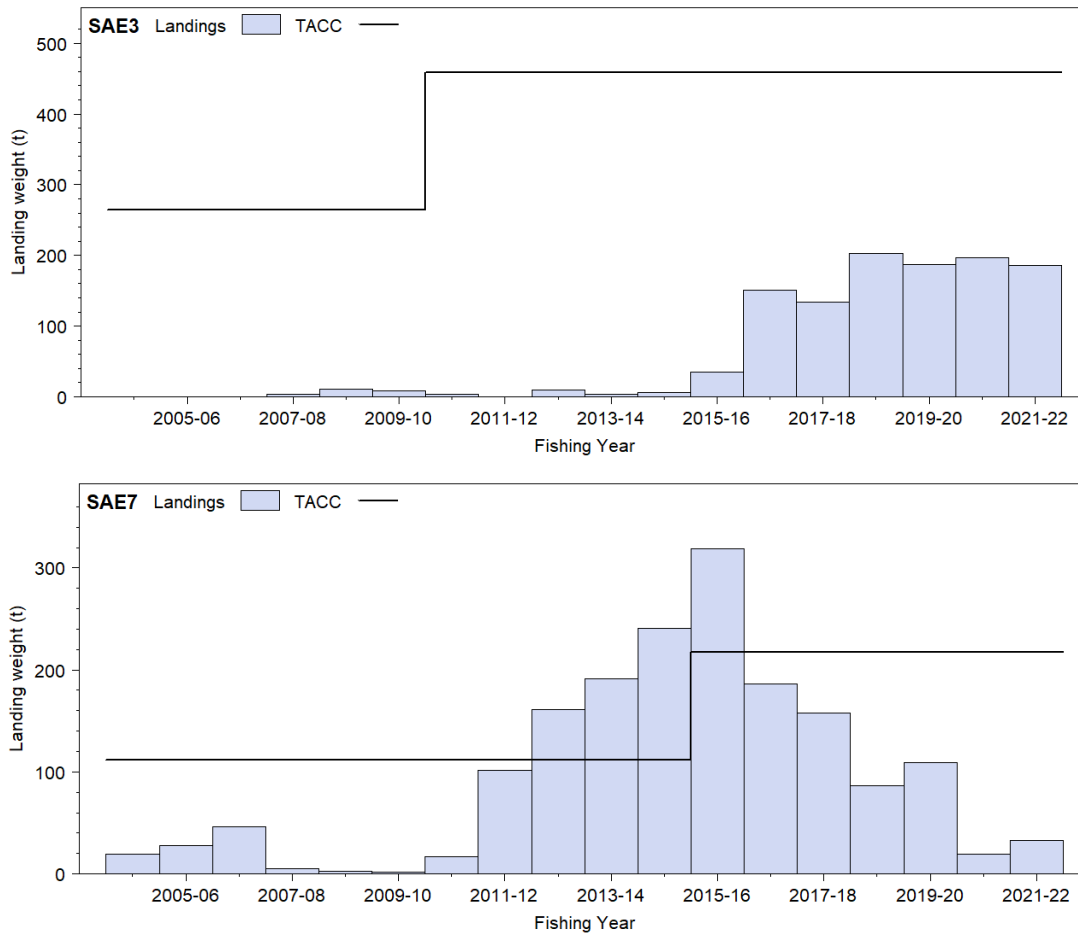
Figure 1: Reported commercial landings and TACC for the main triangle shell stocks: SAE 3 (top) and SAE 7 (bottom).

2.   BIOLOGY

Crassula aequilatera occurs from the Bay of Plenty southwards on the east coast of both main islands, and on the Wellington-Manawatu coast. No information is available concerning its distribution on the west coast of the South Island. In the North Island this species is most abundant between 3 m and 5 m depths, and in the South Island between 4 m and 8 m depths. Maximum length is variable between areas, ranging from 39 mm to 74 mm (Cranfield & Michael 2002). The sexes are separate, and they are broadcast spawners; they are reasonably fast growing and reach maximum size in 2–3 years. Nothing is known of their larval life.

3.   STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, the boundaries of stocks of surf clams are likely to be the continuous lengths of exposed sandy beaches between geographical features (rivers, headlands, etc.). Circulation patterns may isolate surf clams genetically as well as ecologically.

4.   ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

See the Introduction – surf clams chapter.

5.   STOCK ASSESSMENT

5.1   Estimates of fishery parameters and abundance

No estimates of fisheries parameters or abundance are available for this species. Early estimates were made of M and $F_{0.1}$, but the Shellfish Working Group considers that the methods were not well documented, and the estimates should not be used.

5.2   Biomass estimates

Biomass has been estimated from SAE 2, 3, 7, and 8 at various times between 1994 and 2015 using stratified random surveying with a hydraulic dredge. Survey size has been expressed either as length of beach (Table 3), or as area (Table 4), which makes comparisons difficult.

In both 2012 (FMA 8) and 2015 (Cloudy Bay, FMA 7), White et al (2012, 2015) conducted a 2-phase stratified random sampling survey. The survey area was stratified by 4 depth strata (0–2 m, 2–4 m, 4–6 m, and 6–8 m, each with respect to Chart Datum). Each station comprised a ~50 m tow, sampling ~80 m^2 of seabed. All commercial species of subtidal surf clams caught were sorted by species. The total weight of each of these species was measured on board. Individuals from each species were collected and measured for shell length along the anterior-posterior axis (to the nearest millimetre). For tows with less than ~500 individuals, the maximum of either 20 individuals or 20% of the total was measured. For tows with higher than ~500 individuals, 10% with an upper limit of ~200 individuals per tow were measured. To subsample large catches and to avoid issues of size sorting inside the dredge, each of the bins was subsampled by tipping one bin into two bins and repeating until the requisite sub sample size was reached. The number and weight of the main bycatch species was also recorded. Both the biomass densities and biomass estimates were calculated for all the commercial species of subtidal surf clams caught.

Table 3:   A summary of biomass estimates in tonnes greenweight (with standard deviation in parentheses) from exploratory surveys of Cloudy Bay (Cranfield et al 1994b) and Clifford Bay in Marlborough (Michael et al 1994), and Foxton Beach on the Manawatu coast (White et al 2012).

Area	Cloudy Bay (SAE 7)	Clifford Bay (SAE 7)	Foxton Beach (SAE 8)
Length of beach (km)	11	21	46[#]
Biomass (t)	53 (22)	358 (152)	7 993 (759)[#]

[#] Biomass was estimated at Foxton Beach from a mix of a systematic survey to the north and a stratified survey to the south of this location.

Table 4:   A summary of biomass estimates in tonnes greenweight from the surveys in SAE 2 (Triantifillos 2008b), SAE 3 (Triantifillos 2008a), and Cloudy Bay (White et al 2015). Unless otherwise stated the CV is less than 20%.

Location	Five sites (SAE 2)	Ashley River to 6 nm south of the Waimakariri River (SAE 3)	Cloudy Bay (SAE 7)
Area surveyed (km^2)	28.0	13.4	5.7
Biomass (t)	471.1	1 567.2	887

5.3   Yield estimates and projections

Estimation of Maximum Constant Yield (*MCY*)

Growth and mortality data from Cloudy Bay in Marlborough and the Kapiti Coast in Manawatu (Cranfield et al 1993) have been used in a yield-per-recruit model to estimate the reference fishing mortality $F_{0.1}$ (Cranfield et al 1994b). The Shellfish Working Group (SFWG) did not accept these estimates of $F_{0.1}$ because there was considerable uncertainty in both the estimates and the method used to generate them. The *MCY* estimates of Triantifillos (2008a, 2008b) and White et al (2012, 2015) that use the full range of $F_{0.1}$ estimates from Cranfield et al (1993) are shown in Table 5. The SFWG recommended that *MCY* estimates are adequate to use to inform management decisions relevant to all surf clam fisheries, with the following caveats: 1) due to high uncertainty in the $F_{0.1}$ values for SAE, the SFWG advised using the lower $F_{0.1}$ values when estimating a sustainable *MCY* for this species; 2) there is a need to account for any substantial catch that has already come out of any surf clam fishery when estimating *MCY*, however there was no consensus on the best way to do this; and 3) an exploitation rate of 34% for SAE 7 (as suggested by the higher *MCY* value) was not recommended due to the current limited knowledge of the dynamics of surf clam species.

Estimates of *MCY* are available from a number of locations and were calculated using Method 1 for a virgin fishery (MPI 2015) with an estimate of virgin biomass B_0, where:

$$MCY = 0.25* F_{0.1} B_0$$

Table 5: *MCY* estimates (t) for *S. aequilatera* from virgin biomass at locations sampled around New Zealand (Triantifillos 2008a, 2008b). The two $F_{0.1}$ values, which are subsequently used to estimate *MCY*, are the minimum and maximum estimates from Cranfield et al (1993).

Location	$F_{0.1}$	MCY
Five sites (SAE 2)	1.12/1.56	131.9/183.7
Ashley River to 6 nm south of the Waimakariri River (SAE 3)	1.06/1.37	415.3/536.8
Cloudy Bay (SAE 7)	1.06/1.37	235.0/303.8
Foxton beach (SAE 8)	1.06/1.37	2238/3117.2

Estimation of Current Annual Yield (*CAY*)
CAY has not been estimated for *S. aequilatera*.

The SFWG recommended moving all surf clam fisheries away from an *MCY* management strategy and towards an exploitation rate management strategy. The SFWG recognised that an exploitation rate approach is more survey intensive, but better allows for the variable nature of biomass for surf clams because it allows greater flexibility in catch (to take greater landings from available biomass) whilst keeping catches sustainable.

6.   STATUS OF THE STOCKS

- **SAE 2 & 3**

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	There is no fishing in SAE 2 Fishing has been quite low in SAE 3 until 2015–16 (average 8.2 t) and increased to 168.7 t on average since 2016–17.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-

Probability of Current Catch or TACC causing decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2008	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	Abundance and length frequency information	
Data not used		
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review the fishery parameters for this species. SAE have slower digging ability relative to PDO therefore are at higher relative risk of mortality during storms.

Fishery Interactions
SAE can be caught together with other surf clam species and non-QMS bivalves.

- **SAE 7**

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Very Likely ($>90\%$) to be at or above the target
Status in relation to Limits	Unlikely ($<40\%$) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Unlikely ($<40\%$) to be occurring

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Fishing was variable between 52 t and 1 t landed between 2002–03 and 2009–10. Landings have then increased dramatically from 1 t in 2009–10 to 319.09 t in 2015–16 when the TACC was increased to 217 t. Since 2015-16, the overall trend has been declining.
Other Abundance Indices	-

Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis

Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing decline below Limits	Current catches at or below the TACC are Unlikely ($< 40\%$) to cause declines below soft or hard limits in the short to mid-term.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely ($< 40\%$)

Assessment Methodology

Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2015	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs	Abundance and length frequency information	
Data not used	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments

Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes.
There is a need to review the fishery parameters for this species.
SAE have slower digging ability relative to PDO therefore are at higher relative risk of mortality during storms.

Fishery Interactions

SAE can be caught together with other surf clam species and non-QMS bivalves.

- **SAE 8**

Stock Status

Year of Most Recent Assessment	2012
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Because of the relatively low levels of exploitation of *S. aequilatera*, it is likely that the stock is still effectively in a virgin state, therefore it is Very Likely ($> 90\%$) to be at or above the target.
Status in relation to Limits	Very Unlikely ($< 10\%$) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely ($< 10\%$) to be occurring
Historical Stock Status Trajectory and Current Status	
-	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Fishing is light in SAE 8.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing decline below Limits	Current catches are Very Unlikely (< 10%) to cause declines below soft or hard limits in the short to medium term.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2012	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	Abundance and length frequency information	
Data not used		
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes.   There is a need to review the fishery parameters for this species.   SAE have slower digging ability relative to PDO therefore are at higher relative risk of mortality during storms.

Fishery Interactions
SAE can be caught together with other surf clam species and non-QMS bivalves.

For all other SAE stocks there is no current evidence of appreciable biomass.

7.   FOR FURTHER INFORMATION

Beentjes, M P; Baird, S J (2004) Review of dredge fishing technologies and practice for application in New Zealand. *New Zealand Fisheries Assessment Report 2004/37*. 40 p.

Brierley, P (Convenor) (1990) Management and development of the New Zealand sub-tidal clam fishery. Report of the surf clam working group, MAF Fisheries. (Unpublished report held in NIWA library, Wellington). 57 p.

Carkeek, W (1966) *The Kapiti Coast*. Reed, Wellington. 187 p.

Cranfield, H J; Doonan, I J; Michael, K P (1994b) Dredge survey of surf clams in Cloudy Bay, Marlborough. *New Zealand Fisheries Technical Report No. 39*. 18 p.

Cranfield, H J; Michael, K P (2001) The surf clam fishery in New Zealand: description of the fishery, its management, and the biology of surf clams. *New Zealand Fisheries Assessment Report 2001/62*. 24 p.

Cranfield, H; Michael, K (2002) Potential area boundaries and indicative TACs for the seven species of surf clam. (Unpublished report held by Fisheries New Zealand).

Cranfield, H J; Michael, K P; Stotter, D R (1993) Estimates of growth, mortality, and yield per recruit for New Zealand surf clams. New Zealand Fisheries Assessment Research Document 1993/20. 26 p. (Unpublished document held by NIWA library, Wellington).

Cranfield, H J; Michael, K P; Stotter, D R; Doonan, I J (1994a) Distribution, biomass and yield estimates of surf clams off New Zealand beaches. New Zealand Fisheries Assessment Research Document 1994/1. 17 p. (Unpublished document held by NIWA library, Wellington.)

Haddon, M; Willis, T J; Wear, R G; Anderlini, V C (1996) Biomass and distribution of five species of surf clam off an exposed west coast North Island beach, New Zealand. *Journal of Shellfish Research 15*: 331–339.

Michael, K; Cranfield, H; Doonan, I; Hadfield, J (1994) Dredge survey of surf clams in Clifford Bay, Marlborough. New Zealand Fisheries Data Report No. 54. (Unpublished document held by NIWA library, Wellington).

Ministry for Primary Industries (2015) Fisheries Assessment Plenary, May 2015: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1475 p.

Triantifillos, L (2008a) Survey of subtidal surf clams in Pegasus Bay, November–December 2007. Prepared by NIWA for Seafood Innovations Limited and SurfCo. Limited. 43 p. (Unpublished Report held by Fisheries New Zealand).

Triantifillos, L (2008b) Survey of subtidal surf clams in Quota Management Area 2, June–August 2008. , Prepared by NIWA for Seafood Innovations Limited and SurfCo. Limited. 40 p. (Unpublished Report held by Fisheries New Zealand).

White, W; Millar, R; Breen, B; Farrington, G (2012) Survey of subtidal surf clams from the Manawatu Coast (FMA 8), October–November 2012. (Unpublished Report held by Fisheries New Zealand Wellington.) 35 p + Addendum.

White, W; Millar, R; Farrington, G; Breen, D; Selveraj, S (2015) Stock assessment of surf clams from Cloudy Bay, NZ. *Institute for Applied Ecology New Zealand Report 15/01*. Published by Applied Ecology New Zealand, an Institute of Auckland University of Technology**.** 34 p.

TROUGH SHELL (MDI)

(*Mactra discors*)
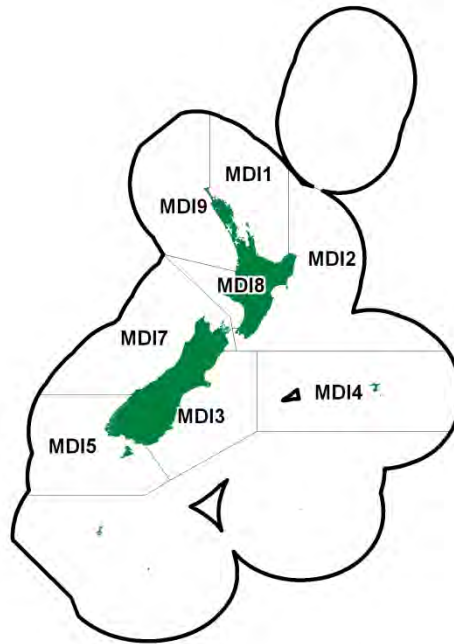
1. FISHERY SUMMARY

This species is part of the surf clam fishery and the reader is guided to the Introduction – surf clams chapter for information common to all relevant species.

1.1 Commercial fisheries

Trough shells (*Mactra discors*) were introduced into Quota Management System on 1 April 2004 with a total TACC of 98 t. No allowances were made for customary or recreational usage, or for other sources of mortality. New survey information for QMA 2 and 3 resulted in increases to a number of surf clam TACCs in these areas from 1 April 2010, including MDI 2. This change included an increase in TACC and a new allowance for other sources of mortality. The total TAC is currently 163 t (Table 1).

Table 1: Current TAC, TACC, and allowances for other sources of mortality for *Mactra discors*.

Fishstock	TAC (t)	TACC (t)	Other sources of mortality (t)
MDI 1	1	1	0
MDI 2	66	63	3
MDI 3	1	1	0
MDI 4	1	1	0
MDI 5	14	14	0
MDI 7	26	26	0
MDI 8	27	27	0
MDI 9	27	27	0

Most reported landings have been from MDI 7. Between 1994 and 1996, landings of a few kilograms were also reported from MDI 3 and MDI 5. No further landings were reported from any of the MDI stocks until 2002–03. Since then the only significant reported catch has been from MDI 7 during the period 2003–04 to 2007–08 when landings ranged between about 1 t and 4 t. Since 2008–09 MDI 7 landings have decreased to very low levels, with no landings recorded during several years including 2018–19. Only very low and sporadic landings of a few kilograms have been recorded from MDI 1, MDI 3, and MDI 5 since 2003–04. Landings and TACCs for Fishstocks with historical landings are shown in Table 2. The recent landings and TACC values for MDI 7 are depicted in Figure 1; landings have always remained well below the TACC.

Table 2: **TACCs and reported landings (t) of trough shell for Fishstocks with landings from 1992–93 to present from CELR and CLR data. See Table 1 for TACCs of stocks that are not landed.**

Fishstock	MDI 1		MDI 3		MDI 5		MDI 7		Total	
	Landing	TACC	Landing	TACC	Landing	TACC	Landing	TACC	Landing	TACC
1992–93	0	–	0	–	0	–	0.25	–	0.25	–
1993–94	0	–	0	–	0	–	2.20	–	2.20	–
1994–95	0	–	0	–	0.03	–	2.40	–	2.43	–
1995–96	0	–	0.05	–	0	–	0.02	–	0.07	–
1996–97	0	–	0	–	0	–	0	–	0	–
1997–98	0	–	0	–	0	–	0	–	0	–
1998–99	0	–	0	–	0	–	0	–	0	–
1999–00	0	–	0	–	0	–	0	–	0	–
2000–01	0	–	0	–	0	–	0	–	0	–
2001–02	0	–	0	–	0	–	0	–	0	–
2002–03	0	–	0	–	0	–	0.69	–	0.69	–
2003–04	0	1	0	1	0	14	2.69	26	2.69	98
2004–05	0	1	0	1	0	14	3.30	26	3.38*	98
2005–06	0.041	1	0	1	0	14	3.21	26	3.53*	98
2006–07	0	1	0	1	0	14	3.89	26	3.89	98
2007–08	0	1	0.02	1	0	14	1.05	26	1.06	98
2008–09	0	1	0	1	0	14	0.01	26	0.01	98
2009–10	0	1	0.06	1	0	14	0.12	26	0.18	98
2010–11	0	1	0	1	0	14	0.01	26	0	160
2011–12	0	1	0	1	0	14	0	26	0	160
2012–13	0	1	0	1	0	14	0.13	26	0.13	160
2013–14	0	1	0.01	1	0	14	0	26	0.01	160
2014–15	0	1	0	1	0	14	0	26	0	160
2015–16	0	1	0	1	0	14	0	26	0	160
2016–17	0	1	0	1	0	14	0.01	26	0.01	160
2017–18	0	1	0	1	0	14	0.03	26	0.03	160
2018–19	0	1	0	1	0	14	0	26	0	160
2019–20	0	1	< 0 .01	1	0	14	0	26	< 0.01	160
2020–21	0	1	0	1	0	14	0	26	0	160
2021–22	0	1	0	1	0	14	0	26	0	160

*In 2004–05 and 2005–06, 71 kg and 277 kg respectively were reportedly landed, but the QMA was not recorded. This amount is included in the total landings for that year.
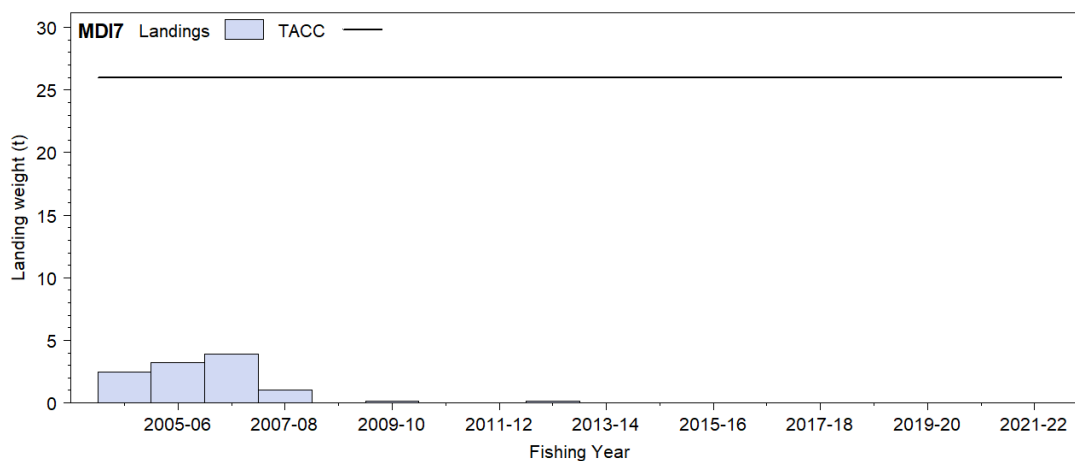
Figure 1: **Reported commercial landings and TACC for MDI 7 (Challenger).**

1.2   Recreational fisheries

Offshore clams such as *M. discors* are likely to have been harvested for recreational use only when washed ashore after storms. There are no estimates of recreational take for this surf clam.

1.3   Customary fisheries

Offshore clams such as *M. discors* are likely to have been harvested for customary use only when washed ashore after storms (Carkeek 1966). There are no estimates of current customary use of this clam.

1.4   Illegal catch

There is no known illegal catch of this clam.

1.5   Other sources of mortality

There is no quantitative information on other sources of mortality. This clam is subject to localised catastrophic mortality from erosion during storms, high temperatures and low oxygen levels in calm summer periods, toxic algae blooms, and excessive freshwater outflow (Cranfield & Michael 2001).

2.   BIOLOGY

M. discors is most abundant in Southland (Te Waewae and Oreti), Otago (Blueskin Bay), Wellington, Manawatu, and Cloudy Bay. Maximum length is variable between areas, ranging from 63 mm to 95 mm (Cranfield et al 1993). The sexes are separate and the species is a broadcast spawner; the larvae are thought to be planktonic for between 20 and 30 days (Cranfield & Michael 2001). Recruitment of spat is to the same depth zone that adults occur in and recruitment between years is highly variable (Conroy et al 1993).

3.   STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, the boundaries of stocks of surf clams are likely to be the continuous lengths of exposed sandy beaches between geographical features (rivers, headlands, etc.). Circulation patterns may isolate surf clams genetically as well as ecologically.

4.   ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

See the Introduction – surf clams chapter.

5.   STOCK ASSESSMENT

5.1   Estimates of fishery parameters and abundance

No estimates of fisheries parameters or abundance are available for this species.

5.2   Biomass estimates

Biomass has been estimated from MDI 2, 3, 7, and 8 at various times between 1994 and 2015 using stratified random surveying with a hydraulic dredge. Survey size has been expressed either as length of beach, in the earlier surveys (Table 3), or as area, in the latter surveys (Table 4), which makes comparisons over time difficult.

In 2015, White et al (2015) conducted a 2-phase stratified random sampling survey. The survey area was stratified by 4 depth strata (0–2 m, 2–4 m, 4–6 m, and 6–8 m, each with respect to Chart Datum). Each station comprised a ~50 m tow that sampled ~80 m² of seabed. All commercial species of subtidal surf clams caught were sorted by species. The total weight of each of these species was measured on board. Individuals from each species were collected and measured for shell length along the anterior-posterior axis (to the nearest millimetre). For tows with less than ~500 individuals, the maximum of either 20 individuals or 20% of the total was measured. For tows with higher than ~500 individuals, 10% with an upper limit of ~200 individuals per tow were measured. To subsample large catches and to avoid issues of size sorting inside the dredge, each of the bins was subsampled by tipping one bin into two bins and repeating until the requisite sub sample size was reached. The number and weight of the main bycatch species was also recorded. Both the biomass densities and biomass estimates were calculated for all the commercial species of subtidal surf clams caught.

Table 3: **A summary of biomass estimates in tonnes green weight (with standard deviation in parentheses) from exploratory surveys in Cloudy Bay (Cranfield et al 1994b) and Clifford Bay in Marlborough (Michael et al 1994) and Foxton Beach on the Manawatu coast (Haddon et al 1996). –, not estimated.**

Area	Cloudy Bay (MDI 7)	Clifford Bay (MDI 7)	Foxton Beach (MDI 8)
Length of beach (km)	11	21	27.5
Biomass (t)	55 (11)	89 (3)	195 (–)

Table 4: **A summary of biomass estimates in tonnes green weight from the surveys in MDI 2 (Triantifillos 2008b), MDI 3 (Triantifillos 2008a), and MDI 7 (White et al 2015). Note: unless otherwise stated the CV is less than 20%.**

Location	Five sites (MDI 2)	Ashley River to 6 nm south of the Waimakariri River (MDI 3)	Cloudy Bay (MDI 7)
Area surveyed (km^2)	28.0	13.4	5.7
Biomass (t)	471.2	0.0	5.9

5.3 Yield estimates and projections

Growth and mortality data from Cloudy Bay, Marlborough and the Kapiti Coast, Manawatu (Cranfield et al 1993) have been used in a yield-per-recruit model to estimate the reference fishing mortality $F_{0.1}$ (Cranfield et al 1994b, Triantifillos 2008a, 2008b). The Shellfish Working Group (SFWG) did not accept these estimates of $F_{0.1}$ because there was considerable uncertainty in both the estimates and the method used to generate them. The *MCY* estimates of Triantafillos (2008b) that use the full range of $F_{0.1}$ estimates from Cranfield et al (1993) are shown in Table 5. The SFWG recommended that *MCY* estimates are adequate to use to inform management decisions relevant to all surf clam fisheries, with the following caveats: 1) due to the uncertainty in $F_{0.1}$ values, for all species other than SAE, the *MCY* estimates should use the $F_{0.1}$ values toward the higher end of the range, and 2) there is a need to account for any substantial catch that has already come out of any surf clam fishery when estimating *MCY*; however there was no consensus on the best method.

All estimates of *MCY* were calculated using Method 1 for a virgin fishery (MPI 2015) from an estimate of virgin biomass B_0, where:

$$MCY = 0.25 * F_{0.1} B_0$$

Table 5: **MCY estimates (t) for *M. discors* from virgin biomass at locations within MDI 2 (Triantifillos 2008b) and MDI 7 (White et al 2015). The two $F_{0.1}$ values, which are subsequently used to calculate MCY, are the minimum and maximum estimates from Cranfield et al. (1993).**

Location	$F_{0.1}$	MCY
Five sites (MDI 2)	0.46/0.64	66.1/102.7
Cloudy Bay (MDI 7)	0.46/0.64	0.7/1.0

CAY has not been estimated for *M. discors*.

The SFWG recommended moving all surf clam fisheries away from an *MCY* management strategy and towards an exploitation rate management strategy. The SFWG recognised that an exploitation rate approach is more survey intensive, but better allows for the variable nature of biomass for surf clams because it allows greater flexibility in catch (to take greater landings from available biomass) whilst keeping catches sustainable.

6. STATUS OF THE STOCKS

- **MDI 2 & 8**

Stock Status	
Year of Most Recent Assessment	2008 for MDI 2 and 1996 for MDI 8
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0

	Overfishing threshold: -
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Catches are minimal in MDI 2 and MDI 8
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2008 for MDI 2 and 1996 for MDI 8	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review fishery parameters for this species.

Fishery Interactions
MDI can be caught together with other surf clam species and non-QMS bivalves.

- **MDI 7**

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -

Status in relation to Target	Because of the relatively low levels of exploitation of *M. discors*, it is likely that the stock is still effectively in a virgin state, therefore it is Very Likely ($> 90\%$) to be at or above the target.
Status in relation to Limits	Very Unlikely ($< 10\%$) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely ($< 10\%$) to be occurring

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Catches have been light, averaging 0.94 t from 2002–03 to 2017–18. There has not been any landing since 2018-19.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing decline below Limits	Current catches are Very Unlikely ($< 10\%$) to cause declines below soft or hard limits in the short to medium term.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely ($< 10\%$)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2015	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review fishery parameters for this species.

Fishery Interactions
MDI can be caught together with other surf clam species and non-QMS bivalves.

For all other MDI stocks there is no current evidence of appreciable biomass.

7. FOR FURTHER INFORMATION

Beentjes, M P; Baird, S J (2004) Review of dredge fishing technologies and practice for application in New Zealand. *New Zealand Fisheries Assessment Report 2004/37*. 40 p.

Brierley, P (Convenor) (1990) Management and development of the New Zealand sub-tidal clam fishery. Report of the surf clam working group, MAF Fisheries (Unpublished report held in NIWA library, Wellington). 57 p.

Carkeek, W (1966) *The Kapiti Coast*. Reed, Wellington. 187 p.

Conroy, A; Smith, P; Michael, K; Stotter, D (1993) Identification and recruitment patterns of juvenile surf clams, *Mactra discors* and *M. murchisoni* from central New Zealand. *New Zealand Journal of Marine and Freshwater Research 27*: 279–285.

Cranfield, H J; Doonan, I J; Michael, K P (1994b) Dredge survey of surf clams in Cloudy Bay, Marlborough. *New Zealand Fisheries Technical Report No. 39.* 18 p.

Cranfield, H J; Michael, K P (2001) The surf clam fishery in New Zealand: description of the fishery, its management, and the biology of surf clams. *New Zealand Fisheries Assessment Report 2001/62.* 24 p.

Cranfield, H J; Michael, K P; Stotter, D R (1993) Estimates of growth, mortality, and yield per recruit for New Zealand surf clams. New Zealand Fisheries Assessment Research Document 1993/20. 26 p. (Unpublished document held in NIWA library, Wellington).

Cranfield, H J; Michael, K P; Stotter, D R; Doonan, I J (1994a) Distribution, biomass and yield estimates of surf clams off New Zealand beaches. New Zealand Fisheries Assessment Research Document 1994/1. 17 p. (Unpublished document held by NIWA library, Wellington).

Haddon, M; Willis, T J; Wear, R G; Anderlini, V C (1996) Biomass and distribution of five species of surf clam off an exposed west coast North Island beach, New Zealand. *Journal of Shellfish Research 15*: 331–339.

Michael, K; Cranfield, H; Doonan, I; Hadfield, J (1994) Dredge survey of surf clams in Clifford Bay, Marlborough. New Zealand Fisheries Data Report No. 54. (Unpublished document held by NIWA library, Wellington).

Ministry for Primary Industries (2015). Fisheries Assessment Plenary, May 2015: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1475 p.

Triantifillos, L (2008a) Survey of subtidal surf clams in Pegasus Bay, November-December 2007. Prepared by NIWA for Seafood Innovations Limited and SurfCo. Limited. (Unpublished Report held by Fisheries New Zealand).

Triantifillos, L (2008b) Survey of subtidal surf clams in Quota Management Area 2, June - August 2008. Prepared by NIWA for Seafood Innovations Limited and SurfCo. Limited. 40 p. (Unpublished Report held by Fisheries New Zealand).

White, W; Millar, R; Breen, B; Farrington, G (2012) Survey of subtidal surf clams from the Manawatu Coast (FMA 8), October–November 2012. (Unpublished Report held by Fisheries New Zealand Wellington.) 35 p.+ Addendum.

White, W, Millar, R; Farrington, G; Breen, D; Selveraj, S (2015) Stock assessment of surf clams from Cloudy Bay, NZ. *Institute for Applied Ecology New Zealand Report 15/01.* Published by Applied Ecology New Zealand, an Institute of Auckland University of Technology. 34 p.

TARAKIHI (TAR)

(*Nemadactylus macropterus, Nemadactylus* sp.)
Tarakihi, King tarakihi
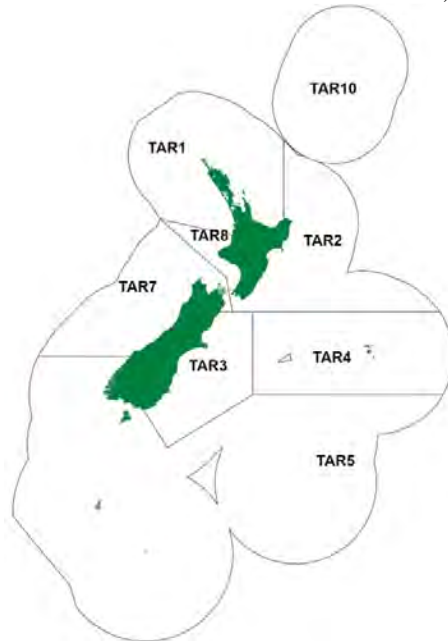
1. FISHERY SUMMARY

1.1 Commercial fisheries

Tarakihi are caught in the coastal waters of the North Island, South Island, Stewart Island, and the Chatham Islands, down to depths of about 250 m. The fishery for tarakihi developed with the introduction of steam trawlers in the 1890s, and by the mid-1930s annual catches had increased to reach about 2000 t. Annual catches increased substantially from the mid-1940s, until stabilising at about 5000–6000 t per annum during 1968–1981 (Table 1).

Figure 1 and Table 2 show the historical landings and TACC values for the main tarakihi stocks. Since the introduction of the QMS in 1986, total landings increased from 4446 t to 6119 t in 2001–02 and remained at around 5000–6000 t until 2018–19, declining to around 4400 t in 2019–20 (

3).

Table 1: Reported total landings (t) of tarakihi from 1968 to 1982–83.

Year	Landings	Year	Landings	Year	Landings
1968	5 683	1974	5 294	1980–81*	4 990
1969	4 082	1975	4 941	1981–82*	5 193
1970	5 649	1976	4 689	1982–83*	4 666
1971	5 702	1977	6 444		
1972	5 430	1978–79*	4 427		
1973	4 439	1979–80*	4 344		

Source - MAF data.
* Sums of domestic catch for calendar years 1978 to 1982, and foreign and chartered vessel catch for fishing year April 1 to March 31.

In October 2001, the TAR 7 TACC was increased slightly to 1088 t although no allocations were made for recreational, customary, or other sources of fishing mortality. In October 2004, the TACCs for TAR 2 and TAR 3 were increased to 1796 t and 1403 t, respectively. From 1 October 2007, the TAC for TAR 1 was increased to 2029 t and the TACC was increased from 1399 to 1447 t. For the fishing year 2018–19, TAR 1, 2, 3, and 7 TACCs were lowered to 1097 t, 1500 t, 1040 t, and 1042 t, respectively. The TACCS were further reduced in 2019–20 to 1045 t, 1350 t, 936 t, and 1024 t, respectively.

TAR 4, 5, 8, and 10 have never been assessed and after some initial adjustments undertaken during the late 1980s their TACCs and TACs remained unchanged.

In most years, the annual catch from TAR 4 has been well below the level of the TACC.
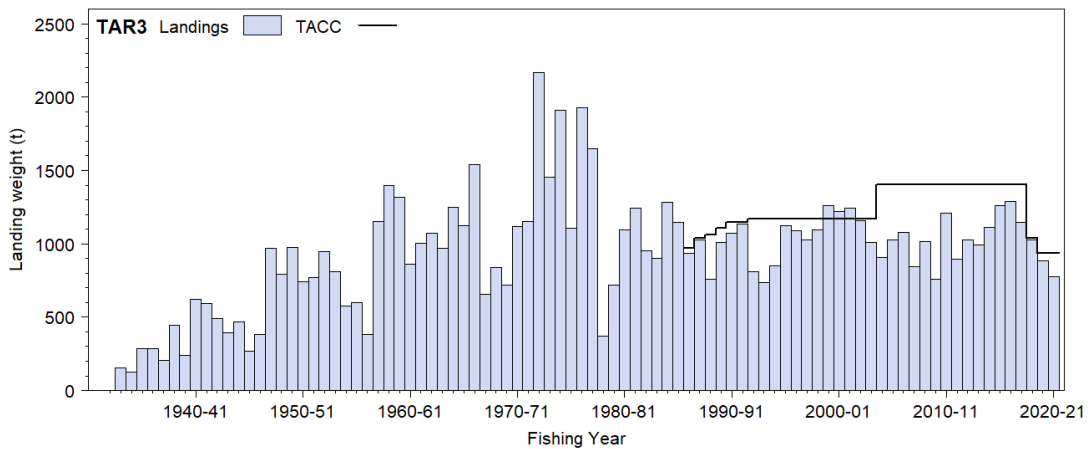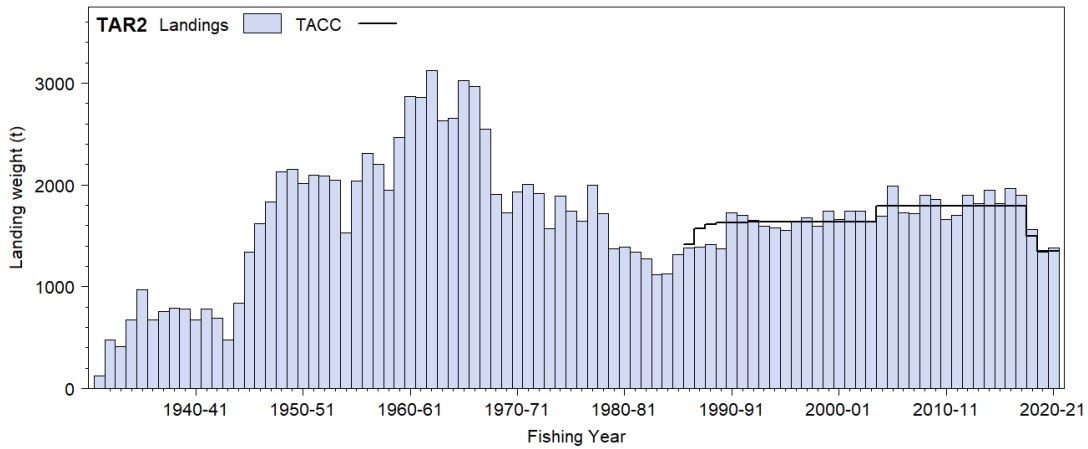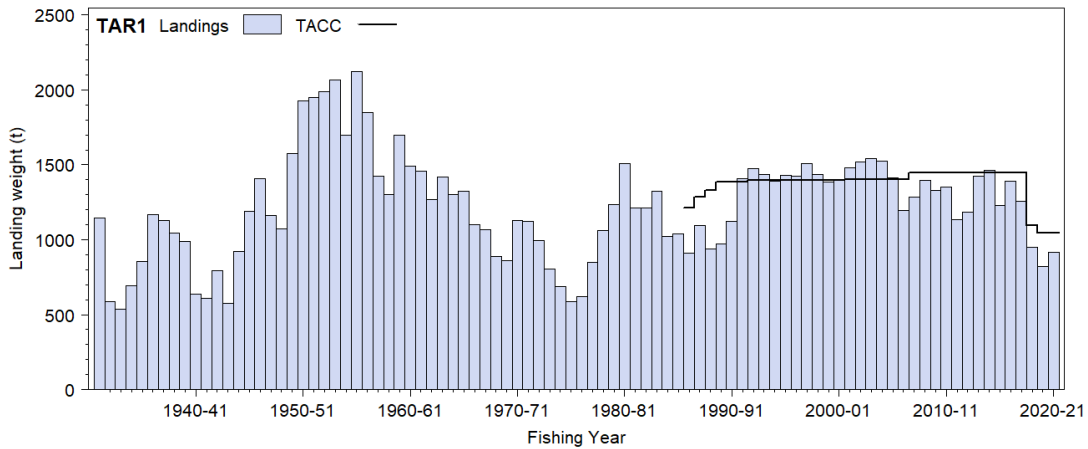
Figure 1: Historical landings and TACCs for the six main TAR stocks. From top to bottom: TAR 1 (Auckland), TAR 2 (Central East), and TAR 3 (South-East Coast). [Continued on next page]
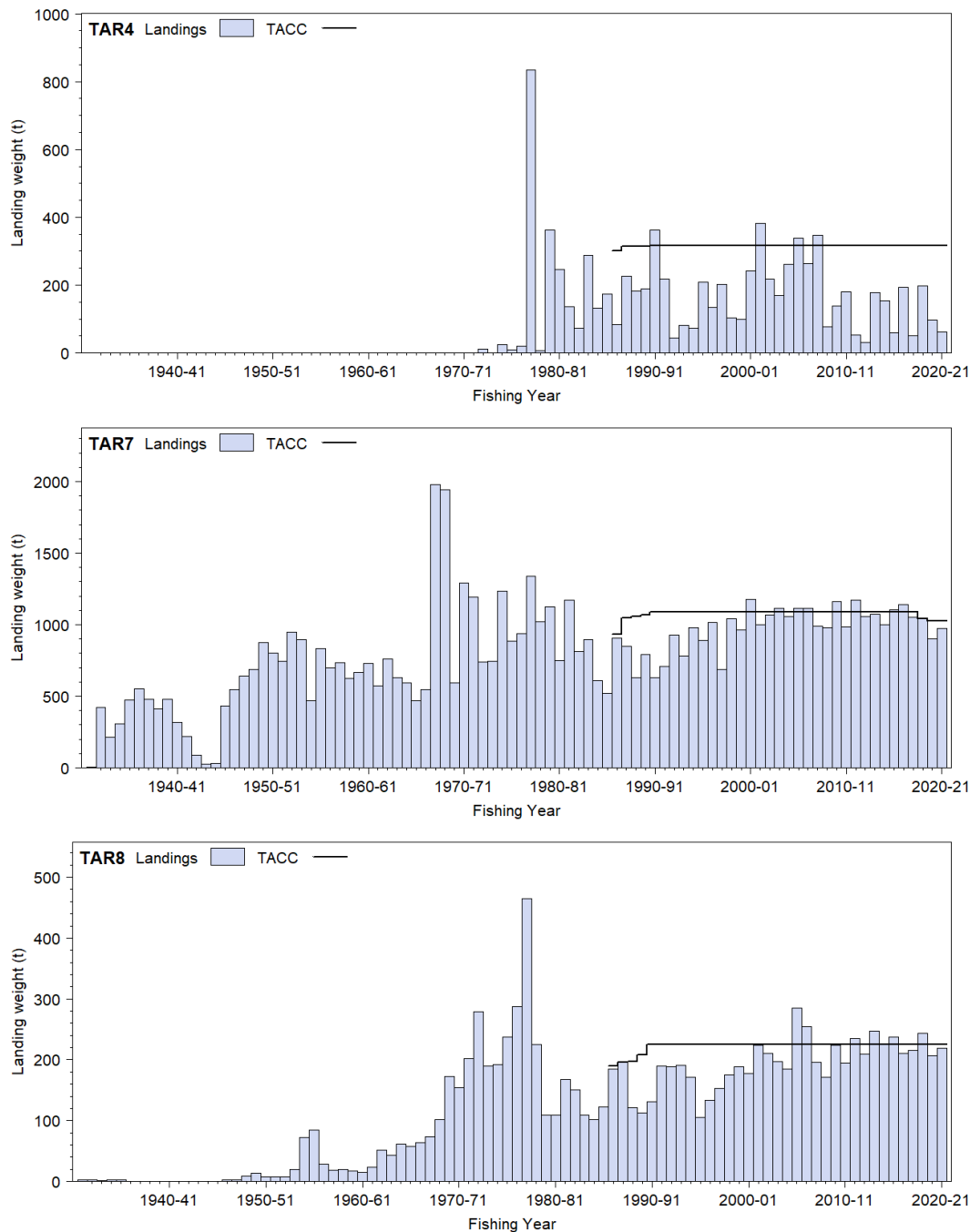
Figure 1: [continued] Historical landings and TACCs for the six main TAR stocks. From top to bottom: TAR 4 (Chatham), TAR 7 (Southland Sub-Antarctic), and TAR 8 (Central West).

Tarakihi are caught by commercial vessels in all areas of New Zealand from the Three Kings Islands in the north to Stewart Island in the south. The main fishing method is bottom trawling. The major fishing grounds are east and west Northland (FMAs 1 and 9), the western Bay of Plenty to Cape Turnagain (FMAs 1 and 2), Cook Strait to the Canterbury Bight (mainly QMA 3), and Jackson Head to Cape Foulwind (QMA 7). The depth distribution of the tarakihi catch tends to increase northwards; most of the catch from the Canterbury Bight is taken within 50–120 m compared with 130–220 m in the east Northland fishery.

During the early 1990s, annual catches of TAR 1 increased to about the level of the TACC and remained at that level during 1991–92 to 2005–06. Annual catches fluctuated over the subsequent years with lower catches in 2006–07 to 2007–08, 2011–12 to 2012–13, and 2015–16, and annual catches approached the

TACC level in 2008–09 to 2010–11, 2013–14 to 2014–15, and 2016–17. The TACC for TAR 1 was reduced in 2018–19 and 2019–20 with the reductions applied to the eastern area of TAR 1. Annual catches from TAR 1 reduced accordingly and were below the TACC in both years.

The distribution of catch between the main areas of TAR 1 has been variable over the last decade. The annual catches from Bay of Plenty declined during 2010–11 to 2019–20 (35% of the TAR 1 catch in 2018–19 to 2019–20), and catches from east Northland increased in 2013–14 to 2017–18 and declined considerably in 2018–19 to 2019–20 (18% of the TAR 1 catch). In recent years, an increasing proportion of the TAR 1 catch has been taken from the west coast of the North Island (48% of the TAR 1 catch in 2018–19 to 2019–20).

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	TAR 1	TAR 2	TAR 3	TAR 4	TAR 5	TAR 7	TAR 8
1931–32	1 146	123	0	0	0	4	2
1932–33	588	481	0	0	0	424	2
1933–34	534	415	152	0	0	215	1
1934–35	691	672	127	0	0	306	2
1935–36	854	969	284	0	0	475	2
1936–37	1 165	673	283	0	0	555	0
1937–38	1 130	758	208	0	0	480	0
1938–39	1 044	788	445	0	27	412	0
1939–40	990	780	239	0	0	480	0
1940–41	637	674	624	0	31	316	0
1941–42	611	779	594	0	26	220	0
1942–43	791	691	491	0	15	87	0
1943–44	573	477	391	0	17	24	0
1944	923	837	466	0	16	29	0
1945	1 189	1 340	269	0	1	432	0
1946	1 410	1 618	383	0	0	545	2
1947	1 162	1 831	970	0	51	643	2
1948	1 075	2 129	793	0	43	688	9
1949	1 575	2 157	973	0	49	873	13
1950	1 925	2 011	743	0	35	803	8
1951	1 948	2 097	772	0	42	747	7
1952	1 990	2 090	948	0	44	949	8
1953	2 066	2 045	809	0	30	896	20
1954	1 697	1 529	578	0	1	470	72
1955	2 124	2 039	599	0	0	833	84
1956	1 850	2 312	384	0	0	699	28
1957	1 423	2 200	1 150	0	12	735	18
1958	1 300	1 952	1 400	0	8	625	20
1959	1 697	2 464	1 315	0	7	666	17
1960	1 489	2 867	862	0	10	732	15
1961	1 456	2 864	1 002	0	15	573	23
1962	1 266	3 126	1 073	0	6	759	52
1963	1 417	2 632	968	0	8	630	43
1964	1 304	2 656	1 250	0	7	593	61
1965	1 324	3 027	1 122	0	11	470	58
1966	1 100	2 964	1 539	0	24	549	64
1967	1 066	2 548	657	0	2	1 981	73
1968	888	1 907	837	0	8	1 941	100
1969	863	1 727	720	0	8	592	173
1970	1 129	1 932	1 120	0	19	1 293	154
1971	1 125	2 006	1 153	0	25	1 192	202
1972	996	1 912	2 169	12	15	741	279
1973	804	1 568	1 455	0	27	747	190
1974	687	1 889	1 913	24	31	1 234	192
1975	584	1 743	1 106	10	482	887	237
1976	620	1 645	1 927	21	143	936	287
1977	849	1 994	1 648	835	53	1 337	465
1978	1 059	1 718	373	6	54	1 021	225
1979	1 236	1 375	717	362	89	1 125	109
1980	1 506	1 391	1 098	246	107	748	109
1981	1 213	1 339	1 242	137	137	1 174	167
1982	1 210	1 277	953	72	117	813	151

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 3: Reported landings (t) of tarakihi by Fishstock from 1983–84 to present and TACCs (t) from 1986–87 to present. QMS data from 1986–present. * FSU data.§ Includes landings from unknown areas before 1986–87.

Fishstock FMA (s)	TAR 1 1 & 9 Landings	TACC	TAR 2 2 Landings	TACC	TAR 3 3 Landings	TACC	TAR 4 4 Landings	TACC	TAR 5 5 & 6 Landings	TACC
1983–84*	1 326	–	1 118	–	902	–	287	–	115	–
1984–85*	1 022	–	1 129	–	1 283	–	132	–	100	–
1985–86*	1 038	–	1 318	–	1 147	–	173	–	48	–
1986–87	912	1 210	1 382	1 410	938	970	83	300	42	140
1987–88	1 093	1 286	1 386	1 568	1 024	1 036	227	314	88	142
1988–89	940	1 328	1 412	1 611	758	1 061	182	314	47	147
1989–90	973	1 387	1 374	1 627	1 007	1 107	190	315	60	150
1990–91	1 125	1 387	1 729	1 627	1 070	1 148	367	316	35	153
1991–92	1 415	1 387	1 700	1 627	1 132	1 148	213	316	55	153
1992–93	1 477	1 397	1 654	1 633	813	1 168	45	316	51	153
1993–94	1 431	1 397	1 594	1 633	735	1 169	82	316	65	153
1994–95	1 390	1 398	1 580	1 633	849	1 169	71	316	90	153
1995–96	1 422	1 398	1 551	1 633	1 125	1 169	209	316	73	153
1996–97	1 425	1 398	1 639	1 633	1 088	1 169	133	316	81	153
1997–98	1 509	1 398	1 678	1 633	1 026	1 169	202	316	21	153
1998–99	1 436	1 398	1 594	1 633	1 097	1 169	104	316	51	153
1999–00	1 387	1 398	1 741	1 633	1 260	1 169	98	316	80	153
2000–01	1 403	1 398	1 658	1 633	1 218	1 169	242	316	58	153
2001–02	1 480	1 399	1 742	1 633	1 244	1 169	383	316	75	153
2002–03	1 517	1 399	1 745	1 633	1 156	1 169	218	316	92	153
2003–04	1 541	1 399	1 638	1 633	1 089	1 169	169	316	53	153
2004–05	1 527	1 399	1 692	1 796	905	1 403	262	316	57	153
2005–06	1 409	1 399	1 986	1 796	1 010	1 403	339	316	62	153
2006–07	1 193	1 399	1 729	1 796	1 080	1 403	263	316	94	153
2007–08	1 286	1 447	1 715	1 796	843	1 403	348	316	50	153
2008–09	1 398	1 447	1 901	1 796	1 017	1 403	77	316	45	153
2009–10	1 332	1 447	1 858	1 796	757	1 403	138	316	81	153
2010–11	1 349	1 447	1 660	1 796	1 207	1 403	180	316	135	153
2011–12	1 134	1 447	1 702	1 796	897	1 403	54	316	151	153
2012–13	1 184	1 447	1 900	1 796	1 026	1 403	31	316	144	153
2013–14	1 425	1 447	1 816	1 796	991	1 403	179	316	126	153
2014–15	1 463	1 447	1 947	1 796	1 112	1 403	154	316	136	153
2015–16	1 229	1 447	1 820	1 796	1 262	1 403	59	316	158	153
2016–17	1 390	1 447	1 967	1 796	1 287	1 403	193	316	151	153
2017–18	1 258	1 447	1 896	1 796	1 144	1 403	51	316	123	153
2018–19	950	1 097	1 563	1 500	1 025	1 040	198	316	122	153
2019–20	822	1 045	1 339	1 350	882	936	96	316	148	153
2020–21	919	1 045	1 380	1 350	774	936	62	316	171	153

FMA (s)	TAR 7 7 Landings	TACC	TAR 8 8 Landings	TACC	TAR 10 10 Landings	TACC	Total Landings	TACC
1983–84*	896	–	109	–	0	–	5 430	–
1984–85*	609	–	102	–	0	–	4 816	–
1985–86*	519	–	122	–	0	–	5 051	–
1986–87	904	930	185	190	0	10	4 446	5 160
1987–88	840	1 046	197	196	0	10	4 855	5 598
1988–89	630	1 059	121	197	0	10	4 090	5 727
1989–90	793	1 069	114	208	0	10	4 473	5 873
1991–92	710	1 087	190	225	2	10	5 417	5 953
1992–93	929	1 087	189	225	0	10	5 158	5 989
1990–91	629	1 087	131	225	< 1	10	5 086	5 953
1993–94	780	1 087	191	225	0	10	4 878	5 990
1994–95	978	1 087	171	225	0	10	5 129	5 991
1995–96	890	1 087	105	225	0	10	5 375	5 991
1996–97	1 013	1 087	133	225	0	10	5 512	5 991
1997–98	685	1 087	153	225	0	10	5 287	5 991
1998–99	1 041	1 087	175	225	0	10	5 501	5 991
1999–00	964	1 087	189	225	0	10	5 719	5 991
2000–01	1 178	1 087	178	225	0	10	5 935	5 991
2001–02	1 000	1 088	223	225	0	10	6 119	5 993
2002–03	1 069	1 088	211	225	0	10	6 008	5 993
2003–04	1 116	1 088	197	225	0	10	5 723	5 993
2004–05	1 056	1 088	184	225	0	10	5 683	6 390
2005–06	1 114	1 088	285	225	0	10	6 205	6 390
2006–07	1 116	1 088	254	225	0	10	5 729	6 390
2007–08	990	1 088	196	225	0	10	5 428	6 438
2008–09	977	1 088	169	225	0	10	5 584	6 438
2009–10	1 162	1 088	226	225	0	10	5 553	6 438
2010–11	983	1 088	194	225	0	10	5 708	6 439
2011–12	1 173	1 088	235	225	0	10	5 346	6 439
2012–13	1 058	1 088	209	225	0	10	5 552	6 439
2013–14	1 073	1 088	248	225	0	10	5 857	6 439
2014–15	1 002	1 088	224	225	0	10	6 038	6 439
2015–16	1 105	1 088	238	225	0	10	5 870	6 439
2016–17	1 139	1 088	210	225	0	10	6 337	6 439
2017–18	1 054	1 088	215	225	0	10	5 742	6 439
2018–19	1 049	1 042	243	225	0	10	5 150	5 383
2019–20	899	1 024	207	225	0	10	4 392	5 059
2020–21	976	1 024	219	225	0	10	4 501	5 059

The target trawl fishery accounts for about 60% of the annual catch from each of these three areas. Most of the remainder of the catch is taken as a bycatch from other inshore trawl fisheries.

During 2004–05 to 2017–18, annual catches from TAR 2 were at about the level of the TACC (1796 t). Annual catches declined considerably in 2018–19 and 2019–20 following the reductions in the TAR 2 TACC. Most of the catch from TAR 2 was taken by the target single bottom trawl fishery.

During 2004–05 to 2013–14, annual catches from TAR 3 were maintained at about 70% of the TACC (1403 t). Catches increased to approach the level of the TACC in 2015–16 to 2016–17 and subsequently declined following reductions in the TAR 3 TACC in 2018–19 and 2019–20. During 1989–90 to 2019–20, most of the catch was taken by the trawl method either targeting tarakihi (34% of total catch) or as a bycatch from the main inshore trawl fisheries, principally red cod (17%) and barracouta (11%). The tarakihi target set net fishery off Kaikōura accounted for 21% of the total TAR 3 catch.

Prior to 2010–11, the total catch from TAR 5 was well below the TACC of 153 t. The annual catches increased to about the level of the TACC in 2011–12 and remained at that level over the subsequent years. Tarakihi are predominantly caught by the inshore bottom trawl fisheries in TAR 5, principally as a bycatch of the stargazer trawl fishery and, more recently, from a target trawl fishery.

Catches from TAR 7 remained at about the level of the TACC of 1088 t during 2000–01 to 2017–18. Catches declined in 2018–19 and 2019–20 corresponding to relatively small reductions in the TAR 7 TACC. The TAR 7 Fishstock encompasses the area off the west coast of the South Island and extends to Cook Strait. The eastern portion of TAR 7 is considered to be a component of the eastern stock of tarakihi. From 2007–08, the eastern portion of TAR 7 (Statistical Areas 017 and part of 018) accounted for about 30% of the annual TAR 7 catch. Catches from TAR 7 are dominated by the target bottom trawl fishery.

The total catch from TAR 8 increased during the 1990s and has remained at about the level of the TACC (225 t) from 1998–99. Since then, most (about 70%) of the annual TAR 8 catch has been taken by the target trawl fishery.

1.2   Recreational fisheries
Tarakihi are taken by recreational fishers using lines and set nets. They are often taken by fishers targeting snapper and blue cod, particularly around the North Island. The allowances within the TAC for each Fishstock are shown in Table 4.

Table 4: Total allowable catches (TAC, t) allowance for customary non-commercial fishing, recreational fishing, and other sources of mortality (t), as well as the total allowable commercial catch (TACC, t) for tarakihi from 2019–20.

Fishstock	TAC	TACC	Customary non-commercial	Recreational	Other Mortality
TAR 1 (FMA 1 & 9)	1 333	1 045	73	110	105
TAR 2	1 658	1 350	100	73	135
TAR 3	1 060	936	15	15	94
TAR 4	316	316	0	0	0
TAR 5 (FMA 5 & 6)	153	153	0	0	0
TAR 7	1 154	1 024	5	23	102
TAR 8	225	225	0	0	0
TAR 10	10	10	0	0	0

1.2.1 Management controls
The main methods used to manage recreational harvests of tarakihi are minimum legal size limits (MLS), method restrictions, and daily bag limits. Fishers can take up to 20 tarakihi as part of their combined daily bag limit (except in the South-East and Southland fisheries management areas including the Fiordland Marine Area where the limit is 15 within a combined daily bag limit of 30 finfish) and the MLS is 25 cm fork length in all areas.

1.2.2 Estimates of recreational harvest

There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and offsite methods where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest for tarakihi were calculated using offsite regional or national telephone/diary surveys (Table 5, Bradford 1998, Boyd et al 2004, Boyd & Reilly 2004). The early telephone/diary method was prone to 'soft refusal' bias during recruitment and overstated catches during reporting (Wright et al 2004). Estimates of harvest from the later telephone/diary surveys were found to be implausibly high for many species. None of the harvest estimates from these telephone/diary surveys are now thought reliable.

Table 5: **Recreational harvest estimates (including catch on amateur charter vessels but excluding catch under customary permits and s111 approvals) for tarakihi stocks (Bradford 1998, Boyd & Reilly 2004, Boyd et al 2004, Hartill et al 2007b, Hartill et al 2013, 2019, Wynne-Jones et al 2014, 2019). The telephone/diary surveys and earlier aerial-access survey ran from December to November but are denoted by the January calendar year. Surveys since 2010 have run through the October to September fishing year but are denoted by the January calendar year. Mean fish weights for offsite surveys were obtained from boat ramp surveys (e.g., Hartill & Davey 2015).**

Stock	Year	Method	Number of fish	Total weight (t)	CV
TAR 1	1996	Telephone/diary	498 000	305	0.08
	2000	Telephone/diary	1 035 000	636	0.19
	2001	Telephone/diary	679 000	417	0.16
	2012	Panel survey	166 540	117	0.22
FMA 1 only	2005	Aerial-access*	-	90	0.18
FMA 1 only	2012	Aerial-access*	-	67	0.15
FMA 1 only	2012	Panel survey	160 414	113	0.22
	2012	Panel survey	166 449	117	0.22
FMA 1 only	2018	Aerial-access*	-	46	0.13
FMA 1 only	2018	Panel survey	59 000	50	0.16
	2018	Panel survey	73 289	62	0.14
TAR 2	1996	Telephone/diary	114 000	65	0.14
	2000	Telephone/diary	310 000	191	0.27
	2001	Telephone/diary	484 000	298	0.18
	2012	Panel survey	110 920	72	0.22
	2018	Panel survey	148 159	110	0.22
TAR 3	1996	Telephone/diary	3 000	-	-
	2000	Telephone/diary	25 000	15	0.51
	2001	Telephone/diary	7 000	4	0.37
	2012	Panel survey	4 208	3	0.42
	2018	Panel survey	6 622	5	0.32
TAR 5	1996	Telephone/diary	3 000	-	-
	2000	Telephone/diary	10 000	6	0.57
	2001	Telephone/diary	13 000	7	0.37
	2012	Panel survey	141	<1	0.73
	2018	Panel survey	5 545	4	0.35
TAR 7	1996	Telephone/diary	69 000	24	0.13
	2000	Telephone/diary	87 000	33	0.18
	2001	Telephone/diary	9 000	3	0.15
	2012	Panel survey	48 107	23	0.38
	2018	Panel survey	31 668	21	0.18
TAR 8	1996	Telephone/diary	46 000	28	0.17
	2000	Telephone/diary	66 000	30	0.38
	2001	Telephone/diary	78 000	36	0.28
	2012	Panel survey	31 340	23	0.30
	2018	Panel survey	37 706	22	0.29

* Aerial-access surveys did not include catches from charter vessels whereas these are included in the panel survey estimates. The estimates for FMA 1 in this table are not, therefore, directly comparable. See Edwards & Hartill (2015) for details.

Onsite surveys provide a more direct means of estimating recreational harvest but are expensive and suited to relatively few fisheries. Hartill et al (2007a) developed a maximum count aerial-access method to combine data from concurrent creel surveys of recreational fishers returning to key ramps and aerial counts of vessels observed to be fishing. The ratio of the aerial count in a particular area to the number of interviewed parties who claimed to have fished in that area at the time of the overflight is used to scale up harvests observed at surveyed ramps, to estimate harvest taken by all fishers returning to all ramps. This approach was first used to estimate snapper harvest in the Hauraki Gulf in 2003–04. It was then extended to cover the whole of FMA 1 in 2004–05 and to provide estimates for other species, including tarakihi (FMA 1 only) (Hartill et al 2007b). This survey was repeated in 2011–12 (Hartill et al 2013) and 2017–18 (Hartill et al 2019).

Problems with the earlier offsite telephone/diary surveys led to the development of a rigorously-designed National Panel Survey (NPS) which was first used for the 2011–12 fishing year (Heinemann et al 2015). The 2011–12 NPS used face-to-face interviews of a random sample of 30 390 households to recruit a panel of 7013 fishers and a further sample of 3000 putative non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information was collected in standardised computer assisted telephone interviews. Harvest estimates from the NPS (Wynne-Jones et al 2014) and the 2011–12 aerial-access survey (Hartill et al 2013) are similar for the FMA 1 portion of TAR 1 (and other key recreational fisheries in FMA 1) and are, therefore, considered to be reasonably accurate and fit for management purposes (Edwards & Hartill 2015). The NPS and a parallel FMA 1 aerial-access survey were repeated for the 2017–18 fishing year and harvest estimates are included in Table 5.

1.3 Customary non-commercial fisheries
No quantitative information on the level of customary non-commercial fishing is available.

1.4 Illegal catch
No quantitative information on the level of illegal tarakihi catch is available.

1.5 Other sources of mortality
No information is available.

2. BIOLOGY

Juvenile tarakihi grow relatively fast, reaching 25 cm fork length (FL) at 4 years of age. Sexual maturity was initially estimated at 25–35 cm FL, and an age of 4–6 years (Annala 1987), but more recent studies indicate 50% maturity is attained at about 33 cm FL and an age of 6 years (Parker & Fu 2011). Growth rates attenuate from an age of 5–6 years (Annala et al 1990).

Growth rates are generally similar for the main tarakihi fish stocks, although recent studies have indicated that the growth rates of tarakihi older than 6 years of age are lower in the Bay of Plenty and east Northland compared with other fishery areas. Tarakihi reach a maximum age of 40+ years (Annala et al 1990).

Tarakihi spawn in summer and autumn. Three main spawning grounds have been identified: Cape Runaway to East Cape, Cape Campbell to Pegasus Bay, and the west coast of the South Island near Jackson Bay. Spawning fish have also been sampled from the Bay of Plenty and east Northland and limited spawning probably occurs throughout the distributional range of tarakihi around New Zealand.

Few larval and post-larval tarakihi have been caught and identified. The post-larvae appear to be pelagic, occur in offshore waters, and are found in surface waters at night. Post-larval metamorphosis to the juvenile stage occurs in spring or early summer when the fish are 7–9 cm FL and 7–12 months old.

Several juvenile nursery areas have been identified in shallower, inshore waters, including the southwest coast of the North Island, Tasman Bay, near Kaikōura, northern Pegasus Bay, Canterbury Bight, Otago, and the Chatham Islands. Juveniles move out to deeper water at a length of about

25 cm FL at an age of 3–4 years. Recent sampling of the TAR 3 trawl catch revealed that a high proportion of the landed catch comprised immature fish. Conversely, TAR 3 set net and TAR 2 trawl landed catches comprised mainly mature fish.

The results of tagging experiments carried out near Kaikōura during 1986 and 1987 indicate that some tarakihi are capable of moving long distances. Fish have been recaptured from as far away as the Kaipara Harbour on the west coast of the North Island, south of Whangarei on the east coast of the North Island, and Timaru on the east coast of the South Island. Age composition of commercial bottom trawl and survey catches along the east coast of New Zealand suggest that juvenile tarakihi move progressively northward from the Canterbury Bight to East Northland as they grow older (McKenzie et al 2017, 2021).

An estimate of natural mortality for tarakihi was derived from the age structures of lightly exploited populations sampled from off the west coast of the South Island in 1971 and 1972. A catch curve analysis yielded total mortality estimates of 0.13 from both samples (Vooren 1973). Estimates of Z for the area near Kaikōura made during 1987 ranged from 0.12 to 0.16 for fish between 8 and 20 years old (Annala et al 1990). An approximation of M was derived from the oldest age observed in the Kaikōura sample (42 years), yielding an estimate of $M = 0.11$. It was concluded that M was no greater than 0.10 and that this value was also the best available estimate of M.

Biological parameters relevant to the stock assessment are shown in Table 6.

Table 6: Estimates of biological parameters of tarakihi.

Fishstock				Estimate		Source
1. Natural mortality (M)						
				0.10 considered best estimate for all areas for both sexes		Annala et al (1989, 1990)

2. Weight = a (length)^b (Weight in g, length in cm fork length)

	Females		Males		Source
	a	b	a	b	
TAR 3	0.04	2.79	0.0433	2.77	Annala et al (1990)
TAR 4	0.023	2.94	0.017	3.02	Annala et al (1989)
TAR 7	0.015	3.058	0.0141	3.07	Manning et al (2008)

3. von Bertalanffy growth parameters

	Females			Males			Source
	K	t_0	$L\infty$	K	t_0	$L\infty$	
TAR 3	0.2009	- 1.103	44.6	0.2085	- 1.397	42.1	Annala et al (1990)
TAR 4	0.2205	- 1.026	44.6	0.1666	- 2.479	44.7	Annala et al (1989)
TAR 7	0.234	- 0.57	45.6	0.252	- 0.41	42.7	Manning (2008)

3. STOCKS AND AREAS

The results of tagging experiments have shown that tarakihi are capable of moving large distances around the coasts of the main islands of New Zealand. The long pelagic larval phase of 7–12 months indicates that larvae will also be widely dispersed. Previously these two factors, in addition to the lack of any evidence of genetic isolation, had been used to suggest that tarakihi around the main islands of New Zealand consist of one continuous stock. Further, because of the large distance between the mainland and the Chatham Islands, and the separation of these two areas by water deeper than that which is usually inhabited by adult tarakihi, the tarakihi around the Chatham Islands were considered to be a separate stock.

Trends in CPUE indices and age compositions from the TAR 1, 2, and 3 fisheries were examined to investigate the stock structure of tarakihi along the east coasts of mainland New Zealand. The fisheries in Canterbury Bight/Pegasus Bay are dominated by younger fish and there is a progressive increase in the proportion of older fish in the catches from TAR 2 and Bay of Plenty and east Northland in TAR 1, while the relative strength of individual year classes is comparable amongst these areas. Trends in CPUE indices are also comparable among these fisheries, lagged by the relative age of recruitment to the respective fishery.

There are distinct spawning grounds in each of the two main islands (off East Cape in the northern area and off Cape Campbell in the south), while there is a preponderance of juvenile fish in Canterbury Bight/Pegasus Bay and Tasman Bay/Golden Bay, and low densities of juvenile tarakihi in East Northland, Bay of Plenty, TAR 2, and along the west coasts of both the North and South Islands. The long pelagic phase of tarakihi may provide a mechanism for the transfer of larvae to the nursery grounds in Canterbury Bight/Pegasus Bay.

These observations indicate considerable connectivity of tarakihi along the east coast of the South Island and North Island. The current stock hypothesis is that the Canterbury Bight/Pegasus Bay area represents the main nursery area for the eastern stock unit. At the onset of maturity, a proportion of the fish migrate northwards to recruit to the East Cape area and, subsequently, the Bay of Plenty and east Northland areas. This hypothesis is further supported by the northward movement of tagged fish from the Kaikōura coast to the Wairarapa, East Cape, and Bay of Plenty areas.

The results from previous tagging studies also indicate some connectivity between Kaikōura and the west coast North Island. However, limited data are available from the west coast North Island to elucidate the degree of the linkage between these areas. Recent age composition data from the west coast North Island revealed similarities and differences in the relative strength of individual year classes compared with the east coast South and North Island fisheries. Further, growth rates of older fish (more than 6 years) sampled from the west coast North Island differed from east Northland, suggesting a lack of connectivity between the fisheries around the north of the North Island.

A more recent study (2018–19 and 2019–20) conducted age composition sampling of all the main tarakihi fisheries around mainland New Zealand (McKenzie et al 2021). The study reaffirmed the similarity in the age structure of the tarakihi populations along the eastern coast of the North Island and South Island. The study also found contrasting pattern in the age structure from the fisheries off the western coast of the North Island and South Island (TAR 7 WCSI, TAR 8, and TAR 1W). The age structure of these fisheries was consistent with the relative strength of individual year classes of juvenile tarakihi sampled from Tasman Bay/Golden Bay. These results support the current stock hypothesis that eastern tarakihi represents a discrete stock unit, while providing strong evidence of a separate western tarakihi stock unit. Limited information is available to ascertain the stock affinity of tarakihi from Southland (TAR 5), although this area supports a relatively small catch of predominantly young tarakihi.

A recent study of population genetic structure of tarakihi (*N. macropterus*) from samples collected around New Zealand and the Chatham Islands (Papa et al 2021). No clear genetic structure was detected for the overall New Zealand area indicating a panmictic genetic structure. However, the study detected weak genetic breaks between the west and east coasts of South Island and between Hawke's Bay and East Northland. The latter observation is consistent with an earlier study that detected two successive genetic breaks between East Cape and East Northland (Gauldie & Johnston 1980). These observations may indicate a more complex population structure of tarakihi around northern North Island than currently assumed from the age composition data (and other fisheries data).

Smith et al (1996) used two genetic techniques to determine that king tarakihi from northern New Zealand is a separate species from tarakihi (*N. macropterus*). King tarakihi are caught at the northern extent of the range of tarakihi (North Cape and Three Kings Islands). Due to concerns that some tarakihi catches were being misreported, as from December 2010, king tarakihi was included within the species definition of the tarakihi QMS Fishstocks (under Fisheries (Commercial Fishing) Regulations 2001). All subsequent catches of king tarakihi should have been included within the TAR 1 TACC. However, modest commercial catches (20–30 t per annum) of king tarakihi (KTA) were reported from FMA 1 in the 2002–03 to 2004–05 fishing years. No additional annual catches of king tarakihi have been reported separately since then.

The magnitude of king tarakihi catches reported within TAR 1 is considered to be small due to the distribution of the main fisheries relative to the known distribution of king tarakihi. Similarly, the magnitude of tarakihi catch misreported as king tarakihi is also considered to have been small.

4.   STOCK ASSESSMENT

An integrated assessment for TAR 7 was conducted in 2008 with data that included the commercial catch, trawl survey biomass and proportions-at-age estimates, CPUE indices, and commercial catch proportions-at-age.

In 2017, a stock assessment was conducted for east coast tarakihi combining eastern TAR 1 (Bay of Plenty and East Northland), TAR 2, and TAR 3. This assessment was updated in 2018 and 2019. A new assessment was conducted in 2021 (Langley 2022).

4.1   Trawl surveys

4.1.1   Relative abundance
Indices of relative biomass are available from *Kaharoa* trawl surveys in TAR 2, TAR 3, and TAR 7 (Table 7 and **Error! Reference source not found.**, 3, and 3a). Note that these estimates were revised in 1996 as a result of new doorspread estimates becoming available from SCANMAR measurements. In TAR 2 no trend is apparent in the biomass estimates. The TAR 2 survey was conducted for four consecutive years: 1993–1996 and then discontinued.

West coast South Island (WCSI) inshore trawl survey
For TAR 7, trawl survey biomass estimates for pre-recruit (less than 25 cm FL) and recruited (at least 25 cm FL) tarakihi were derived for the west coast South Island and Tasman Bay/Golden Bay (TBGB) areas of the WCSI inshore trawl survey. The TBGB area is considered to be a primary nursery ground for tarakihi in TAR 7. A substantial proportion of the TAR 7 commercial catch is taken from the west coast portion of the survey area. For comparability with the commercial CPUE indices it is appropriate to partition the trawl survey biomass indices by area and size category.

Biomass estimates for the west coast strata of the survey area are relatively stable through the time series, aside from higher than usual estimates in 2005 and 2017 (Figure 2). Off the west coast, most of the survey biomass comprises recruited fish. In contrast, pre-recruited fish make up most of the TBGB survey biomass. Biomass estimates in TBGB fluctuate more than those for the west coast and the CVs for pre-recruited fish are often high. Throughout the time series, total biomass of the west coast has been substantially greater than for TBGB. Total biomass estimates showed a gradually declining trend until 2003, a sharp increase in 2005 and 2017, followed by a return to levels similar to those seen from 1997 to 2003 (MacGibbon et al 2022). The 2021 biomass of 969 t is below the time series mean. Almost 99% of the biomass was juvenile fish in 2022, while the adult biomass (over 31 cm) was 98% of the total, compared with 81% in 2019. Of the total tarakihi biomass, over 98% was off the west coast (957 t), and 80% (1011 t) of the total was at depths less than 200 m. Juvenile biomass was noticeably lower than in 2019 and was a much smaller proportion of the total biomass compared with other years.

Length frequencies of tarakihi through the time series show smaller fish are more abundant in TBGB than off the west coast.

East coast South Island trawl survey
The ECSI winter surveys from 1991 to 1996 (depth range 30–400 m) were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range; but these were discontinued after the fifth in the annual time series, because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007, and this time included strata in the 10–30 m depth range, to monitor elephantfish and red gurnard which were officially included in the list of target species in 2012. Six surveys (2007, 2012, 2014, 2016, 2018, and 2021) surveys provide full coverage of the 10–30 m depth range.

Tarakihi biomass in the core strata peaked in 1993 due to a single large catch off Timaru resulting in a high CV of 55%. Overall, however, the biomass has been trending down since 2007 and the 2021 biomass dropped by 45%, the lowest in the time series (Table 7, Figure 3). Pre-recruit core strata biomass was a major but variable component of tarakihi total biomass estimates on all surveys, ranging from 18% to 60% of total biomass, and in 2021 it was 30%. Similarly, juvenile core strata biomass (based on

length-at-50% maturity) was also a large component of total biomass, but the proportion was relatively constant over the time series (56–80%) and in 2021 it was the lowest at 56% (Figure 3a). There was virtually no tarakihi caught in the 10–30 m strata in any of the six surveys, and hence the shallow strata are of no value for monitoring tarakihi. The distribution of tarakihi hotspots varies, but, overall, this species is consistently well represented over the entire survey area, most commonly from 30 to about 150 m.

The size distributions of tarakihi in each of the thirteen ECSI core strata winter trawl surveys were similar and were multi-modal, with smaller modes representing individual cohorts (Beentjes et al in prep). The 0+ and 1+ and sometimes the 2+ cohorts are evident in most surveys. The 0+ and 1+ cohorts were present in the 2021 survey, but there were fewer larger fish over 25 cm than for any previous survey. Overall, tarakihi off the ECSI were generally smaller than those from the west coast South Island (Stevenson & MacGibbon 2018) and the east coast North Island (Parker & Fu 2011), suggesting that, like Tasman Bay/Golden Bay, Pegasus Bay and the Canterbury Bight are important nursery grounds for juvenile tarakihi (Beentjes et al 2012, McKenzie et al 2017). The tarakihi sampled by the ECSI trawl surveys are dominated by 2–5 year old fish. There is considerable variation in the relative abundance of individual age classes amongst surveys, indicating high inter-annual variability in recruitment.
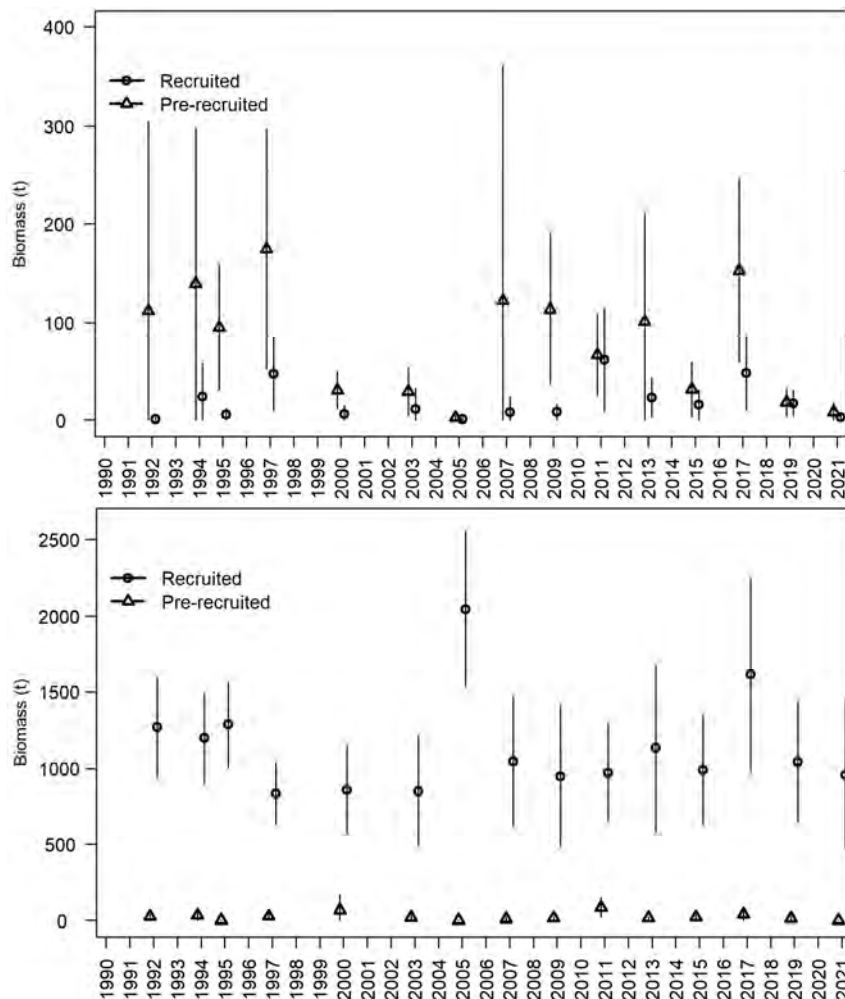

Figure 2: Biomass estimates of pre-recruit (under 25 cm fork length) and recruited (at least 25 cm fork length) for the WCSI inshore trawl survey for Tasman Bay and Golden Bay only (top plot) and west coast South Island only (bottom plot). Error bars are ± two standard deviations.

Table 7: Relative biomass indices (t) and coefficients of variation (CV) for tarakihi for Cape Runaway to Cook Strait, ECSI – summer and winter, and Tasman Bay to Haast survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 and 9 equivalent to current strata 13, 16, and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (25 cm FL).

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
Cape Runaway to Cook Strait	TAR 2	1991	KAH9304	885	27	–	–	–	–	–	–	–	–	–	–
		1992	KAH9402	1 128	20	–	–	–	–	–	–	–	–	–	–
		1993	KAH9502	791	23	–	–	–	–	–	–	–	–	–	–
		1994	KAH9602	943	15	–	–	–	–	–	–	–	–	–	–
ECSI (winter)	TAR 3			30–400 m		10–400 m		30–400 m		10–400 m		30–400 m		10–400 m	
		1991	KAH9105	1 712	33	–	–	305	38	–	–	1 414	33	–	–
		1992	KAH9205	932	26	–	–	288	26	–	–	614	28	–	–
		1993	KAH9306	3 805	55	–	–	2 282	62	–	–	1 522	46	–	–
		1994	KAH9406	1 219	41	–	–	494	31	–	–	725	35	–	–
		1996	KAH9606	1 656	24	–	–	519	30	–	–	1 137	27	–	–
		2007	KAH0705	2 589	24	–	–	822	30	–	–	1 766	24	–	–
		2008	KAH0806	1 863	29	–	–	739	44	–	–	1 123	25	–	–
		2009	KAH0905	1 519	36	–	–	525	42	–	–	994	42	–	–
		2012	KAH1207	1 661	25	–	–	584	34	–	–	1 077	29	–	–
		2014	KAH1402	2 380	23	–	–	818	26	–	–	1 562	26	–	–
		2016	KAH1605	1 462	31	–	–	342	40	–	–	1 121	33	–	–
		2018	KAH1803	1 409	26	–	–	409	28	–	–	1 000	28	–	–
		2021	KAH2104	775	38			236	56			539	33		
ECSI (summer)	TAR 3	1996	KAH9618	3 818	21	–	–	–	–	–	–	–	–	–	–
		1997	KAH9704	2 036	24	–	–	–	–	–	–	–	–	–	–
		1998	KAH9809	4 277	24	–	–	–	–	–	–	–	–	–	–
		1999	KAH9917	2 606	15	–	–	–	–	–	–	–	–	–	–
		2000	KAH0014	1 510	13	–	–	–	–	–	–	–	–	–	–
WCSI inshore	TAR 7	1992	KAH9204	1 409	14	–	–	–	–	–	–	–	–	–	–
		1994	KAH9404	1 420	14	–	–	–	–	–	–	–	–	–	–
		1995	KAH9504	1 389	11	–	–	–	–	–	–	–	–	–	–
		1997	KAH9701	1 087	12	–	–	–	–	–	–	–	–	–	–
		2000	KAH0004	964	19	–	–	–	–	–	–	–	–	–	–
		2003	KAH0304	912	20	–	–	–	–	–	–	–	–	–	–
		2005	KAH0503	2 050	12	–	–	–	–	–	–	–	–	–	–
		2007	KAH0704	1 089	21	–	–	–	–	–	–	–	–	–	–
		2009	KAH0904	1 088	22	–	–	–	–	–	–	–	–	–	–
		2011	KAH1104	1 188	15	–	–	–	–	–	–	–	–	–	–
		2013	KAH1305	1 272	22	–	–	–	–	–	–	–	–	–	–
		2015	KAH1503	1 058	17	–	–	–	–	–	–	–	–	–	–
		2017	KAH1703	1 857	18	–	–	–	–	–	–	–	–	–	–
		2019	KAH1902	1 094	19	–	–	–	–	–	–	–	–	–	–
		2021	KAH2103	969	25	–	–	–	–	–	–	–	–	–	–

*Assuming areal availability, vertical availability, and vulnerability equals 1.0. Biomass is only estimated outside 10 m depth. Note: because trawl survey biomass estimates are indices, comparisons between different seasons (e.g., summer and winter ECSI) are not strictly valid.
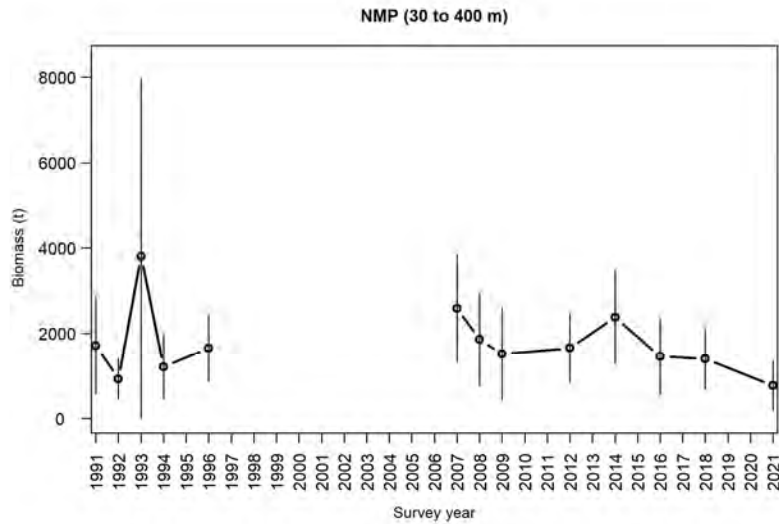
Figure 3: Tarakihi total biomass for the ECSI winter surveys in core strata (30–400 m). Error bars are ± two standard errors.
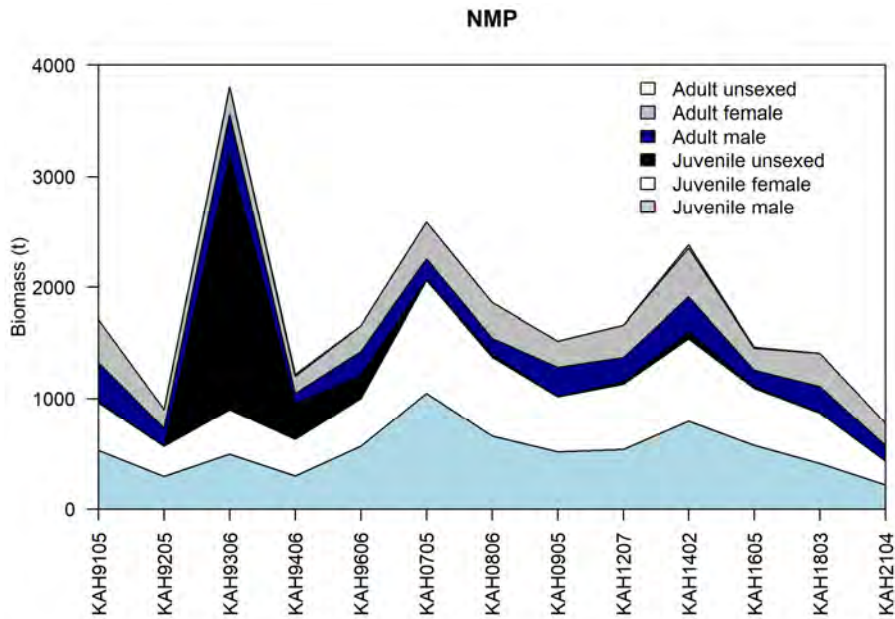
Figure 2a: Tarakihi juvenile and adult biomass for ECSI winter surveys in core strata (30–400 m), where juvenile is below, and adult is equal to or above, the length at which 50 % of fish are mature.

North Island trawl surveys

Summer surveys in the Bay of Plenty (from Mercury Islands to Cape Runaway) were carried out from 1983 to 1999. These surveys were extended to 250 m, in February 1996 (KAH9601) and 1999 (KAH9902), so that tarakihi depths would be covered. However, the estimates of biomass were low (35 t CV 46% in 1996 and 50 t CV 27% in 1999). Most of the catch in the 1999 survey was taken in depths of 150 to 200 m.

4.2   CPUE analyses

CPUE indices have routinely been derived for tarakihi from the main inshore fisheries in TAR 1, TAR 2, and TAR 3. The 2021 CPUE analysis was extended to include the main tarakihi trawl fisheries from TAR 5, western TAR 7, and TAR 8 (Table 8).

Table 8: Names and descriptions of the tarakihi CPUE series accepted by the Inshore Working Group in 2021. Also shown is the error distribution that had the best fit to the distribution of standardised residuals for the positive catch component of the model.

Name	Code	QMA	Method	Statistical Areas	Target species	Data format	Distribution
West coast North Island	WCNI-BT	TAR 1	BT	045, 046, 047	TAR	Event	Lognormal
East Northland	ENLD-BT	TAR 1	BT	002, 003	TAR	Event	Weibull
Bay of Plenty and east coast North Island	BPLE-TAR2-BT	TAR 1 TAR 2	BT	008, 009, 010, 011, 012, 013, 014, 015	TAR, SNA, BAR, SKI, WAR, GUR, TRE, JDO	Daily	Lognormal
Area 18 target set net	TAR3-SN	TAR 3	SN	018	TAR	Daily	Lognormal
Eastern Cook Strait	Cook-BT	TAR 7	BT	017, 018	TAR, STA, BAR, WAR, GSH	Daily	Lognormal
West coast South Island	WCSI-BT	TAR 7	BT	033, 034, 035, 036	TAR, RCO, BAR, WAR, GUR	Daily	Lognormal
Taranaki Bight	TAR8-BT	TAR 8	BT	039, 040, 041	TAR	Daily	Lognormal
Southland	TAR5-BT	TAR 5	BT	025, 030	STA, TAR	Daily	Lognormal

The individual CPUE data sets either maintained the individual trawl event records or aggregated daily catch and effort data (approximating the CELR data format). Event-based catch and effort data were available for the TAR 1 trawl fisheries from 1993–94. These event-based data were utilised for those fisheries where there had been appreciable changes in the spatial distribution of fishing effort which had influenced the catch rates of tarakihi. The daily aggregated catch and effort data were available from 1989–90 to 2019–20 for all fisheries.

For the trawl fisheries, CPUE was modelled as two components: 1) the magnitude of the positive tarakihi catch (assuming either a lognormal or Weibull error distribution) and 2) the presence/absence of tarakihi in the catch (binomial model). Combined annual CPUE indices were derived from the year effects determined from the two models. For the TAR 3 set net fishery and the WCNI-BT and TAR 8 trawl fisheries, the CPUE indices were derived from the lognormal CPUE model of positive tarakihi catch (due to the small proportion of zero catches in the data set).

The CPUE series for the eastern fisheries have been incorporated in the stock assessment of eastern tarakihi. The 2021 CPUE analyses amalgamated the Bay of Plenty and TAR 2 fisheries to derive a single CPUE series, following the amalgamation of these fisheries for the purpose of sampling the age composition of the tarakihi catch. CPUE indices were also developed for the mixed inshore trawl fishery in eastern Cook Strait (Cook-BT) (Statistical Areas 017, 018). The tarakihi fishery in this area catches larger (and older) tarakihi than the trawl fishery in the Pegasus Bay/Canterbury Bight area. A review of the TAR3-BT CPUE analysis highlighted conflicting trends between the CPUE indices and the tarakihi abundance indices from the ESCI inshore trawl survey, with diagnostic analyses indicating that the CPUE analysis was not adequately accounting for large changes in targeting behaviour (from red cod to tarakihi). The TAR3-BT CPUE series was therefore excluded from the 2021 eastern tarakihi stock assessment—the main index of abundance for this area coming from the ECSI trawl survey

The BPLE-TAR2-BT CPUE series reached a peak during 2000–01 to 2004–05 (Figure 4). There were corresponding peaks in the CPUE indices from the ENLD-BT, Cook-BT, and TAR3-SN fisheries at about the same time. More recently, the Cook-BT and TAR3-SN CPUE indices increased considerably from 2015–16 to 2019–20. There was no corresponding increase in the BPLE-TAR2-BT CPUE indices. The ENLD-BT CPUE indices declined considerably during 2008–09 to 2019–20, particularly following higher catches taken in 2013–14 to 2018–19.

The northern WCNI trawl fishery (WCNI-BT) CPUE indices declined considerably from the late 1990s following an increase in the overall level of catch from the fishery.

CPUE indices were developed for the TAR 7 mixed trawl fishery targeting TAR, BAR, WAR, RCO, and STA off the west coast of the South Island (Statistical Areas 033, 034, 035, 036). The indices were evaluated by comparing them with the biomass estimates derived from the *Kaharoa* west coast South Island trawl survey for an area and the length range of fish comparable with that of the commercial

catch. The trends in the two sets of indices deviated markedly during 1989–90 to 2003–04 and, on that basis, the entire time series of CPUE indices was rejected as an index of stock abundance.

The CPUE indices from the target tarakihi fishery in TAR 8 increased during the late 1990s and 2000s and stabilised at a higher level during 2011–12 to 2019–20. Recent age composition sampling from the TAR 8 fishery revealed that recent catches were composed of a broad range of age classes with evidence of relatively strong recruitment over the last few years (fish aged 4–6 years).

The CPUE indices from the Southland trawl fishery fluctuated during 1989–90 to 2009–10 with peaks in CPUE during 1993–94 to 1996–97 and in 2002–03 and 2004–05. The CPUE indices increased considerably from 2009–10 to 2015–16 and remained at the higher level for the four subsequent years. Recent age composition sampling from the TAR 5 fishery suggest recent catches were predominantly composed of relatively young fish (aged 4–5 years).
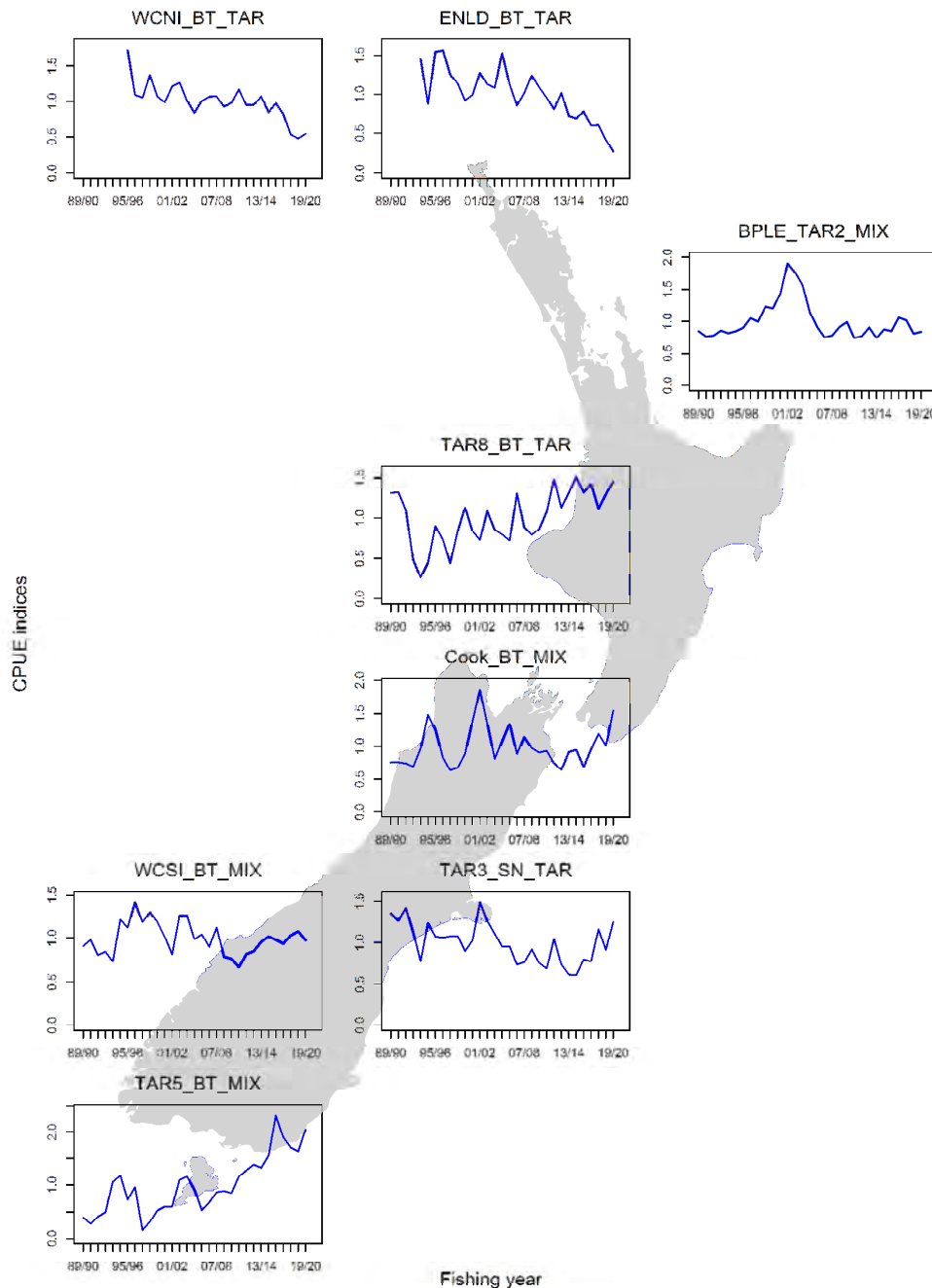

Figure 4: A comparison of the standardised CPUE series from TAR 1, TAR 2, TAR 3, TAR 5, TAR 7, and TAR 8.

4.3   Stock assessment models

East coast North and South Islands (TAR 1E, 2, 3, and TAR 7E)

In 2017, an assessment of the east coast mainland New Zealand tarakihi stock was conducted. The assessment was based on the hypothesis of a single east coast stock of tarakihi, as described in Section 3. The area included within the assessment encompasses the east coast of the South Island (TAR 3), eastern Cook Strait (including a portion of TAR 7), the central east coast of the North Island (TAR 2), Bay of Plenty (TAR 1), and east Northland (TAR 1). For 2021, the 2017 base case (single area) assessment model was updated, and a more complex three-region spatially structured model was developed as an alternative.

The 2021 assessment was conducted using an integrated age structured population model implemented in Stock Synthesis. The assessment models incorporated the available catch, CPUE indices, trawl survey biomass estimates and age/length frequency distributions, and recent commercial age composition data.

The current stock hypothesis assumes a relatively complex spatial structure for the east coast tarakihi population: juvenile tarakihi reside predominantly in the Canterbury Bight/Pegasus Bay area and, coinciding with the onset of sexual maturity, a proportion of the population migrates along the east coast, extending progressively northwards with increased age and terminating in the East Northland area. The 2021 assessment used a similar fishery configuration to the 2017 assessment, reflecting the spatial scale and information content of the various input data sets. The model options structured the input data into three main model regions: east coast South Island (including eastern Cook Strait), Bay of Plenty and central east coast North Island combined (TAR2-BPLE), and East Northland. The east coast South Island region included three commercial fisheries: the Canterbury Bight/Pegasus Bay trawl fishery (TAR3-BT), Kaikōura set net fishery (TAR3-SN), and the eastern Cook Strait trawl fishery (CS-BT). The other two regions each included a commercial trawl fishery and a relatively small non-commercial fishery.

The main input data sets included in the assessment model(s) are as follows:

- Fishery specific annual catches 1932–2020 (2020 = 2019–20 fishing year), including an allowance for unreported catch (an additional 20% of the reported catch prior to the introduction of the QMS in 1986 and an additional 10% of the unreported catch from 1986 onwards) (Figure 5).
- Recent CPUE indices: TAR3-SN, Cook-BT, combined TAR2-BPLE-BT, and ENLD-BT.
- *Kaharoa* inshore ECSI trawl survey biomass estimates and age/length compositions (both winter (n = 13) and summer (n = 5) time series).
- *Kaharoa* inshore ECSI winter trawl survey juvenile (2 year) abundance indices (n = 8).
- *Kaharoa* inshore ECNI trawl survey biomass estimates and length compositions (n = 3).
- Recent commercial age composition data: TAR3-BT (n = 6), TAR3-SN (n = 4), CS-BT (n = 3), TAR2-BT and BPLE-BT combined (n = 7), and ENLD-BT (n = 4).
- Age composition derived from the *James Cook* trawl survey of Pegasus Bay-Cape Campbell in 1987.

In addition, a number of age compositions from early trawl surveys were considered in the 2017 model development phase. These data were uninformative and were not included in the 2021 assessment.
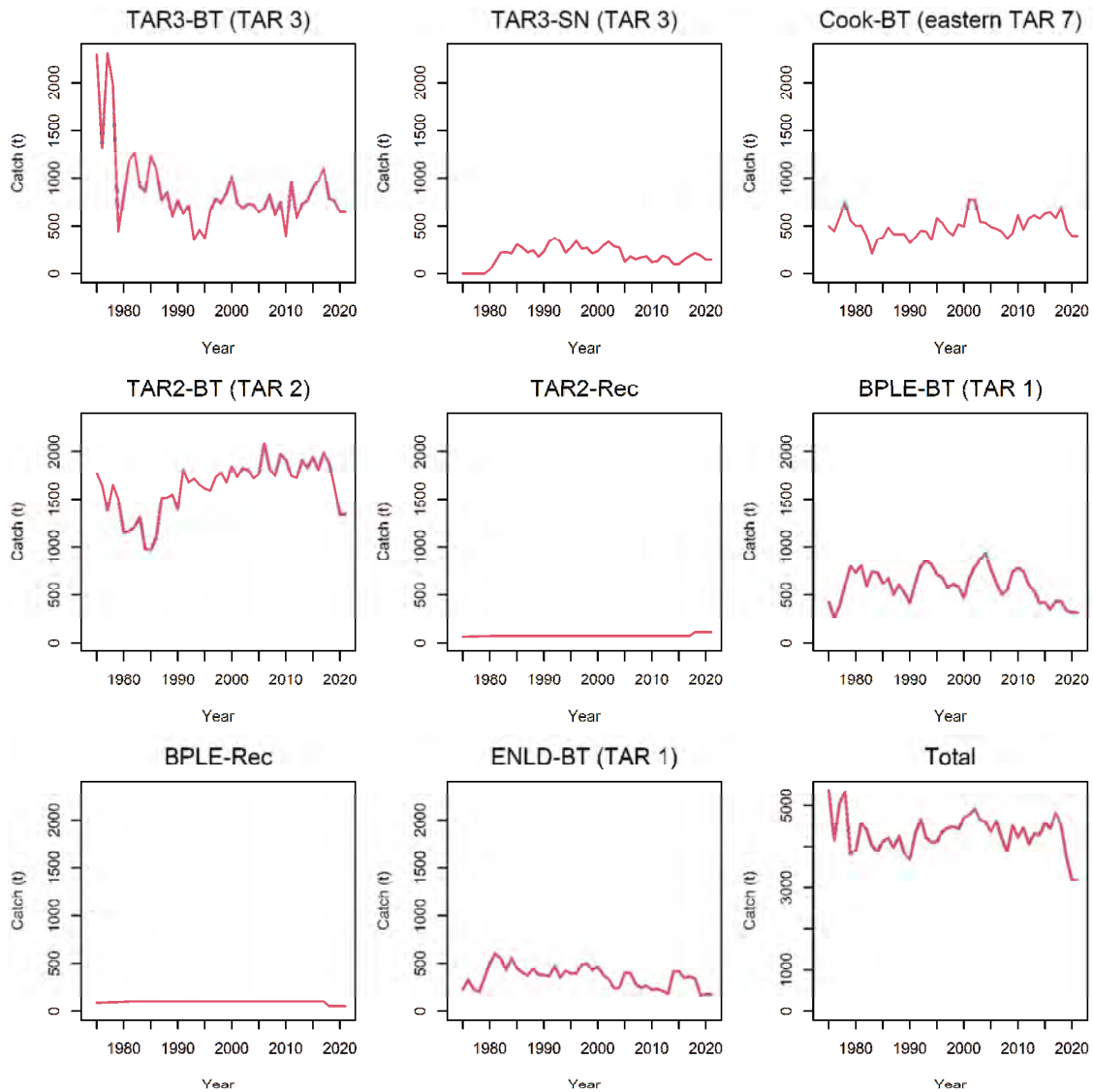
Figure 5: Annual catches of tarakihi by fishery included in the base eastern tarakihi stock assessment. The specific commercial fisheries are: TAR3-BT (TAR 3), TAR3-SN (TAR 3), Cook-BT (includes catch from TAR 2 and eastern TAR7), TAR2-BT (TAR 2), and BPLE-BT (TAR 1), ENLD-BT (TAR 1). Rec is recreational fishery.

The assessment models were structured to include 40 age classes combining both sexes. The key biological parameters are presented in Table 9.

Table 9: Biological parameters included in the east coast tarakihi assessment model for the base model.

Parameter	Value (fixed)
Natural mortality	0.10 y^{-1}
Growth parameters	Length Age 1 = 15.37, k = 0.2009, $Linf$ = 44.6
Proportion mature	Age based
	Ages 1–3, 0; Age 4, 0.25; Age 5, 0.5; Ages 6+, 1.0
SRR steepness	0.9
SigmaR	0.6

For the 2021 assessment two contrasting sets of models were configured: a single region, spatially aggregated model and a three-region, spatially structured model (Table 10). The single region model is comparable with the base case model from the 2017 stock assessment. The single region model was structured as a single population. The age composition of the catch from each fishery was mediated by the selectivity of the individual fisheries. For the ENLD-BT fishery, the oldest age classes were assumed to be fully vulnerable (logistic selectivity) based on the higher proportion of older fish observed in the

fishery age composition compared with the other fisheries. The selectivity of the other fisheries (and surveys) was parameterised using a double normal function, allowing for lower vulnerability of the older age classes. Thus, all sets of CPUE indices and surveys monitored the relative abundance of the single population mediated by the fishery-specific selectivity.

The three-region spatial model was configured to approximate the stock hypothesis; i.e., each region included a discrete population with recruitment in the southern (ECSI) region only and age-specific movement of fish northwards between adjacent regions. The movement rate of tarakihi from TAR 3 to TAR2-BPLE was allowed to vary annually (during 1990–2019) to enable the model to fit to different trends in the recent CPUE indices from the two regions. Within each region, the oldest age classes in the population were assumed to be fully vulnerable to the key fisheries (Cook-BT, TAR2-BPLE-BT, and ENLD-BT), whereas other fisheries and surveys were parameterised using a double normal function. Fishery catches were taken from the population in each respective region and the abundance indices (CPUE and/or trawl survey) were taken to represent trends in relative abundance in that region.

Annual recruitment was derived from a Beverton-Holt spawner-recruit relationship (SRR). The base model options assumed a high value for steepness ($h = 0.9$) on the basis that recruitment was considered to be most strongly influenced by the prevailing oceanographic conditions during the long pelagic phase of post larval tarakihi. Inter-annual variability in recruitment was estimated as deviates from the SRR for the period that was informed by the age composition data and recent abundance indices (i.e., 1980–2020). Recruitment deviates were assumed to have a relatively high degree of variability (*sigmaR* = 0.6).

The relative weightings applied to the main data sets were equivalent for the final range of model options, allowing a direct comparison of the model fits (likelihood components) among the individual models. For the recent CPUE indices, each series was assigned a coefficient of variation (CV) of 20%, whereas the individual trawl survey biomass estimates were weighted by the CV from the individual survey. Most of the recent commercial age composition data sets were assigned a moderate weighting (effective sample sizes of 30). Substantial changes in the relative weightings of individual data sets did not substantially change the model results, indicating broad consistency amongst the key input data sets.

For the 2017 assessment, preliminary modelling included the entire catch history from 1932. However, for the spatially structured models, the fits to the CPUE and age composition data from the East Northland model were poor and the model estimated an implausibly large biomass for the East Northland region. These issues could not be resolved within the modelling framework and appeared to be attributable to the large catches allocated to the East Northland fishery prior to 1965. For this period, the allocation of catches to each region was based on port of landing and all landings in Auckland were attributed to East Northland. This assumption is likely to be incorrect, although no other information is available to apportion the early catch amongst the East Northland and Bay of Plenty fisheries.

Table 10: The number of estimated parameters included in the two main model options.

Parameter	Model option	
	Single region	Three region
Ln R_0	1	1
RecDevs	41	41
Selectivity	33	27
Initial F	5	5
Movement	0	34
Total	80	108

The regional distribution of catch is considered to be more reliable from about 1965 onwards. For the 2017 assessment, the main model options included two models that were initialised in 1975. Initial (1975) conditions were determined by estimating (five) fishery specific levels of fishing mortality (Initial Fs) that were informed by an assumed equilibrium level of catch in the initialisation period. The fishery specific levels of equilibrium catch were set at the average fishery catch from the preceding 10 years (i.e., 1965–1974).

For the current (2021) assessment, the two main sets of model options (single region and three-region spatially structured model) were initialised in 1975, and model sensitivities incorporated uncertainty in the initial equilibrium catch levels or included the entire catch history (unexploited population initialised in 1932).

Overall, the single region and spatially structured models yielded very similar biomass trajectories and estimates of reference (SB_0) and current biomass (Figure 6). The model results were very similar regardless of whether the models were initialised in 1975 or 1932. Likelihood profiles of the R_0 parameter determining overall stock size revealed that the lower bound of the parameter estimate was informed by the overall magnitude of historical catch and the age composition data from the TAR3-BT and TAR3-SN fisheries and the upper bound of the parameter was informed by age composition data from the ENLD-BT fishery and CPUE indices from ENLD-BT and TAR2-BPLE-BT fisheries.
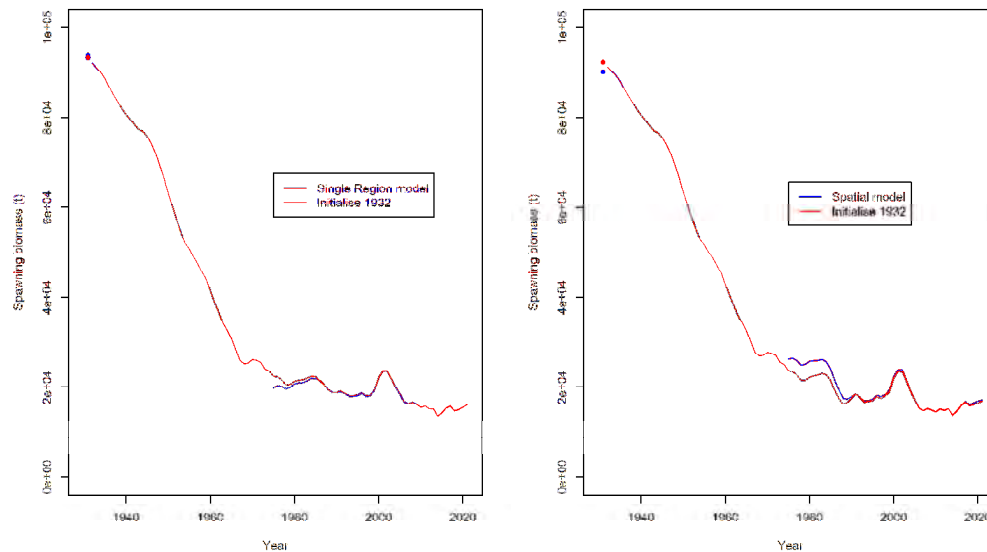
Figure 6: A comparison of the biomass trajectories (median of MCMCs) from the single region model (left) and spatially structured model (right) initialised at 1975 (blue line) or 1932 (red line). The corresponding estimates of the equilibrium, unexploited biomass SB_0 (points) are plotted (arbitrarily) at 1931.

Both sets of models provide a good fit to the age composition data from the fisheries and ECSI trawl survey. The models also provide a good fit to the ECSI trawl survey abundance indices (all biomass and 2 year age-based indices). The increased parameterisation of the three-region spatially structured model results in a considerable overall improvement in the fit to the range of CPUE indices compared with the single-region model, particularly for the last 3–4 years (Figure 7). The single-region model is unable to accommodate the contradictory trends between the increasing CPUE indices from the TAR3-SN and Cook-BT fisheries with the sharp decline in the CPUE indices from ENLD-BT, while CPUE from TAR2-BPLE-BT remained relatively stable (Figure 7). In contrast, the three-region spatially structured model has the capacity to account for variability in regional abundance due to regional-scale differences in exploitation rates; for example, the recent decline in the ENLD-BT CPUE indices followed a period of higher catch from that area. The three-region spatial model also has considerable flexibility to fit to the differential trends in the CPUE indices via inter-annual variation in movement of fish from TAR 3 to TAR2-BPLE regions.

There are limited observations available to strongly inform the movement parameters of the spatial model. The increased number of parameters may be accounting for inter-annual variation in the movement of mature tarakihi and/or variation in the distribution of recruitment between the regions or other spatial dynamics not accounted for explicitly within the assessment model. Additionally, the movement parameters may simply be accounting for sampling error in the individual sets of CPUE indices (i.e., nuisance parameters). On balance, the Plenary selected the three-region spatial model as the preferred model option ('base case') and the single-region model was retained as a credible alternative model option. The final set of model sensitivities were conducted for the three-region 'base case' model.
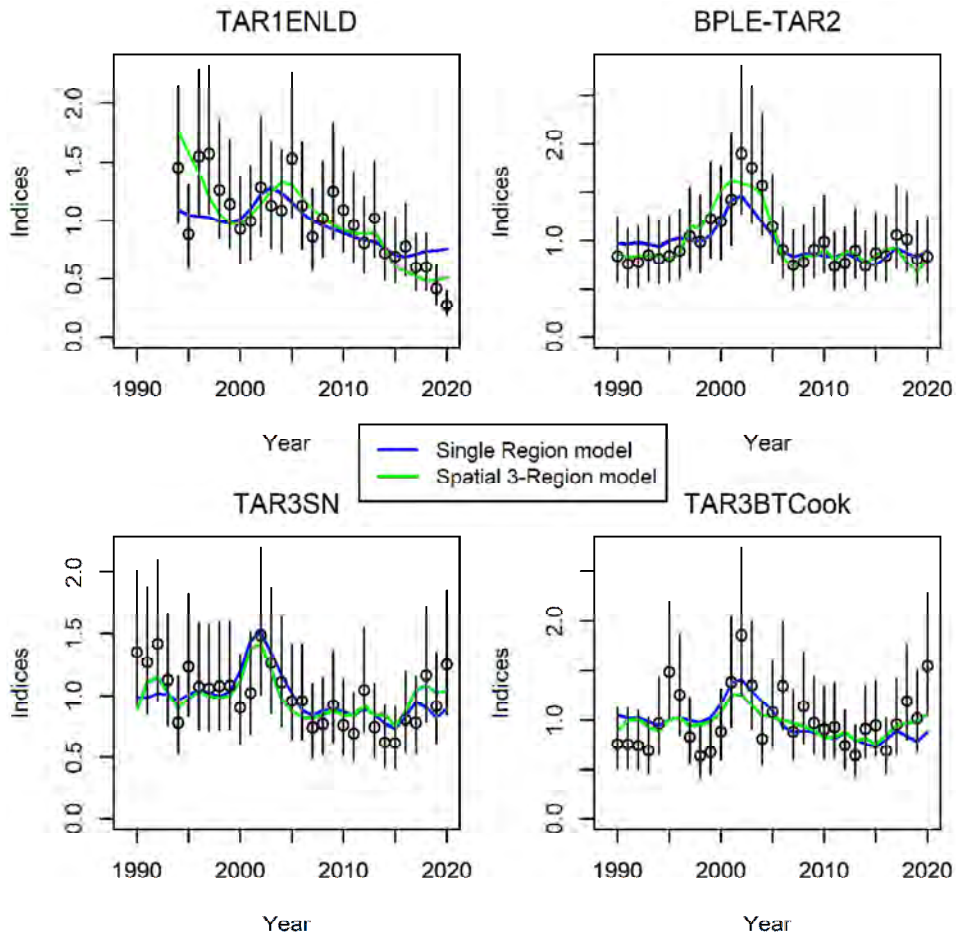
Figure 7: The fit to the individual sets of CPUE indices from the single-region model and three-region spatial model ('base case').

Overall, the model results indicate the stock has been in a depleted state since the mid-1970s. This followed a period of relatively high catches (5000–7000 t per annum) during the 1950s and early 1960s. The recent CPUE indices and the associated levels of catch are highly influential in determining the estimate of average recruitment (R_0) and, hence, equilibrium, unexploited biomass (SB_0). The overall levels of depletion are linked to the estimates of Initial F (in 1975) informed by the assumed level of initial equilibrium catches.

Estimates of stock status were determined for each model option using an MCMC approach (sampling from 1 million MCMC draws at an interval of 1000). Model sensitivities were conducted for the base model option (three-region spatially structured model) to investigate the influence of five key assumptions (Table 11). Current stock status was defined as the mid-year spawning biomass (male and female fish) in 2020–21 relative to equilibrium, unexploited biomass (SB_{2021}/SB_0). Current fishing mortality was estimated relative to a reference fishing mortality that corresponds to the default target biomass of 40% of SB_0 (i.e., $F_{2021}/F_{SB40\%}$).

Table 11: Description of model sensitivities.

Sensitivity	Description
InitialCatchVar	Uncertainty associated with Initial Equilibrium Catches SE of ln(Catch) = 1.0
LowM	$M = 0.08$
Maturity	Length based maturity OGIVE Logistic function parameters $Mat50 = 33.56$, $Matslp = -0.45$
Steepness 0.8	$h = 0.8$
Start1932	Entire catch history, unexploited equilibrium conditions in 1932.

Spawning biomass is estimated to have declined to about 20–30% SB_0 by the initial period of the assessment model in 1975 (Table 12). Spawning biomass tended to decline over the subsequent years, following an increase in total catches during the 1990s, moderated by variation in recruitment, especially a period of higher recruitment during the mid-late 1990s. Spawning biomass is estimated to have been below the default soft limit since the mid-2000s, and current spawning biomass (2021) is estimated to be at 19% (three-region spatially structured model) and 17% (single-region model) of the unexploited, equilibrium biomass level (SB_{2021}/SB_0 = 0.193 or 0.171) (Table 12). Spawning biomass increased slightly from the lowest level in 2014 (Figure 8a and Figure 8b), following above average recruitment in 2011–2012 (Figure 9a and Figure 9b) and recent reductions in TACC and catch. Recruitment was estimated to be below average in 2017 and 2018, while the most recent year classes (2019 and 2020) were estimated to be at about the average level.

The stock status is similar for the range of model options and sensitivities, although the stock status is more pessimistic for the model sensitivities with lower productivity parameters. For the base case parameterisation, the singe-area and three area models estimate a high probability (60% three-region spatial model or 86% single-region model) that the spawning biomass is below the soft limit, and a very low probability (< 1%) of being below the hard limit of 10% SB_0 (Table 12).

Table 12: Estimates of current (SB_{2021} 2020–21) and equilibrium, unexploited spawning biomass (SB_0) (median and the 95% confidence interval from the MCMCs) and probabilities of current biomass being above specified levels for the three-region base case model and associated sensitivities and the single-region model.

Model option	SB_0 (t)	SB_{2021} (t)	SB_{2021}/SB_0	Pr ($SB_{2021} > X\%SB0$)		
				40%	20%	10%
Base	**88 256**	**17 009**	**0.193**	**0.000**	**0.421**	**0.999**
Three-region, spatial	(84 776–92 076)	(11 246–22 596)	(0.128–0.252)			
InitialCatchVar	85 123	15 675	0.184	0.000	0.305	0.997
	(80 298–89 833)	(9914–20 907)	(0.119–0.243)			
LowM	103 724	16 322	0.157	0.000	0.048	0.954
	(99 242–108 383)	(9167–21 624)	(0.089–0.21)			
Maturity	71 847	10 187	0.142	0.000	0.018	0.924
	(69 006–75 119)	(6232–14 249)	(0.087–0.196)			
Start1932	91 580	16 699	0.183	0.000	0.281	0.995
	(89 227–94 136)	(10 700–21 520)	(0.117–0.236)			
Steepness 0.8	95 243	17 633	0.185	0.000	0.337	0.982
	(91 082–99 834)	(10 032–24 095)	(0.108–0.253)			
Single Region	**93 785**	**16 123**	**0.171**	**0.000**	**0.144**	**0.991**
	(88 756–98 577)	(10 391–21 223)	(0.114–0.223)			
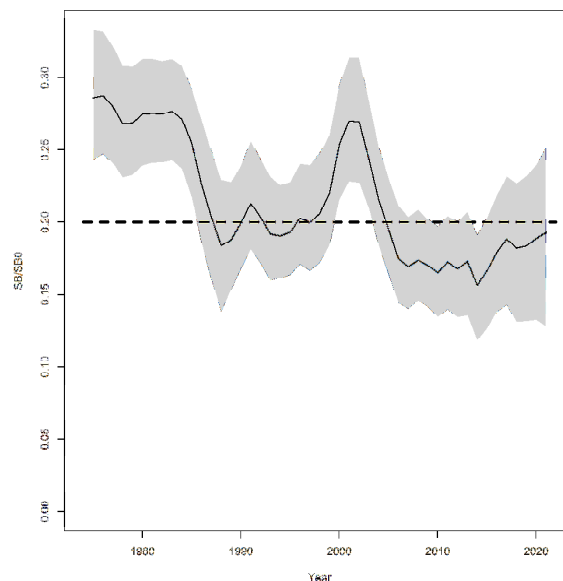
Figure 8a: Annual trend in spawning biomass relative to the SB_0 biomass level for the three-region spatial model (base model), including the 20% SB_0 soft limit. The line represents the median and the shaded area represents the 95% confidence interval.

Figure 8b: Annual trend in spawning biomass relative to the *SB₀* biomass level for the single-region model, including the 20% *SB₀* soft limit. The line represents the median and the shaded area represents the 95% confidence interval.

Figure 9a: Annual recruitments from the three-region spatial model (base model). The line represents the median and the shaded area represents the 95% confidence interval.
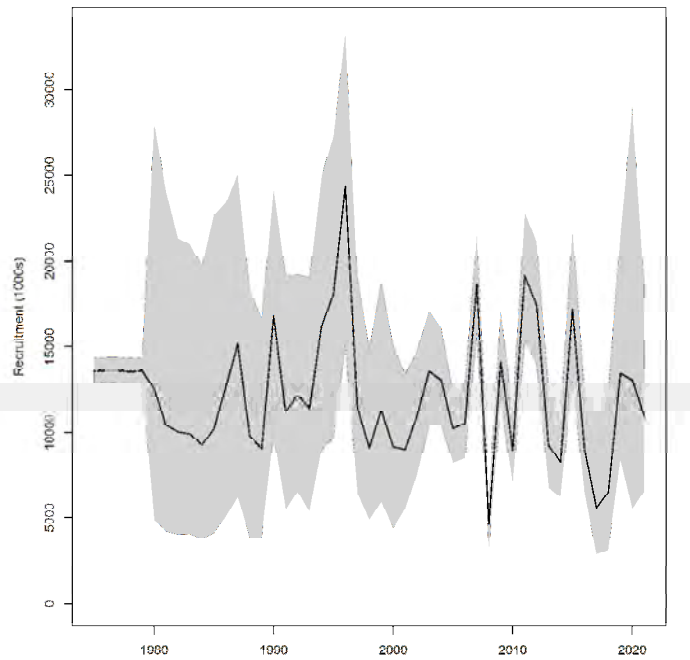
Figure 9b: Annual recruitments from the single region model. The line represents the median and the shaded area represents the 95% confidence interval.

Annual fishing mortality rates are estimated to have exceeded the level of fishing mortality that corresponds to default target biomass level (i.e., $F_{SB40\%}$) throughout the model period (from 1975) (Figure 10a and Figure 10b). From 2000, fishing mortality rates are estimated to have increased steadily to a maximum level in 2017. Fishing mortality rates declined considerably in 2019 and 2020, following the reductions in TACC, although current fishing mortality rates are estimated to remain well above the reference level (i.e., $F_{2021}/F_{SB40\%} = 1.62$ three-region model; 1.89 single-region model) (Table 13). The estimates of current fishing mortality rates are similar for the range of model options and sensitivities. Equilibrium yields at the target biomass level are estimated to be about 4100–4300 t compared with current total 2019–20 model catches of 3191 t (including 10% unreported catch).

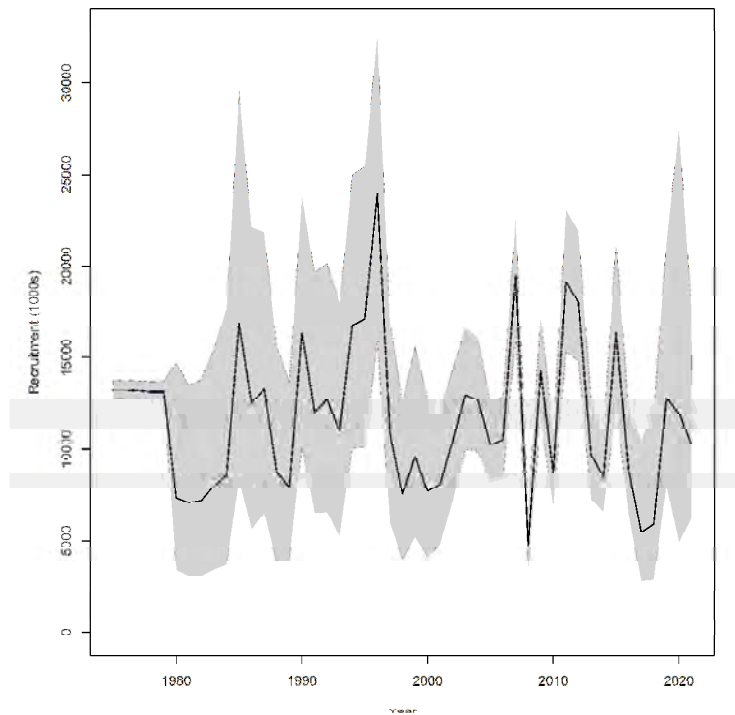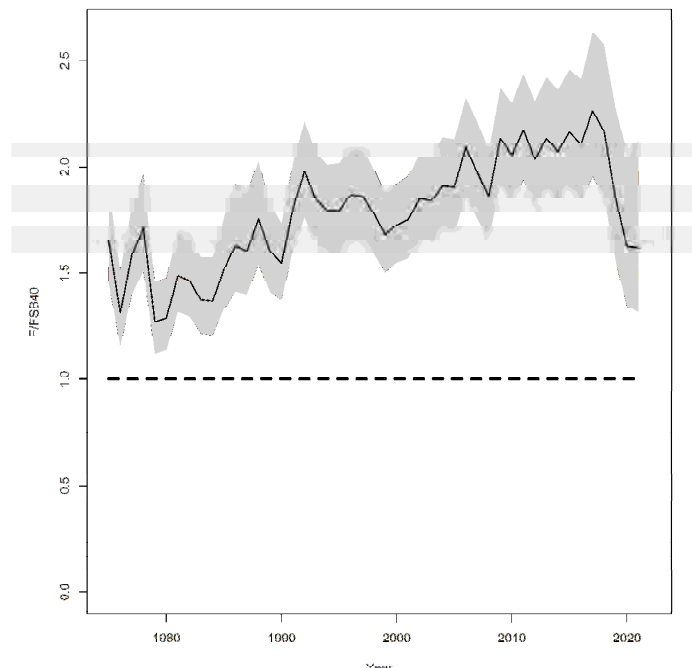**Figure 10a: Annual trend in fishing mortality relative to the $F_{SB40\%}$ interim target biomass level for the three-region spatial model (base model). The line represents the median and the shaded area represents the 95% credible interval.**

1780
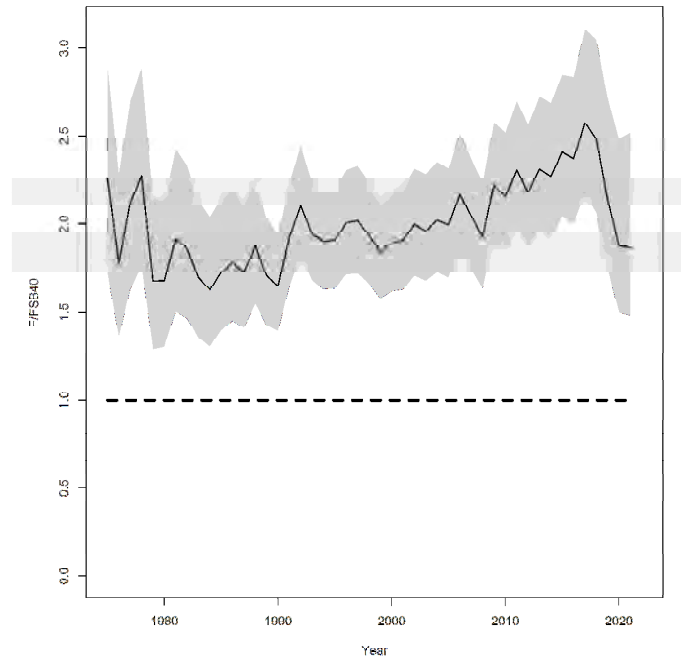
Figure 10b: Annual trend in fishing mortality relative to the $F_{SB40\%}$ interim target biomass level for the single-region model. The line represents the median and the shaded area represents the 95% credible interval.

Table 13: Estimates of current (F_{2021} 2020–21) and reference levels of fishing mortality ($F_{SB40\%}$) (median and the 95% confidence interval from the MCMCs) and the probability of fishing mortality being below the level of fishing mortality associated with the interim target biomass level for the three-region base case model and associated sensitivities and the single-region model with base case parameters. The associated levels of $F_{SB40\%}$ equilibrium yield (t) are also presented.

Model option	$F_{SB40\%}$	$F_{2021}/F_{SB40\%}$	$Pr(F_{2021}<F_{SB40\%})$	$F_{SB40\%}$ Yield
Base	**0.093**	**1.619**	**0.000**	**4 213**
Three-region, spatial		**(1.312–2.122)**		**(4 007–4 482)**
InitialCatchVar	0.093	1.744	0.000	4 094
		(1.384–2.306)		(3 845–4 355)
LowM	0.079	2.007	0.000	4 268
		(1.619–2.74)		(4 017–4 647)
Maturity	0.078	1.996	0.000	4 065
		(1.568–2.698)		(3 848–4 347)
Start1932	0.093	1.625	0.000	4 378
		(1.326–2.159)		(4 211–4 679)
Steepness 0.8	0.086	1.724	0.000	4 223
		(1.325–2.444)		(4 003–4 514)
Single-Region	**0.82**	**1.885**	**0.000**	**4 059**
		(1.507–2.571)		**(3 850–4 274)**

Projections

For each model option, stock projections (Table 14) were conducted for the 5-year period following the terminal year of the model (i.e., 2021–22 to 2025–26). During the projection period, recruitment was derived from the SRR with deviates sampled from the normal distribution (standard deviation *sigmaR* =0.6). Recent (10 year and 20 year) model estimates of recruitment were equivalent to the SRR recruitment average level (i.e., average recruitment deviates ~ 0).

Stock projections were based on the status quo (2019–20) commercial and recreational catches, including the 10% allowance for unreported catch. The 2019–20 annual catch for TAR 3 was ~10% less than the TACC.

Table 14: Estimated stock status (and 95% confidence intervals) and the probabilities of the spawning biomass being above default biomass limits and interim target level in 2026 (5 years) from catch based projections for the three-region base case and associated sensitivities and for the single-region model with base case parameters.

Model option	SB_{2026}/SB_0	Pr ($SB_{2026} > X\%SB_0$)		
		10%	20%	40%
Base Three-region	**0.206** (0.108–0.313)	**0.987**	**0.542**	**0.001**
InitialCatchVar	0.171 (0.086–0.29)	0.935	0.302	0.000
LowM	0.145 (0.069–0.23)	0.848	0.092	0.000
Maturity	0.146 (0.073–0.228)	0.865	0.099	0.001
Start1932	0.211 (0.122–0.329)	0.995	0.591	0.003
Steepness 0.8	0.160 (0.069–0.273)	0.879	0.221	0.001
Single-Region	**0.192** (0.105–0.312)	**0.981**	**0.441**	**0.001**

Qualifying Comments

The stock assessment is strongly dependent on the CPUE series as the primary indices of stock abundance. Fishery independent surveys are conducted within the ECSI area only and principally monitor the abundance of juvenile tarakihi. A comparison between the trends in abundance from the ECSI trawl survey and the corresponding fishery (TAR3-BT) revealed that the CPUE standardisation procedures were not adequate to account for large-scale changes in the operation of the fishery (in the absence of trawl resolution data). The reliability of other CPUE indices may be reduced by recent changes in the operation of the fisheries in response to the recent reductions in TACCs.

The relationship between TAR 5 (Southland) and the eastern tarakihi stock is unclear. The limited age composition data available from the TAR 5 fishery are consistent with the corresponding data from TAR3-BT fishery. However, the increasing trend in CPUE from TAR5-BT is not consistent with recent trends in TAR3-BT CPUE indices and ECSI trawl survey biomass indices. Consequently, the 2021 assessment does not include the TAR 5 Fishstock.

Future research considerations

- Continue and possibly intensify catch sampling monitoring of the stock in all areas as it rebuilds. Increased emphasis should be on the collection of data from the East Northland fishery to ensure monitoring of the full age structure of the population. Additional sampling of the age composition of the eastern Cook Strait fishery (Cook-BT) would also be beneficial because limited data are currently available from this area.

- Investigate the distribution of juvenile tarakihi along the eastern coasts of the North Island and South Island, including Southland (TAR 5), to evaluate the reliability of the estimates of year class strength from the *Kaharoa* ECSI trawl surveys.

- Improve understanding of the spatial structure of the length/age composition of the tarakihi population from analysis of available catch sampling data.

- Reinstate the *Kaharoa* ECNI trawl survey (FMA 2) to derive further fisheries-independent indices of abundance for tarakihi. The abundance indices and age compositions derived from the reinstated trawl survey should be compared with the previous trawl surveys conducted in the early 1990s (archived otoliths are available from those surveys).

- Consider conducting more tagging studies to obtain better information about fish movements.

- Take changes in fishing technology and operation into account when designing catch sampling schemes and analysing CPUE data. Alternatively, consider adding a parameter (estimated or fixed) that defines a (linear) increase in catchability through time. Improve understanding of fishing behaviour related to targeting or avoiding tarakihi.

- Improve monitoring of the abundance of tarakihi within the ENLD fishery area to verify the recent decline in the CPUE indices from this fishery.

- Increase biological sampling during the spawning season and examine gonads to obtain better staging information to inform the maturity ogive.

- Investigate mechanisms for estimating the incidental mortality of tarakihi in FMAs 3 and 7, which have a relatively large number of small tarakihi.

- Investigate the potential of currents and gyres (especially the one off ECNI) to act as dispersal or retention mechanisms for larval and juvenile tarakihi, especially in terms of the observation that FMA 3 receives most of the recruitment.

- Develop a stock assessment for western tarakihi, incorporating the data available from the west coast of the South Island (catch, trawl surveys, CPUE indices, and age compositions), Tasman Bay/Golden Bay (trawl surveys), and the west coast of the North Island (catch, CPUE indices and age compositions).

- Conduct regular (annual or biennial) updates of the base case assessment model to monitor the performance of the stock rebuild strategy. The model updates would incorporate additional catches, CPUE indices, trawl survey biomass indices, and length/age compositions.

- Investigate the magnitude of unreported tarakihi catches from the main fisheries before and after the introduction of the QMS.

TAR 7

An integrated statistical catch-at-age stock assessment for TAR 7 was carried out in 2008 for data up to the end of the 2006–07 fishing year (Manning 2008). The model partitioned by age (0–45 years) and sex was fitted to the trawl survey relative abundance indices (1992–2007), survey proportions-at-age data (1995–2007), and WCSI fishery catch-at-age data (2005–2007). The stock boundary assumed in the model included the west coast of the South Island, Tasman Bay, and Golden Bay, but not eastern Cook Strait (a catch history was compiled for the model stock that excluded eastern Cook Strait). A summary of the model's annual cycle is given in Table 15. The base case model (R4.1) was fit to trawl survey biomass indices (lognormal likelihood) and proportion-at-age data (multinomial likelihood), U_{max} was set at 0.8, steepness was assumed to be 0.75, and M was fixed at 0.1. The base case model assumed an equilibrium biomass at the beginning of the population reconstruction in 1940. One sensitivity R4.5 was the same as R4.1 but was also fitted to the CPUE data (lognormal likelihood). The other sensitivity (R4.6) also included the CPUE data; however, the model was started in 1985 from a non-equilibrium start. Model run 4.5 was very similar to the base case (4.1) in terms of biomass trajectory and stock status, but sensitivity 4.6 was more pessimistic in terms of stock status (Table 16). None of the three estimated a mean or median stock status that is below B_{MSY} and the stock is expected to rebuild, on average, for all three runs under current levels of removals and with average recruitment (Figure 11).

Table 15: The TAR 7 model's annual cycle (Manning 2008). Processes within each time step are listed in the time step in which they occur in particular order (e.g., in time step 3, new recruits enter the model partition first followed by the application of natural and fishing mortality to the partition). *M*, the proportion of natural mortality assumed during each time step. *F*, the nominal amount of fishing mortality assumed during each time step as a proportion of the total catch in the stock area. Age, the proportion of fish growth that occurs during each time step in each model year.

Time step	Duration	Process applied	Proportions M	F	Age	Observations
1	Oct–Apr	Mortality (*M*, *F*)	0.58	0.74	0.90	Survey relative biomass (KAH)
						Survey proportions-at-age (KAH)
						Survey proportions-at-age (JCO)
						Survey proportions-at-length (KAH)
						Fishery catch-at-age
						Fishery relative abundance (CPUE)
2	May (instantaneous)	Spawning Age incrementation	0.00	0.00	0.00	NIL
3	May–Sept	Recruitment Mortality (*M*, *F*)	0.42	0.26	0.10	Fishery catch-at-age

Table 16: MCMC initial and current biomass estimates for the TAR 7 model runs R4.1, 4.5, and 4.6. B_0, virgin or unfished biomass; B_{2007}, mid-year biomass in 2007 (current biomass); (B_{2007} / B_0) %, B_0 as a percentage of B_{2007}; Min, minimum; Max, maximum; Qi, ith quantile. The interval $(Q_{0.025}, Q_{0.975})$ is a Bayesian credible interval (a Bayesian analogue of frequentist confidence intervals).

			R4.1			R4.5
	B_0	B_{2007}	(B_{2007} / B_0) %	B_0	B_{2007}	(B_{2007} / B_0) %
Min	13 010	4 340	33.4	12 810	4 180	32.6
$Q_{0.025}$	14 290	6 060	42.3	13 780	5 350	39.1
Median	16 440	9 010	54.7	15 640	7 880	50.4
Mean	16 570	9 180	54.9	15 730	8 020	50.6
$Q_{0.975}$	19 630	13 410	68.3	18 310	11 500	63.0
Max	22 030	16 510	75.0	21 430	15 420	72.0

			R4.6
Min	14 660	4 150	28.3
$Q_{0.025}$	18 350	6 490	34.7
Median	24 540	10 190	41.6
Mean	25 680	10 940	41.9
$Q_{0.975}$	40 600	19 890	50.5
Max	63 300	34 700	58.3
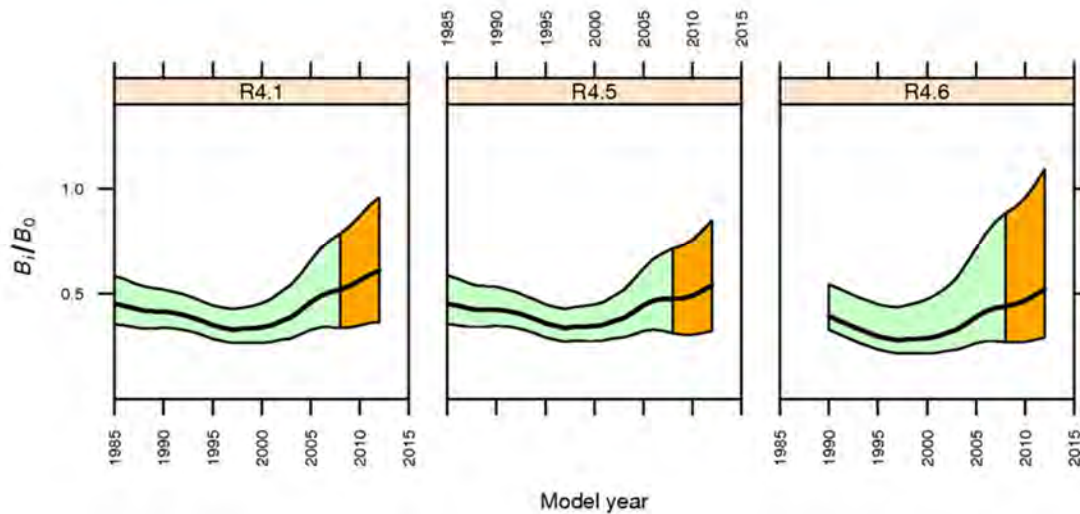
Figure 11: Relative *SSB* trajectories (green) and projected status assuming a future constant catch equal to the current catch (orange) calculated from the MCMC runs for model runs 4.1, 4.5, and 4.6 in the quantitative stock assessment of TAR 7. The shaded region indicates the 95% credibility region about median SSB (dotted lines) calculated from each model's *SSB* posterior distribution.

B_{MSY} proxy

Tarakihi is classified as a Low Productivity stock which, according to the Operational Guidelines for the Harvest Strategy Standard for New Zealand Fisheries, corresponds to a B_{MSY} proxy of 40% B_0. This decision was made taking all factors into account, but with greatest emphasis on the HSS Operational Guidelines, and considering the three Low Productivity parameters for TAR were attributed greater weight than the two Medium Productivity parameters for determining productivity.

TAR 4, 5, 8

Estimates of current absolute biomass for TAR 4, 5, 8 are not available.

5. STATUS OF THE STOCKS

- **TAR 1E, TAR 2, TAR 3, TAR 7E (Eastern Cook Strait)**

Tarakihi off the east coast of the North Island and South Island are considered to represent a single stock. The spatial domain of the stock assessment encompasses the area from North Cape to Slope Point (southern boundary of TAR 3), including the eastern approaches to Cook Strait (within TAR 7 and TAR 2).

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Base case three-region model
Reference Points	Target: Interim target of 40% SB_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Interim overfishing threshold: $F_{SB40\%}$
Status in relation to Target	$SB_{2020–21}$ was estimated to be 19% SB_0; Exceptionally Unlikely (< 1%) to be at or above the target
Status in relation to Limits	Soft Limit: Likely (> 60%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing threshold: Virtually Certain (> 99%) that overfishing is occurring
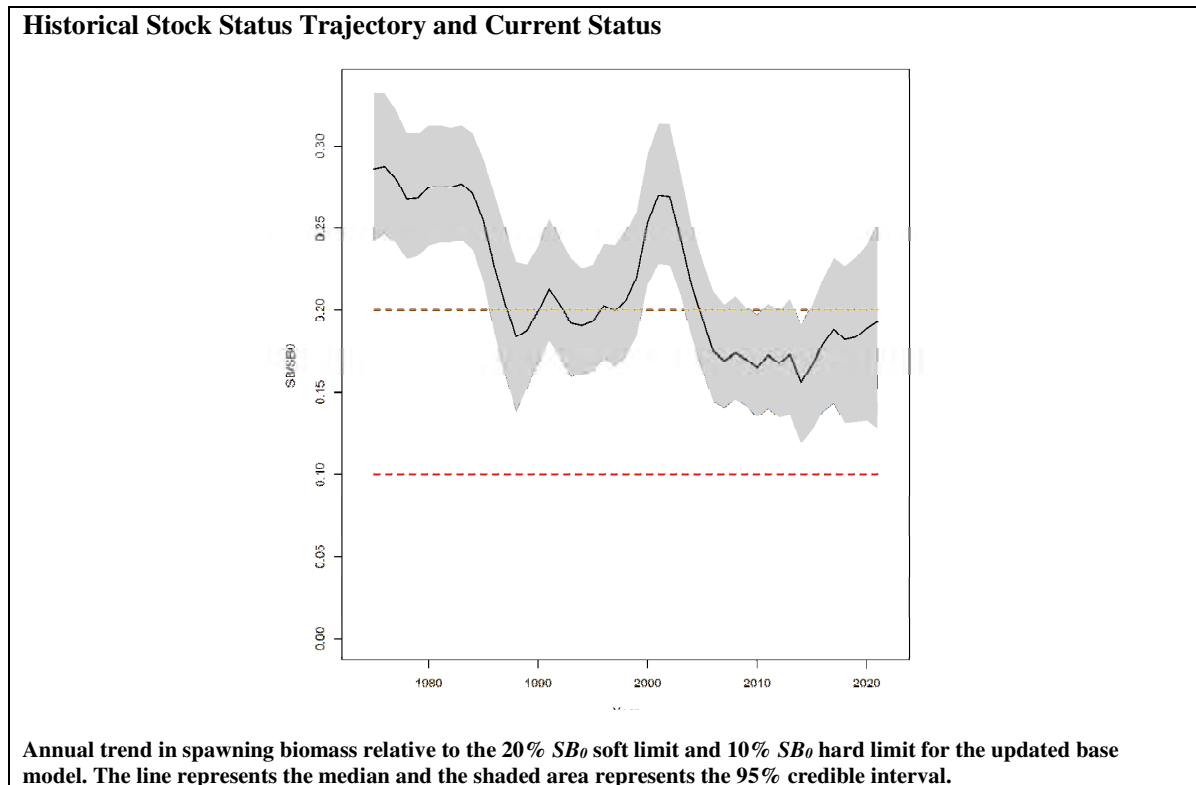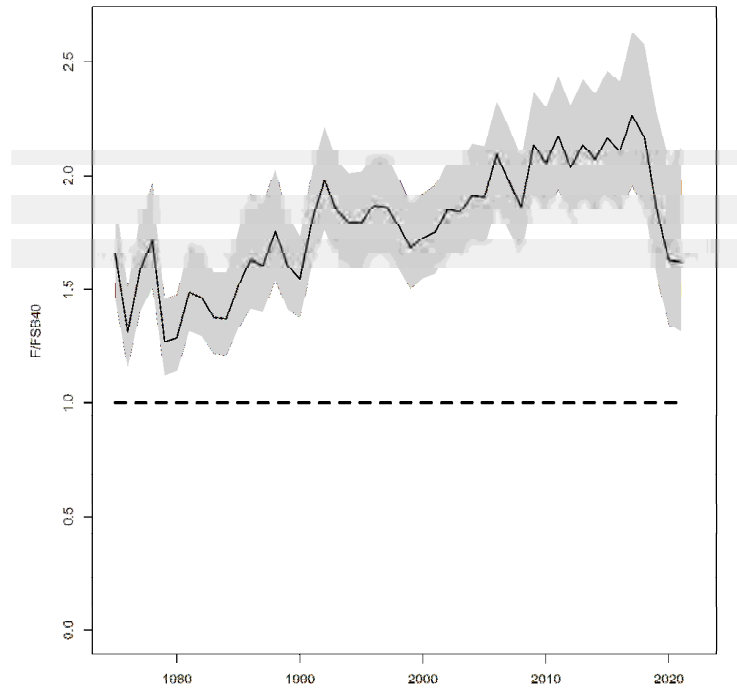
Historical Stock Status Trajectory and Current Status

Annual trend in spawning biomass relative to the 20% SB_0 soft limit and 10% SB_0 hard limit for the updated base model. The line represents the median and the shaded area represents the 95% credible interval.

Annual trend in fishing mortality relative to the $F_{SB40\%}$ interim target biomass level for the updated base model. The line represents the median and the shaded area represents the 95% credible interval.
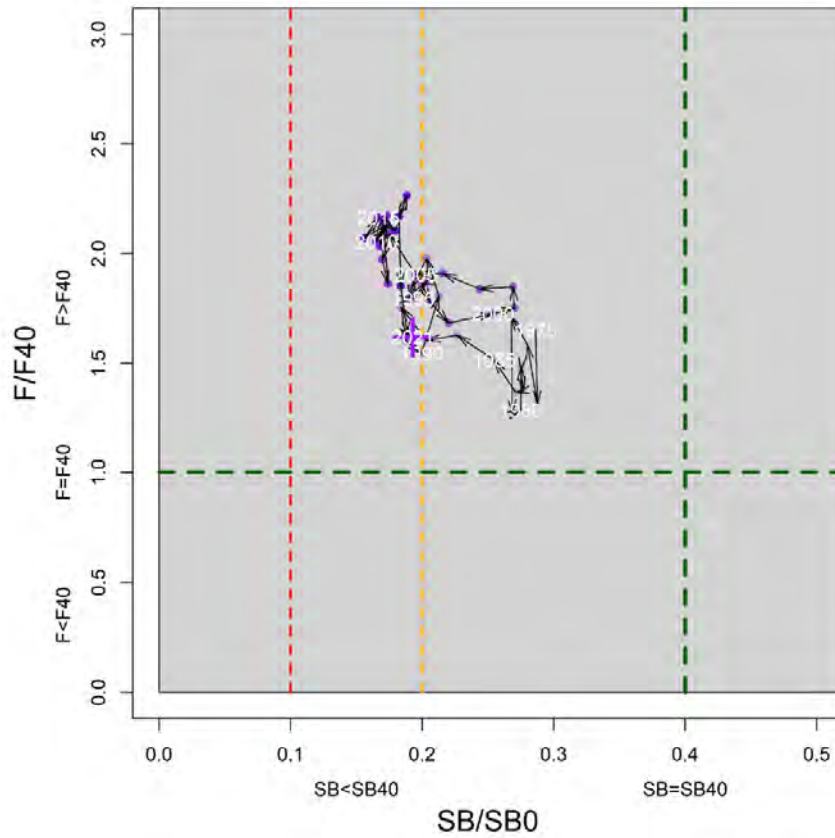
Annual spawning biomass and fishing mortality compared to the $SB_{40\%}$ interim target biomass level and corresponding fishing mortality reference for the updated base model (median values from MCMCs).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	There has been a general decline in spawning biomass since the late 1980s, moderated by fluctuations in recruitment. Spawning biomass is estimated to have been below the soft limit (20% SB_0) since the early 2000s.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality rates increased during 2000–2017 and then declined in 2018–19 and 2019–20 following TACC reductions. For the base model, current fishing mortality rate is estimated to be 1.62 times the level of fishing mortality that corresponds to the interim target biomass level ($F_{SB40\%}$).
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Stock projections were conducted for a 5-year period assuming the current (2019–20) level of catch across fisheries. Spawning biomass was projected to increase slightly over the next 5 years at the current level of catch.
Probability of Current Catch or TACC causing decline biomass to remain below or to decline below Limits	Current Catch Soft Limit: About as Likely as Not (40–60%) to remain below Hard Limit: Very Unlikely (< 10%) to decline below TACC Not included because the assessed stock boundaries do not match QMA boundaries.
Probability of Current Catch or TACC causing overfishing to continue or to increase	Fishing mortality is projected to decline at current (2019–20) catch levels but is Likely (> 60%) to remain above the reference level over the next 5 years.

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured Stock Synthesis model with MCMC estimation	
Assessment Dates	Latest assessment: 2022	Next assessment: 2026
Overall assessment of quality rank	1 – High Quality	
Main data inputs (rank)	- Commercial catch history	1 – High Quality
	- CPUE indices	1 – High Quality
	- Recent commercial age frequency	1 – High Quality
	- *Kaharoa* trawl survey abundance estimates and age/length frequencies	1 – High Quality
	- *Kaharoa* trawl survey 2 year abundance estimates	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Development of three-region spatially structured model - Refinement to CPUE indices incorporated in the assessment model, including combining BPLE and TAR2 CPUE indices - Inclusion of trawl CPUE indices from eastern Cook Strait - Inclusion of *Kaharoa* trawl survey 2 year abundance estimates - Exclusion of TAR3-BT CPUE indices	
Major Sources of Uncertainty	- Uncertainty in the stock structure and movement dynamics - Limited catch and effort data from the ENLD fishery may reduce the reliability of the indices for the last 2–3 years - Uncertainty in the maturity ogive	

Qualifying Comments
The three-region spatial model was formulated to account for differences in the trends in recent CPUE indices. The estimates of stock status from the base case model (three-region) were comparable with estimates of stock status from a less complex single-region model. Projections are based on the distribution of catch across fisheries remaining constant. If the ratio of catch across fisheries changes, the projections will change. There is a poor match between the assessed stock area and the TAR QMAs.

Fishery Interactions
TAR 1E. The main fishing method is trawling. Target tarakihi trawls catch snapper, John dory, gemfish, and trevally in East Northland; and snapper, trevally, and gemfish in the Bay of Plenty. TAR 2. This is mostly (80%) a TAR target fishery. The main fishing method is trawling. The following species are the main fish bycatch in this fishery: red gurnard, gemfish, and blue warehou. TAR 3. The main fishing method is trawling. The following species are the main fish bycatch in this fishery: red cod, barracouta, and flatfish. The tarakihi target set net fishery bycatch includes very small amounts of ling and spiny dogfish. TAR 7E. The main fishing method is trawling. The following species are the main fish bycatch in this fishery: red cod, barracouta, and ghost shark.

- **TAR 1W western stock**

The eastern area of TAR 1 is included within the east coast stock assessment. The western area of TAR 1 accounted for approximately 40% of the annual TAR 1 catch in 2006–07 to 2017–18 and increased to 60% in 2019–20 (following reductions in TACC applied to the eastern area of TAR1).

Stock Status	
Year of Most Recent Assessment	2021
Assessment Runs Presented	Standardised lognormal CPUE indices derived from trawls targeting tarakihi in the northern area of TAR 1W (Statistical Areas 045–047), 1993–94 to 2019–20
Reference Points	Target: B_{MSY} (value to be determined) Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY} (value to be determined)
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
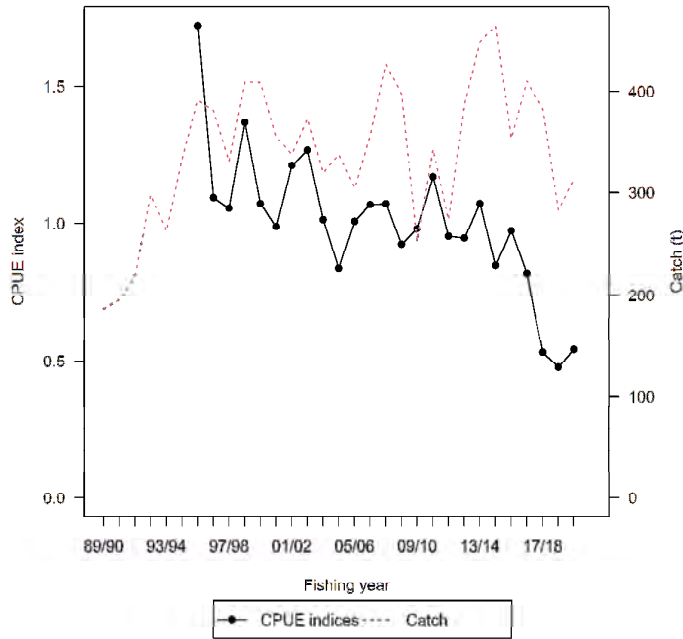
Standardised lognormal CPUE indices for the northern area of TAR 1W and the annual tarakihi catch from the corresponding area.
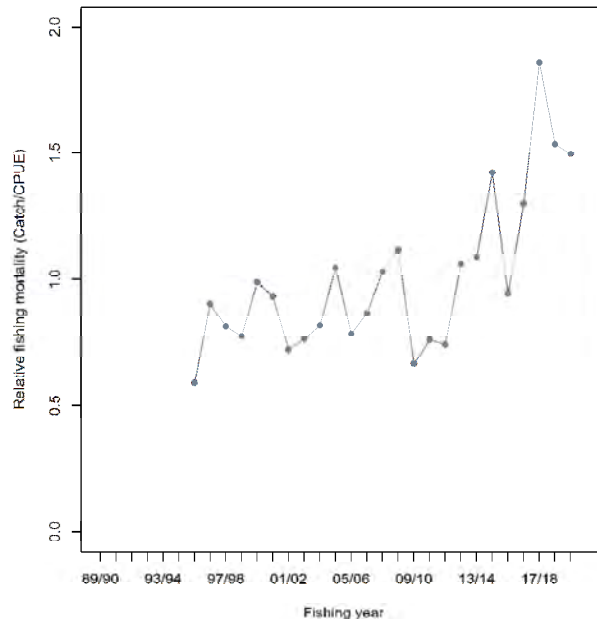
Fishing intensity (catch/CPUE) for the northern TAR 1W fishery.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE indices declined by about 25% from the period 1996–97 to 1999–2000 compared with 2014–15 to 2016–17 (by 25%) and were substantially lower in 2017–18 to 2019–20 (45% of the 1996–97 to 1999–2000 level).
Recent Trend in Fishing Intensity or Proxy	Relative fishing intensity increased (by 85%) from the period 2000–01 to 2013–14 compared with 2017–18 to 2019–20.
Other Abundance Indices	- WCNI trawl survey catch rates were consistent with the CPUE series for the equivalent area.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing decline biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing overfishing to continue or to increase	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	CPUE analysis of trawl catch and effort data	
Assessment Dates	Latest assessment: 2021	Next assessment: 2024
Overall assessment of quality rank	1 – High Quality	
Main data inputs (rank)	- Bottom trawl catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- CPUE analysis limited to target tarakihi trawls (excluding SNA and TRE)	
Major Sources of Uncertainty	- Only part of the west coast TAR stock is monitored by this series - Relative abundance prior to 1994–95	

Qualifying Comments
The CPUE indices were derived for the northern area of the fishery only (Statistical Areas 045–047). This area accounted for most of the TAR 1W catch. Since the mid-1990s, a target trawl fishery has developed in the North Taranaki Bight in the southern area of TAR 1W. CPUE trends from this area differed markedly from the northern area of the fishery. Thus, the CPUE indices represent the trends in abundance for the northern area of the fishery and do not represent the overall trends in tarakihi abundance in TAR 1W. The catch of TAR from Statistical Areas 045–047 consisted largely of adult fish with the highest proportion of fish >15 years of all west coast fisheries. Declining abundance therefore suggests a decline in spawner biomass on the west coast. Reference points based on CPUE were not determined because, based on the east coast TAR stock assessment, biomass may have declined substantially before the start of the series, and a west coast TAR full quantitative stock assessment is scheduled for 2024.

Fishery Interactions
The main fishing method is trawling. Target tarakihi trawls catch snapper and trevally as bycatch.

- **TAR 4**

For TAR 4, the fishery around the Chatham Islands appears to have been lightly fished for several years.

- **TAR 5**

Insufficient information is available to determine the status of TAR 5.

- **TAR 7**

Stock Structure Assumptions
For the purpose of this assessment the west coast South Island and Tasman Bay areas of TAR 7 are assumed to be a discrete stock. The eastern Cook Strait area of TAR 7 is considered to be part of the eastern stock of tarakihi.

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	Time series of WCSI trawl survey biomass, most recent survey 2019
Reference Points	Target: Not established but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	In 2007, the range of model results for TAR 7 estimated that the stock was Likely (> 60%) to be at or above B_{MSY} (40% B_0). Trawl survey recruited biomass index for WCSI 2017 was higher than in 2007, suggesting the stock is still Likely (> 60%) to be above B_{MSY} level.
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
Trawl survey biomass estimates from the west coast South Island area of TAR 7 (excluding Tasman Bay/Golden Bay).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The WCSI trawl survey biomass index has remained stable since 2006–07.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Biomass (WCSI) is expected to stay steady over the next 3–5 years assuming current (2012–13) catch levels.

Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) for current catch and TACC Hard Limit: Very Unlikely (< 10%) for current catch and TACC	
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown	

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	West coast South Island trawl survey biomass	
Assessment Dates	Latest assessment: 2019	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Survey biomass and length frequency	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- The time series of CPUE indices from the TAR 7 WCSI fishery is no longer used because it was not considered to represent a reliable index of stock abundance, at least during 1989–90 to 2006–07.	
Major Sources of Uncertainty	- Stock structure is currently uncertain. The eastern Cook Strait area of the TAR 7 fish stock is considered to be part of the eastern stock of tarakihi, although the extent of the interaction between tarakihi around coastal New Zealand is unknown.	

Qualifying Comments
-

Fishery Interactions
The main fishing method is trawling. The major target trawl fisheries occur at depths of 100–200 m and tarakihi are also taken as a bycatch at other depths. TAR 7 is reported as bycatch in target barracouta and red cod bottom trawl fisheries. Smooth skates are caught as a bycatch in this fishery.

- **TAR 8**

Insufficient information is available to determine the status of TAR 8.

7. FOR FURTHER INFORMATION

Anon (2007) TAR 2 Adaptive Management Programme Report: 2005/06 fishing year. AMP-WG-06/19. 30 p. (Unpublished report held by Fisheries New Zealand.)

Annala J H (1987) The biology and fishery of tarakihi, *Nemadactylus macropterus*, in New Zealand waters. *Fisheries Research Division Occasional Publication No. 51*. 16 p.

Annala, J H (1988) Tarakihi. New Zealand Fisheries Assessment Research Document 1988/28. 31 p. (Unpublished document held by NIWA library, Wellington.)

Annala, J H; Wood, B A; Hadfield, J D; Banks, D A (1990) Age, growth, mortality and yield-per-recruit estimates of tarakihi from the east coast of the South Island during 1987. MAF Fisheries Greta Point Internal Report No. 138. 23 p. (Unpublished report held by NIWA library, Wellington.)

Annala, J H; Wood, B A; Smith, D W (1989) Age, growth, mortality, and yield-per-recruit estimates of tarakihi from the Chatham Islands during 1984 and 1985. Fisheries Research Centre Internal Report No. 119. 23 p. (Unpublished report held by NIWA library, Wellington.)

Beentjes, M P (2011) TAR 3 catch sampling in 2009–10 and a characterisation of the commercial fishery (1989–90 to 2009–10). *New Zealand Fisheries Assessment Report 2011/52*. 71 p.

Beentjes, M P; MacGibbon, D J; Ladroit, Y (in prep) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2021 (KAH2104). Draft New Zealand Fisheries Assessment Report.

Beentjes, M P; MacGibbon, D; Parkinson, D (2016) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2016 (KAH1605). *New Zealand Fisheries Assessment Report 2016/61*. 135 p.

Beentjes, M P; Parker, S; Fu, D (2012) Characterisation of TAR 2 & TAR 3 fisheries and age composition of landings in 2010/11. *New Zealand Fisheries Assessment Report 2012/25*. 68 p.

Beentjes, M P; Walsh, C; Buckthought, D (2017) Catch at age of tarakihi from east coast South Island and Bay of Plenty trawl surveys. *New Zealand Fisheries Assessment Report 2017/03* 39 p.

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 national marine recreational fishing survey: diary results and harvest estimates. (Unpublished New Zealand Fisheries Assessment Research Report for the Ministry of Fisheries Project REC2000-01 held by Fisheries New Zealand, Wellington.) 92 p.

Boyd, R O; Reilly, J L (2004) 1999/2000 National Marine Recreational Fishing Survey: harvest estimates. (Unpublished New Zealand Fisheries Assessment Research Report for the Ministry of Fisheries Project REC9803 held by Fisheries New Zealand, Wellington.) 28 p.

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished report held by Fisheries New Zealand.)

Edwards, C T T; Hartill, B (2015) Calibrating between offsite and onsite amateur harvest estimates. *New Zealand Fisheries Assessment Report 2015/49*. 23 p.

Field, K; Hanchet, S M (2001) Catch-per-unit-effort analysis for tarakihi (*Nemadactylus macropterus*) in TAR l, 2, 3, and 7. *New Zealand Fisheries Assessment Report 2001/60*. 73 p.

Francis, M P; Paul, L J (2013) New Zealand inshore finfish and shellfish commercial landings, 1931–82. *New Zealand Fisheries Assessment Report 2013/55*. 136 p.

Francis, R I C C; Hurst, R J; Renwick, J A (2001) An evaluation of catchability assumptions in New Zealand stock assessments. *New Zealand Fisheries Assessment Report 2001/1*. 37 p.

Gauldie R W; Johnston A J (1980) The geographical distribution of phosphoglucomutase and glucose phosphate isomerase alleles of some New Zealand fishes. *Comparative Biochemistry and Physiology Part B: Comparative Biochemistry 66*: 171–183.

Hanchet, S M; Field, K (2001) Review of current and historical data for tarakihi (*Nemadactylus macropterus*) Fishstocks TAR 1, 2, 3, and 7, and recommendations for future monitoring. *New Zealand Fisheries Assessment Report 2001/59*. 42 p.

Hartill, B; Bian, R; Armiger, H; Vaughan, M; Rush, N (2007b) Recreational marine harvest estimates of snapper, kahawai and kingfish in QMA 1 in 2004–05. *New Zealand Fisheries Assessment Report 2007/26*. 44 p.

Hartill, B; Bian, R; Davies, N M (2010) A review of approaches used to estimate recreational harvests in New Zealand between 1984 and 2007. 59 p. (Unpublished Final Research Report held by Fisheries New Zealand, Wellington.)

Hartill, B; Bian, R; Rush, N; Armiger, H (2013) Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2011–12. *New Zealand Fisheries Assessment Report 2013/70*. 44 p.

Hartill, B; Bian, R; Rush, N; Armiger, H (2019) Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2017–18. *New Zealand Fisheries Assessment Report 2019/23*. 39 p.

Hartill, B; Davey, N (2015) Mean weight estimates for recreational fisheries in 2011–12. *New Zealand Fisheries Assessment Report 2015/25*. 37 p.

Hartill, B; Watson, T; Cryer, M; Armiger, H (2007a) Recreational marine harvest estimates of snapper and kahawai in the Hauraki Gulf 2003–04. *New Zealand Fisheries Assessment Report 2007/25*. 55 p.

Heinemann, A; Wynne-Jones, J; Gray, A; Hill, L (2015) National Panel Survey of marine recreational fishers 2011–12 rationale and methods. *New Zealand Fisheries Assessment Report 2015/48*. 94 p.

Kendrick, T H (2006) Updated catch-per-unit-effort indices for three substocks of tarakihi in TAR 1, 1989–90 to 2003–04. *New Zealand Fisheries Assessment Report 2006/14*. 66 p.

Kendrick, T H; Bentley, N; Langley, A (2011) Report to the Challenger Fishfish Company: CPUE analyses for FMA 7 Fishstocks of gurnard, tarakihi, blue warehou, and ghost shark. (Unpublished client report held by Trophia Limited, Kaikoura).

Langley, A (2011) Characterisation of the Inshore Finfish fisheries of Challenger and South East coast regions (FMAs 3, 5, 7 & 8). (Unpublished client report available from http://www.seafoodindustry.co.nz/SIFisheries.)

Langley, A D (2014) Updated CPUE analyses for selected South Island inshore finfish stocks. *New Zealand Fisheries Assessment Report 2014/40*. 116 p.

Langley, A D (2017) Fishery characterisation and Catch-Per-Unit-Effort indices for tarakihi in TAR 1, TAR 2 and TAR 3. *New Zealand Fisheries Assessment Report 2017/44*. 122 p.

Langley, A D (2018) Stock assessment of tarakihi off the east coast of mainland New Zealand. *New Zealand Fisheries Assessment Report 2018/05*. 85 p.

Langley, A D (2019) An update of the assessment of the eastern stock of tarakihi for 2019. *New Zealand Fisheries Assessment Report 2019/41*. 29 p.

Langley, A D (2021) Fishery characterisation and Catch-Per-Unit-Effort indices for tarakihi in TAR 1, TAR 2, TAR 3, TAR 5, TAR 7, and TAR 8. *New Zealand Fisheries Assessment Report 2021/71*. 126 p.

Langley, A D (2022) A stock assessment of eastern tarakihi for 2021. *New Zealand Fisheries Assessment Report 2022/07*. 68 p.

Langley, A D; Starr, P (2012) Stock relationships of tarakihi off the east coast of mainland New Zealand, including a feasibility study to undertake an assessment of the tarakihi stock(s). *New Zealand Fisheries Assessment Report 2012/30*. 69 p.

Lydon, G J; Middleton, D A J; Starr, P J (2006) Performance of the TAR 3 Logbook Programmes. AMP-WG-06/20. (Unpublished manuscript available from Fisheries New Zealand, Wellington.)

MacGibbon, D J (2019) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2019 (KAH1902) *New Zealand Fisheries Assessment Report 2019/64*. 87 p.

MacGibbon, D J; Beentjes, M P; Lyon, WL; Ladroit, Y (2019) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2018 (KAH1803). *New Zealand Fisheries Assessment Report 2019/03*. 136 p.

MacGibbon, D J; Walsh, C; Buckthought, D; Bian, R (2022) Inshore trawl survey off the west coast South Island and in Tasman Bay and Golden Bay, March–April 2021 (KAH2103). *New Zealand Fisheries Assessment Report 2022/11*. 9 p.

McKenzie, J R; Beentjes, M; Armiger, H; Bradley, A; Spong, K; Walsh, C; Buckthought, D; Stevenson, M; Taylor, R; Evans, O; Bian, R; Parsons, D; Sutton, C; Hart, A; Ó Maolagáin, C; Patke, S; Langley, A; Kater, D; Sykes, J; O'Driscoll, M; Qureshi, Y; Miller, A; Bodie, C; Smith, M; Hartill, B; Toman, D; Maggs, J; Bagley, N (2021) Fishery characterisation and age composition of tarakihi in TAR 1, 2, 3, 5, 7, and 8, for 2018–19 and 2019–20. *New Zealand Fisheries Assessment Report 2021/79*. 119 p.

McKenzie, J R; Beentjes, M P; Parker, S; Parsons, D M; Armiger, H; Wilson, O; Middleton, D; Langley, A; Buckthought, D; Walsh, C; Bian, R; Ó Maolagáin, C; Stevenson, M; Sutton, C; Spong, K; Rush, N; Smith, M (2017) Fishery characterisation and age composition of tarakihi in TAR 1, 2 and 3 for 2013/14 and 2014/15. *New Zealand Fisheries Assessment Report 2017/36*. 80 p.

McKenzie, J R; Walsh, C; Bian, R (2015) Characterisation of TAR 1 fisheries and age composition of landings in 2010/11 from Industry at-sea catch sampling. *New Zealand Fisheries Assessment Report 2015/74*. 47 p.

Manning, M J (2008) Stock assessment of tarakihi in TAR 7. Presentation to the Southern Inshore FAWG, Wellington, 2 May 2008.

Manning, M J; Stevenson, M L; Horn, P L (2008) The composition of the commercial and research tarakihi (*Nemadactylus macropterus*) catch off the west coast of the South Island during the 2004–2005 fishing year. *New Zealand Fisheries Assessment Report 2008/17*. 65 p.

Methot, R D (2009) User manual for Stock Synthesis: Model Version 3.04. (Updated September 9, 2009), 159 p.

Northern Inshore Fisheries Company Ltd (2001) Tarakihi (TAR 1) - revised 30/04/01 Proposal to manage TAR 1 as part of an Adaptive Management Programme.

Papa, Y; Halliwell, A G; Morrison, M A; Wellenreuther, M; Ritchie P A (2021) Phylogeographic structure and historical demography of tarakihi (*Nemadactylus macropterus*) and king tarakihi (*Nemadactylus* n.sp.) in New Zealand. *New Zealand Journal of Marine and Freshwater Research*. DOI: 10.1080/00288330.2021.1912119

Parker, S; Fu, D (2011) Age composition of commercial tarakihi (Nemadactylus macropterus) in quota management area TAR 2 in fishing year 2009–10. *New Zealand Fisheries Assessment Report 2011/59*. 35p.

Phillips, N L; Hanchet, S M (2003) Updated catch-per-unit-effort (CPUE) analysis for tarakihi (*Nemadactylus macropterus*) in TAR 2 (east coast North Island) and CPUE analysis of tarakihi in Pegasus Bay/Cook Strait (mainly TAR 3). *New Zealand Fisheries Assessment Report 2003/53*. 54 p.

Richard, Y; Abraham, E R (2013) Risk of commercial fisheries to New Zealand seabird populations. *New Zealand Aquatic Environment and Biodiversity Report No. 109*. 58 p.

SeaFIC (2003) Report to the Adaptive Management Programme Fishery Assessment Working Group. TAR 3 Adaptive Management Programme Proposal for the 2004–05 fishing year (dated 11 November 2003). (Unpublished document held by Fisheries New Zealand.)

Smith, P J; Roberts, C D; McVeagh, S M; Benson, P G (1996) Genetic evidence for two species of tarakihi (Teleostei: Cheilodactylidae: *Nemadactylus*) in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research 30*(2): 209–220.

Starr, P J (2007) Procedure for merging Ministry of Fisheries landing and effort data, version 2.0. Report to the Adaptive Management Programme Fishery Assessment Working Group: Document 2007/04. 17 p. (Unpublished document held by Fisheries New Zealand, Wellington.)

Starr, P J; Kendrick, T H; Lydon, G J; Bentley, N (2007) Report to the Adaptive Management Programme Fishery Assessment Working Group: Two year review of the TAR 3 Adaptive Management Programme. AMP-WG-07/12. (Unpublished report held by Fisheries New Zealand, Wellington.) 68 p.

Stevenson, M L (2006) Trawl survey of the west coast of the South Island and Tasman and Golden Bays, March–April 2005 (KAH0503). *New Zealand Fisheries Assessment Report 2006/4*. 69 p.

Stevenson, M L (2007) Inshore trawl survey of the west coast of the South Island and Tasman and Golden Bays, March–April 2007 (KAH0704). *New Zealand Fisheries Assessment Report 2007/41*. 64 p.

Stevenson, M L (2012) Inshore trawl survey of the west coast of the South Island and Tasman and Golden Bays, March–April 2011. *New Zealand Fisheries Assessment Report 2012/50*. 77 p.

Stevenson, M L; Horn, P L (2004) Growth and age structure of tarakihi (*Nemadactylus macropterus*) off the west coast of the South Island. New Zealand Fisheries Assessment Research Document 2004/11 21 p. (Unpublished document held by NIWA library, Wellington.)

Stevenson, M L; MacGibbon, D J (2018) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2017 (KAH1703). *New Zealand Fisheries Assessment Report 2018/18*. 93 p.

Sullivan, K J (1981) Trends in the Canterbury Bight trawl fishery from 1963 to 1976. *Fisheries Research Division Occasional Publication No. 19*.

Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished document held by NIWA library, Wellington.)

Vooren, C M (1973) The population dynamics of the New Zealand, *Cheilodactylus macropterus* (Bloch and Schneider), and changes due to fishing: an exploration. *In*: Fraser, R. (Comp.), *Oceanography of the South Pacific*, pp 493–502. New Zealand National Commission for UNESCO, Wellington.

Walsh, C; Horn, P; McKenzie, J; Ó Maolagáin, C; Buckthought, D; Stevenson, M; Sutton, C (2016) Age determination protocol for tarakihi (*Nemadactylus macropterus*). *New Zealand Fisheries Assessment Report 2016/13*. 37 p.

Wright, P; McClary, D; Boyd, R O (2004) 2000/2001 National Marine Recreational Fishing Survey: direct questioning of fishers compared with reported diary data. (Final Research Report for Ministry of Fisheries Project REC2000–01: Objective 2 held by Fisheries New Zealand.)

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019) National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24*. 104 p.

Wynne-Jones,J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.

TOOTHFISH (TOT)
(outside EEZ)

(*Dissostichus mawsoni* and *Dissostichus eleginoides[1]*)
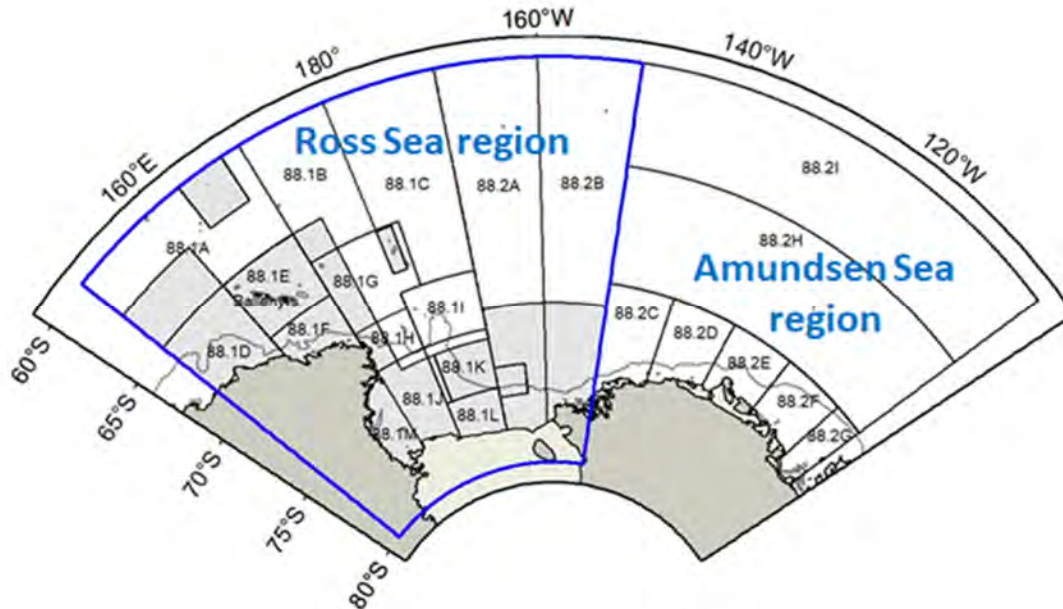
The Ross Sea Region (CCAMLR Statistical Subareas 88.1 and small-scale research units (SSRUs) 88.2A and 88.2B), and the Amundsen Sea Region (SSRUs 88.2C–I) used for management and the 1000 m depth contour. Shaded regions indicate the Ross Sea region MPA boundaries and include the Special Research Zone, Krill Research Zone, and General Protected Zones (i), (ii), and (iii).

1. FISHERY SUMMARY

This working group report is a summary of the Ross Sea and Amundsen Sea toothfish fisheries in CCAMLR (Statistical Subareas 88.1 and 88.2) and includes the catches of all participating countries. These fisheries occur entirely on the high seas within the area covered by the Convention for the Conservation of Antarctic Marine Living Resources (the Convention Area). They are managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

Finfish fisheries in Antarctic waters are managed in accordance with the CAMLR Convention, in particular the objective and principles defined in Article II. The Convention Area covers the area south of the Antarctic Convergence (varying from 60° S in the Pacific Sector to 45° S in the western Indian Ocean Sector) (Figure 1). In 2016, CCAMLR adopted a Marine Protected Area in the Ross Sea Region (CCAMLR 2016c), which came into effect on 1 December 2017.

1.1 Commercial fisheries
Toothfish are large nototheniids endemic to Antarctic and Sub-Antarctic waters. There are two species: Antarctic toothfish (*Dissostichus mawsoni*) and Patagonian toothfish (*Dissostichus eleginoides*). Both have a circumpolar distribution, although *D. mawsoni* has a more southern distribution.

Commercial bottom longline fisheries targeting Patagonian toothfish occur around many of the Sub-Antarctic islands and plateaux south of the Sub-Antarctic Front[2]. To date, the main Olympic longline fishery for Antarctic toothfish outside an EEZ and within the Convention Area has taken place in Statistical Subarea 88.1, with smaller fisheries scattered around the Antarctic continental slope except

---

[1] Note: this report does not cover the Patagonian toothfish (*Dissostichus eleginoides*) fishery in the New Zealand Exclusive Economic Zone.
[2] Zone found between 48° S and 58° S in the Indian and Pacific Ocean and between 42° S and 48° S in the Atlantic Ocean.

for the Weddell Sea. Statistical Subarea 88.1 is divided into three broad ecological regions: a region of northern seamounts, ridges, and banks; a region of shallow water (< 800 m) on the Ross Sea shelf in the extreme south; and a region in between covering the continental slope (800–2000 m). The main longline fishery occurs on the continental slope.
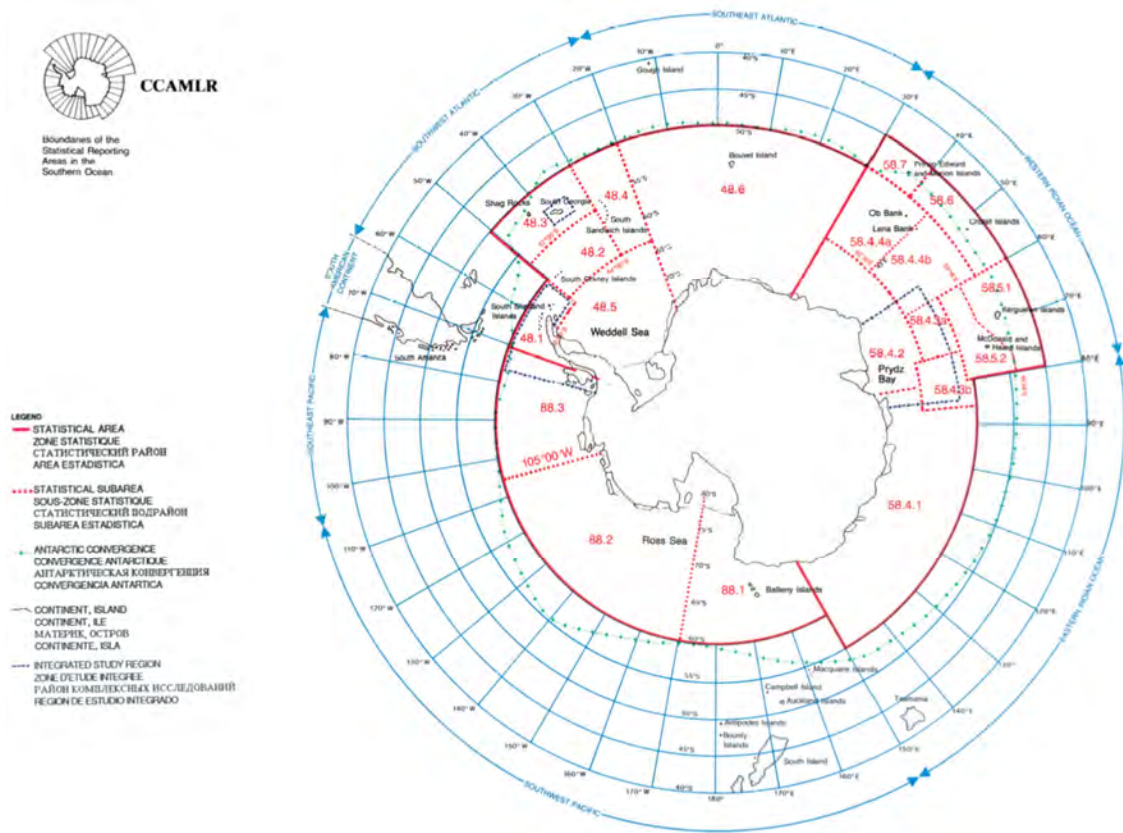
Figure 1: Map of CAMLR Convention area (https://www.ccamlr.org/en/organisation/convention-area) showing Statistical Subareas and Divisions.

The longline fishery for *Dissostichus* spp. in Statistical Subarea 88.1 was initiated as a new fishery by New Zealand in 1996–97, using a single longline vessel (Table 1). Since then, vessels from a number of countries have returned each summer to fish in this area and the adjacent Statistical Subarea 88.2 fishery. The exploratory longline fishing season in Statistical Subarea 88.1 and 88.2 begins on the 1 December and most fishing is completed by February.

The catch of toothfish in Statistical Subarea 88.1 and SSRUs 88.2A&B (the Ross Sea region) showed a steady increasing trend during the early period of the fishery, almost reaching the Total Allowable Catch (TAC) of about 3000 t between 2004–05 and 2006–07. In 2007–08 and 2008–09, the TAC was under-caught in Statistical Subarea 88.1 due to the severe ice conditions in 2007–08 and the early closure of the fishery by the CCAMLR Secretariat in 2008–09 because of overestimation of projected catch rates. The catches have been close to the catch limits since 2009–10, with the closure of the fishery by CCAMLR based on catch projections using daily catch reports (CCAMLR Secretariat 2016b). In 2017–18 and in 2018–19, the TAC was again under-caught in the Ross Sea region due to the early closure of the fishery by the CCAMLR Secretariat, because of difficulties in projecting catch for many vessels competing for a relatively small catch limit. In the 2020–21 season, the total catch was slightly above the TAC and in 2021–22 the total catch was slightly below the TAC.

The catch of toothfish in Statistical Subarea 88.2 began in 2003–04 and exceeded catch limits in 2004–05 and 2005–06. Failure to reach the catch limit in the following four years was primarily due to the low fishing effort in the southern SSRUs 88.2C–G because of the ice conditions. The catch was close to the catch limit between 2010–11 and 2017–18, with the closure of the fishery by CCAMLR based

on the daily catch reports, but limits have been higher since 2018–19. Figure shows historical landings and TACs for Statistical Subareas 88.1 and 88.2.

Table 1: Estimated catches (t) of *Dissostichus* spp. by area for the 1996–97 to present (Source: FAO STATLANT data; CCAMLR 2017a, 2017b). – denotes has not been estimated, but likely to be 0 t. IUU is illegal, unreported, and unregulated catch.

Season	Reported catch	Estimated IUU catch	Total	Statistical Subarea 88.1 Catch limit**	Reported catch	Estimated IUU catch	Total	Statistical Subarea 88.2 Catch limit
1996–97	< 1	0	< 1	1 980*	0	0	0	1 980*
1997–98	42	0	42	1 510	0	0	0	63
1998–99	297	0	297	2 281	0	0	0	0
1999–00	751	0	751	2 090	0	0	0	250
2000–01	660	0	660	2 064	0	0	0	250
2001–02	1 325	92	1 417	2 508	41	0	41	250
2002–03	1 831	0	1 831	3 760	106	0	106	375
2003–04	2 197	240	2 437	3 250	374	0	374	375
2004–05	3 105	28	3 133	3 250	411	0	411	375
2005–06	2 969	0	2 969	2 964	514	15	529	487
2006–07	3 091	0	3 091	3 032	347	0	347	547
2007–08	2 259	272	2 531	2 700	416	0	416	567
2008–09	2 448	0	2 448	2 700	484	0	484	567
2009–10	2 869	0	2 869	2 850	314	0	314	575
2010–11	2 839	0	2 839	2 850	590	0	590	575
2011–12	3 178	–	3 178	3 282	424	–	424	530
2012–13	3 006	–	3 006	3 282	475	–	475	530
2013–14	2 823	–	2 823	3 044	426	–	426	390
2015–16	2 684	–	2 684	2 870	618	–	618	619
2016–17	2 821	–	2 821	2 870	624	–	624	619
2017–18	2 825	–	2 825	3 157	609	–	609	619
2018–19	3 047	–	3 047	3 157	753	–	753	1 000
2019–20	2 972	–	2 972	3 140	643	–	643	894
2020–21	3 146	–	3 146	3 140	530	–	530	804
2021–22***	3 288	–	3 288	3 495		–		923
2022–23***				3 495				923

* A single catch limit in 1996–97 applied to all of Statistical Subareas 88.1 and 88.2.
** Catch limits include catch set aside for research activities.
*** Catches not yet reported
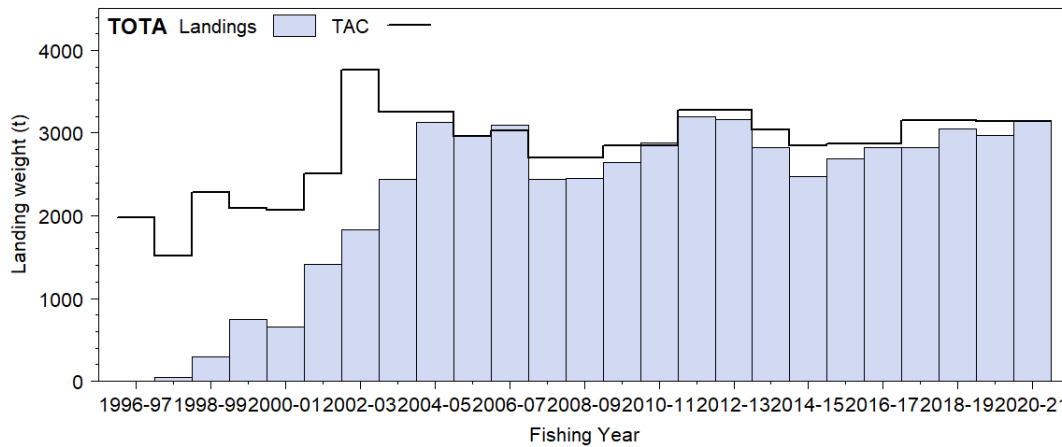
Figure 2: The landings of toothfish and catch limits (TACs) from 1997–98 to present in Statistical Subarea 88.1 and SSRUs 88.2A-B (TOTA), and 1999–00 to present in SSRUs 88.2C–H (TOTB). [Continued on next page]
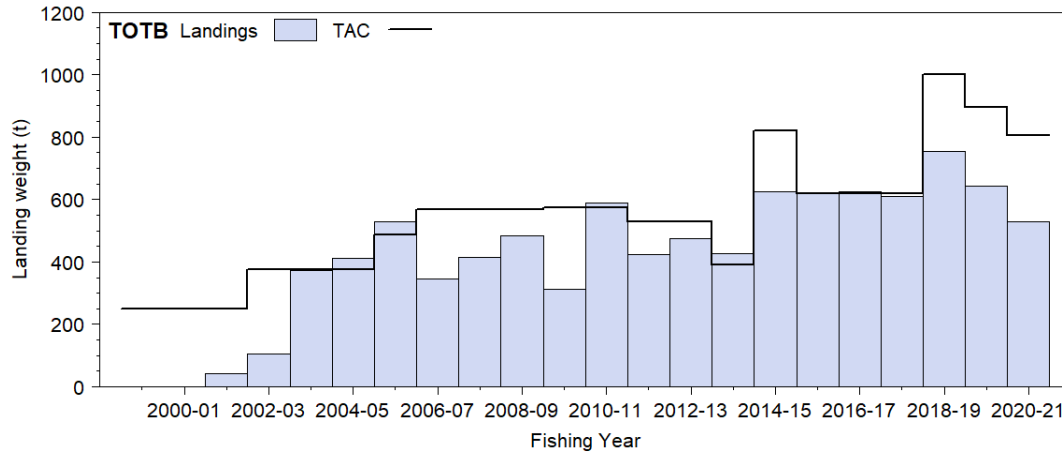
Figure 2: [continued] The landings of toothfish and catch limits (TACs) from 1997–98 to present in Statistical Subarea 88.1 and SSRUs 88.2A-B (TOTA), and 1999–00 to present in SSRUs 88.2C–H (TOTB).

The toothfish catch from these areas almost entirely comprises Antarctic toothfish. Since the start of the fishery, 153 t of Patagonian toothfish have been caught in Statistical Subareas 88.1 and 88.2, almost entirely from the north of Statistical Subarea 88.1 (SSRUs 88.1A, 88.1B, and 88.1C) (CCAMLR 2017a). The data in **Error! Reference source not found.** are collated from monthly reporting (vessel to flag state to CCAMLR) and annual reporting (FAO STATLANT reports to CCAMLR from flag state).

The number, size, and related catch limits of the Ross Sea region have varied through time (see also Delegations of New Zealand, Norway, and the United Kingdom 2014). On 1 December 2017, three new management zones resulting from the implementation of the Ross Sea region MPA were defined: A General Protection Zone (GPZ), a Special Research Zone (SRZ on the slope area), and a Krill Research Zone (KRZ) (Figure). Catch limits were applied to the region outside the MPA and north of 70° S, outside the MPA and south of 70° S, and the SRZ. Spatial management, including allocation of catch among regions, will be reconsidered following evaluation of fishing effort redistribution after implementation of the MPA.

Although the total catch limit in Statistical Subarea 88.1 has rarely been exceeded, the local catch limit for 88.1B, 88.1C and 88.1G has been exceeded in various years, due to relatively small catch limits, a large number of vessels, and high but variable catch rates (CCAMLR Secretariat 2016a).

Ice conditions and bycatch limits are important factors influencing the spatial distribution of fishing effort. In 2002–03, 2003–04, and 2007–08 heavy ice conditions meant that little catch was taken in SSRUs 88.1J–L. An ice index was created for the Ross Sea region indicating the proportion of fishing grounds clear of sea ice (CCAMLR 2016a, Fenaughty & Parker 2015).
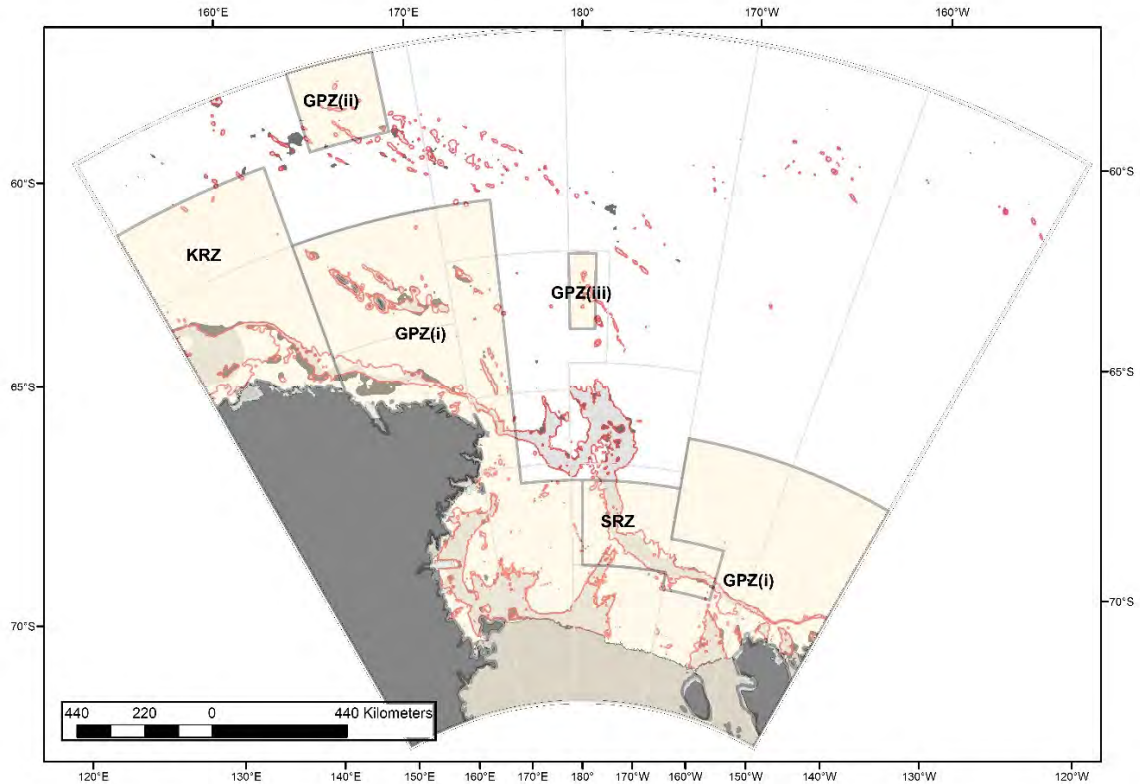
Figure 3: Ross Sea region Marine Protected Area in effect as of 1 December 2017 (CM 91-05).

The SSRUs in Statistical Subarea 88.2 were redefined for the 2011–12 season with the northern boundaries of SSRUs 88.2C–G truncated at 70º 50' S to separate a region of seamounts in the north from the shelf/slope grounds in the south. The northern parts of those SSRUs were then amalgamated to form a new SSRU 88.2H and a separate catch limit was set for each of the northern and southern regions. The area north of 65° S (SSRU 88.2I) has always been closed to fishing.

In addition to the catch limits on the target toothfish species, other management rules have been adopted by CCAMLR via conservation measures. These include:

- gear restrictions (CCAMLR Conservation Measure (CM) 10-05 (2018));
- daily reporting requirements (CM 23-07 (2016));
- a Catch Documentation Scheme (CM 10-05 (2018));
- restrictions on bycatch (CM 33-03 (2019));
- measures to minimise local depletion of toothfish (CM 41-09 (2019));
- measures to minimise impacts to identified Vulnerable Marine Ecosystems (CM 22-09 (2012));
- non-fish bycatch mitigation measures (CM 25-02 (2019)); and
- the Ross Sea region MPA (CM 91-05 (2016)).

In 2005–06, the macrourid (rattail) bycatch limits were exceeded for SSRUs 88.2C–G resulting in the area being closed before the toothfish catch limit was reached.

The CCAMLR Convention Area extends to 60° S in the Pacific Basin but the bathymetric features and oceanographic conditions that toothfish inhabit extend north of this boundary. The northern extent of the range of Antarctic toothfish is not well known in the area. Two research surveys in the south Pacific under the auspices of the South Pacific Regional Fisheries Management Organisation (SPRFMO) were conducted in 2016 and 2017 with catch limits of 30 t in each year and were restricted to two small research areas between near 150° W longitude and 59° S latitude (COMM-04-WP-09_rev4). Twenty-nine tonnes were landed in each year and all were Antarctic toothfish, except for two small Patagonian toothfish in 2017. This catch was included as removals from the Ross Sea region stock assessment (Mormede 2017, Dunn 2019).

In 2018 a proposal for an exploratory longline fishery was made by New Zealand in the area to better determine the distribution and population characteristics of Antarctic toothfish on the Pacific-Antarctic Ridge system within the SPFRMO Convention Area between 140–155° W and 52–60° S over three years (SC6-DW03-Rev2-NZ, COMM7-Prop13.1, Figure 1). The total allowable catch was set at 140 t each year for 2019, 2020, 2021, and was agreed by the Commission in 2019 (ANNEX-7l-COMM7-CMM-14a-2019-Exploratory-Toothfish-NZ). An EU proposal for a one-year exploratory fishery in the southern SPRFMO area on the South Tasman Rise (COMM7-Prop14.1-rev-1) was also approved for 2019–20 with a catch limit of 45 t of toothfish (likely to be Patagonian toothfish in that area, ANNEX -7m-COMM7-CMM-14c-2019). The exploratory fishery was extended for three more years (COMM 10-Prop 07.1) with a proposed catch limit of 240 t (SC9-DW01-rev-1). The framework for fishing, tagging, and data collection for both exploratory fisheries closely mirrors that of CCAMLR making the data comparable for analysis. A total of 77 t in 2020 and 24 t in 2021 were caught in the SPRFMO Convention area and were included in the 2021 stock assessment for the Ross Sea region.

1.2 Recreational fisheries
There is no recreational toothfish fishery in Statistical Subareas 88.1 and 88.2.

1.3 Customary non-commercial fisheries
There is no customary toothfish fishery in Statistical Subareas 88.1 and 88.2.

1.4 Illegal catches
Based on aerial surveillance and other sources of intelligence, the level of illegal, unreported, and unregulated (IUU) catch is thought to be low (Table 1). CCAMLR stopped estimating the level of IUU catch from 2011, but estimated the level of IUU effort instead. IUU effort in recent years in the Convention Area has typically been comprised of vessels using gillnets which is currently prohibited under CM 22-04 and the catch rates for this method cannot be reliably estimated. However, CCAMLR has estimated that there has been no IUU effort in Statistical Subareas 88.1 and 88.2 since 2010–11 (CCAMLR 2017a).

1.5 Other sources of mortality
Any longline gear that is baited and set, but not successfully retrieved, may result in unaccounted mortality of toothfish or other species. Bottom longline gear is most often lost due to interactions of downlines with moving sea ice, but may also result from tidal currents submerging floats, or gear failure during line retrieval.

Webber & Parker (2011) estimated line loss from 2008 to 2011 to be in the range 3–8% (expressed in terms of percent of all hooks set that are lost attached to sections of lines). Longline hooks only have the potential to catch once. Once a fish is on the hook, or the bait is gone, the hooks are effectively not able to fish anymore. Assuming that these hooks caught toothfish at the same rate as those on lines that were retrieved, and that all the toothfish caught on lost lines die as a result of being caught, then an additional 175–244 tonnes of Antarctic toothfish fishing related mortality from the commercial fishery may be unaccounted for annually.

A small quantity of toothfish is taken by other scientific research programmes in most years, typically less than 5 tonnes.

Observers monitor discards, with up to 40% of all hooks hauled being directly observed, and no discarding of dead toothfish has been reported to date. However, in 2014 it was reported that some small toothfish had been released untagged but alive by Ukrainian vessels in Statistical Subarea 88.2, as they were too small to process. Fish are occasionally lost from the line near the surface and recorded as lost.

Antarctic toothfish are occasionally caught with evidence of squid depredation (i.e., sucker marks and large flesh wounds), but the amount of depredation due to large squid is insignificant at the scale of the fishery. Until 2022, there had been no reported instances of depredation of toothfish by cetaceans or pinnipeds in the Ross Sea region; in 2021, a leopard seal was observed taking 1 toothfish and, in 2022, 3 toothfish from a longline on the Ross Sea shelf survey.

## 2.	BIOLOGY

The Antarctic toothfish has a circumpolar distribution south of the Antarctic convergence (about 60° S). A summary of the biology of Antarctic toothfish, and related references, are given in detail by Hanchet et al (2015). Although it is primarily a demersal species, adults can be neutrally buoyant and are known to inhabit the pelagic zone at times (Near et al 2003). Early growth has been well documented (Horn 2002, Horn et al 2003) with fish reaching about 60 cm TL after five years and about 100 cm TL after ten years. Growth slows after about 10 years as fish reach the adult stage. The maximum recorded age is 48 years and maximum length recorded is 250 cm. Ages have been validated by following modes: in juvenile fish by tetracycline marking, and lead-radium dating in adult fish (Horn et al 2003, Brooks et al 2011). There is a significant difference in growth between sexes with maximum average lengths of 170 cm and 180 cm for males and females respectively (Horn 2002).

Hanchet et al (2008) developed a hypothetical life history of Antarctic toothfish in the Ross Sea. Fish spawn to the north of the Antarctic continental slope, mainly on the ridges and banks of the Pacific-Antarctic Ridge during winter or spring.

The first winter longline survey of Antarctic toothfish in the northern Ross Sea region was successfully completed during June and July 2016 and confirmed toothfish spawning in this region (Stevens et al 2016, Parker et al 2019). Fertilised Antarctic toothfish eggs were found to be large (greater than 3.5 mm diameter) and pelagic (found in the upper 200 m of the water column). Spawning may occur from mid-July through August (Stevens et al 2016). A second winter survey was conducted in September and October 2019 with results reported to CCAMLR in 2020 (Parker et al 2020). Additional information on the timing, distribution, stock structure, and potentially early life history will be derived from the exploratory fishery in the SPRFMO area. The SPRFMO fishery will also have some fishing during August–October, which will greatly enhance information about spawning, which occurs in the winter and is typically inaccessible further south due to sea ice. SPRFMO samples have already shown that the fish inhabiting seamounts just north of the CCAMLR Convention Area are abundant, mostly Antarctic toothfish, all adult sizes, and in spawning or post-spawning condition during late winter. The spatial distribution of spawning has not yet been determined.

Hanchet et al (2008) postulated that depending on the exact location of spawning, eggs and larvae become entrained by the Ross Sea gyres (a counter-clockwise rotating western gyre located around the Balleny Islands and a larger clockwise rotating eastern gyre covering the rest of the Ross Sea region) and move either west, settling out around the Balleny Islands and adjacent Antarctic continental shelf, south onto the Ross Sea shelf, or eastwards with the eastern Ross Sea gyre settling out along the continental slope and shelf to the east of the Ross Sea in Statistical Subarea 88.2. Additional particle tracking simulations to examine the effects of sea ice and directional swimming behaviours of early pelagic juveniles by Behrens et al (2021) incorporating buoyancy measurements of eggs from Parker et al (2021) suggest differences in recruitment success from different spawning areas and the need for some directional swimming to reach the coastal current and appropriate depths for settling to a demersal lifestyle.

As the juveniles grow, it is hypothesised that they move west, back towards the Ross Sea shelf, and then move out into deeper water (greater than 1000 m). The fish gradually move northwards as they mature, feeding in the slope region in depths of 1000–1500 m, where they gain condition before moving north onto the Pacific-Antarctic ridge to start the cycle again. It is not known how long spawning fish remain in the northern area. It is currently thought that toothfish remain in the Pacific-Antarctic ridge region for up to 2–3 years (although this pattern may be different for males versus females) and then they move southwards back onto the shelf and slope where productivity is higher and food is more plentiful. A multidisciplinary approach incorporating otolith chemistry, age data, and Lagrangian particle simulations reached similar conclusions (Ashford et al 2012). The authors further postulated that the entire life cycle is structured by ocean circulation such that not just eggs and larvae, but also juvenile and adult fish, are transported downstream by ocean currents between nursery grounds, feeding grounds, and spawning grounds.

The age and length at recruitment to the Ross Sea fishery varies between areas and between years. In the northern SSRUs (88.1A–88.1G), toothfish recruit at a length of about 130 cm to the fishery. In the southern SSRUs (88.1H–88.1M), the length at recruitment depends on the depth of fishing. In some years, fish have been fully recruited at a length of about 80 cm (age 7–8), whereas in other years fish have not been fully recruited until at least 100 cm (age 10). In Statistical Subarea 88.2, toothfish recruit at a length of about 130 cm in the northern SSRU (88.2H) but at a length of about 60–80 cm (age 5–8) in the southern SSRUs (88.2C–G) (Stevenson et al 2014).

Estimates of maturity, based on hindcasting from the presence of post-ovulatory follicles in the ovaries and forecasting from the assessment of oocyte developmental stage, suggested that the mean age and length at 50% spawning for females on the Ross Sea slope were 16.6 y and 133.2 cm and the mean age and length at 50% maturity for males were 12.8 y and 120.4 cm (Parker & Grimes 2010). These estimates were updated in 2012 to 16.9 y and 135 cm for females and 12.0 y and 109 cm for males on the Ross Sea slope (Parker & Marriott 2012). Regional spawning ogives show similar relationships for the Ross Sea north and shelf areas and for Statistical Subarea 88.2.

The natural mortality rate M was estimated by Dunn et al (2006) using the methods of Chapman-Robson (1960), Hoenig (1983), and Punt et al (2005). Estimates of M derived from these methods ranged from 0.11 to 0.17 y^{-1}. After a consideration of possible biases, Dunn et al (2006) proposed that a value of 0.13 y^{-1} be used for stock modelling with a range of 0.11–0.15 y^{-1} for sensitivity analyses. They noted that further work is required on values of M and in possible changes of M with age. Biological parameters relevant to the stock assessment are shown in Table 2.

Antarctic toothfish feed on a wide range of prey but are primarily piscivorous with the observed diet varying by location (Fenaughty et al 2003, Stevens et al 2014). The most important prey species of fish caught in the main fishery are grenadiers (*Macrourus* spp.). In continental slope waters, *Macrourus* spp., the icefish *Chionobathyscus dewitti*, eel cods (*Muraenolepis* spp.), and cephalopods are predominant in the diet, whereas on oceanic seamounts *Macrourus* spp., violet cod (*Antimora rostrata*), and cephalopods are important. In the southern Ross Sea, subadult and adult toothfish feed mainly on nototheniids (*Trematomus* spp.) and icefish, whereas in McMurdo Sound, the stomachs of adult toothfish sampled through holes in the ice have been observed to contain mainly Antarctic silverfish (*Pleuragramma antarcticum*) (Eastman 1985, Parker et al 2016). In the open oceanic waters in the north of the Ross Sea region, Antarctic toothfish feed on small squid (Yukhov 1971). The diet of Antarctic toothfish also varies with their size. Crustaceans are more common prey items in smaller toothfish, whereas squid are more common in larger toothfish, likely reflecting the different spatial distributions of small versus large toothfish.

Table 2: Estimates of biological parameters for Antarctic toothfish.

Biological parameters								Reference
1. Natural mortality (*M*)								
Males	Females							
0.13	0.13							Dunn et al (2006)

2. Weight = a(length)^b (Weight in kg, length in cm fork length)

	Males			Females				
a	*b*		*a*	*b*				
0.000001247	2.990		0.000007361	3.105				Dunn & Parker (2019)

3. von Bertalanffy growth parameters

		Males				Females		
K	t_0	L_∞	*c.v*	*K*	t_0	L_∞	*c.v.*	
0.101	-0.292	164.1	0.101	0.082	-0.712	180.5	0.101	Dunn & Parker (2019)

4. Maturity

	Males		Females					
A_{50}	$\pm A_{to95}$		A_{50}	$\pm A_{to95}$				
11.99	5.25		16.92	7.68				Parker & Marriott (2012)

The main predators of toothfish are likely to be odontocetes (sperm whales, historically), type C killer whales, and pinnipeds (Weddell seals) (Eisert et al 2013, 2014, Pinkerton et al 2010, Torres et al 2013). The scale or spatial distribution of predation is unknown.

3. STOCKS AND AREAS

The number of stocks or populations of *D. mawsoni* in the Southern Ocean is currently unknown. However, several studies looking at genetics, parasites, otolith microchemistry, stable isotopes, larval dispersal simulations, and movements of fish from tag-recapture data have produced information leading to improved knowledge of stock structure.

A genetic analysis was carried out by Parker et al (2002) using random amplified polymorphic DNA (RAPD) markers. They concluded that samples taken from McMurdo Sound (Statistical Subarea 88.1) and the Bellingshausen Sea (Statistical Subarea 88.3 (Figure 1)) were from two different genetic groups. Smith & Gaffney (2000) detected little genetic diversity in mitochondrial DNA (mtDNA) samples between the Pacific (Statistical Subarea 88.1), Indian Ocean (Division 58.4.2), and Atlantic Ocean (Statistical Subarea 48.1) sectors. One mtDNA method showed no genetic variation, and two other mtDNA methods showed only weak genetic diversity between regions. Smith & Gaffney (2000) also found only weak genetic variation using nuclear DNA introns. They concluded that despite the weak genetic diversity in Antarctic toothfish there was evidence for differentiation between the ocean sectors. Kuhn & Gaffney (2008) expanded the work of Smith & Gaffney (2000) by examining nuclear and mitochondrial single nucleotide polymorphisms (SNPs) on tissue samples collected from Statistical Subareas 48.1, 88.1, and 88.2, and Division 58.4.1. They found broadly similar results to those of the earlier studies, with some evidence for significant genetic differentiation between the three ocean sectors but limited evidence for differentiation within ocean sectors. Suggestions of weak diversity were also reported by Mugue et al (2013).

The assumption of separate stocks is supported by oceanic gyres, which may act as juvenile retention systems, and by the location of recaptures of adult tagged fish (Hanchet et al 2008, Parker et al 2014). Most adult tagged fish have been recaptured close to where they were originally tagged, often within 100 km (Parker & Mormede 2015). However, tagged fish have also been recaptured having moved longer distances within Statistical Subarea 88.1(Parker & Mormede 2017a). Few fish have been observed to move between Statistical Subareas 88.1 and 88.2: Ten fish have moved from Statistical Subarea 88.1 to Statistical Subarea 88.2, and nine moved from Statistical Subarea 88.2 to Statistical Subarea 88.1. Additionally, some long-distance movements of more than 2000 km been observed: one fish tagged in McMurdo Sound in SSRU 88.1M was recaptured after 18 years at liberty almost 2500 km to the northeast, in SSRU 88.2H; one fish was released in Statistical Subarea 48.4 and recaptured in Statistical Subarea 88.2, and one fish was released in Statistical Subarea 88.1 and recaptured in Statistical Subarea 58.4.1 (CCAMLR Secretariat 2016a).

Tana et al (2014) compared otolith microchemistry signatures between the north of the Ross Sea (88.1B-C) and north of the Amundsen Sea (88.2H). Preliminary results found differences in the microchemistry of both edges and nuclei between the two areas, providing some evidence for separate Ross Sea and Amundsen Sea stocks. Pinkerton et al (2014a) compared carbon and nitrogen stable isotope values in muscle tissue samples collected from the slope and north of the Ross Sea and north of the Amundsen Sea. Carbon signatures were similar within the Ross Sea, but different between the Ross Sea and Amundsen Sea suggesting that they form separate spawning populations. Parker (2014) reviewed the stock structure of Antarctic toothfish in Statistical Area 88 including information from genetic studies, otolith microchemistry, stable isotopes, tagging, size and age structure, growth dynamics, and egg and larval dispersal simulations and concluded that there was no evidence to change existing stock boundaries.

For stock assessment purposes, all Statistical Subarea 88.1 and SSRUs 88.2A and 88.2B are treated as a single Ross Sea region stock ('Ross Sea' typically refers to the Ross Sea shelf area). SSRUs 88.2C–H) are treated as a second Amundsen Sea region stock. Both Statistical Subareas include closed SSRUs from which fishing has been excluded for varying numbers of years. The stock affinity of the assessed stocks with toothfish in surrounding areas is not well understood, and assessments in the medium term will consider alternative stock structures including developing a combined Statistical Subareas 88.1 and 88.2 assessment.

Information about stock structure will be collected from the exploratory fishery in the SPRFMO Area as well, including genetic samples, size and age distributions, and otoliths for microchemistry. Surveying in discrete spatial strata will enable mapping of fish density (through CPUE) and documentation of movement patterns through tagging.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the 2022 Fisheries Assessment Plenary. Further information can be found in the Aquatic Environment and Biodiversity Annual Review 2021 (Fisheries New Zealand 2021), online at https://www.mpi.govt.nz/dmsdocument/51472-Aquatic-Environment-and-Biodiversity-Annual-Review-AEBAR-2021-A-summary-of-environmental-interactions-between-the-seafood-sector-and-the-aquatic-environment.

4.1 Incidental catch (fish and invertebrates)

The bycatch of fish species in the Statistical Subareas 88.1 and 88.2 fisheries was last characterised by Moore and Parker (2021). The main bycatch species in these fisheries are macrourids, which contributed around 5% of the total catch by weight and about 30% of the total catch by number per year (
Table 3, Table 4). Taxonomic studies have shown that specimens originally identified in the Ross Sea region as *Macrourus whitsoni* comprise two sympatric species: *Macrourus whitsoni* and *Macrourus caml* (McMillan et al 2012) with different biology and ecology (Pinkerton et al 2013). Work is in progress to determine the degree of overlap of these two species both within the Ross Sea region and circum-Antarctic. The other major bycatch group is skates (rajids, mainly *Amblyraja georgiana* and *Bathyraja* cf. *eatonii*). Skates made up about 10% of the total landings by weight in 1997–98 and 1998–99, but the reported catches of skates then decreased due to a tag release programme and the live release of untagged skates. In both programmes, all live skates are released and as a result are not included in catch data. Other fish bycatch species, including moray cods (*Muraenolepis* spp.), morid cods (mainly *Antimora rostrata*), icefish (mainly *Chionobathyscus dewitti*), and rock cods (*Trematomus* spp.) each contribute 1% or less of the overall catch (Stevenson et al 2014).

Table 3: Catches of managed bycatch species (macrourids, rajids, and other species) in the Ross Sea region. Live rajids cut from the longlines and released are not included in estimated of catch. Numbers of rajids released include tagged and not tagged. Source: fine-scale data.

Season	Macrourids Catch limit (t)	Macrourids Reported catch (t)	Rajids Catch limit (t)	Rajids Reported catch (t)	Rajids Number released	Other species Catch limit (t)	Other species Reported catch (t)
1996–97	–	0	–	0	–	–	0
1997–98	–	9	–	5	–	50	1
1998–99	–	22	–	39	–	50	5
1999–00	–	74	–	41	–	50	7
2000–01	–	61	–	9	–	50	11
2001–02	100	158	–	25	–	50	10
2002–03	610	65	250	11	1 932	100	12
2003–04	520	319	163	23	3 703	180	23
2004–05	520	462	163	69	5 705	180	22
2005–06	474	266	148	5	16 463	160	17
2006–07	485	153	152	38	8 786	160	41
2007–08	426	112	133	4	8 474	160	18
2008–09	430	183	135	7	9 018	160	15
2009–10	430	119	142	8	9 052	160	15
2010–11	430	190	142	4	5 456	160	8
2011–12	430	143	164	1	2 241	160	4
2012–13	430	127	164	4	5 711	160	10
2013–14	430	129	152	2	5 534	160	15
2014–15	430	92	142	6	12 981	160	26
2015–16	430	93	143	6	6 016	160	21
2016–17	430	67	143	4	3 866	160	11
2017–18	485	82	157	8	6 052	157	14
2018–19	485	147	157	9	8 885	157	25
2019–20	485	118	157	15	20 027	157	32
2020–21	485	125	157	10	9 482	157	31

Current catch limits for macrourids in Statistical Subarea 88.1 were derived from biomass estimates from the IPY-2008 trawl survey for the slope of the Ross Sea (see below). In each of the 2003–04, 2004–

05, and 2005–06 seasons, the bycatch limit for *Macrourus* spp. was exceeded in at least one of the SSRUs leading to the closure of the fishery in those areas. No bycatch limit has been exceeded since then. The catch limit for macrourids in Statistical Subarea 88.2 remains at 16% of the toothfish catch limit for each management area.

Current catch limits for rajids and other species in Statistical Subarea 88.2 are proportional to the catch limit of *Dissostichus* species in each small-scale research unit (SSRU) based on CM 33-03 (Table 4). Catch limits for rajids or for other species have never been exceeded.

Table 4: Catches of managed bycatch species (macrourids, rajids, and other species) in Statistical Subarea 88.2. Rajids cut from the longlines and released are not included in these estimates. Source: fine-scale data.

Season	Macrourids		Rajids			Other species	
	Catch limit (t)	Reported catch (t)	Catch limit (t)	Reported catch (t)	Number released	Catch limit (t)	Reported catch (t)
1996–97	–	0	–	0	–	–	0
1997–98	–	0	–	0	–	–	0
1998–99	–	0	–	0	–	–	0
1999–00	–	0	–	0	–	–	0
2000–01	–	0	–	0	–	–	0
2001–02	40	0	–	0	–	20	0
2002–03	60	18	–	0	–	140	8
2003–04	60	37	50	0	107	140	8
2004–05	60	20	50	0	–	140	3
2005–06	78	84	50	< 1	923	100	12
2006–07	88	54	50	< 1	–	100	13
2007–08	88	17	50	0	–	100	4
2008–09	90	58	50	< 1	265	100	13
2009–10	92	49	50	0	–	100	15
2010–11	92	51	50	< 1	169	100	13
2011–12	84	29	50	< 1	–	120	11
2012–13	84	25	50	0	–	120	8
2013–14	62	7	50	< 1	28	120	3
2014–15	99	19	50	1	192	120	6
2015–16	99	52	50	< 1	861	120	3
2016–17	99	22	31	1	314	99	2
2017–18	99	22	31	0	104	99	3
2018–19	143	21	45	< 1	217	143	3
2019–20	143	42	45	< 1	571	143	5
2020–21	143	16	45	< 1	194	143	3

4.2 Population assessments for rajids and macrourids

Rajids

Preliminary estimates of the age and growth of *Amblyraja georgiana* in the Ross Sea suggested that these skates initially grow very rapidly for about five years, after which growth almost ceases (Francis & Ó Maolagáin, 2005). However, Francis & Gallagher (2008) presented an alternative interpretation of age and growth in *A. georgiana* that is radically different from the published interpretation. By counting fine growth bands in the caudal thorns instead of broad diffuse bands, they generated growth curves that suggest much slower growth, greater ages at maturity (about 20 years compared with 6–11 years) and greater maximum ages (28–37 years compared with 14 years). Several pieces of circumstantial evidence support the new interpretation, but a validation study is required to determine which growth scenario is correct. Updated length-weight relationships for skates were provided by Francis (2010).

An experimental skate tagging programme in the Ross Sea fishery was started in 2000, and a preliminary assessment of skates completed by Dunn et al (2007). A fishery-wide tagging programme and sampling programme for skates was instituted by CCAMLR in 2008–09. It was anticipated that this initiative would lead to more Antarctic skates being tagged in Statistical Subareas 88.1 and 88.2. However, only 1907 and 99 skates were tagged in Statistical Subareas 88.1 and 88.2 respectively in 2008–09. This programme was extended for the 2009–10 season but discontinued in 2010–11. A 2-year skate tagging and age validation programme was implemented for the 2019–20 and 2020–21 fishing seasons (SC-CAMLR XXXVII paragraph 5.7).

Mormede & Dunn (2010) provided a characterisation of skate catches in the Ross Sea region. The paper concluded that aspects of the catch history were very uncertain, including the species composition, the weight and number of skates caught, the proportion discarded, and the survival of those fish that were

tagged. Although the size composition of the commercial catch was uncertain before 2009 because of the low numbers sampled each year, data collected in 2008–10 resulted in improved estimates of the length frequency of the catch. Tag data were also improved, with a total of about 3300 *Amblyraja georgiana* and 700 *Bathyraja* cf. *eatoni* tagged and a total of 179 skates recaptured as of 2010. A tagging programme for skates was implemented in the Ross Sea region in 2020 for two seasons, with some vessels volunteering to inject skates tagged and released with either strontium chloride or oxytetracycline (Parker & Francis 2019) to mark thorns to validate age estimation.

Macrourids

In 2011, it was recognised that specimens originally identified in the Ross Sea region as *M. whitsoni* did in fact comprise two sympatric species: *M. whitsoni* and *M. caml* (Smith et al 2011, McMillan et al 2012). *M. caml* grows larger than *M. whitsoni* and is about 20% heavier for a given length (Pinkerton et al 2013). The two species can be distinguished morphologically through two main characters (number of rays in the left pelvic fin; number of rows of teeth in the lower jaw). The distribution of *M. whitsoni* and *M. caml* seems to almost completely overlap by depth and area, with both appearing to be abundant between depths of 900 and 1900 m. Catches of females of both species exceed that of males (especially for *M. caml*) and this sex-selectivity cannot be explained by size or age of fish (Pinkerton et al 2013). It is almost certain that previous work which was presumed to have been carried out on *M. whitsoni* would actually have been carried out on a mix of the two species. However, it is now possible to distinguish between the species based on their otolith morphometrics (Pinkerton et al 2014b), so otoliths collected in previous years of the fishery or from toothfish stomachs can be identified to species.

Otolith ageing data show that the two species have very different growth rates (Pinkerton et al 2013). *M. whitsoni* approaches full size at about 10–15 years of age and can live to at least 27 years, whereas *M. caml* reaches full size at about 15–20 years and can live for over 60 years. Sexual maturity in female *M. whitsoni* is reached at 52 cm and 16 years, but in female *M. caml* at 46 cm and 13 years. Gonad staging data imply that the spawning period of both species is protracted extending from before December to after February.

The IPY trawl survey of the Ross Sea slope was carried out in 2008 leading to a biomass estimate of macrourids for the first time. Biomass and yield estimates of *Macrourus* spp. for the Ross Sea fishery based on extrapolations under three different density assumptions from the trawl survey were given by Hanchet et al (2008) (Table 5). The resulting biomass estimates had a CV of about 0.3.

Table 5: Biomass estimates of *Macrourus* spp. from the trawl surveys for the BioRoss 400–600 and 600–800 m and IPY-CAML 600–1200 and 1200–2000 m strata and extrapolated biomass estimates (with CVs) for the remaining strata based on three methods of extrapolation.

Survey	Depth range (m)	Biomass (t)	Extrapolated biomass (t)		
			constant density	CPUE (all vessels)	CPUE (NZ vessels)
BioRoss – 88.1H	400–600	230	230 (49)	230 (49)	230 (49)
BioRoss – 88.1H	600–800	3 531	3 531 (38)	3 531 (38)	3 531 (49)
SSRU 88.1H west	800–1200		92 (50)	83 (54)	103 (55)
SSRU 88.1H west	1200–2000		713 (40)	1 114 (49)	1 038 (47)
IPY - 88.1H	600–1200	975	975 (50)	975 (50)	975 (50)
IPY - 88.1H	1200–2000	3 356	3 356 (40)	3 356 (40)	3 356 (40)
SSRU 88.1 I	600–1200		3 297 (50)	7 883 (51)	5 992 (50)
SSRU 88.1 I	1200–2000		4 670 (40)	11 168 (42)	8 576 (41)
SSRU 88.1 K	600–1200		1 539 (50)	5 027 (51)	2 774 (51)
SSRU 88.1 K	1200–2000		2 998 (40)	5 995 (45)	9 111 (43)
HIK Sub-total			21 410		
SSRU 88.2 A+B	600–1200		1 404 (50)	1 396 (58)	857 (60)
SSRU 88.2 A+B	1200–2000		4 087 (40)	525 (70)	—
88.2 A, B Sub-total			5 491		
Total			26 892 (29)	41 823(28)	36 542(30)

Yield estimates were calculated using the constant density assumption when extrapolating the biomass estimate across the slope region, noting that this would provide a more precautionary estimate of yield than one based on extrapolations using longline CPUE data. The resulting biomass estimate for SSRUs 88.1HIK was 21 410 t which gave a yield estimate of 388 t. This yield estimate was then apportioned across the 5 SSRUs taking into account maximum historical catches (Table 6). The catch limits per SSRU detailed in Table 6 have been used by CCAMLR since the 2009–10 season.

Table 6: Estimated yield, maximum historic catch, and revised catch limit of *Macrourus spp*. for the Ross Sea fishery.

Region	Estimated yield	Maximum historic catch	Revised catch limit
88.1BCG	–	34	40
88.1HIK	} 388	390	320
88.1JL		52	70
88.1M	0	0	0
88.2AB	100	8	0
Total	488		430

Additional trawl-based surveys (18 tows in 4 strata) were carried out in 2015 on TAN1502 (O'Driscoll & Double 2015) and in 2019 (TAN1901), but the new information has not yet been used to develop updated biomass estimates for *Macrourus* spp (or other bycatch species) on the Ross Sea slope.

The use of acoustic data to monitor trends in relative abundance of macrourids has also been explored (O'Driscoll et al 2012, Ladroit et al 2014). These studies have shown positive correlations between acoustic targets and longline catches of grenadiers, and the acoustic target strength distribution of single targets is similar to that predicted, based on the expected size range of grenadiers. However, variability in spatial coverage between years means that it is currently not possible to obtain a consistent time series of relative abundance estimates for grenadiers from acoustic data collected opportunistically by New Zealand vessels in the fishery. Recent acoustic research on toothfish suggests that the target strength of toothfish may overlap that of grenadiers (O'Driscoll et al 2018).

Identification of levels of risk from bycatch

Risk categorisation tables were prepared for rajids and macrourids by O'Driscoll (2005) based on the risk status categories of Castro et al (1999). *Amblyraja georgiana* were categorised as risk category 3, which are "species that are exploited by directed fisheries or bycatch, and have a limited reproductive potential, and/or other life history characteristics that make them especially vulnerable to overfishing, and/or that are being fished in their nursery areas". The risk to *A. georgiana* is mitigated due to the requirement to cut rajids from longlines while still in the water and release them.

Macrourus whitsoni were categorised as between risk category 2 and 3 but this analysis predates the realisation of two species of *Macrourus* in the Ross Sea. Risk category 2 includes "species pursued in directed fisheries, and/or regularly found in bycatch, whose catches have not decreased historically, probably due to their higher reproductive potential".

Ecosystem effects associated with bycatch are thought to be less likely than those associated with predation release (see Section 4.6).

Mitigation measures

Since the start of the 2000–01 season, rajids likely to survive have been cut free and released at the surface as a measure to reduce rajid mortality. The survival of at least some of these skates has been demonstrated by the recapture of over 130 tagged skates as of 2010 (Mormede & Dunn 2010), and by the results of survivorship experiment in tanks carried out by the UK.

There is a 'move-on' rule in place to help prevent excessive fishing in localised areas of high abundance of bycatch species. This rule requires a vessel to move to another location at least 5 nm distant if the bycatch of any one species is equal to or greater than 1 tonne in any one set. The vessel is not allowed to return to within 5 nm of the location where the bycatch exceeded 1 tonne for a period of at least five days.

4.3 Incidental capture of protected species (seabirds and marine mammals)

Only two seabirds have ever been caught in this toothfish fishery: both were Southern giant petrels (*Macronectes giganteus*). One was caught in 2003–04 and the second in 2013–14 (Table 7). None have been reported since 2014. Considerable effort has been put into mitigation of seabird captures in the fishery, through implementation of CCAMLR Conservation Measures regarding line sink rate, use of streamer lines, seasonal restrictions on fishing, prohibition of offal dumping, line weighting, and only

allowing daytime setting under strict conditions.

Table 7: Seabird incidental mortality limit, reported seabird incidental mortality, incidental mortality rate, and estimated incidental mortality in Statistical Subareas 88.1 and 88.2.

Season	Incidental mortality limit	Incidental mortality rate (seabirds/thousand hooks)	Estimated incidental mortality
1997–98		0	0
1998–99		0	0
1999–00		0	0
2000–01		0	0
2001–02	3*	0	0
2002–03	3*	0	0
2003–04	3*	0.0001	1
2004–05	3*	0	0
2005–06	3*	0	0
2006–07	3*	0	0
2007–08	3*	0	0
2008–09	3*	0	0
2009–10	3*	0	0
2010–11	3*	0	0
2011–12	3*	0	0
2012–13	3*	0	0
2013–14	3*	0.0001	1
2014–15	3*	0	0
2015–16	3*	0	0
2016–17	3*	0	0
2017–18	3*	0	0
2018–19	3*	0	0
2019–20	3*	0	0
2020–21	3*	0	0

* Per vessel during daytime setting.

Assessments of the potential risk of interaction between seabirds and longline fisheries (ranging from low to high) have remained unchanged since 2007. The risk levels of seabirds in the fishery in Statistical Subarea 88.1 is category 1 (low) south of 65° S, category 3 (average) north of 65° S, and overall is category 3 (SC-CAMLR-XXX, Annex 8, paragraph 8.1).

Implementation of the required CCAMLR Conservation Measures has meant that seabird captures have been successfully avoided during this toothfish longline fishery. There is a high degree of certainty in the estimates provided of seabird captures, given the high level of observer coverage (100% of vessels covered by two observers, up to 40% of all hooks hauled directly observed).

4.4 Maintenance of ecological relationships

FEMA workshops

Developments in evaluating ecosystem effects of the Antarctic toothfish fishery were discussed at the FEMA (Fisheries and Ecosystem Models in the Antarctic) and FEMA II workshops (SC-CAMLR-XXVI/BG/6, paragraphs 45 to 48 and SC-CAMLR-XXVIII/3). The FEMA and FEMA II workshops noted that the fishery for Antarctic toothfish may affect ecological relationships in the Ross Sea region by influencing interactions between toothfish and its predators or interactions between toothfish and its prey. Effects of fishing may also "cascade" through marine food-webs as indirect effects.

The FEMA II workshop also noted that the escapement level of 50% is the proportion of spawning biomass permitted to escape the fishery over the long term, and that as a consequence, the sub-mature fish would have a much higher escapement (e.g., > 90% for fish < 100 cm) (SC-CAMLR-XXVIII, Annex 3, figure 1). However, the FEMA II workshop noted that the escapement level in the decision rule for the spawning biomass may need to be modified upwards if the size/age classes of *Dissostichus* spp. that are important prey for predators are reduced below the level needed to safeguard predators.

Effects on predators of toothfish

The predators of toothfish include Type C killer whales, odontocetes (sperm whales (historically)) and Weddell seals (Eisert et al 2013, 2014, Torres et al 2013, Pinkerton et al 2010). A mass-balance food-web model suggested that toothfish formed about 6–7% of the diet of its predators at the scale of the Ross Sea averaged over a year (Pinkerton et al 2010). The model does not exclude the possibility that the consumption of toothfish in particular locations at particular times of the year, or by particular

components of predator populations may be important to some predators, even though the model suggests that the total consumption of toothfish by all individuals of a predator species is relatively low. Few data are available on consumption of toothfish by marine mammals, and results derived from this model should be treated as preliminary until better information can be obtained.

With respect to Weddell seals, Pinkerton et al (2008) and Eisert et al (2013) reviewed information on interactions with toothfish from habitat overlap estimates, diver observations, animal-mounted cameras, stomach contents, vomit and scat (faecal) analysis, stable isotopes of carbon and nitrogen, and also compared natural mortality rates of Antarctic toothfish in McMurdo Sound with potential consumption by Weddell seals. Energetic analyses of other potential Weddell seal prey in McMurdo Sound compared to Weddell seal seasonal dietary requirements suggest that toothfish are likely to be important preys during particular times of year and in particular locations but are unlikely to be a major dietary component throughout the year (Eisert et al 2013). The contribution of toothfish to Weddell seal diets is being investigated over two time scales, (1) using scat DNA analysis during the post-breeding/moult period (identified as a period potentially requiring increased food intake to recover body condition lost during lactation), and (2) using stable isotope analysis of whiskers to obtain a dietary record for an entire annual cycle. Seals have been marked by injection of ^{15}N-labelled glycine in the 2013–14 season for recapture in the 2014–15 season. The ^{15}N-label is detectable as a spike in the values for whiskers and provides a time-stamp for the stable isotope pattern preserved in whiskers. In addition, winter foraging areas are being investigated using satellite-linked data loggers deployed on Weddell seals to investigate potential spatial overlap with the fishery and to identify areas of particular importance to these predators.

Torres et al (2013) considered the available evidence regarding the importance of toothfish as prey for killer whales in the Ross Sea. Killer whales with toothfish in their mouths have been observed in McMurdo Sound (Eisert et al 2014), but the proportion of toothfish consumed by killer whales in the Ross Sea in general is not known. The available data—on habitat overlap, stable isotopes, and a comparison between natural mortality rates of Antarctic toothfish in McMurdo Sound and potential consumption by killer whales—were limited and inconclusive. At present, the balance of evidence suggests that toothfish are likely to be significant in the diet of type C killer whales in McMurdo Sound in summer, but it is not possible to say whether toothfish are an important prey item to type C killer whales in other locations on the Ross Sea shelf or at the scale of the whole Ross Sea shelf and slope (Torres et al 2013). An important consideration for type C killer whales, as for Weddell seals, is that toothfish, due to their large mass and high energy content, may be a unique food resource that is required to support periods of high energy demand such as lactation (Eisert et al 2014). Field work on this issue includes: (a) collecting dart (small tissue) biopsies for stable isotope analysis and (b) compiling a photo-identification catalogue of killer whales that can be used to study habitat use, migration patterns, and to estimate abundance from mark-recapture analysis.

Effects on prey of toothfish
The mass-balance food-web model suggested that toothfish consumed 64% of the annual production of demersal species as prey items (Pinkerton et al 2010), and so a reduction of the toothfish population might lead to a large reduction on the mortality of these species through a 'predation release' effect. As toothfish are large and mobile, their prey species are long-lived, and functional predator diversity seems to be low, then the potential predation release effect is likely to be high in the Ross Sea region (Pinkerton & Bradford-Grieve 2014). Mormede et al (2014d) described the development of a spatially explicit minimum realistic model of demersal fish population dynamics, predator–prey interactions, and fishery removals based on the spatial population model (SPM) for toothfish in the Ross Sea. The model includes *D. mawsoni* as well as macrourids and channichthyids, the two groups that make up about 50% of *D. mawsoni* prey. The model indicates that channichthyids, with a relatively high productivity, would be expected to substantially increase in abundance within fished locations as predation pressure by toothfish is decreased, particularly in SSRU 88.1H where historical fishery removals have been most concentrated. Macrourids would be expected to show a modest increase in biomass based on their lower productivity.

Cascading ecological effects

Changes to the abundance of toothfish prey species may have effects on other species in the food-web through second-order effects (e.g., a 'keystone' effect[3] or trophic cascades[4]), however, these are likely to be dependent on the particular ecosystem and are difficult to predict. The potential ecosystem effects of fishing in the Ross Sea region were investigated using mixed trophic impact (MTI) analysis (Pinkerton & Bradford-Grieve 2014). Overall, Antarctic toothfish had moderate trophic importance in the Ross Sea food web as a whole and the MTI analysis did not support the hypothesis that changes to toothfish will cascade through the ecosystem by simple trophic effects. Because of limitations to MTI analysis, cascading effects on the Ross Sea ecosystem due to changes in the abundance of toothfish cannot be ruled out, but, for such changes to occur, a mechanism other than simple trophic interactions is likely to be involved.

Between 2001 and 2013 the number of breeding pairs of Adélie penguins at colonies in the southwestern Ross Sea more than doubled. It has been suggested that this increase was caused by the fishery for Antarctic toothfish leading to mesopredator release of Antarctic silverfish (*Pleuragramma antarctica*), a shared prey of toothfish and Adélie penguins (Lyver et al 2014, Ainley et al 2016). The study of Pinkerton et al (2016) brought together information from multiple models to estimate the biomass of silverfish that could be released from predation through the effects of the toothfish fishery. New (unpublished) diet data for toothfish over the Ross Sea shelf were used. The results of the modelling were inconsistent with predation release of silverfish due to the toothfish fishery being responsible for recent increases in the number of Adélie penguins breeding in the southwestern Ross Sea (Pinkerton et al 2016). The cause of the increase in Adélie penguins breeding in the Ross Sea region remains unknown.

4.5   Effects of fishing on biogenic habitats

In 2006, the United Nations General Assembly (UNGA) agreed the Sustainable Fisheries Resolution (61/105), which calls on States and RFMOs or other arrangements to ensure fish stocks are managed sustainably and to prevent significant adverse impacts on vulnerable marine ecosystems (VMEs, UNGA Resolution 61/105, OP80–OP91). The 23 taxa included as VME indicator taxa (Parker & Bowden 2010) are defined in the CCAMLR VME taxa classification guide, which is available on the CCAMLR website (http://www.ccamlr.org/pu/e/sc/obs/vme-guide.pdf).

CCAMLR has implemented several Conservation Measures pertaining to VMEs that form an approach to constrain gear types used, constrain areas fished, monitor fishing effort for evidence of VMEs, and to provide information in order to evaluate the potential effects of fishing on VMEs.

Sharp et al (2009) developed a bottom fishing impact assessment method, which was revised by Sharp (2010), and subsequently adopted by the Commission and used to summarise the current spatially-resolved fishing footprint and potential impact (% mortality) within the fishing footprint. This assessment method has demonstrated that regardless of the distribution of VMEs within the fishing footprint, the level of impact is exceptionally low.

Parker et al (2010) analysed spatial patterns of VME taxa from fishery bycatch in the Ross Sea region. Some taxa are relatively common as bycatch (e.g., Porifera, anemones, stylasterid hydrocorals) and the detectability of habitats containing these taxa with autoline longline gear is moderate to high (e.g., 70+%), enabling the use of fishery longline bycatch as a monitoring tool. This study also showed that VME taxa distributions vary spatially within the Ross Sea, and that some areas have shown no evidence of VME taxa despite consistent fishing effort.

Following fishery impacts, the potential recovery times for the VME taxa in the Ross Sea with the lowest productivities were evaluated with a spatially explicit production model (Dunn et al 2010). This model also showed that with the current understanding of fishing gear performance, fishing effort

---

[3] Keystone predators maintain biodiversity by preferentially consuming competitively dominant prey species. If keystone predators are removed or their biomass reduced, abundance of some prey species can increase to levels where they start to exclude subordinate competitors.
[4] Trophic cascade: reorganisation of the lower trophic levels of an ecosystem due to the change in abundance of a predator.

distribution, and VME taxon life history, fishery impacts are low and recovery is likely to take place under the current management response to high bycatch levels. However, methods to determine the presence of high densities of rare taxonomic groups or unique community assemblages specific to the Ross Sea Region may need to be developed.

CCAMLR maintains a register of designated VMEs with two designated on the Admiralty seamount in the Ross Sea as well as several shallow water VMEs in Terra Nova Bay. VME Risk Areas have also been designated based on an observed fishery bycatch of over 10 kg or litres of VME taxa in a 1200-m longline segment. A total of 59 VME Risk Areas have been designated in Statistical Subarea 88.1 and 16 in Statistical Subarea 88.2, each closing a 1 nautical mile radius area surrounding the location of the bycatch observation to bottom fishing until reviewed by the Commission.

4.6   Ecosystem indicators

At present our ability to predict the effects of the toothfish fishery on ecosystem relationships in the Ross Sea region is limited. There is a need to develop and implement appropriate monitoring in the Ross Sea to ascertain how species and ecological relationships are affected by the fishery as a main objective of the Ross Sea MPA (CM 91-05). Monitoring should focus on species most likely to be affected by the toothfish fishery in the first instance. Baseline data on toothfish diet have been developed for some areas. Periodic analysis of the stomach contents of toothfish can be used to look for changes in toothfish diet that may be indicative of changes to the demersal fish community, although power analysis is needed to determine the effect size detectable. Better direct information is required on the abundance of *Macrourus* spp. and icefish on the Ross Sea slope, which will require significant trawl survey effort. Research continues to test the extent to which acoustic methods could be used to detect changes in *Macrourus* spp. abundance at the fishery scale (O'Driscoll et al 2012, Ladroit et al 2014).

Annual surveys of toothfish abundance in the southwest Ross Sea have been carried out since the 2011–12 season and the intention is for these to continue annually. As well as providing an index of abundance of 5–10-year-old toothfish this survey provides information on changes to the availability of toothfish to predators in this region, especially in McMurdo Sound and Terra Nova Bay.

5.   STOCK ASSESSMENT

Estimates of biomass and long term yield (using the CCAMLR Decision Rules) were provided in 2021 for Antarctic toothfish for the Ross Sea region stock (Statistical Subarea 88.1 and Statistical Subarea 88.2 SSRUs 88.2A and B) based on analyses using catch-at-age from the commercial fishery, tag-recapture data, and estimates of biological parameters as reported below (Grüss et al. 2021c). This was the eleventh stock assessment of the Ross Sea fishery.

In 2014, the approach used in previous assessments of the Amundsen Sea stock (Statistical Subarea 88.2 SSRUs 88.2C–H) was rejected by CCAMLR because the models were unable to fit the patterns in the tag recapture data. Instead, a two-year research plan was developed by CCAMLR to collect the data required to address uncertainties in the previous assessment model. Two area models for the Amundsen Sea stock have been developed (Mormede et al 2013, Mormede et al 2014a, Mormede et al 2014b, Mormede et al 2015b, Mormede et al 2016), and the two-year research plan was extended through the 2020–21 season). The key aspects of the plan, including derivation of catch limits are discussed below under Section 5.2(ii).

5.1   Estimates of fishery parameters and abundance indices

CPUE indices

A standardised CPUE analysis of Antarctic toothfish in the Ross Sea fishery showed a gradually increasing trend through 2008 followed by a slight decline until 2012; CPUE has been stable since (Grüss et al. 2021a, **Error! Reference source not found.**).

The patterns of increase and declines in the annual CPUE indices are thought to reflect a combination of either good or poor ice conditions, vessel crowding, increasing fisher experience, improved knowledge of optimum fishing practice, improvements in gear, and regulation changes (i.e., move-on

rules and research set requirements), and will also be affected by movement patterns of toothfish rather than toothfish abundance (Maunder et al 2006).
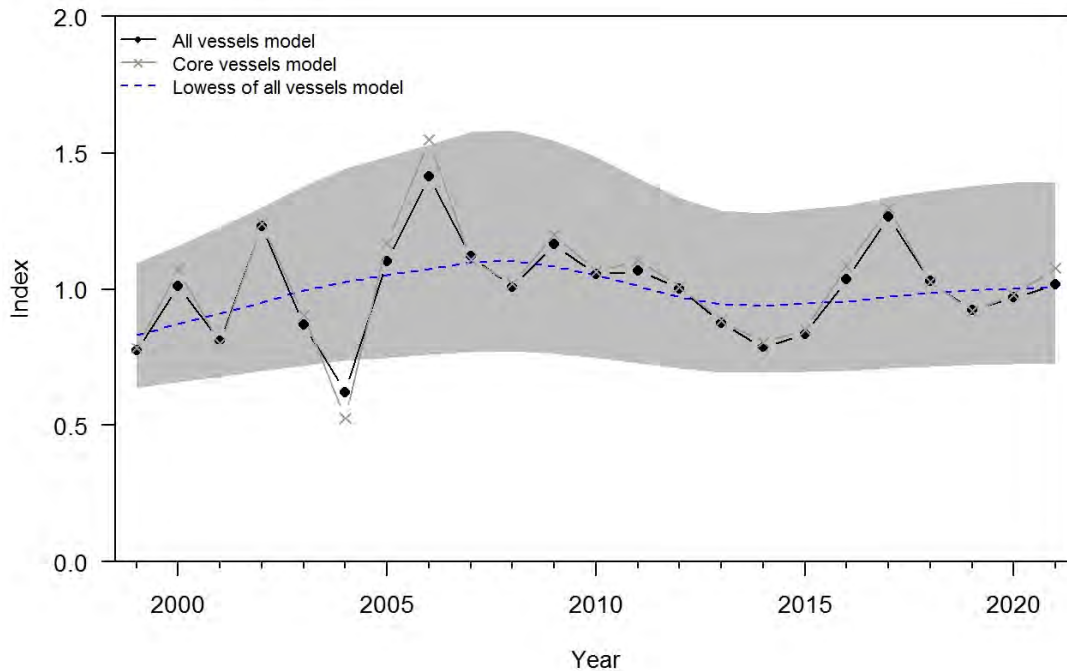
Figure 4: Relative CPUE indices (scaled to have mean of one) for the 'all vessels' model and the core vessels (involved in the fishery for at least four years) model for the Ross Sea fishery, 1999–2021. Blue dashed line shows loess fit with 95% confidence intervals (grey area).

A standardised CPUE analysis of Antarctic toothfish in SSRU 88.2H shows a steep decline at the beginning of the fishery when there had still been little fishing in the area followed by a more recent increase. Standardised CPUE in SSRUs 88.2C–G shows an increase over time with levelling off in the most recent years. In both SSRU 88.2H and SSRUs 88.2C–G the confidence bounds are very wide for the first part and later part of the time series (Large et al 2015) (Figure). There has been little consistent fishing effort in Statistical Subarea 88.2 until recent years and, as for the Ross Sea, the patterns of increase and declines in the CPUE indices are thought to reflect a combination of fishery and environmental factors rather than toothfish abundance (Maunder et al 2006). The CPUE analysis in 88.2H has not been updated since 2015.
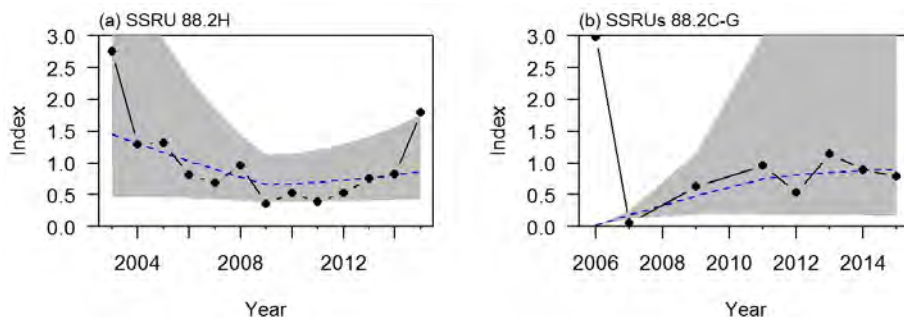
Figure 5: Relative CPUE indices (scaled to have mean of one) for (a) the SSRU 88.2H fishery, and (b) the SSRU 88.2C–G fishery, 2003–2015. Blue dashed lines show smoothed fit with 95% confidence intervals (grey area).

Mark-recapture data

The tagging program for *Dissostichus* spp. in the Ross Sea was first initiated in the 2000–01 season in Statistical Subarea 88.1 by New Zealand vessels participating in the fishery (Parker & Mormede 2017a). Since then, the toothfish tagging programme has been made a requirement for all vessels participating

in the fishery in both the Ross Sea region and Amundsen Sea region.

An index of vessel-specific tag detection performance for the Ross Sea fishery using a case-control methodology was developed by Mormede & Dunn (2013) and further refined into the calculation of effective tag release survival rate and effective tag detection rate of recaptured fish (Mormede 2014). The method controls for the inter-annual spatial and temporal variability of commercial fishing operations from which tagged fish are released and recaptured.

Between 2001 and 2021, approximately 9 000 *Dissostichus* spp. have been tagged in Statistical Subareas 88.1 and 88.2, with just over 54 000 and more than 15 000 *D. mawsoni* in the Ross Sea and SSRUs 88.2C–H, respectively (Grüss et al 2021a,b). Recaptured fish at liberty for more than six years and within-season recaptures were not used in the assessment.

In 88.2, although more than 2500 tags had been released on the shelf and slope of Statistical Subarea 88.2 (SSRUs 88.2C–G) by 2014, few fish had been recaptured, likely reflecting the inconsistent pattern of fishing in these areas. The Scientific Committee recognised the need to develop an estimate of abundance for the south of 88.2 and recommended a two-year research plan to collect the necessary information (SC-CAMLR-XXXIII 2014, paragraph 3.168). As part of the approved research plan, fishing effort in the south was restricted to four fishing blocks for the 2014–15 and 2015–16 fishing seasons to increase the likelihood of tagged fish being recaptured. This approach has led to an increase in the tag recapture rate. The Scientific Committee considered that the research plan was providing the information necessary to develop the stock assessment and recommended that it be extended with increased tagging rate in the north to 3 fish per tonne, consistent with the rate in the south (CCAMLR 2016c, SC paragraphs 3.215 and 3.216). At its 2018 meeting, the CCAMLR Scientific Committee recommended that the research plan in place for SSRUs 882C–H continues in the 2018–19 season following Scientific Committee advice (SC-CAMLR-XXXVII, paragraphs 3.183-3.188). This arrangement has been continued through the 2020-21 season with small changes in catch limit based on CCAMLR trend analysis procedures.

Catch-at-age data
Strata for the Antarctic toothfish length and age frequency data were determined after split into four strata based on area, N70, S70, SRZ and Other (areas now part of the General Protection Zone (GPZ) or the Krill Research Zone (KRZ)). On average, about 500 Antarctic toothfish otoliths collected by observers were selected for ageing each year, and used to construct annual area-specific age-length keys (ALKs) for the Ross Sea region. In the Ross Sea, ALKs for each sex were applied to the fisheries defined above separately. The ALKs were applied to the scaled length-frequency distributions for each year to produce annual catch-at-age distributions (Grüss et al 2021a). In the Amundsen Sea region (SSRU 88.2C–H) fishery, otoliths were only available from the New Zealand fleet, which did not fish there every year. Therefore, for this fishery, a single ALK for each sex using otolith ages from all available years was used to construct annual age frequencies for SSRU 88.2H, and SSRU 88.2C–G fisheries separately.

Recruitment surveys
Eleven years of an annual research longline survey of sub-adult (70–110 cm long) toothfish have now been carried out in the southern Ross Sea (Hanchet et al 2012, Parker et al 2013b, Mormede et al 2014c, Hanchet et al 2015, Dunn et al 2016, Large et al 2017, Stevens et al 2018, Parker et al 2019, Parker et al. 2020, Devine et al. 2021, Devine & Prasad (in prep)). Catches have increased since 2016 and there are changes in the length and age structure. Fewer small fish and more large-sized fish have been present since 2016 in the core strata. The age distribution also showed a smaller group of fish aged 10–20 remaining in the survey area. This suggests a slower movement of fish out of the shelf area compared with the early years of the survey. The survey age structure and local biomass estimations were incorporated into the 2021 assessment (Grüss et al. 2021c).

Parameter estimates
A list of parameter values used for the assessments is given in Table 8.

Table 8: Parameter values for *D. mawsoni* in Statistical Subareas 88.1 and 88.2.

Component	Parameter	Male	Female	All	Units
		Male	**Female**	**All**	
Natural mortality	M	0.13	0.13		y^{-1}
VBGF	K	-0.292	-0.712		y^{-1}
	t_0	0.101	0.082		y
	L_∞	164.06	180.49		cm
	c.v.	0.101	0.101		
Length to mass	'a'	0.00001247	0.00007361		cm, kg
Length to mass	'b'	2.990	3.105		
Length to mass variability (CV)				0.1	
Maturity	A_{m50}	11.99	16.92		y
Range: 5% to 95% maturity		9.3–16.3	9.3–23.9		y
Recruitment variability	σ_R			0.6	
Stock recruit steepness (Beverton-Holt)	h			0.75	
Ageing error (CV)				0.1	
Initial tagging mortality				10%	
Instantaneous tag loss rate (single tagged)				0.062	y^{-1}
Instantaneous tag loss rate (double tagged)				0.0084	y^{-1}
Tag detection rate				99.3%	
Tagging related growth retardation (TRGR)				0.5	y

5.2 Biomass estimates

(i) The Ross Sea fishery (Statistical Subarea 88.1 and SSRUs 88.2A and 88.2B)

The stock assessment model

The model was sex- and age-structured, with ages from 1–50, where the last age group was a plus group (Grüss et al. 2021c). The annual cycle was broken into three discrete time steps, nominally summer (November–April), winter (May–October), and end-winter (age-incrementation) (Table 9).

The model was run from 1995 to 2021 and was initialised assuming an equilibrium age structure at an unfished equilibrium biomass, i.e., a constant recruitment assumption. Recruitment was assumed to occur at the beginning of the first (summer) time step. Recruitment sex ratio was assumed to be 50:50 and was parameterised as a year class strength multiplier (assumed to have mean equal to one over a defined range of years), multiplied by an average (unfished) recruitment (R_0) and a spawning stock-recruitment relationship. In this model, the year class strength multipliers were assumed fixed, and set equal to 1.

Table 9: Annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

Step	Period	Processes	M^1	Age^2	Observations	
					Description	M^3
1	Nov–April	Recruitment and fishing mortality	0.5	0.0	Tag-recapture	0.5
					Catch-at-age proportions	0.5
2	May–November	Spawning	0.5	0.0		
3	-	Increment age	0.0	1.0		

[1.] M is the proportion of natural mortality that was assumed to have occurred in that time step.
[2.] Age is the age fraction, used for determining length at age, which was assumed to occur in that time step.
[3.] M is the proportion of the natural mortality in each time step that was assumed to have taken place at the time each observation was made.

The base-case model was implemented as a single-area, multiple fishery model. A single area was defined with the catch removed using three main concurrent fisheries (N70, S70, SRZ), with additional fisheries for IUU, and catches of the Ross Sea stock in the SPRFMO Area. Selectivity for each fishery was parameterised by a sex-based double-normal ogive (i.e., domed selectivity). In the 2013 assessment, the selectivity allowed for annual selectivity shifts that shifted the ogive left or right (shelf fishery) with changes in the mean depth of the fishery (slope and north fisheries in the Ross Sea) but this was removed in 2015 following CCAMLR recommendation. The double-normal selectivity was parameterised using four estimable parameters and allowed for differences in maximum selectivity by sex; the maximum selectivity was fixed at one for males but estimated for females. The double-normal

selectivity ogive was employed because it allowed the estimation of a declining right-hand limb in the selectivity curve.

Fishing mortality was applied only in the first (summer) time step. The process was to remove half of the natural mortality occurring in that time step, then apply the mortality from the fisheries instantaneously, then to remove the remaining half of the natural mortality.

The population model structure includes tag-release and tag-recapture events. Each tagged fish was assigned an age-sex based on its length and the modelled population structure of fish at that age and sex. Tagging from each year was applied as a single tagging event. The usual population processes (natural mortality, fishing mortality, etc.) were then applied over the tagged and untagged components of the model simultaneously. Tagged fish were assumed to suffer a retardation of growth from the effect of tagging (TRGR), equal to 0.5 of a year for the year immediately following release.

Model estimation

The model parameters were estimated using Bayesian analysis, first by maximising an objective function (MPD), which is the combination of the likelihoods from the data, prior expectations of the values of those parameters, and penalties that constrain the parameterisations; and second, by estimating the Bayesian posterior distributions using Markov chains Monte Carlo (MCMC). Initial model fits were evaluated at the MPD, by investigating model fits and residuals. Parameter uncertainty was estimated using MCMCs. These were estimated using a burn-in length of 5×10^5 iterations; with every 1000th sample taken from the next 1×10^6 iterations (i.e. a final sample of length 1000 was taken).

Observation assumptions

The catch proportions-at-age data for 1998–2020 were fitted to the modelled proportions-at-age composition using a multinomial likelihood. Following previous recommendations of WG-SAM that CPUE indices were not indexing changes in abundance, the CPUE indices were not used. Tag-release events were defined for the 2001–2020 years, weighted by the vessel-specific tag survival rate. Within-season recaptures were ignored. Tag-release events were assumed to have occurred at the end of the first (summer) time step, following all (summer) natural and fishing mortality.

The estimated number of scanned fish (i.e., those fish that were caught and inspected for a possible tag) was derived from the sum of the scaled length frequencies from the vessel observer records multiplied by the vessel-specific tag detection rate, plus the numbers of fish tagged and released. Tag recapture events were assumed to occur at the end of the first (summer) time step and were assumed to have a detection probability of 85% to account for unlinked tags.

For each year, the recovered tags at length for each release event were fitted, in 10 cm length classes (range 40–230 cm), using a binomial likelihood.

Process error and data weighting

Additional variance, assumed to arise from differences between model simplifications and real-world variation, was added to the sampling variance for all observations, following the methods of Francis (2011). Adding such additional errors to each observation type has two main effects: (i) it alters the relative weighting of each of the data sets (observations) used in the model, and (ii) it typically increases the overall uncertainty of the model, leading to wider credible bounds on the estimated and derived parameters. The additional variance, termed process error, was estimated for each MPD run, and the total error assumed for each observation was calculated by adding process error and observation error. A single process error was estimated for each of the observation types (i.e., one for the catch-at-age data and one for the tag-recapture data).

Penalties

Two types of penalties were included within the model. First, the penalty on the catch constrained the model from returning parameter estimates where the population biomass was such that the catch from an individual year would exceed the maximum exploitation rate. Second, a tagging penalty discouraged population estimates that were too low to allow the correct number of fish to be tagged. These penalties had no effect on the model outcome.

Priors

The parameters estimated by the models, their priors, the starting values for the minimisation, and their bounds are given in Table 10. In models presented here, priors were chosen to be relatively non-informative and that also encouraged conservative estimates of B_0.

Table 10: Number (N), start values, priors, and bounds for the free parameters (when estimated) for the Ross Sea base-case.

Parameter		N	Start value	Prior	Bounds	
					Lower	Upper
B_0		1	80 000	Uniform-log	1×10^4	1×10^6
Male fishing selectivities	a_1		8.0	Uniform	1.0	50.0
	s_L		4.0	Uniform	1.0	50.0
	s_R	9	10.0	Uniform	1.0	500.0
Female fishing selectivities	a_{max}		1.0	Uniform	0.01	10.0
	a_1		8.0	Uniform	1.0	50.0
	s_L		4.0	Uniform	1.0	50.0
	s_R	12	10.0	Uniform	1.0	500.0
YCS	YCS	7	1.0	Lognormal	0.001	100.0
Survey biomass	CV	1	0.001	Uniform	0	10.0

Base case and sensitivity models

The estimates of B_0 and current status for the base case (R1) and a sensitivity test (R2) are described in Table 11. The base-case model excluded quarantined mark-recapture and length data (but included catch removals from quarantined trips). A sensitivity model (R2) was carried out, which excluded the initial three years of tag-release data (2001–2003) and associated tag-recapture data. The initial three years of tag-release and associated tag recapture data (3.9% of all available tag data) were identified as potentially different in quality to the tag data since 2004, and this was a pilot targeting small fish to understand whether Antarctic toothfish tagging was feasible and to learn more about toothfish movement. Tagging was only introduced as a requirement in 2004 (under CM41-01/C), extending the pilot scheme to all vessels. The sensitivity evaluated the impact of removing these data on the base model.

Model estimates

MCMC samples from the posterior were estimated. MCMC diagnostics suggested no evidence of poor convergence in the key biomass parameters and between-sample autocorrelations were low.

Table 11: Median MCMC estimates (and 95% credible intervals) of B_0, B_{2021}, and B_{2021} as % B_0 for the 2019 base case model, the 2021 base case model (R1) and models R1 and R.2.

Model	B_0	B_{2021}	B_{2021} (% B_0)
2019	71 730 (65 890–78 730)	–	–
R1	78 373 (71 999–85 663)	49 034 (43 463–55 882)	62.7 (59.9–65.6)
R2	78 065 (71 729–86 362)	48 875 (43 229–56 554)	62.7 (59.8–65.9)

Key output parameters for the base case and the sensitivity are summarised in Table 12. Biomass was estimated as 63% B_0 (95% CIs 60–66%). Table 12 shows the estimated yields following the CCAMLR decision rules. The catch limit for the base case was 3495 t for the 2021–22 and 2022–23 seasons. The current stock status trajectory and uncertainty relative to the CCAMLR decision rules are shown in Figure 6.

Table 12: Estimated risks and the catch limit using the CCAMLR decision rules for the 2019 and the 2021 base case and the sensitivity model.

Model	Pr($SSB < 50\% B_0$)	Pr($SSB < 20\% B_0$)	Catch limit (t)
2019 base case	0.50	<0.01	3 140
2021 base case	0.50	<0.01	3 495
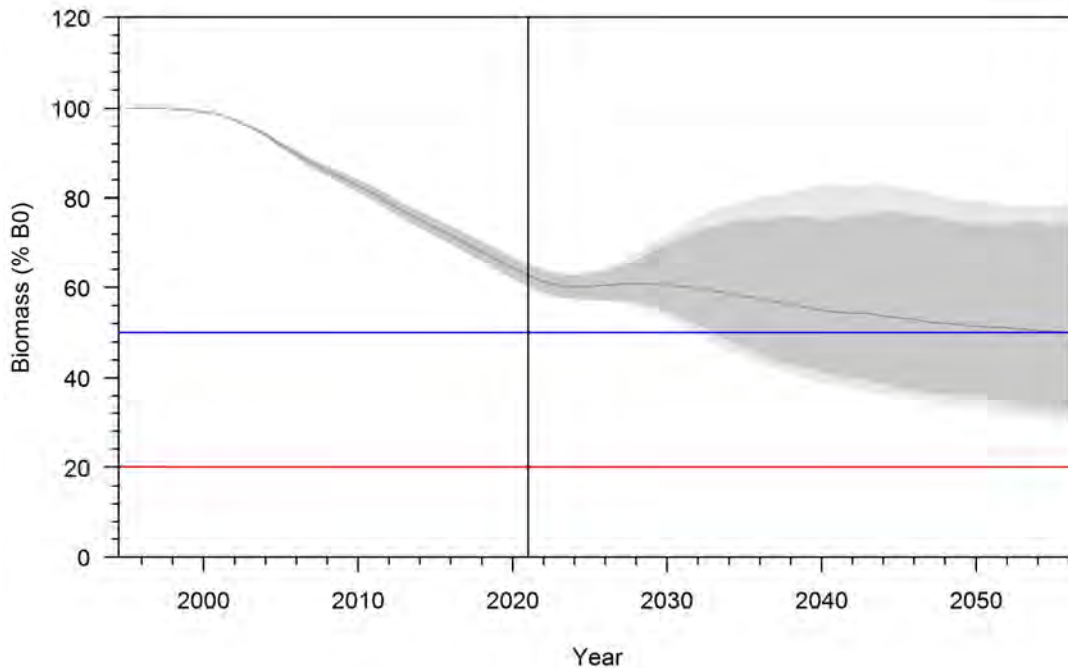
Figure 6: MCMC estimates of the spawning stock biomass trajectory as a percentage of initial biomass (black line) with the 90% and 95% (dark and light grey shading respectively), projected out to 2056 for the base case model run. Horizontal lines correspond to 50% B_0 and 20% B_0.

Diagnostic plots of the observed proportions-at-age of the catch versus expected values show little evidence of inadequate model fit. Estimated selectivity curves appeared reasonable, although the right-hand limb parameters lacked convergence. Post-MCMC analyses of the non-convergence in these parameters showed no evidence that the estimates of initial biomass were unduly influenced. The tag-recapture data are well fitted and provide most of the information on abundance in the model.

Year class strengths were estimated for the years 2003 to 2015. Estimates showed that there was stronger than average recruitment in 2005, 2013 and 2014, and weaker than average recruitment in 2003 and 2008. Fits to the survey biomass indices were within the confidence interval of the survey, although the trend in the survey is not represented well. This is likely a function of a number of factors including recent YCS not currently estimated, fewer older fish caught in the 2015 survey than previously (Hanchet et al 2015), and the amount of commercial fishing prior to the survey.

(ii) The Amundsen Sea region fishery (Statistical Subarea 88.2 SSRUs 88.2C–H)
There is no current stock assessment of the Amundsen Sea region fishery. A single area stock assessment model of the Amundsen Sea region was unable to fit the trends in the tag-recapture data, which came almost entirely from SSRU 88.2H (Mormede et al 2014a). Fits to the tag data from a two-area developmental model (SSRUs C-G versus SSRU H) were more encouraging but identified the need for additional recaptures of tagged fish from the southern SSRUs 88.2C–G (Mormede et al 2014b).

Fishing in the Amundsen Sea region (SSRUs 882C–H) has been managed through a research plan since the 2015 fishing season. The aim of the research plan is to collect sufficient information to carry out a reliable stock assessment of the toothfish stock in that area. The key feature of the initial two-year research plan was to restrict fishing effort to grounds in SSRUs 88.2C–G which had been fished previously to facilitate the recapture of previously tagged toothfish during year 1.

Four fishing grounds were identified in the Amundsen Sea region where fishing should take place based on an analysis by Hanchet & Parker (2014). The tagging rate was also increased from 1 tag per tonne to 3 tags per tonne so that more tagged fish would be available for recapture in year 2 and subsequent years. Analysis of ice conditions by Hanchet & Parker (2014) demonstrated that in most years one or

more of the grounds were inaccessible or unfishable due to ice, and so some flexibility was necessary in prescribing areas where fishing would be allowed.

Catch limits for the Amundsen Sea region research plan were derived from Petersen biomass estimates based on recaptures of tagged fish from SSRU 88.2H. Parker & Mormede (2014) demonstrated that estimates of biomass for SSRU 88.2H were biased upwards for each successive year that the tagged fish had been at liberty, probably as a result of immigration of untagged fish from a source population (Parker 2014). Therefore, CCAMLR agreed that a catch limit for SSRU 88.2H should be based on the number of recaptures of tagged fish which had been at liberty for a single year. The resulting biomass estimate of 5000 tonnes was multiplied by an exploitation rate of 4% to give a catch limit of 200 tonnes for 88.2H.

CCAMLR also agreed that an estimate of biomass for the Amundsen Sea region should be based on the number of recaptures of tagged fish from SSRU 88.2H which had been at liberty for all years could apply to the entire stock in SSRUs 88.2C–H. The resulting estimate of biomass of 20 649 tonnes (Goncharov & Petrov 2014) was multiplied by an exploitation rate of 3% to give a catch limit of 619 tonnes for the entire stock. It should be noted that this latter estimate of biomass and yield did not include any tag recapture data (i.e., number of tagged fish released, tagged fish recaptured, or scanned fish) from the south and was based on the assumption that all fish tagged in the north would have been available for recapture in the south. By subtraction, the catch limit for 88.2C-G (constrained to 4 research blocks) was 419 t which had the added effect of releasing many more tagged fish in the south given the increase in TAC. This was considered a good mechanism to release many tagged fish in the southern areas in just two years to obtain a mark-recapture biomass estimate more quickly.

The final research plan for the Amundsen Sea region was approved for two years and had the following components:
(i)   the catch limits were adopted for 2014–15 and 2015–16
(ii)   the catch limit for SSRU 88.2H was 200 tonnes
(iii)   the fishing in SSRUs 88.2C–G was restricted to four fishing areas (research blocks)
(iv)   the combined catch limit for SSRUs 88.2C–G was 419 tonnes, with no more than 200 tonnes to be taken from any one of the fishing grounds in (iii)
(v)   toothfish to be tagged at the rate of 3 fish per tonne in SSRUs 88.2C–G and 1 fish per tonne in SSRU 88.2H

Some preliminary model runs for the Amundsen Sea region using a two-area model were carried out to assess the utility of the results of the experiment (Mormede et al 2016) and FSA recommended further work be undertaken on the model structure (CCAMLR 2016, FSA paragraph 3.127). The Scientific Committee considered that the research plan was providing the information necessary to develop the stock assessment and recommended it be extended by a further two years with increased tagging rate in the north to 3 fish per tonne, consistent with the rate in the south (CCAMLR 2016, SC paragraphs 3.215 and 3.216).

In the Amundsen Sea region in the 2016 and 2017 seasons, a total of 19 tagged fish (excluding within season recaptures) were recaptured in the research blocks in the South Amundsen Sea region, confirming the utility of the research plan to recapture tagged fish and providing key information on the size of the population in the south. Although only four tagged fish were recaptured (excluding within season recaptures) in the north (SSRU 882H) in 2017, the increase in tagging rate to 3 fish per tonne in the 2017 season has increased the number of tagged fish at liberty and therefore the number of recaptures of tagged fish was thought likely to continue to increase in the 2019 season. Estimates of local biomass based on mark-recapture data were updated in 2020 and 2022, which followed the trend analysis rules (CAMLR-XXXVI 2017, Annex 7 paragraph 4.33) to set catch limits for individual fishing areas. The resulting catch limits were 230 t in research block 1, 223 t in research block 2, 204 t in research block 3, 154 t in research block 4, and 102 t in SSRU88.2H (SC-CAMLR 40 2021 table 3).

No validated age data are available since 2014 for the north of the Amundsen Sea region, and exist only for 2014, 2015, and 2017 from the south of the Amundsen Sea region to support the development of a stock assessment (Parker & Mormede 2017c).

5.3 Yield estimates and projections

Yields were estimated for the Ross Sea stock using the methods described by Mormede et al (2015a). For each sample from the posterior distribution estimated for each model, the stock status was projected forward 35 years under a scenario of a constant annual catch (i.e., for the period 2022–2056). Recruitment for 2003–2015 was as estimated in the model, and for 2016–2050 was assumed to be lognormally distributed with a standard deviation of 0.6 with a Beverton-Holt stock-recruitment steepness $h = 0.75$. Future catch was assumed to follow the split between fisheries as defined in CM 91-05 (i.e., 19%, 66%, and 15% of the total future catch was allocated to the N70, S70, and SRZ fisheries respectively).

The decision rules are $rule_1 = \max(Pr[SSB_i < 0.2 \times B_0]) \le 0.10$, where i is any year in the projection period, and $rule_2 = Pr[SSB_{+35} < 0.5 \times B_0] \le 0.50$. They were evaluated by calculating the maximum future catch that meets both decision rule criteria.

The constant catch for which there was median escapement of 50% of the median pre-exploitation spawning biomass level at the end of the 35-year projection period was 3495 t (Table 12). At this yield there is a less than 10% chance of spawning biomass dropping to less than 20% of the initial biomass. The catch was split among the three areas using the agreed proportions. This resulted in 664 t in the N70 area (SSRUs 88.1A, B, C, part of G), 2307 t on the slope (SSRUs 88.1G, H, I, K) and 459 t in the SRZ, with 65 t taken from the predicted SRZ catch limit (524 t) for a directed research survey for sub-adult toothfish on the shelf for the 2021 survey.

6. STATUS OF THE STOCKS

Stock structure assumptions

Uncertainty remains with respect to spawning dynamics and early life history of Antarctic toothfish. The present hypothesis is that Antarctic toothfish in Statistical Subareas 88.1 and 88.2 spawn to the north of the Antarctic continental slope, mainly on the ridges and banks of the Pacific-Antarctic Ridge. It has been recommended that for stock assessment purposes Statistical Subarea 88.1 and SSRUs 88.2A and 88.2B be treated as a 'Ross Sea' stock and Statistical Subarea 88.2 SSRU 88.2C–H be treated as a separate 'Amundsen Sea' stock.

In 2014, the Commission of CAMLR recognised that though there had been a large number of tagged fish recaptured in SSRU 882H, very few tags had been recaptured in 882C–G and a change in management was required to address this issue. It is also noted that the stock affinity of the toothfish in Statistical Subareas 88.1 and 88.2 with toothfish in surrounding areas is not well understood; however, the current stock structure used in the stock assessments should be continued.

- **Ross Sea stock**

Stock Status	
Year of Most Recent Assessment	2021
Assessment Runs Presented	A single base case model (R1.1) was accepted by CCAMLR.
Reference Points	Target: CCAMLR decision rule 2[4]: 50% B_0 after 35 years with $Pr(SSB > 20\% B_0) \ge 0.9$ for a constant catch harvest strategy (Soft) Limit: CCAMLR decision rule 1: 20% B_0 with $Pr(SSB > 20\% B_0) \ge 0.9$ Hard Limit: 10% B_0 Overfishing threshold: Not defined
Status in relation to Target	B_{2021} was estimated to be 66% B_0. Virtually Certain (> 99%) to be at or above the long term target (50% B_0)
Status in relation to Limits	B_{2021} is Exceptionally Unlikely (< 1%) to be below both soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status

First data point = 1995
Last data point = 2021

Trends in spawning biomass and exploitation rate over time.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Estimates of biomass have never been below 50% B_0, and the fishery is still in a fish-down phase.
Recent Trend in Fishing Intensity or Proxy	Fishing pressure increased early in the fishery and has stabilised at about target levels.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	The CPUE indices are not deemed to be an index of abundance. The catch-at-age data, although a relatively short time series, is showing indication of truncation of the right-hand limb, which is captured in the stock assessment. For assessments, the tag-recapture data provide the best information on stock size, but the total number of fish recaptured is small and may introduce bias into the model. Spatial population operating models have indicated that the stock assessment is likely to be negatively biased (precautionary). Although the absolute stock size is uncertain, the available evidence (tag recapture data, catch rates, age frequency data) suggests that the stock has been lightly exploited to date.

Projections and Prognosis	
Stock Projections or Prognosis	The biomass of the stock is expected to decline slowly over the 35-year projection period to the target level under constant catch.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2021	Next assessment: 2023
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Multi-year tag-recapture data - Commercial catch-at-age proportions - Sub-adult survey series (2012 onwards) to estimate annual year class strength	1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	Commercial CPUE	3 – Low Quality: not believed to be indexing abundance
Changes to Model Structure and Assumptions	-	
Major sources of Uncertainty	The model assumes homogenous mixing of tags within the population, which is unlikely to be true in the short term. Bias was estimated to be about 30% conservative (Mormede et al 2014f). Other major sources of uncertainty include estimates of initial mortality of tagged fish, detection rates of tagged fish, natural mortality rate, stock structure and migration patterns, stock-recruit steepness, and natal fidelity assumptions with respect to other areas.	

Qualifying Comments
For the base case and sensitivity models, current biomass is estimated to be between 60% and 66% B_0. The precautionary yield, using the CCAMLR decision rules[5] consistent with previous fishing activities and with the Ross Sea region MPA, was 3495 t. At its 2021 meeting CCAMLR agreed to set the catch limit to 3495 t for the Ross Sea for the 2021-22 and the 2022-23 seasons (SC-CAMLR-40 2021).

Fishery Interactions
Main bycatch species are macrourids and rajids for which there are catch limits and move-on rules. Rajids can be released alive.

---

[5] Yield estimates are calculated by projecting the estimated current status under a constant catch assumption, using the decision rules:
  1. Choose a yield, γ_1, so that the probability of the spawning biomass dropping below 20% of its median pre-exploitation level over a 35-year harvesting period is 10% (the depletion probability);
  2. Choose a yield, γ_2, so that the median escapement in the *SSB* at the end of a 35 year period is 50% of the median pre-exploitation level (the level of escapement); and
  3. Select the lower of γ_1 and γ_2 as the yield.
In the models, the depletion probability was calculated as the proportion of samples from the Bayesian posterior where the predicted future spawning stock biomass (*SSB*) was below 20% of B_0 in that respective sample in any one year, for each year over a 35-year projected period. The level of escapement was calculated as the proportion of samples from the Bayesian posterior where the predicted future status of the *SSB* was below 50% of B_0 in that respective sample at the end of a 35-year projected period.

- **Amundsen Sea stock (Statistical Subarea 88.2 SSRUs 88.2C-H)**

Stock Status	
Year of Most Recent Assessment	2021
Assessment Runs Presented	An estimate of biomass for the north area (SSRU 88.2H) was available from tag recapture data. Biomass estimates and catch limit determinations were made using CCAMLR's trend analysis rules.
Reference Points	No reference points were used for the assessment. Each of the estimates of biomass were multiplied by an exploitation rate based on a general yield model.
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass in the northern hills area based on tag recapture data has been trending down. No data are available for the southern area.
Recent Trend in Fishing Intensity or Proxy	Fishing pressure in the northern hills area has been increasing as seen by an increased number of tags recovered. No data are available for the southern area.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	The CPUE indices for the northern area have been declining to 2009 and increasing slightly since, but are not deemed to be an index of abundance. The catch-at-age data, when age length keys are applied annually, is showing an indication of truncation of the right-hand limb. The paucity of otoliths each year makes annual age length keys uncertain, and is seen as a priority work to improve upon. There has been no change in the sex ratio in this fishery.

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	N/A (no defined reference level)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial quantitative stock assessment	
Assessment Method	Tag based or CPUE based biomass estimate multiplied by exploitation rate	
Assessment Dates	Latest assessment: 2021	Next assessment: 2022
Overall assessment quality rank	2 – Medium or Mixed Quality for the north and Low Quality for the south	
Main data inputs (rank)	- Multi-year tag-recapture data (north)	1 – High Quality
	- Multi-year tag-recapture data (south)	3 – Low Quality
	- Commercial catch-at-age proportions (north)	1 – High Quality
	- Commercial catch-at-age proportions (south)	3 – Low Quality

	- Catch at age from annual age length keys where possible (north)	1 – High Quality
	- Catch at age from annual age length keys where possible (south)	3 – Low Quality
Data not used (rank)	Commercial CPUE	3 – Low Quality
Changes to Model Structure and Assumptions	A two-area model has been developed and requires further data to index the south area biomass. A research plan was set in place in the south to increase knowledge about the biomass in this area.	
Major Sources of Uncertainty	The estimate of biomass for SSRUs 88.2C–H is extremely uncertain because it assumes homogenous mixing of tags within the population (i.e. fish which leave the north are available for recapture in the south). No separate assessment or estimate of abundance is currently available for the southern area (SSRUs 88.2C–G) and this is the priority for further work. Other sources of uncertainty include estimates of initial mortality of tagged fish, detection rates of tagged fish, natural mortality rate, stock structure and migration patterns, stock-recruit steepness, and natal fidelity assumptions with respect to other areas	

Qualifying Comments

At its 2021 meeting, the CCAMLR Scientific Committee recommended the catch limits that were set using CCAMLR's trend analysis rule algorithm and a CPUE by seabed area analogy (SC-CAMLR-40, Paragraphs 3.93. 3.95).

Fishery Interactions

Main bycatch species are macrourids and rajids for which there are catch limits and move-on rules. Rajids can be released alive.

7. FOR FURTHER INFORMATION

Ainley, D; Crockett, E L; Eastman, J T; Fraser, W R; Nur, N; O'Brien, K; Salas, L A; Siniff, D B (2016) How overfishing a large piscine mesopredator explains growth in Ross Sea penguin populations: A framework to better understand impacts of a controversial fishery. *Ecological Modelling 349*: 69–75.

Ashford, J; Dinniman, M; Brooks, C; Andrews, A; Hofmann, E; Cailliet, G; Jones, C; Ramanna, N. (2012) Does large-scale ocean circulation structure life history connectivity in Antarctic toothfish (*Dissostichus mawsoni*)? *Canadian Journal of Fisheries and Aquatic Sciences 69*: 1–17.

Brooks, C M; Andrews, A H; Ashford, J R; Ramanna, N; Jones, C D; Lundstrom, C; Cailliet, G M (2011) Age estimation and lead-radium dating of Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea. *Polar Biology 34*: 329–338.

Castro, J.I., Woodley, C.M.; Brudek, B.L. (1999) A preliminary evaluation of the status of shark species. *FAO Fisheries Technical Paper No. 380*. 72 p.

CCAMLR XXXIII (2014) Report of the thirty third meeting of the Commission. CCAMLR, Hobart, Australia. 255 p.

CCAMLR (2015) Report of the thirty-fourth meeting of the Commission. CCAMLR, Hobart, Australia. 215 p.

CCAMLR (2016) Report of the thirty-fifth meeting of the Commission. CCAMLR, Hobart, Australia. 229 p.

CCAMLR (2017a) Fishery Report 2017: Exploratory fishery for Dissostichus spp. in Subarea 88.1. CCAMLR, Hobart, Australia. 32 p.

CCAMLR (2017b) Fishery Report 2017: Exploratory fishery for Dissostichus spp. in Subarea 88.2. CCAMLR, Hobart, Australia. 17 p.

CCAMLR (2017c) Report of the thirty-sixth meeting of the Commission. CCAMLR, Hobart, Australia. 219 p.

CCAMLR Secretariat (2016a) Long-distance movements of tagged Patagonian (*Dissostichus eleginoides*) and Antarctic toothfish (*D. mawsoni*). CCAMLR, Hobart, Australia WG-FSA-16/25r1. 11 p.

CCAMLR Secretariat (2013) Mapping trends in activity of illegal, unreported and unregulated (IUU) fishing in the CCAMLR Convention Area. CCAMLR XXXIII/BG/01.

CCAMLR Secretariat (2016b) Measurement of capacity in CCAMLR exploratory fisheries in Statistical Subareas 88.1 and 88.2: Secretariat update 2016. CCAMLR, Hobart, Australia WG-FSA-16/05. 18 p.

Chapman, D G; Robson, D S (1960) The analysis of a catch curve. *Biometrics 16:* 354–368.

Delegations of New Zealand, Norway and the United Kingdom. (2014) Medium-term research plan for the Ross Sea toothfish fishery. CCAMLR WG-FSA-14/60.

Devine, J; Parker, S; Prasad, M (2021) 2021 Ross Sea shelf survey results. CCAMLR document WG-FSA-2021/23.

Devine, J.; Prasad, M. (in prep) 2022 Ross Sea shelf survey results. CCAMLR document WG-FSA-22/XX.

TOOTHFISH (TOT)

Dunn, A; Jones, C.; Mormede, S.; Parker, S J (2016). Results of the fifth Ross Sea shelf survey to monitor abundance of sub-adult Antarctic toothfish in the southern Ross Sea, February 2016, and notification for continuation in 2017. CCAMLR, Hobart, Australia WG-SAM-16/14. 33 p.

Dunn, A; Hanchet, S M; Ballara, S; Francis, M P (2007) Preliminary investigations of an assessment model for skates in the Ross Sea. CCAMLR WG-SAM-07/4.

Dunn, A; Horn, P L; Hanchet, S M (2006) Revised estimates of the biological parameters for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea. CCAMLR WG-SAM-06/08.

Dunn, A; Parker, S J; Mormede, S (2010) Development of methods for evaluating the management of benthic impacts from longline fishing using spatially explicit production models. CCAMLR WG SAM 10/19.

Eastman, J T (1985) The evolution of neutrally buoyant notothenioid fishes: their specializations and potential interactions in the Antarctic marine food web. *In*: Siegfried, W R; Condy, P R; Laws, R M (Eds), pp. 430–436, *Antarctic Nutrient Cycles and Food Webs*. Berlin: Springer.

Eisert, R; Pinkerton, M H; Newsome, S D; Oftedal, O T (2013) A critical re-examination of the evidence for a possible dependence of Weddell Seals (*Leptonychotes weddellii*) on Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea, Antarctica. CCAMLR WG-EMM-13/28.

Eisert, R; Pinkerton, M H; Torres, L; Currey, R; Ensor, P H; Ovsyanikova, E N; Visser, I N; Oftedal, O T (2014) Update on the Top Predator Alliance project, 2013–14 season: Killer whales. CCAMLR WG-EMM-14/52.

Fenaughty, J M; Parker, S J (2015) Quantifying the impacts of ice on demersal longlining in CCAMLR Subarea 88.1 with updated information on the 2014/15 season. CCAMLR, Hobart, Australia WG-FSA-15/35. 15 p.

Fenaughty, J M; Stevens, D W; Hanchet, S M (2003) Diet of the Antarctic toothfish (*Dissostichus mawsoni*) from the Ross Sea, Antarctica (Subarea 88.1). *CCAMLR Science 10:* 113–123.

Fisheries New Zealand (2021) Aquatic Environment and Biodiversity Annual Review 2021. Compiled by the Aquatic Environment Team, Fisheries Science and Information, Fisheries New Zealand, Wellington, New Zealand. 779 p.

Francis, M P; Ó Maolagáin, C (2005) Age and growth of the Antarctic Skate (*Amblyraja georgiana*) in the Ross Sea. *CCAMLR Science 12*: 183–194.

Francis, M P (2010) Revised biological parameters for the Antarctic skates *Amblyraja georgiana* and *Bathyraja cf. eatonii* from the Ross Sea. CCAMLR WG-FSA-10/27.

Francis, M P; Gallagher, M J (2008) Revised age and growth estimates for Antarctic starry skate (*Amblyraja georgiana*) from the Ross Sea. CCAMLR WG-FSA-08/21.

Francis, R I C C (2011) Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences 68*: 1124–1138.

Goncharov, S M; Petrov, A F (2014) Stock assessment and proposed TAC for Antarctic toothfish (TOA) in the Subarea 88.2 H in the season 2014–2015. CCAMLR, Hobart, Australia WG-FSA-14/14. 4 p.

Grüss, A; Devine, J; Parker, S (2021a) Characterisation of the toothfish fishery in the Ross Sea region through 2020/21. CCAMLR document WG-FSA-2021/24.

Grüss, A; Devine, J; Parker, S (2021b) Summary of the toothfish fishery and tagging program in the Amundsen Sea region (small-scale research units 882C–H) to 2020/21. CCAMLR document WG-FSA-2021/25.

Grüss, A; Dunn, A; Parker, S (2021c) Assessment model for Antarctic toothfish (Dissostichus mawsoni) in the Ross Sea region to 2020/21. CCAMLR document WG-FSA-2021/26.

Hanchet, SM (2010) Updated species profile for Antarctic toothfish (*Dissostichus mawsoni*). CCAMLR WG-FSA-10/24.

Hanchet, S M; Sharp, B; Mormede, S; Parker, S J; Vacchi, M (2015) Results of the fourth CCAMLR sponsored research survey to monitor abundance of sub-adult Antarctic toothfish in the southern Ross Sea, February 2015 and further development of the time series. CCAMLR, Hobart, Australia WG-SAM-15/44. 25 p.

Hanchet, S M; Mormede, S; Parker, S J; Dunn, A; Jo, H-S (2012) Results of a CCAMLR-sponsored research survey to monitor abundance of pre-recruit Antarctic toothfish in the southern Ross Sea, February 2012. CCAMLR WG-FSA-12/41.

Hanchet, S M; Parker, S J (2014) Towards the development of an assessment of stock abundance for Subarea 88.2 SSRUs 88.2C–G. CCAMLR WG-FSA-14/59.

Hanchet, S M; Dunn, A; Parker, S J; Horn, P; Stevens, D, Mormede, S (2015) The Antarctic toothfish (*Dissostichus mawsoni*): biology, ecology, and life history in the Ross Sea region. *Hydrobiologia 761 (1)*: 397–414. doi:10.1007/s10750-015-2435-6.

Hanchet, S M; Rickard, G J; Fenaughty, J M; Dunn, A; Williams, M J (2008) A hypothetical life cycle for Antarctic toothfish *Dissostichus mawsoni* in Antarctic waters of CCAMLR Statistical Area 88. *CCAMLR Science 15:* 35–54.

Hanchet, S M; Stevenson, M L; Jones, C; Marriott, P M; McMillan, P J; O'Driscoll, R L; Stevens, D W; Stewart, A L; Wood, B A (2008) Biomass estimates and size distributions of demersal finfish on the Ross Sea shelf and slope from the New Zealand IPY-CAML survey, February-March 2008. CCAMLR WG-FSA-08/31.

Hoenig, J M (1983) Empirical use of longevity data to estimate mortality rates. *Fisheries Bulletin 81*: 899–903.

Horn, P L (2002) Age and growth of Patagonian toothfish (*Dissostichus eleginoides*) and Antarctic toothfish (*D. mawsoni*) in waters from the subantarctic to the Ross Sea, Antarctica. *Fisheries Research 56:* 275–287.

Horn, P L; Sutton, C P; DeVries, A L (2003) Evidence to support the annual formation of growth zones in otoliths of Antarctic toothfish (*Dissostichus mawsoni*). *CCAMLR Science 10:* 125–138.

Kuhn, K L; Gaffney, P M (2008) Population subdivision in the Antarctic toothfish (*Dissostichus mawsoni*) revealed by mitochondrial and nuclear single nucleotide polymorphisms (SNPs). *Antarctic Science 20*: 327–338.

Ladroit, Y; O'Driscoll, R L; Mormede, S (2014) Using acoustic echo counting to estimate grenadier abundance in the Ross Sea (SSRU88.1I). *CCAMLR WG-FSA-14/62.*

Large, K; Hanchet, S M; Mormede, S (2015) A characterisation of the toothfish fishery in Subareas 88.1 and 88.2 from 1997–98 to 2014–15. CCAMLR, Hobart, Australia. WG-FSA-15/36. 43 p.

Large, K; Robinson L; Parker S (2017) Results of the sixth Ross Sea shelf survey to monitor abundance of sub-adult Antarctic toothfish in the southern Ross Sea, January 2017. CCAMLR WG-SAM-17/01. 25 p.

Lyver, P O'B; Barron; M; Barton K J; Ainley D G; Pollard, A; Gordon, S; McNeill, S; Ballard, G; Wilson, P R (2014) Trends in the breeding population of Adélie penguins in the Ross Sea, 1981–2012: A coincidence of climate and resource extraction effects. *PLoS ONE 9(3)*: e91188. doi:10.1371/journal.pone.0091188.

Maunder, M N; Sibert, J R; Fonteneau, A; Hampton, J; Kleiber, P; Harley, S J (2006) Interpreting catch per unit effort data to assess the status of individual stocks and communities. *ICES Journal of Marine Science 63:* 1373–1385.

McMillan, P J; Iwamoto, T; Stewart, A; Smith, P J (2012) A new species of grenadier, genus *Macrourus* (Teleostei, Gadiformes, Macrouridae) from the southern hemisphere and a revision of the genus. *Zootaxa 3165:* 1–24.

Moore, B; Parker, S (2021) Catches and data available on bycatch species from the toothfish fishery in the Ross Sea region (Subarea 88.1 and SSRUs 88.2A-B through 2020-2021.CCAMLR document WG-FSA-2021/32.

Mormede, S (2014) Calculating effective releases and recaptures for stock assessments based on tag detection and tagging mortality indices. CCAMLR, Hobart, Australia WG-SAM-14/30. 6 p.

Mormede, S (2017) Assessment models for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea region to 2016/17. CCAMLR, Hobart, Australia WG-FSA-17/37 rev. 1. 17p.

Mormede, S; Dunn, A (2010) Characterisation of skate catches in the Ross Sea region. CCAMLR WG–FSA–10/25. 21 p.

Mormede, S; Dunn, A (2013) Quantifying vessel performance in the CCAMLR tagging program: spatially and temporally controlled measures of tag-detection rates. *CCAMLR Science 20:* 73–80.

Mormede, S; Dunn, A; Hanchet, S M (2013) Assessment models for Antarctic toothfish (*Dissostichus mawsoni*) in Subarea 88.2 SSRUs 88.2C–H for the years 2002–03 to 2012–13. CCAMLR WG-FSA-13/52. 26 p.

Mormede, S; Dunn, A; Hanchet, S M (2014a) Investigating emigration in stock assessment models of Antarctic toothfish (*Dissostichus mawsoni*) in Subarea 882 SSRUs 882C–H. CCAMLR WG-FSA-14/56. 15 p.

Mormede, S; Dunn, A; Hanchet, S M (2014b) Preliminary investigations into a two-area stock assessment model for Antarctic toothfish (*Dissostichus mawsoni*) in the Amundsen Sea Region. CCAMLR WG-FSA-14/57. 12 p.

Mormede, S; Dunn, A; Hanchet, S M (2015a) Assessment models for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea region for the years 1997–98 to 2014–15. CCAMLR, Hobart, Australia WG-FSA-15/38. 18 p.

Mormede, S; Dunn, A; Hanchet, S M; Parker, S J (2014f) Spatially explicit population dynamics operating models for Antarctic toothfish in the Ross Sea region. *CCAMLR Science 21*: 19–37.

Mormede, S; Large, K; Hanchet, S M (2016) Progress towards an assessment of Antarctic toothfish (*Dissostichus mawsoni*) in Subarea 88.2 SSRUs 882C–H for the years 2002–03 to 2015–16 using a two-area model. CCAMLR, Hobart, Australia *WG-FSA-16/44*. 22 p.

Mormede, S; Parker, S J; Dunn, A; Hanchet, S M (2015b) Potential modelling structures for a two-area stock assessment model for Antarctic toothfish (*Dissostichus mawsoni*) in the Amundsen Sea Region. CCAMLR, Hobart, Australia *WG-SAM-15/49*. 13 p.

Mormede, S; Parker, S J; Hanchet, S M; Dunn, A; Gregory, S (2014c) Results of the third CCAMLR sponsored research survey to monitor abundance of sub-adult Antarctic toothfish in the southern Ross Sea, February 2014 and development of the time series. CCAMLR WG-FSA-14/51. 23 p.

Mormede, S; Pinkerton, M H; Dunn, A; Hanchet, S M; Parker, S J (2014d) Development of a spatially-explicit minimum realistic model for Antarctic toothfish (*Dissostichus mawsoni*) and its main prey (Macrouridae and Channichthyidae) in the Ross Sea. CCAMLR WG-EMM-14/51.

Mugue, N S; Petrov, A F; Zelenina, D A; Gordeev, I I; Sergeev, A A (2013) Low genetic diversity and temporal stability in the Antarctic toothfish (*Dissostichus mawsoni*) from near-continental seas of the Antarctica. CCAMLR WG-FSA-13/07.

Near, T J; Russo, S E; Jones, C D; DeVries, A L (2003) Ontogenetic shift in buoyancy and habitat in the Antarctic toothfish, *Dissostichus mawsoni* (Perciformes: Nototheniidae). *Polar Biology 26*: 124–128.

O'Driscoll, R L (2005) Risk categorization for *Macrourus whitsoni* and *Amblyraja georgiana* in the Ross Sea. CCAMLR WG-FSA 05/21.

O'Driscoll, R; Double, M (2015) Voyage Report TAN1502. NIWA report WLG2015-21, April 2015. 93 p.

O'Driscoll, R L; Canese, S; Ladroit, Y; Parker, S J; Ghigliotti, L; Mormede, S; Vacchi, M (2018) First in situ estimates of acoustic target strength of Antarctic toothfish (*Dissostichus mawsoni*). *Fisheries Research 206*: 79–84.

O'Driscoll, R L; Hanchet, S M; Miller, B S (2012) Can acoustic methods be used to monitor grenadier (Macrouridae) abundance in the Ross Sea region? *Journal of Ichthyology 52(10):* 700–708.

O'Driscoll, R L; Hanchet, S M; Wood, B A (2005) Approaches to monitoring and assessing the abundance of rattails (*Macrourus* spp.) and skates in the Ross Sea. CCAMLR WG-FSA 05/22.

Parker, R W; Paige, K N; DeVries, A L (2002) Genetic variations amongst populations of the Antarctic toothfish: evolutionary insights and implications for conservation. *Polar Biology 25*: 256–261.

Parker, S J (2014) Analysis of seamount-specific catch and tagging data in the Amundsen Sea, SSRU 88.2H. CCAMLR, Hobart, Australia WG-SAM-14/27. 23 p.

Parker, S J; Bowden, D A (2010) Identifying taxonomic groups vulnerable to bottom longline fishing gear in the Ross Sea region. *CCAMLR Science 17:* 105–127.

Parker, S J; Cole, R G; Hanchet, S M (2010) Spatial scales of benthic invertebrate habitats from fishery bycatch and video transect data in the Ross Sea region, CCAMLR WG-EMM-10/28.

Parker, S J; Dunn, A; Mormede, S; Hanchet, S M (2013a) Descriptive analysis of the toothfish (*Dissostichus* spp.) tagging programme in Subareas 88.1 & 88.2 for the years 2000–01 to 2012–13. CCAMLR WG-FSA-13/49.

Parker, S, Finucci, B., Francis, M. (2020). Tagging and recapture protocols for skates in the Ross Sea region. Document SC-39-BG-31. CCAMLR, Hobart, Australia. 9 p.

Parker, S J; Grimes, P J (2010) Length and age at spawning of Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea. *CCAMLR Science 17*: 53–73.

Parker, S J; Hanchet, S M; Horn, P L (2014) Stock structure of Antarctic toothfish in Statistical Area 88 and implications for assessment and management. CCAMLR WG-SAM-14/26.

Parker, S J; Hanchet, S M; Mormede, S; Dunn, A; Sarralde, R (2013b) Results of a CCAMLR sponsored research survey to monitor abundance of subadult Antarctic toothfish in the southern Ross Sea, February 2013. CCAMLR *WG-SAM-13/32*. 31 p.

Parker, S J; Marriott, P (2012) Indexing maturation of Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea region. CCAMLR *WG-FSA-12/40*.

Parker, S J; Mormede, S (2014) Seamount-specific biomass estimates from SSRU 88.2H in the Amundsen Sea derived from mark-recapture data. CCAMLR WG-FSA-14/58.

Parker, S J; Mormede, S (2015) Descriptive analysis of the toothfish (*Dissostichus* spp.) tagging programme in Subareas 88.1 & 88.2 for the years 2000–01 to 2014–15. CCAMLR, Hobart, Australia WG-FSA-15/37. 32 p.

Parker, S J; Mormede, S (2017a) Mark-recapture inputs to the 2017 Ross Sea region stock assessment (Subarea 88.1 and SSRUs 88.2A-B). CCAMLR, Hobart, Australia WG-FSA-17/36. 8 p.

Parker, S J; Mormede, S (2017b) A characterisation of the toothfish fishery in the Ross Sea region (Subarea 88.1 and SSRUs 88.2A–B) to 2016–17. CCAMLR, Hobart, Australia WG-FSA-17/07. 22 p.

Parker, S J; Mormede, S (2017c) The toothfish fishery and tagging program in the Amundsen Sea region (SSRUs 882C–H) to 2016/17. CCAMLR, Hobart, Australia WG-FSA-17/39. 15 p.

Parker, S J; Mormede, S; DeVries, A; Hanchet, S M; Eisert, R (2015). Have toothfish returned to McMurdo Sound, Antarctica? *Antarctic Science 28(1):*1–6.

Parker, S J;, Stevens, D W; Ghigliotti, L; La Mesa, M; Di Blasi, D; Vacchi, M (2019) Winter spawning of Antarctic toothfish *Dissostichus mawsoni* in the Ross Sea region. *Antarctic Science 31(5)*: 1–11. https://doi.org/10.1017/S0954102019000282.

Parker, S J; Mormede, S; Hanchet, S M; DeVries, A; Canese, S; Ghigliotti, L (2019) Monitoring Antarctic toothfish in McMurdo Sound to evaluate the Ross Sea region Marine Protected Area. *Antarctic Science 31(4)*: 195–207.https://doi.org/10.1017/S0954102019000245

Pinkerton, M H; Bradford-Grieve, J M (2014) Characterizing foodweb structure to identify potential ecosystem effects of fishing in the Ross Sea, Antarctica. *ICES Journal of Marine Science.,* DOI.10.1093/icesjms/fst230.Pinkerton, M H; Bradford-Grieve, J M; Hanchet, S M (2010) A balanced model of the food web of the Ross Sea, Antarctica. *CCAMLR Science 17:*1–31.

Pinkerton, M H; Bury, S J; Brown, J C S; Forman, J; Kilmnik, A (2014a) Stable isotope analysis of tissue samples to investigate trophic linkages of Antarctic toothfish (*Dissostichus mawsoni*) in the Ross and Amundsen Sea regions. *CCAMLR WG-EMM-14/50.*

TOOTHFISH (TOT)

Pinkerton, M H; Dunn, A; Hanchet, S M (2008) Trophic overlap of Weddell seals (*Leptonychotes weddelli*) and Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea, Antarctica. CCAMLR WG-EMM-08/43.

Pinkerton, M H; McMillan, P J; Forman, J; Marriott, P; Horn, P; Bury, S J; Brown, J (2013) Distribution, morphology and ecology of *Macrourus whitsoni* and *M. caml* (gadiformes, macrouridae) in the Ross Sea region. *CCAMLR Science 20*: 37–61.

Pinkerton, M. H., and Bradford-Grieve, J. M. (2014) Characterizing foodweb structure to identify potential ecosystem effects of fishing in the Ross Sea, Antarctica. – *ICES Journal of Marine Science 71*: 1542–1553.

Pinkerton, M H; O Maolagain, C; Forman, J; Marriott, P (2014b) Discrimination of two species of grenadier (Gadiformes, Macrouridae), *Macrourus whitsoni* and *M. caml*, in the Ross Sea region of the Southern Ocean (CCAMLR Subareas 88.1 and 88.2) on the basis of otolith morphometrics. CCAMLR WG-FSA-14/63.

Pinkerton, M H; Lyver, P O'B; Stevens, D W; Forman, J; Eisert, R; Mormede S (2016) Increases in Adélie penguins in the Ross Sea: could the fishery for Antarctic toothfish be responsible? *Ecological Modelling 337*: 262–271.

Punt, A E; Smith, D C; Koopman, M T (2005) Using information for 'data-rich' species to inform assessments of 'data-poor' species through Bayesian stock assessment methods. Final Report to Fisheries Research and Development Corporation Project no. 2002/094. 243 p. Primary Industries Research Victoria, Queenscliff.

SC-CAMLR-XXXIII (2014) Report of the thirty third meeting of the Scientific Committee. CCAMLR, Hobart, Australia.

SC-CAMLR-38 (2019) Report of the thirty eight meeting of the Scientific Committee. CCAMLR, Hobart, Australia.

SC-CAMLR-40 (2021) Report of the fortieth meeting of the Scientific Committee. CCAMLR, Hobart, Australia.

Sharp, B R (2010) Revised impact assessment framework to estimate the cumulative footprint and impact on VME taxa of New Zealand bottom longline fisheries in the Ross Sea region. CCAMLR WG SAM-10/20.

Sharp, B R; Parker, S J; Smith, N (2009) An impact assessment framework for bottom fishing methods in the CCAMLR Convention Area. *CCAMLR Science 16:* 195–210.

Smith, P; Gaffney, P M (2000) Population genetics of Patagonian toothfish (*Dissostichus eleginoides*) and fillet identification of Patagonian toothfish and Antarctic toothfish *D. mawsoni*. CCAMLR WG–FSA–00/53.

Smith, P J; Steinke, D; McMillan, P J; Stewart, A L; McVeagh, M; Diaz De Astarloa, J M; Welsford, D; Ward, R D (2011) DNA barcoding highlights a cryptic species of grenadier (genus *Macrourus*) in the Southern Ocean. *Journal of Fish Biology 78(1):* 355–65.

Stevens, D W; Dunn, M R; Pinkerton, M H; Forman, J S (2014) Diet of Antarctic toothfish (*Dissostichus mawsoni*) from the Ross Sea region, Antarctica. *Antarctic Science 26:* 502–512.

Stevens, D W; Di Blasi, D; Parker, S (2016) Summary of the results of the first winter longline survey to the northern Ross Sea region to investigate toothfish reproductive life history. CCAMLR document WG-FSA-16/XX, Hobart, Australia.

Stevenson, M L; Hanchet, S M; Mormede, S; Dunn, A (2014) A characterisation of the toothfish fishery in Subareas 88.1 and 88.2 from 1997–98 to 2013–14. CCAMLR, Hobart, Australia WG-FSA-14/52.

Tana, R; Hicks, B J; Pilditch, C; Hanchet, S M (2014) Preliminary examination of otolith microchemistry to determine stock structure in Antarctic toothfish (*Dissostichus mawsoni*) between SSRU 88.1C and 88.2H. CCAMLR WG-SAM-14/33.

Torres, L; Pinkerton, M H; Pitman, R; Durban, J; Eisert, R (2013) To what extent do type C killer whales (*Orcinus orca*) feed on Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea, Antarctica? CCAMLR WG-EMM-13/29.

Webber, D N; Parker, S J (2011) Estimating unaccounted fishing mortality in the Ross Sea and 88.2C–G bottom longline fisheries targeting Antarctic toothfish. CCAMLR WG-FSA-11/48.

Yukhov, V L (1971). The range of *Dissostichus mawsoni* Norman and some features of its biology. *Journal of Ichthyology* 11: 8–18.

TREVALLY (TRE)

(*Pseudocaranx dentex*)
Araara
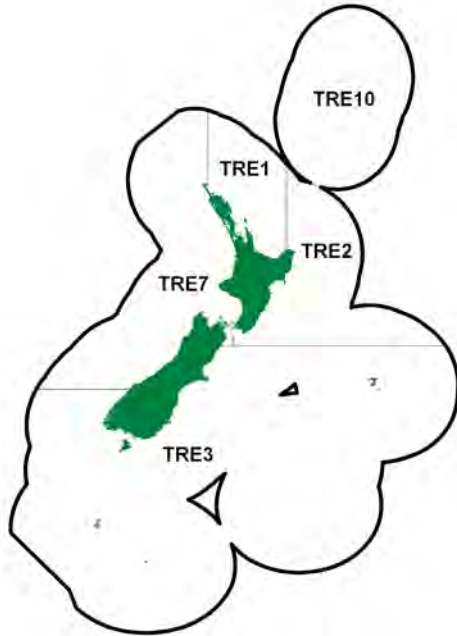
1.   FISHERY SUMMARY

Trevally was introduced into the QMS in 1986 with five QMAs. A Total Allowable Catch (TAC) was set under the provisions of the 1983 Fisheries Act initially at 3220 t. Since the introduction into the QMS there have been no recreational or customary allocations in TRE 1, 3, 7, or 10; therefore, the total allowable commercial catch (TACC) is the same as the TAC. In 2010, TRE 2 was allocated a 100 t recreational catch, 1 t customary catch, and 7 t for other mortality, combining to make a 350 t TAC.

1.1   Commercial fisheries
Trevally is caught around the North Island and the north of the South Island, with the main catches from the northern coasts of the North Island. Trevally is taken in the northern coastal mixed trawl fishery, mostly with snapper. Since the mid-1970s trevally has been taken by purse seine, mainly in the Bay of Plenty (BoP), in variable but often substantial quantities. Set net fishermen take modest quantities.

Historical estimated and recent reported trevally landings and TACCs are shown in Tables 1 and 2, and Figure 1 shows the historical and recent landings and TACC values for the main trevally stocks.

Trevally landings peaked during the 1970s, with total landings exceeding 6000 t in 1977 and 1978, before declining for all three main trevally stocks: TRE 1, TRE 2, and TRE 7. TRE 1 landings have ranged from 790 t to 1718 t since the introduction of the TACC in 1986–87, with the 2017–18 landings the highest since 1986–87, reducing to 1300 t in 2019–20, and increasing to 1664 t in 2020–21. TRE 2 landings have fluctuated around the TACC of 241 t since it was introduced and have exceeded the TACC in several recent fishing years including 2018–19 when just under 270 t of landings were recorded. Landings from TRE 7 have been under the TACC since 2003–04, and the lowest landings were recorded in 2020–21, at 1147 t.

TREVALLY (TRE)

Table 1: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	TRE 1	TRE 2	TRE 3	TRE 7	Year	TRE 1	TRE 2	TRE 3	TRE 7
1931–32	9	0	0	0	1957	788	235	0	374
1932–33	6	0	0	0	1958	856	197	1	409
1933–34	30	0	0	3	1959	980	175	0	433
1934–35	27	0	0	3	1960	1 141	191	1	686
1935–36	0	0	0	0	1961	1 144	368	0	567
1936–37	0	0	0	0	1962	1 415	431	0	658
1937–38	20	4	0	4	1963	1 284	348	0	769
1938–39	53	10	2	8	1964	1 329	395	2	639
1939–40	17	9	0	6	1965	1 581	344	2	673
1940–41	12	13	0	7	1966	1 568	382	0	1 151
1941–42	17	6	0	4	1967	1 121	472	1	1 512
1942–43	90	1	0	1	1968	1 425	504	0	1 547
1943–44	190	2	0	1	1969	1 428	474	0	1 378
1944	401	2	0	19	1970	2 010	490	0	1 740
1945	307	9	0	23	1971	3 060	779	1	2 109
1946	316	12	2	19	1972	2 738	946	0	2 309
1947	317	8	1	28	1973	1 950	616	0	2 381
1948	432	7	0	34	1974	2 365	687	0	2 077
1949	291	9	0	39	1975	1 470	361	0	1 679
1950	402	39	0	60	1976	2 659	1 026	0	1 994
1951	470	57	0	82	1977	3 749	558	0	2 176
1952	310	73	0	63	1978	3 627	518	1	2 381
1953	376	90	0	136	1979	2 566	449	1	2 658
1954	471	132	0	116	1980	1 471	330	0	2 545
1955	609	120	0	193	1981	1 524	229	0	2 957
1956	556	124	0	179	1982	2 102	135	0	2 548

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns. Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 2: Reported landings (t) of trevally by Fishstock from 1983 to present and TACCs (t) from 1986–87 to present. QMS data from 1986 to present. [Continued on next page]

Fishstock FMA (s)	TRE 1 1		TRE 2 2		TRE 3 3, 4, 5, 6		TRE 7 7, 8, 9		TRE 10 10	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983*	1 534	-	77	–	3	–	2 165	–	0	–
1984*	1 798	-	335	–	1	–	1 707	–	0	–
1985*	1 887	-	162	–	1	–	1 843	–	0	–
1986*	1 431	-	161	–	3	–	1 830	–	0	–
1986–87	982	1 210	237	190	< 1	20	1 626	1 800	0	10
1987–88	1 111	1 210	267	219	< 1	20	1 752	1 800	0	10
1988–89	818	1 413	177	235	< 1	20	1 665	2 010	0	10
1989–90	1 240	1 493	275	237	18	20	1 589	2 146	0	10
1990–91	1 011	1 495	273	238	8	22	2 016	2 153	0	10
1991–92	1 169	1 498	197	238	< 1	22	1 367	2 153	< 1	10
1992–93	1 328	1 505	247	241	< 1	22	1 796	2 153	< 1	10
1993–94	1 162	1 506	230	241	< 1	22	2 231	2 153	0	10
1994–95	1 242	1 506	179	241	< 1	22	2 138	2 153	0	10
1995–96	1 175	1 506	211	241	< 1	22	2 019	2 153	0	10
1996–97	1 174	1 506	317	241	< 1	22	1 843	2 153	0	10
1997–98	1 027	1 506	223	241	3	22	2 102	2 153	0	10
1998–99	1 469	1 506	284	241	24	22	2 148	2 153	0	10
1999–00	1 424	1 506	309	241	3	22	2 254	2 153	0	10
2000–01	1 049	1 506	211	241	< 1	22	1 888	2 153	0	10
2001–02	1 085	1 506	243	241	< 1	22	1 856	2 153	0	10
2002–03	1 014	1 507	270	241	< 1	22	2 029	2 153	0	10
2003–04	1 111	1 507	251	241	< 1	22	2 186	2 153	0	10
2004–05	977	1 507	319	241	< 1	22	1 945	2 153	0	10
2005–06	1 149	1 507	417	241	< 1	22	1 957	2 153	0	10
2006–07	790	1 507	368	241	< 1	22	1 739	2 153	0	10
2007–08	847	1 507	230	241	< 1	22	1 797	2 153	0	10
2008–09	855	1 507	302	241	< 1	22	2 018	2 153	0	10
2009–10	814	1 507	261	241	< 1	22	1 966	2 153	0	10
2010–11	1 408	1 507	245	241	< 1	22	1 922	2 153	0	10
2011–12	1 050	1 507	186	241	< 1	22	1 895	2 153	0	10
2012–13	1 301	1 507	197	241	< 1	22	1 842	2 153	0	10
2013–14	1 431	1 507	303	241	< 1	22	1 610	2 153	0	10
2014–15	1 447	1 507	220	241	< 1	22	1 824	2 153	0	10
2015–16	1 576	1 507	285	241	< 1	22	1 949	2 153	0	10
2016–17	1 506	1 507	304	241	< 1	22	1 728	2 153	0	10
2017–18	1 718	1 507	273	241	< 1	22	1 768	2 153	0	10
2018–19	1 394	1 507	269	241	< 1	22	1 427	2 153	0	10
2019–20	1 300	1 507	232	241	< 1	22	1 589	2 153	0	10

Table 2 [Continued]

Fishstock FMA (s)	TRE 1 1		TRE 2 2		TRE 3 3, 4, 5, 6		TRE 7 7, 8, 9		TRE 10 10	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2020–21	1 664	1 507	240	241	< 1	22	1 147	2 153	0	10

FMA (s)	Total	
	Landings	TACC
1983*	3 779	–
1984*	3 841	–
1985*	3 893	–
1986*	3 425	–
1986–87	2 845	2 230
1987–88	3 131	3 259
1988–89	2 651	3 688
1989–90	3 122	3 906
1990–91	3 308	3 918
1991–92	2 733	3 921
1992–93	3 371	3 931
1993–94	3 624	3 932
1994–95	3 559	3 932
1995–96	3 405	3 932
1996–97	3 333	3 932
1997–98	3 355	3 932
1998–99	3 925	3 932
1999–00	3 989	3 932
2000–01	3 148	3 932
2001–02	3 185	3 933
2002–03	3 313	3 933
2003–04	3 548	3 933
2004–05	3 241	3 933
2005–06	3 524	3 933
2006–07	2 897	3 933
2007–08	2 875	3 933
2008–09	3 175	3 933
2009–10	3 042	3 933
2010–11	3 575	3 933
2011–12	3 131	3 933
2012–13	3 340	3 933
2013–14	3 344	3 933
2014–15	3 521	3 933
2015–16	3 810	3 933
2016–17	3 538	3 933
2017–18	3 759	3 933
2018–19	3 090	3 933
2019–20	3 122	3 933
2020–21	3 051	3 933
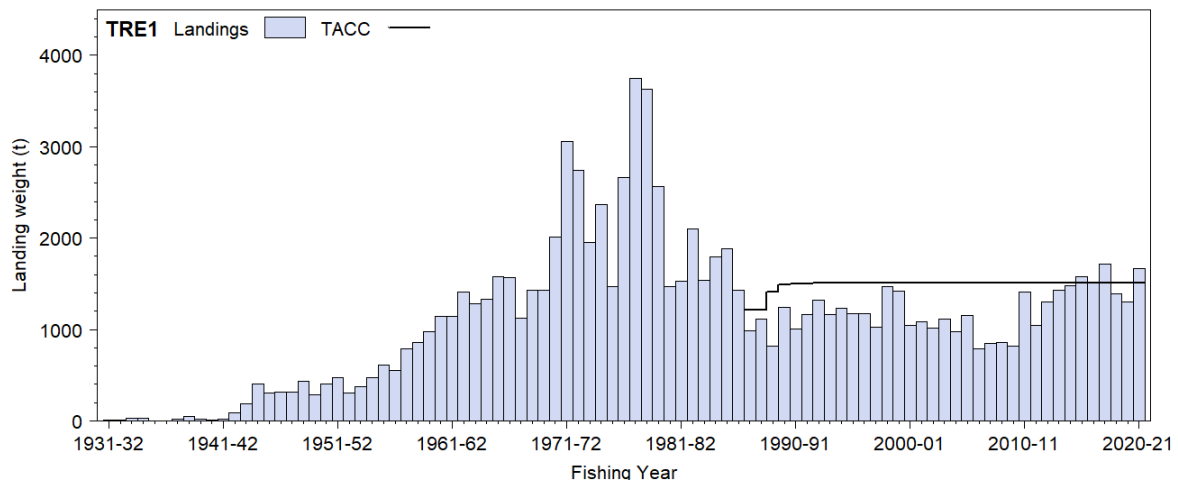
Figure 1: Historical landings and TACCs (t) for the three main TRE stocks. TRE 1 (Auckland). [Continued on next page]
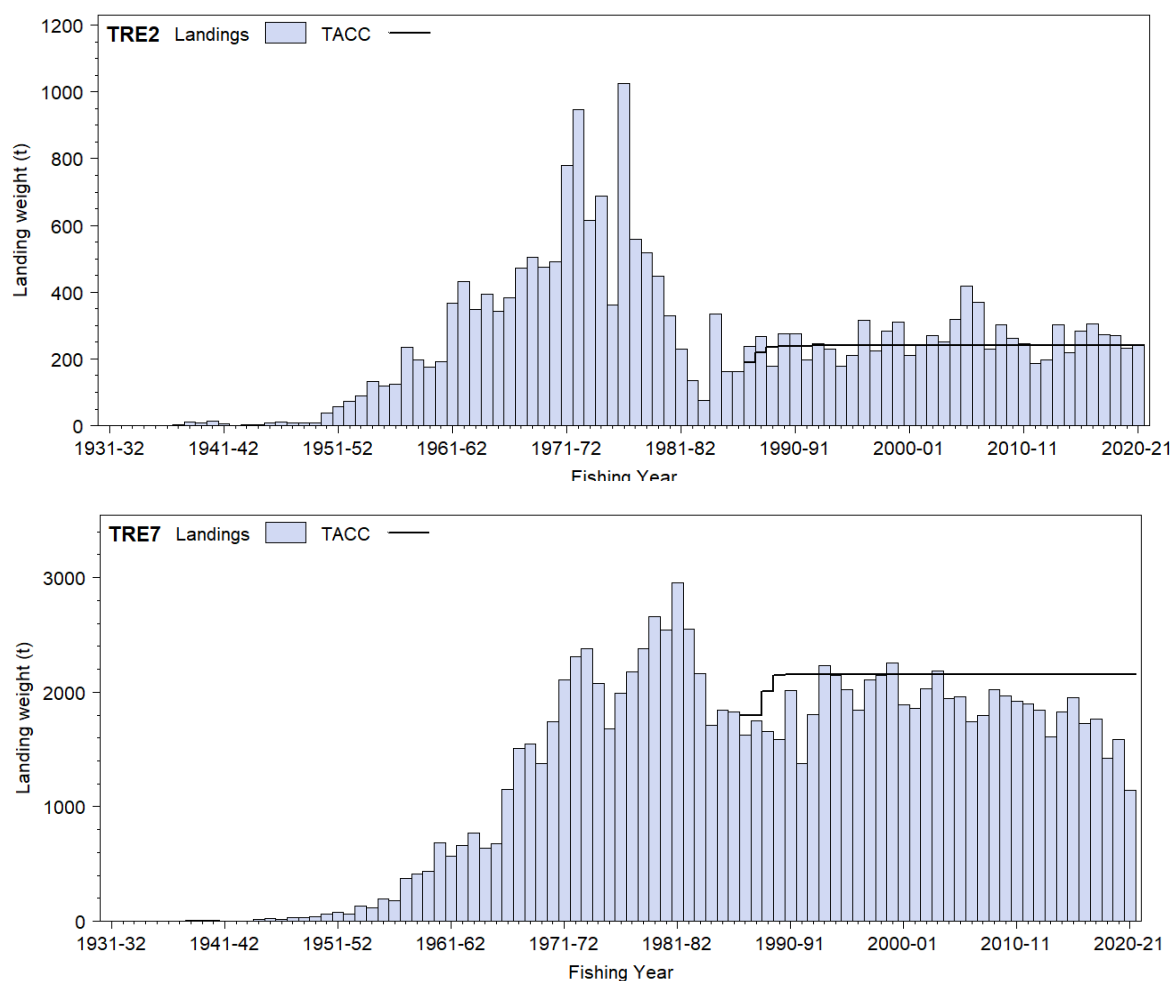
Figure 1 [Continued]: Historical landings and TACCs (t) for the three main TRE stocks. TRE 2 (Central East) and TRE 7 (Challenger).

1.2 Recreational fisheries

Recreational fishers catch trevally by line and set net methods. Although highly regarded as a table fish, some trevally may be used as bait.

1.2.1 Management controls

The main methods used to manage recreational harvests of trevally are minimum legal size limits (MLS), method restrictions, and daily bag limits. Fishers can take up to 20 trevally as part of their combined daily bag limit (except in the South-East and Southland fisheries management areas including the Fiordland Marine Recreational Fishing Area where the limit is 30 (within a combined daily bag limit of 30 finfish) and the MLS is 25 cm in all areas.

1.2.2 Estimates of recreational harvest

Recreational catch estimates are given in Table 3. There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity, and offsite methods where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest for trevally were calculated using offsite telephone-diary surveys in 1996 (Bradford 1998), 2000 (Boyd & Reilly 2004), and 2001 (Boyd et al 2004).

The harvest estimates provided by these telephone diary surveys are no longer considered reliable for various reasons. With the early telephone/diary method, fishers were recruited to fill in diaries by way of a telephone survey that also estimates the proportion of the population that is eligible (likely to fish). A 'soft refusal' bias in the eligibility proportion arises if interviewees who do not wish to co-operate falsely state that they never fish. The proportion of eligible fishers in the population (and, hence, the

harvest) is thereby underestimated. Pilot studies for the 2000 telephone/diary survey suggested that this effect could occur when recreational fishing was established as the subject of the interview at the outset. Another equally serious cause of bias in telephone/diary surveys was that diarists who did not immediately record their day's catch after a trip sometimes overstated their catch or the number of trips made. There is some indirect evidence that this may have occurred in all the telephone/diary surveys (Wright et al 2004).

The recreational harvest estimates provided by the 2000 and 2001 telephone diary surveys are thought to be implausibly high for many species; therefore an alternative maximum count aerial-access onsite method was developed to provide a more direct means of estimating recreational harvests for suitable fisheries. The maximum count aerial-access approach combines data collected concurrently from two sources: a creel survey of recreational fishers returning to a subsample of ramps throughout the day; and an aerial survey count of vessels observed to be fishing at the approximate time of peak fishing effort on the same day. The ratio of the aerial count in a particular area to the number of interviewed parties who claimed to have fished in that area at the time of the overflight was used to scale up harvests observed at surveyed ramps, to estimate harvest taken by all fishers returning to all ramps. The methodology is further described by Hartill et al (2007).

Table 3: Recreational harvest estimates for trevally stocks (Bradford 1998, Boyd & Reilly 2004, Boyd et al 2004, Hartill et al 2007, 2013, 2019, Wynne-Jones et al 2014, 2019). The telephone/diary surveys and earlier aerial-access survey ran from December to November but are denoted by the January calendar year. The surveys since 2010 have been run throughout the October to September fishing year and are denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey harvest estimates).

Stock	Year	Method	Number of fish	Total weight (t)	CV
TRE 1	1996	Telephone/diary	194 000	234	0.07
	2000	Telephone/diary	701 000	677	0.13
	2001	Telephone/diary	449 000	434	0.19
	2005	Aerial-access *	–	105	0.18
	2012	Aerial-access *	–	124	0.12
	2012	Panel survey	139 473	165	0.11
	2018	Aerial-access *	–	145	0.09
	2018	Panel survey	95 097	125	0.09
TRE 2	1996	Telephone/diary	9 000	13	0.19
	2000	Telephone/diary	153 000	160	0.60
	2001	Telephone/diary	32 000	339	0.23
	2012	Panel survey	10 308	11	0.24
	2018	Panel survey	10 988	17	0.24
TRE 3	1996	Telephone/diary	2 000	3[†]	–
	2000	Telephone/diary	10 000	10	0.45
TRE 3	2001	Telephone/diary	2 000	12	0.46
	2012	Panel survey	859	1	0.73
	2018	Panel survey	221	<1	0.59
TRE 7	1996	Telephone/diary	67 000	70	0.11
	2000	Telephone/diary	69 000	81	0.27
	2001	Telephone/diary	107 000	124	0.21
	2012	Panel survey	23 123	32	0.16
	2018	Panel survey	31 879	68	0.17

* Aerial-access surveys did not include catches from charter vessels, whereas these are included in the panel survey estimates. The estimates for FMA 1 in this table are not, therefore, directly comparable. See Edwards & Hartill (2015) for details.
† No harvest estimate available in the survey report; the estimate presented is calculated as average fish weight for all years and areas multiplied by the number of fish estimated caught.

This aerial-access method was first employed and optimised to estimate snapper harvests in the Hauraki Gulf in 2003–04. It was then extended to survey the wider FMA 1 fishery in 2004–05 and to provide estimates for other species, including trevally (Hartill et al 2007). This survey was repeated in 2011–12 (Hartill et al 2013) and 2017–18 (Hartill et al 2019).

In response to the cost and scale challenges associated with onsite methods, in particular the difficulties in sampling other than trailer boat fisheries, offsite approaches to estimating recreational fisheries harvest have been revisited. This led to the development and implementation of a national panel survey

for the 2011–12 fishing year (Wynne-Jones et al 2014), repeated for the 2017–18 fishing year (Wynne-Jones et al 2019). The panel surveys used face-to-face interviews of a random sample of about 30 000 New Zealand households to recruit a panel of fishers and non-fishers for a full year. Panel members were contacted regularly about their fishing activities and catch information in standardised phone interviews.

Aerial-access surveys conducted in FMA 1 in 2011–12 (Hartill et al 2013) and 2017–18 (Hartill et al 2019) provide independent harvest estimates for comparison with those generated from the concurrent national panel survey. Both survey types appear to provide plausible results that corroborate each other in TRE 1 and are therefore considered to be broadly reliable (Hartill et al 2013).

1.3 Customary non-commercial fisheries
Trevally is an important traditional and customary food fish for Māori. No quantitative information is available on the current level of customary non-commercial take.

1.4 Illegal catch
No quantitative information is available on the level of illegal trevally catch. An estimate of historical illegal catch is incorporated in the TRE 7 stock assessment model catch history (see Section 4.3.2).

1.5 Other sources of mortality
No quantitative estimates are available regarding the impact of other sources of mortality on trevally stocks. Trevally are known to occur in sheltered harbour and estuarine ecosystems particularly as juveniles. Some of these habitats are known to have suffered substantial environmental degradation.

2. BIOLOGY

Trevally are both pelagic and demersal in behaviour. Juvenile fish up to 2 years old are found in shallow inshore areas including estuaries and harbours. Young fish enter a demersal phase from about 1 year old until they reach sexual maturity. At this stage adult fish move between demersal and pelagic phases. Schools occur at the surface, in midwater and on the bottom, and are often associated with reefs and rough substrate. Schools are sometimes mixed with other species such as kōheru and kahawai. The occurrence of trevally schools at the surface appears to correlate with settled weather conditions rather than with a specific time of year.

Surface schooling trevally feed on planktonic organisms, particularly euphausiids. On the bottom, trevally feed on a wide range of invertebrates.

Trevally are known to reach in excess of 40 years of age. The growth rate is moderate during the first few years, but after sexual maturity at 32 to 37 cm fork length (FL), the growth rate becomes very slow. The largest fish are typically around 60 cm FL and weigh about 4.5 kg; however, larger fish of 6–8 kg are occasionally recorded.

Fecundity is relatively low until females reach about 40 cm FL. They appear to be batch spawners, releasing small batches of eggs over periods of several weeks or months during the summer. Biological parameters relevant to stock assessment are shown in Table 4.

Table 4: Estimates of biological parameters.

Fishstock			Estimate	Source
1. Natural mortality (*M*)			See Section 4.1.4	
2. Weight = a(length)^b (Weight in g, length in cm fork length)			Both sexes	
	a		*b*	
TRE 1	0.016		3.064	James (1984)
TRE 1 (BoP)	0.0291		2.8861	Parsons et al (2021)
3. von Bertalanffy growth parameters			Both sexes	
	L_∞	*k*	t_0	
TRE 1	47.55	0.29	-0.13	Walsh et al (1999)
TRE 1 (BoP)	43.50	0.36	-0.13	McKenzie (in prep)
TRE 7	46.21	0.28	-0.25	

3.   STOCKS AND AREAS

There are no new data that would alter the stock boundaries given in previous assessment documents.

4.   STOCK ASSESSMENT

4.1   TRE 1
The TRE 1 QMA is believed to contain two biological stocks: East Northland (EN) to Hauraki Gulf (HG), and Bay of Plenty. Stock assessments for each of these stocks were rejected by the Northern Inshore Working Group in 2015 and 2016. The Bay of Plenty assessment was rejected on account of strong conflict between abundance indices (standardised bottom trawl CPUE and aerial sightings).

The East Northland to Hauraki Gulf assessment was not initially attempted because the abundance index, based on standardised bottom trawl CPUE (there are insufficient aerial sightings data for the East Northland area), showed conflicting trends in the positive-catch and proportion-of-zero-catch models. This conflict was due to a trend of increasing reporting of low catches in a tow. CPUE analysis was therefore conducted on data that had been amalgamated to the trip level, which successfully eliminated conflict between the positive-catch and proportion-of-zero-catch models. The resulting standardised bottom trawl CPUE index was accepted by the working group as an index of abundance (Figure 2), but an assessment was not attempted due to the lack of contrast within the index.
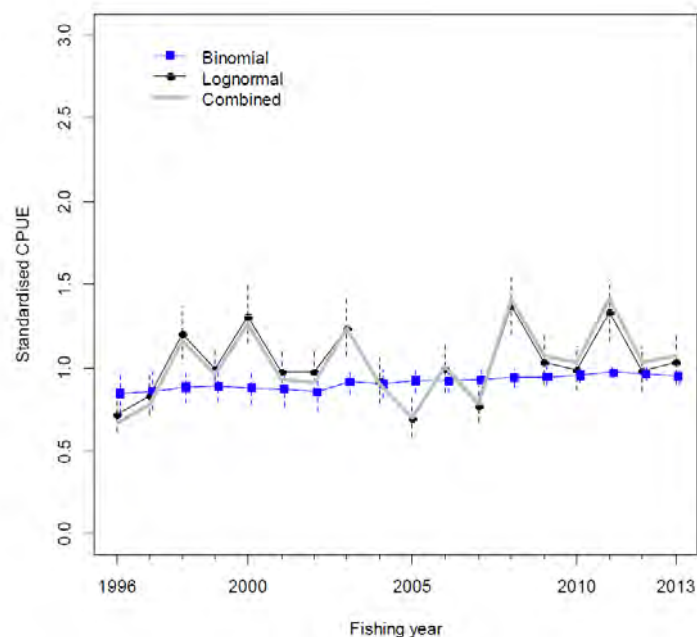
Figure 2: Indices of abundance accepted for the East Northland to Hauraki Gulf stock. Standardised bottom trawl CPUE produced from TCEPR/TCER data forms rolled-up to the trip level. Note that it is the combined index which is accepted as an index of abundance.

Patterns seen in the time series of catch at-age data from TRE 1 suggest that the Bay of Plenty and East Northland regions are likely to constitute two biological sub-stocks (McKenzie et al 2016). An age-based total catch-history assessment model for the Bay of Plenty trevally sub-stock was unable to achieve plausible assessment results when both the aerial sightings and bottom trawl CPUE abundance indices were fitted or when the model was fitted to the aerial sightings index on its own (McKenzie et al 2015). The model was, however, able to achieve plausible estimates for B_0 when the aerial index was excluded, achieving acceptable fits to both the bottom trawl CPUE and the bottom trawl age composition data (McKenzie et al 2015). The working group accepted that the bottom-trawl-index-only model provided a basis for a future assessment of the Bay of Plenty sub-stock; and also recommended that the aerial sightings index should be dropped from future Bay of Plenty assessments due to inconsistency with the other observational data in the model, i.e., catch history, catch-at-age, and bottom trawl CPUE. The

working group recommended that assessments for the TRE 1 east Northland and Bay of Plenty sub-stocks should be undertaken, after completion of the next catch-at-age study for TRE 1.

A new assessment for TRE 1 Bay of Plenty was conducted in 2022, with the aerial sightings index dropped, and incorporating updated bottom trawl CPUE and new age composition data.

4.1.1 CPUE
Bay of Plenty
A standardised CPUE index of abundance was used in the 2022 assessment (Table 5, Figure 3). The CPUE data set comprised catch and effort records from the bottom trawl fishery targeting trevally, snapper, tarakihi, John dory, or red gurnard within Bay of Plenty during 1989–90 to 2020–21. Fishing effort records were aggregated by vessel fishing day in a format consistent with the CELR reporting format.

Table 5: Standardised single trawl CPUE indices (relative year effects) for Bay of Plenty from 1989–90 to 2020–21.

Fishing year	CPUE index	Fishing year	CPUE index
1989–90	0.893	2005–06	1.081
1990–91	0.731	2006–07	0.695
1991–92	0.317	2007–08	1.481
1992–93	0.725	2008–09	0.954
1993–94	0.920	2009–10	1.138
1994–95	0.596	2010–11	1.462
1995–96	0.735	2011–12	1.113
1996–97	0.945	2012–13	0.950
1997–98	0.502	2013–14	0.925
1998–99	1.258	2014–15	0.817
1999–00	1.284	2015–16	1.381
2000–01	1.006	2016–17	1.585
2001–02	0.994	2017–18	1.485
2002–03	0.657	2018–19	1.035
2003–04	0.633	2019–20	1.365
2004–05	1.051	2020–21	2.138
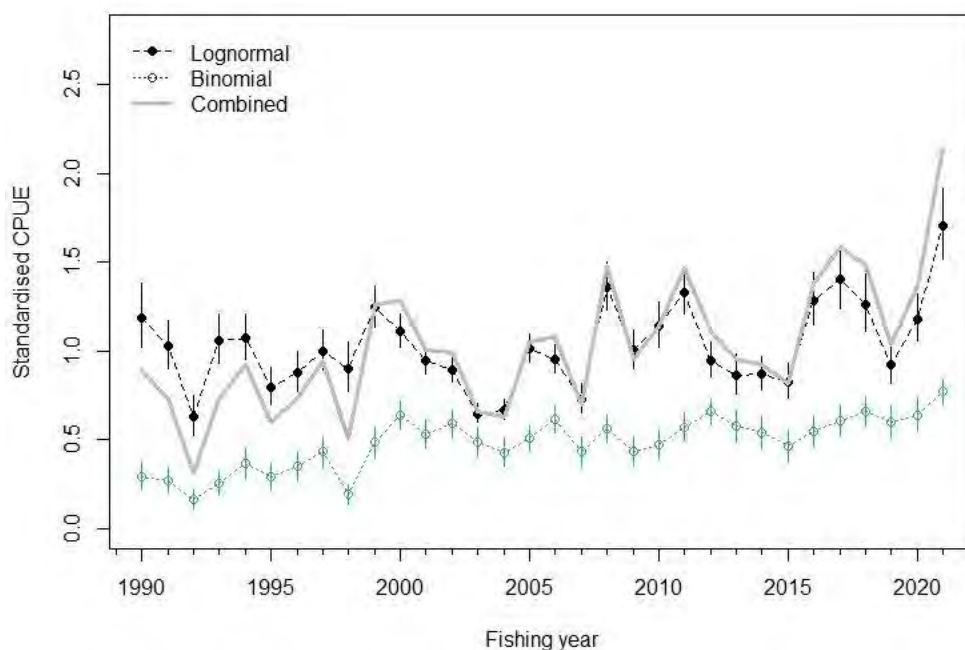
Figure 3: Indices of abundance accepted for the Bay of Plenty stock. Standardised bottom trawl CPUE produced from TCEPR/TCER data aggregated by vessel fishing day. Note that it is the combined index which is accepted as an index of abundance.

The standardised CPUE analysis included two components: a positive trevally catch component modelled assuming a lognormal error structure and a binomial model of the presence/absence of trevally in the vessel daily catch. The CPUE final index multiplied the annual indices from the separate models to derive a combined index.

From 1989–90 to 2020–21, the CPUE indices have an irregular but upward trend, with an approximate doubling over the period.

4.1.2 Catch history

Commercial catch records for TRE 1 Bay of Plenty date back to 1931. Before that time the stock is assumed to have been lightly exploited and close to its unexploited state. It is likely that reported catches prior to 1970 are underestimates of the true catch due to large-scale discarding of fish (James 1984). Since 1931, allowances have been made in the catch history for recreational, illegal catch, and discards. A small amount of catch is assigned to bottom trawl from methods that are not bottom trawl, purse seine, or recreational (e.g., PSH, bottom longline, bottom pair trawl). The final catch history in the assessment model is presented in Figure 4.
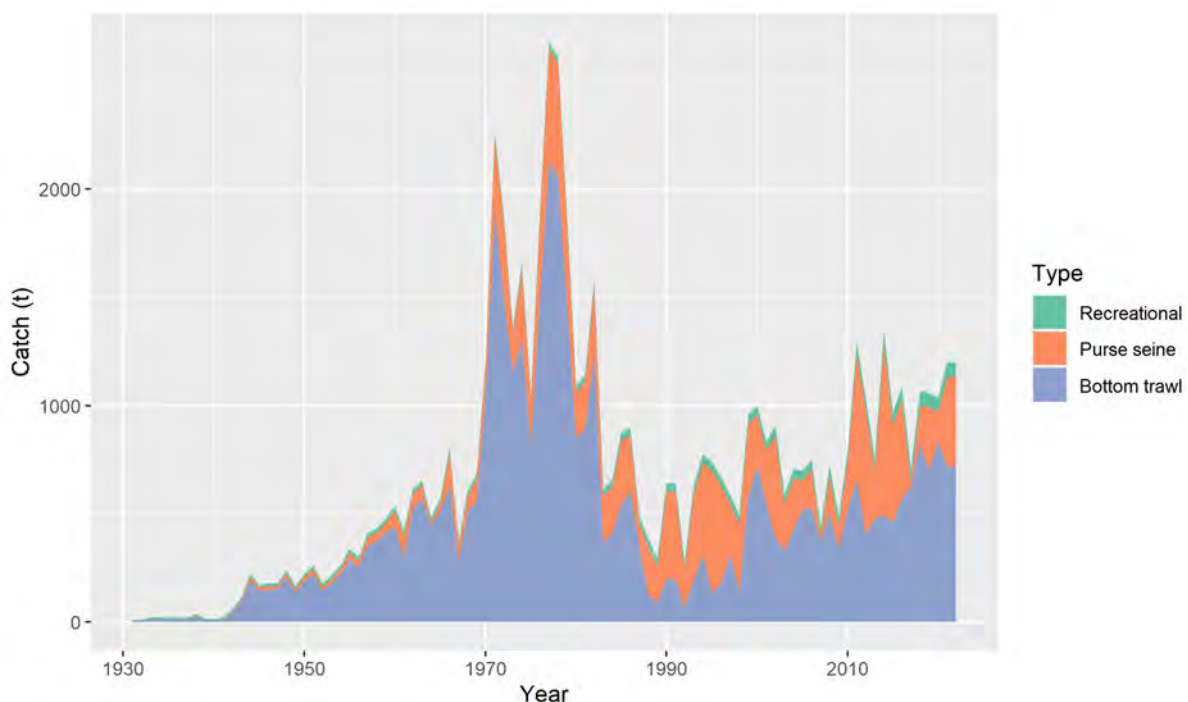
Figure 4: Catch history for the Bay of Plenty area of the TRE 1 fishery including total annual reported commercial catch, estimated discards, illegal catch, and recreational catch.

4.1.3 Catch at age

A time series of age frequency distributions is available from the bottom trawl fishery within Bay of Plenty from 1997–98 to 2019–20 (8 observations). There is also a time series from the purse seine fishery from 1997–98 to 2012–13 (9 observations), which exhibited considerable variability and were down-weighted in the assessment model.

4.1.4 Estimates of natural mortality

Following previous assessments, natural mortality was assumed to be 0.10 based on an observed maximum age of about 45 years (estimated using the equation $M = \log_e 100/\text{maximum age}$, where maximum age is the age to which 1% of the population survives in an exploited stock). Estimates of stock status were sensitive to the value of natural mortality and the final mode of the posterior distribution (MPD) model runs included sensitivity runs using a lower value of 0.075 and a higher value of 0.125.

4.1.5 Model structure

The age structured population model encompasses the 1931–2022 period. The model structure is non-sexed with 1–30 year age classes, including an accumulating age class for older fish (30+ years). The age structure of the population at the start of the model is assumed to be in an unexploited, equilibrium state.

The biological parameter for natural mortality is the same as that used in previous trevally assessments, with Bay of Plenty specific estimates for growth and weight-length (see Table 6). For the base model, natural mortality was invariant with age at a value of 0.10. A Beverton-Holt spawning stock recruitment relationship (SRR) was assumed with steepness (h) fixed at 0.85 and the standard deviation of the natural logarithm of recruitment (σ_R) was fixed at 0.6. Recruitment deviates were estimated for the 1970–2015 years.

Table 6: Biological parameters for the Bay of Plenty area in TRE 1.

Fishstock			Estimate	Source
1. Natural mortality (*M*)			See Section 4.1.4	
2. Weight = a(length)^b (Weight in g, length in cm fork length).				
			Both sexes	
	a		*b*	
	0.0291		2.8861	Parsons et al (2021)
3. von Bertalanffy growth parameters				
			Both sexes	
	L_∞	k	t_0	
	43.5	0.36	-0.13	McKenzie (in prep)

Separate fishery selectivities were estimated for the main bottom trawl fishery (double normal parameterisation) and the purse seine fishery (double normal parameterisation), and a double normal selectivity was estimated outside the assessment model for the recreational fishery. The CPUE indices were linked to the vulnerable biomass of the main bottom trawl fishery.

The model was fitted to: (a) a bottom trawl CPUE index for the years 1990 to 2021, (b) a commercial proportions-at-age series for 1998 to 2020. The weighting of the individual data sets followed the approach of Francis (2011). The final assessment model adopted a CV of 27% for the time series of CPUE indices. The highly variable purse seine age composition data were assigned a low weighting in the likelihood (effective sample size of one).

During model development, a range of options was investigated to examine the key structural assumptions of the model. The most influential assumption was the value of natural mortality (0.10), and the MPD final model runs included sensitivity runs using a lower value of 0.075 and a higher value of 0.125. Other MPD final model run sensitivities were: (a) including the northern part of TRE 2 as part of the stock, and (b) starting the model in a non-equilibrium state in 1983 and dropping the uncertain catch history before then. Sensitivities were undertaken as MPDs, with the base model run taken through a Markov chain Monte Carlo (MCMC) analysis. The right-hand limbs of the trawl and purse seine selectivities were estimated to be flat in the MPD and were fixed at these values for the MCMC runs.

Model projections for a five-year period (2023–27) were conducted. These projections were conducted with catch assumed to be either at the 2022 level, or twenty percent higher. In the projection period, recruitment variation was incorporated in the model with the recruitment deviates resampled from the last ten years (2012–2021), or over the whole period (1970–2021). Parameter uncertainty was determined using an MCMC approach.

4.1.6 Results

The base assessment model indicates that the spawning biomass declined in the 1970s consistent with the high catch taken during this period (Figure 5). From the mid-1980s the spawning biomass increased to 66.4% B_0 (45.2, 95.2) in 2022 (median and 95% credible interval) (Table 7). Recruitment is highly uncertain, but is estimated to have decreased from 1970 to the early 1990s, and subsequently increased to higher but variable levels (Figure 6). Fishing intensity was highest from 1970 to 1985, following the increase in landings over this period (Figure 7).

Of the MPD sensitivities investigated, the most influential was the value of natural mortality (0.10 in the base model). The estimated current status of the stock can vary from 46% B_0 to 84% B_0 depending on the value of natural mortality assumed (0.075 or 0.125, respectively) (Table 8). Incorporating the northern part of TRE 2 into the assessment resulted in little difference to the estimated status of the stock, as did using a non-equilibrium model starting in 1983.
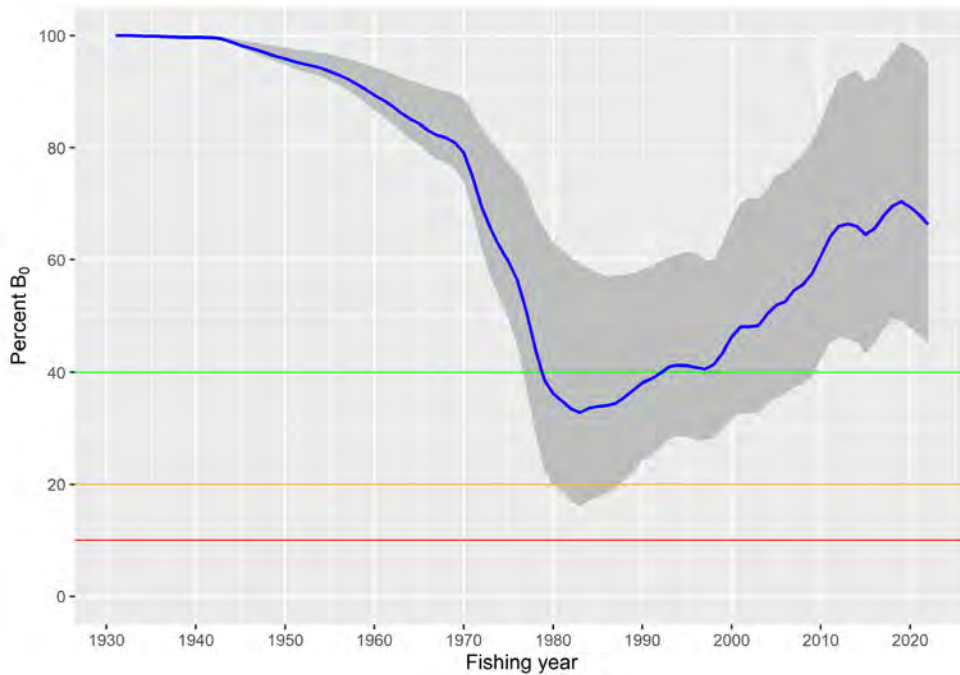
Figure 5: Spawning stock biomass from the MCMC model fits for the base model, with 95% credible interval. Horizontal lines are the 40% target (green), soft limit (20% B_0), and hard limit (10% B_0).

Table 7: Virgin biomass (B_0) and current stock status (% B_0) for the base model with medians and 95% credible intervals. Estimates are derived from MCMC analysis.

Model	B_0 (thousands of tonnes)	B_{2022}(% B_0)
Base	27.1 (21.7, 49.1)	66.4 (45.2, 95.2)
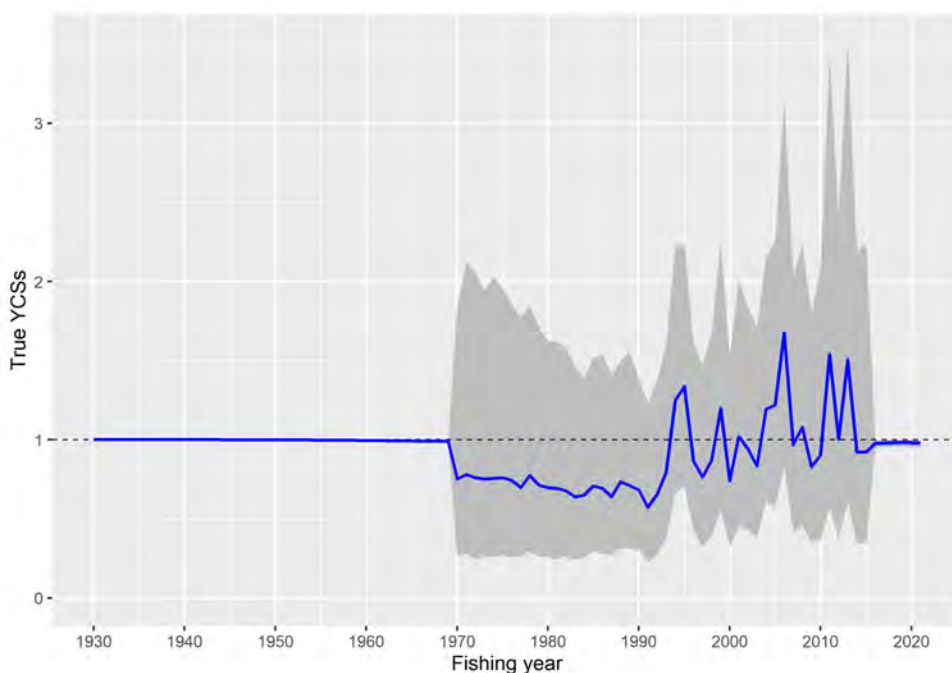
Figure 6: True year class strengths (YCSs) from the MCMC model fits for the base model, with 95% credible interval.
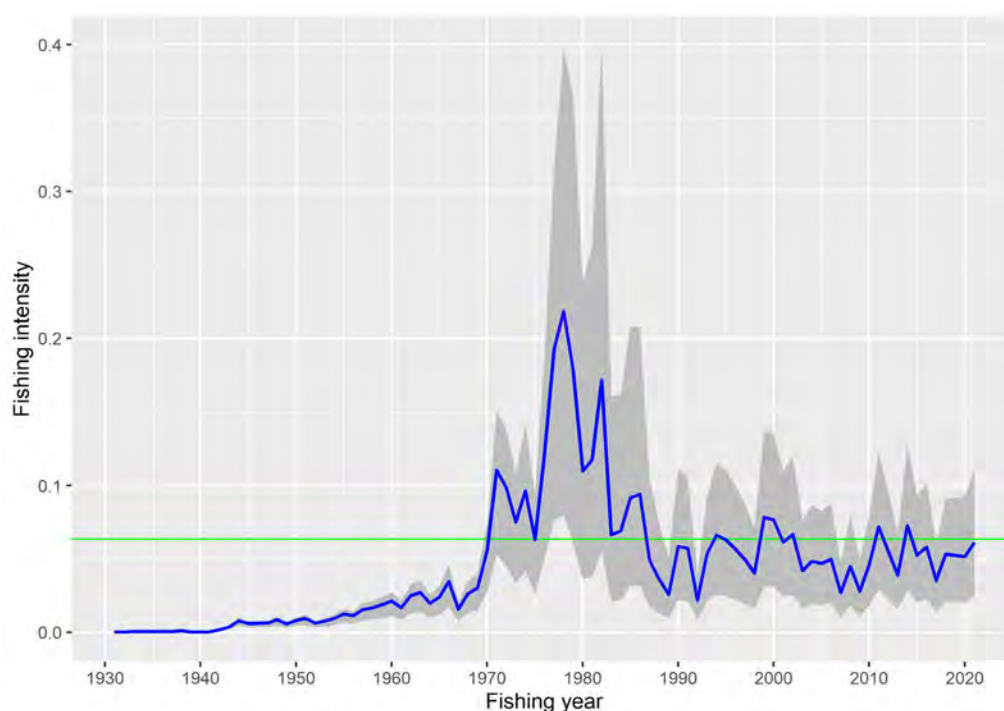
Figure 7: Fishing intensity (total annual landing divided by *SSB*), with 95% credible interval. The horizontal green line is the target fishing intensity corresponding to the 40% *B₀* target (MPD calculation).

Table 8: Virgin biomass (*B₀*) and current stock status (% *B₀*) for the base model and sensitivities on the natural mortality. Estimates are derived from MPD analysis.

Model	B_0 (thousands of tonnes)	B_{2022}(% B_0)
Base ($M = 0.10$)	24.0	65
$M = 0.075$	25.0	46
$M = 0.125$	26.9	84

4.1.7   Yield estimates and projections

Stock projections, for a five-year period, were conducted for the base model. The projections used either the current assumed 2021–22 catch, or the current catch plus twenty percent. YCSs were sampled from either the last 10 years (2012–2021), or from the start of when YCSs were estimated (1970–2021). For all projection scenarios, there is a low probability that the target biomass will decline below the target level (Table 9, Figure 8).

Table 9: Stock status in the last year (2027) of the five-year forecast period for the base model using either the assumed current catch in 2021–22, or the current catch plus twenty percent. Recruitment was resampled from recent estimates (2012–2021) or long-term estimates (1970–2021).

Projection	$\Pr(SB_{2027} > X\% \; SB_0)$		
	10%	20%	40%
current catch, recent recruitment	1	1	0.966
catch plus 20%, recent recruitment	1	1	0.904
current catch, long-term recruitment	1	1	0.955
catch plus 20%, long-term recruitment	1	1	0.905
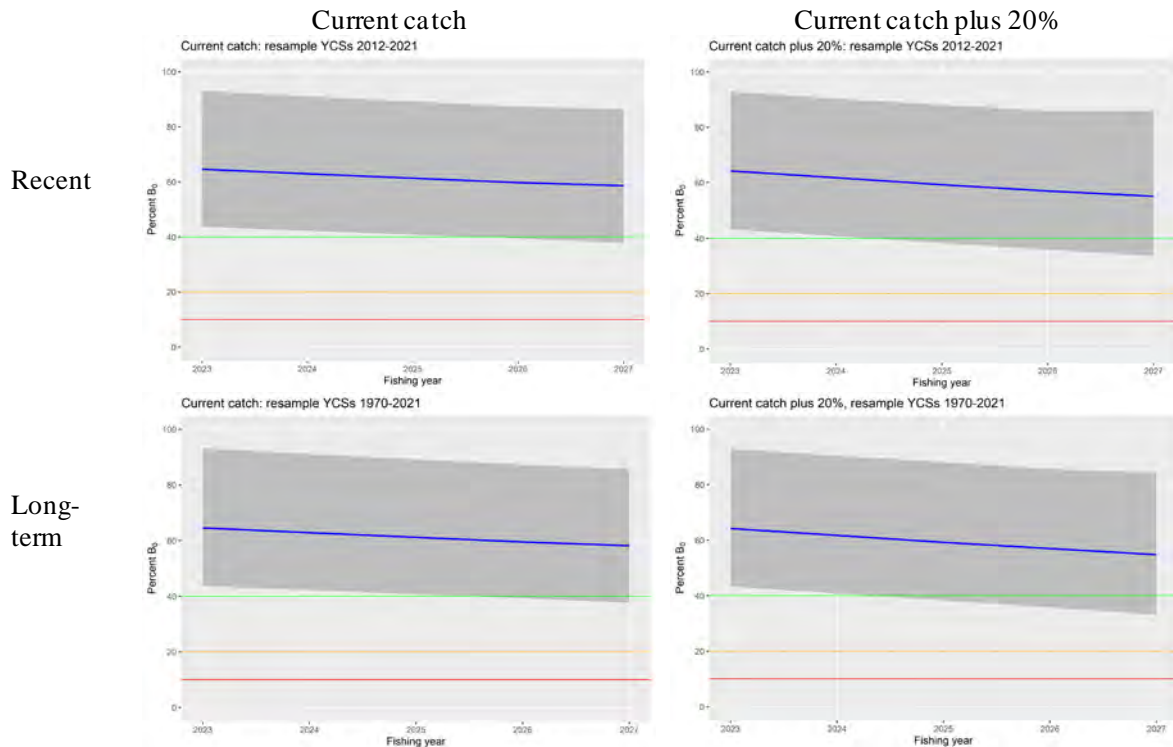
Figure 8: Spawning stock biomass with 95% credible interval during the five-year forecast period for the base model using either the assumed current catch in 2021–22, or the current catch plus twenty percent. Recruitment was resampled from recent estimates (2012–2021) or long-term estimates (1970–2021).

4.1.8 Future Research Considerations

- Undertake simultaneous catch sampling in TRE 1 and TRE 2 to resolve stock relationships and to validate years of recent strong recruitment estimated by the model.
- Further explore CPUE standardisation, including the incorporation of appropriate environmental covariates, sensitivity to the inclusion of key vessels, and potential influences of efficiency creep.
- Explore alternative parameterisation of growth and associated assessment model sensitivities

4.2 TRE 2

High annual variability in standardised CPUE indices, and narrow confidence intervals led the Northern Inshore Working Group to conclude that trevally in TRE 2 are probably part of the TRE 1 biological stock in the Bay of Plenty, with abundance in TRE 2 fluctuating markedly according to the movement of fish into and out of this QMA. Stock assessments for TRE 2 will in future be done in conjunction with TRE 1.

A new CPUE analysis for TRE 2 was conducted in 2018 (Schofield et al 2018). Combined (binomial/Weibull) indices were produced for 1989–90 to 2016–17 using data aggregated to vessel-day resolution, and for 2006–07 to 2016–17 using tow resolution data. There was good correspondence between the two indices for the overlapping period.

Comparison of CPUE trends between the TRE 2 combined series and the TRE 1 BoP index (Figure 9) showed good correspondence between 1989–90 and 2006–07, but a poor relationship thereafter.

For TRE 2, the working group considered that the large variations in the early part of the series, over relatively short time periods, suggest that factors in addition to changes in abundance may be influencing the index.
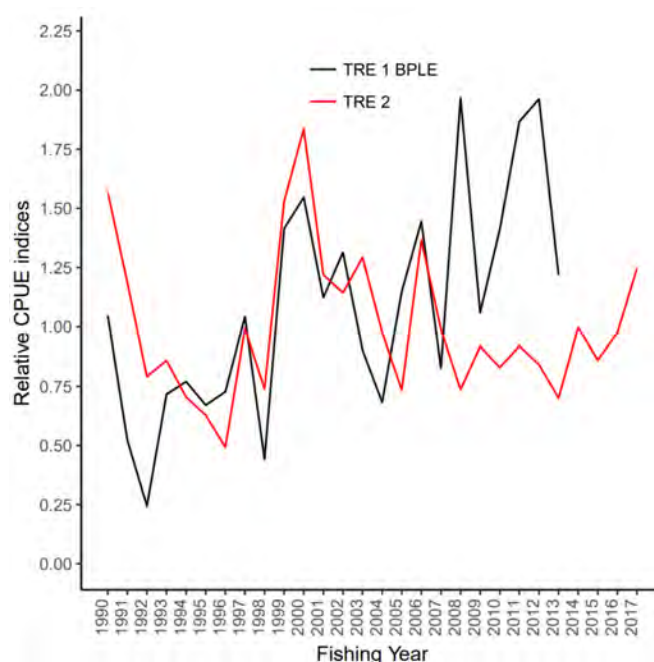
Figure 9: Standardised CPUE for TRE 2 (Schofield et al 2018) and TRE 1 Bay of Plenty (BoP, McKenzie et al 2016).

Data were further analysed in 2022 (McKenzie in prep.) and an attempt was made to develop a stock assessment linking BoP trevally and TRE 2(N), but this was unsuccessful.

4.3   TRE 7

The TRE 7 stock assessment was revised and updated in 2015 (Langley 2015). Recent analyses have revealed considerable differences in TRE 7 age composition data and trends in CPUE indices among the three main fishing areas within the TRE 7 Fishstock; i.e., Ninety Mile Beach (NMB), South Taranaki Bight (STB), and the core area of the fishery between North Taranaki Bight and Tauroa Point (KMNTB). The apparent spatial heterogeneity within TRE 7 indicated that the assumption of a single stock was not appropriate. Attempts to incorporate spatial structure within the TRE 7 assessment model were not successful due to inadequate historical catch-at-age data from the STB and NMB areas (Langley 2015). The final 2015 stock assessment was limited to the core area of the fishery (KMNTB) only. This area accounted for 60% of the total TRE 7 commercial catch from 1944 to 2012–13 and 70% of the catch from recent years (2010–2011 to 2012–13).

4.3.1   CPUE

A standardised CPUE index of abundance was used in the 2015 assessment (Table 10). The CPUE data set comprised catch and effort records from the single bottom trawl fishery targeting trevally or snapper within the core area of the fishery (KMNTB area) during 1990–91 to 2012–13. Fishing effort records were aggregated by vessel fishing day in a format consistent with the CELR reporting format. The final data set excluded one of the vessels that dominated the fishery in recent years. The trend in catch rate of trevally for this vessel differed considerably from the remainder of the fleet and there were also marked differences in the overall age composition of the trevally catches taken by this vessel (Langley 2015).

The standardised CPUE analysis included two components: a positive trevally catch component modelled assuming a Weibull error structure and a binomial model of the presence/absence of trevally in the vessel daily catch. The CPUE final index multiplied the annual indices from the separate models to derive a combined index.

The CPUE indices increase markedly after 2007–08. There were considerable changes in the operation of the fishery during that period related to an increased degree of targeting trevally following the reduction in the TACC for snapper in 2005–06. The CPUE standardisation accounts for a component of the change in the operation of the fishery, although it is unknown whether the shift in targeting is fully accounted for in the final CPUE indices.

Table 10: Standardised single trawl CPUE indices (relative year effects) from 1990–90 to 2012–13 (Langley 2015).

Fishing year	CPUE index	Fishing year	CPUE index
1989–90	–	2001–02	0.805
1990–91	1.291	2002–03	0.882
1991–92	1.202	2003–04	0.783
1992–93	0.862	2004–05	0.620
1993–94	1.181	2005–06	0.855
1994–95	0.980	2006–07	0.685
1995–96	0.888	2007–08	0.920
1996–97	0.830	2008–09	0.819
1997–98	0.782	2009–10	0.828
1998–99	0.992	2010–11	1.209
1999–00	0.764	2011–12	1.055
2000–01	0.678	2012–13	1.023

4.3.2 Catch history

Commercial catch records for TRE 7 date back to 1944. Before that time the stock is assumed to have been lightly exploited and close to its unexploited state. It is likely that reported catches prior to 1970 are underestimates of the true catch due to large-scale discarding of fish (James 1984). Total annual TRE 7 catches were apportioned by fishery area and fishing method (single and pair bottom trawl) (Figure 10). The base assessment model included annual catches from the KMNTB area only. A separate fishery was configured to account for the catch by the single dominant vessel operating in the bottom trawl fishery in recent years.

Since 1944, there has also been a recreational and customary catch as well as an illegal or non-reported catch. For the purposes of modelling the KMNTB component of the TRE 7 stock, it is necessary to make allowance for mortality due to discarded fish, recreational catch, customary catch, and non-reported catch. The final catch history included in the assessment model is presented in Table 11.

4.3.3 Catch at age

A time series of age frequency distributions is available from the target TRE 7 single trawl fishery within KMNTB from 1997–98 to 2012–13 (nine observations). The age sampling data from the dominant single trawl vessel were excluded from the age frequency samples for 2009–10 and 2012–13. There are also some age frequency samples for the pair trawl method from the late 1990s and early 2000s (three observations). Previous comparisons found no significant difference between the age composition of catches made by pair and single trawl methods (Hanchet 1999).

In addition, two sources of age frequency data are available from the 1970s: (1) a series covering the years 1971–74 derived from research sampling carried out by the vessel *James Cook*, and (2) a series derived from market sampling carried out in the 1974–1976 and 1978–1979 fishing years (five observations). There is considerable variability amongst the latter series with the result that these data were relatively uninformative in the assessment modelling and, hence, were down-weighted in the final model options.

4.3.4 Estimate of natural mortality (*M*)

Following previous assessments, natural mortality was assumed to be 0.10 based on an observed maximum age of about 40 years (using the regression method of Hoenig 1983). Estimates of stock status were sensitive to the value of natural mortality and the final model runs included a sensitivity run using a lower value of 0.083, corresponding to an assumed maximum age of 50 years.
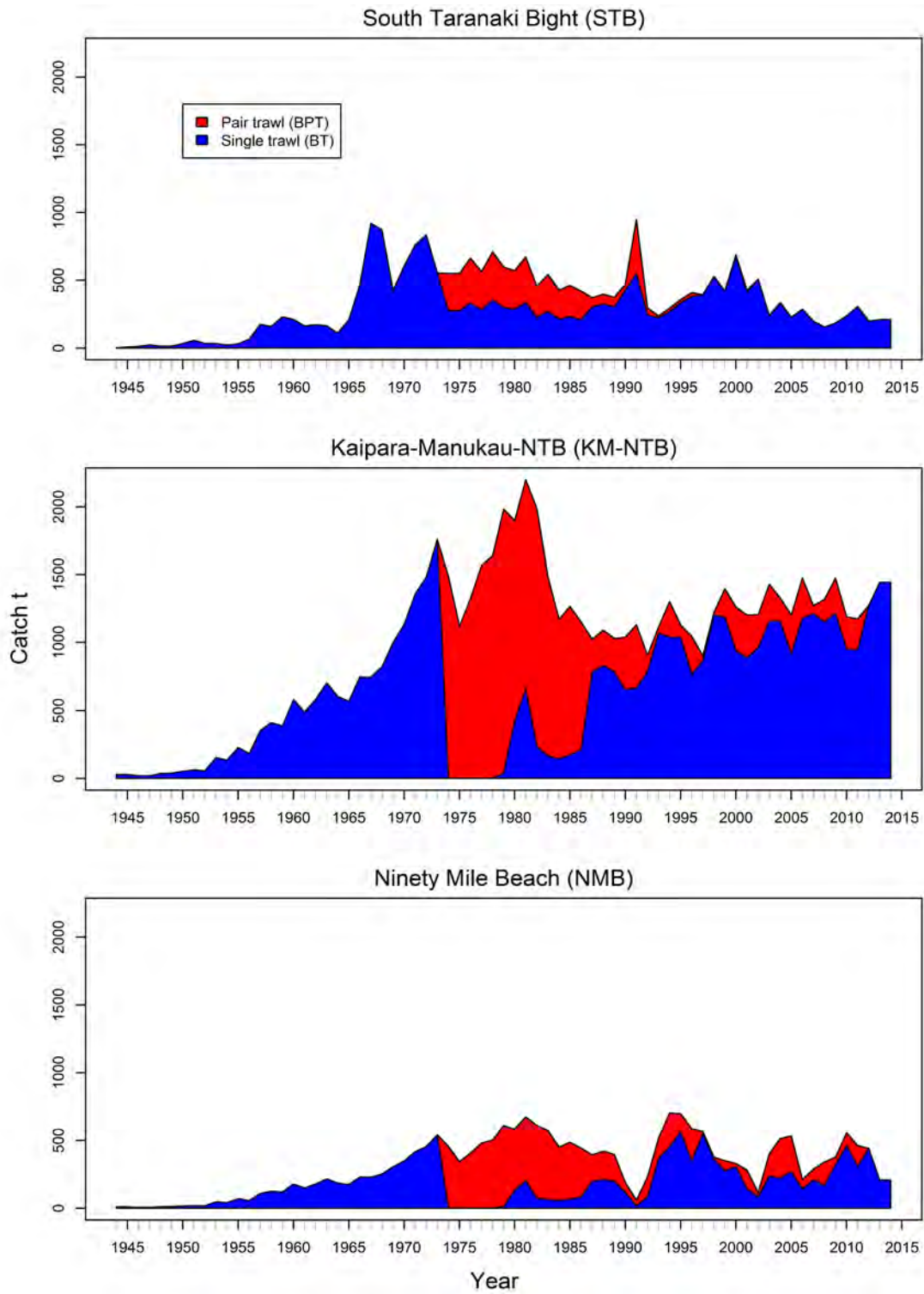
Figure 10: Total TRE 7 commercial catch history formulated for the stock assessment, apportioned by fishing method and sub-area of TRE 7.

Table 11: Catch history (t) for the KMNTB area of the TRE 7 fishery including total annual reported commercial catch, estimated discarded (D) commercial catch, estimated non-reported commercial catch, recreational catch, and customary catch. (The year denotes the year at the end of the fishing year.)

Year	Reported landings	D	Under-reported catch	Rec. catch	Cust. catch	Total	Year	Reported landings	D	Under-reported catch	Rec. catch	Cust. catch	Total
1944	14	9	5	14	15	57	1980	1 582	0	317	70	12	1 981
1945	15	10	5	16	15	60	1981	1 833	0	367	70	12	2 282
1946	10	7	3	18	15	53	1982	1 659	0	331	70	12	2 072
1947	11	5	2	20	15	53	1983	1 237	0	247	70	12	1 566
1948	21	10	5	23	15	74	1984	975	0	195	70	12	1 252
1949	23	13	3	25	15	79	1985	1 053	0	211	70	12	1 346
1950	31	16	6	27	15	95	1986	959	0	192	70	12	1 233
1951	37	19	7	29	15	107	1987	929	0	93	70	12	1 104
1952	33	17	6	31	15	102	1988	1 001	0	90	70	12	1 173
1953	90	45	18	33	15	201	1989	951	0	76	70	12	1 109
1954	79	40	16	36	15	186	1990	971	0	68	70	12	1 121
1955	134	67	27	38	15	281	1991	1 065	0	64	70	12	1 211
1956	108	54	22	40	15	238	1992	863	0	43	70	12	988
1957	207		41	42	15	409	1993	1 070	0	43	70	12	1 195
1958	241		49	44	15	470	1994	1 264	0	38	70	12	1 384
1959	228		45	46	15	449	1995	1 106	0	22	70	12	1 210
1960	411	88	82	48	10	639	1996	1 034	0	10	70	12	1 126
1961	346	74	69	51	10	550	1997	892	0	9	70	12	983
1962	411	88	82	53	10	644	1998	1 208	0	12	70	12	1 302
1963	499		99	55	10	770	1999	1 382	0	14	70	12	1 478
1964	429	92	86	57	10	673	2000	1 246	0	13	70	12	1 341
1965	402	86	81	59	10	638	2001	1 189	0	12	70	12	1 283
1966	597	33	119	61	10	820	2002	1 192	0	12	70	12	1 286
1967	595	33	119	64	10	821	2003	1 414	0	14	70	12	1 510
1968	652	36	130	66	10	894	2004	1 314	0	13	70	12	1 409
1969	795	44	159	68	10	1 076	2005	1 190	0	12	70	12	1 284
1970	945	0	189	70	10	1 214	2006	1 461	0	15	70	12	1 558
1971	1 130	0	226	70	10	1 436	2007	1 259	0	12	70	12	1 353
1972	1 233	0	247	70	10	1 560	2008	1 305	0	12	70	12	1 399
1973	1 468	0	294	70	10	1 841	2009	1 460	0	14	70	12	1 556
1974	1 239	0	248	70	10	1 567	2010	1 177	0	12	70	12	1 271
1975	933	0	187	70	10	1 200	2011	1 161	0	11	70	12	1 254
1976	1 102	0	221	70	10	1 403	2012	1 260	0	13	70	12	1 355
1977	1 306	0	261	70	10	1 647	2013	1 429	0	14	70	12	1 525
1978	1 367	0	273	70	10	1 720	2014	1 429	0	14	70	12	1 525
1979	1 653	0	331	70	10	2 064							

4.3.5 Model structure

The age structured population model encompasses the 1944–2014 period. The model structure includes two sexes and 1–40 year age classes, including an accumulating age class for older fish (40+ years). The age structure of the population at the start of the model is assumed to be in an unexploited, equilibrium state. The biological parameters are those used in previous assessments and equivalent for the two sexes (see Table 4). For the base model, natural mortality was invariant with age at a value of 0.1. A Beverton-Holt spawning stock recruitment relationship (SRR) was assumed with steepness (h) fixed at 0.85 and the standard deviation of the natural logarithm of recruitment (σ_R) was fixed at 0.6. Recruitment deviates were estimated for the 1970–2008 years.

Separate fishery selectivities were estimated for the main bottom trawl fishery (double normal parameterisation) and the pair trawl fishery (logistic), and a double normal selectivity was estimated for the *James Cook* research trawl age samples. The CPUE indices were linked to the vulnerable biomass of the main bottom trawl fishery.

The model was fitted to: (a) a combined (either trevally or snapper targeted) bottom trawl CPUE index for the years 1990 to 2013, (b) a research sampling proportions-at-age series for 1971 to 1974, (c) a market sampling proportions-at-age series covering 1974 to 1976 and 1978 to 1979, (d) a commercial proportions-at-age series for 1997 to 2013. The weighting of the individual data sets followed the approach of Francis (2011). The final assessment model adopted a CV of 16% for the time series of CPUE indices. The recent bottom trawl age composition data were assigned a moderately high weighting in the likelihood (ESS of about 50).

During model development, a range of options was investigated to examine the key structural assumptions of the model. The most influential assumption was the value of natural mortality, and a lower value of natural mortality (0.083) was used as a key model sensitivity. An additional sensitivity run was conducted assuming a lower value of steepness for the SRR (0.7 compared with 0.85), and with M=0.1).

The base model estimates a low selectivity of older fish for the bottom trawl (BT) fishery. The age composition data appear to be uninformative regarding the selectivity of the oldest age classes and, hence, the selectivity was sensitive to the prior for the associated parameters. An additional selectivity was conducted that assumed a prior value which corresponded to a high selectivity of the older age classes (0.8 for the oldest age class) (*BTselect*).

The base model encompassed the KMNTB area only. The spatial stratification of the TRE 7 Fishstock was primarily based on differences in the age composition of trevally amongst sub-areas of TRE 7. However, limited sampling has been conducted in the other areas and, although some differences in age structure of the catch are apparent among areas, there are some similarities in the age structures from the three areas. Spatial differences in age composition could be attributable to differences in fishery selectivity and/or variability in the sampled component of the catch. On that basis, an alternative model was formulated based on a single stock hypothesis, including the entire catch from TRE 7 within the framework of the KMNTB model (*AllCatch*). The *AllCatch* model provides estimates of yield that are consistent with the total TRE 7 catch and the TACC.

Further model runs were undertaken to explore the influence of two key data sets in the assessment: the recent (2007–2013) CPUE indices and the 1998–2001 bottom pair trawl (BPT) age composition data.

Model projections for a five year period (2015–2019) were conducted using the *AllCatch* model. These projections were conducted with annual commercial catch assumed to be either at the level of the TACC or equivalent to the annual catch from the 2012–13 fishing year and included additional allowances for customary and recreational catch. In the projection period, recruitment variation was incorporated in the model with the recruitment deviates simply constrained by the assumed variation in the deviates (σ_R = 0.60). Parameter uncertainty was determined using a Markov chain Monte Carlo (MCMC) approach.

4.3.6 Results

The assessment models indicate that the spawning biomass gradually declined during the 1940s and 1950s. The rate of decline increased in the 1960s and 1970s consistent with the increase in the total annual catch. The extent of the reduction in the spawning biomass during the 1970s was informed by the 1998–2001 age composition data from the BPT fishery. The proportion of older fish included in the age composition provide information regarding the level of fishing mortality in the preceding period. Thus, the estimation of the level of depletion will also be influenced by the assumed value of M (i.e., higher depletion with lower M). The spawning biomass remained relatively stable during the late 1990s and 2000s.

The stock status of the KMNTB component of TRE 7 has been assessed relative to a default target biomass level of 40% SB_0 and associated soft limit and hard limits of 20% and 10% SB_0 (Ministry of Fisheries 2008). Stock status conclusions are specific to the area encompassed by the base assessment model (i.e., KMNTB). For the base model, spawning biomass was maintained at about 50% SB_0 during the late 1990s and 2000s and there is a very low probability that the biomass declined below the target biomass during that period (Figure 11). The spawning biomass is estimated to have increased from 2010 to 2014 and the base model estimates that current biomass (SB_{2014}) is above the target biomass level (Tables 12 and 13).
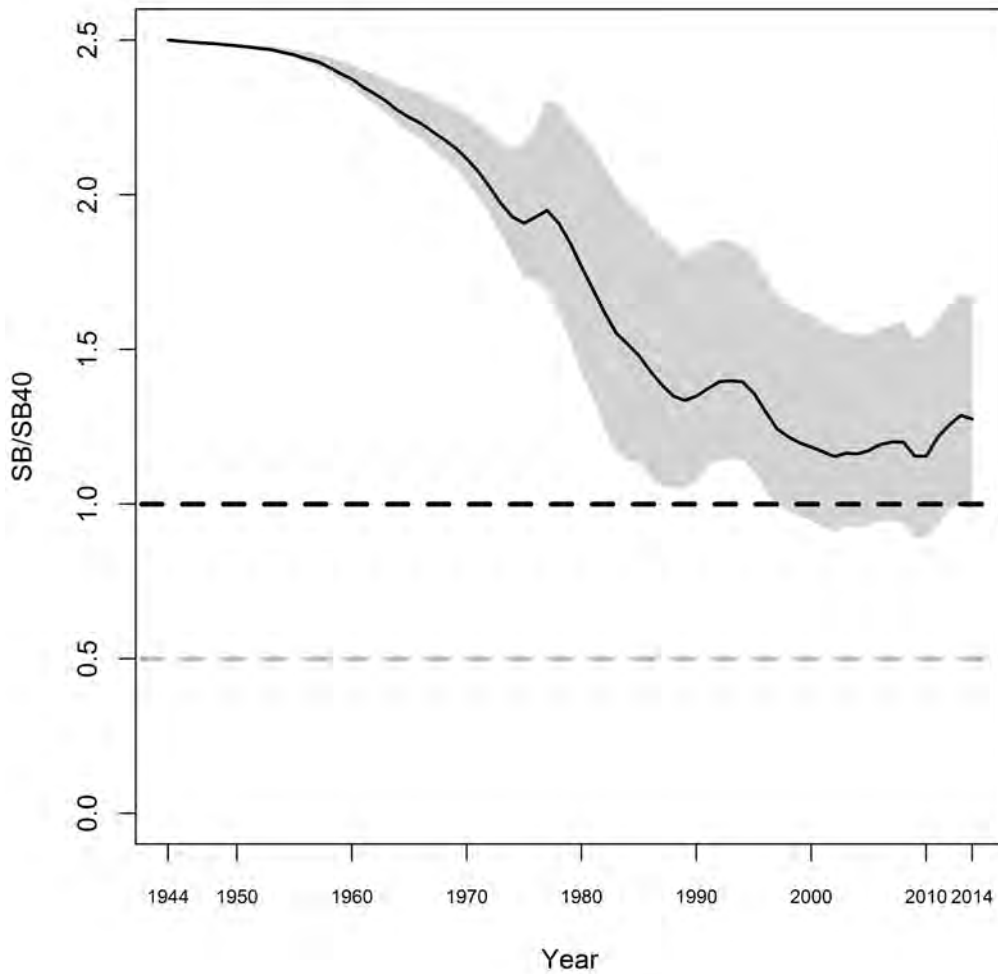
Figure 11: Spawning biomass (female only) trajectory from MCMC model fits for the base model, with 95% credible intervals.

Table 12: Biomass and yield estimates (medians, with 95% confidence intervals in parentheses) for the base model and sensitivities. Estimates are derived from MCMC analysis. Model results are limited to the KMNTB area of TRE 7, except for the *AllCatch* sensitivity which represents the entire TRE 7 area.

Model option	SB_0	SB_{2014}	$SB_{40\%}$	SB_{2014}/SB_0	$SB_{2014}/SB_{40\%}$
Base	22 339	11 526	8 935	0.510	1.275
	(18 493–36 213)	(73 84–23 808)	(7 397–14 485)	(0.393–0.669)	(0.982–1.672)
M low	21 026	8 399	8 410	0.399	0.998
	(18 692–26 268)	(5 774–13 446)	(7 477–10 507)	(0.305–0.525)	(0.762–1.313)
Steep70	23 557	11 483	9 423	0.489	1.224
	(19 723–39 933)	(7 384–26 688)	(7 889–15 973)	(0.368–0.682)	(0.92–1.704)
BTselect	20 436	9 698	8 174	0.474	1.184
	(17 787–27 121)	(6 708–16 116)	(7 115–10 848)	(0.371–0.619)	(0.927–1.549)
AllCatch	34 363	16 873	13 745	0.49	1.226
	(29 348–50 375)	(11 247–32 361)	(11 739–20 150)	(0.381–0.66)	(0.951–1.649)

Table 13: Estimates of target fishing mortality ($F_{SB40\%}$) and current fishing mortality (F_{2014}) relative to the target level (medians, with 95% confidence intervals in parentheses) for the base model and sensitivities. Estimates are derived from MCMC analysis. Model results are limited to the KMNTB area of TRE 7, except for the *AllCatch* sensitivity which represents the entire TRE 7 area.

Model option	$F_{SB40\%}$	$F_{2014}/F_{SB40\%}$	$Pr\ (F_{2014}<F_{SB40\%})$
Base	0.0877 (0.0844-0.0904)	0.678 (0.338-1.024)	0.969
M low	0.0768 (0.0742-0.079)	1.067 (0.69-1.517)	0.365
Steep70	0.077 (0.0741-0.0795)	0.776 (0.351-1.183)	0.851
BTselect	0.0885 (0.0855-0.0908)	0.796 (0.49-1.12)	0.902
AllCatch	0.0872 (0.0843-0.0896)	0.591 (0.319-0.862)	0.999

Current levels of fishing mortality are estimated to be below the $F_{SB40\%}$ level for all model options with the base level of natural mortality ($M=0.1$). The model sensitivity with the lower M estimated current fishing mortality to be at about the $F_{SB40\%}$ level (Table 13 and Figure 12).
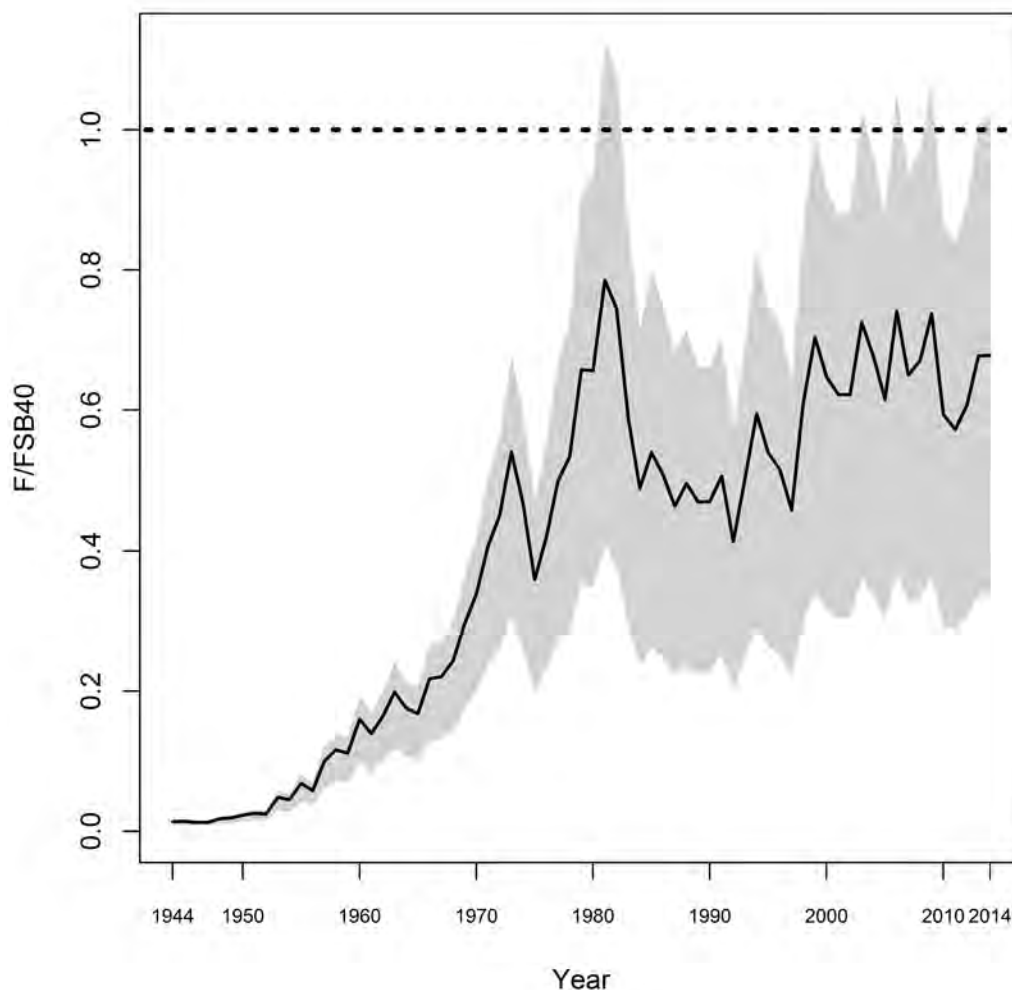
Figure 12: Fishing mortality (female only) relative to the overfishing threshold ($F_{SB40\%}$) (median of MCMCs) for the base model run. 95% credible intervals were derived from MCMC. The dashed, black horizontal line represents the default overfishing threshold.

Stock status from the model sensitivities is comparable to the base model, although the status is less optimistic for the *Low M* sensitivity (Tables 12–14 and Figure 13). For the *Low M* sensitivity, current biomass was estimated to be at about the target biomass level with no associated risk that the stock biomass has approached the biomass limit reference points. The stock status from the *AllCatch* model, that includes all the TRE 7 catch, is very similar to the base model, although the estimate of equilibrium yield is considerably higher, which is consistent with the magnitude of catch included in the *AllCatch* model.

Table 14: Probability (Pr) of the KMNTB component of the TRE 7 stock being above key reference points in 2014. Estimates are derived from MCMC analysis.

	$Pr\,(B_{2014}>0.1B_0)$	$Pr\,(B_{2014}>0.2B_0)$	$Pr\,(B_{2014}>0.4B_0)$
Base	1.000	1.000	0.961
M low	1.000	1.000	0.492
Steep70	1.000	1.000	0.899
BTselect	1.000	1.000	0.909
AllCatch	1.000	1.000	0.931
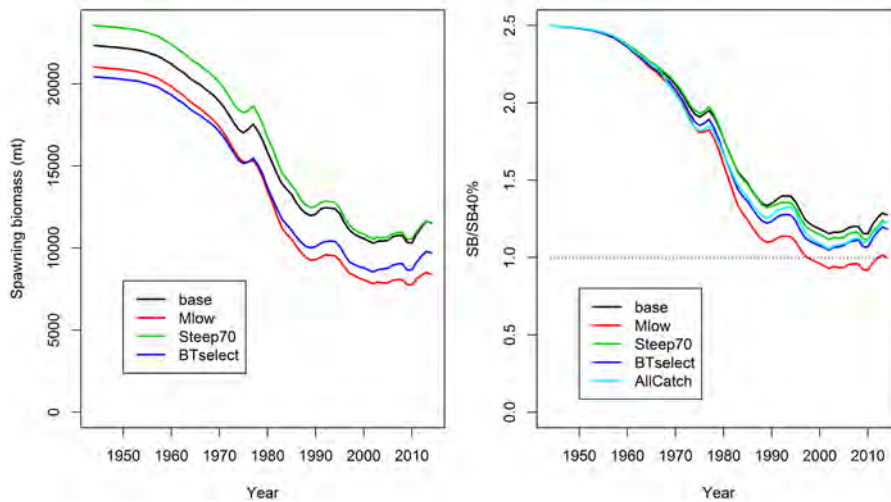
Figure 13: Median spawning biomass (female only) trajectories from MCMC model fits for the base model and sensitivities. The horizontal line in the right panel represents the target biomass level.

Further model runs were undertaken to explore the influence of two key data sets in the assessment. There is some concern regarding the reliability of the recent (2007–2013) CPUE indices due to changes in the targeting behaviour of the trawl fleet. A model trial was conducted that down-weighted the later indices (by increasing the CV to 30%). The BPT age composition data from 1998–2001 are influential in determining the extent of the stock depletion during the preceding period. A model trial was conducted that assigned a high weight (ESS 200) to these BPT age data to ensure that the estimated levels of fishing mortality were entirely consistent with the age composition data (i.e., to ensure a good fit to the 'plus group' in the age composition). Both model trials resulted in a reduction in the current stock status relative to SB_0 compared with the base model (by approximately 10%), although in both the current stock status was estimated to be above the target biomass level. On that basis, it was concluded that the overall conclusions of the assessment were not overly sensitive to either set of data.

4.3.7 Yield estimates and projections

Stock projections, for a five-year period, were conducted for the *AllCatch* model. The projections used either the TACC or a constant catch equivalent to the 2013 catch level; i.e., 2153 t for the TACC projection and 1952 t for the 2013 catch projection. For the TACC projection, the spawning biomass is projected to decline slightly (by 3%) during the projection period, although there is a low probability that the biomass will decline below the target biomass level (Table 15). For the constant catch projection, projected biomass is maintained at the current (2014) level. The $F_{40\%B0}$ yield at the 2014 biomass level is 2949 t (1987–5557 t) for the *AllCatch* model that includes the entire TRE 7 catch. The current TACC is 2153 t.

Table 15: Stock status in the terminal year (2019) of the five-year forecast period for the *AllCatch* model using either the current TACC or the 2013 catch in the projections.

Model option	SB_{2019}/SB_0	Pr($SB_{2019} > X\%SB_0$)		
		10%	20%	40%
AllCatch (with TACC projection)	0.478 (0.355–0.659)	1.000	1.000	0.863
AllCatch (with 2013 catch projection)	0.494 (0.374–0.671)	1.000	1.000	0.924

5.   STATUS OF THE STOCKS

- **TRE 1**

Stock Structure Assumptions
Trevally occurring along the east coast of the North Island are believed to comprise two stocks: (i) east Northland and Hauraki Gulf, and (ii) Bay of Plenty.

Bay of Plenty

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Base model run
Reference Points	Interim Target: 40% SB_0 Soft Limit: 20% SB_0 Hard Limit: 10% SB_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Likely (> 60%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Exceptionally Unlikely (< 1%) to be below
Status in relation to Overfishing	Overfishing is About as Likely as Not (40–60%) to be occurring

Historical Stock Status Trajectory and Current Status

Spawning stock biomass from the MCMC for the base model, with 95% credible interval. Horizontal lines are the 40% target (green), soft limit (orange), and hard limit (red).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Spawning biomass has declined slightly from a peak in 2018.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has been increasing slightly over the last 5 years.
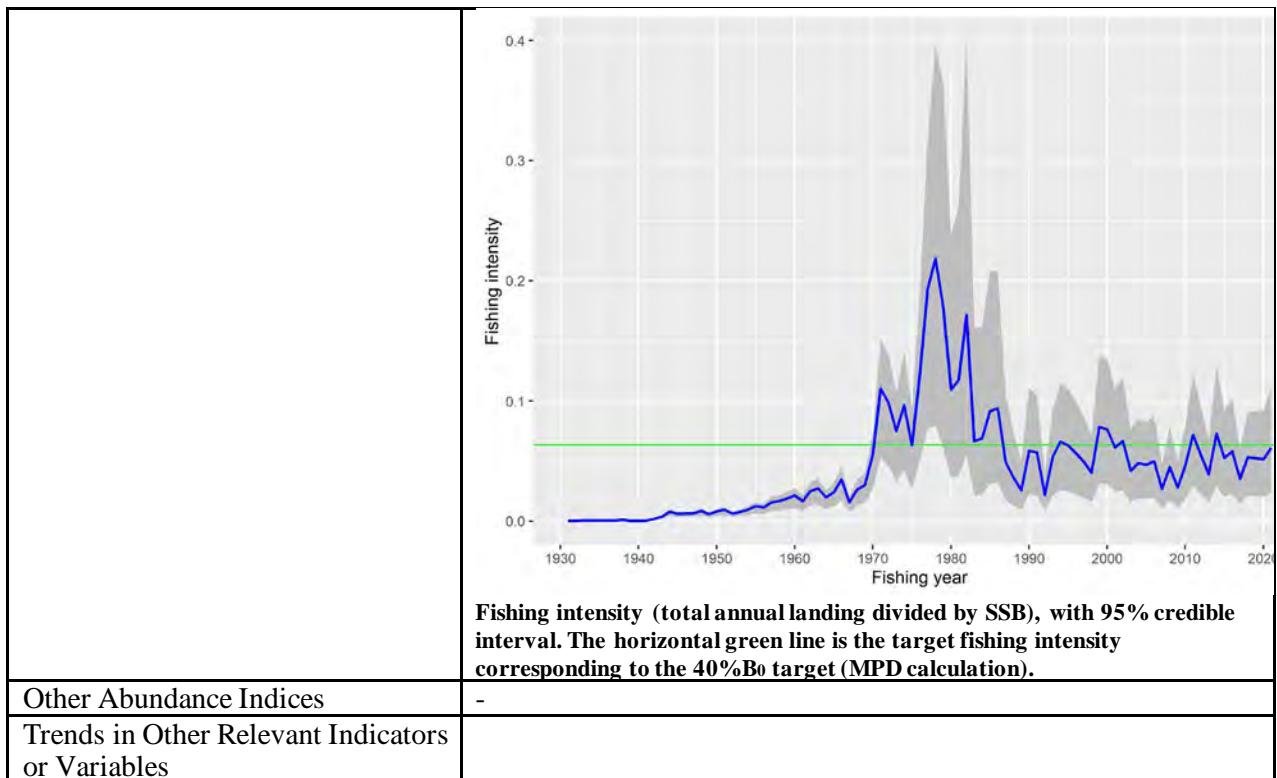
Fishing intensity (total annual landing divided by SSB), with 95% credible interval. The horizontal green line is the target fishing intensity corresponding to the 40%B0 target (MPD calculation).

Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	

Projections and Prognosis	
Stock Projections or Prognosis	Model projections indicate that the biomass will decline slightly, but with low probability of dropping below 40% SB_0 by 2027.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits (5 years)	Very Unlikely (< 10%) to decline below Soft and Hard Limits at current catch.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%) at current catch

Assessment Methodology and Evaluation		
Assessment Type	Level 1 – Full Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2022	Next assessment: 2027
Overall assessment quality rank	1 – High Quality	

Main data inputs (rank)	- Standardised CPUE index of abundance	1 – High Quality
	- Proportions at age data from the commercial fisheries	1 – High Quality
Data not used (rank)	BoP trawl survey	3 – Low Quality: Not reliable for trevally
	Aerial sightings index	3 – Low Quality: Not reliable for trevally
Changes to Model Structure and Assumptions	- No previously accepted assessment	
Major Sources of Uncertainty	- Annual variability in BT CPUE index, possible resulting from varying catchability as this species is semi-pelagic.	

Qualifying Comments
- There is no corroborating information (outside the model) supporting estimated recent high recruitment, or fishery independent support for the strong increase in biomass. - The stock relationship between the Bay of Plenty and TRE 2(N) is unknown.

Fishery Interactions
Main QMS bycatch species are snapper, red gurnard, John dory, and tarakihi.

East Northland and the Hauraki Gulf

Preliminary assessments have previously been undertaken for the EN/HG stock, using abundance indices derived from standardised CPUE analyses, bottom trawl catch-at-age data, and catch history. There is currently no accepted index of abundance for the EN/HG stock, and no assessment.

- **TRE 2**

There is no accepted stock assessment for TRE 2. Trevally in TRE 2 are thought to be part of the biological stock located in the Bay of Plenty (TRE 1); therefore, future assessments for TRE 2 will be undertaken in conjunction with TRE 1.

- **TRE 7**

Stock Structure Assumptions

Trevally occurring along the west coast of the North Island are believed to comprise a single stock.

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	A base case model based on the main fishery area only (Kaipara-Manukau-Northern Taranaki Bight; KMNTB); this represents about 70% of recent (2010–11 to 2012–13) TRE 7 catches
Reference Points	Interim Target: 40% SB_0 Soft Limit: 20% SB_0 Hard Limit: 10% SB_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Very Likely (> 90%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Exceptionally Unlikely (< 1%) to be below
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status
Spawning biomass (female only) relative to the interim target biomass ($SB_{40\%}$) (median of MCMC samples) for the base model run. 95% credible intervals were derived from MCMC samples. The dashed, black horizontal line represents the default target biomass level and the grey line represents the default soft limit (20% SB_0).

1850

Fishery and Stock Trends

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Spawning biomass is estimated to have declined gradually during the 1940s and 1950s. The rate of decline increased from the 1960s to the mid-1980s consistent with the increase in the total annual catch. Since the mid-1990s spawning biomass has remained relatively stable.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality rates are estimated to have been relatively stable since the late 1990s, at a level below $F_{SB40\%}$. **Annual fishing mortality relative to the level of fishing mortality that corresponds to the default target spawning biomass from the KMNTB base assessment model. The solid line represents the median of the MCMC samples and the shaded area represents the 95% credible interval.**
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis

Projections and Prognosis	
Stock Projections or Prognosis	Model projections indicate that the biomass of TRE 7 is About as Likely as Not (40–60%) to decline over the next 5 years (to 2019), but with low probability of dropping below 40% SB_0 by 2019.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits (5 years)	Exceptionally Unlikely (< 1%) to decline below Soft and Hard Limits
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured Stock Synthesis model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2015	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	

Main data inputs (rank)	- Standardised CPUE index of abundance	1 – High Quality
	- Proportions at age data from the commercial fisheries and trawl surveys	1 – High Quality
Data not used (rank)	- Bottom pair trawl CPUE, 1973–74 to 1984–85	3 – Low Quality: does not index abundance
Changes to Model Structure and Assumptions	- The stock assessment was based on data from KMNTB only. The fishery catch, CPUE, and age composition data sets were reconfigured accordingly. The model was re-run with the total TRE 7 catch to calculate the total expected yield at $F_{SB40\%}$. Projections were based on the model for the entire area, using both the 2014 catch and the 2014 TACC.	
Major Sources of Uncertainty	- Reliability of CPUE as an index of stock abundance as a result of recent increases in the degree of targeting of trevally - Whether results for the KMNTB sub-area reflect changes in biomass in the other two sub-areas within TRE 7 - Reliability of the pair trawl age composition data (1998–2001), which strongly influence estimates of B_0 and exploitation rates during the period of peak catch	

Qualifying Comments

- The stock assessment was based on the KMNTB sub-area only, and the extent to which it is reflective of the other two (smaller) sub-areas is unknown.

Fishery Interactions

Main QMS bycatch species are snapper, red gurnard, John dory, and tarakihi.

6.   FOR FURTHER INFORMATION

Annala, J H; Sullivan, K J; O'Brien, C J (1999) Report from the Fishery Assessment Plenary, April 1999: stock assessments and yield estimates. 430 p. (Unpublished report held in NIWA library, Wellington).

Annala, J H et al (Comps.) (2004) Report from the Fishery Assessment Plenary, May 2004: stock assessment and yield estimates. (Unpublished report held in NIWA library, Wellington.)

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 national marine recreational fishing survey: diary results and harvest estimates. (Unpublished draft New Zealand Fisheries Assessment Report for the Ministry of Fisheries project REC2000-03, held by Fisheries New Zealand.) 92 p.

Boyd, R O; Reilly, J L (2004) 1999–2000 National Marine Recreational Fishing Survey: harvest estimates. (Unpublished draft New Zealand Fisheries Assessment Report for the Ministry of Fisheries Project REC9803 held by Fisheries New Zealand.) 28 p.

Bradford, E (1997) Estimated recreational catches from Ministry of Fisheries North region marine recreational fishing surveys, 1993–94. New Zealand Fisheries Assessment Research Document 1997/7. 16 p. (Unpublished report held in NIWA library, Wellington.)

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished report held in NIWA library, Wellington.)

Edwards, C T T; Hartill, B (2015) Calibrating between offsite and onsite amateur harvest estimates. New Zealand Fisheries Assessment Report 2015/49. 23 p.

Francis, R I C C (2011) Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68: 15.

Francis, M P; Bradford, E; Paul, L J (1999) Trevally catch per unit effort in TRE 7. New Zealand Fisheries Assessment Research Document 1999/13. 27 p. (Unpublished report held in NIWA library, Wellington.)

Francis, M P; Paul, L J (2013) New Zealand inshore finfish and shellfish commercial landings, 1931–82. New Zealand Fisheries Assessment Report 2013/55. 136 p.

Gilbert, D J (1988) Trevally. New Zealand Fisheries Assessment Research Document 1988/29. 28 p. (Unpublished report held by NIWA library.)

Hanchet, S M (1999) Stock assessment of Trevally (Caranx georgianus) in TRE 7. New Zealand Fisheries Assessment Research Document 1999/55. 20 p. (Unpublished report held by NIWA library, Wellington.)

Hartill, B; Bian, R; Armiger, H; Vaughan, M; Rush, N (2007) Recreational marine harvest estimates of snapper, kahawai, and kingfish in QMA 1 in 2004–05. New Zealand Fisheries Assessment Report 2007/26. 44 p.

Hartill, B; Bian, R; Rush, N; Armiger, H (2013) Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2011–12. New Zealand Fisheries Assessment Report 2013/70. 44 p.

Hartill, B; Bian, R; Rush, N; Armiger, H (2019). Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2017–18. New Zealand Fisheries Assessment Report 2019/23. 39 p.

Hoenig, J M (1983) Empirical use of longevity data to estimate mortality rates. Fisheries Bulletin 81: 899–903.

James, G D (1980) Tagging experiments on trawl-caught trevally, Caranx georgianus, off north-east New Zealand. New Zealand Journal of Marine and Freshwater Research 14 (3): 249–254.

James, G D (1984) Trevally. *Caranx georgianus*: age determination, population biology and fishery. Ministry of Agriculture and Fisheries. *Fisheries Research Bulletin 25*. 51 p.

Kendrick, T H; Bentley, N (2010) Fishery characterisation and catch-per-unit-effort indices for trevally in TRE 7; 1989–90 to 2007–08. *New Zealand Fisheries Assessment Report 2010/41.*

Langley, A D (2001) Length and age composition of trevally in commercial landings from TRE 1 and TRE 7, 1999–2000. *New Zealand Fisheries Assessment Report 2001/42.* 32 p.

Langley, A D (2002a) Length and age composition of trevally in commercial landings from TRE 1 and TRE 7, 2000–01. *New Zealand Fisheries Assessment Report 2002/19.* 34 p.

Langley, A D (2002b) Analysis of catch and effort data from the TRE 7 fishery. *New Zealand Fisheries Assessment Report 2002/32.* 28 p.

Langley, A D (2003) Length and age composition of trevally in commercial landings from TRE 1, 2001–02. *New Zealand Fisheries Assessment Report 2003/48.* 18 p

Langley, A D (2004) Length and age composition of trevally (*Pseudocaranx dentex*) in commercial landings from the TRE 1 purse-seine fishery, 2002–03. *New Zealand Fisheries Assessment Report 2004/39.* 17 p.

Langley, A D (2015) Stock assessment of TRE 7. *New Zealand Fisheries Assessment Report 2015/45.* 76 p.

Langley, A D; Maunder, M (2009) Stock assessment of TRE 7. *New Zealand Fisheries Assessment Report 2009/49.* 42 p.

Maunder, M N; Langley, A D (2004) Integrating the standardisation of catch-per-unit-effort into stock assessment models: testing a population dynamics model and using multiple data types. *Fisheries Research 70 (2–3)*: 389–395.

McKenzie, A (2008) Standardised CPUE analysis and stock assessment of the west coast trevally fishery (TRE 7). *New Zealand Fisheries Assessment Report 2008/44.*

McKenzie, A (in prep) Stock assessment of Bay of Plenty trevally (TRE 1) for 2021–22. New Zealand Fisheries Assessment Report.

McKenzie, J R; Parsons, D M; Bian, R; Doonan, I (2016) Assessment of the TRE 1 stocks in 2015. *New Zealand Fisheries Assessment Report 2016/48.* 98 p.

Ministry of Fisheries (2008) Harvest Strategy Standard for New Zealand fisheries. 25 p. Available at http://fs.fish.govt.nz/Page.aspx?pk=61&tk=208&se=&sd=Asc&filSC=&filAny=False&filSrc=False&filLoaded=False&filDCG=9&filDC=0&filST=&filYr=0&filAutoRun=1.

Parsons, D M; Bian, R; Parkinson, D; MacGibbon, D J (2021) Trawl surveys of the Hauraki Gulf and Bay of Plenty in 2019 and 2020 to estimate the abundance of juvenile snapper. *New Zealand Fisheries Assessment Report 2021/08.* 127 p.

Schofield, M I; Langley, A D; Middleton, D A J (2018) Characterisation and catch-per unit-effort (CPUE) analyses for FMA 2 trevally (TRE 2). (Draft New Zealand Fisheries Assessment Report held by Fisheries New Zealand.)

Taylor, P R (2011) Developing indices of relative abundance from observational aerial sightings of inshore pelagic finfish; step 1, exploring that data. *New Zealand Fisheries Assessment Report 2014/34.* 66 p.

Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished report held by NIWA library, Wellington.)

Walsh, C; McKenzie, J M (2010) Review of length and age sampling for trevally in TRE 1 and TRE 7. *New Zealand Fisheries Assessment Report 2010/09.* 27 p.

Walsh, C; McKenzie, J M; Ó Maolagáin, C; Buckthought, D; Blackwell, R; James, G D; Rush, N (2010) Length and age composition of commercial trevally landings in TRE 1 and TRE 7, 2006–07. *New Zealand Fisheries Assessment Report 2010/9.* 62 p.

Walsh, C; McKenzie, J; Ó Maolagáin, C; Stevens, D (1999) Length and age composition of trevally in commercial landings from TRE 1 and TRE 7, 1997–98. *NIWA Technical Report 66*.

Wright, P; McClary, D; Boyd, R O (2004) 2000/2001 National Marine Recreational Fishing Survey: direct questioning of fishers compared with reported diary data. (Unpublished Final Research Report for Ministry of Fisheries Project REC2000–01: Objective 2, held by Fisheries New Zealand.) Available at http//fs.fish.govt.nz.

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24.* 104 p.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67.* 139 p.

TRUMPETER (TRU)

(*Latris lineata*)
Kohikohi
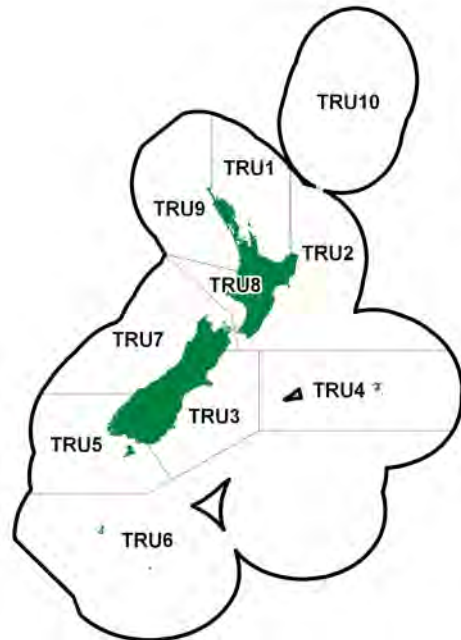
1.   FISHERY SUMMARY

1.1   Commercial fisheries

Historical estimated landings are shown in Table 1 for the main trumpeter stocks. Total reported landings of trumpeter ranged between 3 t and 44 t until the fishing year 1990–91, after which landings increased steadily to reach 162 t in 1995–96 (Tables 2 and 3). Total landings subsequently decreased to a minimum of 25 t in 2000–01 and 2001–02, before once again increasing to over 100 t in the 2007–08, 2010–11 and 2011–2012 fishing years. In 2013–14 to 2020–21 total annual landings averaging just over 60 t were recorded. Historic under-reporting is probable (Paul 1999).

Most landings of trumpeter have come from the east coast between the eastern Bay of Plenty and Southland. There have been changes over time in contributions from different parts of the east coast, but the reason for this is not known. Until the early 1950s most landings were made in QMA 3. From the mid 1950s until the mid 1980s most landings were in QMA 2 (Table 1). The rapid increase in landings after the mid-1980s has come predominantly from QMAs 3 and 4 (Table 3), reportedly from an increase in line fishing on the outer shelf and in the Mernoo Bank region. Figure 1 shows the historical landings for TRU from 1936.

Most trumpeter is taken as bycatch in line-fisheries; a small amount is trawled, and from the 1970s it has also been taken by setnet. Only a small proportion of trumpeter is targeted. Catches are irregular with no seasonal trend and are likely to be driven by fishing activities for other species. No information on changes in fishing effort is available.

Trumpeter have been managed under the Quota Management System in New Zealand since 1 October 1988, at which time an original TACC of 100 t was set. The TACC was increased to 144 t in October 2001 following a period of declining landings. This TACC has never been reached; the 110 t landed in 2010–11 was the highest since 1996–97. In recent years (2006–07 to 2019–20), most landings have come from TRU 3 east coast South Island and TRU 4 on the Chatham Rise (Table 3), with small landings also coming from TRU 2, 5, and 7 (south-eastern North Island and South Island). Trumpeter are also taken by recreational fishers in southern New Zealand, and although good estimates of recreational catch are not available, they may be around one-third to one-half of the commercial catch.
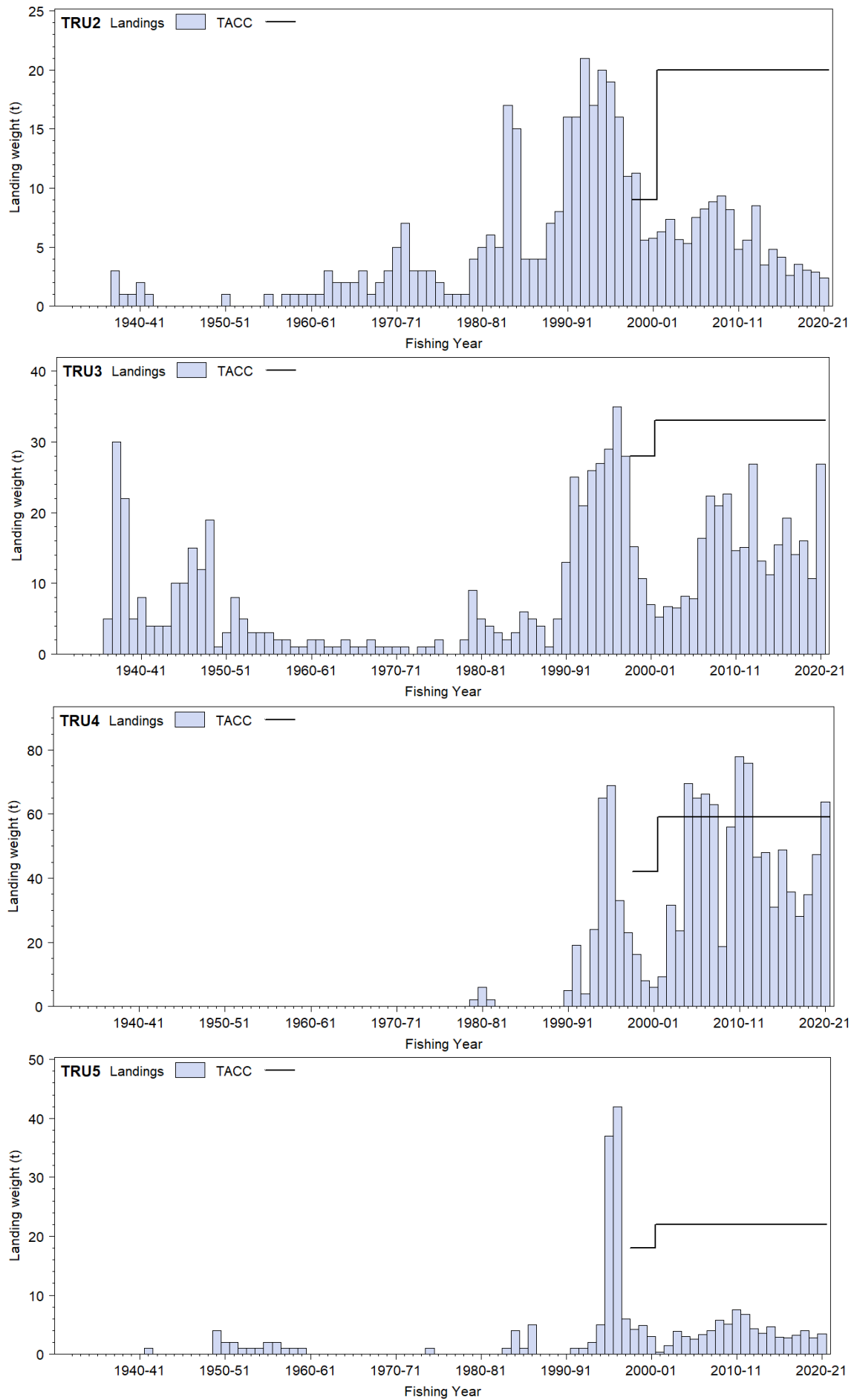
Figure 1: Reported commercial landings and TACCs for the four main TRU stocks. Top to bottom: TRU 2 (Central East), TRU 3 (South East Coast), TRU 4 (South East Chatham Rise), and TRU 5 (Southland).

Table 1: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	TRU 1	TRU 2	TRU 3	TRU 4	Year	TRU 1	TRU 2	TRU 3	TRU 4
1931–32	0	0	0	0	1957	0	1	2	0
1932–33	0	0	0	0	1958	0	1	1	0
1933–34	0	0	0	0	1959	0	1	1	0
1934–35	0	0	0	0	1960	0	1	2	0
1935–36	0	0	0	0	1961	0	1	2	0
1936–37	0	0	5	0	1962	0	3	1	0
1937–38	0	3	30	0	1963	0	2	1	0
1938–39	0	1	22	0	1964	0	2	2	0
1939–40	0	1	5	0	1965	0	2	1	0
1940–41	0	2	8	0	1966	0	3	1	0
1941–42	0	1	4	0	1967	0	1	2	0
1942–43	0	0	4	0	1968	0	2	1	0
1943–44	0	0	4	0	1969	0	3	1	0
1944	0	0	10	0	1970	0	5	1	0
1945	0	0	10	0	1971	0	7	1	0
1946	0	0	15	0	1972	0	3	0	0
1947	0	0	12	0	1973	0	3	1	0
1948	0	0	19	0	1974	0	3	1	0
1949	0	0	1	0	1975	0	2	2	0
1950	0	1	3	0	1976	0	1	0	0
1951	0	0	8	0	1977	0	1	0	0
1952	0	0	5	0	1978	0	1	2	0
1953	0	0	3	0	1979	0	4	9	2
1954	0	0	3	0	1980	0	5	5	6
1955	0	1	3	0	1981	0	6	4	2
1956	0	0	2	0	1982	2	21	6	0

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings.

Table 2: Reported total landings (t) of trumpeter from 1931 to 1982. Values for 1931 to 1944 are April–March years, listed against the April year. Fisheries Annual Report (1931 to 1974) or FSU data (Paul 1999).

Year	Landing	Year	Landings	Year	Landings	Year	Landings	Year	Landings
1936	20	1946	16	1956	5	1965	4	1974	5
1937	41	1947	13	1957	5	1966	5	1975	4
1938	30	1948	19	1958	3	1967	7	1976	3
1939	37	1949	6	1959	3	1968	5	1977	3
1940	17	1950	6	1960	3	1969	5	1978	6
1941	11	1951	11	1961	3	1970	7	1979	17
1942	5	1952	11	1962	4	1971	10	1980	10
1943	5	1953	5	1963	3	1972	4	1981	12
1944	11	1954	5	1964	3	1973	5	1982	37
1945	11	1955	6						

Table 3: Reported landings (t) of trumpeter by QMA and fishing year, 1983–84 to present*. [Continued on next page].

Fishstock FMA	TRU 1 1		TRU 2 2		TRU 3 3		TRU 4 4		TRU 5 5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1982–83	0	-	5	-	3	-	0	-	0	-
1983–84	1	-	17	-	2	-	0	-	1	-
1984–85	0	-	15	-	3	-	0	-	4	-
1985–86	0	-	4	-	6	-	0	-	1	-
1986–87	0	-	4	-	5	-	0	-	5	-
1987–88	0	-	4	-	4	-	0	-	0	-
1988–89	0	-	7	-	1	-	0	-	0	-
1989–90	0	-	8	-	5	-	0	-	0	-
1990–91	3	-	16	-	13	-	5	-	0	-
1991–92	1	-	16	-	25	-	19	-	1	-
1992–93	3	-	21	-	21	-	4	-	1	-
1993–94	3	-	17	-	26	-	24	-	2	-
1994–95	2	-	20	-	27	-	65	-	5	-
1995–96	2	-	19	-	29	-	69	-	37	-
1996–97	2	-	16	-	35	-	33	-	42	-
1997–98	1	-	11	-	28	-	23	-	6	-
1998–99	< 1	1	11	9	15	28	16	42	4	18
1999–00	< 1	1	6	9	11	28	8	42	5	18
2000–01	< 1	1	6	9	7	28	6	42	3	18
2001–02	< 1	3	6	20	5	33	9	59	< 1	22
2002–03	< 1	3	7	20	7	33	32	59	1	22
2003–04	1	3	6	20	7	33	24	59	4	22
2004–05	< 1	3	5	20	8	33	70	59	3	22
2005–06	< 1	3	7	20	8	33	65	59	3	22
2006–07	< 1	3	8	20	16	33	66	59	3	22

Table 3 [Continued]

Fishstock FMA	TRU 1 1 Landings	TACC	TRU 2 2 Landings	TACC	TRU 3 3 Landings	TACC	TRU 4 4 Landings	TACC	TRU 5 5 TACC	Landings
2007–08	1	3	9	20	22	33	63	59	4	22
2008–09	< 1	3	9	20	21	33	19	59	6	22
2009–10	< 1	3	8	20	22	33	56	59	5	22
2010–11	< 1	3	5	20	15	33	78	59	8	22
2011–12	< 1	3	6	20	15	33	76	59	7	22
2012–13	< 1	3	8	20	27	33	47	59	4	22
2013–14	< 1	3	3	20	13	33	48	59	4	22
2014–15	0	3	5	20	11	33	31	59	4	22
2015–16	< 1	3	4	20	15	33	49	59	3	22
2016–17	< 1	3	3	20	19	33	36	59	3	22
2017–18	< 1	3	4	20	14	33	28	59	3	22
2018–19	< 1	3	3	20	16	33	35	59	4	22
2019–20	< 1	3	3	20	11	33	47	59	3	22
2020–21	< 1	3	2	20	27	33	64	59	3	22

Fishstock FMA	TRU 6 6 Landings	TACC	TRU 7 7 Landings	TACC	TRU 8 8 Landings	TACC	TRU 9 9 Landings	TACC	Total Landings	TACC
1982–83	0	-	0	-	0	-	0	-	8	-
1983–84	0	-	0	-	0	-	0	-	21	-
1984–85	0	-	0	-	0	-	0	-	22	-
1985–86	0	-	0	-	0	-	0	-	11	-
1986–87	0	-	2	-	0	-	0	-	16	-
1987–88	0	-	0	-	0	-	0	-	8	-
1988–89	0	-	1	-	0	-	0	-	9	-
1989–90	0	-	0	-	1	-	0	-	14	-
1990–91	0	-	7	-	0	-	0	-	44	-
1991–92	0	-	4	-	0	-	0	-	69	-
1992–93	0	-	4	-	2	-	0	-	56	-
1993–94	0	-	6	-	0	-	0	-	78	-
1994–95	0	-	4	-	0	-	0	-	123	-
1995–96	0	-	6	-	0	-	0	-	162	-
1996–97	2	-	3	-	< 1	-	< 1	-	133	-
1997–98	< 1	-	3	-	< 1	-	0	-	72	-
1998–99	0	0	3	2	< 1	0	0	0	50	100
1999–00	0	0	2	2	< 1	0	0	0	33	100
2000–01	0	0	3	2	< 1	0	< 1	0	25	100
2001–02	0	0	5	6	< 1	1	0	0	25	144
2002–03	0	0	3	6	< 1	1	< 1	0	51	144
2003–04	0	0	2	6	< 1	1	< 1	0	44	144
2004–05	0	0	4	6	< 1	1	0	0	90	144
2005–06	0	0	4	6	< 1	1	0	0	88	144
2006–07	0	0	4	6	< 1	1	0	0	99	144
2007–08	< 1	0	2	6	< 1	1	< 1	0	101	144
2008–09	0	0	2	6	< 1	1	< 1	0	63	144
2009–10	0	0	3	6	< 1	1	0	0	95	144
2010–11	< 1	0	4	6	< 1	1	< 1	0	110	144
2011–12	< 1	0	4	6	< 1	1	< 1	0	108	144
2012–13	< 1	0	6	6	< 1	1	< 1	1	93	144
2013–14	0	0	5	6	< 1	1	< 1	0	74	144
2014–15	0	0	4	6	1	1	0	0	56	144
2015–16	0	0	4	6	1	1	< 1	0	76	144
2016–17	0	0	3	6	1	1	< 1	0	65	144
2017–18	0	0	3	6	< 1	1	< 1	0	52	144
2018–19	0	0	4	6	< 1	1	< 1	0	62	144
2019–20	< 1	0	3	6	< 1	1	< 1	0	67	144
2020–21	< 1	1	2	6	< 1	1	< 1	2	99	147

*The data in this table have been updated from those published in previous Plenary Reports by using the data through 1996−97 in table 41 on p. 288 of the "Review of Sustainability Measures and Other Management Controls for the 1998−99 Fishing Year - Final Advice Paper" dated 6 August 1998. There are no landings reported from TRU 10, which has a TAC of 0

1.2 Recreational fisheries

Results from four separate recreational fishing surveys undertaken in the 1990s are shown in Table 4. Most of the estimated recreational catch in these surveys was taken in FMAs 3, 5 and 7.

The harvest estimates provided by telephone-diary surveys are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel

members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 5. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 4: Estimated number of trumpeter caught by recreational fishers by FMA using telephone-diary surveys. Surveys were carried out in different years in MAF Fisheries regions: South in 1991–92, Central in 1992–93, North in 1993–94 and National in 1996 (Bradford 1998).

FMA	Survey	Number	CV (%)
1991–92			
FMA 3	South	6 000	29
FMA 5	South	6 000	33
FMA 7	South	8 000	-
1992–93			
FMA 2	Central	1 000	-
FMA 3	Central	3 000	-
FMA 5	Central	1 000	-
FMA 7	Central	0	-
FMA 8	Central	0	-
1993–94			
FMA 1+9	North	0	-
FMA 2	North	1 000	-
FMA 8	North	0	-
1996			
FMA 1	National	< 500	-
FMA 2	National	1 000	-
FMA 3	National	13 000	19
FMA 5	National	21 000	19
FMA 7	National	3 000	-

Table 5: Recreational harvest estimates for trumpeter stocks (Wynne-Jones et al 2014, 2019). Mean fish weights were obtained from boat ramp surveys (Hartill & Davey 2015, Davey et al 2019).

Stock	Year	Method	Number of fish	Total weight (t)	CV
TRU 1	2011–12	Panel survey	898	1.3	0.83
	2017–18	Panel survey	0	0	-
TRU 2	2011–12	Panel survey	787	1.1	0.82
	2017–18	Panel survey	32	<1	1.01
TRU 3	2011–12	Panel survey	2 870	4.0	0.41
	2017–18	Panel survey	8 070	21.0	0.34
TRU 5	2011–12	Panel survey	1 505	2.1	0.42
	2017–18	Panel survey	0	0	-
TRU 7	2011–12	Panel survey	215	0.3	0.83
	2017–18	Panel survey	142	<1	1.00
TRU 8	2011–12	Panel survey	273	0.4	1.03
	2017–18	Panel survey	0	0	-

1.3 Customary non-commercial fisheries
The customary non-commercial take has not been quantified.

1.4 Illegal catch
There is no quantitative information on illegal fishing activity or catch.

1.5 Other sources of mortality
No quantitative estimates are available regarding the impact of other sources of mortality on trumpeter stocks. Trumpeter principally occur on deep coastal reefs, where they are taken in net and line fisheries targeted at other species.

TRUMPETER (TRU)

2.   BIOLOGY

Trumpeter have a Southern Hemisphere distribution in cool temperate waters. They occur in New Zealand, Australia, the Sub-Antarctic islands of the southern Indian and Atlantic oceans, the Foundation Seamount in the central South Pacific, and possibly off Chile (Roberts 2003, Tracey & Lyle 2005). In New Zealand, trumpeter occur from the Three Kings Islands through all of mainland New Zealand to the Auckland Islands; however they are rare north of East Cape and Cape Egmont (Kingsford et al 1989, Francis 1996, 2001). The greatest concentrations of trumpeter apparently occur on the Chatham Rise and around the southern South Island and Stewart Island.

Trumpeter have an extended larval and post-larval duration of up to 9 months in surface waters (Tracey & Lyle 2005), resulting in extensive drift of young fish among geographic regions. Juveniles are largely sedentary, but some adults are highly migratory with tagged fish travelling 650 km from Tasmania to southern New South Wales, and 5800 km from Tasmania to St Paul Island in the southern Indian Ocean (Lyle & Murphy 2002). This suggests that there is one circum-global genetic stock in the Southern Hemisphere, although analysis of otolith morphometrics from Tasmania and St Paul and Amsterdam Islands showed regional variation (Tracey et al 2006) suggesting that migration and inter-breeding may be limited.

Trumpeter occur mainly over rocky reefs ranging from shallow inshore waters to deep reefs on the central continental shelf. In New Zealand, they apparently range from a depth of a few metres down to about 200 m. In Australia some reports indicate they may go as deep as 300 m (reviewed by Paul 1999). Fish inhabiting inshore reefs tend to be smaller, whereas fish from deep reefs tend to be much larger. Trumpeter initially settle on to inshore reefs at the end of their long postlarval period, where they remain for several years, before migrating into deeper areas as they reach maturity (Tracey & Lyle 2005).

Some biological traits differ between New Zealand and Tasmanian populations. Notably, trumpeter are thought to spawn in winter (July) in New Zealand (Graham 1939b), and late winter to spring in Australia (peaking around September in Tasmania) (Ruwald et al 1991, Furlani & Last 1993, Morehead 1998, Morehead et al 1998, 2000, Furlani & Ruwald 1999). However, the New Zealand data seem to be based on limited sampling, and it is uncertain whether the apparent regional difference is real.

Trumpeter grow to about 110–120 cm fork length (FL) and 25–27 kg weight in New Zealand and Australia (Gomon et al 1994, Paul 1999, Francis 2001). Nothing is known about growth, longevity or maturity in New Zealand waters. However, because of their importance for aquaculture in Australia, a comprehensive study has recently been completed on their age and growth in Tasmania (Tracey & Lyle 2005, Tracey et al 2006). Partial validation of age estimates was completed there by comparison of otolith growth in known-age reared fish and wild fish (enabling validation of the time of formation of the first growth band), and tracking a strong wild cohort over seven years (ages 1+ to 7+). Although full validation was not achieved, the authors considered their ages validated up to and beyond the size and age of habitat transition.

In Australia, trumpeter grow rapidly during the first 4–5 years, reaching about 45 cm FL at that stage, and moving offshore to deeper water (Tracey & Lyle 2005, Tracey et al 2006). At that time, there is a reduction in growth rate. They reach a maximum age of about 43 years (though the largest fish in the samples was 95 cm FL, which is well below the reported maximum length of 120 cm), and there are no clear differences between males and females (although small sample sizes of fish older than 10 years meant that the power to detect differences was low). Similarly, no differences were found in growth rates between fish from Tasmania and St Paul and Amsterdam Islands. Growth rates are seasonally variable, at least for the first few years, with maximum growth in late summer-autumn. It is thought that maturation coincides with the offshore movement to deep habitat.

In New Zealand, the only population information available for trumpeter comes from a 6-year survey (1994–1999) in Paterson Inlet, Stewart Island. Chadderton & Davidson (2003) carried out underwater visual counts, and obtained comprehensive length-frequency distributions from 1065 fish caught by rod at 12–15 different sites. Their length-frequency data show two or three clear juvenile cohorts which progress through time (a strong cohort was also found in Tasmania by Tracey & Lyle (2005)).

Chadderton & Davidson (2003) interpreted this as evidence of variable annual recruitment pulses. Their largest fish was 46.9 cm FL with few fish over 40 cm in most years. This is consistent with evidence from Australia of offshore migration at about 45 cm, though the migration may occur at a slightly smaller size in the New Zealand population.

3.   STOCKS AND AREAS

There are no data relevant to stock boundaries in New Zealand. Trumpeter are potentially wide-ranging, and there is one circum-global genetic stock in the Southern Hemisphere, although analysis of otolith morphometrics from Tasmania and St Paul and Amsterdam Islands showed regional variation (Tracey et al 2006) suggesting that migration and inter-breeding may be limited. Therefore there may be localised populations in areas of suitable habitat as they seem to be restricted to rocky reef habitat.

4.   STOCK ASSESSMENT

4.1   Estimates of fishery parameters and abundance
No estimates are available.

4.2   Biomass estimates
No estimates are available.

4.3   Yield estimates and projections
No estimate of *MCY* is available.

The level of risk to the stock by harvesting trumpeter at recent catch levels cannot be determined.

No estimates of current biomass, fishing mortality, or other information are available which would permit the estimation of *CAY*.

4.4   Other factors
There is anecdotal information from Australia and New Zealand that localised populations of trumpeter can be quickly depleted.

5.   STATUS OF THE STOCKS

No estimates of current and reference biomass are available. It is not known if recent catch levels are sustainable.

6.   FOR FURTHER INFORMATION

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished document held in NIWA library, Wellington.)

Chadderton, W L; Davidson, R J (2003) Baseline monitoring report on fish from the proposed Paterson Inlet (Waka a Te Wera) marine reserve, Stewart Island (Rakiura) 1994 to 1999. Prepared by Davidson Environmental Ltd for Department of Conservation, Southland. Research, survey and monitoring report 168. 47 p.

Davey, N; Hartill, B; Carter, M (2019) Mean weight estimates for recreational fisheries in 2017–18. *New Zealand Fisheries Assessment Report 2019/25*. 36 p

Francis, M P (1996) Geographic distribution of marine reef fishes in the New Zealand region. *New Zealand Journal of Marine and Freshwater Research* 30: 35–55.

Francis, M (2001) *Coastal fishes of New Zealand. An identification guide*. Third edition. Reed Publishing, Auckland. 103 p.

Furlani, D; Last, P (1993) Trumpeter. *In*: Kailola *et al.* (Eds), Australian Fisheries Resources. Bureau of Resource Sciences, Canberra: 403.

Furlani, D M; Ruwald, F P (1999) Egg and larval development of laboratory-reared striped trumpeter *Latris lineata* (Forster in Bloch and Schneider 1801) (Percoidei: Latridiidae) from Tasmanian waters. *New Zealand Journal of Marine and Freshwater Research* 33: 153–162.

Gomon, M F; Glover, J C M; Kuiter, R H (eds) (1994) *The fishes of Australia's south coast*. State Print, Adelaide. 992 p.

Graham, D H (1938) Fishes of Otago Harbour and adjacent seas, with additions to previous records. *Transactions and Proceedings of the Royal Society of New Zealand* 68(3): 399–419.

Graham, D H (1939a) Food of the fishes of Otago Harbour and adjacent sea. *Transactions of the Royal Society of New Zealand* 68(4): 421–36.

Graham, D H (1939b) Breeding habits of the fishes of Otago Harbour and adjacent seas. *Transactions and Proceedings of the Royal Society of New Zealand* 69(3): 361–372.

Graham, D H (1956) *A Treasury of New Zealand Fishes*. Reed, Wellington. 424 p.

Hartill, B; Davey, N (2015) Mean weight estimates for recreational fisheries in 2011–12. *New Zealand Fisheries Assessment Report 2015/25*.

Kingsford, M J; Schiel, D R; Battershill, C N (1989) Distribution and abundance of fish in a rocky reef environment at the subantarctic Auckland Islands, New Zealand. *Polar biology 9*: 179–186.

Lyle, J; Murphy, R (2002) Long distance migration of striped trumpeter. *Fishing today* 14(6): 16.

Morehead, D T (1998) Effect of capture, confinement and repeated sampling on plasma steroid concentrations and oocyte size in female striped trumpeter *Latris lineata* (Latrididae). *Marine and freshwater research*, *49*(5), 373–377.

Morehead, D T; Pankhurst, N W; Ritar, A J (1998) Effect of treatment with LHRH analogue on oocyte maturation, plasma sex steroid levels and egg production in female striped trumpeter *Latris lineata* (Latrididae). *Aquaculture* 169: 315–331.

Morehead, D T; Ritar, A J; Pankhurst, N W (2000) Effect of consecutive 9- or 12-month photothermal cycles and handling on sex steroid levels, oocyte development, and reproductive performance in female striped trumpeter *Latris lineata* (Latrididae), *Aquaculture:189 (3–4)*: 293–305.

Paul, L J (1999) A summary of biology and commercial landings, and a stock assessment of the trumpeter, *Latris lineata* (Bloch and Schneider 1801) (*Latrididae*) in New Zealand waters. New Zealand Fisheries Assessment Research Document 1999/8. 20 p. (Unpublished document held by NIWA library, Wellington.)

Ruwald, F P; Searle, L D; Oates, L A (1991) A preliminary investigation into the spawning and larval rearing of striped trumpeter, *Latris lineata*. Technical Report, Sea Fisheries Research Laboratory, Division of Sea Fisheries, Tasmania, No: 44. 17 p.

Roberts, C D (2003) A new species of trumpeter (Teleostei; Percomorpha; Latridae) from the central South Pacific Ocean, with a taxonomic review of the striped trumpeter *Latris lineata*. *Journal of the Royal Society of New Zealand* 33. 731–754.

Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished report held by NIWA library, Wellington.)

Tracey, S R; Lyle, J M (2005) Age validation, growth modelling, and mortality estimates for striped trumpeter (*Latris lineata*) from southeastern Australia: making the most of patchy data. *Fishery Bulletin* 103: 169–182.

Tracey, S R; Lyle, J M; Duhamel, G (2006) Application of elliptical Fourier analysis of otolith form as a tool for stock identification. *Fisheries Research* 77: 138–147.

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report.2019/24.* 108 p

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67.*

TUATUA (TUA)

(*Paphies subtriangulata*)
Tuatua
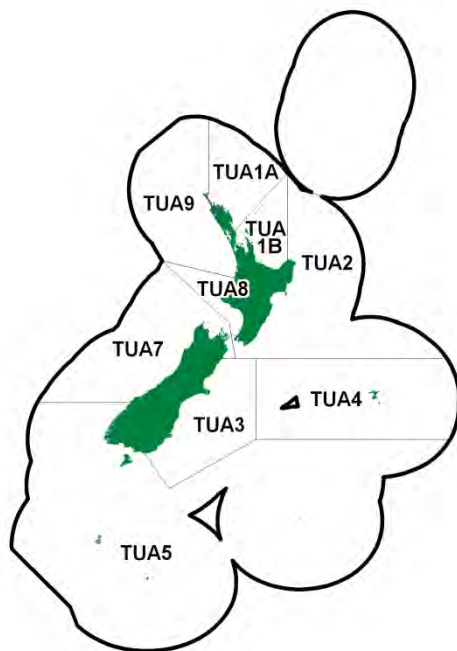
1. FISHERY SUMMARY

Tuatua (*Paphies subtriangulata*) were introduced into the QMS on 1 October 2005. The fishing year runs from 1 October to 30 September, and commercial catches are measured in greenweight. In October 2005 all TUA QMAs were allocated customary, recreational, and other sources of mortality allowances, and a TACC was introduced for TUA 9. A breakdown of each QMA TAC is listed in Table 1.

1.1 Commercial fisheries

QMA boundaries for tuatua were set the same as those established for FMAs, except for FMA 1 (the area between North Cape and Cape Runaway), which was divided into two QMAs, TUA 1A and TUA 1B, on either side of Te Arai Point (Pakiri Beach). The formerly specified historic commercial areas within TUA 1B (Papamoa domain to Maketu Beach, Bay of Plenty) and TUA 9 (i.e., Ninety Mile Beach, Hokianga Harbour to Maunganui Bluff, and specific areas between Maunganui Bluff to the North Head of the Kaipara Harbour) were revoked, and regulations were amended to remove the commercial daily catch limits for tuatua, which were no longer applicable. Commercial fishing was allowed to continue only in TUA 9 in the specified commercial area of the Kaipara Harbour entrance. A TACC of 43 t, which reflected the average of the reported landings taken from the Kaipara fishery between 1990–91 and 2003–04, was allocated to the TUA 9 stock in recognition that commercial tuatua fishing was constrained to the Kaipara Harbour entrance.

There is no minimum legal size (MLS) for tuatua, although fishers probably favour large individuals. Tuatua are available for harvest year-round, so there is no apparent seasonality in the fishery. Significant landings since 1989–90 have been reported from TUA 9 only (Table 2), and there have been no reported landings from TUA 5, TUA 6, and TUA 8. Landings from TUA 9 reached a peak of 192 t in 1997–98, and subsequently decreased, ranging from 4 to 76 t (average 32 t) between 1998–99 and 2003–04. This decline in commercial catches from the Kaipara bed is probably related to historic participants retiring from the fishery. The commercial effort had greatly reduced by 1992, post moratorium implementation, and catches were then influenced by the fact that commercial fishing is intermittent with only one or two fishers involved. No landings were reported from TUA 9 for 2004–05 to 2010–11. Since 2011-12 landings have fluctuated, exceeding 5 t in 2012-13 and 2015-16, but dropping to 0.6 t in 2016-17. There have been minimal landings reported since 2017–18.

Table 1: Current Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) for tuatua.

Fishstock	TAC	Customary	Recreational	Other Mortality	TACC
TUA 1A	84	40	40	4	0
TUA 1B	126	60	60	6	0
TUA 2	7	3	3	1	0
TUA 3	7	3	3	1	0
TUA 4	3	1	1	1	0
TUA 5	3	1	1	1	0
TUA 7	3	1	1	1	0
TUA 8	5	2	2	1	0
TUA 9	102	26	26	7	43

Table 2: Reported landings (t) of tuatua (*Paphies subtriangulata*) by Fishstock since 1989–90. Data up to 2003–04 taken from page 163 of MFish's Initial Position Paper (IPP), dated 31 March 2005, data since from CELR and CLR (early CELR and CLR data erroneously record commercial landings from FMA 9 as FMA 1 because permit holders were not filling in the forms correctly). There have been no reported landings of tuatua in TUA 1B, TUA 2, TUA 5, TUA 6, and TUA 8.

Year	TUA 1	TUA 1A	TUA 3	TUA 4	TUA 7	TUA 9	Total	TACC
1989–90	0	-	0	0	0	69.015	69.015	-
1990–91	0	-	0	0	0.176	68.245	68.421	-
1991–92	0	-	0	0	1.667	82.002	83.669	-
1992–93	0	-	0	0	0.891	109.280	110.171	-
1993–94	0	-	0.042	0	0	177.165	177.207	-
1994–95	0	-	0	0	0	182.262	182.262	-
1995–96	0	-	0	0	0	100.016	100.016	-
1996–97	0	-	0.125	0	0.005	68.575	68.705	-
1997–98	0	-	0.184	0	0	192.262	192.446	-
1998–99	0	-	0	0	0	76.205	76.205	-
1999–00	0	-	0	0	0	44.450	44.450	-
2000–01	0	-	0	0	0	16.150	16.150	-
2001–02	0	-	0	0	0	4.900	4.900	-
2002–03	0	-	0	0	0	36.160	36.160	-
2003–04	0	-	0.054	0	0	34.336	34.390	-
2004–05	0	-	0	0	0	0	0	-
2005–06	-	0	0	0	0	0	0	43
2006–07	-	0	0	0	0	0	0	43
2007–08	-	0	0	0	0	0	0	43
2008–09	-	0	0	0	0	0	0	43
2009–10	-	0	0	0	0	0	0	43
2010–11	-	0	0	0	0	0	0	43
2011–12	-	0	0	0	0	4.881	4.881	43
2012–13	-	0	0	0	0	5.294	5.294	43
2013–14	-	0	0	0.02	0	0	0.02	43
2014–15	-	0.012	0	0	0	1.801	1.801	43
2015–16	-	0	0	0	0	5.939	5.939	43
2016–17	-	0	0	0	0	0.58	0.58	43
2017–18	-	0	0	0	0	0	0	43
2018-19	-	0	0.004	0	0	0	0.004	43
2019–20	-	0	0.001	0	0	0	0.001	43
2020–21	-	0	0	0	0	0	0	43

1.2 Recreational fisheries

Tuatua support an extensive recreational fishery, with harvesting occurring in all stocks wherever there are accessible beds, particularly in the upper North Island. Tuatua are harvested entirely by hand gathering, and there is no MLS (although large tuatua are preferred). There is a recreational daily catch limit of 150 tuatua per person, except in the Auckland - Coromandel region where the limit has been 50 per day per person since November 1999.

The harvest estimates provided by telephone-diary surveys between 1993 and 2001 are no longer considered reliable for various reasons but a more reliable National Panel Survey was conducted for the first time throughout the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The panel survey was repeated in 2017–18 (Wynne-Jones et al. 2019). Harvest estimates (in numbers of tuatua) are given in Table 3 (from Wynne-Jones et al. 2014 and Wynne-Jones et al. 2019).

Table 3: Recreational harvest estimates for tuatua stocks from the national panel survey in 2011–12 (Wynne-Jones et al. 2014) and 2017–18 (Wynne-Jones et al. 2019). Mean weights were not available from boat ramp surveys to convert these estimates to weights.

Stock	Number of tuatua	CV
2011–12 (national panel survey)		
TUA 1A	297 826	0.45
TUA 1B	267 380	0.52
TUA 2	14 222	0.84
TUA 3	2 102	0.77
TUA 7	14 503	0.88
TUA 8	42 608	0.47
TUA 9	231 109	0.49
TUA total	869 751	0.26
2017–18 (national panel survey)		
TUA 1A	31 059	0.72
TUA 1B	249 308	0.57
TUA 2	9 205	0.78
TUA 3	11 439	0.71
TUA 5	10 629	1.00
TUA 7	3 020	1.01
TUA 8	29 998	0.72
TUA 9	219 744	0.40
TUA total	564 401	

1.3 Customary non-commercial fisheries

In common with many other intertidal shellfish, tuatua are an important customary species taken as kaimoana. Both oral tradition and the numerous middens of *P. triangulata* shells around the coastline clearly show that this fishery has been an important one to Maori for at least several hundred years.

Māori customary fishers utilise the provisions under both the recreational fishing regulations and the various customary regulations. Many tangata whenua harvest tuatua under their recreational allowance and these are not included in records of customary catch. Customary reporting requirements vary around the country. Customary fishing authorisations issued in the South Island and Stewart Island would be under the Fisheries (South Island Customary Fishing) Regulations 1999. Many rohe moana / areas of the coastline in the North Island and Chatham Islands are gazetted under the Fisheries (Kaimoana Customary Fishing) Regulations 1998 which require reporting on authorisations. In the areas not gazetted, customary fishing permits would be issued would be under the Fisheries (Amateur Fishing) Regulations 2013, where there is no requirement to report catch.

The information on Māori customary harvest under the provisions made for customary fishing can be limited (Table 4). These numbers are likely to be an underestimate of customary harvest as only the catch approved and harvested in kilograms and numbers are reported in the table.

Table 4: Fisheries New Zealand records of customary harvest of tuatua (approved and reported as weight (kg) and numbers), since 2001–02. – no data. [Continued on next page].

	TUA 1A				TUA 1B			
	Weight (kg)		Numbers		Weight (kg)		Numbers	
Fishing year	Approved	Harvested	Approved	Harvested	Approved	Harvested	Approved	Harvested
2001–02	–	–	–	–	–	–	–	–
2002–03	–	–	–	–	–	–	–	–
2003–04	–	–	–	–	–	–	–	–
2004–05	–	–	–	–	–	–	–	–
2005–06	–	–	–	–	–	–	–	–
2006–07	–	–	–	–	–	–	–	–
2007–08	–	–	–	–	75	25	–	–
2008–09	–	–	–	–	346	285	–	–
2009–10	75	75	–	–	215	180	2 000	2 000
2010–11	100	100	–	–	50	30	–	–
2011–12	–	–	–	–	–	–	–	–
2012–13	–	–	–	–	–	–	–	–
2013–14	–	–	–	–	–	–	–	–
2014–15	–	–	–	–	–	–	–	–
2015–16	–	–	–	–	–	–	–	–
2016–17	–	–	–	–	35	35	–	–
2017–18	–	–	–	–	40	40	400	400
2018–19	–	–	–	–	80	80	–	–
2019–20	–	–	–	–	–	–	–	–
2020–21	–	–	–	–	–	–	–	–

Table 4 [continued]

	TUA 2				TUA 3			
	Weight (kg)		Numbers		Weight (kg)		Numbers	
Fishing year	Approved	Harvested	Approved	Harvested	Approved	Harvested	Approved	Harvested
2001–02	–	–	–	–	–	–	60	60
2002–03	–	–	–	–	–	–	–	–
2003–04	–	–	300	265	–	–	–	–
2004–05	–	–	–	–	–	–	–	–
2005–06	–	–	–	–	–	–	–	–
2006–07	–	–	–	–	–	–	–	–
2007–08	–	–	–	–	–	–	–	–
2008–09	–	–	–	–	–	–	–	–
2009–10	–	–	–	–	–	–	–	–
2010–11	–	–	–	–	–	–	150	150
2011–12	–	–	–	–	–	–	–	–
2012–13	–	–	–	–	–	–	–	–
2013–14	–	–	–	–	–	–	–	–
2014–15	–	–	–	–	–	–	–	–
2015–16	–	–	–	–	–	–	–	–
2016–17	–	–	–	–	–	–	–	–
2017–18	–	–	–	–	–	–	–	–
2018–19	–	–	–	–	–	–	–	–
2019–20	–	–	–	–	–	–	–	–
2020–21	–	–	–	–	–	–	–	–

	TUA 4				TUA 9			
	Weight (kg)		Numbers		Weight (kg)		Numbers	
Fishing year	Approved	Harvested	Approved	Harvested	Approved	Harvested	Approved	Harvested
2001–02	–	–	–	–	–	–	60	60
2002–03	–	–	–	–	–	–	–	–
2003–04	–	–	–	–	–	–	–	–
2004–05	–	–	–	–	–	–	–	–
2005–06	–	–	–	–	–	–	–	–
2006–07	–	–	–	–	–	–	–	–
2007–08	–	–	–	–	–	–	–	–
2008-09					–	–	–	–
2009–10	–	–	300	300	–	–	–	–
2010–11	–	–	–	–	–	–	–	–
2011–12	–	–	–	–	100	70	–	–
2012–13	–	–	–	–	–	–	–	–
2013–14	–	–	–	–	–	–	–	–
2014–15	–	–	100	100	–	–	–	–
2015–16	–	–	–	–	–	–	–	–
2016–17	–	–	100	100	–	–	–	–
2017–18	2	2	–	–	–	–	–	–
2018–19	–	–	–	–	–	–	–	–
2019–20	–	–	–	–	–	–	–	–
2020–21	–	–	–	–	–	–	–	–

1.4 Illegal catch

The illegal catch of tuatua is probably significant in some areas, with some recreational fishers exceeding their bag limit, but no quantitative information on the level of illegal catch is available.

1.5 Other sources of fishing-related mortality

No quantitative information on the level of other sources of mortality is available. Tuatua are generally sedentary and beds are susceptible to localised depletion, not only by harvesting pressure, but also by habitat disturbance and degradation. Incidental mortality of tuatua is likely in the Kaipara Harbour dredge fishery if tuatua are damaged during encounters with the dredge. Changes in bank stability could arise from dredging operations and might cause additional incidental mortality. However, the level of dredge-related mortality is unknown. As suspension feeders, tuatua may also be adversely affected by high sedimentation loads in the water column. In some areas, such as Ninety Mile Beach, Dargaville and Muriwai, vehicles driven along the beach pass directly over tuatua beds, increasing mortality either directly by damaging tuatua or indirectly by adversely modifying surface sand conditions leading to desiccation of tuatua.

2. BIOLOGY

Tuatua (*Paphies subtriangulata*) belong to the family Mesodesmatidae, a group of moderate to large wedge-shaped surf clams that include toheroa (*Paphies ventricosum*), deepwater tuatua (*Paphies*

donacina), and pipi (*Paphies australis*). *P. subtriangulata* is extensively distributed around New Zealand in localised abundant populations, but mainly occurs around the North Island, and at more scattered locations in the northern South Island, Stewart Island, and the Chatham Islands.

Tuatua are ecological markers of fine, clean, fluid sands on ocean beaches with moderate wave exposure The densest beds are found in the zone from the low intertidal to the shallow subtidal (down to about 4 m depth). The tuatua is a suspension feeder with short siphons. It is usually wedged only a few centimetres into the sand, with the straight siphonal end often characteristically exposed and discoloured by a green or brown algal film. Individuals are often dragged about the surface and redistributed by swash and backwash before actively burrowing back into the sand.

Tuatua have separate sexes (1:1 sex ratio) and reproduce by broadcast spawning, synchronously releasing eggs and sperm into the water column for external fertilisation. In north-eastern New Zealand, two main spawning periods have been documented, one between September and November, the other between February and April. Spawning events have been observed *in situ* at high water on a number of occasions, with only a small proportion of the population participating in each event. These spawning events were synchronous with pipi spawning in the same area.

Planktonic larval development takes about two to three weeks, so larvae have the potential to disperse widely if conditions allow. Larval settlement is thought to occur high in the intertidal, but spat and juveniles are highly mobile, moving around with the tidal flow before reburying themselves rapidly. Tuatua appear to migrate down the beach to occupy the lower intertidal and shallow subtidal as they grow larger. Growth appears to be rapid but variable, with tuatua reaching 40–70 mm shell length in about 3 years. Maximal length is variable among areas, ranging from about 50 to 80 mm, and the maximum age is probably about 5 or more years. Highly variable recruitment has been observed on the northwest coast of the North Island, and this is likely to occur in other areas. As in other surf clams, natural mortality is likely to be high.

A length-weight relationship has been estimated for tuatua sampled from East Auckland, and a southern population (probably Dunedin) where weight (in g) = a (length (in mm))^b, where a = 0.2 x 10^{-3} and b = 2.927. Data source: D. Allen unpublished data. Because the samples were from one northern and one southern population, the estimated relationship may not be representative of other populations.

3. STOCKS AND AREAS

Little is known of the stock structure of tuatua. There have been no biological studies directly relevant to the identification of separate stocks of *P. subtriangulata* around New Zealand, although "stocks" are likely to be linked by larval dispersal. For management purposes stock boundaries are based on FMAs, with the exception of TUA 1, which was divided into TUA 1A and TUA 1B on either side of Te Arai Point because there are likely to be significant differences in the state and use of the tuatua beds between the Northland and Hauraki Gulf / Bay of Plenty areas, and the respective alignment of recreational and customary fishing interests to those management areas. The circulation patterns that maintain the separation of the surf zone habitat to form a self-contained ecosystem also retain planktonic larvae of surf clams probably isolating surf clams genetically as well as ecologically.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance
There are no estimates of fishery parameters or abundance for any tuatua fishstock.

4.2 Biomass estimates
There is no time series of biomass surveys for tuatua either in the bed in the Kaipara Harbour entrance where commercial harvesting by dredge occurs now, or anywhere else that would indicate whether tuatua populations are changing in response to past and current levels of harvesting.

4.3 Yield estimates and projections

MCY has not been estimated for *P. subtriangulata*. *CAY* has not been estimated for *P. subtriangulata*.

5. STATUS OF THE STOCKS

There are no estimates of biomass or sustainable yields of tuatua for any tuatua stock and the status of all stocks is unknown. Because natural mortality is high and recruitment is variable, the biomass of tuatua is likely to be highly variable.

- **TUA -** *Paphies subtriangulata*

Stock Status	
Year of Most Recent Assessment	No formal assessment conducted for any of the stocks
Assessment Runs Presented	Recruited biomass (shells ≥ 50mm)
Reference Points	Target: Undefined Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Undefined
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	-

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Landings are less than a quarter of the TACC and have generally been declining since 2002–03.

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	-	
Assessment Method	-	
Assessment Dates	-	Next assessment: Unknown
Overall assessment quality rank		
Main data inputs (rank)		
Data not used (rank)		
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments

Landings are thought to have been declining in recent times because of economic rather than biological reasons.

Fishery Interactions

Interactions with other species are currently being characterised.

6. FOR FURTHER INFORMATION

Beu, A G; De Rooij-Schuiling, L A (1982) Subgeneric classification of New Zealand and Australian species of *Paphies lesson* (Bivalvia: Mesodesmatidae), and names for the two species of tuatua in New Zealand. *New Zealand Journal of Zoology* 9: 211–230.

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 national marine recreational fishing survey: diary results and harvest estimates. Final Research Report for Ministry of Fisheries Project REC2000/03 (Unpublished report held by Fisheries New Zealand, Wellington).

Boyd, R O; Reilly, J L (2002) 1999/2000 National marine recreational fishing survey: harvest estimates. Final Research Report for the Ministry of Fisheries Project 1998/03 28 p. (Unpublished report held by Fisheries New Zealand, Wellington).

Bradford, E (1998) Harvest estimates from the 1996 national marine recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished report held by NIWA library, Wellington).

Cranfield, H J; Michael, K P; Stotter, D; Doonan, I J (1994) Distribution, biomass and yield estimates of surf clams off New Zealand beaches. New Zealand Fisheries Assessment Research Document 1994/1. 27 p. (Unpublished report held by Fisheries New Zealand, Wellington).

Grant, C M (1994) Demographics and reproduction of the tuatua *Paphies subtriangulata*. Unpublished MSc thesis. University of Auckland, Auckland, New Zealand. 120 p.

Grant, C M; Creese, R G (1995) The reproductive cycle of the tuatua-*Paphies subtriangulata* (Wood, 1828), in New Zealand. *Journal of Shellfish Research* 14: 287–292.

Grant, C M; Hooker, S H; Babcock, R C; Creese, R G (1998) Synchronous spawning and reproductive incompatibility of two bivalve species: *Paphies subtriangulata* and *Paphies australis*. *Veliger* 41: 148–156.

Haddon, M; Wear, R (1987) Biology of feeding in the New Zealand paddle crab *Ovalipes catharus* (Crustacea, Portunidae). *New Zealand Journal of Marine and Freshwater Research* 21: 55–64.

Ministry of Fisheries Science Group (Comps.) (2006) Report from the Fishery Assessment Plenary, May 2006: stock assessments and yield estimates. 875 p. (Unpublished report held in NIWA library, Wellington.)

Morton, J E; Miller, M C (1968) *The New Zealand sea shore*. Collins, Auckland, New Zealand. 638 p.

Powell, A W B (1979) *New Zealand Mollusca: marine, land and freshwater shells*. Collins, Auckland, New Zealand. 500 p.

Redfearn, P (1987) Larval shell development of the northern tuatua, *Paphies subtriangulata* (Bivalvia, Mesodesmatidae). *New Zealand Journal of Marine and Freshwater Research* 21: 65–70.

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019) National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24*. 104 p.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014). National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*.

WHITE WAREHOU (WWA)

(Seriolella caerulea)
Warehou

1.   FISHERY SUMMARY

1.1   Commercial fisheries

White warehou are predominantly taken as bycatch from target trawl fisheries on hoki and silver warehou, and to a lesser extent, hake, ling and scampi. White warehou are mostly caught in 150 to 800 m depth by larger vessels owned or chartered by New Zealand fishing companies.

Prior to the establishment of the EEZ on 1 March 1978, white warehou landings were combined with both silver and blue (or common) warehou as 'warehous'. An estimate of total white warehou catches for 1970 to 1977 calendar years has been made (Table 1). From 1978–79 to 1982–83 annual catches of up to 900 t during the fishing year were reported, mainly from Southland and the Chatham Rise (Table 2).

Annual catches of white warehou have been variable, ranging from 315 t in the 1978–79 fishing year to 3694 t in 1996–97 (Tables 2 and 3). White warehou entered the Quota Management System on 1 October 1998, with an initial Total Allowable Commercial Catch (TACC) of 3374 t. The TACCs for each QMA are given in Table 3. A nominal allowance of 1 t was made for both recreational and customary catch in each of WWA 2–7. TACCs were increased from 1 October 2006 in WWA 3 to 583 t, in WWA 4 to 330 t, and in WWA 7 to 127 t. In these stocks, landings had previously been above the TACC for a number of years; the TACCs were increased to the average of the previous 7 years plus an additional 10%. Despite this change the catch in WWA 3 in 2006–07 was well above the new TACC, but has been under the TACC since 2007–08. From 1 October 2007, WWA 5 was merged with WWA 6 to create WWA 5B, with a TACC of 2617 t. TACCs have been under-caught in WWA 4 and 5B in recent years. In WWA 7 landings have fluctuated, approaching the available quota in the fishing years 2012–13 and 2013–14, and exceeding it in 2017–18. Since 2017–18 reported landings have been the lowest since the mid-1980s. Figure 1 shows the historical landings and TACC values for the main white warehou stocks.

White warehou are almost entirely caught from 300–700 m bottom trawls targeted on hoki, squid, ling and silver warehou (Ballara & Baird 2012), with a smaller amount caught by midwater trawl. Until the introduction of electronic reporting by the > 28m trawl fleet on 1 October 2017, most catch was recorded on Trawl Catch Effort and Processing Returns. In 2013 and 2014, about 20% of the west coast South Island (WCSI) white warehou catch was reported on the TCER form (Ballara 2015). From 1990 to 2014, 52 238 t of white warehou catch was reported: 70% from the Sub-Antarctic area, 24% from off the east coast South Island (ECSI) and across the Chatham Rise, and 4% from the WCSI (Ballara 2015).

WHITE WAREHOU (WWA)

Target fishing on white warehou has been reported from around Mernoo Bank, the Stewart-Snares shelf, Puysegur Bank and on the west coast of the South Island, with the best catch rates recorded in the southern areas. Target fisheries accounted for only 8% of the total white warehou catch for the years from 1988–89 to 1994–95. In the Sub-Antarctic, 36% of catches are from target fishing, although since 2003 this has been over 50% in most years; the remainder was primarily from tows targeting ling, hoki, and silver warehou (Ballara 2015). The greatest catches in this area are from waters off the Stewart-Snares shelf, near the Puysegur Bank, and off the Auckland Islands Shelf. About 63% of the catch from off the ECSI and the Chatham Rise was from hoki target tows, with only 1% from white warehou targeted tows (Ballara 2015). The highest catches were from the east coast statistical areas. There appeared to be no definite season for white warehou catches in those areas. Catches off the WCSI were from bottom and mid-water hoki and hake tows, and were restricted to the months in which those target fisheries operated (June–September).

Table 1: Estimated catch (t) of white warehou for years 1970 to 1977.

Vessel nationality	1970*	1971*	1972	1973	1974	1975	1976	1977
Japanese	17	25	222	447	234	1 453	1 558	334
Russian	NA	NA	1 300	1 200	1 480	40	440	1 260
Korean	-	-	-	-	-	-	-	400
Total	17	25	1 522	1 647	1 714	1 493	1 998	1 994

* Japanese data only.

Table 2: Reported landings (t) of white warehou by fishing year and area, by foreign licensed and joint venture vessels, 1978–79 to 1983–83. The EEZ areas correspond approximately to the QMAs as indicated. Fishing years are from 1 April to 31 March. The 1983–83 is a six month transitional period from 1 April to 30 September. No data are available for the 1980–81 fishing year.

EEZ area	B	C(M)	C(1)	D	E(B)	E(P)	E(C)	E(A)	F(E)	F(W)	G	H	
QMA area	1& 2		3	4				6		5	7	8 & 9	Total
1978–79	1	20	10	1	0	5	0	141	86	26	20	6	315
1979–80	2	8	5	230	57	5	4	312	34	97	42	0	795
1980–81	-	-	-	-	-	-	-	-	-	-	-	-	-
1981–82	0	41	2	53	0	2	5	153	27	248	10	1	542
1982–83	0	375	1	88	0	11	0	198	39	137	33	0	882
1983–84	0	167	5	49	0	0	0	12	9	34	24	0	300

Note: The EEZ area E(A) also included part of QMA 5, south of 48º30' S.

Table 3: Reported landings (t) of white warehou by fishstock and fishing year, 1982–83 to present. The data in this table has been updated from that published in previous Plenary Reports by using the data through 1996–97 in table 44 on p. 296 of the "Review of Sustainability Measures and Other Management Controls for the 1998–99 Fishing Year - Final Advice Paper" dated 6 August 1998. Data since 1997–98 are based on catch and effort returns. There are no landings reported from QMA 10. [Continued on next page]

Fishstock	WWA 1		WWA 2		WWA 3		WWA 4		WWA 5(5B)*	
FMA	1		2		3		4		5 (&6)*	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1982–83	0	-	35	-	179	-	69	-	248	-
1983–84	0	-	28	-	111	-	33	-	282	-
1984–85	0	-	2	-	123	-	39	-	150	-
1985–86	0	-	5	-	589	-	61	-	277	-
1986–87	0	-	10	-	239	-	29	-	167	-
1987–88	< 1	-	9	-	431	-	26	-	113	-
1988–89	6	-	1	-	118	-	43	-	843	-
1989–90	1	-	9	-	484	-	16	-	555	-
1990–91	2	-	12	-	695	-	88	-	568	-
1991–92	6	-	22	-	589	-	113	-	833	-
1992–93	2	-	13	-	281	-	106	-	560	-
1993–94	6	-	34	-	197	-	23	-	1 235	-
1994–95	4	-	41	-	327	-	243	-	1 936	-
1995–96	2	-	68	-	566	-	137	-	1 555	-
1996–97	3	-	89	-	508	-	220	-	2 309	-
1997–98	2	-	31	-	516	-	153	-	1 217	-
1998–99	< 1	4	34	73	398	399	120	220	1 269	2 127
1999–00	< 1	4	48	73	559	399	277	220	1 112	2 127
2000–01	< 1	4	21	73	661	399	303	220	703	2 127
2001–02	0	4	8	73	446	399	262	220	921	2 127
2002–03	< 1	4	20	73	852	399	397	220	1 462	2 127
2003–04	< 1	4	47	73	458	399	365	220	1 141	2 127
2004–05	< 1	4	24	73	347	399	365	220	1 568	2 127
2005–06	< 1	4	35	73	589	399	312	220	1 176	2 127
2006–07	< 1	4	10	73	733	583	304	330	1 484	2 127
2007–08	< 1	4	43	73	345	583	207	330	*1 431	*2 617

Table 3 [continued]

Fishstock FMA	WWA 1 1		WWA 2 2		WWA 3 3		WWA 4 4		WWA 5(5B)* 5 (&6)*	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2008–09	< 1	4	22	73	302	583	85	330	1 644	2 617
2009–10	< 1	4	7	73	355	583	179	330	1 106	2 617
2010–11	< 1	4	12	73	391	583	81	330	787	2 617
2011–12	< 1	4	3	73	204	583	112	330	978	2 617
2012–13	< 1	4	6	73	174	583	117	330	1 037	2 617
2013–14	< 1	4	8	73	302	583	110	330	1 373	2 617
2014–15	< 1	4	7	73	225	583	69	330	447	2 617
2015–16	< 1	4	5	73	269	583	51	330	699	2 617
2016–17	< 1	4	5	73	288	583	52	330	637	2 617
2017–18	< 1	4	6	73	282	583	57	330	649	2 617
2018–19	< 1	4	5	73	212	583	91	330	681	2 617
2019–20	< 1	4	3	73	185	583	72	330	336	2 617
2020–21	< 1	4	6	73	123	583	34	330	633	2 617

Fishstock FMA	WWA 6 6		WWA 7 7		WWA 8 8		WWA 9 9		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1982–83	7	-	24	-	<1	-	0	-	562	-
1983–84	24	-	29	-	<1	-	0	-	510	-
1984–85	12	-	15	-	<1	-	0	-	342	-
1985–86	43	-	81	-	<1	-	0	-	1 058	-
1986–87	144	-	15	-	<1	-	0	-	573	-
1987–88	20	-	28	-	<1	-	0	-	629	-
1988–89	16	-	10	-	0	-	0	-	1 040	-
1989–90	291	-	83	-	0	-	0	-	1 438	-
1990–91	278	-	69	-	1	-	0	-	1 713	-
1991–92	1 028	-	45	-	0	-	0	-	2 636	-
1992–93	645	-	125	-	2	-	0	-	1 734	-
1993–94	592	-	69	-	0	-	0	-	2 156	-
1994–95	185	-	80	-	0	-	0	-	2 816	-
1995–96	50	-	62	-	0	-	0	-	2 440	-
1996–97	494	-	71	-	0	-	0	-	3 694	-
1997–98	126	-	98	-	< 1	-	< 1	-	2 155	-
1998–99	412	490	73	60	< 1	1	0	0	2 306	3 374
1999–00	211	490	153	60	< 1	1	0	0	2 351	3 374
2000–01	119	490	90	60	< 1	1	0	0	1 897	3 374
2001–02	219	490	85	60	< 1	1	< 1	0	1 941	3 374
2002–03	457	490	158	60	0	1	0	1	3 346	3 374
2003–04	211	490	135	60	0	1	0	1	2 357	3 374
2004–05	436	490	123	60	< 1	1	0	1	2 863	3 374
2005–06	250	490	133	60	0	1	0	1	2 495	3 374
2006–07	563	490	121	127	0	1	0	0	3 215	3 735
2007–08	N/A	N/A	90	127	0	1	< 1	0	2 116	3 735
2008–09	N/A	N/A	110	127	< 1	1	< 1	0	2 164	3 735
2009–10	N/A	N/A	44	127	< 1	1	0	0	1 691	3 735
2010–11	N/A	N/A	52	127	< 1	1	0	0	1 324	3 735
2011–12	N/A	N/A	77	127	< 1	1	< 1	0	1 375	3 735
2012–13	N/A	N/A	118	127	< 1	1	0	0	1 452	3 735
2013–14	N/A	N/A	115	127	< 1	1	< 1	0	1 908	3 735
2014–15	N/A	N/A	98	127	0	1	0	0	846	3 735
2015–16	N/A	N/A	44	127	0	1	< 1	0	817	3 735
2016–17	N/A	N/A	87	127	0	1	0	0	1 069	3 735
2017–18	N/A	N/A	139	127	0	1	0	0	1 134	3 735
2018–19	N/A	N/A	40	127	< 1	1	< 1	0	1 029	3 735
2019–20	N/A	N/A	47	127	0	1	0	0	643	3 735
2020–21	N/A	N/A	21	127	0	1	< 1	1	818	3 736

* In 2007–08 WWA 5 was merged with WWA 6 to create WWA 5B. The landings and TACC for WWA 5B are presented after 2007–08 in the WWA 5(5B)* column.
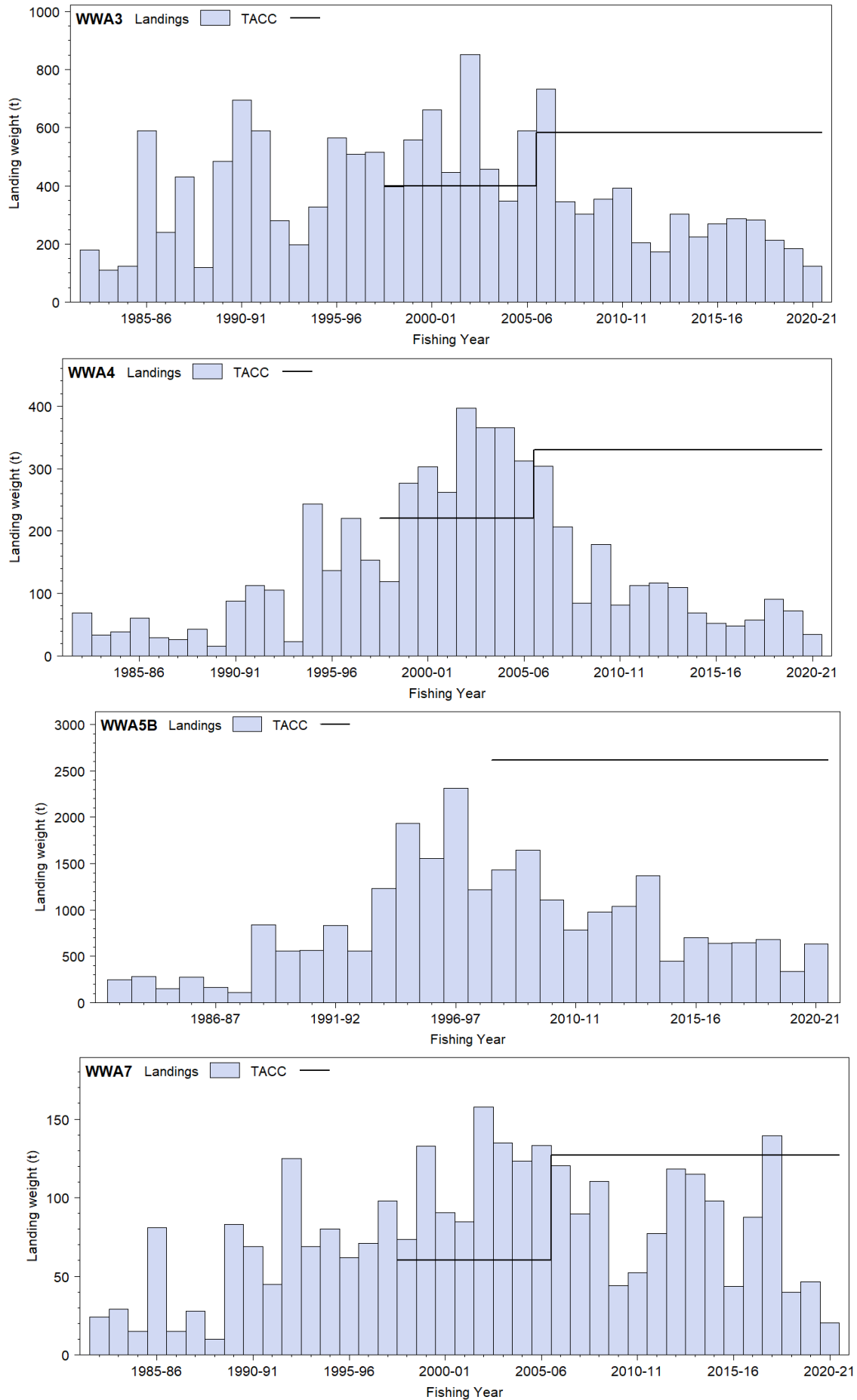
WHITE WAREHOU (WWA)

Figure 1: Reported commercial landings and TACC for the four main WWA stocks. WWA 3 (South East Coast), WWA 4 (South East Chatham Rise) and WWA 5B* (Southland, Sub-Antarctic) and WWA 7 (Challenger).

1.2   Recreational fisheries

The recreational take of white warehou is likely to be very small given its distribution and depth preferences.

1.3   Customary non-commercial fisheries

No quantitative information is available on the current level of customary non-commercial take.

1.4   Illegal catch

Silver warehou were reported as white warehou when the latter was a non QMS species. Compliance investigations in 1988 successfully proved that substantial quantities of silver warehou were reported as white warehou, but catch statistics were not altered as a result. The true extent of misreporting is unknown and thus the accuracy of annual catch records cannot be determined.

1.5   Other sources of mortality

No information is available on other sources of mortality.

2.   BIOLOGY

Adult white warehou range between 40 and 60 cm fork length (FL) and reach a maximum length and weight of 67 cm and 5.7 kg respectively. White warehou were aged by Gavrilov (1979) who gives the maximum age as 12 years, but this was likely to be an underestimate because he read whole otoliths and scales (Horn & Sutton 1996). Ageing of white warehou was partially validated by Horn (1999, 2001), based on a dataset of otoliths, covering all months of the year, collected during 1992–98 from the Chatham Rise and Sub-Antarctic. Growth of females is significantly faster than that of males and thus females are significantly larger at age than males (Horn 2001). Females also attain larger maximum size than males. Fish grow rapidly until they spawn (at about 3 or 4 years), and growth is much slower after 6–8 years (Horn 2001).

Table 4: Estimates of biological parameters of white warehou.

Fishstock									Estimate	Source
1. Weight = a(length)^b (Weight in g, length in cm, total length).										
	Female			Male			Both sexes			
	a	b		a	b		a	b		
Chatham Rise	0.0177	3.069		0.0247	2.981		0.0200	3.037		Horn (1999)
Sub-Antarctic	0.0106	3.197		0.0138	3.132		0.0111	3.188		Horn (1999)

	2. von Bertalanffy growth parameters (4-parameter curve)									
	Female				Males					
	L_∞	k	t_0	P		L_∞	k	t_0	P	
Chatham Rise	61.0	0.131	0.14	0.350		57.1	0.153	0.19	0.328	Horn (2001)
Sub-Antarctic	70.2	.058	0.22	0.281		62.4	0.098	0.14	0.297	Horn (2001)

Instantaneous natural mortality (*M*) was estimated (using several methods) to be between 0.20 and 0.28, and to be higher for males relative to females (Horn 1999). The Working Group considered the data inadequate for establishing a difference in M by sex and recommended the use 0.25 for both sexes in any stock assessment modelling with sensitivity tests of plus or minus 0.05.

Ripe and running ripe fish have been recorded from the ECNI, Chatham Rise, WCSI, off Puysegur, and in the Sub-Antarctic, especially off the Stewart-Snares shelf. Most ripe and running ripe females were seen in waters off the WCSI in July–October, in the Sub-Antarctic (off Puysegur and between the Stewart-Snares shelf and the Auckland Islands Shelf) in March–December, and the western Chatham Rise from May–October) (Ballara 2015). These data suggest that the spawning season may extend from winter to late spring, or that there are multiple stocks with differences in the timing of their spawning seasons.

Sex ratio data derived from scaled length frequencies appear to show a slight bias towards males. On the Chatham Rise sex ratios vary from 1.0:1 to 1.4:1 (males to females). In the southern area, ratios vary from 0.7:1 to 4.2:1, but sample sizes at either extreme of the range are very small. There are insufficient data to enable detection of any changes in sex ratio with season.

Feeding records from the Fisheries New Zealand research database *trawl* show salps as the predominant prey item observed in white warehou stomachs. Gavrilov & Markina (1979) noted salps (*Iasis*) and the tunicate *Pyrosoma* as major food items. Horn et al (2011) found that the diet on the Chatham Rise was dominated by pelagic tunicates (mainly *Iasis* and *Salpa* species), with the remainder comprising mostly small crustaceans (amphipods, copepods, and euphausiids). An unknown but small component of the crustacean prey was ingested unintentionally owing to a common commensal relationship between some crustaceans (primarily amphipods) and tunicates.

3. STOCKS AND AREAS

The existence of three possible spawning areas for white warehou (Mernoo Bank, Puysegur Bank and the west coast of the South Island) at the same time of year, suggests the possibility of three separate stocks. Bagley & Hurst (1997) proposed the following Fishstock areas: WWA 1 (QMAs 1, 2, 3 and 4), WWA 5 (QMAs 5 and 6) and WWA 7 (QMAs 7, 8 and 9) for white warehou. However, TACs were set for each QMA (1–9) in 1998 and each Fishstock is managed separately (note WWA 5 and WWA 6 were merged to form Fishstock WWA 5B in 2007–08).

4. STOCK ASSESSMENT

No assessments are available for any stocks for white warehou, therefore estimates of biomass and yield are not available.

4.1 Estimates of fishery parameters and abundance

CPUE analyses were carried out for Chatham Rise and Sub-Antarctic fisheries (Ballara 2015). The Chatham Rise stock showed increased CPUE from 1994 to 2006, but flatter since then (Table 5). The pattern did not match the trawl survey but neither series indicates a problem with WWA abundance in this area. The Sub-Antarctic fishery showed an initial decline to 1997 but was very flat since then (Table 5). There is little data available for the WCSI fishery with low catches and many years with less than 100 records. There are quite strong impacts of varying vessels and target species and the WG queried the reliability of the CPUE as abundance indicators.

Table 5: **Chatham Rise and Sub-Antarctic TCEPR tow-by-tow lognormal CPUE indices by fishing year, where 1993–94 is 1994.**

Year	Chatham Rise	Sub-Antarctic	Year	Chatham	Sub-Antarctic
1992	-	1.73	2004	1.34	0.75
1993	-	1.26	2005	1.14	0.82
1994	0.67	2.00	2006	1.45	0.87
1995	0.79	2.57	2007	1.39	0.94
1996	0.71	2.69	2008	1.10	0.93
1997	0.75	1.03	2009	1.04	0.78
1998	0.75	0.80	2010	1.22	0.79
1999	0.73	1.24	2011	1.11	0.71
2000	0.82	0.93	2012	1.16	0.63
2001	0.95	0.79	2013	1.15	0.80
2002	0.87	0.67	2014	1.20	0.83
2003	1.23	0.75			

4.2 Biomass estimates

Several time series of relative abundance estimates are available from trawl surveys, but these estimates may not be reliable indicators of relative abundance because of large fluctuations between years and moderate to high CVs. The larger biomass estimates are generally associated with moderate to high CVs (i.e., over 40%), having resulted from one or two large catches. Smaller biomass estimates have lower CVs, but this could be because the survey missed the main white warehou schools.

The Chatham Rise trawl surveys show an increase in biomass up until 2004, then a decrease to 2010 and flat since then (Table 6, Figure 2). Although the CVs are quite high, the period of increased abundance coincided with stronger recruitment of small fish to the shallow strata in 2001 and 2002 and

to the deeper strata in 2004. The length data from the surveys showed the progression of a mode from 30 cm in 2001 to 45 cm in 2004. The survey time series may be an adequate monitoring tool, despite the high CVs.

Table 6: Biomass indices (t) for white warehou from *Tangaroa* trawl surveys.

Year	Sub-Antarctic Summer (Nov–Dec)	Sub-Antarctic Autumn	Sub-Antarctic Spring	Southland	Chatham Rise Summer (Jan)	WCSI Winter
1991	1 605	-	-	-	-	-
1992	243	256	350	-	2 227	-
1993	293	907	-	18	2 939	-
1994	-	-	-	46	1 606	-
1995	-	-	-	2	734	-
1996	-	239	-	102	533	-
1997	-	-	-	-	2 287	-
1998	-	2 887	-	-	1 009	-
1999	-	-	-	-	3 136	-
2000	266	-	-	-	2 385	-
2001	2 433	-	-	-	4 262	12
2002	853	-	-	-	6 881	-
2003	709	-	-	-	3 685	-
2004	1 061	-	-	-	7 932	-
2005	538	-	-	-	4 542	-
2006	646	-	-	-	2 929	-
2007	1 707	-	-	-	2 853	-
2008	2 283	-	-	-	1 899	-
2009	2 093	-	-	-	3 667	-
2010	-	-	-	-	983	-
2011	390	-	-	-	1 861	-
2012	1 259	-	-	-	1 925	65
2013	-	-	-	-	2 030	26
2014	211	-	-	-	1 299	-

The Sub-Antarctic summer time series does not appear useful to monitor abundance. Length modes do not follow the series and CVs are high from occasional large catches. More stations in the area of white warehou abundance could possibly increase the utility of the survey. Autumn, spring, and the Southland surveys also do not appear to be useful, and the fish appear to remain in the southern area all year. Biomass estimates from the Chatham Rise survey are much higher than for the Sub-Antarctic survey, although catches are much lower.
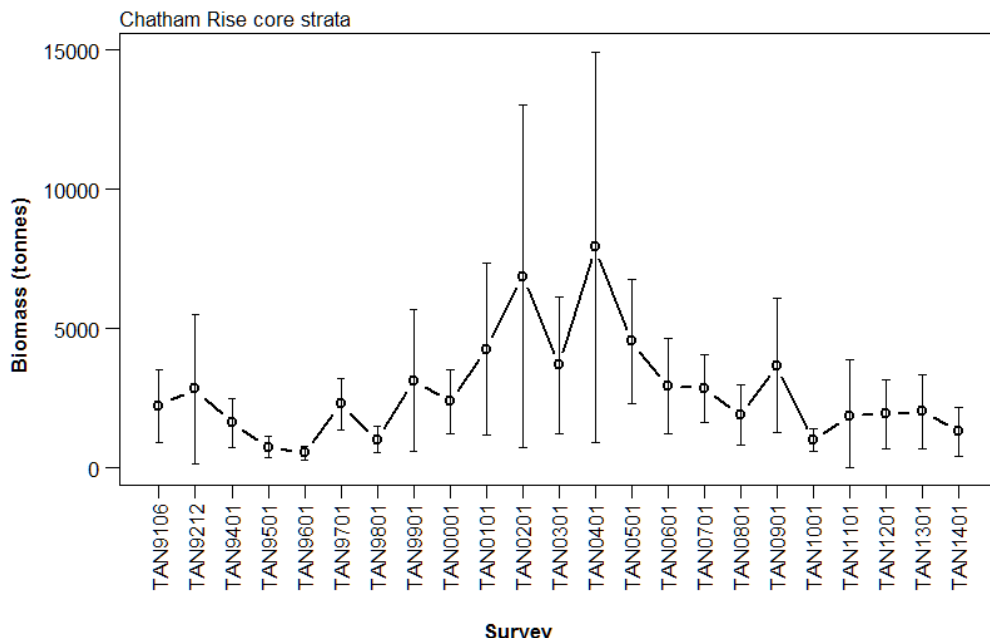

Figure 2: Doorspread biomass estimates, for all white warehou (± CV) from the Chatham Rise *Tangaroa* surveys from 1991 to 2014.

There were two recent surveys on the WCSI but these covered only the northern area. It appears that much of the WWA biomass is further down the WCSI so these surveys may not be able to monitor the stock abundance in WWA 7.

4.3 Yield estimates and projections

MCY cannot be determined. Problems with mis-reporting of silver warehou as white warehou and the lack of consistent catch histories make *MCY* estimates based on catch data alone unreliable. Also the amount of effort on white warehou relates very closely to effort on other target species such as hoki and silver warehou. Large fluctuations in the availability of white warehou to the trawl, as indicated by trawl surveys, are also likely to apply to commercial fishing operations. Estimates of *M* need to be determined.

CAY cannot be estimated because of the lack of current biomass estimates.

4.4 Other factors

None

5. STATUS OF THE STOCKS

It is not known whether recent catches are sustainable or if they are at levels that will allow the stock to move towards a size that will support the maximum sustainable yield.

TACCs were increased from 1 October 2006 in WWA 3 to 583 t, in WWA 4 to 330 t, and in WWA 7 to 127 t. In these stocks landings were above the TACC for a number of years and the TACCs have been increased to the average of the previous 7 years plus an additional 10%.

6. FOR FURTHER INFORMATION

Bagley, N.W.; Hurst, R.J. (1997). A summary of the biology and commercial landings and a stock assessment of white warehou *Seriolella caerulea* Guichenot, 1848 (Stromateoidei: Centrolophidae) in New Zealand waters. New Zealand Fisheries Assessment Research Document 1997/13. 34 p. (Unpublished document held by NIWA library, Wellington.)

Ballara S.L.; Baird, S.J. (2012). Fishery characterisation and standardised CPUE analyses for white warehou, *Seriolella caerulea*, 1989–90 to 2009–10. *New Zealand Fisheries Assessment Report 2012/49*. 265 p.

Ballara S.L. (2015). Fishery characterisation and standardised CPUE analyses for white warehou, *Seriolella caerulea*, 1989–90 to 2013–14. *New Zealand Fisheries Assessment Report 2015/66*.

Cousseau, M.B.; Fortciniti, L.; Ubaldi, G. (1993). Species of the Genus *Seriolella* in Southwest Atlantic waters. *Japanese Journal of Icthyology 40(2)*: 183–187.

Gavrilov, G.M (1979). *Seriolella* of the New Zealand plateau. Report of the Pacific Ocean Scientific Research Institute of Fisheries and Oceanography (TRINO). (In Russian, English translation held in NIWA, Wellington.)

Gavrilov, G M; Markina, N P (1979). The feeding ecology of fishes of the genus *Seriolella* (fam. Nomeidae) on the New Zealand plateau. *Journal of Ichthyology 19(6)*: 128–135.

Horn, P.L. (1999). A validated ageing method and updated stock assessment for white warehou (*Seriolella caerulea*) in New Zealand waters. New Zealand Fisheries Assessment Research Document 1999/44. (Unpublished document held by NIWA library, Wellington.)

Horn, P.L. (2001). Validated ageing methods for blue warehou (*Seriolella brama*) and white warehou (*S. caerulea*) in New Zealand waters. *Marine and Freshwater Research 52*: 297–310.

Horn, P.L.; Sutton, C.P. (1996). Validated ages, growth, and productivity parameters for silver warehou (*Seriolella punctata*) off the south and east coasts of South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research 30*: 301–312.

Horn, P.L.; Burrell, T.; Connell, A.; Dunn, M.R. (2011). A comparison of the diets of silver (*Seriolella punctata*) and white (*Seriolella caerulea*) warehous. *Marine Biology Research 7*: 576–591.

Hurst, R.J.; Bagley, N.W. (1992). Results of a trawl survey of barracouta and associated finfish near the Chatham Islands, New Zealand, December 1985. *New Zealand Fisheries Technical Report* 30. 36 p.Kerstan, M; Sahrhage, D (1980) Biological investigation on fish stocks in the waters off New Zealand. *Mitteilungen aus dem Institut fur Seefischerei der Bundesforschungsanstalt fur Fischerei, Hamburg*: 29. 168 p.

McDowall, R.M. (1980). *Seriolella caerulea* Guichenot, 1884 in New Zealand waters (Stromateoidei: Centrolophidae). *Journal of the Royal Society of New Zealand 10(1)*: 65–74.

McDowall, R M (1982). The centrolophid fishes of New Zealand (Pisces: Stromateoidei). *Journal of the Royal Society of New Zealand 12*: 103–142.

New Zealand Fishing Industry Board (NZFIB) (1996). The New Zealand seafood industry economic review 1994–1996. New Zealand fishing industry board, Wellington. 65p.

YELLOW-EYED MULLET (YEM)

(*Aldrichetta forsteri*)
Aua
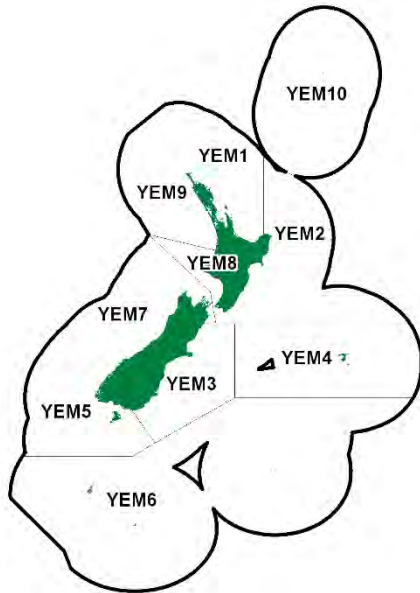
1.   FISHERY SUMMARY

1.1   Commercial fisheries

Yellow-eyed mullet entered the Quota Management System (QMS) on 1 October 1998. There is very little published information on the commercial fishery for yellow-eyed mullet apart from brief comments about its use as bait. From 1934 to 1972 information from catch records indicate that yellow-eyed mullet was taken by "other nets", meaning nets other than trawl or Danish seine. Catch by gear-type data from the Fisheries Statistics Unit (FSU) records between 1982–83 and 1988–89 show a predominant use of setnets and gillnets (about 95.5% of total catch) over beach seine and drag net (about 4.5% of total catch).

There is the potential for incorrect assignment of yellow-eyed mullet in landings records because of similarity in the common names of grey mullet and yellow-eyed mullet and the possibility that some fishers refer to both as *mullet*. A second possible classification error may arise from erroneous use of the names *herring* or *sprat*. The level of error in the landings data due to misidentification is not known.

Before 1960 the majority of the recorded landings of yellow-eyed mullet was taken in Northland. Between 1960 and 1968, there was a marked increase in landings from Lake Ellesmere. Regular records are also available for Napier beginning in 1941, and Manukau Harbour. Apart from Lake Ellesmere, records for the South Island are generally incomplete.

Pre-1980, landings of yellow-eyed mullet by QMA were low, perhaps as a result of under-reporting. Landings increased in the early 1980s due to an increase in landings in QMA 9, and to a lesser extent in QMA 1. In the 1990s landings in QMA 1 equaled and often exceeded landings in QMA 9. Landings have remained below 20 t in QMA 9 since the fishing year 1993-94 with the exception of the 1999–00 landings, which was almost triple that of the previous year and more than double the landings recorded in QMA 1. Most recently, in 2010–11 to 2019–20, an average of 14 t of annual landings were recorded in QMA 1, compared to 10 t in QMA 9.

Yellow-eyed mullet landings have fluctuated over time, with a peak of 68 t being recorded in 1986–87. The high landings recorded since the mid 1980s most likely reflect increased fishing in the Auckland area in response to an increase in market demand for yellow-eyed mullet. An annual average of 37 t of total landings were recorded between 1996–97 and 1999–2000, and an average of 27 t between 2000–01 and

2019–20. Strong seasonal trends are evident in the landings data for each QMA with annual peaks mostly in July–August, indicating a winter fishery.

A breakdown of the current Total Allowable Catch (TAC) is shown in Table 1. Historical estimated and recent reported yellow-eyed mullet landings and TACCs are shown in Tables 2 and 3, while Figure 1 shows the historical landings and TACC values for the main YEM stocks.

Commercial landings of yellow-eyed mullet have been generally been below the TACC in each QMA since this species was introduced into the QMS on 1 October 1998. YEM 8 and YEM 3 landings however exceeded the TACCs slightly in 2005–06 and 2014–15 respectively.

Table 1: Recreational and customary non-commercial allowances (t), Total Allowable Commercial Catches (TACC, t) and Total Allowable Catches (TAC, t) declared for YEM.

Fishstock		FMA	TAC	TACC	Customary	Recreational
YEM 1	Auckland (East)	1	50	20	15	15
YEM 2	Central (East)	2	14	2	4	8
YEM 3	South-east (Coast)	3	14	8	2	4
YEM 4	South-east (Chatham)	4	0	0	0	0
YEM 5	Southland	5	2	1	1	1
YEM 6	Sub-Antarctic	6	0	0	0	0
YEM 7	Challenger	7	20	5	5	10
YEM 8	Central (West)	8	18	3	5	10
YEM 9	Auckland (West)	9	38	30	4	4

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	YEM 1	YEM 9	Year	YEM 1	YEM 9
1931-32	0	0	1957	19	0
1932-33	0	0	1958	22	0
1933-34	0	0	1959	20	0
1934-35	0	0	1960	9	0
1935-36	0	0	1961	20	0
1936-37	0	0	1962	19	1
1937-38	0	0	1963	8	1
1938-39	1	0	1964	9	0
1939-40	0	0	1965	6	3
1940-41	0	0	1966	4	5
1941-42	0	0	1967	23	4
1942-43	0	0	1968	19	2
1943-44	1	0	1969	17	2
1944	0	0	1970	17	1
1945	9	0	1971	14	1
1946	52	0	1972	7	1
1947	65	0	1973	0	0
1948	71	0	1974	0	0
1949	81	0	1975	11	0
1950	31	0	1976	11	0
1951	36	0	1977	2	0
1952	13	0	1978	1	0
1953	13	0	1979	1	0
1954	15	0	1980	2	1
1955	28	0	1981	5	4
1956	28	0	1982	4	2

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings.

Table 3: Reported landings (t) of yellow-eyed mullet by fishstock and fishing year, 1983–84 to present. The data in this table has been updated from that published in previous Plenary Reports using the data through to 1996–97 in table 47 on p. 304 of the "Review of Sustainability Measures and Other Management Controls for the 1999–2000 Fishing Year – Final Advice Paper" dated 6 August 1998. There are no landings from FMA 10, which has a TACC of 0 [Continued on next page].

Fishstock FMA	YEM 1 1		YEM 2 2		YEM 3 3		YEM 4 4		YEM 5 5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1982–83	2	-	35	-	3	-	0	-	0	-
1983–84	2	-	28	-	5	-	0	-	0	-
1984–85	12	-	2	-	1	-	0	-	0	-
1985–86	24	-	5	-	7	-	0	-	0	-
1986–87	14	-	10	-	4	-	0	-	0	-
1987–88	11	-	9	-	9	-	0	-	0	-
1988–89	3	-	1	-	4	-	0	-	0	-
1989–90	1	-	9	-	17	-	0	-	0	-
1990–91	21	-	12	-	13	-	0	-	0	-
1991–92	15	-	22	-	23	-	0	-	0	-
1992–93	32	-	13	-	1	-	1	-	0	-
1993–94	53	-	34	-	2	-	0	-	0	-
1994–95	32	-	41	-	1	-	0	-	0	-
1995–96	19	-	68	-	2	-	0	-	0	-
1996–97	32	-	89	-	7	-	< 1	-	0	-
1997–98	10	-	31	-	< 1	-	0	-	0	-
1998–99	16	10	34	1	7	6	0	0	0	0
1999–00	10	10	48	1	7	6	0	0	0	0
2000–01	9	10	21	1	5	6	0	0	0	0
2001–02	6	20	8	2	< 1	8	0	0	0	0
2002–03	9	20	< 1	2	4	8	0	0	0	0
2003–04	4	20	< 1	2	6	8	0	0	0	0
2004–05	4	20	< 1	2	1	8	0	0	< 1	0
2005–06	3	20	1	2	3	8	0	0	0	0
2006–07	5	20	< 1	2	5	8	0	0	< 1	0
2007–08	3	20	< 1	2	3	8	0	0	0	0
2008–09	6	20	< 1	2	< 1	8	0	0	0	0
2009–10	15	20	< 1	2	4	8	0	0	0	0
2010–11	10	20	< 1	2	7	8	0	0	0	0
2011–12	9	20	< 1	2	5	8	0	0	0	0
2012–13	14	20	< 1	2	3	8	0	0	0	0
2013–14	15	20	< 1	2	4	8	0	0	< 1	0
2014–15	19	20	< 1	2	9	8	0	0	< 1	0
2015–16	16	20	< 1	2	6	8	0	0	< 1	0
2016–17	15	20	0	2	3	8	0	0	< 1	0
2017–18	13	20	< 1	2	4	8	0	0	< 1	0
2018–19	16	20	< 1	2	4	8	0	0	< 1	0
2019–20	13	20	< 1	2	5	8	0	0	< 1	0
2020–21	16	20	< 1	2	8	8	0	0	0	1

Fishstock FMA	YEM 6 6		YEM 7 7		YEM 8 8		YEM 9 9		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1982–83	0	-	0	-	5	-	5	-	17	-
1983–84	0	-	0	-	5	-	26	-	26	-
1984–85	0	-	3	-	3	-	33	-	33	-
1985–86	0	-	4	-	2	-	61	-	61	-
1986–87	0	-	6	-	0	-	68	-	68	-
1987–88	0	-	4	-	0	-	43	-	43	-
1988–89	0	-	5	-	0	-	21	-	21	-
1989–90	0	-	0	-	3	-	11	-	11	-
1990–91	0	-	10	-	0	-	21	-	21	-
1991–92	0	-	14	-	1	-	25	-	25	-
1992–93	0	-	2	-	5	-	31	-	31	-
1993–94	0	-	3	-	4	-	20	-	20	-
1994–95	0	-	8	-	2	-	18	-	18	-
1995–96	0	-	4	-	0	-	10	-	10	-
1996–97	0	-	5	-	2	-	11	-	58	-
1997–98	0	-	0	-	0	-	2	-	12	-
1998–99	0	0	2	4	< 1	2	9	33	34	56
1999–00	0	0	1	4	< 1	2	26	33	44	56
2000–01	0	0	< 1	4	< 1	2	12	33	28	56
2001–02	0	0	3	5	0	3	15	30	24	68
2002–03	0	0	< 1	5	< 1	3	19	30	34	68
2003–04	0	0	1	5	0	3	11	30	22	68
2004–05	0	0	0	5	< 1	3	7	30	13	68
2005–06	0	0	0	5	4	3	4	30	14	68
2006–07	0	0	< 1	5	3	3	9	30	23	68
2007–08	0	0	< 1	5	2	3	9	30	17	68
2008–09	0	0	2	5	2	3	10	30	20	68
2009–10	0	0	2	5	3	3	5	30	30	68
2010–11	0	0	2	5	2	3	17	30	38	68
2011–12	0	0	< 1	5	2	3	13	30	29	68
2012–13	0	0	< 1	5	2	3	5	30	25	68
2013–14	0	0	< 1	5	< 1	3	11	30	31	68

YELLOW-EYED MULLET (YEM)

Table 3 [continued]

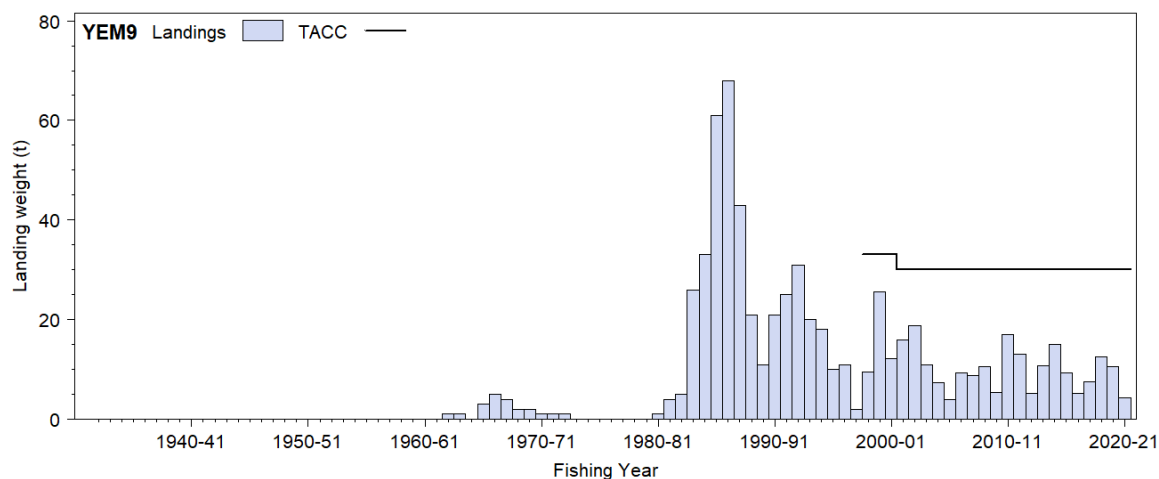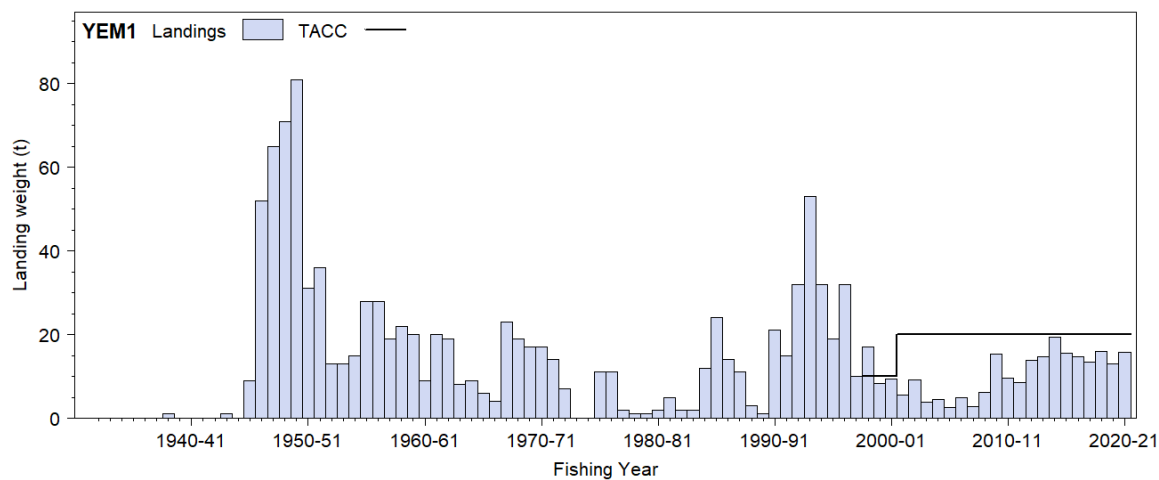| Fishstock	YEM 6		YEM 7		YEM 8		YEM 9		Total	
FMA	6		7		8		9			
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2014–15	0	0	< 1	5	1	3	15	30	45	68
2015–16	0	0	< 1	5	2	3	9	30	39	68
2016–17	0	0	< 1	5	< 1	3	5	30	24	68
2017–18	0	0	< 1	5	< 1	3	7	30	25	68
2018–19	0	0	< 1	5	0	3	13	30	33	68
2019–20	0	0	< 1	5	< 1	3	11	30	29	68
2020–21	0	0	< 1	5	< 1	3	4	30	29	69

Figure 1: Reported commercial landings and TACCs for the two main YEM stocks. YEM 1 (Auckland East) and YEM 9 (Auckland West).

1.2 Recreational fisheries

Yellow-eyed mullet are a popular recreational species throughout New Zealand, particularly in YEM 1. Numbers of fish and harvest tonnages for yellow-eyed mullet taken by recreational fishers estimated using telephone-diary surveys are presented in Table 4. The harvest estimates provided by these telephone-diary surveys are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In addition, some confusion probably arises between grey and yellow-eyed mullet during surveys, and the incorrect use of names like herring and sprat adds further uncertainty.

In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year (Wynne-Jones et al 2014). The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand

1882

households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 5. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 4: Estimated number of yellow-eyed mullet and unassigned mullet (MUU) harvested by recreational fishers by Fishstock and survey. Surveys were carried out in different years in MAF Fisheries regions: South in 1991–92, Central in 1992–93, and North in 1993–94 (Bradford 1996) and National in 1996 (Bradford 1998) and 1999–00 (Boyd & Reilly 2005). Estimates of CV and harvest tonnages are not presented where sample sizes are considered too small. The mean weight (100 g) used to convert numbers to catch weight is from Manikiam (1963) and considered the best available estimate. Survey tonnages are presented as a range to reflect the uncertainty in the estimate. It is assumed that some proportion of unassigned mullet are yellow-eyed mullet.

Fishstock	Survey	Total Number	CV (%)	Estimated Harvest Range (t)	Point Estimate (t)
1991–92					
QMA 1	South	1 000			
QMA 3	South	29 000	34	1–5	
QMA 7	South	3 000			
QMA 9	South	2 000			
1992–93					
QMA 1	Central	14 000			
QMA 2	Central	57 000			
1993–94					
QMA 1	North	289 000	15	25–33	
QMA 2	North	7 000			
QMA 8	North	1 000			
QMA 9	North	52 000	33	2–8	
1996					
Yellow-eyed mullet					
QMA 1	National	91 000	14	5–15	9
QMA 2	National	80 000	-	-	-
QMA 3	National	38 000	-	-	-
QMA 5	National	2 000	-	-	-
QMA 7	National	66 000	19	5–10	7
QMA 8	National	74 000	21	5–10	7
QMA 9	National	31 000	-	-	-
Unassigned mullet					
QMA 1	National	43 000	23	3–5	4
QMA 2	National	1 000	-	-	-
QMA 3	National	6 000	-	-	-
QMA 7	National	16 000	-	-	-
QMA 8	National	5 000	-	-	-
QMA 9	National	1 000	-	-	-
1999–00					
YEM 1	National	342 000	28	12–21	-
YEM 2	National	432 000	72	6–36	-
YEM 3	National	168 000	29	6–11	-
YEM 5	National	7 000	88	0–1	-
YEM 7	National	86 000	37	3–6	-
YEM 8	National	89 000	33	3–6	-
YEM 9	National	127 000	53	3–10	-

1.3   Customary non-commercial fisheries
No quantitative information is available on the current level of customary non-commercial take.

1.4   Illegal catch
No quantitative information is available on the level of illegal catch.

1.5   Other sources of mortality
No quantitative estimates are available about the impact of other sources of mortality on yellow-eyed mullet stocks. Yellow-eyed mullet principally occur in sheltered harbour and estuarine ecosystems. Some of these habitats are known to have suffered environmental degradation.

Table 5: **Recreational harvest estimates for yellow-eyed mullet stocks from national panel surveys (Wynne-Jones et al 2014, 2019). Mean fish weights were obtained from boat ramp surveys (Hartill & Davey 2015 and Davey et al 2019).**

Stock	Year	Method	Number of fish	Total weight (t)	CV
YEM 1	2011–12	Panel survey	57 504	11.5	0.26
	2017–18	Panel survey	39 584	11.5	0.30
YEM 2	2011–12	Panel survey	12 053	2.4	0.38
	2017–18	Panel survey	10 629	3.1	0.60
YEM 3	2011–12	Panel survey	8 326	1.7	0.36
	2017–18	Panel survey	12 576	3.7	0.58
YEM 5	2011–12	Panel survey	0	0	-
	2017–18	Panel survey	251	0.1	1.00
YEM 7	2011–12	Panel survey	15 792	3.2	0.33
	2017–18	Panel survey	10 804	3.2	0.33
YEM 8	2011–12	Panel survey	11 762	2.4	0.36
	2017–18	Panel survey	19 818	5.8	0.34
YEM 9	2011–12	Panel survey	20 535	4.1	0.34
	2017–18	Panel survey	14 830	4.3	0.49

2. BIOLOGY

The yellow-eyed mullet, *Aldrichetta forsteri* (Cuvier & Valenciennes 1836), is a member of the Mugilidae family (mullets). It is found in New Zealand, Norfolk Island and Australia. Its range extends from North Cape to Stewart Island in New Zealand and from the Murchison River in Western Australia, across South Australia and around Tasmania, to the Hawkesbury River in New South Wales. It is typically a schooling species that occurs commonly along coasts, in estuaries and in lower river systems, with juveniles sometimes observed in freshwater where they have been observed feeding on algae. In New Zealand, the species is widely but erroneously known as herring.

Yellow-eyed mullet are omnivorous and feed on a wide range of food types including algae, crustaceans, diatoms, molluscs, insect larvae, fish, polychaetes, coelenterates, fish eggs and detritus.

Egg development begins in July and maturity occurs by late December. Generally, spawning is during summer from late December to mid-March although there is some evidence in females from Canterbury to suggest biennial spawning, with peaks in winter and summer. Yellow-eyed mullet appear to leave their estuarine habitat to spawn in coastal waters, with eggs and larvae being found in surface waters up to 33 km offshore. There is no information available on the age of recruitment into estuarine systems of New Zealand waters.

Within estuaries and river systems, yellow-eyed mullet are separated to some extent by age, with older fish preferring more saline water and juveniles sometimes found in freshwater. The larger fish also prefer deeper water than juveniles.

M was estimated from the equation $M = \log_e 100/\text{maximum age}$, where maximum age is the age to which 1% of the population survives in an unexploited stock. Using 7 years for the maximum age results in an estimate of $M = 0.66$. The maximum age used here is for a yellow-eyed mullet taken in Wellington Harbour in 1963.

Biological parameters relevant to stock assessment are shown in Table 6.

Table 6: Estimates of biological parameters of yellow-eyed mullet.

Fishstock		Estimate	Source
1. Natural mortality (*M*)			
		Both Sexes	NIWA (unpub. Data)
Wellington Harbour		0.66	
2. Weight = a(length)[b] (Weight in g, length in cm fork length).			
		Both Sexes	
	a	b	
Lake Ellesmere	0.0068	3.2	Gorman (1962)

3.   STOCKS AND AREAS

No information is available to determine the stock structure of yellow-eyed mullet in New Zealand waters. Because catches are generally taken locally within harbours and estuarine systems that are relatively easy to identify, boundaries for Fishstocks take this natural division into account.

4.   STOCK ASSESSMENT

4.1   Estimates of fishery parameters and abundance
No estimates of fishery parameters or stock abundance are available for yellow-eyed mullet.

4.2   Biomass estimates
Biomass estimates are not available for any stocks.

4.3   Yield estimates and projections
Estimates of *MCY* are not available.

No estimates of current biomass, fishing mortality, or other information are available which would permit the estimation of *CAY*.

4.4   Other factors
Because of the highly localised nature of the fishery and the relatively high landings taken recently, particularly in the Manukau Harbour, yellow-eyed mullet may be susceptible to localised depletion.

Concern has been expressed by the Working Group about the effects of the small-meshed nets used to fish yellow-eyed mullet on other species within estuarine systems. For example, species such as grey mullet may suffer increased pressure as a consequence of increased target fishing for yellow-eyed mullet.

5.   STATUS OF THE STOCKS

Estimates of current and reference biomass are not available. It is not known if recent catch levels are sustainable.

6.   FOR FURTHER INFORMATION

Boyd, R O; Reilly, J L (2005) 1999–2000 national marine recreational fishing survey: harvest estimates. Draft New Zealand Fisheries Assessment Report. (Unpublished report held by Fisheries New Zealand, Wellington.)

Bradford, E (1996) Marine recreational fishing survey in the Ministry of Fisheries North Region, 1993–94. *New Zealand Fisheries Data Report* No: 80.

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished report held by NIWA library, Wellington.)

Cuvier, G; Valenciennes, A (1836) Histoire naturelle des poissons. Tome 11. Chez F.G. Levrault, Paris. 506 p.

Davey, N; Hartill, B; Carter, M (2019) Mean weight estimates for recreational fisheries in 2017–18. *New Zealand Fisheries Assessment Report. 2019/25.* 36 p.

YELLOW-EYED MULLET (YEM)

Gorman, T B S (1962) Yellow-eyed mullet *Aldrichetta forsteri* Cuvier and Valenciennes in Lake Ellesmere. *New Zealand Fisheries Technical Report* No. 7. 20 p.

Hartill, B; Davey, N (2015) Mean weight estimates for recreational fisheries in 2011–12. *New Zealand Fisheries Assessment Report 2015/25*.

Manikiam, J S (1963) Studies on the yellow-eye mullet. Unpublished thesis submitted to the Victoria University of Wellington for the degree of Master of Science.

Taylor, P R ; Paul, L J (1998) A summary of biology, commercial landings, and stock assessment of yellow-eyed mullet, *Aldrichetta forsteri* (Cuvier and Valenciennes, 1836) *(Mugiloidei: Mugilidae)*. New Zealand Fisheries Assessment Research Document 1998/17. 34 p. (Unpublished report held by NIWA library, Wellington.)

Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished report held by NIWA library, Wellington.)

Webb, B F (1973b) Fish populations of the Avon-Heathcote estuary. 2. Breeding and gonad maturity. *New Zealand Journal of Marine and Freshwater Research* 7(1): 45–66.

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report. 2019/24*. 108 p.

Wynne-Jones,J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*.

Fisheries Assessment Plenary

May 2022

Stock Assessments and Stock Status
Volume 3: Red Gurnard to Yellow-eyed Mullet