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November 2014 – 30th Anniversary

Stock Assessments and Stock Status
Volume 2: Rock Lobster to Yellowfin Tuna

Compiled by the Fisheries Science Group

Ministry for Primary Industries
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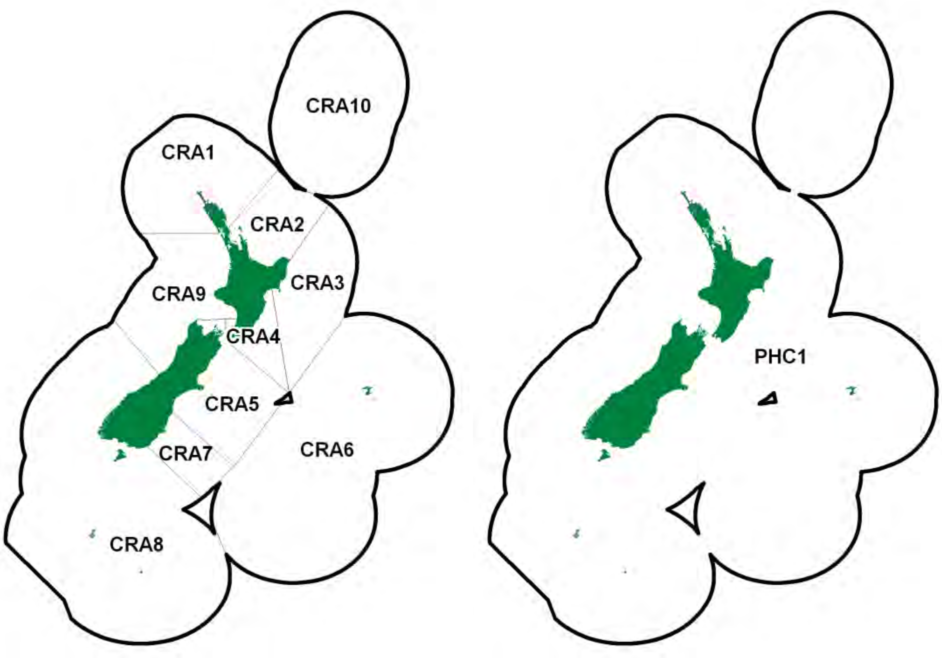
ROCK LOBSTER (CRA and PHC)

(*Jasus edwardsii*, *Sagmariasus verreauxi*)
Koura papatea, Pawharu



1. FISHERY SUMMARY

Two species of rock lobsters are taken in New Zealand coastal waters. The red rock lobster (*Jasus edwardsii*) supports nearly all the landings and is caught all around the North and South Islands, Stewart Island and the Chatham Islands. The packhorse rock lobster (*Sagmariasus verreauxi*) is taken mainly in the north of the North Island. Packhorse lobsters (PHC) grow to a much larger size than do red rock lobsters (CRA) and have different shell colouration and shape.

The rock lobster fisheries were brought into the Quota Management System (QMS) on 1 April 1990, when Total Allowable Commercial Catches (TACCs) were set for each Quota Management Area (QMA) shown above. Before this, rock lobster fishing was managed by input controls, including minimum legal size (MLS) regulations, a prohibition on the taking of berried females and soft-shelled lobsters, and some local area closures. Most of these input controls have been retained, but the limited entry provisions were removed and allocation of individual transferable quota (ITQ) was made to the previous licence holders based on catch history.

Historically, three rock lobster stocks were recognised for stock assessment purposes:
- NSI – the North and South Island (including Stewart Island) red rock lobster stock
- CHI – the Chatham Islands red rock lobster stock
- PHC – the New Zealand packhorse rock lobster stock

In 1994, the Rock Lobster Fishery Assessment Working Group (RLFAWG) agreed to divide the historical NSI stock into three substocks based on groupings of the existing QMAs (without assigning CRA 9):
- NSN – the northern stocks CRA 1 and 2
- NSC – the central stocks CRA 3, 4 and 5
- NSS – the southern stocks CRA 7 and 8

Since 2001, these historical stock definitions have not been used and assessments have been carried out at the Fishstock level, i.e. for CRA 1, CRA 2 etc. The fishing year runs from 1 April to 31 March.

The management of seven of the nine rock lobster QMAs involves the operation of “management procedures” (MPs), which include a “decision rule” to convert observed abundance (standardised CPUE) into a TACC for the following year. These rules have been evaluated through computer simulation and found to meet the requirements of the Fisheries Act. The seven QMAs which use this methodology are CRA 2, CRA 3, CRA 4, CRA 5, CRA 7, CRA 8 and CRA 9 (see Section 4 for a detailed discussion of each rule). MPs are currently (in 2014) being evaluated for CRA 1 and CRA 3, leaving CRA 6 as the only rock lobster QMA without a formal management procedure. CRA 6 has also never used a formal stock assessment to set catch limits. The TACC for CRA 10 is nominal because it is not fished commercially. The TACC for PHC 1 increased from 30 t in 1990 to its current value of 40.3 t at the beginning of the 1992–93 fishing year following quota appeals.

Summary of management actions by QMA since 1990 for rock lobster:

QMA	Type of management	Frequency of review	Year MP implemented	Year of TACC changes since 1990
CRA 1 (Northland)	Formal stock assessment[1]	Unspecified[1]	Not applicable[1]	1991, 1992, 1993
CRA 2 (Bay of Plenty)	Management procedure (MP)	5 years	2014	1991, 1992, 1997, 2014
CRA 3 (Gisborne)	Management procedure (MP)	5 years	2009[1]	1991, 1992, 1993, 1996, 1997, 1998, 2005, 2009, 2012, 2013, 2014
CRA 4 (Wairarapa)	Management procedure (MP)	5 years	2007[2]	1991, 1992, 1999, 2009, 2010, 2011 , 2013, 2014
CRA 5 (Marlborough/Kaikoura)	Management procedure (MP)	5 years	2008[3]	1991, 1992, 1993, 1999
CRA 6 (Chatham Islands	Not assessed	Unspecified	Not applicable	1991, 1993, 1997, 1998
CRA 7 (Otago)	Management procedure (MP)	5 years	1996	1991, 1992, 1993, 1999, 2001, 2004, 2006, 2008, 2009, 2010, 2011, 2012, 2013, 2014
CRA 8 (Stewart Island/Fiordland)	Management procedure (MP)	5 years	1996	1991, 1992, 1993, 1999, 2001, 2004, 2006, 2008, 2009, 2011
CRA 9 (Westland, Taranaki)	Management procedure (MP)	5 years	2014	1991, 1992, 2014
CRA 10 (Kermadec Island)	Not assessed	Unspecified	Not applicable	–
PHC 1 (all NZ)	Not assessed	Unspecified	Not applicable	1991, 1992

[1] CRA 1 and CRA 3 are being assessed and management procedures are being prepared for implementation in April 2015
[2] voluntary TACC reductions based on an MP were made by the CRA 4 Industry in 2007 and 2008. The MP was implemented by MPI in 2009
[3] the CRA 5 MP was implemented by MPI in 2012 but industry had operated a voluntary rule since 2008

TACs (Total Allowable Catch, which includes commercial and all non-commercial catches) were set for the first time in 1997–98 for three CRA QMAs (Table 1). Setting TACs is a requirement under the Fisheries Act 1996 and consequently TACs have been set since 1997–98 whenever adjustments have been made to the TACCs. Figure 1 shows historical commercial landings and TACC values for all CRA stocks.

The MLS in the commercial fishery for red rock lobster is based on tail width (TW), except in the Otago fishery. For Otago (CRA 7), the MLS for commercial fishing is a tail length (TL) of 127 mm, which applies to both sexes. The female MLS in all other rock lobster QMAs except Southern (CRA 8) has been 60 mm TW since mid-1992. For Southern (CRA 8), the female MLS has been 57 mm TW since 1990. The male MLS has been 54 mm TW since 1988, except in Otago (MLS described above) and Gisborne (CRA 3), where it is 52 mm TW for the June-August period.

A closed season applies in CRA 6 from 01 March to 30 April in each year.

Special conditions have applied to the Gisborne (CRA 3) fishery from April 1993. During June, July and August, commercial fishers are permitted to retain males at least 52 mm TW. These measures changed the commercial CRA 3 fishery to a mainly winter fishery for male lobsters from 1993 to 2002. The fishery was closed to all users from September to the end of November from 1993. This changed in 2000, when the beginning date for the closure was changed to 1 October. Since 2008–09 commercial fishers have closed, by voluntary agreement, Statistical Areas 909 and 910 from the beginning of September to mid-January and Statistical Area 911 from mid-December to mid-January. Fishers in Statistical Area 911 have voluntarily landed only males above 54 mm TW in June to August since 2009.

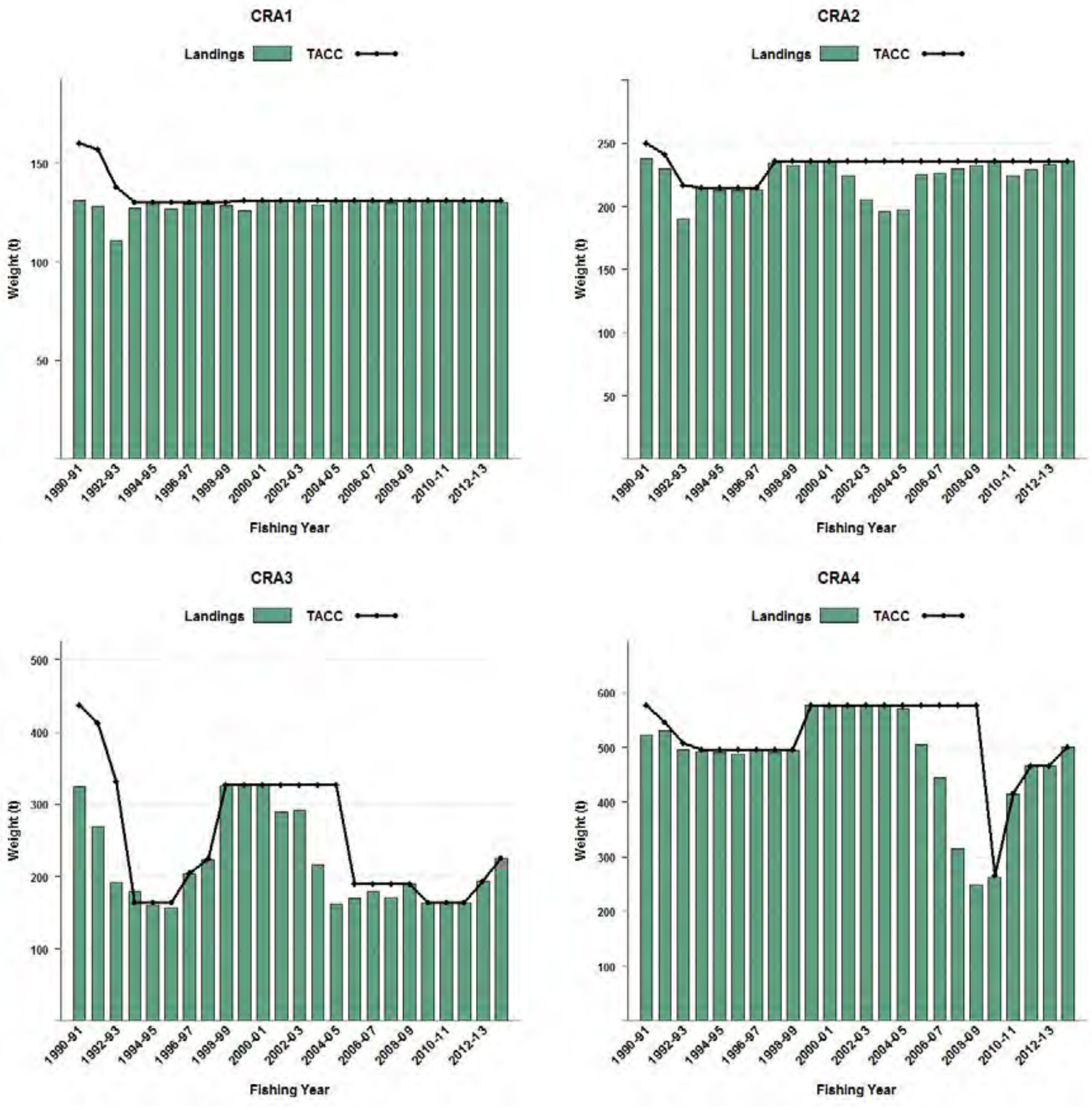


Figure 1: Historical commercial landings and TACC for the 9 main CRA stocks and PHC 1. [Continued on next page]

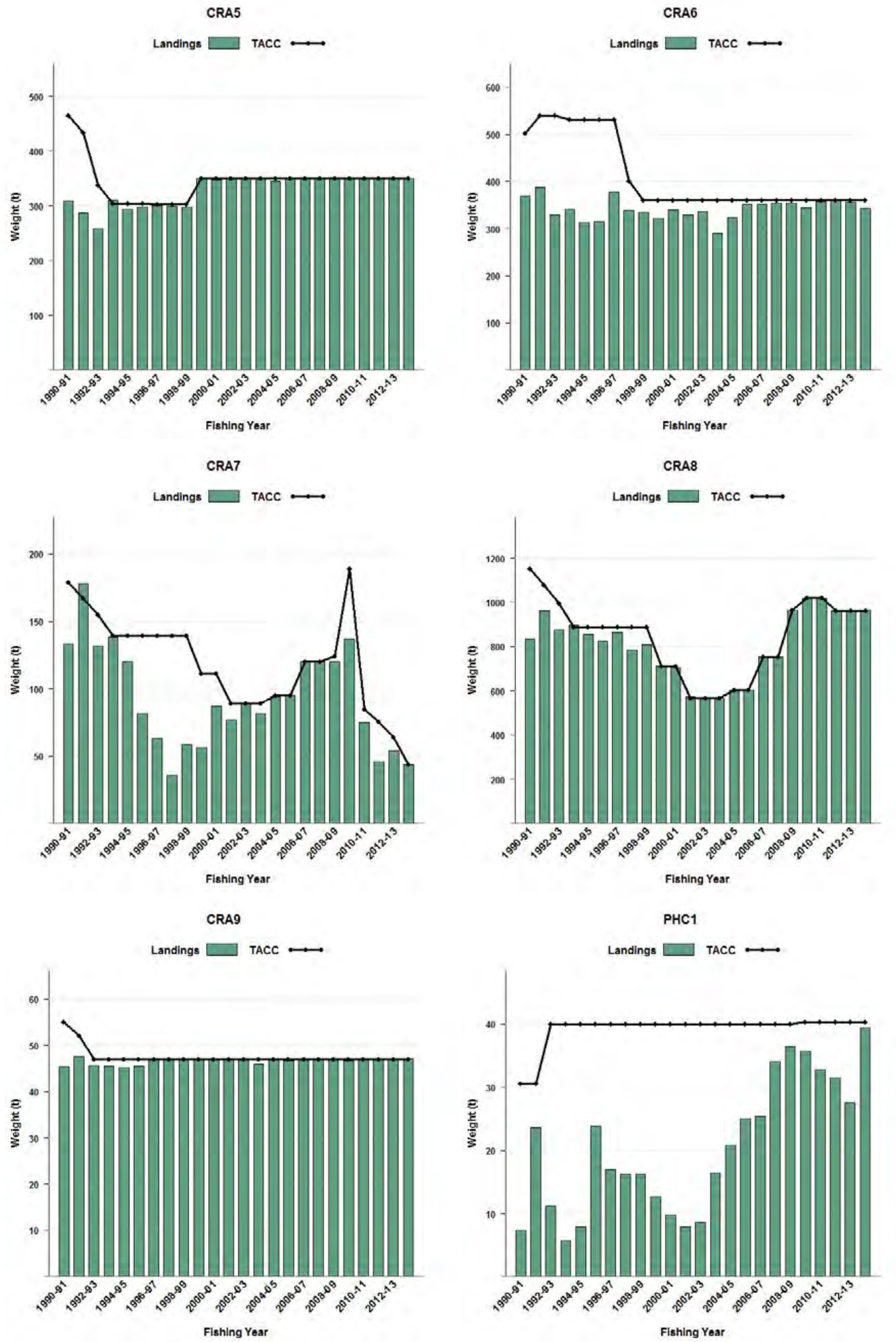


Figure 1 [cont]: Historical landings and TACC for the 9 main CRA stocks and PHC 1.

For recreational fishers, the red rock lobster MLS has been 54 mm TW for males since 1990 and 60 mm TW for females since 1992 in all areas of NZ. The commercial and recreational MLS for packhorse rock lobster is 216 mm TL for both sexes.

1.1 Commercial fisheries

Table 1 provides a summary by fishing year of the reported commercial catches, TACCs and TACs by Fishstock (CRA). The Quota Management Reports (QMRs) and their replacement Monthly Harvest Reports (MHRs; since 1 October 2001) provide the most accurate information on landings. Other sources of annual catch estimates include the Licensed Fish Receiver Returns (LFRRs) and the Catch, Effort, and Landing Returns (CELRs).

Table 1: Reported commercial catch (t) from QMRs or MHRs (after 1 October 2001), commercial TACC (t) and total TAC (t) (where this quantity has been set) for *Jasus edwardsii* by rock lobster QMA for each fishing year since the species was included in the QMS on 1 April 1990. '–': TAC not set for QMA or catch not available (current fishing year).

	CRA 1			CRA 2			CRA 3			CRA 4		
Fishing Year	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC
1990–91	131.1	160.1	–	237.6	249.5	–	324.1	437.1	–	523.2	576.3	–
1991–92	128.3	157.0	–	229.7	241.3	–	268.8	411.9	–	530.5	545.7	–
1992–93	110.5	138.0	–	190.3	216.6	–	191.5	330.9	–	495.7	506.7	–
1993–94	127.4	130.5	–	214.9	214.6	–	179.5	163.9	–	492.0	495.7	–
1994–95	130.0	130.5	–	212.8	214.6	–	160.7	163.9	–	490.4	495.7	–
1995–96	126.7	130.5	–	212.5	214.6	–	156.9	163.9	–	487.2	495.7	–
1996–97	129.4	130.5	–	213.2	214.6	–	203.5	204.9	–	493.6	495.7	–
1997–98	129.3	130.5	–	234.4	236.1	452.6	223.4	224.9	379.4	490.4	495.7	–
1998–99	128.7	130.5	–	232.3	236.1	452.6	325.7	327.0	453.0	493.3	495.7	–
1999–00	125.7	131.1	–	235.1	236.1	452.6	326.1	327.0	453.0	576.5	577.0	771.0
2000–01	130.9	131.1	–	235.4	236.1	452.6	328.1	327.0	453.0	573.8	577.0	771.0
2001–02	130.6	131.1	–	225.0	236.1	452.6	289.9	327.0	453.0	574.1	577.0	771.0
2002–03	130.8	131.1	–	205.7	236.1	452.6	291.3	327.0	453.0	575.7	577.0	771.0
2003–04	128.7	131.1	–	196.0	236.1	452.6	215.9	327.0	453.0	575.7	577.0	771.0
2004–05	130.8	131.1	–	197.3	236.1	452.6	162.0	327.0	453.0	569.9	577.0	771.0
2005–06	130.5	131.1	–	225.2	236.1	452.6	170.1	190.0	319.0	504.1	577.0	771.0
2006–07	130.8	131.1	–	226.5	236.1	452.6	178.7	190.0	319.0	444.6	577.0	771.0
2007–08	129.8	131.1	–	229.7	236.1	452.6	172.4	190.0	319.0	315.2	577.0[1]	771.0
2008–09	131.0	131.1	–	232.3	236.1	452.6	189.8	190.0	319.0	249.4	577.0[1]	771.0
2009–10	130.9	131.1	–	235.2	236.1	452.6	164.0	164.0	293.0	262.2	266.0	461.0
2010–11	130.8	131.1	–	224.8	236.1	452.6	163.7	164.0	293.0	414.8	415.6	610.6
2011–12	130.4	131.1	–	229.0	236.1	452.6	163.9	164.0	293.0	466.2	466.9	661.9
2012–13	130.9	131.1	–	234.3	236.1	452.6	193.3	193.3	322.3	466.3	466.9	661.9
2013–14	130.2	131.1	–	235.7	236.1	452.6	224.2	225.5	354.5	499.4	499.7	694.7
2014–15	–	131.1	–	–	200.0	416.5	–	261.0	390.0	–	467.0	662.0

	CRA 5			CRA 6			CRA 7			CRA 8		
Fishing Year	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC
1990–91	308.6	465.2	–	369.7	503.0	–	133.4	179.4	–	834.5	1152.4	–
1991–92	287.4	433.7	–	388.3	539.6	–	177.7	166.8	–	962.7	1077.0	–
1992–93	258.8	337.7	–	329.4	539.6	–	131.6	154.5	–	876.5	993.7	–
1993–94	311.0	303.7	–	341.8	530.6	–	138.1	138.9	–	896.1	888.1	–
1994–95	293.9	303.7	–	312.5	530.6	–	120.3	138.9	–	855.6	888.1	–
1995–96	297.6	303.7	–	315.3	530.6	–	81.3	138.9	–	825.6	888.1	–
1996–97	300.3	303.2	–	378.3	530.6	–	62.9	138.7	–	862.4	888.1	–
1997–98	299.6	303.2	–	338.7	400.0	480.0	36.0	138.7	–	785.6	888.1	–
1998–99	298.2	303.2	–	334.2	360.0	370.0	58.6	138.7	–	808.1	888.1	–
1999–00	349.5	350.0	467.0	322.4	360.0	370.0	56.5	111.0	131.0	709.8	711.0	798.0
2000–01	347.4	350.0	467.0	342.7	360.0	370.0	87.2	111.0	131.0	703.4	711.0	798.0
2001–02	349.1	350.0	467.0	328.7	360.0	370.0	76.9	89.0	109.0	572.1	568.0	655.0
2002–03	348.7	350.0	467.0	336.3	360.0	370.0	88.6	89.0	109.0	567.1	568.0	655.0
2003–04	349.9	350.0	467.0	290.4	360.0	370.0	81.4	89.0	109.0	567.6	568.0	655.0
2004–05	345.1	350.0	467.0	323.0	360.0	370.0	94.2	94.9	114.9	603.0	603.4	690.4
2005–06	349.5	350.0	467.0	351.7	360.0	370.0	95.0	94.9	114.9	603.2	603.4	690.4
2006–07	349.8	350.0	467.0	352.1	360.0	370.0	120.2	120.2	140.2	754.9	755.2	842.2
2007–08	349.8	350.0	467.0	356.0	360.0	370.0	120.1	120.2	140.2	752.4	755.2	842.2
2008–09	349.7	350.0	467.0	355.3	360.0	370.0	120.3	123.9	143.9	966.0	966.0	1053.0
2009–10	349.9	350.0	467.0	345.2	360.0	370.0	136.5	189.0	209.0	1018.3	1019.0	1110.0
2010–11	350.0	350.0	467.0	357.4	360.0	370.0	74.8	84.5	104.5	1018.3	1019.0	1110.0
2011–12	350.0	350.0	467.0	359.7	360.0	370.0	45.7	75.7	95.7	961.2	962.0	1053.0
2012–13	350.0	350.0	467.0	355.9	360.0	370.0	53.8	63.9	83.9	960.8	962.0	1053.0
2013–14	350.0	350.0	467.0	343.6	360.0	370.0	44.0	44.0	64.0	963.7	962.0	1053.0
2014–15	–	350.0	467.0	–	360.0	370.0	–	66.0	86.0	–	962.0	1053.0

Table 1 (continued):

	CRA 9			Total		
Fishing Year	Catch	TACC	TAC	Catch[1]	TACC[1]	TAC[1]
1990–91	45.3	54.7	–	2907.4	3777.8	–
1991–92	47.5	51.5	–	3020.9	3624.5	–
1992–93	45.7	47.1	–	2629.9	3264.9	–
1993–94	45.5	47.0	–	2746.2	2913.0	–
1994–95	45.2	47.0	–	2621.5	2913.0	–
1995–96	45.4	47.0	–	2548.6	2913.0	–
1996–97	46.9	47.0	–	2690.5	2953.3	–
1997–98	46.7	47.0	–	2584.2	2864.1	1312.0
1998–99	46.9	47.0	–	2726.0	2926.2	1275.6
1999–00	47.0	47.0	–	2748.5	2850.2	3442.6
2000–01	47.0	47.0	–	2795.9	2850.2	3442.6
2001–02	46.8	47.0	–	2593.0	2685.2	3277.6
2002–03	47.0	47.0	–	2591.1	2685.2	3277.6
2003–04	45.9	47.0	–	2451.5	2685.2	3277.6
2004–05	47.0	47.0	–	2472.3	2726.4	3318.8
2005–06	46.6	47.0	–	2475.8	2589.4	3184.8
2006–07	47.0	47.0	–	2604.6	2766.6	3362.0
2007–08	47.0	47.0	–	2472.5	2766.6	3362.0
2008–09	47.0	47.0	–	2640.7	2981.0	3576.5
2009–10	46.6	47.0	–	2688.8	2762.2	3362.6
2010–11	47.0	47.0	–	2781.7	2807.3	3407.7
2011–12	47.0	47.0	–	2753.0	2792.8	3393.2
2012–13	47.0	47.0	–	2792.2	2810.3	3410.7
2013–14	47.1	47.0	–	2837.9	2855.4	3455.8
2014–15	–	60.8	115.8	–	2857.8	3560.3

[1]ACE was shelved voluntarily by the CRA 4 Industry: to 340 t in 2007–08 and 250 t in 2008–09

Table 2: Reported standardised CPUE (kg/potlift) for *Jasus edwardsii* by QMA from 1979–80 to 2013–14. Sources of data: from 1979–80 to 1988–89 from the QMS-held FSU data; from 1989–90 to 2013–14 from the CELR data held by the Ministry for Primary Industries, using the "F2" algorithm corrected for "LFX" destination code landings (see text for definition), except for CRA 5, which uses the "B4" algorithm. See Booth et al. (1994) for a discussion of problems with the QMS-held FSU data; see Starr (2014) for a discussion of the standardisation methodology, including the procedure for preparing the data for analysis. '–': no data.

Fishing year	CRA 1	CRA 2	CRA 3	CRA 4	CRA 5	CRA 6	CRA 7	CRA 8	CRA 9
1979–80	0.820	0.517	0.783	0.827	0.612	2.189	0.969	1.965	1.258
1980–81	0.984	0.621	0.868	0.802	0.745	2.019	0.853	1.708	1.368
1981–82	0.925	0.517	0.857	0.859	0.664	2.298	0.725	1.643	1.037
1982–83	1.000	0.431	0.926	0.925	0.731	1.661	0.468	1.407	0.866
1983–84	0.950	0.353	0.847	0.839	0.654	1.630	0.405	1.060	0.893
1984–85	0.882	0.342	0.686	0.761	0.662	1.301	0.542	1.026	0.852
1985–86	0.823	0.396	0.655	0.728	0.543	1.372	0.723	1.213	0.756
1986–87	0.805	0.358	0.569	0.772	0.479	1.505	0.826	1.078	0.877
1987–88	0.752	0.312	0.404	0.674	0.401	1.323	0.697	1.134	0.892
1988–89	0.660	0.339	0.416	0.568	0.350	1.269	0.409	0.850	0.887
1989–90	0.689	0.346	0.451	0.559	0.372	1.126	0.330	0.834	–
1990–91	0.599	0.473	0.429	0.515	0.362	1.178	0.425	0.810	0.830
1991–92	0.682	0.417	0.289	0.517	0.300	1.228	0.984	0.795	0.866
1992–93	0.600	0.389	0.244	0.497	0.295	1.124	0.396	0.674	0.938
1993–94	0.663	0.430	0.502	0.543	0.357	1.031	0.611	0.897	1.173
1994–95	0.848	0.517	0.982	0.693	0.373	1.006	0.459	0.798	0.943
1995–96	1.172	0.726	1.564	0.911	0.446	1.048	0.291	0.861	1.361
1996–97	0.996	0.930	1.960	1.225	0.602	1.083	0.247	0.806	1.147
1997–98	0.970	1.080	2.481	1.424	0.851	1.036	0.178	0.689	1.066
1998–99	1.063	1.092	2.092	1.624	1.093	1.277	0.258	0.704	1.416
1999–00	0.894	0.847	1.960	1.466	1.117	1.280	0.226	0.753	0.958
2000–01	1.151	0.751	1.362	1.374	1.315	1.218	0.346	0.915	1.197
2001–02	1.193	0.545	1.036	1.176	1.500	1.201	0.500	0.988	1.137
2002–03	1.120	0.427	0.685	1.209	1.571	1.309	0.606	1.151	1.486
2003–04	1.057	0.434	0.564	1.245	1.639	1.262	0.596	1.716	1.729
2004–05	1.336	0.510	0.452	0.948	1.441	1.443	0.888	1.883	2.134
2005–06	1.361	0.473	0.559	0.815	1.350	1.504	1.289	2.287	2.086
2006–07	1.706	0.553	0.565	0.675	1.436	1.755	1.784	2.781	2.154
2007–08	1.773	0.554	0.586	0.590	1.490	1.550	1.548	3.046	1.760
2008–09	1.722	0.511	0.672	0.744	1.578	1.687	1.715	4.085	1.312
2009–10	1.720	0.442	0.885	1.040	1.923	1.476	1.087	3.929	1.572
2010–11	1.519	0.395	1.209	1.036	1.896	1.552	0.806	3.214	2.293
2011–12	1.502	0.376	1.752	1.254	1.867	1.528	0.694	3.167	1.967
2012–13	1.692	0.408	2.432	1.409	1.912	1.534	0.685	3.301	2.914
2013–14	1.476	0.358	2.260	1.194	1.731	1.492	2.291	3.397	2.770

Problems with rock lobster commercial catch and effort data

There are two types of data on the Catch Effort Landing Return (CELR) form: the top part of each form contains the fishing effort and an estimated catch associated with that effort. The bottom part of the form contains the landed catch and other destination codes, which may span several records of effort. Estimated catches from the top part of the CELR form often show large differences from the catch totals on the bottom part of the form, particularly in some QMAs, such as CRA 5 and CRA 8 (Vignaux & Kendrick 1998; Bentley et al. 2005). Substantial discrepancies were identified in 1997 between the estimated and weighed catches in CRA 5 (Vignaux & Kendrick 1998) and were attributed to fishers including all rock lobster catch in the estimated total, including those returned to the sea by regulation. This led to an overestimate of CPUE, but this problem appeared to be confined to CRA 5, and was remedied by providing additional instruction to fishers on how to properly complete the forms.

After 1998, all CELR catch data used in stock assessments have been modified to reflect the landed catch (bottom of form) rather than the estimated catch (top of form). This resulted in changes to the CPUE values compared to those reported before 1998.

In 2003, it was concluded that the method used to correct estimated to landed catch ("Method C1", Bentley et al. 2005) was biased because it dropped trips with no reported landings, leading to estimates of CPUE that were too high. In some areas, this bias was getting worse because of an increasing trend of passing catches through holding pots to maximise the value of the catch. The catch/effort data system operated by MPI does not maintain the link between catch derived from the effort expended on a trip with the landings recorded from the trip. Therefore, catches from previous trips, held in holding pots, can be combined with landings from the active trip.

Beginning in 2003, the catch and effort data used in these analyses were calculated using a revised procedure described as "Method B4" in Bentley et al. (2005). This procedure sums all landings and effort for a vessel within a calendar month and allocates the landings to statistical areas based on the reported area distribution of the estimated catches. The method assumes that landings from holding pots tend to balance out at the level of a month. In the instances where there are vessel/month combinations with no landings, the method drops all data for the vessel in the month with zero landings and in the following month, with the intent of excluding uncertain data in preference to incorrectly reallocating landings.

In 2012, the rock lobster WG agreed to change from method "B4" to method "F2", a new procedure designed to correct estimated catch data to reflect landings. The new procedure is thought to better represent the estimation/landing process and should be more robust to data errors and other uncertainties. The "F2" method uses annual estimates, by vessel, of the ratio of landed catch divided by estimated catch to correct every landing record in a QMA for the vessel. Vessels are removed entirely from the analysis when the ratio is less than 0.8 (overestimates of landed catch) or greater than 1.2 (underestimates of landed catch). Testing of the "F2" method was undertaken to establish that CPUE series based on the new procedure did not differ substantially from previous series. In general, the differences tended to be minor for most QMAs, with the exception of CRA 1 and particularly CRA 9, where there were greater differences (Starr 2014). Additional work completed in June 2013 determined that the problems with the CRA 9 standardised CPUE analysis could be resolved if vessels that had landed less than 1 t in a year were excluded from the analysis (Breen 2014). Consequently, the standardised CPUE analyses reported in Table 2 use the F2 algorithm, scaled to the combined "L", "F" and "X" landings (see following paragraph). The only exception to this is CRA 5, which uses the "B4" algorithm because of the poor reporting practices used in the 1990s (Vignaux & Kendrick 1998).

The data used to calculate the standardised (Table 2) and arithmetic (Table 4) CPUE estimates have been subjected to error screening (Bentley et al. 2005) and the estimated catches have been scaled using the F2 algorithm (or B4 for CRA 5) to the combined landings made to Licensed Fish Receivers (destination code "L"), Section 111 landings for personal use (destination code "F") and legal discards (destination code “X”). The RLFAWG has accepted the use of these additional destination codes because of the increasing practice of returning legal lobsters to the sea as overall abundance has increased. The estimates of CPUE would be biased if discarded legal fish were not included in the analysis. The reporting of releases using destination code “X” became mandatory on 1 April 2009, so this correction was not available before that date.

Methods for calculating the standardised and arithmetic CPUE estimates are documented in Starr (2014).

Descriptions of Fisheries

***Jasus edwardsii*, CRA 1 and CRA 2**

CRA 1 extends from Kaipara Harbour on the west coast to Bream Bay, south of Whangarei (Figure 2). This QMA includes the Three Kings Islands, designated with a separate statistical area (901). Commercial fishing occurs on both sides of the North Island peninsula, as well as on the Three Kings.

A TAC has never been set for CRA 1 because the TACC has remained unchanged since the early 1990s (Table 2). Commercial landings have remained at or near the 131 t TACC since the early 1990s (Table 2). In the 2012–13 fishing year, there were 14 vessels operating in CRA 1, a total that has remained unchanged since the early 2000s (Starr 2014).

CPUE levels in CRA 1 and CRA 2 differ: CRA 1 has always had higher catch rates than CRA 2, even in the 1980s when catch rates were generally lower. CPUE in CRA 1 has been near to or above 1.5 kg/potlift since 2005–06, compared to 0.6 kg/potlift or less in CRA 2 since 2000–01 (Table 2). CRA 2 currently has the lowest CPUE of all nine CRA QMAs, and has been below 0.5 kg/potlift for 8 of the most recent 13 fishing years.

***Jasus edwardsii*, CRA 3, CRA 4 and CRA 5**

CRA 3 extends from East Cape to below the Mahia peninsula (Figure 2). Commercial fishing occurs throughout this QMA. TACs and TACCs have been set for this QMA six times since the mid-2000s. Twenty-three vessels caught at least one tonne of rock lobster. This is the lowest number of vessels in the series (Starr 2014)

CPUE trends have differed among these three QMAs, with CRA 3 CPUE peaking in 1997–98, CRA 4 in 1998–99, and CRA 5 in 2008–09 (Table 2). However, these QMAs all show approximately the same pattern: low CPUEs in the 1980s (below 1 kg/potlift) followed by a strong rise in CPUE beginning in the early 1990s (first in CRA 3, followed closely by CRA 4 and finally by CRA 5 in the late 1990s). CRA 3 and CRA 4 dropped from their respective peaks in the late 1990s to lows in the mid-2000s followed by a rising trend to 2012–13 in both QMAs. CPUE in both QMAs dropped in 2013–14 relative to their 2012–13 highs, but still remain at relatively high levels.

Both CRA 3 and CRA 4 are currently near the high CPUE levels observed in the late 1990, with both of these series approaching their respective peaks in 1997–98s. The 2013–14 CRA 3 CPUE is just below the 2012–13 level, the second highest in the series. CRA 4 has not yet reached such a high level, and CPUE in this QMA dropped 15% relative to 2012–13, to about 1.2 kg/potlift. CRA 5 has remained high throughout the 2000s, although the 2013–14 CPUE index dropped 9% relative to the 2012–13 index (Table 2).

***Jasus edwardsii*, CRA 6**

Mean annual CPUE in the Chatham Island fishery was higher than in the other New Zealand QMAs in the 1980s (Table 2). However, CPUE declined after the mid-1980s to levels similar to those observed in other QMAs (Table 2). CPUE has fluctuated around 1.5 kg/potlift since 2001–02, peaking at 1.75 kg/potlift in 2006–07, the highest value since the mid-1990s.

Jasus edwardsii, CRA 7 and CRA 8

Catch rates are generally low in CRA 7 compared with those in CRA 8, except for 2013–14, when CPUE rose by 230% to 2.3 kg/potlift. CPUE in CRA 7 was stable but low (often below 0.5 kg/potlift) until the early 2000s, while CRA 8 showed a similar pattern, but at a higher level (Table 2). Both QMAs then showed spectacular increases in CPUE, peaking in the late 2000s at around 1.8 kg/potlift in CRA 7 and rising to more than 4 kg/potlift in CRA 8. The CRA 8 annual CPUE of greater than 4.0 kg/potlift observed in 2008–09 is the highest of any of the rock lobster QMAs over the 35 years of record (Table 2). CPUE declined by 60% in CRA 7 from 2008–09 to 2011–12 while the decline in CRA 8 was 23% between 2008–09 and 2011–12. CPUE in both these QMAs rose between 2012–13 and 2013–14, although the rise in CRA 8 was minor (3%) compared to the nearly 2.5 times increase seen in CRA 7. The 2013–14 CPUE index for CRA 7 is the highest in the series, having more than doubling the 2012–13 index (Table 2).

Jasus edwardsii, CRA 9

Mean annual CPUE had been near to or less than 1.0 kg per potlift from 1981–82 to 1994–95, followed by a strong increase that peaked in 2006–07, with CPUE exceeding 2 kg/potlift between 2004–05 and 2006–07. CPUE dropped to a low of 1.3 kg/potlift in 2008–09 but rose to 2.9 kg/potlift in 2012–13 and then declined to 2.8 kg/potlift in 2013–14, the two highest levels in the series (Table 2).

Sagmariasus verreauxi, PHC stock

QMS reported landings of the PHC stock more than halved between 1998–99 and 2001–02 and were below 30 t/year up to 2007–08 (Table 3). Landings have since exceeded 30 t/year, except for 2012–13, when 27.5 t were reported. The 2013–14 annual landing total of nearly 39 t is the largest annual total since entering the QMS in 1990–91 and approaches the annual TACC.

Jasus edwardsii CPUE by statistical area

Table 4 shows arithmetic statistical area CPUEs for the most recent six years, for all rock lobster statistical areas reported on CELR forms (Figure 2). The values of CPUE and the trends in the fisheries vary within and between CRA areas.

Table 3: Reported landings and TACC for *Sagmariasus verreauxi* (PHC) from 1990–91 to 2010–11. Data from QMR or MHR (after 1 Oct 2001).

Fishing Year	Landings (t)	TACC (t)	Fishing Year	Landings (t)	TACC (t)
1990–91	7.4	30.5 [1]	2002–03	8.6	40.3
1991–92	23.6	30.5	2003–04	16.4	40.3
1992–93	11.1	40.3	2004–05	20.8	40.3
1993–94	5.7	40.3	2005–06	25.0	40.3
1994–95	7.9	40.3	2006–07	25.4	40.3
1995–96	23.8	40.3	2007–08	34.0	40.3
1996–97	16.9	40.3	2008–09	36.4	40.3
1997–98	16.2	40.3	2009–10	35.7	40.3
1998–99	16.2	40.3	2010–11	32.8	40.3
1999–00	12.6	40.3	2011–12	31.6	40.3
2000–01	9.8	40.3	2012–13	27.5	40.3
2001–02	3.4	40.3	2013–14	38.8	40.3

[1] entered QMS at 27 t in 1990–91, but raised immediately to 30.5 in first year of operation due to quota appeals

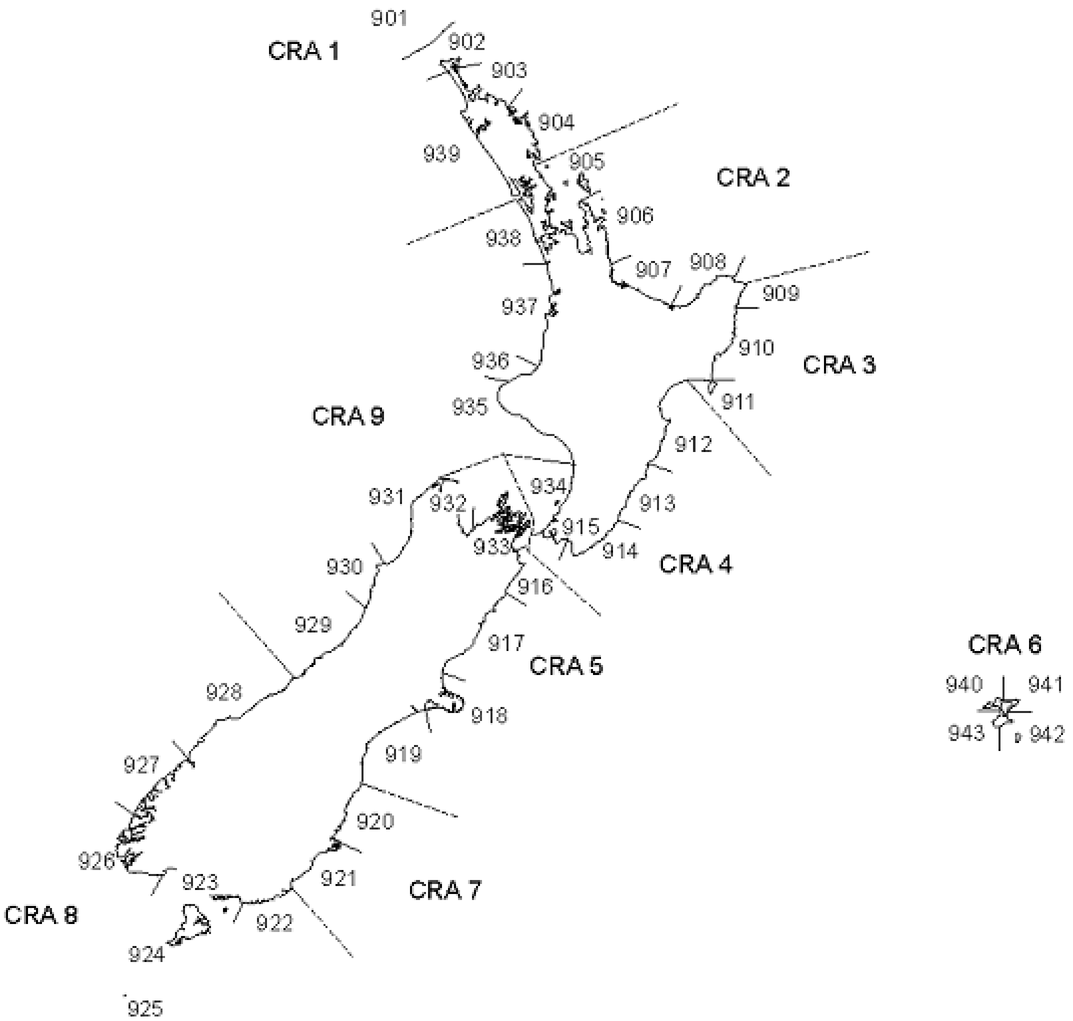


Figure 2: Rock lobster statistical areas as reported on CELR forms.

Table 4: Arithmetic CPUE (kg/potlift) for each statistical area for the six most recent fishing years. Data are from the MPI CELR database and estimated catches have been corrected by the amount of fish landed from the bottom part of the form using the "F2" algorithm scaled to the "LFX" destination code (see Section 1 in text for explanation). '–': value withheld because fewer than three vessels were fishing or there was no fishing.

CRA	Stat Area	08/09	09/10	10/11	11/12	12/13	13/14	CRA	Stat Area	08/09	09/10	10/11	11/12	12/13	13/14
1	901	3.88	3.64	2.95	2.77	2.58	2.03	6	940	1.42	1.13	1.37	1.32	1.69	1.53
1	902	2.16	2.36	1.84	1.39	1.45	1.85	6	941	1.35	1.18	1.33	1.32	1.56	1.52
1	903	0.99	1.07	0.86	0.76	1.38	1.15	6	942	1.64	1.67	1.37	1.61	1.49	1.42
1	904	–	–	–	0.46	0.54	0.49	6	943	1.53	1.25	1.49	1.48	1.82	1.75
1	939	1.23	2.15	1.43	1.89	2.98	2.57	7	920	2.37	0.98	0.67	0.69	0.64	1.85
2	905	0.60	0.51	0.40	0.37	0.43	0.39	7	921	2.57	1.84	1.11	0.62	0.65	1.51
2	906	0.45	0.39	0.38	0.35	0.37	0.31	8	922	–	–	–	–	–	–
2	907	0.83	0.70	0.61	0.57	0.51	0.51	8	923	3.77	–	–	–	–	2.39
2	908	0.49	0.45	0.42	0.47	0.44	0.39	8	924	4.08	4.26	3.61	4.05	3.90	3.36
3	909	1.10	1.13	1.29	1.52	–	2.41	8	925	–	–	–	–	2.69	–
3	910	0.75	0.94	1.18	1.43	1.82	1.65	8	926	3.33	2.77	2.77	3.33	3.20	3.91
3	911	0.57	0.73	1.02	1.69	2.34	2.14	8	927	3.86	3.95	2.33	2.47	3.68	3.60
4	912	0.69	0.73	0.76	0.87	0.88	0.66	8	928	6.23	5.45	4.40	4.57	5.01	4.61
4	913	0.81	1.10	1.23	1.58	1.93	1.47	9	929	–	–	–	–	–	–
4	914	0.55	1.08	1.08	1.32	1.59	1.53	9	930	–	–	–	–	–	–
4	915	0.84	1.30	0.94	1.31	1.37	1.54	9	931	–	–	2.86	–	–	–
4	934	–	–	–	2.04	–	–	9	935	3.37	1.45	2.68	3.23	6.77	–
5	916	2.33	2.23	2.32	2.15	1.37	1.50	9	936	–	–	–	–	–	–
5	917	1.47	2.25	2.38	2.75	2.64	2.12	9	937	–	–	–	–	–	–
5	918	1.82	–	–	–	–	–	9	938	–	–	–	–	–	–
5	919	–	–	–	–	–	–								
5	932	–	–	–	–	–	–								
5	933	0.76	0.74	0.76	0.72	0.73	0.62								

Table 5: All available estimates of recreational rock lobster harvest (in numbers and in tonnes by QMA, where available) from regional telephone and diary surveys in 1992, 1993, 1994, 1996, 2000 and 2001 (Bradford 1997, 1998; Teirney et al. 1997; Boyd & Reilly 2002). 2011–12 data from Large Scale Multi-species Survey (unpublished: data provided by the Marine Amateur Fisheries Fishery Assessment Working Group (Neville Smith, MPI, MAFWG Chair, pers. comm..); '–' : not available.

QMA/FMA	Number	c.v. (%)	Nominal point estimate (t)
Recreational Harvest South Region 1 Sept 1991 to 30 Nov 1992			
CRA5	65 000	31	40
CRA7	8 000	29	7
CRA8	29 000	28	21
Recreational Harvest Central Region 1992–93			
CRA1	1 000	–	–
CRA2	4 000	–	–
CRA3	8 000	–	–
CRA4	65 000	21	40
CRA5	11 000	32	10
CRA8	1 000	–	
Northern Region Survey 1993–94			
CRA1	56 000	29	38
CRA2	133 000	29	82
CRA9	6 000	–	–
1996 Survey			
CRA1	74 000	18	51
CRA2	223 000	10	138
CRA3	27 000	–	–
CRA4	118 000	14	73
CRA5	41 000	16	35
CRA7	3 000	–	–
CRA8	22 000	20	16
CRA9	26 000	–	–
2000 Survey			
CRA1	107 000	59	102.3
CRA2	324 000	26	235.9
CRA3	270 000	40	212.4
CRA4	371 000	24	310.9
CRA5	151 000	34	122.3
CRA7	1 000	63	1.3
CRA8	13 000	33	23.3
CRA9	65 000	64	52.8
2001 Roll Over Survey			
CRA1	161 000	68	153.5
CRA2	331 000	27	241.4
CRA3	215 000	48	168.7
CRA4	419 000	22	350.5
CRA5	226 000	22	182.4
CRA7	10 000	67	9.4
CRA8	29 000	43	50.9
CRA9	34 000	68	27.7
National panel survey: Oct 2011–Sep 2012			
CRA1	29 700	30	23.98
CRA2	58 500	24	40.86
CRA3	13 900	33	8.07
CRA4	53 800	17	44.17
CRA5	49 300	23	43.47
CRA7	400	103	0.23
CRA8	5 200	60	6.93
CRA9	15 500	30	17.96
Northland : 1 Apr 2013–31 Mar 2014			
CRA1	50 400	17	37.3

1.2 Recreational fisheries

There are two broad approaches to estimating recreational fisheries harvest: A) the use of "onsite" or access point methods where participants are surveyed at the point of fishing or of access to the fishing activity; B) "offsite" methods where post-event interviews and/or diaries are used to collect data from participants.

Historically, the method used to obtain recreational harvest estimates was a regional telephone and diary survey approach (an "offsite" method B). Table 5 provides the survey years, rock lobster survey estimates and the appropriate citations. These surveys provide estimates in numbers of fish captured and use mean rock lobster weight obtained from fish measured at boat ramps to convert the estimates to captures by weight.

The harvest estimates provided by these historical telephone diary surveys are no longer considered reliable by the MAFWG. Participants in the early surveys were recruited to fill in diaries by way of a telephone survey that also estimated the proportion of the population that was likely to fish recreationally. Subsequently, it was realised that a "soft refusal" bias would occur in the eligibility proportion if interviewees who do not wish to co-operate falsely stated that they did not fish. This bias resulted in an underestimate of the population of recreational fishers and consequently an underestimate of the harvest. 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 source of bias in these telephone/diary surveys was that diarists tended to overstate their catch, the number of trips made, and did not report non-productive trips.

Table 6: Historical recreational and customary catch estimates used in recent CRA assessments. All ramped catches started from 20% of the 1979 estimate of recreational catch. The rationales for setting these catches are presented in Table 7.

QMA	First year	Last year	"Base" Recreational catch (t)	Notes: Recreational Catch	Customary catch (t)	Notes: Customary catch
CRA 1 [6]	1945	2013	1994=40.152 1996=53.058 2011=24.089 2013=40.747	Ramped from 1945; after 1979, the mean unstandardised Area 903/904 SS CPUE in each year was scaled by the mean of the ratios of the "base recreational catches" relative to the unstandardised SS CPUE	10	Constant from 1945
CRA 2 [1]	1945	2012	1994=95.424 1996=149.856 2011=42.161	Ramped from 1945; after 1979, the CRA 2 SS CPUE in each year was scaled by the mean of the ratios of the "base recreational catches" relative to the standardised SS CPUE	10	Constant from 1945
CRA 3 [6]	1945	2013	1992=4.272 1996=14.418 2011=8.069	Ramped from 1945; after 1979, the CRA 3 SS CPUE in each year was scaled by the mean of the ratios of the "base recreational catches" relative to the standardised SS CPUE	20	Constant from 1945
CRA 4 [3]	1945	2010	46.709 (=mean of 1994/1996 estimates)	Ramped from 1945; after 1979, the CRA 4 SS CPUE in each year was scaled by the ratio of the mean "base recreational catches" relative to the mean of the standardised SS CPUE in 1994/1996	20	Constant from 1945
CRA 5 [4]	1945	2009	30.424 (=mean of 1994/1996 estimates)	Ramped from 1945; after 1979, the Area 917 unstandardised SS CPUE in each year was scaled by the ratio of the mean "base recreational catches" relative to the mean of the unstandardised Area 917 SS CPUE in 1994/1996	10	Constant from 1945
CRA 6	–	–	–	Not used	–	–
CRA 7 [5]	1945	2011	4.362 (=mean of 1992/1996 /2000/2001 estimates)	Ramped from 1945; after 1979, the CRA 7 SS CPUE in each year was scaled by the ratio of the mean "base recreational catches" relative to the mean of the standardised SS CPUE in 1992/1996 /2000/2001	1	Constant from 1974
CRA 8 [5]	1945	2011	15.549 (=mean of 1992/1996 /2000/2001 estimates)	Ramped from 1945; after 1979, the CRA 8 SS CPUE in each year was scaled by the ratio of the mean "base recreational catches" relative to the mean of the standardised SS CPUE in 1992/1996 /2000/2001	6	Constant from 1974
CRA 9 [7]	1945	2012	2011=17.96	Ramped from 1945; after 1979, the CRA 9 SS CPUE in each year was scaled by the ratio of the "base recreational catch" relative to the 2011 standardised SS CPUE	1	Constant from 1963

[1] Starr et al. (2014a);[2] Starr et al. (2009); [3] Starr et al. (2012); [4] Starr et al. (2011); [5] Starr et al. (2013); [6] see Section 1.3; [7] Breen (2014)

Table 7: Basis for setting recreational and customary catch estimates used in recent CRA assessments. SS: spring/summer. The recreational survey estimates are provided in Table 6.

QMA	Notes: Recreational Catch	Notes: Customary Catch
CRA 1	Annual estimates for 1994/1996/2011/2013 generated by multiplying estimates in numbers by appropriate mean weight. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table 9) was then added to the survey estimates	MPI Compliance estimate
CRA 2 [1]	Annual estimates for 1994/1996/2011 generated by multiplying estimates in numbers by appropriate mean weight. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table 9) was then added to the survey estimates	MPI Compliance estimate
CRA 3 [2]	Annual estimates for 1992/1996/2011 generated by multiplying estimates in numbers by appropriate mean weight. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table 9) was then added to the survey estimates	MPI Compliance estimate
CRA 4 [3]	Mean of 1994 and 1996 recreational survey estimates in numbers X 1994/96 SS mean weight from catch sampling. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table 9) was added to the calculated time series.	MPI Compliance estimate, supported by returns of numbers of lobster harvested under Kaimoana regulations
CRA 5 [4]	Mean of 1994 and 1996 recreational survey estimates in numbers X 1994/96 SS mean weight from catch sampling. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table 9) was added to the calculated time series.	By WG agreement
CRA 6	Not used	Not used
CRA 7 [5] CRA 8 [5]	Mean of recreational survey estimates (mean in numbers: 1992/1996 and 2000/2001) X mean SS weight from catch sampling in same years. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table 9) was then added to the survey estimates	Expanded from estimates provided by MPI Compliance which were thought to be too low by the WG
CRA 9 [5]	Annual estimate for 2011 generated by multiplying estimates in numbers by 2011 mean weight. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table 9) was then added to the survey estimates	MPI Compliance estimate

[1] Starr et al. (2014a);[2] Breen et al. (2009); [3] see Section 5; [4] Starr et al. (2011); [5] Breen (2014)

The recreational harvest estimates provided by the 2000 and 2001 telephone diary surveys were thought by the MAFWG to be implausibly high, which led to the development of alternative “onsite” methods for estimating recreational harvest. These methods provided direct estimates of recreational harvest in fisheries that were suitable for this form of survey. However, “onsite” methods tend to be costly and difficult to mount, leading to a reconsideration of the “offsite” approach. This process led to the implementation of a national panel survey during the 2011–12 finfish fishing year which used face-to-face interviews of a random sample of New Zealand households to recruit a panel of participants and non-participants for the full year (Table 5). The panel members were contacted regularly about their fishing activities and catch information was collected using standardised phone interviews. A new “onsite” CRA 1 survey was completed for 2013–14, extending from Rangiputa to Mangawhai Heads, which covers most of Areas 903 and 904 (Table 5: Holdsworth, pers. comm.). This area is estimated to represent 70% of the total CRA 1 recreational catch.

Table 6 presents the recreational catch estimates used in all recent rock lobster stock assessments and Table 7 presents the rationale used when setting the levels presented in Table 6. The RLFAWG has little confidence in the early estimates of recreational catch, but is hopeful that the national panel survey has provided more reliable estimates of recreational catch in those QMAs with a relatively large number of participants.

1.3 CRA 1 and CRA 3 recreational catch

Recreational catch estimates were required for the 2014 CRA 1 and CRA 3 stock assessments. The RLFAWG agreed to use an approach consistent with that used since 2010 for the CRA 2, CRA 4, CRA 5, CRA 7, CRA 8, and CRA 9 assessments. This approach allows recreational catch to vary with abundance, as reflected by the spring-summer CPUE index series. In most instances (CRA 2, CRA 4, CRA 7, CRA 8 and CRA 9), the standardised SS CPUE for the entire QMA is used. In other instances, the unstandardised SS CPUE from a statistical area that represents the majority of recreational effort is used (e.g., Area 917 in CRA 5). This was done for CRA 1 in recognition that the majority of the recreational fishery takes place in Areas 903 and 904 (Holdsworth, pers. comm.) which are areas with much lower CPUE than the remaining three CRA 1 statistical areas (see Table 4). CRA 3 used the standardised CPUE from the entire QMA given the relative similarity of the area-specific CPUEs (Table 4). Recreational catches in CRA 1 and CRA 3 were calculated by year using the algorithm documented in Eq. 1, based on values given in Table 8. The RLFAWG did not accept the estimates from the 2000 and 2001 National surveys for reasons noted in Section 1.2.

Table 8. Information used to estimate recreational catches for CRA 1 and CRA 3. '–': not used.

Category	CRA 1	CRA 3
Catch estimates in numbers		
1992	–	8 000
1994	56 000	–
1996	74 000	27 000
2011	29 739	13 912
2013	50 430	–
Derived values		
1992/1994/1996 SS mean weight (kg) [1]	0.717	0.534
1992 catch estimate (t)	–	4.27
1994 catch estimate (t)	40.15	–
1996 catch estimate (t)	53.06	14.42
2011 mean weight (kg) [1]	0.810	0.580
2011 catch estimate (t)	24.09	8.07
2013 mean weight (kg) [1]	0.810	–
2013 catch estimate (t)	40.75	–
CPUE series used for scaling	Area 903/904 unstandardised	CRA 3 SS standardised
Reconstructed catch in 1979 (t)	42.70	9.61
20% of 1979 catch (t)	12.55	4.27
Maximum Section 111 catch (t)	5.02	2.94

[1] estimated from commercial SS catch sampling data using 54 and 60 mm MLS and appropriate years

$$
\begin{aligned}
{}^{q}W_y &= {}^{q}w_y \; {}^{q}N_y \\
{}^{CRA2}S &= \left({}^{CRA2}W_{94} \big/ {}^{CRA2}CPUE_{94} + {}^{CRA2}W_{96} \big/ {}^{CRA2}CPUE_{96} + {}^{CRA2}W_{11} \big/ {}^{CRA2}CPUE_{11} \right) \Big/ 3 \\
{}^{CRA9}S &= {}^{CRA9}W_{11} \big/ {}^{CRA9}CPUE_{11} \\
{}^{q}\hat{W}_i &= {}^{q}S * {}^{q}CPUE_i \;\; \text{if } i >= 1979 \\
{}^{q}\hat{W}_{1945} &= 0.2 * {}^{q}\hat{W}_{1979} \\
{}^{q}\hat{W}_i &= {}^{q}\hat{W}_{i-1} + \frac{({}^{q}\hat{W}_{1979} - {}^{q}\hat{W}_{1945})}{(1979-1945)} \;\; \text{if } i > 1945 \,\&\, i < 1979
\end{aligned}
$$

Eq. 1

where

y: subscripts 1994, 1996 and 2011 for CRA2 and 2011 for CRA9

${}^{q}w_y =$ mean spring/summer weight >= MLS for sampled lobster in year y for QMA q

${}^{q}N_y =$ mean numbers lobster in survey year y for QMA q

${}^{q}CPUE_i =$ spring/summer standardised CPUE from 1979 to 2011 for QMA q

${}^{q}\hat{W}_i =$ estimated recreational catch by weight for year i for QMA q

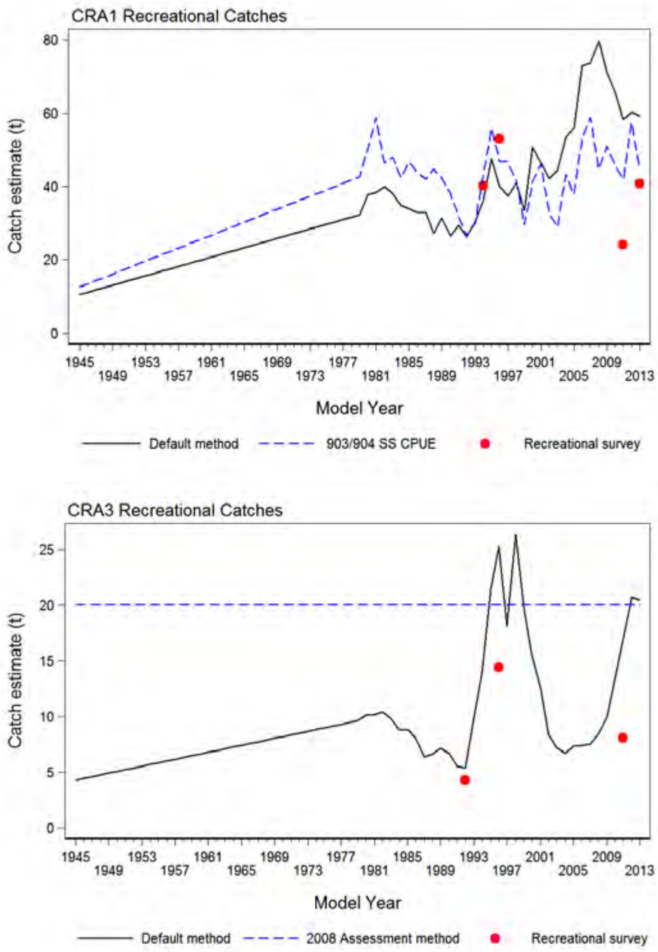


Figure 3. Recreational catch trajectories (kg) for the 2014 stock assessment of CRA 1 [left panel] and CRA 3 [right panel]. Section 111 catches have been added to each recreational catch trajectory. CRA 1 recreational catches ([left panel] blue dashed line) were made proportional to the mean unstandardised Area 903/904 CPUE after 1979, scaled to the mean catch weight estimated from the relevant recreational diary surveys. An alternative CRA 1 recreational catch trajectory ([left panel] black solid line), scaled to the overall CRA 1 standardised SS CPUE and used in a sensitivity run, is also presented. CRA 3 recreational catches ([right panel] black solid line) were made proportional to the mean standardised SS CPUE after 1979, scaled to the mean catch weight estimated from the relevant recreational diary surveys. The CRA 3 recreational catch trajectory used in the 2008 stock assessment ([right panel] blue dashed line) is shown for comparison.

This algorithm was adopted by the RLFAWG for estimating recreational catches from 2010, assuming that these catches vary proportionally to abundance and uses appropriate SS CPUE to scale the catch estimates (either total SS CPUE or specific statistical areas). For CRA 1, the resulting recreational catch trajectory (left panel, Figure 3) shows a relatively consistent level of catch since the early 1980s, reflecting the stable, but low CPUEs in Areas 903/904. The method appears to capture the relative level of harvest from the 1994, 1996 and 2013 surveys relatively well while it overestimates the 2011 survey (left panel, Figure 3). The CRA 3 recreational catch trajectory follows the pattern of the CRA 3 SS CPUE (right panel, Figure 3), while capturing the relative level of the 1992 and 2011 surveys used to scale the series. However, the 1996 catch estimate overestimates the survey index value in the same year.

1.4 Section 111 commercial landings

Commercial fishermen are allowed to take home lobsters for personal use under the provisions of Section 111 of the Fisheries Act. These lobsters are required to be declared on landing forms using the destination code “F”. The maximum total in any fishing year for these landings by QMA has ranged from less than 1 t (CRA 6) to nearly 16 t (CRA 8) (Table 9).

Table 9: Section 111 commercial landings (in kg, summed from landing destination code “F”) by fishing year and QMA.

Fishing Year	CRA1	CRA2	CRA3	CRA4	CRA5	CRA6	CRA7	CRA8	CRA9
1992–93	5	–	–	–	–	–	–	–	–
1999–2000	–	–	–	–	8	–	–	–	–
2000–01	3	–	–	–	30	–	–	–	–
2001–02	111	227	136	648	465	–	77	253	5
2002–03	489	609	495	2 660	1 960	–	152	1 954	907
2003–04	2 221	1 025	372	3 399	2 928	60	93	1 679	973
2004–05	3 554	733	311	3 706	3 191	87	95	3 505	1 636
2005–06	3 083	775	993	3 680	4 388	2	153	4 572	2 133
2006–07	5 016	1 284	981	3 110	5 102	19	289	5 813	1 219
2007–08	3 831	1 032	1 167	2 706	5 412	411	929	7 786	1 461
2008–09	3 628	1 185	1 374	2 188	6 110	538	1 498	9 571	1 597
2009–10	4 010	1 370	2 253	3 222	6 244	299	1 688	10 721	2 264
2010–11	3 669	1 186	2 182	4 699	6 584	284	429	13 538	1 851
2011–12	4 159	1 169	2 214	4 730	4 829	473	80	14 913	1 899
2012–13	4 212	1 189	2 576	5 835	7 215	1 027	98	15 824	1 847
2013–14	3 942	1 658	2 941	4 797	6 629	1 005	141	13 232	1 710
Maximum	5 016	1 658	2 941	5 835	7 215	1 027	1 688	15 824	2 264

1.5 Customary non-commercial fisheries

The Ministry of Fisheries provided preliminary estimates of the Mäori customary catch for some Fishstocks for the 1995–96 fishing year. The estimates for the 1995–96 fishing year were: CRA 1, 2.0 t, CRA 2, 16.5 t; CRA 8, 0.2 t; CRA 9, 2.0 t; and PHC 1, 0.5 t.

MPI provided tables of customary permits and realised catches for the CRA 1 and CRA 3 stock assessments, some by weight and some by numbers of lobsters. On the basis of the information in these tables, MPI concluded that it was appropriate to continue to use 10 t and 20 t constant customary catch estimates for CRA 1 and CRA 3 respectively. (Alicia McKinnon, MPI, *pers. comm.*).

Given this information, the 2014 stock assessments used a constant catch of 10 t/year and 20 t/year to represent the customary catches in CRA 1 and CRA 3 respectively (Table 6; Figure 3). Table 6 presents the customary catch estimates used in all recent rock lobster stock assessments and Table 7 presents the rationale used when setting the levels presented in Table 6. The RLFAWG has little confidence in these estimates.

1.6 Illegal catch

MPI (previously Ministry of Fisheries) Compliance has in the past provided estimates of illegal catch in two categories: catch that subsequently was reported against quota (columns labelled ‘R’ in Table 10) and catch which is outside of the MPI catch reporting system (columns labelled ‘NR’ in Table 10). Table 10 shows all the available illegal catch estimates by CRA QMA. When these data are used in stock assessments, missing cells are filled in by interpolation (for missing years) or by extrapolation (to extend the series after 2004–05). The illegal catches for these filled-in years are apportioned between the ‘R’ and ‘NR’ categories within each QMA (q) using the mean proportion $r_q = \sum R_{q,y} \big/ \sum I_{q,y}$, where $R_{q,y}$ is the “reported” (‘R’) catch for those years with MPI Compliance estimates in the QMA and $I_{q,y}$ is the total illegal catch in the same years. This quantity is then subtracted from the total reported QMR/MHR catch to avoid counting the same catch twice when using these catches in stock assessments and the total illegal catch is summed.

Table 10: Available estimates of illegal catches (t) by CRA QMA from 1990, as provided by MPI Compliance over a number of years. R (reported): illegal catch that will eventually be processed though the legal catch/effort system; NR (not reported): illegal catch outside of the catch/effort system. Cells without data or missing rows have been deliberately left blank.

Fishing	CRA 1		CRA 2		CRA 3		CRA 4		CRA 5		CRA 6		CRA 7		CRA 8		CRA 9	
Year	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR
1990		38		70		288.2		160.1		178		85	34	9.6	25	5		12.8
1992		11		37		250		30		180		70	34	5	60	5		31
1994		15		70	5	37		70		70		70		25		65		18
1995		15		60	0	63		64		70		70		15		45		12
1996	0	72	5	83	20	71	0	75	0	37	70	0	15	5	30	28	0	12
1997					4	60												
1998					4	86.5												
1999					0	136								23.5		54.5		
2000					3	75		64										
2001		72		88	0	75												
2002					0	75	9	51		40		10		1		18		1
2003					0	89.5			5	47								
2004							10	30										
2005																		
2006																		
2007																		
2008																		
2009																		
2010																		
2011														1		3		
2012																		
2013																		

MPI has provided estimates of current and historical illegal catches for the CRA 1 and CRA 3 stock assessments, as well as estimates of the proportion of illegal catch that was eventually reported as legal catch in this QMA. MPI pointed to estimates given in the past (Table 10) and suggested that the 72 t and 89.5 t estimates of illegal catch should be used in the upcoming CRA 1 and CRA 3 stock assessments. Sensitivity analyses were carried out with half and double of the illegal catch estimates in both CRA 1 and CRA 3.

Given this advice from MPI, the 2014 CRA 1 stock assessment used a constant catch of 72 t/year to fill in the missing years between 2002 to 2013 while the 2014 CRA 3 stock assessment used a constant catch of 89.5 t/year to fill in the missing years between 2004 to 2013 (Table 10).

Table 11: Export discrepancy estimates by year for all of New Zealand (McKoy, pers. comm.). The QMA export discrepancy catch is calculated using the fraction for the reported QMA commercial catch $C_{q,y}$ relative to the total NZ commercial catch C_y, starting with the total NZ export discrepancy for that year I_y: $I_{q,y} = I_y\left(C_{q,y}/C_y\right)$. This calculation is not performed for CRA 9 as there were no estimates of commercial catch available from 1974 to 1978. The average ratio of the export discrepancy catch for each QMA $\overline{P}_q$ relative to the reported QMA commercial catches is used in each CRA QMA to estimate illegal catches prior to 1990: $I_{q,y} = \overline{P}_q C_{q,y}$ if $y<1974 \| \left(y>1980 \& y<1990\right)$.

Year	Estimates of total export discrepancies (t) I_y	QMA	$\overline{P}_q = \sum_{y=1974}^{1980} I_{q,y} \Big/ \sum_{y=1974}^{1980} C_{q,y}$
1974	463	CRA 1	0.192
1975	816	CRA 2	0.171
1976	721	CRA 3	0.164
1977	913	CRA 4	0.183
1978	1146	CRA 5	0.187
1979	383	CRA 6	0.181
1980	520	CRA 7	0.183
		CRA 8	0.187
		CRA 9	–

Illegal catch estimates before 1990 have been derived from unpublished estimates of discrepancies between reported catch totals and total exported weight that were developed for the period 1974 to 1980 (Table 11; McKoy pers. comm.). For years prior to 1973 and from 1981–82 to 1989–90, illegal catch was estimated using the average ratio of annual exports of rock lobster relative to the reported catch in each year from 1974 to 1980 (Table 11). This ratio was calculated for each QMA by assuming that the exports are distributed by QMA in the same proportion as the reported catches. This procedure has also been applied to CRA 9 even though there are no commercial catch estimates available for this QMA from 1974 to 1978 using interpolation.

The RLFAWG members have little confidence in the estimates of illegal catch because the estimates cannot be verified.

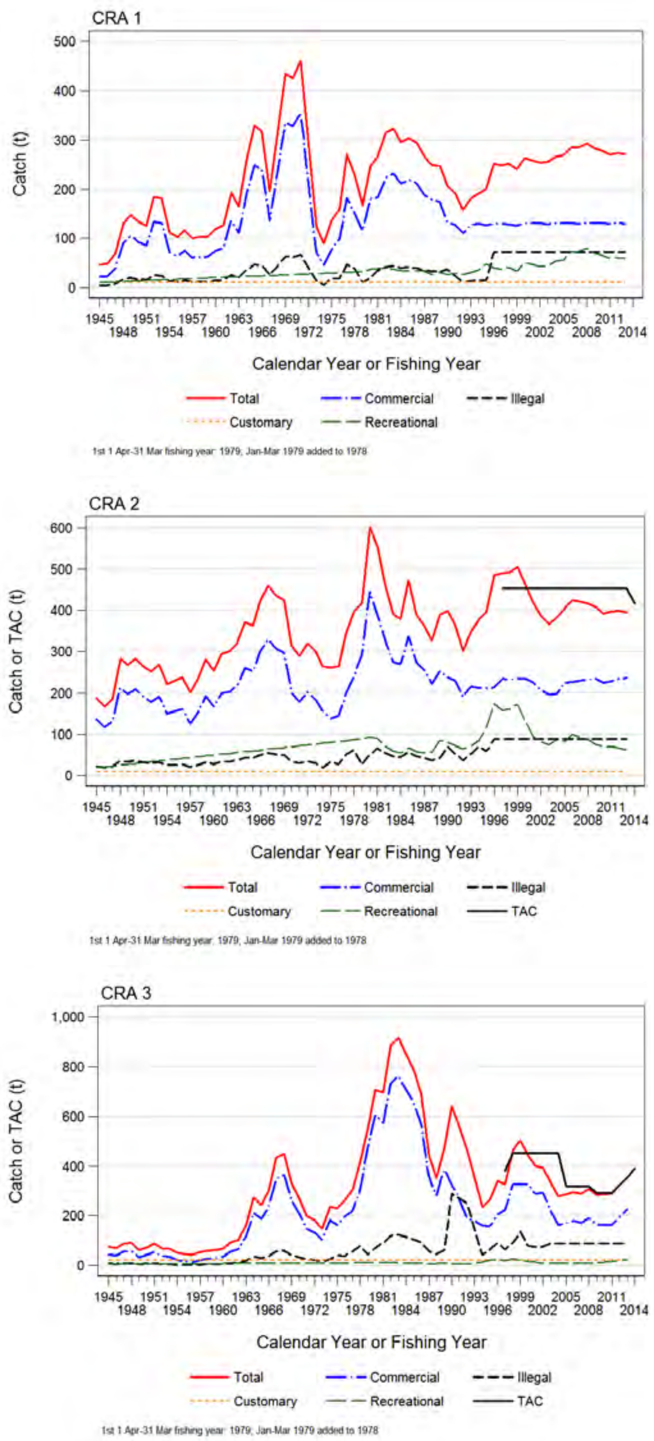


Figure 4: Catch trajectories (t) from 1945 to 2011 and TACs (if in place) from the year of establishment to 2013 for CRA 1 to CRA 9, showing current best estimates for commercial, recreational, customary and illegal categories. Also shown is the sum of these four catch categories. Note that calendar year catches are plotted from 1945 to 1977. Statutory fishing years (1 April to 31 March) catches are plotted from 1979 on. Catches for 1978 are for 15 months, including January to March 1979. **[Continued on next page]**

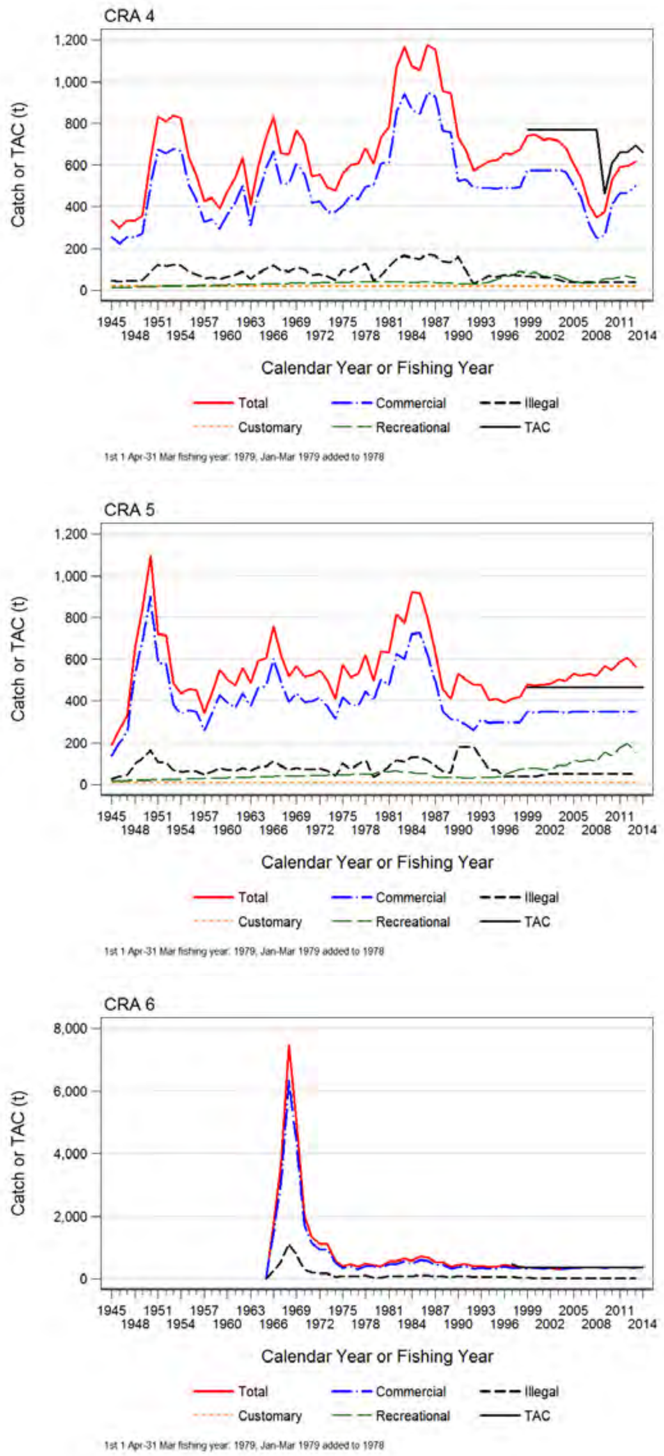


Figure 4 [cont]: **Catch trajectories (t) from 1945 to 2011 and TACs (if in place) from the year of establishment to 2013 for CRA 1 to CRA 9.**

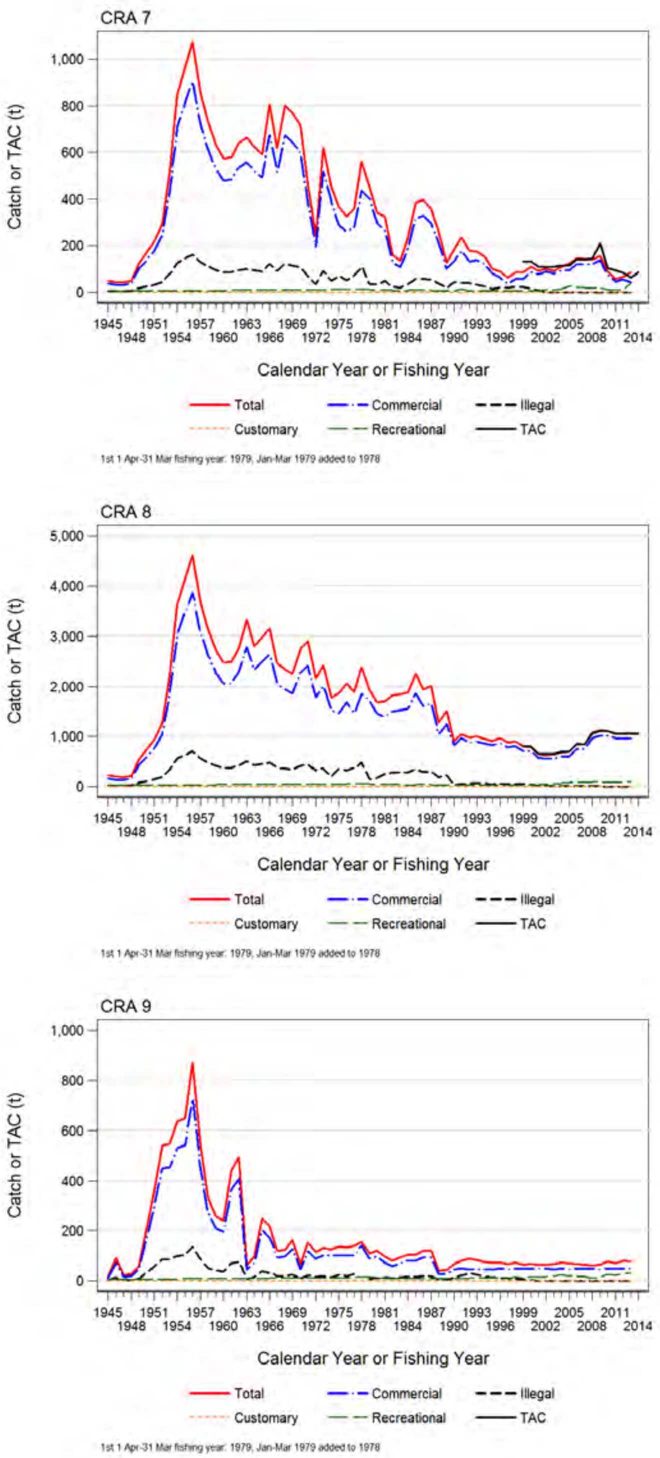


Figure 4 [cont]: Catch trajectories (t) from 1945 to 2011 and TACs (if in place) from the year of establishment to 2013 for CRA 1 to CRA 9.

1.7 Other sources of mortality

Other sources of mortality include handling mortality caused by the return of under-sized and berried female lobsters to the water, and predation by octopus and other predators within pots. Although these mortalities cannot be quantified, all rock lobster assessments assume that handling mortality is 10% of returned lobsters.

1.8 Time series of mortalities

Plots of all rock lobster catches by QMA from 1945 are presented in Figure 4. Commercial catches before 1979 have been obtained from unpublished reports (Annala, pers. comm.). Historical estimates of recreational, customary and illegal catches have been generated for each stock assessment and these have been extended using the same rules for those assessments that are not current. In some instances (notably CRA 6 and CRA 9), there has never been a formal stock assessment. Finally, a TAC is plotted for the 7 CRA QMAs which have one.

2. BIOLOGY

Although lobsters cannot be aged in numbers sufficient for use in fishery assessments, they are thought to be relatively slow-growing and long-lived. *J. edwardsii* and *S. verreauxi* occur both in New Zealand and southern Australia. The following summary applies only to *J. edwardsii* in New Zealand.

Sexual maturity in females is reached from 34–77 mm TW (about 60–120 mm carapace length), depending on locality within New Zealand. For instance, in CRA 3, 50% maturity appears to be realised near 40 mm TW while most females in the south and south-east of the South Island do not breed before reaching MLS.

Mating takes place after moulting in autumn, and the eggs hatch in spring into the short-lived naupliosoma larvae. Most of the phyllosoma larval development takes place in oceanic waters tens to hundreds of kilometres offshore over at least 12 months. Near the edge of the continental shelf the final-stage phyllosoma metamorphoses into the settling stage, the puerulus. Puerulus settlement takes place mainly at depths less than 20 m, but not uniformly over time or between regions. Settlement indices measured on collectors can fluctuate widely from year to year.

Values used for some biological parameters in stock assessments are shown in Table 12.

Table 12: Values used for some biological parameters.

1. Natural mortality (*M*) [1]

Area	Both Sexes
CRA 1, 2 ,3, 4, 5, 7, 8	0.12

[1] This value has been used as the mean of an informative prior; *M* was estimated as a parameter of the model and is usually substantially updated.

2. Fecundity = a TW^b (TW in mm) (Breen & Kendrick 1998)[2]

Area	*a*	*b*
NSN	0.21	2.95
CRA 4 & CRA 5	0.86	2.91
NSS	0.06	3.18

[2] Fecundity has not been used by post-1999 assessment models.

3. Weight = a TW^b (weight in kg, TW in mm) (Breen & Kendrick, Ministry of Fisheries unpublished data)

	Females		Males	
Area	***a***	***b***	***a***	***b***
CRA 1, 2, 3, 4, 5	1.30 E-05	2.5452	4.16 E-06	2.9354
NSS	1.04 E-05	2.6323	3.39 E-06	2.9665

Long-distance migrations of rock lobsters have been observed in some areas. During spring and early summer, variable proportions of usually small males and immature females move various distances against the current from the east and south coasts of the South Island towards Fiordland and south Westland.

Growth modelling

The primary sources of information for growth are tag-recapture and catch sampling data. Lobsters have been caught, measured, tagged and released, then recaptured and re-measured at some later time (and in some instances re-released and re-recaptured later). Since 1998, statistical length-based models have been used to estimate the expected increment-at-size, which is represented stochastically by growth transition matrices for each sex. Growth increments-at-size are assumed to be normally distributed with means and variances determined from the growth model. The transition matrices contain the probabilities that a lobster will move into specific size bins given its initial size.

The growth model contains parameters for expected increment at 50 mm and 80 mm TW, a shape parameter (1 = linear), the c.v. of the increment for each sex, the minimum standard deviation and the observation error. This model is over-parameterised if all parameters are estimated, so the final two, and sometimes three, parameters are fixed.

Since 2006, the growth model applied to the tag-recapture data has been a continuous model – giving a predicted growth increment for any time at liberty greater than 30 days – whereas the older versions assumed specific moulting periods between which growth did not occur. For assessment models developed since 2006, tag-recapture records from lobsters at liberty for fewer than 30 days have been excluded. Other basic data grooming is performed, but the robust likelihood fitting procedure precludes the need for extensive grooming of outliers. Growth parameters are estimated simultaneously with other parameters of the assessment model in an integrated way, so that growth estimates might be affected by the size frequency and CPUE data as well as the tag-recapture data.

Settlement indices

Annual levels of puerulus settlement have been collected from 1979 at sites in Gisborne, Napier, Castlepoint, Kaikoura, Moeraki, Chalky Inlet, Halfmoon Bay, and Jackson Bay (Table 13). Each site has at least one group of three collectors that are checked monthly when possible, and the monthly catches of the puerulus from each collector are used as the basis for producing a standardised index of settlement (Forman et al. 2014). Standardised settlement indices are available for each major site (Table 14).

Table 13: Location of collector groups used for the standardisation of puerulus settlement indices, the years of operation, and the number of collectors monitored within each group at the last sampling.

QMA	Key site	Collector groups	Years of operation	Number of collectors
CRA 3	Gisborne	Whangara (GIS002)	1991–Present	5
		Tatapouri (GIS003)	1994–2006	5
		Kaiti (GIS004)	1994–Present	5
CRA 4	Napier	Port of Napier (NAP001)	1979–Present	5
		Westshore (NAP002)	1991–1999	3
		Cape Kidnappers (NAP003)	1994–Present	5
		Breakwater (NAP004)	1991–2002	3
CRA 4	Castlepoint	Castlepoint (CPT001)	1983–Present	9
		Mataikona (CPT002)	1991–2006	5
		Orui (CPT003)	1991–Present	5
CRA 5	Kaikoura	South peninsula (KAI001)	1981–Present	5
		South peninsula (KAI002)	1988–2003	3
		North peninsula (KAI003)	1980–Present	5
		North peninsula (KAI004)	1992–2003	3
		South Kaikoura (KAI005)	2008–Present	3
		Hamuri Bluff (KAI006)	2008–Present	3
CRA 7	Moeraki	Wharf (MOE002)	1990–2006	3
		Pier (MOE007)	1998–Present	6
CRA 8	Halfmoon Bay	Wharf (HMB001)	1980–Present	8
		Thompsons (HMB002)	1988–2002	3
		Old Mill (HMB003)	1990–2002	3
		The Neck (HMB004)	1992–2002	3
		Mamaku Point (HMB005)	1992–2002	3
CRA 8	Chalky Inlet	Chalky Inlet (CHI001)	1986–2004	5
			2010 –2012	4
CRA 8	Jackson Bay	Wharf (JAC001)	1999–Present	5
		Jackson Head (JAC002)	1999–2006	3

Table 14: Standardised puerulus settlement indices by calendar year (source: J. Forman & A. McKenzie, NIWA). '–': no usable sampling was done; 0.00: no observed settlement.

	Gisborne CRA 3	Napier CRA 4	Castlepoint CRA 4	Kaikoura CRA 5	Moeraki CRA 7	Halfmoon Bay CRA 8	Chalky Inlet CRA 8	Jackson Bay CRA 8
1979	-	0.84	-	-	-	-	-	-
1980	-	1.52	-	-	-	-	-	-
1981	-	2.06	-	1.19	-	8.09	-	-
1982	-	1.00	-	0.02	-	0.38	-	-
1983	-	1.24	1.41	0.76	-	4.58	-	-
1984	-	0.41	1.34	0.25	-	0.38	-	-
1985	-	0.19	0.86	0.35	-	0.00	-	-
1986	-	-	0.50	0.11	-	0.11	0.07	-
1987	3.16	-	1.69	1.22	-	1.60	1.95	-
1988	2.73	1.51	0.97	0.54	-	0.20	1.61	-
1989	0.96	1.08	1.51	0.89	-	0.54	2.19	-
1990	0.43	1.14	0.93	0.29	-	0.44	1.92	-
1991	1.03	2.26	1.94	5.91	0.00	0.84	1.06	-
1992	2.71	2.40	2.41	6.80	0.15	0.62	0.39	-
1993	1.71	1.91	1.46	3.41	0.00	0.00	0.13	-
1994	2.94	1.42	0.93	0.92	0.00	1.11	2.33	-
1995	1.05	1.06	0.88	1.08	0.11	0.32	0.56	-
1996	1.62	1.68	1.31	0.82	1.11	0.31	2.26	-
1997	0.97	1.29	1.15	1.68	0.66	0.53	1.52	-
1998	1.73	1.09	1.67	2.27	0.65	0.26	0.43	-
1999	0.27	0.29	0.34	1.53	0.14	0.24	1.04	0.56
2000	0.88	0.66	0.49	1.34	3.85	1.21	1.26	0.54
2001	1.10	1.32	0.76	0.49	2.36	1.71	0.99	0.66
2002	0.92	1.17	0.72	1.30	0.93	1.31	0.69	1.96
2003	2.67	1.32	0.76	5.21	7.21	3.45	1.59	1.01
2004	0.71	1.05	0.65	1.75	0.44	0.14	0.21	0.21
2005	2.43	1.28	1.17	2.30	0.10	0.00	-	1.96
2006	0.27	0.58	0.64	1.91	0.06	0.13	-	0.55
2007	0.35	1.03	0.88	1.26	0.03	0.46	-	0.25
2008	0.62	0.59	0.89	2.45	0.09	0.09	-	0.19
2009	1.70	0.75	0.92	0.49	0.52	0.96	-	0.18
2010	0.61	1.30	1.60	1.98	1.39	1.69	5.50	2.50
2011	0.18	0.36	0.89	0.46	0.91	0.13	1.49	3.07
2012	0.65	0.78	0.65	1.61	0.84	0.21	4.25	8.86
2013	0.91	1.16	1.65	0.69	1.46	0.98	-	18.71

3. STOCKS AND AREAS

There is no evidence for genetic subdivision of lobster stocks within New Zealand based on biochemical genetic and mtDNA studies. The observed long-distance migrations in some areas and the long larval life probably result in genetic homogeneity among areas. Gene flow at some level probably occurs to New Zealand from populations in Australia (Chiswell et al. 2003).

Subdivision of stocks on other than genetic grounds has been considered (Booth & Breen 1992; Bentley & Starr 2001). There are geographic discontinuities in the prevalence of antennal banding, size at onset of maturity in females, migratory behaviour, fishery catch and effort patterns, phyllosoma abundance patterns and puerulus settlement levels. These observations led to division of the historical NSI stock into three substocks (NSN, NSC, and NSS) for assessments in the 1990s. Cluster analysis based on similarities in CPUE trends between rock lobster statistical areas provided support for those stock definitions (Bentley & Starr 2001).

Since 2001 these historical stock definitions have not been used, and rock lobsters in each of the CRA QMA areas have been assumed to constitute separate Fishstocks for the purposes of stock assessment and management.

Sagmariasus verreauxi forms one stock centred in northern New Zealand and may be genetically subdivided from populations of the same species in Australia.

4. DECISION RULES AND MANAGEMENT PROCEDURES

This section presents evaluations of the existing CRA 2, CRA 3, CRA 4, CRA 5, CRA 7, CRA 8 and CRA 9 management procedures (MP) for the 2015–16 fishing year, based on CPUE data extracted in early November 2014 and standardised as described below. New management procedures for CRA 2 and CRA 9 were implemented in 2014 and are new to this section of the Report. New MPs have been developed for CRA 1 and CRA 3 in 2014, and may be used to set catch limits for the 2015–16 fishing year; the outcome will be reported in next year's Report.

4.1 Data preparation

Data were obtained from the Ministry for Primary Industries catch/effort mandatory reporting system, groomed (Bentley et al 2005) and the estimated catches scaled either to the LFR ("L") landings using the "B4" procedure or to the combined LFR, Destination "X" and Section 111 (Destination "F") landings (designated "LFX" below). These methodologies are described in Section 1.3, in Bentley et al (2005) and in Starr (2013). The data preparation procedures differ between MPs, depending on what methods were used when the MPs were evaluated. All data were aggregated by fishing year, month, rock lobster statistical area and vessel prior to being processed by the standardisation procedure (Maunder & Starr 1995; Bentley et al 2005, Starr 2013), which uses month, statistical area and year as explanatory variables. Each QMA analysis was done separately.

These MPs use annual standardised CPUE estimates based on an "offset year" which is the AW season combined with the preceding SS season, whereas the statutory rock lobster fishing year consists of the SS season and the preceding AW season. All rule evaluations below are based on the offset year extending from 1 October 2013 to 30 September 2014 to produce a proposed a TAC or TACC (depending on the rule) for the fishing year, which begins on 1 April 2015 and extends to 31 March 2016.

Standardisation for the offset year management procedure analyses follows the suggestion of Francis (1999) and calculates "canonical" coefficients and standard errors for each year, which allows calculation of standard errors for every coefficient including the base year coefficient. Each standardised index is scaled by the geometric mean of the simple arithmetic CPUE indices (using the summed annual catch divided by summed annual effort for each offset year). The geometric mean CPUE is preferred to the arithmetic mean because it is less affected by outliers than the arithmetic mean. This procedure scales the standardised indices to CPUE levels consistent with those observed by fishermen.

4.2 Management Procedure for CRA 2

The management procedure for CRA 2 is based on a stock assessment and MP evaluations completed in 2013 (Starr et al 2014). Specifications for the CRA 2 MP include:

a) the output variable is TACC (tonnes) and the input variable is offset year (October–September) standardised CPUE (kg/potlift), calculated in November and scaled to the "LFX" destination code using the "F2" data preparation procedure, is used as the input variable.

b) the management procedure is to be evaluated every year (no "latent year"); and

c) there are no thresholds for maximum change, but a minimum 5% change.

Figure 5 shows the relationship between CPUE and the TACC for the CRA 2 MP: between a CPUE of 0 and 0.5 kg/potlift, the TACC increases linearly with CPUE to a plateau of 200 tonnes (Equation 2B), which extends to a CPUE of 0.5 kg/potlift (Equation 2C). As CPUE increases above 0.5 kg/potlift, TACC increases in steps with a width of 0.1 kg/potlift and a height of 10% of the preceding TACC (Equation 2D).

Eq. 2A $TACC'_{y+1} = 0.0$ **for** $I_y = 0.0$

Eq. 2B $TACC'_{y+1} = \left(\frac{200}{0.5-0.3}\right)\left(I_y - 0.3\right)$ **for** $0.0 < I_y \leq 0.3$

Eq. 2C $TACC'_{y+1} = 200.0$ **for** $0.3 < I_y \leq 0.5$

Eq. 2D $TACC'_{y+1} = 200\left(1.10^{\text{int}\left(\left(I_y-0.5\right)/0.1\right)+1}\right)$ **for** $I_y > 0.5$

where $TACC'_{y+1}$ is the provisional TACC result from the rule and I_y is the input offset-year CPUE.

The Minister accepted and implemented this management procedure for the 2013–14 fishing year. The TACC decreased in 2013-14 in accordance with the rule evaluation (Table 15). In November 2014, the standardised offset-year CPUE was 0.3661 kg/potlift. The rule generated a proposed TACC of 200 t for 2015–16, no change to the current TACC.

Table 15: History of the CRA 2 management procedure and proposed limit to the commercial fishery in the 2015–16 fishing year. "Rule result" is the result of the management procedure after operation of all its components including thresholds; '–': to be determined by the Minister

Year of analysis	Applied to fishing year	Offset-year CPUE at time of analysis (kg/potlift)	Rule result: TACC (t)	TACC (t)	TAC (t)
2013	2014–15	0.3668	200.0	200.0	416.5
2014	2015–16 (proposed)	0.3661	200.0	–	–

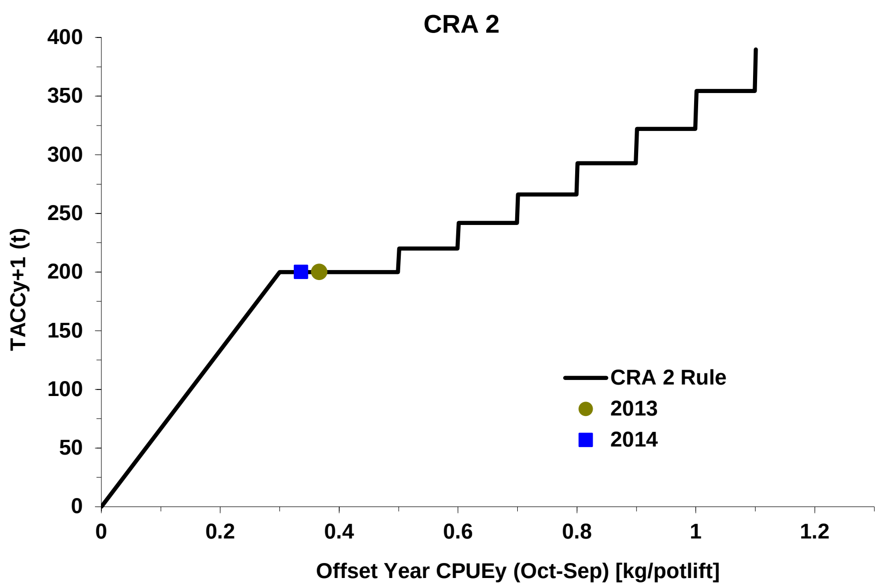


Figure 5: The CRA 2 management procedure, showing the provisional TACC in year y+1 as a function of offset year CPUE in year y, and showing the 2013 and 2014 results.

4.3 Management Procedure for CRA 3

In 2009, an operating model based on the 2008 stock assessment model (Breen et al 2009), updated with an additional year of catch and CPUE data, was used to develop a management procedure for CRA 3. Length frequency data were not updated, and all other model assumptions, modelling choices and inputs were unchanged. There had been no previous management procedure for this stock. After consideration of base case and robustness trial results, a small set of final candidates was presented to the statutory consultation round, and the Minister chose Rule 2a. This management procedure is specified as follows:

1. A conditional initial fixed TAC applies for 3 years (2010–11, 2011–12 and 2012–13) and is set at 293 tonnes, unless offset-year CPUE falls below 0.75 kg/potlift or increases above 1.08 kg/potlift. If the CPUE falls outside these limits, the initial TAC expires and the harvest control rule equations determine the TAC;
2. The conditional initial fixed TAC will expire after the 2012–13 fishing year and the harvest control rule equations will determine the TAC;
3. Offset-year standardised CPUE calculated in November will be used as input to the rule to determine the TAC for the statutory fishing year that begins in the following April;
4. The management procedure is to be evaluated every year (no “latent year”), based on offset-year CPUE;
5. The provisional TAC (before minimum and maximum change rules operate, and exclusive of considering the initial fixed TAC determined by the rule), is given by:

   Eq. 3A $$TAC'_{y+1} = 275\left(\frac{I_y + 3}{4}\right)^3$$ **for** $0 < I_y \le 1$ **and**

   Eq. 3B $$TAC'_{y+1} = 275\left(1 + \frac{0.5\left(I_y - 1\right)}{0.6}\right)$$ **for** $I_y > 1$

   where TAC'_{y+1} is the provisional TAC result from the rule and I_y is the input offset-year CPUE.
6. After the initial fixed TAC expires, if the procedure results in a TAC that does not change by more than 5%, no change will be made; and if the procedure results in a TAC that changes by more than 10%, the TAC will be changed by 10% only.

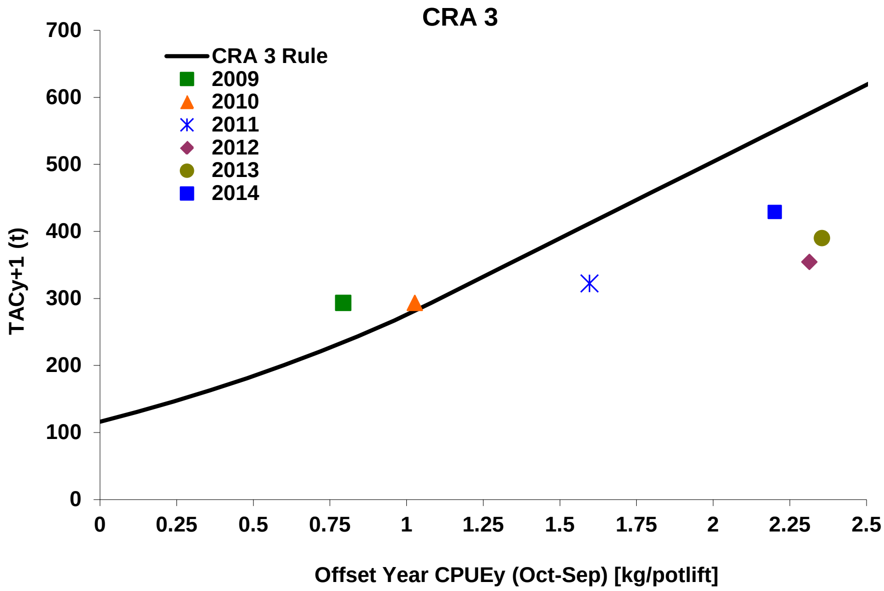


Figure 6: The CRA 3 management procedure, showing the provisional TAC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACs resulting from the rule evaluations performed in 2009 through 2014.

This decision rule was evaluated using the B4 algorithm scaled to the "L" destination code landings.

The relation between CPUE and provisional TAC (before minimum and maximum change limits operate, and ignoring the initial fixed TAC) is illustrated by the solid line in Figure 6, which also shows the results of the first five years of operation of the CRA 3 MP.

The Minister accepted and implemented this management procedure for the 2010–11 fishing year. Since 2011 the TACC has been increased each year by the maximum increase allowed of 10% (Table 16). In 2014, CPUE was 2.2013 kg.potlift, which again would give a TAC increase greater than 10%. If this rule was used for another year, the TAC would be increased by 10% to 428.95 t. If the same allowances were applied, the TACC would be 299.95 t.

Table 16: History of the CRA 3 management procedure and proposed TAC limit in the 2015-16 fishing year. "Rule result" is the result of the management procedure after operation of all its components including thresholds; '–': to be determined by the Minister

Year of analysis	Applied to fishing year	Offset-year CPUE at time of analysis (kg/potlift)	Rule result: TAC (t)	TACC (t)	TAC (t)
2009	2010–11	0.794	293	164	293
2010	2011–12	1.027	293	164	293
2011	2012–13	1.597	322.3	193.3	322.3
2012	2013–14	2.314	354.53	225.5	354.5
2013	2014–15	2.3551	389.95	260.95	389.95
2014	2015–16 (proposed)	2.2013	428.95	–	–

4.4 Management Procedure for CRA 4

The management procedure for CRA 4 is based on a stock assessment and MP evaluations completed in 2011 (Breen et al 2012). Specifications for the CRA 4 MP include:

d) the output variable is TACC (tonnes) and the input variable is offset year (October–September) standardised CPUE (kg/potlift), calculated in November and scaled to the “L” destination code using the “B4” data preparation procedure

e) the management procedure is to be evaluated every year (no “latent year”); and

f) there are no thresholds for minimum and maximum change, except a maximum 25% increase limit below the first plateau.

Figure 7 shows the relationship between CPUE and the TACC for the CRA 4 MP: below a CPUE of 0.5 kg/potlift, the TACC is zero (Equation 4A); between a CPUE of 0.5 and 0.9 kg/potlift, the TACC increases linearly with CPUE to a plateau of 467 tonnes (Equation 4B), which extends to a CPUE of 1.3 kg/potlift (Equation 4C). As CPUE increases above 1.3 kg/potlift, TACC increases in steps with a width of 0.1 kg/potlift and a height of 7% of the preceding TACC (Equation 4D).

Eq. 4A $TACC'_{y+1} = 0$ **for** $I_y \le 0.5$

Eq. 4B $TACC'_{y+1} = \left(\frac{467}{0.9-0.5}\right)\left(I_y - 0.5\right)$ **for** $0.5 < I_y \le 0.9$

Eq. 4C $TACC'_{y+1} = 467$ **for** $0.9 < I_y \le 1.3$

Eq. 4D $TACC'_{y+1} = 467\left(1.07^{\mathrm{int}\left(\left(I_y-1.3\right)/0.1\right)+1}\right)$ **for** $I_y > 1.3$

where $TACC'_{y+1}$ is the provisional TACC result from the rule and I_y is the input offset-year CPUE.

The Minister accepted and implemented this management procedure for the 2012–13 fishing year. The TACC increased in 2013-14 but was reduced in 2014-15 in accordance with the rule evaluation (Table 17). In November 2014, the standardised offset-year CPUE was 1.168 kg/potlift. The rule generated a proposed TACC of 467 t for 2015–16, no change to the current TACC.

Table 17: History of the CRA 4 management procedure and proposed limit to the commercial fishery in the 2015–16 fishing year. “Rule result” is the result of the management procedure after operation of all its components including thresholds; ‘–’: to be determined by the Minister

Year of analysis	Applied to fishing year	Offset-year CPUE at time of analysis (kg/potlift)	Rule result: TACC (t)	TACC (t)	TAC (t)
2011	2012–13	1.194	466.9	466.9	661.9
2012	2013–14	1.374	499.69	499.7	694.7
2013	2014–15	1.293	467.0	467.0	662.0
2014	2015–16 (proposed)	1.168	467.0	–	–

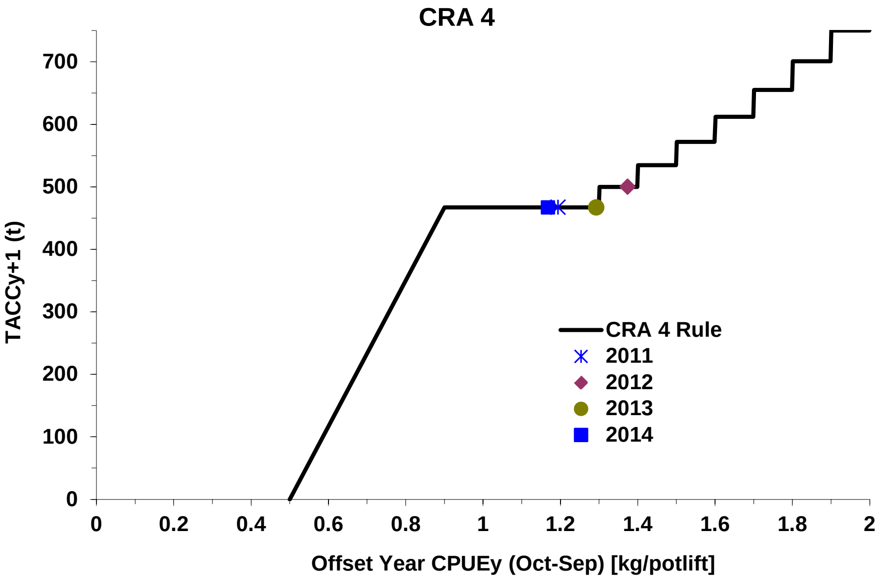


Figure 7: The CRA 4 management procedure, showing the TACC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACCs resulting from the rule evaluations performed in 2011 through to 2014.

4.5 Management Procedure for CRA 5

The management procedure for CRA 5 is based on a stock assessment and MP evaluation completed in 2010 (Breen et al 2011). Specifications for the CRA 5 MP include:

a) the output variable is TACC (tonnes) and offset year (October–September) standardised CPUE (kg/potlift), calculated in November and scaled to the "L" destination code using the "B4" data preparation procedure, is to be used as the input variable;

b) the management procedure is to be evaluated every year (no "latent year"); and

c) there are no thresholds for minimum and maximum change.

Figure 8 shows the relationship between CPUE and the TACC for the CRA 5 MP: below a CPUE of 0.3 kg/potlift, the TACC is zero (Equation 5A); between a CPUE of 0.3 and 1.4 kg/potlift, the TACC increases linearly with CPUE to a plateau of 350 tonnes (Equation 5B), which extends to a CPUE of 2.0 kg/potlift (Equation 5C). As CPUE increases above 2.0 kg/potlift, TACC increases in steps with a width of 0.2 kg/potlift and a height of 5% of the preceding TACC (Equation 5D).

Eq. 5A $TACC'_{y+1} = 0$ **for** $I_y \le 0.3$

Eq. 5B $TACC'_{y+1} = \left(\dfrac{350}{1.4-0.3}\right)\left(I_y - 0.3\right)$ **for** $0.3 < I_y \le 1.4$

Eq. 5C $TACC'_{y+1} = 350$ **for** $1.4 < I_y \le 2.0$

Eq. 5D $TACC'_{y+1} = 350\left(1.05^{\mathrm{int}\left(\left(I_y-2.0\right)/0.2\right)+1}\right)$ **for** $I_y > 2.0$

where $TACC'_{y+1}$ is the TACC result from the rule and I_y is the input offset-year CPUE.

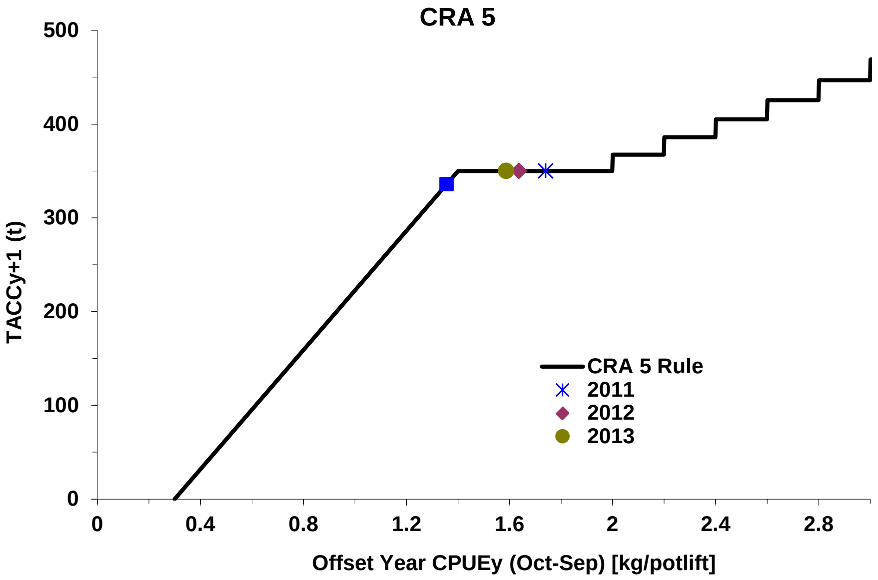


Figure 8: The CRA 5 management procedure, showing the TACC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACCs resulting from the rule evaluations performed in 2011 through to 2014.

The Minister accepted and implemented this management procedure for the 2012-13 fishing year. The 2010-11 CPUE of 1.74 kg/potlift gave a TACC of 350 t, which became a TAC of 467 t after non-commercial allowances of 117 t were added. For 2013–14, the rule generated a proposed TACC of 350 t (Table 18). In November 2014, the standardised offset-year CPUE was 1.3554 kg/potlift. The rule generated a proposed TACC of 335.81 t for 2015–16, a reduction of 4.05% as the CPUE lies to the left of the plateu (Figure 8).

Table 18: History of the CRA 5 management procedure and proposed limit to the commercial fishery in the 2015–16 fishing year. "Rule result" is the result of the management procedure after operation of all its components including thresholds; '–': to be determined by the Minister

Year of analysis	Applied to fishing year	Offset-year CPUE in year of analysis (kg/potlift)	Rule result: TACC (t)	TACC (t)	TAC (t)
2011	2012–13	1.740	350	350	467
2012	2013–14	1.636	350	350	467
2013	2014–15	1.587	350	350	–
2014	2015–16 (proposed)	1.3554	335.81	–	–

4.6 Management Procedure for CRA 7

CRA 7 has been managed since 1996 using management procedures based on observed CPUE, which originally was CRA 8 CPUE. In 2007, a separate management procedure was accepted by the Minister of Fisheries for CRA 7 for the 2008–09 fishing year.

The current CRA 7 management procedure is based on management procedure evaluations made in 2012 (Haist et al 2013), which used an operating model based on the 2012 joint stock assessment for CRA 7 and CRA 8 (Haist et al 2013). The output variable is TACC (tonnes) and offset year (October–September) standardised CPUE (kg/potlift), calculated in November and scaled to the "LFX" destination code using the "F2" data preparation procedure, is used as the input variable.

Rules evaluated in 2012 were plateau rules. The "meanings" of parameters in the generalised rule are given in Table 19. In 2013 the Minister adopted rule 39, for which the specific parameter values are also shown in Table 19. The minimum change is 10% and the maximum change is 50%. There is no latent year.

The CRA 7 rule (Figure 8) is described by:

Eq. 6A $TACC_{y+1} = 0$ **for** $I_y < par5$

Eq. 6B $TACC_{y+1} = par2 \dfrac{I_y - par5}{par3 - par5}$ **for** $par5 < I_y < par3$

Eq. 6C $TACC_{y+1} = par2$ **for** $par3 \le I_y \le par4$

Eq. 6D $TACC_{y+1} = par2\left(1 + 0.5\dfrac{I_y - par4}{par6 - par4}\right)$ **for** $I_y > par4$

where $TACC_{y+1}$ is the provisional TACC (before application of minimum and maximum change rules) in year y+1 and I_y is offset-year CPUE (kg/potlift) in year y.

Table 19: Parameters for the generalised plateau rule for CRA 7 adopted by the Minister in early 2013.

par	"meaning"	rule 39 values
par2	plateau height	80
par3	left plateau	1
par4	right plateau	1.75
par5	CPUE at TACC=0	0.17
par6	slope parameter	3.0

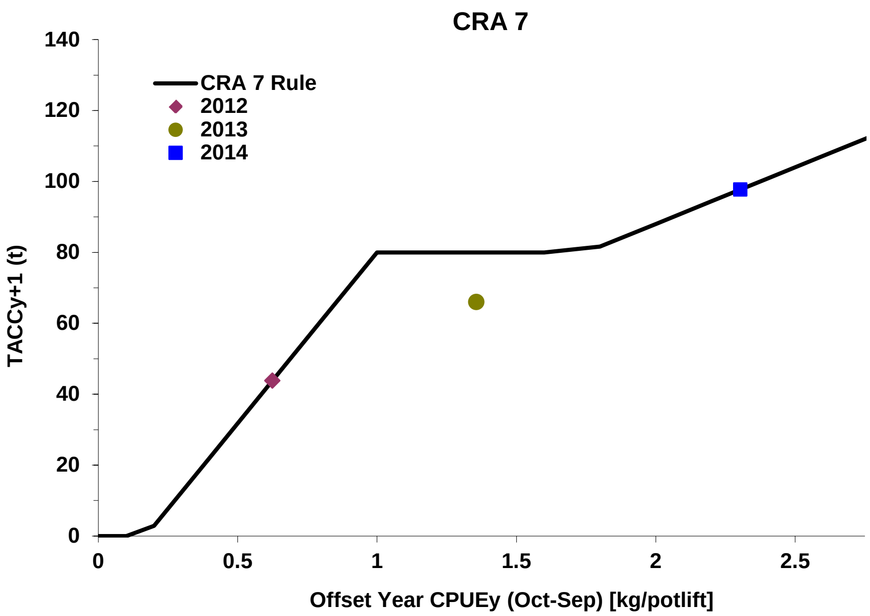


Figure 9: The CRA 7 management procedure, showing the TACC as a function of offset year CPUE, and showing TACCs resulting from the rule evaluations performed in 2012 through to 2104.

The Minister accepted this rule in early 2013 for the 2013–14 fishing year. The input offset-year CPUE was 0.625 kg/potlift, which generated a TACC of 43.96 t, rounded to 44 t by MPI, which in turn generated a TAC of 64 t when the non-commercial allowances of 20 t were added (Table 20). CPUE doubled in 2012–13 to 1.356 kg/potlift, resulting in a provisional TACC of 80 t. But this would have been a larger increase than the 50% maximum allowed by the rule. The TACC was set at 66.0 t and the TAC was set at 86.0 t. In November 2014, CPUE had increased further to 2.3036 kg/potlift, a 48% increase, which gives a proposed TACC of 97.72 t (Figure 9).

Table 20: History of the CRA 7 management procedure and proposed limit to the commercial fishery in the 2015–16 fishing year. "Rule result" is the result of the management procedure after operation of all its components including thresholds.

Year	Applied to fishing year	Offset-year CPUE (kg/potlift)	Rule result: TACC (t)	TACC (t)	TAC (t)
2012	2013–14	0.625	43.96	44.0	64.0
2013	2014–15	1.356	66	66.0	86.0
2014	2014–16 (proposed)	2.3036	97.72	–	–

4.7 Management Procedure for CRA 8

CRA 8 has been managed since 1996 using management procedures based on the observed CPUE in the fishery. These have been revised several times, most recently in 2013, when a new management procedure was accepted by the Minister of Primary Industries for CRA 8 for the 2013-14 fishing year. If the allowances are unchanged, the 2013 management procedure is identical to the previous one but generates a TACC instead of a TAC.

The current management procedure uses the most recent offset-year (October–September) standardised CPUE, scaled to the "LFX" destination code using the "F2" data preparation procedure, as input to generate a proposed TACC. There is no latent year; the minimum change threshold is 5% and there is no maximum change threshold.

The harvest control rule driving the CRA 8 management procedure is shown in Figure 10. TACC is constant over a wide range of CPUE; decreasing at a faster rate than CPUE when CPUE is below a threshold (1.9 kg/potlift) and increasing more slowly when CPUE is above a threshold (3.7 kg/potlift). The plateau affords stability of TACC, a performance quality requested by the CRA 8 commercial industry.

Formally, this rule is given by:

Eq. 7A $$TACC_{y+1} = 0 \qquad \textbf{for } I_y < par5$$

Eq. 7B $$TACC_{y+1} = par2\frac{I_y - par5}{par3 - par5} \qquad \textbf{for } par5 < I_y < par3$$

Eq. 7C $$TACC_{y+1} = par2 \qquad \textbf{for } par3 \le I_y \le par4$$

Eq. 7D $$TACC_{y+1} = par2\left(1 + 0.5\frac{I_y - par4}{par6 - par4}\right) \qquad \textbf{for } I_y > par4$$

where $TACC_{y+1}$ is the provisional TACC (before application of minimum and maximum change rules) in year y+1 and I_y is offset-year CPUE (kg/potlift) in year y.

In November 2012, the standardised offset-year CPUE was 3.346 kg/potlift, which led to an unchanged TACC of 962 t (Table 22). The offset-year CPUE for 2012–13 was 3.377, slightly increased from 2011–12, which resulted in a TACC that was 1.6% greater than the existing

TACC of 962 t. This increase was below the minimum change threshold of 5% and consequently there was no increase for 2014–15. In November 2014, CPUE was 3.5615, again giving a TACC on the plateau (Figure 10)

Table 21: Parameters for the plateau rule for CRA 8 adopted by the Minister in 2012.

par	"meaning"	rule 1 values
par2	plateau height	962
par3	left plateau	1.9
par4	right plateau	3.7
par5	CPUE at TACC=0	0.4535
par6	slope parameter	8.6244

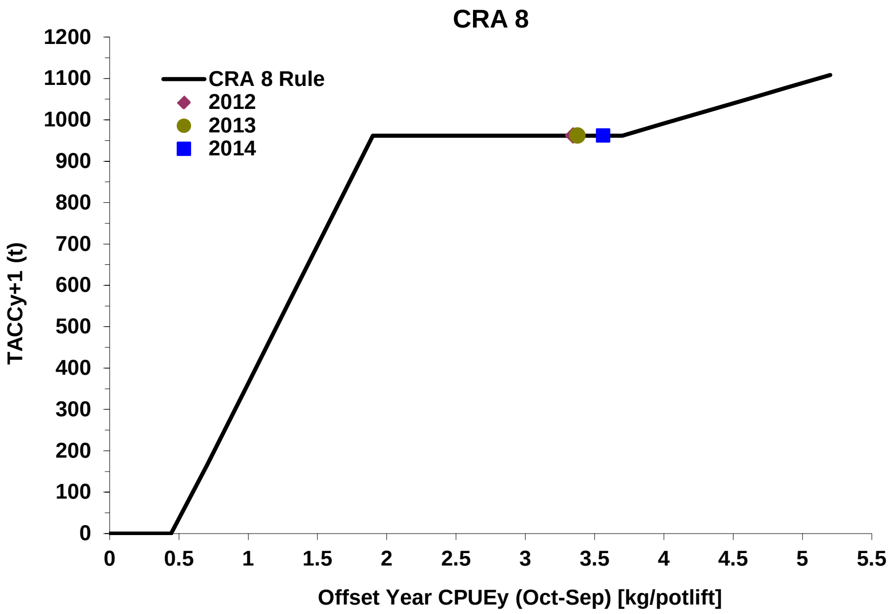


Figure 10: The CRA 8 management procedure, showing TACCs resulting from the rule evaluations performed in 2012 through to 2014.

Table 22: History of the new CRA 8 management procedure and proposed limit to the commercial fishery in the 2015–16 fishing year. "Rule result" is the result of the management procedure after operation of all its components including thresholds.

Year	Applied to fishing year	Offset-year CPUE (kg/potlift)	Rule result: TAC (t)	Rule result: TACC(t)	TACC (t)	TAC (t)
2012	2013-14	3.346	–	962	962	1053
2013	2014–15	3.377	–	962	962	1053
2014	2015–16 (proposed)	3.5615	–	962	–	–

4.8 Management Procedure for CRA 9

The management procedure for CRA 9 is based on a simple surplus-production stock assessment model and MP evaluations completed in 2013 (Breen 2014). Specifications for the CRA 9 MP include:

g) the output variable is TACC (tonnes) and the input variable is offset year (October–September) standardised CPUE (kg/potlift), calculated in November and scaled to the

"LFX" destination code using the "F2" data preparation procedure, is used as the input variable.

h) the management procedure is to be evaluated every year (no "latent year"); and

i) there is a threshold for maximum change of 15% (applied to increases only), and a minimum 5% change.

Figure 11 shows the relationship between CPUE and the TACC for the CRA 9 MP: below a CPUE of 0.5 kg/potlift, the TACC is zero (Equation 8A); between a CPUE of 0.5 and 1.0 kg/potlift, the TACC increases linearly with CPUE to a plateau of 40 tonnes (Equation 8B), which extends to a CPUE of 1.4 kg/potlift (Equation 8C). As CPUE increases above 1.4 kg/potlift, TACC increases in steps with a width of 0.75 kg/potlift and a height of 15% of the preceding TACC (Equation 8D).

Eq. 3A $$TACC'_{y+1} = 0.0 \qquad \textbf{for } I_y < 0.5$$

Eq. 3B $$TACC'_{y+1} = \left(\frac{40}{1.0-0.5}\right)\left(I_y - 0.5\right) \qquad \textbf{for } 0.5 < I_y \le 1.0$$

Eq. 3C $$TACC'_{y+1} = 40.0 \qquad \textbf{for } 1.0 < I_y \le 1.4$$

Eq. 3D $$TACC'_{y+1} = 40\left(1.15^{\operatorname{int}\left(\left(I_y-1.4\right)/0.15\right)+1}\right) \qquad \textbf{for } I_y > 1.4$$

where $TACC'_{y+1}$ is the provisional TACC result from the rule and I_y is the input offset-year CPUE.

The Minister accepted and implemented this management procedure for the 2013–14 fishing year. The TACC increased in 2013-14 in accordance with the rule evaluation (Table 23). In November 2014, the standardised offset-year CPUE was 2.095 kg/potlift. The rule generated a proposed TACC of 46 t for 2015–16, a decrease of 24.3% to the current TACC.

Table 23: History of the CRA 9 management procedure and proposed limit to the commercial fishery in the 2015–16 fishing year. "Rule result" is the result of the management procedure after operation of all its components including thresholds; '–': to be determined by the Minister

Year of analysis	Applied to fishing year	Offset-year CPUE at time of analysis (kg/potlift)	Rule result: TACC (t)	TACC (t)	TAC (t)
2013	2014–15	3.141	60.8	60.8	115.8
2014	2015–16 (proposed)	2.095	46.0	–	–

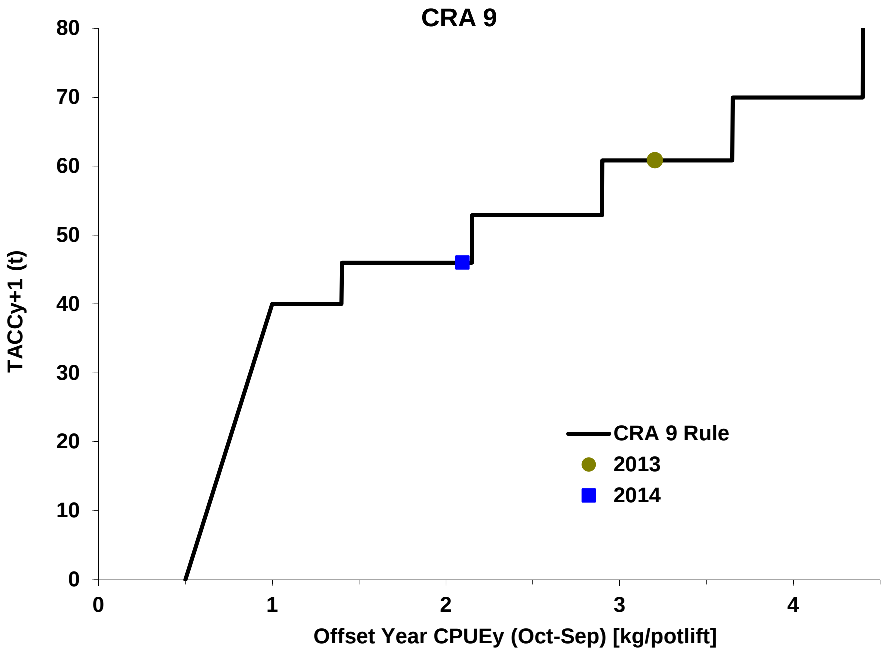


Figure 11: The CRA 9 management procedure, showing the provisional TACC in year y+1 as a function of offset year CPUE in year y, and showing the TACCs resulting from the rule evaluations performed in 2013 and 2014.

5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was last updated for the November 2012 Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of the rock lobster fisheries; a more detailed summary from an issue-by issue perspective is available in the Ministry's Aquatic Environment and Biodiversity Annual Review (http://www.mpi.govt.nz/news-resources/publications.aspx).

The environmental effects of rock lobster fishing have been covered more extensively by Breen (2005) and only those issues deemed most important there, or of particular relevance to fisheries management are covered here.

5.1 Ecosystem role

Rock lobsters are predominantly nocturnal (Williams and Dean 1989). Their diet is reported to be comprised primarily of molluscs and other invertebrates (Booth 1986; Andrew and Francis 2003). Survey and experimental work has shown that predation by rock lobsters in marine reserves is capable of influencing the demography of surf clams of the genus *Dosinia* (Langlois, Anderson et al 2005; Langlois, Anderson et al 2006).

Predation by rock lobsters has been implicated in contributing to trophic cascades in a number of studies in New Zealand and overseas (Mann and Breen 1972; Babcock, Kelly *et al* 1999; Edgar and Barrett 1999). For example, in Leigh marine reserve rock lobsters and snapper preyed on urchins, the densities of urchins decreased and kelp beds re-established in the absence of urchin grazing (Shears and Babcock 2003). This implies that rock lobster fishing is one of a number of factors that may alter the ecosystem from one more dominated by kelp beds to one more dominated by urchin barrens. Trophic cascades are hard to demonstrate however, as controlled experiments are difficult, food webs are complex and environmental factors are changeable (Breen 2005).

Published scientific observations support predation upon rock lobsters by octopus (Brock *et al* 2003), rig (King &Clarke 1984), blue cod, groper, southern dogfish (Pike 1969) and seals (Yaldwyn 1958, cited in Kensler 1967).

5.2 Fishery interactions (fish and invertebrates)

The levels of incidental catch landed from rock lobster potting were analysed for the period from 1989 to 2003 (Table 26, Bentley *et al* 2005). Non- rock lobster catch landed ranged from 2 to 11 percent of the estimated rock lobster catch weight per QMA over this period. These percentages are based on estimated catches only and it is likely that not all bycatch is reported (only the top five species are requested) and that the quality of the weight estimates will vary between species There were 129 species recorded landed from lobster pots over this period. The most frequently reported incidental species caught (comprising on average greater than 99% of the bycatch per QMA) were, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets.

5.3 Fishery interactions (seabirds and mammals)

Recovery of shags from lobster pots has been documented in New Zealand. One black shag (*Phalacrcorax carbo*) of 41 recovered dead from a Wairarapa banding study was found drowned in a crayfish pot hauled up from 12m depth (Sim and Powlesland 1995). A survey of rock lobster fishers on the Chatham Islands (Bell 2012) reported no shag bycatch in the past 5 years (2007/08 to 2011/12 fishing season), only 2 shag captures between 5-10 years ago (2001/02 to 2006/07 fishing season) and 18 shags caught more than 10 years ago (prior to 2000/01 season). The fishers suggested the lack of reported shag captures in the past five years was attributable to changes in pot design and baiting methodologies.

From January 2000 there have been eighteen reported entanglements of sixteen marine mammals attributed to commercial or recreational rock lobster pot lines from around New Zealand, mainly around Kaikoura (DOC Marine Mammal Entanglement Database, available for the DOC Kaikoura office). No mortalities were observed, although mortalities are likely to be caused by prolonged entanglement, and therefore might not be observed within the same area. CRA 5 commercial fishermen work to a voluntary code of practice to avoid entanglements, recreational fishers do not. The commercial fishermen in CRA 5 also cooperate with the Department of Conservation to assist releases when entanglements occur.

5.4 Benthic impacts

Potting is the main method of targeting rock lobster and is usually assumed to have very little direct impact on non-target species. No information exists regarding the benthic impacts of potting in New Zealand.

A study on the impacts of lobster pots was completed in a report on the South Australian rock lobster fisheries (Casement and Svane 1999). This fishery is likely to be the most comparable to New Zealand as the same species of rock lobster is harvested and many of the same species are present, although the details of pots and how they are fished may differ. The report concluded that the mass of algae removed in pots probably has no ecological significance.

Two other studies provide results from other parts of the world, but the comparability of these studies to New Zealand is questionable given differences in species and fishing techniques. The Western Australia Fishery Department calculated the proportion of corals (the most sensitive fauna) likely to be impacted by potting and concluded they were low; i.e. between 0.1 and 0.3% per annum (Department of Fisheries Western Australia 2007). This kind of calculation for the New Zealand fishery would require better habitat maps than currently exist for most parts of the coast (Breen 2005) as well as finer scale catch information than the Ministry currently possesses. Direct effects of potting on the benthos have been studied in Great Britain (Eno *et al* 2001) and 4 weeks of intensive potting resulted in no significant effects on any of the rocky-reef fauna quantified. Observations in this paper indicated sea pens were bent (but not damaged) and one species of coral was damaged by pots.

The only regulatory limitation on where lobster pots can be used is inside marine reserve boundaries; however, in Fiordland four areas within marine reserves have been designated for commercial pot storage due to the shortage of suitable space (Fiordland Marine Guardians 2008). Likewise, in the Taputeranga marine reserve (Wellington) an area is designated for vessel mooring and the storage of 'holding pots' by commercial fishermen.

5.5 Other considerations

An area near North Cape is currently closed to packhorse lobster fishing to mitigate sub-legal handling disturbance in this area. This closure was generated due to the smaller sizes of animals there and results from a tagging study that showed movement away from this area into nearby fished areas (Booth 1979).

5.6 Key information gaps

Breen (2005) identified that the most likely areas to cause concern for rock lobster fishing in a detailed risk assessment were: ghost fishing, everyday bycatch and its effect on bycatch species, effects on habitats and protected species, and indirect effects on marine communities caused by the removal of large predators. At this time no prioritisation has been applied to this list.

6. STOCK ASSESSMENT

A new stock assessment was completed in 2013 for CRA 2 using the multi-stock length-based model. An operating model was also developed for CRA9 using a production model to enable management procedures to be evaluated for this stock. The CRA 9 results are also reported in this report. This section also repeats stock assessment results for other stocks from previous Mid-Year Plenary documents. The text relating to these other stocks has not been updated from the originals and reflects the TAC, TACC and allowances that were current at the time each assessment was completed.

6.1 CRA 1

This section describes a new stock assessment made for CRA 1 in 2014.

Model structure

A single-stock version of the multi-stock length-based model (MSLM, Haist et al. 2009) was fitted to data from CRA 1, including seasonal standardised CPUE from 1979-2013, length frequencies from observer and voluntary (logbook) catch sampling, and tag-recapture data. Historical catch rate data from 1963-73 was not included. The model used an annual time step from 1945 through 1978 and then used a seasonal time step with autumn-winter (AW, April through September) and spring-summer (SS) from 1979 through 2013. The model had 93 length bins, 31 for each sex group (males, immature and mature females), each 2 mm TW wide, beginning at a left-hand edge of 30 mm TW.

The reconstruction assumed that the stock was unexploited before 1945. MLS and escape gap regulations in 1945 differed from those in 2013. To accommodate these differences, the model incorporated a time series of MLS regulations by sex and modelled escape gap regulation changes by estimating separate selectivity functions before and after 1993. A comparison of landed commercial grade weights with observer length frequency data converted to an equivalent weight distribution indicated that it was not necessary to adjust for the discarding of legal lobsters in CRA 1. Data used in the assessment and their sources are listed in Table 24.

Table 24: Data types and sources available for the 2014 stock assessment of CRA 1. Fishing years are named from the first 9 months, *viz.* 1998–99 is called 1998. NA – not applicable or not used; MPI – NZ Ministry for Primary Industries; NZ RLIC – NZ Rock Lobster Industry Council Ltd.; FSU – Fisheries Statistics Unit; CELR – catch and effort landing returns; NIWA – National Institute of Water and Atmosphere.

Data type	Data source	CRA 1 Begin year	CRA 1 End year
CPUE	FSU & CELR	1979	2013
Observer proportions-at-size	MPI and NZ RLIC	1997	2013
Logbook proportions-at-size	NZ RLIC	1993	2013
Tag recovery data	NZ RLIC & MFish	1975	2013
Historical MLS regulations	Annala (1983), MPI	1950	2013
Escape gap regulation changes	Annala (1983), MPI	1945	2013
Puerulus settlement	NIWA	NA	NA
Retention	NZ RLIC	NA	NA

The assessment assumed that recreational catch was proportional to the combined unstandardised SS CPUE from statistical areas 903 and 904 (east coast, North Island) from 1979 through 2013. Recreational surveys from 1994, 1996, 2011 and 2013 were used to calculate the mean ratio of recreational catch to the SS CPUE. This ratio was used to estimate recreational catch for 1979-2013 based on the SS CPUE. It was assumed that recreational catch increased linearly from 20% of the 1979 value in 1945 to the 1979 value.

The initial population in 1945 was assumed to be at an unfished equilibrium. Each season, the number of male, immature female and mature female lobsters in each size class were updated as a result of:

Recruitment: Each year, new recruits to the model were added equally for each sex for each season as a normal distribution with a mean size (32 mm) and standard deviation (2 mm), truncated at the smallest size class (30 mm). Recruitment in a specific year was determined by the parameters for base recruitment and parameters for the deviations from base recruitment. The vector of recruitment deviations in natural log space was assumed to be normally distributed with a mean of zero. Recruitment deviations were estimated for 1945 through 2011.

Mortality: Natural, fishing and handling mortalities were applied to each sex category in each size class. Natural mortality was assumed to be constant and independent of sex and length. Fishing mortality was determined from observed catch and model biomass, modified by legal sizes, sex-specific vulnerabilities and selectivity. Handling mortality was assumed to be 10% for fish returned to the water. Two fisheries were modelled: one that operated only on fish above the size limit, excluding berried females (SL fishery – consisting of legal commercial and recreational) and one that did not respect size limits and restrictions on berried females (NSL fishery – the illegal fishery plus the Mäori customary fishery). Selectivity and vulnerability functions were otherwise the same for the SL and NSL fisheries. Vulnerability by sex category and season was estimated relative to males in AW, which were assumed to have the highest vulnerability. Instantaneous fishing mortality rates for each fishery were calculated using Newton-Raphson iterations (three and five iterations were trialed, and three iterations were used after finding little difference) using catch, model biomass and natural mortality.

Fishery selectivity: A three-parameter fishery selectivity function was assumed, with parameters describing the shapes of the ascending and descending limbs and the size at which vulnerability is at a maximum. Selectivity was estimated separately for males and females over two separate epochs, pre- and post-1993. As in previous assessments, the descending limb of the selectivity curve was fixed to prevent under-estimating the vulnerability of large lobsters.

Growth and maturation: For each size class and sex category, a growth transition matrix specified the probability of an individual lobster remaining in the same size class or growing into each of the other size classes, including smaller size classes. Maturation of females was estimated as a two-parameter logistic curve from the maturity-at-size information in the size frequency data.

Model fitting:
A total negative log-likelihood function was minimised using AD Model Builder™. The model was fitted to standardised CPUE using a lognormal likelihood, to proportions-at-length with a multinomial likelihood and to tag-recapture data with a robust normal likelihood. For the CPUE likelihoods, CVs for each index value were initially set at the standard error from the GLM analysis. Process error was subsequently added to these CVs.

Proportions-at-length, assumed to be representative of the commercial catch, were available (see Table 1) from observer catch sampling and voluntary logbooks. These data were summarised by area/month strata and weighted by the commercial catch taken in each stratum, the number of lobsters measured and the number of days sampled. Data from observers and logbooks were fitted separately. Fitting the length data followed the procedure used in 2013 for CRA 2, which differed from previous assessments which normalised across males, immature and mature females before fitting, thus fixing the sex ratios to those observed in the data. For this assessment, proportions were normalised and fitted within each sex category, with the model also estimating proportions-at-sex using a multinomial likelihood. These data were weighted within the model using the method of Francis (2011). One length frequency sample was removed from the data set because of the enormous residuals (greater than 800) generated when fitting to these data.

In the base case and all the sensitivity runs but one, it was assumed that CPUE was directly proportional to the vulnerable biomass. All runs assumed no stock-recruit relationship. Base case explorations involved experimentally weighting the datasets and inspecting the resulting standard deviations of normalised residuals and medians of absolute residuals, estimating the growth, maturity and selectivity parameters and experimenting with the fitting method for proportions-at-length. The tagging data were fitted well in this model and it was not necessary to fix the growth CV as has been done in most previous rock lobster stock assessments.

Parameters estimated in the base case and their priors are provided in Table 25. Informed normal priors were used to constrain the selectivity parameters for both sexes. This step was necessary because there were no length frequency data available to inform the first epoch (which ended in 1992 and the LF data started in 1993). The mean of the prior for each selectivity parameter was taken from the median of the posterior for the same parameter from the 2013 CRA 2 stock assessment and a CV of 20% was assumed. Fixed parameters and their values are given in Table 26.

Model projections
Bayesian inference was used to estimate the uncertainty in model estimates and short-term projections. This procedure was conducted in the following steps:

1. Model parameters were estimated by AD Model Builder™ using maximum likelihood and the prior probability distributions. These estimates are called the MPD (mode of the joint posterior distribution) estimates.

2. Samples from the joint posterior distribution of parameters were generated with Markov chain Monte Carlo (MCMC) simulations using the Metropolis-Hastings algorithm. Twenty-two million simulations were done, starting from the base case MPD, and 1000 samples were saved.

3. From each sample of the posterior, 4-year projections (2014–2017) were generated using the 2013 catches, with annual recruitment randomly sampled from a distribution based on the model's estimated recruitments from 2002–11.

Table 25: Parameters estimated and priors used in the base case assessment for CRA 1. Prior type abbreviations: U – uniform, N – normal, L – lognormal.

Parameter	Prior Type	No. of parameters	Bounds	Mean	SD	CV
ln(*R0*) (mean recruitment)	U	1	1–25	–	–	–
M (natural mortality)	L	1	0.01–0.35	0.12	–	0.4
Recruitment deviations	N [1]	67	-2.3–2.3	0	0.4	
ln(*qCPUE*)	U	1	-25–0	–	–	–
Increment at TW=50 (male & female)	U	2	1–20	–	–	–
ratio of TW=80 increment to TW=50 increment (male & female)	U	2	0.001–1.000	–	–	–
shape of growth curve (male & female)	U	2	0.1–15.0	–	–	–
TW at 50% probability female maturation	U	1	30–80	–	–	–
difference between TWs at 95% and 50% probability female maturation	U	1	3–60	–	–	–
Relative vulnerability (all sexes and seasons)	U	4	0.01–1.0	–	–	–
Shape of selectivity left limb (males & females)	N	2	1–50	males=4.1; females=9,2	males=0.82; females=1.84	–
Size at maximum selectivity (males & females)	N	2	30–90	males=55; females=64	males=11; females=12.8	–

[1] Normal in natural log space = lognormal (bounds equivalent to –10 to 10)

Table 26: Fixed values used in base case assessment for CRA 1.

Value	CRA 1
Shape parameter for CPUE vs biomass	1.0
Minimum std. dev. of growth increment	1.6
Std. dev. of observation error of increment	0.6
Shape of growth density-dependence	0.0
Handling mortality	10%
Process error for CPUE	0.25
Year of selectivity change	1993
Current male size limit (mm TW)	54
Current female size limit (mm TW)	60
First year for recruitment deviations	1945
Last year for recruitment deviations	2011
Relative weight for male length frequencies	2.52
Relative weight for immature female length frequencies	1.0
Relative weight for mature female length frequencies	2.23
Relative weight for proportions-at-sex	14
Relative weight for CPUE	2.8
Relative weight for tag-recapture data	0.7

Performance Indicators and Results

Vulnerable biomass in the assessment model was determined by the MLS, selectivity, relative sex and seasonal vulnerability and berried state for mature females. All mature females in AW were assumed to be berried and not vulnerable to the SL fishery, and not berried, and thus vulnerable, in SS.

Agreed indicators are summarised in Table 27. After inspection of the vulnerable biomass trajectory, the RLFAWG agreed to keep *Bref* as defined in the previous (2002) stock assessment (mean 1979–1988 biomass), using the current MLS and selectivity.

Base case results (Figure 12 and Table 28) suggest that AW biomass decreased to a low point in the early-1970s, remained low until the mid-1990s and has increased since. Median projected biomass, with current catches over four years, was slightly higher than the current biomass. Estimated current biomass is well above *Bref* and neither current nor projected biomass was near the soft limit of 20% *SSB0*.

MCMC sensitivity trials were also made:

- *Uniform M:* same as the base case except that *M* was estimated with an uninformative prior

- *Alt recreational catch*: uses an alternative procedure to estimate recreational catch, resulting in an increasing catch series
- *Half illegal catch*: uses half the base case illegal catch trajectory
- *Double illegal catch*: uses twice the base case illegal catch trajectory
- *Fixed M=0.2*: same as the base case except *M* fixed at 0.2

Results from the base case and sensitivity trials are compared in Table 27.

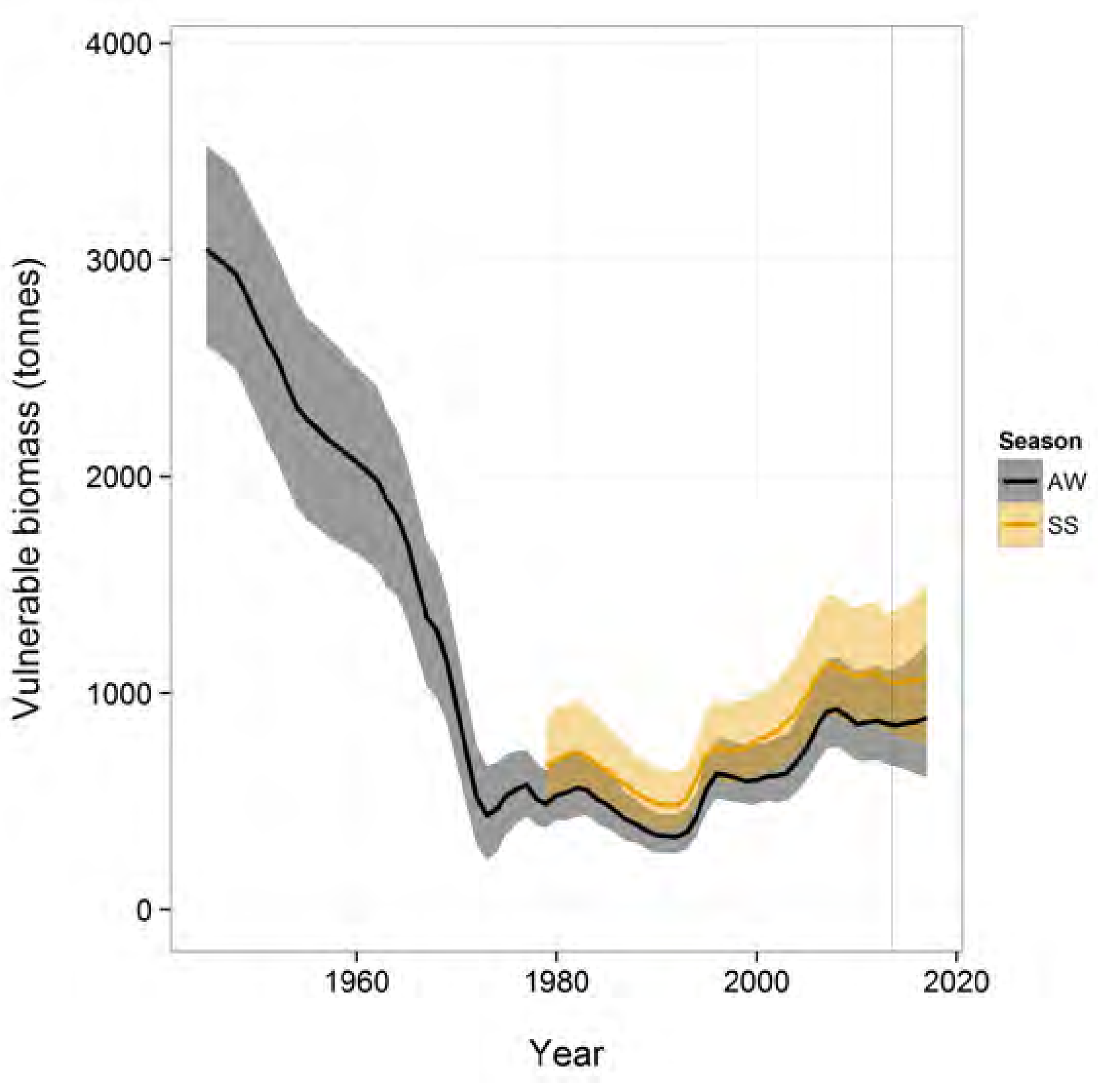


Figure 12: Posterior distributions of the CRA 1 base case vulnerable biomass and projected vulnerable biomass by season from 1945 to 2013. Shaded areas show the 90% credibility intervals and the solid line is the median of the posterior distributions. The vertical line shows 2013, the final fishing year of the model reconstruction. Biomass before 1979 is annual, but is plotted using the AW coding.

Table 27: Performance indicators used in the CRA 1 stock assessment.

	Reference points
Bmin	The lowest beginning AW vulnerable biomass in the series
Bcurrent	Beginning of season AW vulnerable biomass for 2014
Bref	Beginning of AW season mean vulnerable biomass for 1979–88
Bproj	Projected beginning of season AW vulnerable biomass (ie, 2017)
Bmsy	Beginning of season AW vulnerable biomass associated with MSY, calculated by doing deterministic forward projections with recruitment *R0* and current fishing patterns
MSY	Maximum sustainable yield (sum of AW and SS SL catches) found by searching across a range of multipliers on *F*.
Fmult	The multiplier that produced *MSY*
SSBcurr	Current spawning stock biomass at start of AW season
SSBproj	Projected spawning stock biomass at start of AW season (2017)
SSBmsy	Spawning stock biomass at start of AW season associated with *MSY*
CPUE indicators	
CPUEcurrent	CPUE at *Bcurrent*
CPUEproj	CPUE at *Bproj*
CPUEmsy	CPUE at *Bmsy*
Performance indicators	
Bcurrent / Bmin	ratio of *Bcurrent* to *Bmin*
Bcurrent / Bref	ratio of *Bcurrent* to *Bref*
Bcurrent / Bmsy	ratio of *Bcurrent* to *Bmsy*
Bproj / Bcurrent	ratio of *Bproj* to *Bcurrent*
Bproj / Bref	ratio of *Bproj* to *Bref*
Bproj / Bmsy	ratio of *Bproj* to *Bmsy*
SSBcurr/SSB0	ratio of *SSBcurrent* to *SSB0*
SSBproj/SSB0	ratio of *SSBproj* to *SSB0*
SSBcurr/SSBmsy	ratio of *SSBcurrent* to *SSBmsy*
SSBproj/SSBmsy	ratio of *SSBproj* to *SSBmsy*
SSBproj/SSBcurr	ratio of *SSBproj* to *SSBcurrent*
USLcurrent	The current exploitation rate for SL catch in AW
USLproj	Projected exploitation rate for SL catch in AW (2017)
USLproj/USLcurrent	ratio of SL projected exploitation rate to current SL exploitation rate
Btotcurrent	Total biomass (all sizes and sex, regardless of maturity) at beginning of AW 2014
Btotcurrent/Btot0	Total biomass[2014]/[equilbrium unfished total biomass]
Ntotcurrent	Total numbers (all sizes and sex, regardless of maturity) at beginning of AW 2014
Ntotcurrent/Ntot0	Total numbers[2014]/[equilbrium unfished total numbers]
Probabilities	
P*(Bcurrent > Bmin)*	probability *Bcurrent* > *Bmin*
P*(Bcurrent > Bref)*	probability *Bcurrent* > *Bref*
P*(Bcurrent > Bmsy)*	probability *Bcurrent* > *Bmsy*
P*(Bproj > Bmin)*	probability *Bproj* > *Bmin*
P*(Bproj > Bref)*	probability *Bproj* > *Bref*
P*(Bproj > Bmsy)*	probability *Bproj* > *Bmsy*
P*(Bproj > Bcurrent)*	probability *Bproj* > *Bcurrent*
P*(SSBcurr>SSBmsy)*	probability *SSBcurr>SSBmsy*
P*(SSBproj>SSBmsy)*	probability *SSBproj>SSBmsy*
P*(USLproj>USLcurr)*	probability SL exploitation rate *proj* > SL exploitation rate *current*
P*(SSBcurr<0.2SSB0)*	soft limit: probability *SSBcurrent* < 20% *SSB0*
P*(SSBproj<0.2SSB0*	soft limit: probability *SSBproj* < 20% *SSB0*
P*(SSBcurr<0.1SSB0)*	hard limit: probability *SSBcurrent* < 10% *SSB0*
P*(SSBproj<0.1SSB0)*	hard limit: probability *SSBproj* < 10% *SSB0*
P(*Bcurr*<50%*Bref*)	soft limit: probability *Bcurr* < 50% *Bref*
P(*Bcurr*<25%*Bref*)	hard limit: probability *Bcurr* < 25% *Bref*
P(*Bproj*<50%*Bref*)	soft limit: probability *Bproj* < 50% *Bref*
P(*Bproj*<25%*Bref*)	hard limit:probability *Bproj*< 25% *Bref*

Table 28: Assessment results: median and probability indicators for CRA 1 from the base case MCMC and sensitivity trials. Biomass in tonnes and CPUE in kg/pot.

indicator	basecase	uniform *M*	Alt recreational catch	Half illegal catch	Double illegal catch	Fixed *M*=0.2
Bmin	315.1	332.9	340.3	286.4	402.8	433.6
Bcurr	850.5	882.3	889.0	779.5	1076.0	1187.4
Bref	493.1	509.5	516.1	451.9	618.5	690.4
Bproj	884.4	926.4	931.4	808.2	1105.3	1213.0
Bmsy	421.0	415.3	427.2	370.3	493.8	268.2
MSY	161.1	166.2	160.5	176.9	137.1	228.4
Fmult	1.92	2.07	1.80	2.16	1.74	6.43
SSBcurr	811.2	823.7	831.9	734.6	975.3	974.0
SSBproj	820.3	846.2	851.9	745.4	983.2	1002.2
SSBmsy	485.1	476.6	472.0	442.1	535.8	397.9
CPUEcurrent	1.36	1.36	1.35	1.36	1.35	1.35
CPUEproj	1.39	1.41	1.39	1.41	1.37	1.37
CPUEmsy	0.635	0.589	0.607	0.609	0.585	0.249
Bcurr/Bmin	2.66	2.64	2.60	2.66	2.63	2.68
Bcurr/Bref	1.73	1.73	1.72	1.73	1.73	1.71
Bcurr/Bmsy	2.00	2.15	2.09	2.09	2.16	4.45
Bproj/Bcurr	1.02	1.03	1.03	1.03	1.02	1.02
Bproj/Bref	1.78	1.80	1.78	1.77	1.77	1.75
Bproj/Bmsy	2.08	2.23	2.19	2.18	2.21	4.54
SSBcurr/SSB0	0.500	0.513	0.514	0.507	0.514	0.684
SSBproj/SSB0	0.506	0.522	0.523	0.514	0.518	0.700
SSBcurr/SSBmsy	1.66	1.74	1.75	1.66	1.81	2.45
SSBproj/SSBmsy	1.68	1.77	1.80	1.68	1.83	2.51
SSBproj/SSBcurr	1.01	1.02	1.01	1.01	1.01	1.02
USLcurrent	0.0845	0.0817	0.083	0.093	0.067	0.0601
USLproj	0.0837	0.0798	0.079	0.092	0.067	0.0610
USLproj/USLcurrent	1.00	0.99	0.98	1.00	1.02	1.02
Btotcurrent	1949	2006	2,014	1,768	2,421	2636
Btotcurrent/Btot0	0.395	0.412	0.412	0.398	0.425	0.627
Ntotcurrent	3,205,570	3,327,850	3,345,750	2,926,430	4,039,080	4,638,490
Ntotcurrent/Ntot0	0.622	0.635	0.648	0.616	0.656	0.800
P(Bcurr>Bmin)	1	1	1	1	1	1
P(Bcurr>Bref)	1	1	1	1	1	1
P(Bcurr>Bmsy)	1	0.999	1	0.999	1	1
P(Bproj>Bmin)	1	1	1	1	1	1
P(Bproj>Bref)	0.999	1	1	0.998	1	0.999
P(Bproj>Bmsy)	0.997	0.998	0.998	0.996	0.999	1
P(Bproj>Bcurr)	0.576	0.611	0.612	0.592	0.552	0.562
P(SSBcurr>SSBmsy)	1	1	1	1	1	1
P(SSBproj>SSBmsy)	0.998	1	0.999	0.997	0.999	1
P(USLproj>USLcurr)	0.507	0.478	0.443	0.486	0.533	0.577
P(SSBcurr<0.2SSB0)	0	0	0	0	0	0
P(SSBproj<0.2SSB0	0	0	0	0	0	0
P(SSBcurr<0.1SSB0)	0	0	0	0	0	0
P(SSBproj<0.1SSB0)	0	0	0	0	0	0

The median *Bref* was larger than the median *Bmsy* in all trials. Current biomass was larger than *Bmin* and *Bmsy* with 100% probability in all cases. Projected biomass was greater than the current biomass with greater than 50% probability in all trials. Projected biomass had a median of over double *Bmsy*, and the probability of being above *Bmsy* was near 100% in all cases.

Indicators based on *SSBmsy*
The historical track of biomass versus fishing intensity is shown in Figure 13. The phase space in the plot is spawning biomass on the abscissa and fishing intensity on the ordinate. Thus high biomass/low fishing intensity is in the lower right-hand corner, where a stock would be when fishing first began, and low biomass/high intensity is in the upper left-hand corner, where an uncontrolled fishery is likely to go. The x-axis is spawning stock biomass *SSB* in year *y* as a proportion of the unfished spawning stock, *SSB0*. *SSB0* is constant for all years of a run, but varies through the 1000 samples from the posterior distribution.

The y-axis is fishing intensity in year *y* as a proportion of the fishing intensity (*Fmsy*) that would have given *MSY* under the fishing patterns in year *y*. Fishing patterns include MLS, selectivity, the seasonal catch split and the balance between SL and NSL catches. *Fmsy* varies every year because the fishing patterns change. It was calculated with a 50-year projection for each year in each run, with the NSL catch held constant at that year's value, deterministic recruitment at *R0* and a range of multipliers on the SL catch *F*s estimated for year *y*. The *F* that gave *MSY* is *Fmsy*, and the multiplier was *Fmult*.

Each point on the figure shows the median of the posterior distributions of biomass ratio and fishing intensity ratio. The vertical line in the figure is the median (line) and 90% interval (shading) of the posterior distribution of *SSBmsy* as a proportion of *SSB0*. This ratio was calculated using the fishing pattern in 2013. The horizontal line in the figure is drawn at 1, the fishing intensity associated with *Fmsy*. The bars at the final year of the plot show the 90% intervals of the posterior distributions of biomass ratio and fishing intensity ratio.

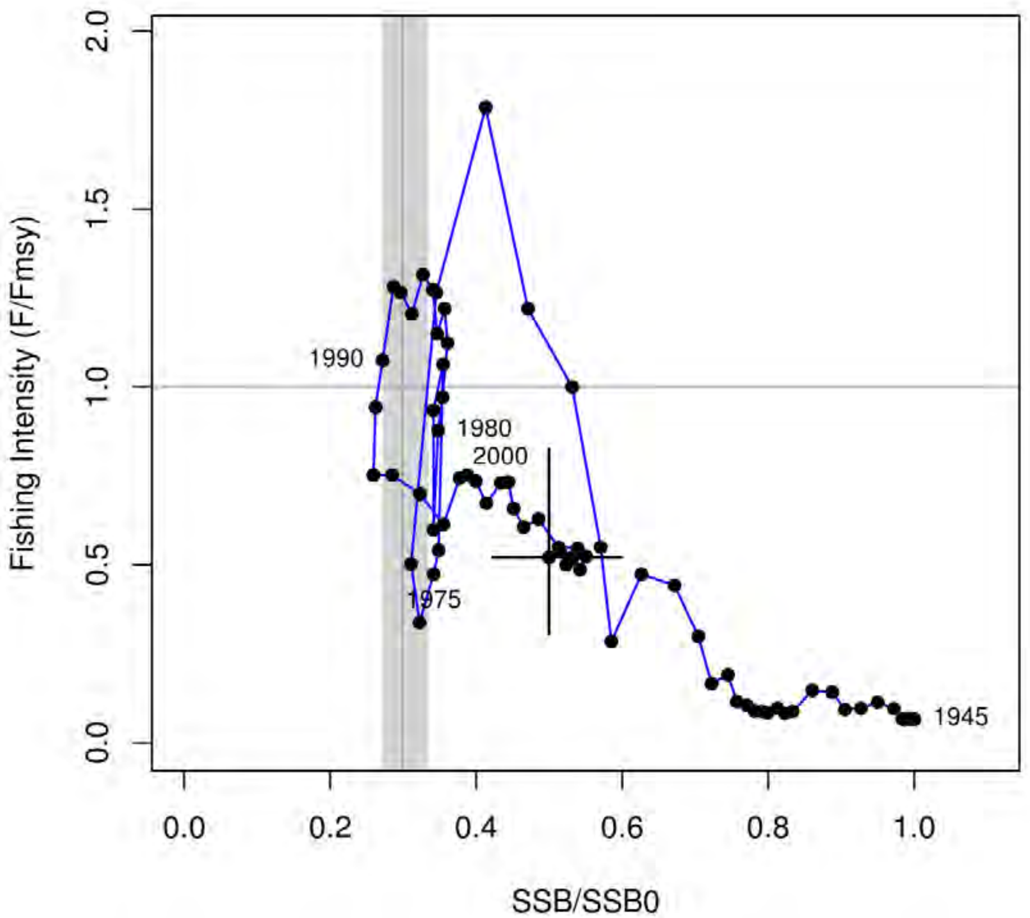


Figure 13: Snail trail summary of the CRA 1 base case model. The line tracks the median values for each axis from the MCMC posteriors and the cross marks the 90% credibility interval on both axes for the final model year (2013). The vertical line in the figure is the median (line) and 90% interval (shading) of the posterior distribution of *SSBmsy*. This ratio was calculated using the fishing pattern in 2013. The horizontal line in the figure is drawn at 1, the fishing intensity associated with *Fmsy*.

6.2 CRA 2

This section describes a new stock assessment for CRA 2 conducted in 2013.

Length frequency sampling and tagging

The CRA 2 fishing industry made a strong commitment to the voluntary logbook programme when it was first introduced in 1993 and has continued to use this design as the primary source of stock monitoring information in this fishery. CRA 2 was also identified in the mid-1990s as an important region for tagging experiments, which resulted in considerable tagging effort expended in this QMA. There is also an auxiliary observer sampling programme in CRA 2. Only 12 sampling days were assigned to this programme in recent years; the primary purpose of this additional sampling serves as a check on the voluntary logbook programme. Both sets of data were used in the 2013 stock assessment.

Model structure

A single-stock version of the multi-stock length-based model (MSLM) (Haist et al 2009) was fitted to data from CRA 2: annual catch rate data from 1963 to 1973, seasonal standardised CPUE from 1979-2012, length frequencies from observer and voluntary (logbook) catch sampling, and tag-recapture data. The model used an annual time step from 1945 through 1978 and then used a seasonal time step with autumn-winter (AW, April through September) and spring-summer (SS) from 1979 through 2011. The model had 93 length bins, 31 for each sex group (males, immature and mature females), each 2 mm TW wide, beginning at left-hand edge 30 mm TW.

The reconstruction assumed that the stock was unexploited before 1945. MLS and escape gap regulations in 1945 differed from those in 2012. To accommodate these differences, the model incorporated time series of MLS regulations by sex and modelled escape gap regulation changes by estimating separate selectivity functions before 1993. Although the model was modified in 2012 to simulate the return of legal lobsters to the sea in CRA 8, a retention analysis of voluntary logbook data indicated this was unnecessary for CRA 2. Data and their sources are listed in Table 29.

The assessment assumed that recreational catch was proportional to SS CPUE from 1979 through 2012. It used recreational surveys from 1994, 1996 and 2011 to calculate the mean ratio of recreational catch to SS CPUE; it used that relation to estimate recreational catch for 1979-2012 from SS CPUE; it assumed that recreational catch increased linearly from 20% of the 1979 value in 1945 to the 1979 value.

Table 29: Data types and sources for the 2013 stock assessment of CRA 2. Fishing years are named from the first 9 months, *viz.* 1998–99 is called 1998. NA – not applicable or not used; MPI – NZ Ministry for Primary Industries; NZ RLIC – NZ Rock Lobster Industry Council Ltd.; FSU: Fisheries Statistics Unit; CELR: catch and effort landing returns; NIWA: National Institute of Water and Atmosphere.

Data type	Data source	CRA 2 Begin year	CRA 2 End year
CPUE	FSU & CELR	1979	2012
Historical CPUE	Annala & King (1983)	1963	1973
Observer proportions-at-size	MPI and NZ RLIC	1986	2012
Logbook proportions-at-size	NZ RLIC	1993	2012
Tag recovery data	NZ RLIC & MFish	1983	2011
Historical MLS regulations	Annala (1983), MPI	1974	2012
Escape gap regulation changes	Annala (1983), MPI	1974	2012
Puerulus settlement	NIWA	NA	NA
Retention	NZ RLIC	NA	NA

The initial population in 1945 was assumed to be in unfished equilibrium. Each season, numbers of male, immature female and mature female lobsters in each size class were updated as a result of:

Recruitment: Each year, new recruits to the model were added equally for each sex for each season as a normal distribution with a mean size (32 mm) and standard deviation (2 mm), truncated at the smallest size class (30 mm). Recruitment in a specific year was determined by the parameters for base recruitment and parameters for the deviations from base recruitment. The vector of recruitment deviations in natural log space was assumed to be normally distributed with a mean of zero. Recruitment deviations were estimated for 1945 through 2010.

Mortality: Natural, fishing and handling mortalities were applied to each sex category in each size class. Natural mortality was assumed to be constant and independent of sex and length. Fishing mortality was determined from observed catch and model biomass, modified by legal sizes, sex-specific vulnerabilities and selectivity. Handling mortality was assumed to be 10% for fish returned to the water. Two fisheries were modelled: one that operated only on fish above the size limit, excluding berried females (SL fishery – including legal commercial and recreational) and one that did not respect size limits and restrictions on berried females (NSL fishery – the illegal fishery plus the Mäori customary fishery). Selectivity and vulnerability functions were otherwise the same for the SL and NSL fisheries. Vulnerability by sex category and season was estimated relative to males in AW, which were assumed to have the highest vulnerability. Instantaneous fishing mortality rates for each fishery were calculated using Newton-Raphson iteration (four iterations, based on previous experiments, for the MPDs and three, based on experiment, for the McMCs) from catch, model biomass and natural mortality.

Fishery selectivity: A three-parameter fishery selectivity function was assumed, with parameters describing the shapes of the ascending and descending limbs and the size at which vulnerability is at a maximum. Selectivity was estimated for two separate epochs, pre–1993 and 1993–2011. As in previous assessments for the past decade, the descending limb of the selectivity curve was fixed to prevent under-estimating vulnerability of large lobsters.

Growth and maturation: For each size class and sex category, a growth transition matrix specified the probability of an individual remaining in the same size class or growing into each of the other size classes. Maturation of females was estimated as a two-parameter logistic curve from the maturity-at-size information in the size frequency data.

Model fitting:
A total negative log-likelihood function was minimised using AD Model Builder™. The model was fitted to standardised CPUE using lognormal likelihood, to proportions-at-length with multinomial likelihood and to tag-recapture data with robust normal likelihood. For the CPUE likelihoods, CVs for each index value were initially set at the standard error from the GLM analysis. Process error was subsequently added to these CVs.

Proportions-at-length, assumed to be representative of the commercial catch, were available (see Table 28) from observer catch sampling and voluntary logbooks: data were summarised by area/month strata and weighted by the commercial catch taken in each stratum, the number of lobsters measured and the number of days sampled. Data from observers and logbooks were fitted separately. Fitting differed from previous assessments, in which proportions-at-length were normalised across males, immature and mature females. In this assessment, proportions were normalised and fitted within each sex class, and the model estimated proportions-at-sex separately with multinomial likelihood. These data were weighted within the model using the method of Francis (2011).

In the base case, it was assumed that CPUE was directly proportional to vulnerable biomass, that growth was density-dependent and that there is no stock-recruit relationship. Base case explorations involved experimentally weighting the datasets and inspecting the resulting standard deviations of normalised residuals and medians of absolute residuals, experimenting with fixed CVs for growth, experimenting with the fitting method for proportions-at-length and the growth model and exploring other model options such as CPUE shape. The growth CV was fixed after early explorations.

Parameters estimated in the base case and their priors are provided in Table 30. Fixed parameters and their values are given in Table 31.

Table 30: Parameters estimated and priors used in the base case assessment for CRA 2. Prior type abbreviations: U – uniform; N – normal; L – lognormal.

Parameter	Prior Type	No. of parameters	Bounds	Mean	SD	CV
ln(*R0*) (mean recruitment)	U	1	1–25	–	–	–
M (natural mortality)	L	1	0.01–0.35	0.12	–	0.4
Recruitment deviations	N [1]	66	-2.3–2.3	0	0.4	
ln($qCPUE$)	U	1	-25–0	–	–	–
ln(qCR)	U	1	-25–2	–	–	–
Increment at TW=50 (male & female)	U	2	1–20	–	–	–
ratio of TW=80 increment to TW=50 increment (male & female)	U	2	0.001–1.000	–	–	–
shape of growth curve (male & female)	U	2	0.1–15.0	–	–	–
TW at 50% probability female maturation	U	1	30–80	–	–	–
difference between TWs at 95% and 50% probability female maturation	U	1	3–60	–	–	–
Relative vulnerability (all sexes and seasons)	U	4	0.01–1.0	–	–	–
Shape of selectivity left limb (males & females)	U	2	1–50	–	–	–
Size at maximum selectivity (males & females)	U	2	30–70	–	–	–
Shape of growth density-dependence	U	1	0–1	–	–	–

[1] Normal in natural log space = lognormal (bounds equivalent to –10 to 10)

Table 31: Fixed values used in base case assessment for CRA 2

Value	CRA 2
Shape parameter for CPUE vs biomass	1.0
Minimum std. dev. of growth increment	1.6
Std. dev. of observation error of increment	0.6
Handling mortality	10%
Process error for CPUE	0.25
CR relative sigma	0.3
Year of selectivity change	1993
Current male size limit (mm TW)	54
Current female size limit (mm TW)	60
First year for recruitment deviations	1945
Last year for recruitment deviations	2010
Relative weight for male length frequencies	2.383
Relative weight for immature female length frequencies	2.308
Relative weight for mature female length frequencies	2.876
Relative weight for proportions-at-sex	10
Relative weight for CPUE	5.0
Relative weight for CR	7.0
Relative weight for tag-recapture data	0.6

Model projections

Bayesian estimation procedures were used to estimate the uncertainty in model estimates and short-term projections. This procedure was conducted in the following steps:

4. Model parameters were estimated by AD Model Builder™ using maximum likelihood and the prior probability distributions. These estimates are called the MPD (mode of the joint posterior distribution) estimates;

5. Samples from the joint posterior distribution of parameters were generated with Markov chain - Monte Carlo (McMC) simulations using the Hastings-Metropolis algorithm; five million simulations were made, starting from the base case MPD, and 1000 samples were saved.

6. From each sample of the posterior, 4-year projections (2013–2016) were generated using the 2012 catches, with annual recruitment randomly sampled from a distribution based on the model’s estimated recruitments from 2001–10.

Performance Indicators and Results

Vulnerable biomass in the assessment model was determined by the MLS, selectivity, relative sex and seasonal vulnerability and berried state for mature females. All mature females were assumed to be berried, not vulnerable to the SL fishery, in AW and not berried, thus vulnerable, in SS.

Agreed indicators are summarised in Table 32. After inspection of the vulnerable biomass trajectory, the RLFAWG agreed that *Bref* should be based on the 1979-81 vulnerable biomass calculated with the current MLS and selectivity.

Base case results (Figure 14 and Table 32) suggested that AW biomass decreased to a low point in the mid-1980s, increased to a high in the mid-1990s and decreased, remaining relatively stable from 2002. Estimated current biomass was about 80% of *Bref*. Median projected biomass, with current catches over four years, was about the same as current biomass. Neither current nor projected biomass was near the soft limit of 20% *SSB0*.

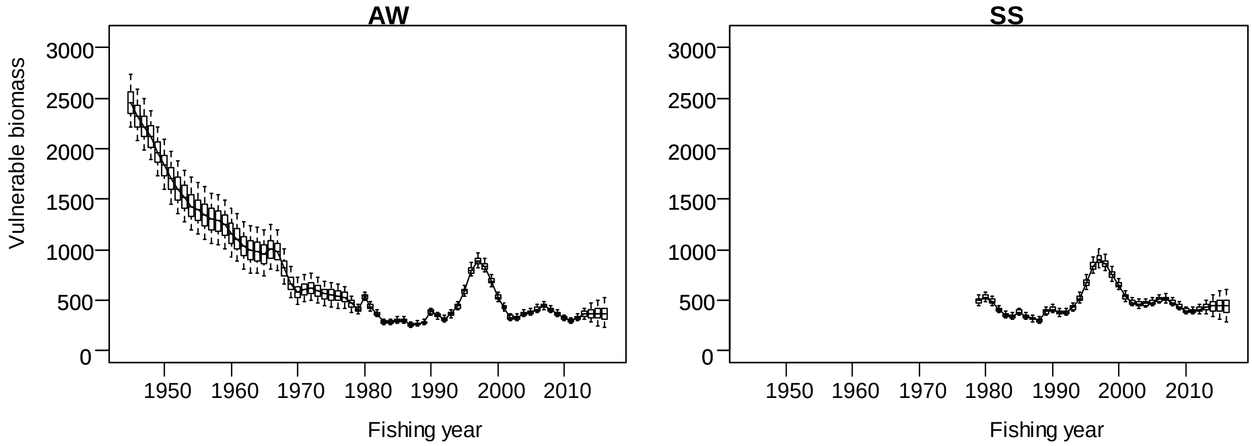


Figure 5: Posterior distributions of the CRA 2 base case McMC vulnerable biomass trajectory by season. Before 1979 there was a single time step, shown in AW. For each year the box spans the 25th and 75th quantiles and the whiskers span the 5th and 95th quantiles.

Table 32: Performance indicators used in the CRA 2 stock assessment. [Continued on next page]

Reference points	
Bmin	The lowest beginning AW vulnerable biomass in the series
Bcurrent	Beginning of season AW vulnerable biomass for the year the stock assessment is performed
Bref	Beginning of AW season mean vulnerable biomass for 1979–81
Bproj	Projected beginning of season AW vulnerable biomass (ie, the year of stock assessment plus 4 years)
Bmsy	Beginning of season AW vulnerable biomass associated with MSY, calculated by doing deterministic forward projections with recruitment *R0* and current fishing patterns
MSY	Maximum sustainable yield (sum of AW and SS SL catches) found by searching a across a range of multipliers on *F*.
Fmult	The multiplier that produced *MSY*
SSBcurr	Current spawning stock biomass at start of AW season
SSBproj	Projected spawning stock biomass at start of AW season
SSBmsy	Spawning stock biomass at start of AW season associated with *MSY*
CPUE indicators	
CPUEcurrent	CPUE at *Bcurrent*
CPUEproj	CPUE at *Bproj*
CPUEmsy	CPUE at *Bmsy*
Performance indicators	
Bcurrent / Bmin	ratio of *Bcurrent* to *Bmin*
Bcurrent / Bref	ratio of *Bcurrent* to *Bref*
Bcurrent / Bmsy	ratio of *Bcurrent* to *Bmsy*
Bproj / Bcurrent	ratio of *Bproj* to *Bcurrent*
Bproj / Bref	ratio of *Bproj* to *Bref*
Bproj / Bmsy	ratio of *Bproj* to *Bmsy*
SSBcurr/SSB0	ratio of *SSBcurrent* to *SSB0*
SSBproj/SSB0	ratio of *SSBproj* to *SSB0*
SSBcurr/SSBmsy	ratio of *SSBcurrent* to *SSBmsy*
SSBproj/SSBmsy	ratio of *SSBproj* to *SSBmsy*
SSBproj/SSBcurr	ratio of *SSBproj* to *SSBcurrent*
USLcurrent	The current exploitation rate for SL catch in AW
USLproj	Projected exploitation rate for SL catch in AW
USLproj/USLcurrent	ratio of SL projected exploitation rate to current SL exploitation rate
Probabilities	
P*(Bcurrent > Bmin)*	probability *Bcurrent > Bmin*
P*(Bcurrent > Bref)*	probability *Bcurrent > Bref*
P*(Bcurrent > Bmsy)*	probability *Bcurrent > Bmsy*
P*(Bproj > Bmin)*	probability *Bproj > Bmin*

Table 32 [Continued]: Performance indicators used in the CRA 2 stock assessment.

P*(Bproj > Bref)*	probability *Bproj > Bref*
P*(Bproj > Bmsy)*	probability *Bproj > Bmsy*
P*(Bproj > Bcurrent)*	probability *Bproj > Bcurrent*
P*(SSBcurr>SSBmsy)*	probability *SSBcurr>SSBmsy*
P*(SSBproj>SSBmsy)*	probability *SSBproj>SSBmsy*
P*(USLproj>USLcurr)*	probability SL exploitation rate *proj* > SL exploitation rate *current*
P*(SSBcurr<0.2SSB0)*	soft limit CRA 8: probability *SSBcurrent* < 20% *SSB0*
P*(SSBproj<0.2SSB0*	soft limit CRA 8: probability *SSBproj* < 20% *SSB0*
P*(SSBcurr<0.1SSB0)*	hard limit CRA 8: probability *SSBcurrent* < 10% *SSB0*
P*(SSBproj<0.1SSB0)*	hard limit CRA 8: probability *SSBproj* < 10% *SSB0*
P(*Bcurr*<50%*Bref*)	soft limit CRA 7: probability *Bcurr* < 50% *Bref*
P(*Bcurr*<25%*Bref*)	hard limit CRA 7: probability *Bcurr* < 25% *Bref*
P(*Bproj*<50%*Bref*)	soft limit (CRA 7): probability *Bproj* < 50% *Bref*
P(*Bproj*<25%*Bref*)	hard limit (CRA 7):probability *Bproj*< 25% *Bref*

MCMC sensitivity trials were also made:

- *CPUEpow:* estimating the relation between biomass and CPUE (linear in the base case) with either 3 or 5 Newton-Raphson iterations in the model
- *OldLFs*: estimating the LF fits in the way that was used in previous stock assessments, fitting to proportions-at-size and proportions-at-sex simultaneously
- *untruncLFs*: fitting to LFs records that had the raw record weights (in the base case, weights were truncated to lie between 1 and 10)
- *noDD*: with the density-dependence parameter for growth turned off
- *HiRec*: using a doubled recreational catch vector

Results from the base case and sensitivity trials are compared in Table 33.

Table 33: Assessment results: median and probability indicators for CRA 2 from the base case McMC and sensitivity trials; biomass in tonnes and CPUE in kg/pot.

indicator	basecase	CPUE pow3	CPUE pow5	Old LFs	Untrunc LFs	noDD	HiRec
Bmin	255.2	303.4	304.5	259.3	282.3	281.5	297.3
Bcurr	365.8	417.2	419.5	360.9	386.4	389.6	425.9
Bref	459.6	493.4	495.4	463.4	518.9	506.0	532.9
Bproj	369.7	424.1	428.0	363.0	388.3	396.3	526.3
Bmsy	268.2	269.0	268.6	306.8	219.1	307.3	364.3
MSY	265.8	272.5	273.1	256.8	277.7	247.8	316.2
Fmult	1.20	1.43	1.44	0.95	1.72	1.03	0.98
SSBcurr	528.8	572.6	574.1	520.2	604.4	568.3	609.0
SSBproj	564.5	607.7	611.5	551.1	634.1	601.4	708.6
SSBmsy	442.8	438.6	438.6	480.8	429.7	494.2	566.1
CPUEcurrent	0.361	0.368	0.368	0.345	0.342	0.359	0.356
CPUEproj	0.416	0.435	0.440	0.402	0.391	0.402	0.529
CPUEmsy	0.283	0.220	0.219	0.333	0.191	0.302	0.343
Bcurr/Bmin	1.429	1.371	1.372	1.391	1.367	1.386	1.429
Bcurr/Bref	0.793	0.847	0.845	0.777	0.743	0.770	0.798
Bcurr/Bmsy	1.361	1.557	1.571	1.173	1.767	1.281	1.169
Bproj/Bcurr	1.014	1.017	1.024	1.012	1.014	1.005	1.239
Bproj/Bref	0.805	0.854	0.864	0.785	0.748	0.784	0.985
Bproj/Bmsy	1.377	1.583	1.595	1.184	1.777	1.295	1.437
SSBcurr/SSB0	0.368	0.395	0.395	0.335	0.449	0.317	0.332
SSBproj/SSB0	0.390	0.418	0.421	0.354	0.472	0.333	0.389
SSBcurr/SSBmsy	1.194	1.305	1.307	1.084	1.411	1.156	1.077
SSBproj/SSBmsy	1.266	1.389	1.385	1.147	1.479	1.217	1.260
SSBproj/SSBcurr	1.064	1.062	1.069	1.057	1.049	1.055	1.177
USLcurrent	0.276	0.240	0.240	0.284	0.261	0.252	0.256
USLproj	0.246	0.215	0.213	0.251	0.234	0.230	0.153
USLproj/USLcurrent	0.885	0.895	0.889	0.883	0.899	0.913	0.607
P(Bcurr>Bmin)	1	1	1	1	1	1	1
P(Bcurr>Bref)	0.001	0.007	0.006	0.000	0.000	0.001	0.000
P(Bcurr>Bmsy)	0.995	1.000	1.000	0.939	1.000	0.965	0.889
P(Bproj>Bmin)	0.918	0.947	0.936	0.926	0.935	0.884	0.987
P(Bproj>Bref)	0.150	0.217	0.222	0.089	0.072	0.130	0.474
P(Bproj>Bmsy)	0.871	0.974	0.976	0.774	0.994	0.798	0.931
P(Bproj>Bcurr)	0.530	0.528	0.556	0.527	0.526	0.511	0.854
P(SSBcurr>SSBmsy)	0.990	1.000	1.000	0.894	1.000	0.955	0.817
P(SSBproj>SSBmsy)	0.908	0.974	0.977	0.826	0.998	0.869	0.920
P(USLproj>USLcurr)	0.323	0.284	0.274	0.268	0.313	0.358	0.019
P(SSBcurr<0.2SSB0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
P(SSBproj<0.2SSB0	0.001	0.000	0.000	0.001	0.000	0.004	0.000

The median *Bref* was larger than the median *Bmsy* in all trials. Current biomass was larger than *Bmin* and *Bmsy* with high probability except in the HiRec trial (89% probable). Projected biomass was about the same as current biomass except in the HiRec trial, where it increased with 85% probability. Projected biomass had a median of 38% above *Bmsy*, and the probability of being above Bmsy varied from 77% in trial OldLFs to 99% in trial untruncLFs.

<u>Indicators based on *SSBmsy*</u>

The historical track of biomass versus fishing intensity is shown in Figure 15. The phase space in the plot is relative spawning biomass on the abscissa and relative fishing intensity on the ordinate; thus high biomass/low fishing intensity is in the lower right-hand corner, where a stock would be when fishing first began, and low biomass/high intensity is in the upper left-hand corner, where an uncontrolled fishery is likely to go. Specifically, the x-axis is spawning stock biomass *SSB* in year *y* as a proportion of the unfished spawning stock, *SSB0*. *SSB0* is constant for all years of a run, but varies through the 1000 samples from the posterior distribution.

The y-axis is fishing intensity in year *y* as a proportion of the fishing intensity (*Fmsy*) that would have given *MSY* under the fishing patterns in year *y*; fishing patterns include MLS, selectivity, the seasonal catch split and the balance between SL and NSL catches. *Fmsy* varies every year because the fishing patterns change. It was calculated with a 50-year projection for each year in each run, with the NSL catch held constant at that year's value, deterministic recruitment at *R0* and a range of multipliers on the SL catch *F*s estimated for year *y*. The *F* (actually *F*s for two seasons) that gave *MSY* is *Fmsy*, and the multiplier was *Fmult*.

Each point on the figure shows the median of the posterior distributions of biomass ratio and fishing intensity ratio. The vertical line in the figure is the median (line) and 90% interval (shading) of the posterior distribution of *SSBmsy* as a proportion of *SSB0*; this ratio was calculated using the fishing pattern in 2012. The horizontal line in the figure is drawn at 1, the fishing intensity associated with *Fmsy*. The bars at the final year of the plot show the 90% intervals of the posterior distributions of biomass ratio and fishing intensity ratio.

The tracksuggests that fishing intensity exceeded *Fmsy* only from 1980–89 and that *SSB* was below *SSBmsy* only from 1986–88. The current position of the stock is near the 1978 position, with fishing intensity just below *Fmsy* and with biomass just above *SSBmsy*.

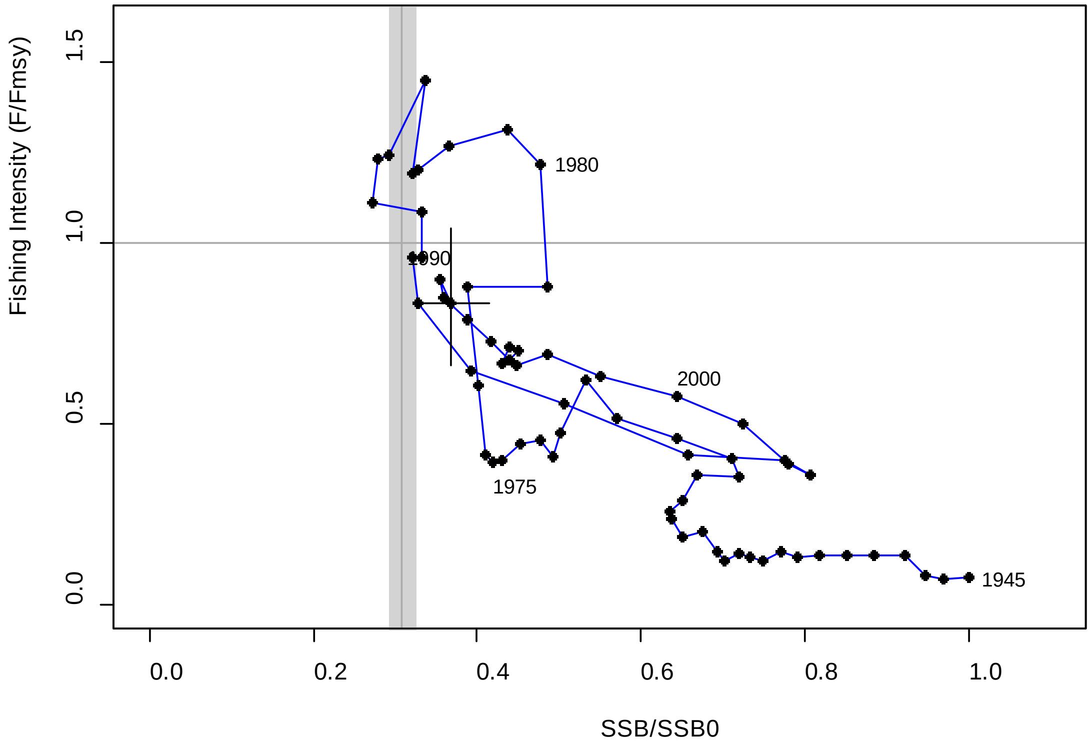


Figure 6: Phase plot that summarises the *SSB* history of the CRA 2 stock. The x-axis is spawning stock biomass *SSB* in each year as a proportion of the unfished spawning stock, *SSB0*. The y-axis is fishing intensity in each year as a proportion of the fishing intensity (*Fmsy*) that would have given *MSY* under the fishing patterns in that year. Each point on the figure shows the median of the posterior distributions of biomass ratio and fishing intensity ratio for one year. The vertical line in the figure is the median (line) and 90% interval (shading) of the posterior distribution of *SSBmsy*; this ratio was calculated using the fishing pattern in 2012. The horizontal line in the figure is drawn at 1, the fishing intensity associated with *Fmsy*. The bars at the final year of the plot (2012) show the 90% intervals of the posterior distributions of biomass ratio and fishing intensity ratio.

6.3 CRA 3

This section reports the 2014 stock assessment for *J. edwardsii* for CRA 3 (Haist et al. in prep.).

This assessment used a single-stock version of the multi-stock length-based model (MSLM) (Haist et al. 2009).

Catch histories for CRA 3 were agreed by the RLFAWG. Other input data to the model included:

- tag-recapture data from 1975–1981 and from 1995–2013,
- standardised CPUE from 1979–2013,
- historical catch rate data from 1963–1973; and
- length frequency data from commercial catches (log book and catch sampling data) from 1989 to 2013.

Because the predicted growth rates were different for the 1975–1981 and 1995–2013 datasets, the RLFAWG agreed that it would be appropriate to fit two growth periods in the model to the two separate tag-recapture datasets. The growth transition matrix for years up to and including 1981 was based on the 1975–1981 tagging dataset. The growth transition matrix for years from 1995 onwards was based on the 1995–2013 tagging dataset . The growth transition matrix for the intervening years, 1982–1994, was based on an interpolation of the early and later growth transition matrices.

The start date for the model was 1945, with an annual time step through 1978 and then switching to a seasonal time step from 1979 onward: autumn/winter (AW) from April through September and spring/summer (SS) from October through March. The last fishing year was 2013, and projections were made through 2017 (four years). Two selectivity epochs were modelled, with the change made in 1993 to capture regulation shifts for the pot escape gaps. Recruitment deviations were estimated from 1945 through 2011. Maximum vulnerability was assumed to be for males in the SS season. The effect of the introduction of the marine reserve was modelled, beginning in 1999 by excluding 10% of the recruitment. The model was fitted to CPUE, the historical catch rate series, length frequency (LF) data and the two tag-recapture datasets. The puerulus settlement index was evaluated in a separate randomisation trial.

A log-normal prior was specified for *M*, with mean 0.12 and c.v. of 0.4. A normal prior was specified for the recruitment deviations in log space, with mean 0 and standard deviation 0.4. Normal priors were used for the size at maximum selectivity for each sex, using the current MLS as the mean. Priors for all other parameters were specified as uniform distributions with wide bounds.

Other model options used in the reference base cases were:

- fishing and natural mortality were assumed to be instantaneous, and *F* was determined with 5 Newton-Raphson iterations;
- selectivity was set to the double normal form used in previous assessments;
- the relation between CPUE and biomass was assumed to be proportional;
- maturity parameters were fixed at the mean of values from the most recent CRA 1 and CRA 3 assessments;
- the growth c.v. was fixed to 0.5 to stabilise the analysis in one base case;
- the growth shape was fixed to 5 in the other base case;
- the right-hand limb of the selectivity curve was fixed to 200;
- dataset weights were adjusted to attempt to obtain standard deviations of normalised residuals of 1.0 or medians of absolute residuals of 0.67.

The RLFAWG considered results from the mode of the joint posterior distribution (MPD) and the results of 14 sets of MPD sensitivity trials:

- with double the estimated recreational catch
- with the illegal catch ramped down from 2001
- with the illegal catch ramped up from 2001
- not fitted to CPUE
- not fitted to LFs
- not fitted to CR
- not fitted to tags
- with *M* fixed to 0.12
- with growth density-dependence estimated
- with the LF record weights not truncated
- with shape parameter for CPUE versus biomass (*CPUEpow*) estimated
- with Newton-Raphson iterations reduced to 3
- with Newton-Raphson iterations increased to 5 for fixed growth shape or reduced to 4 for fixed growth CV
- with logistic selectivity

Most base case results showed limited sensitivity to these trials, except when major data sets were removed. Indicator ratios were reasonably stable.

The model was then fitted to the puerulus index time series as well as the other data, with a range of lags from settlement to recruitment to the model at 32 mm TW. For each base case and for each lag, the function value from fitting to the actual data was compared to the distribution of function values obtained when fitting to randomised data (resampled with replacement). This is a test of the signal in the puerulus index: the null hypothesis is that there is no signal; the research hypothesis predicts that the actual-data function value will be in the lower tail of the distribution. For both base cases and at all lags, the null hypothesis had to be accepted.

The assessment was based on Markov chain – Monte Carlo (MCMC) simulation results. We started the simulations for each of the two base cases at the MPD, and made a chain of five million, with 1000 samples saved. From the joint posterior distribution of parameter estimates, forward projections were made through 2017. In these projections, catches and their seasonal distributions were assumed to remain constant at their 2013 values. Recruitment was re-sampled from 2002–11, and the estimates for 2012–13 were overwritten. The most recent ten years of estimates are considered the best information about likely future recruitments in the short term.

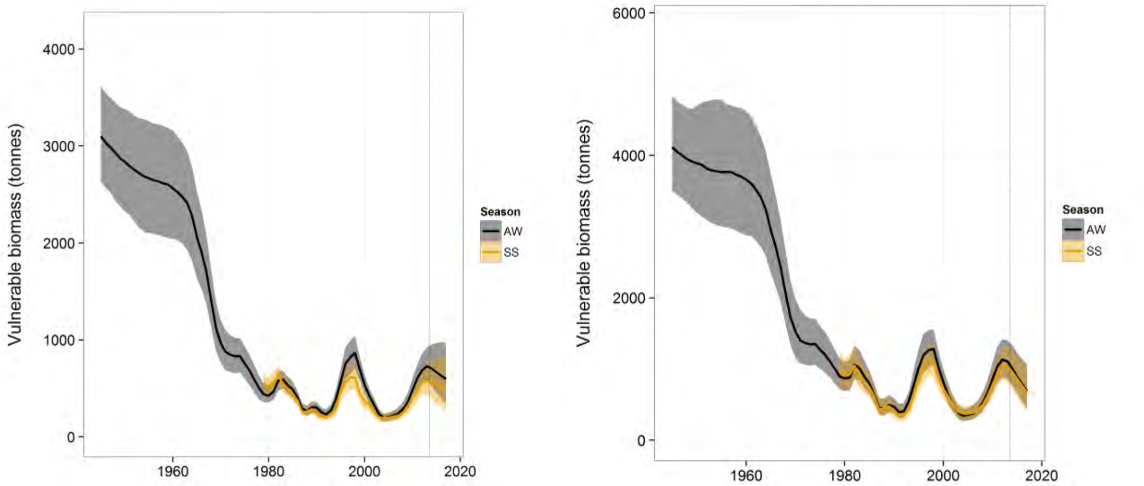


Figure 76: CRA 3: posterior of the trajectory of vulnerable biomass by season, for the fixed growth CV base (left) and the fixed growth shape base case. Shaded areas show the 50% and 90% credibility intervals and the heavy solid line is the median of the posterior distribution. The vertical line shows 2013, the final fishing year of the model reconstruction.

The RLFAWG agreed on a set of indicators. Some of these were based on beginning of season AW vulnerable biomass: the biomass legally and functionally available to the fishery, taking MLS, female maturity, selectivity-at-size and seasonal vulnerability into account. The limit indicator *Bmin* was defined as the nadir of the vulnerable biomass trajectory (using current MLS), 1945-2007. Current biomass, *B2014*, was taken as vulnerable biomass in AW 2014, and projected biomass, *B2017*, was taken from AW 2017.

A biomass indicator associated with *MSY* or maximum yield, *Bmsy*, was calculated by doing deterministic forward projections for 50 years, using the mean of estimated recruitments from 1979-2011. This period was chosen to represent the recruitments estimated from adequate data, and represents the best available information about likely long-term average recruitment. The non-size-limited (NSL) catches (customary and illegal) were held constant at their assumed 2013 values. The SL fishery mortality rate *F* was varied to maximise the annual size-limited (SL) catch, and associated AW biomass was taken as *Bmsy*. *MSY* was the maximum yield (the sum of AW and SS SL catches) found by searching across a range of multipliers (from 0.1 to 2.5) on the 2013 AW and SS *F* values. This was done for each of the 1000 samples from the joint posterior distribution. If the *MSY* were still increasing with the highest *F* multiplier, the *MSY* and *Bmsy* obtained with that multiplier were used. The multiplier, *Fmult*, was also reported as an indicator. The *MSY* and *Bmsy* calculations were based on the growth parameters estimated from the second (1996–2013) tag dataset.

We also used as indicators the exploitation rate associated with the SL catch from 2013 and 2017: *USL2013* and *USL2017*. For the first time in 2013, MPI requested a total biomass indicator and its comparison with *B0* and a total numbers indicator and its comparison with *N0*.

Some previous assessments used biomass in 1974-79 as a target indicator, *Bref*. This appeared to be based on an early assessment in which biomass in that period appeared relatively stable, whereas the biomass in Figure 16 is decreasing strongly at that time. This assessment therefore reported biomass against *Bref* but the RLFAWG did not consider it a target indicator.

The assessment was based on the medians of posterior distributions of these indicators, the posterior distributions of ratios of these indicators, and probabilities that various propositions were true in the posterior distributions.

The primary diagnostics used to evaluate the convergence of the MCMC were the appearance of the traces, running quantiles and moving means. Some of the growth increment parameters, about which there was limited information in the tag data, were poorly converged. Diagnostic plots of the indicators, however, tended to be more acceptable than those of the estimated parameters.

The posterior trajectory of vulnerable biomass by season from 1976 (Figure 16) shows a nadir near 2004, a strong increase in the 1990s followed by a sharp decrease, then another strong increase in the late 2000s, and variable projections with an decreasing median.

The assessment results are summarised in Table 34. Current biomass (*B2014*) was above *Bmin* in all runs, and the median result was 3.0 to 3.5 times *Bmin*. Current biomass was also above *Bmsy* in all of runs, and the median result was between 3 and 5 times *Bmsy*. Current SL exploitation rate was 16% to 24%. Current and projected spawning stock biomass were estimated at about 1.5 times *SSBmsy*. Total biomass was estimated at more than half *B0*, and total numbers at 76% to 90% of *N0*.

Table 34: Quantities of interest to the assessment from the two base case MCMCs; see text for explanation; all biomass values are in tonnes. [Continued on next page]

	fixed *GCV* 5%	median	95%	fixed *Gshape* 5%	median	95%
Bmin	156.3	194.3	235.7	265.6	334.3	412.9
B2014	524.7	704.1	956.1	765.8	1001.2	1335.0
Bref	508.1	633.8	777.3	915.0	1134.7	1418.8
B2017	338.2	596.3	964.8	435.7	690.1	1065.9
Bmsy	173.8	212.8	252.4	173.0	211.7	261.6
MSY	210.2	242.6	282.0	177.1	212.4	253.0
Fmult	4.80	6.02	7.79	5.57	7.34	9.37
SSB2013	1104.9	1243.7	1405.3	2061.3	2389.7	2842.6
SSB2017	1035.2	1273.0	1576.9	1785.2	2241.2	2896.9
SSBmsy	771.5	880.8	1008.2	1351.9	1544.9	1786.7
CPUE2013	1.782	2.094	2.477	1.467	1.714	2.005
CPUE2017	0.774	1.662	2.799	0.609	1.003	1.517
CPUEmsy	0.233	0.288	0.351	0.156	0.196	0.241
B2014/Bmin	2.89	3.64	4.61	2.45	3.01	3.73
B2014/Bref	0.846	1.119	1.497	0.679	0.886	1.121
B2014/Bmsy	2.609	3.333	4.405	3.820	4.725	5.827
B2017/B2014	0.566	0.846	1.157	0.510	0.686	0.903
B2017/Bref	0.526	0.943	1.500	0.399	0.608	0.898
B2017/Bmsy	1.639	2.797	4.554	2.239	3.234	4.640
SSB2013/SSB0	0.619	0.697	0.804	0.930	1.068	1.254
SSB2017/SSB0	0.582	0.713	0.892	0.803	0.995	1.273
SSB2013/SSBmsy	1.247	1.410	1.610	1.357	1.549	1.800
SSB2017/SSBmsy	1.174	1.433	1.792	1.172	1.449	1.831
SSB2017/SSB2013	0.861	1.019	1.196	0.787	0.930	1.123
USL2013	0.188	0.238	0.305	0.123	0.157	0.202
USL2017	0.180	0.292	0.514	0.163	0.252	0.399
USL2017/USL2013	0.830	1.210	1.965	1.164	1.599	2.244
Btot2013	2485.0	2898.7	3438.1	4814.6	5821.1	7170.6
Btot2013/Btot0	0.417	0.495	0.593	0.560	0.672	0.809
Ntot2013	7400000	8950000	11200000	15200000	19200000	25000000
Ntot2013/Ntot0	0.627	0.756	0.948	0.744	0.909	1.137
P(B2014>Bmin)	1.00			1.00		
P(B2014>Bref)	0.75			0.19		
P(B2014>Bmsy)	1.00			1.00		
P(B2017>Bmin)	1.00			0.99		

Table 34 [Continued]: Quantities of interest to the assessment from the two base case MCMCs; see text for explanation; all biomass values are in tonnes.

P(B2017>Bref)	0.44	0.02
P(B2017>Bmsy)	1.00	1.00
P(B2017>B2014	0.21	0.02
P(SSB2013>SSBmsy)	1.00	1.00
P(SSB2017>SSBmsy)	1.00	1.00
P(USL2017>USL2013	0.77	1.00
P(SSB2013<0.2SSB0)	0.00	0.00
P(SSB2017<0.2SSB0	0.00	0.00
P(SSB2013<0.1SSB0)	0.00	0.00
P(SSB2017<0.1SSB0)	0.00	0.00

Biomass increased in only a small percentage of projections, and the median decrease was 15–31%. Projected biomass had a large 5% to 95% uncertainty around it. *B2017* was above *Bmin* and *Bmsy* in virtually all runs, and the median result was about 3 times *Bmsy*. Projected CPUE had a median of 1.0 to 1.7 kg/potlift.

These results suggest a stock that is well above *Bmin* and *Bmsy*, with no concerns from spawning stock biomass, total biomass or total numbers. There is a projected decrease at current catch levels, but the stock is projected to stay well above *Bmin* and *Bmsy*. Under current catches and recent recruitments the model predicted a 75% probability of biomass decrease over four years.

The historical track of biomass versus fishing intensity is shown in Figure 17. The phase space in the plot is relative spawning biomass on the abscissa and relative fishing intensity on the ordinate; thus high biomass/low fishing intensity is in the lower right-hand corner, where a stock would be when fishing first began, and low biomass/high intensity is in the upper left-hand corner, where an uncontrolled fishery is likely to go. Specifically, the x-axis is spawning stock biomass SSB in year y as a proportion of the unfished spawning stock, *SSB0*. *SSB0* is constant for all years of a run, but varies through the 1000 samples from the posterior distribution.

The y-axis is fishing intensity in year y as a proportion of the fishing intensity (*Fmsy*) that would have given *MSY* under the fishing patterns in year y; fishing patterns include MLS, selectivity, the seasonal catch split and the balance between SL and NSL catches. *Fmsy* varies every year because the fishing patterns change. It was calculated with a 50-year projection for each year in each run, with the NSL catch held constant at that year's value, deterministic recruitment at *R0* and a range of multipliers on the SL catch *F*s estimated for year *y*. The *F* that gave *MSY* is *Fmsy*, and the multiplier was *Fmult*.

Each point on the figure shows the median of the posterior distributions of biomass ratio and fishing intensity ratio. The vertical line in the figure is the median (line) and 90% interval (shading) of the posterior distribution of *SSBmsy* as a proportion of *SSB0*; this ratio was calculated using the fishing pattern in 2012. The horizontal line in the figure is drawn at 1, the fishing intensity associated with *Fmsy*. The bars at the final year of the plot show the 90% intervals of the posterior distributions of biomass ratio and fishing intensity ratio.

The tracks suggests that fishing intensity exceeded *Fmsy* only in the fixed growth CV base case from 1983–91 and that *SSB* was below *SSBmsy* only in limited periods that vary between the two base cases. The current position of the stock is well above *SSBmsy* and well below *Fmsy*.

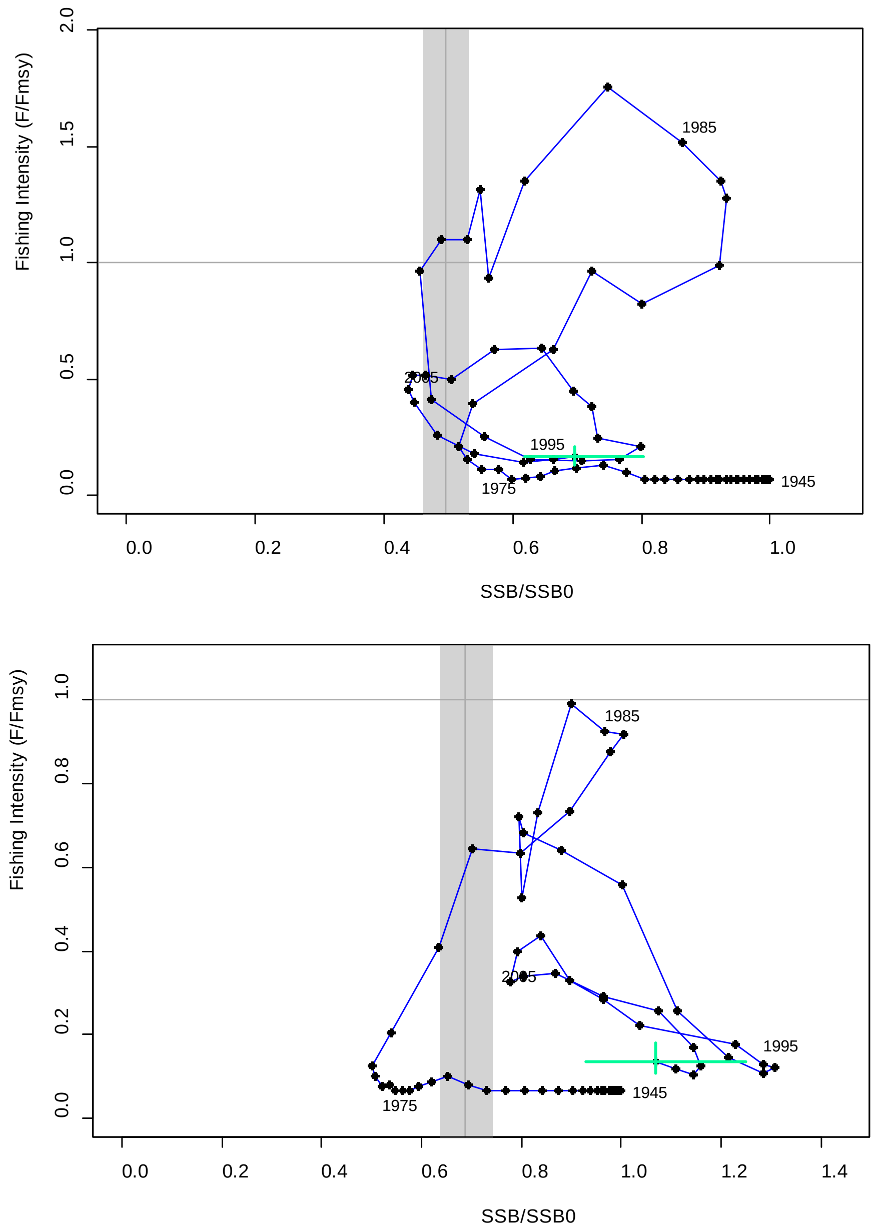


Figure 17: CRA 3: Snail trails from the two base case MCMCs: fixed growth CV on the left. The phase space in the plot is relative spawning biomass on the abscissa and relative fishing intensity on the ordinate; thus high biomass/low fishing intensity is in the lower right-hand corner, where a stock would be when fishing first began, and low biomass/high intensity is in the upper left-hand corner, where an uncontrolled fishery is likely to go. Specifically, the x-axis is spawning stock biomass *SSB* in year y as a proportion of the unfished spawning stock, *SSB0*. *SSB0* is constant for all years of a run, but varies through the 1000 samples from the posterior distribution. The y-axis is fishing intensity in year y as a proportion of the fishing intensity (*Fmsy*) that would have given *MSY* under the fishing patterns in year y; fishing patterns include MLS, selectivity, the seasonal catch split and the balance between SL and NSL catches. *Fmsy* varies every year because the fishing patterns change. It was calculated with a 50-year projection for each year in each run, with the NSL catch held constant at that year's value, deterministic recruitment at *R0* and a range of multipliers on the SL catch *F*s estimated for year y. The *F* that gave MSY is *Fmsy*, and the multiplier was *Fmult*. Each point on the figure shows the median of the posterior distributions of biomass ratio and fishing intensity ratio. The vertical line in the figure is the median (line) and 90% interval (shading) of the posterior distribution of *SSBmsy* as a proportion of *SSB0*; this ratio was calculated using the fishing pattern in 2012. The horizontal line in the figure is drawn at 1, the fishing intensity associated with *Fmsy*. The bars at the final year of the plot show the 90% intervals of the posterior distributions of biomass ratio and fishing intensity ratio.

Four MCMC sensitivity trials were run for each of the two base case MCMCs:

- with *M* fixed to 0.12, using the covariance matrix was from a run with *M* fixed to 0.20
- with a uniform prior on *M*; for the fixed growth shape base the covariance matrix was from the base case
- fitted to the puerulus index with lag of 2 years between settlement and recruitment to the model
- fitted to a single combined tag data file
    - this was based on examination of the tag residuals, showing positive for the most recent years

The major stock assessment conclusions were not challenged by these trials.

6.4 CRA 4

This section reports the assessment for CRA 4 conducted in 2011.

Model structure

A single-stock version of the multi-stock length-based model (MSLM) (Haist et al 2009) was fitted to two series of catch rate indices from different periods, and to size frequency, puerulus settlement and tagging data. The model used an annual time step from 1945 to 1978 and then switched to a seasonal time step with AW and SS from 1979 through 2010. The model had 93 length bins, 31 for each sex group (males, immature and mature females), each 2 mm TW wide, beginning at left-hand edge 30 mm TW.

Significant catches occurred in the historical series for CRA 4. Different MLS regulations existed in the past and pots were not required to have escape gaps. The model incorporated a time series of sex-specific MLS regulations. Data and their sources are listed in Table 35.

The assessment assumed that recreational catch was equal to the mean of the 1994 and 1996 recreational surveys, was proportional to SS CPUE from 1979 through 2010, and that it increased linearly from 20% of the 1979 value in 1945 up to the 1979 value (see Section 1.3).

Table 35: Data types and sources for the 2011 assessment for CRA 4. Year codes apply to the first 9 months of each fishing year, viz 1998-99 is called 1998. NA – not applicable or not used; MFish – NZ Ministry of Fisheries; NZRLIC – NZ Rock Lobster Industry Council.

Data type	Data source	Begin year	End year
Historical catch rate CR	Annala & King (1983)	1963	1973
CPUE	FSU & CELR	1979	2010
Observer proportions-at-size	MFish and NZ RLIC	1986	2010
Logbook proportions-at-size	NZ RLIC	1997	2010
Tag recovery data	NZ RLIC & MFish	1982	2011
Historical MLS regulations	Annala (1983), MFish	1945	2010
Escape gap regulation changes	Annala (1983), MFish	1945	2010
Puerulus settlement	NIWA	1979	2010

The initial population in 1945 was assumed to be in equilibrium with average recruitment and with no fishing mortality. Each season the number of male, immature female and mature female lobsters within each size class was updated as a result of:

Recruitment. Each year, new recruits to the model were added equally for each sex for each season, as a normal distribution with a mean size (32 mm) and standard deviation (2 mm), truncated at the smallest size class (30 mm). Recruitment in a specific year was determined by the parameter for base recruitment and a parameter for the deviation from base recruitment. The vector of log recruitment deviations was assumed to be normally distributed with a mean of zero. Recruitment deviations were estimated for 1945 through 2011.

Mortality. Natural, fishing and handling mortalities were applied to each sex category (male, immature female and mature female) in each size class. Natural mortality was estimated, but was assumed to be constant and independent of sex and length. Fishing mortality was determined from observed catch and model biomass, modified by legal sizes, sex-specific vulnerabilities and selectivity curves. Handling mortality was assumed to be 10% of fish returned to the water. Two fisheries were modelled: one fishery that operated only on fish above the size limit (SL fishery – including legal commercial and recreational) and one that did not (NSL fishery – all of the illegal fishery plus the Mäori customary fishery). It was assumed that size limits and the prohibition on berried females applied only to the SL fishery. Otherwise, the selectivity and vulnerability functions were the same for the SL and NSL fisheries. Relative vulnerability was calculated by assuming (after experimentation) that females in the SS had the highest vulnerability and that the vulnerability of all other sex categories by season are equal to or less than the SS females. Instantaneous fishing mortality rates for each fishery were calculated using Newton-Raphson iteration (four iterations after experiment) based on catch and model biomass.

Fishery selectivity: A three-parameter fishery selectivity function was assumed, with parameters describing the shapes of the ascending and descending limbs and the size at which vulnerability is at a maximum. Changes in regulations over time (for instance, changes in escape gap regulations) were modelled by estimating two separate selectivity epochs, pre–1993 and 1993–2010. As in previous assessments for the past decade, the descending limb of the selectivity curve was fixed to prevent under-estimation of vulnerability of large lobsters.

Growth and maturity. For each size class and sex category, a growth transition matrix specified the probability of an individual remaining in the same size class or growing into each of the other size classes. Maturation of females was estimated as a two-parameter logistic curve from the maturity-at-size information in the size frequency data.

Model fitting

A total negative log likelihood function was minimised using AD Model Builder™. The model was fitted to historical catch rate, standardised CPUE and puerulus settlement data using lognormal likelihood. The model was fitted to proportions-at-length with multinomial likelihood and tag-recapture data with robust normal likelihood. For the CPUE and puerulus lognormal likelihoods, CVs for each index value were initially set at the standard error from the GLM analysis. Process error was subsequently added to these CVs. A fixed CV of 0.3 was used for the historical catch rate data. The robust normal likelihood was used for the tagging data. Proportions-at-length, assumed to be representative of the commercial catch, were available from observer catch sampling for all years after 1985 and from voluntary logbooks for some years from 1997. Data were summarised by area/month strata and weighted by the commercial catch taken in each stratum, the number of lobsters measured and the number of days sampled. Size data from each source (research sampling or voluntary logbooks) were fitted separately. Seasonal proportions-at-length summed to one across males, immature and mature females. Experiments (randomisation trials) were conducted to determine whether puerulus settlement data contained a signal with respect to recruitment to the model and, if so, at what lag. Based on the results. the final base case was fit to recruitment data with an assumed lag of 1 year between settlement and recruitment to the model.

Table 36: Parameters estimated and priors used in basecase assessments for CRA 4. Prior type abbreviations: U – uniform; N – normal; L – lognormal. [Continued on next page]

Parameter	Prior Type	No. of parameters	Bounds	Mean	SD	CV
ln(*R0*) (mean recruitment)	U	1	1–25	–		–
M (natural mortality)	L	1	0.01–0.35	0.12		0.4
Recruitment deviations	N [1]	67	-2.3–2.3	0	0.4	
ln(*qCPUE*)	U	1	-25-0	–		–
ln(*qCR*)	U	1	-25-2	–		–
ln(*qpuerulus*)	U	1	-25-0	–		–
Increment at TW=50 (male & female)	U	2	0.1-20.0	–		–
difference between increment at TW=50 and increment at TW=80 (male & female)	U	2	0.001-1.000	–		–
shape of growth curve (male & female)	N	2	0.1-15.0	5.0	0.5	
TW at 50% probability female maturation	U	1	30–80	–		–
TW at 95% probability female maturation minus TW at 50% probability female maturation	N	1	5-80	14	2.8	–
Relative vulnerability (all sexes and seasons) [2]	U	3	0.01-1.0	–		–

Table 36 [Continued]:

Parameter	Prior Type	No. of parameters	Bounds	Mean	SD	CV
Shape of selectivity left limb (males & females)	U	2	1–50	–		–
Size at maximum selectivity (males & females)	U	2	30-80	–		–
						–

[1] Normal in natural log space = lognormal (bounds equivalent to –10 to 10)
[2] Relative vulnerability of females in SS was fixed at 1

In the base case, it was assumed that biomass was proportional to CPUE, that growth is not density dependant, that there is no stock-recruit relationship and that there was no migration between stocks. Base case explorations involved experimentally weighting the datasets and inspecting the resulting standard deviations of normalised residuals and medians of absolute residuals, experimenting with a new procedure for weighting the LF data, experimentally fixing parts of the growth estimation, experimenting with the sex and season for maximum vulnerability, experimenting with fixing parts of the maturation ogive and exploring other model options such as density-dependence and selectivity curves. The growth C.V. was estimated and then fixed in the McMC simulations. Priors were placed on the growth shape parameters to avoid unrealistic curves and on the parameter determining the width of the maturation curve. Recruitment deviations were estimated for 1945–2011.

Parameters estimated in each model and their priors are provided in Table 35. Fixed parameters and their values are given in Table 37. CPUE, the historical catch rate, proportions-at-length and tagging data were given relative weights directly by a relative weighting factor.

Table 37: Fixed values used in base case assessment for CRA 4

Value	CRA 4
shape parameter for CPUE vs biomass	1.0
minimum std. dev. of growth increment	0.9
Std dev of observation error of increment	1.0
Std dev of historical catch per day	0.30
Handling mortality	10%
Process error for CPUE	0.25
Year of selectivity change	1993
Current male size limit	54
Current female size limit	60
First year for recruitment deviations	1945
Last year for recruitment deviations	2011
Relative weight for length frequencies	3.15
Relative weight for CPUE	4
Relative weight for CR	4
Relative weight for puerulus	1
Relative weight for tag-recapture data	0.8

Model projections

Bayesian estimation procedures were used to estimate the uncertainty in model estimates and short-term projections. This procedure was conducted in the following steps:

a) Model parameters were estimated by AD Model Builder™ using maximum likelihood and the prior probabilities. The point estimates are called MPD (mode of the joint posterior) estimates;

b) Samples from the joint posterior distribution of parameters were generated with Markov chain - Monte Carlo (McMC) simulations using the Hastings-Metropolis algorithm; two million simulations were made, starting from the base case MPD, and 1000 samples were saved. From each sample of the posterior, 4-year projections (2011–2014) were generated with an assumed current-catch scenario (Table 38);

c) Future annual recruitment was randomly sampled with replacement from the model's estimated recruitments from 2002-11 (except for the no-puerulus sensitivity trial which resampled from 1998–2007).

Table 38: Catches (t) used in the four-year projections. Projected catches are based on the current TACC for CRA 4, and the current estimates of recreational, customary and illegal catches. SL= commercial+recreational-reported illegal; NSL=reported illegal+unreported illegal+customary

Commercial	Recreational	Reported Illegal	Unreported Illegal	Customary	SL	NSL
466.9	58.6	5.3	34.7	20.0	520	60

Performance Indicators and Results

Vulnerable biomass in the assessment model was determined by the MLS, selectivity, relative sex and seasonal vulnerability and berried state for mature females. All mature females were assumed to be berried (and not vulnerable to the fishery) in AW and not berried (thus vulnerable) in SS.

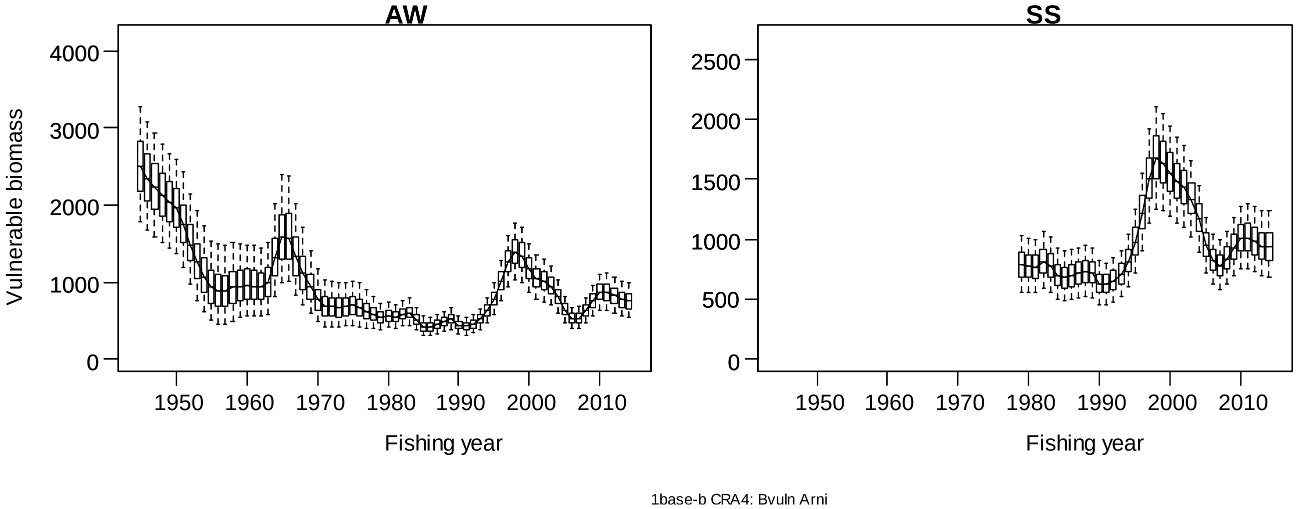


Figure 18: Posterior distributions of the CRA 4 base case McMC biomass vulnerable trajectory. Before 1979 there was a single time step, shown in AW. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th quantiles.

Agreed indicators are summarised in Table 38. Base case results (Table 39) suggested that biomass decreased to a low point in 1991, then increased to a high in 1998 (Figure 18), decreased to 2006 and has increased again. The current vulnerable stock size (AW) is about 1.7 times the reference biomass and the spawning stock biomass is close to SSB_{msy} (Table 39). Projected biomass would decrease at the level of current catches over the next 4 years (Figure 18).

Table 39: Performance indicators used in the CRA 4 stock assessment [Continued on next page]

Reference points	
Bmin	The lowest beginning AW vulnerable biomass in the series
Bcurrent	Beginning of season AW vulnerable biomass for the year the stock assessment is performed
Bref	Beginning of AW season mean vulnerable biomass for 1979–88
Bproj	Projected beginning of season AW vulnerable biomass (ie, the year of stock assessment plus 4 years)
Bmsy	Beginning of season AW vulnerable biomass associated with MSY, calculated by doing deterministic forward projections with recruitment *R0* and current fishing patterns
MSY	Maximum sustainable yield (sum of AW and SS SL catches) found by searching a across a range of multipliers on F.
Fmult	The multiplier that produced *MSY*
SSBcurr	Current spawning stock biomass at start of AW season
SSBproj	Projected spawning stock biomass at start of AW season
SSBmsy	Spawning stock biomass at start of AW season associated with *MSY*
CPUE indicators	
CPUEcurrent	CPUE at *Bcurrent*
CPUEproj	CPUE at *Bproj*
CPUEmsy	CPUE at *Bmsy*
Performance indicators	
Bcurrent / Bmin	ratio of *Bcurrent* to *Bmin*
Bcurrent / Bref	ratio of *Bcurrent* to *Bref*
Bcurrent / Bmsy	ratio of *Bcurrent* to *Bmsy*
Bproj / Bcurrent	ratio of *Bproj* to *Bcurrent*
Bproj / Bref	ratio of *Bproj* to *Bref*
Bproj / Bmsy	ratio of *Bproj* to *Bmsy*
SSBcurr/SSB0	ratio of *SSBcurrent* to *SSB0*
SSBproj/SSB0	ratio of *SSBproj* to *SSB0*

Table 39 [Continued]: Performance indicators used in the CRA 4 stock assessment

SSBcurr/SSBmsy	ratio of *SSBcurrent* to *SSBmsy*
SSBproj/SSBmsy	ratio of *SSBproj* to *SSBmsy*
SSBproj/SSBcurr	ratio of *SSBproj* to *SSBcurrent*
USLcurrent	The current exploitation rate for SL catch in AW
USLproj	Projected exploitation rate for SL catch in AW
USLproj/USLcurrent	ratio of SL projected exploitation rate to current SL exploitation rate
Probabilities	
P(Bcurrent > Bmin)	probability *Bcurrent* > *Bmin*
P(Bcurrent > Bref)	probability *Bcurrent* > *Bref*
P(Bcurrent > Bmsy)	probability *Bcurrent* > *Bmsy*
P(Bproj > Bmin)	probability *Bproj* > *Bmin*
P(Bproj > Bref)	probability *Bproj* > *Bref*
P(Bproj > Bmsy)	probability *Bproj* > *Bmsy*
P(Bproj > Bcurrent)	probability *Bproj* > *Bcurrent*
P(SSBcurr>SSBmsy)	probability *SSBcurr>SSBmsy*
P(SSBproj>SSBmsy)	probability *SSBproj>SSBmsy*
P(USLproj>USLcurr)	probability SL exploitation rate *proj* > SL exploitation rate *current*
P(SSBcurr<0.2SSB0)	soft limit: probability *SSBcurrent* < 20% *SSB0*
P(SSBproj<0.2SSB0	soft limit: probability *SSBproj* < 20% *SSB0*
P(SSBcurr<0.1SSB0)	soft limit: probability *SSBcurrent* < 10% *SSB0*
P(SSBproj<0.1SSB0)	soft limit: probability *SSBproj* < 10% *SSB0*

A series of MCMC sensitivity trials was also made, including trials with low estimated vulnerability for immature females, exclusion of puerulus data, using a different lag (3 years) for fitting the puerulus data, fixed M, using a higher weight for the LF data and using an alternative recreational catch vector. The assessment results from the base case and sensitivity trials calculated as a series of agreed indicators (Table 39) are shown in Table 40.

The sensitivity trials run were:
lovuln ; trial with low estimated vulnerability for immature females;
no poo: not fitted to puerulus data;
poolag3: fitted to puerulus data with a lag of 3 years;
fixedM: with M fixed to 0.16;
hiLFwt: fitted using a high weighting for the LF dataset, and;
hiRecCat: fitted using an historical catch vector based on doubling the recreational catch estimates.

<u>Indicators based on vulnerable biomass (AW) and *Bmsy*</u>
In the base case and for sensitivity trials, except fixed *M* and high LF weight, the median value for *Bref* was larger than the median for *Bmsy*. In the base case and for all trials, current and projected biomass levels were larger than *Bref* and *Bmsy* reference levels by substantial factors. Projected biomass decreased in nearly all runs but remained well above the reference levels in the base case and for all trials.

Table 40: Assessment results – medians of indicators described in Table 38 from the base case and sensitivity trials; the lower part of the table shows the probabilities that events are true; biomass in t and CPUE in kg/potlift. [Continued on next page]

Indicator	basecase	lovuln	nopoo	poolag3	fixed*M*	hiLFwt	hiRecCat
Bmin	407	398	416	355	365	321	423
Bcurr	862	844	941	742	674	805	898
Bref	514	495	521	438	477	411	536
Bproj	751	727	770	607	571	663	831
Bmsy	377	385	374	343	547	416	408
MSY	680	655	676	662	532	610	715
Fmult	4.05	3.76	4.44	3.81	1.50	2.96	3.57
SSBcurr	2 615	809	2 496	1 826	1 513	1 999	2 654
SSBproj	2 796	829	2 457	1 690	1 576	2 147	2 864
SSBmsy	2 646	652	2 387	1 757	1 739	2 143	2 675
CPUEcurrent	0.91	0.91	1.01	0.91	0.91	0.95	0.91
CPUEproj	0.77	0.75	0.78	0.69	0.74	0.73	0.83
CPUEmsy	0.29	0.31	0.29	0.30	0.68	0.38	0.31
Bcurr/Bmin	2.12	2.11	2.27	2.08	1.87	2.52	2.11
Bcurr/Bref	1.68	1.70	1.82	1.69	1.42	1.96	1.68
Bcurr/Bmsy	2.30	2.20	2.56	2.15	1.26	1.94	2.21

Table 40 [Continued]: Assessment results – medians of indicators described in Table 39 from the base case and sensitivity trials; the lower part of the table shows the probabilities that events are true; biomass in t and CPUE in kg/potlift.

Bproj/Bcurr	0.87	0.86	0.82	0.82	0.85	0.83	0.93
Bproj/Bref	1.46	1.47	1.49	1.38	1.22	1.61	1.56
Bproj/Bmsy	2.01	1.90	2.08	1.78	1.08	1.60	2.04
SSBcurr/SSB0	0.65	0.43	0.67	0.62	0.46	0.58	0.63
SSBproj/SSB0	0.69	0.44	0.65	0.57	0.48	0.62	0.68
SSBcurr/SSBmsy	0.98	1.24	1.04	1.04	0.87	0.93	0.99
SSBproj/SSBmsy	1.05	1.27	1.01	0.96	0.91	1.01	1.07
SSBproj/SSBcurr	1.07	1.03	0.96	0.92	1.04	1.08	1.08
USLcurrent	0.24	0.24	0.21	0.27	0.31	0.25	0.23
USLproj	0.30	0.31	0.30	0.38	0.40	0.34	0.25
USLproj/USLcurrent	1.28	1.29	1.38	1.39	1.29	1.36	1.07
P(*Bcurr>Bmin*)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P(*Bcurr>Bref*)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P(*Bcurr>Bmsy*)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P(*Bproj>Bmin*)	1.00	1.00	0.99	1.00	1.00	1.00	1.00
P(*Bproj>Bref*)	1.00	1.00	0.91	1.00	0.94	1.00	1.00
P(*Bproj>Bmsy*)	1.00	1.00	0.99	1.00	0.69	1.00	1.00
P(*Bproj>Bcurr*)	0.01	0.02	0.18	0.01	0.02	0.01	0.12
P(*SSBcurr>SSBmsy*)	0.39	1.00	0.64	0.71	0.01	0.13	0.45
P(*SSBproj>SSBmsy*)	0.73	1.00	0.52	0.35	0.10	0.53	0.79
P(*USLproj>USLcurr*)	1.00	1.00	0.91	1.00	1.00	1.00	0.83
P(*SSBcurr<0.2SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P(*SSBproj<0.2SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P(*SSBcurr<0.1SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P(*SSBproj<0.1SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Indicators based on SSBmsy

SSBmsy is biomass of mature females associated with *Bmsy.* The historical track of biomass versus fishing intensity is shown in Figure 19. The phase space in the plot shows biomass on the x-axis and fishing intensity on the y-axis. High biomass/low intensity is in the lower right-hand corner, the location of the stock when fishing first began, and low biomass/high intensity is in the upper left-hand corner, in a period when the fishery was largely uncontrolled. Note that fishing patterns include MLS, selectivity and the seasonal catch split, and note that *Fmsy* varies in each year because fishing patterns change. The reference *SSBmsy* in Figure 19 has been calculated using the 2010 fishing pattern.

Fmsy varies every year because the fishing patterns change. It was calculated with a 50-year projection for each year in each run, with the NSL catch held constant at that year's value, deterministic recruitment at *R0* and a range of multipliers on the SL catch *F*s estimated for year *y*. The *F* (actually separate *F*s for two seasons) that gives *MSY* is *Fmsy* and the multiplier is *Fmult*. Each point on the figure was plotted as the median of the posterior distributions of biomass ratio and fishing intensity ratio.

6.5 CRA 5

This section reports the assessment for CRA 4 conducted in 2010.

Model structure

A single-stock version of the multi-stock length-based model (MSLM) (Haist et al 2009) was fitted to two series of catch rate indices from different periods, and to size frequency, puerulus settlement and tagging data. The model used an annual time step for 1945-78 and then a seasonal time step (autumn-winter (AW): April to September, and spring-summer (SS): October to March).

Significant catches occurred in the early part of the time series for CRA 5. Different MLS regulations existed at this time and pots were not required to have escape gaps. The model incorporated a time series of sex-specific MLS regulations. Data and their sources are listed in Table 40.

The assessment assumed that recreational catch was equal to survey estimates in 1994 and 1996, proportional to area 917 AW CPUE in other years from 1979-2009, and increased linearly from 20% of the 1979 value in 1945 up to the 1979 value.

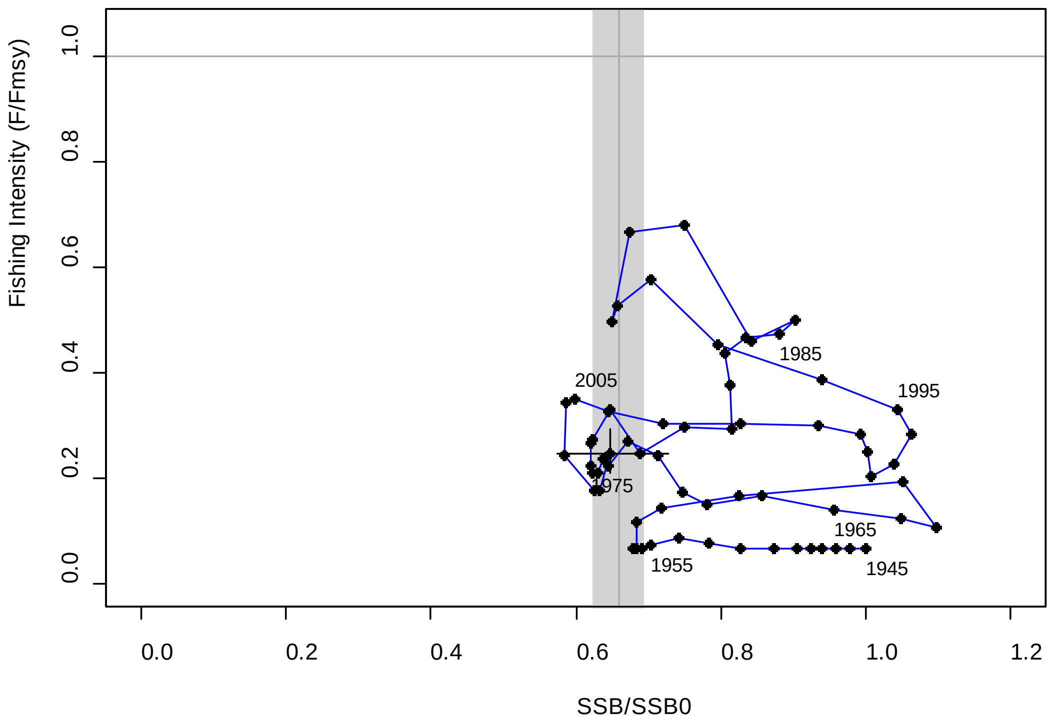


Figure 8: Phase plot that summarises the *SSB* history of the CRA 4 stock. The x-axis is spawning stock biomass *SSB* in year *y* as a proportion of the unfished spawning stock, *SSB0*. *SSB0* is constant for all years of a run, but varies through the 1000 runs. The y-axis is fishing intensity in year *y* as a proportion of the fishing intensity (*Fmsy*) that would have given *MSY* under the fishing patterns in year *y*; fishing patterns include MLS, selectivity, the seasonal catch split and the balance between SL and NSL catches. The vertical line in the figure is the median (line) and 90% interval (shading) of the posterior distribution of *SSBmsy* (the spawning stock biomass associated with *MSY*) as a proportion of *SSB0*; this ratio was calculated using the fishing pattern in 2010. The horizontal line in the figure is drawn at 1, the fishing intensity associated with *Fmsy*. The bars at the final year of the plot show the 90% intervals of the posterior distributions of biomass ratio and fishing intensity ratio.

The initial population in 1945 was assumed to be in equilibrium with average recruitment and with no fishing mortality. Each season the number of male, immature female and mature female lobsters within each size class is updated as a result of:

a) **Recruitment**. Each year, new recruits were added equally for each sex season, as a normal distribution with a mean size (32 mm) and standard deviation (2 mm), truncated at the smallest size class (30 mm). Recruitment in a specific year was determined by the parameter for base recruitment and a parameter for the deviation from base recruitment. The vector of recruitment deviations was assumed to be normally distributed with a mean of zero.

b) **Mortality**. Natural, fishing and handling mortalities were applied to each sex category (male, immature female and mature female) in each size class. Natural mortality was estimated, but was assumed to be constant and independent of sex and length. Fishing mortality was determined from observed catch and model biomass, modified by legal sizes, sex-specific vulnerabilities and selectivity curves.

   Two fisheries were modelled: one fishery that operated only on fish above the size limit (SL fishery – including legal commercial and recreational) and one that did not (NSL fishery - most of the illegal fishery plus the Mäori customary fishery). It was assumed that size limits and the prohibition on berried females applied only to the SL fishery. Otherwise, the selectivity and vulnerability functions were the same for the SL and NSL fisheries. Relative vulnerability was calculated by assuming that the males in the AW had the highest vulnerability and that the vulnerability of all other sex categories by season are equal to or less than the AW males. Instantaneous fishing mortality rates for each fishery were calculated using Newton-Raphson iteration based on catch and model biomass. Handling mortality rate was assumed to be 10% of all lobsters that were released.

c) **Fishery selectivity:** A three-parameter fishery selectivity function was assumed, with parameters describing the shapes of the ascending and descending limbs and the size at which vulnerability is at a maximum. Changes in regulations over time (for instance, changes in escape gap regulations) were modelled by estimating two separate selectivity epoch, pre-1993 and 1993-2009.

d) **Growth and maturity**. For each size class and sex category, a growth transition matrix specified the probability of an individual remaining in the same size class or growing into each of the other size classes. Maturation of females was estimated as a two-parameter logistic curve from the maturity-at-size information in the size frequency data.

Model fitting

A total negative log likelihood function was minimised using AD Model Builder™. The model was fitted to historical catch rate, standardised CPUE and puerulus settlement data using lognormal likelihood. The model was fitted to proportions-at-length with multinomial likelihood and tag-recapture data with robust normal likelihood. For the CPUE and puerulus lognormal likelihoods, CVs for each index value were initially set at the standard error from the GLM analysis. Process error was subsequently added to these CVs so that the overall standard deviation of the standardised (Pearson) residuals was near 1.0. A fixed CV of 0.3 was used for the historical catch rate data. The robust normal likelihood was used for the tagging data so that data outliers (defined as observations with a standardised residual greater than 3.0) would be downweighted. Proportions-at-length, assumed to be representative of the commercial catch, were available from both observer catch sampling and voluntary logbooks; these were fitted separately. Data were summarised by area/month strata and weighted by the commercial catch taken in each stratum, the number of lobsters measured and the number of days sampled. Size data from each source (research sampling or voluntary logbooks) were fitted separately. Seasonal proportions-at-length summed to one across males, immature and mature females. Experiments (randomisation trials) were conducted to establish that puerulus settlement data contained a signal about recruitment.

In the base case, the model's options for fitting a non-linear relation between biomass and CPUE, having density-dependent growth, having a stock-recruit relation and having movements between stocks were all turned off. The base case was obtained by weighting CR, LFs and tags so that standard deviations of normalised residuals were close to 1; CPUE data were intentionally upweighted to force an acceptable fit and puerulus data were also upweighted. It was decided to fix the value of growth c.v. to that estimated in growth-only fits to the tagging data, and to put a prior on the growth shape parameters to avoid unrealistic curves. Recruitment deviations were estimated for the whole time series.

Table 41: Data types and sources for the 2010 assessment for CRA 5. Year codes apply to the first 9 months of each fishing year, viz 1998-99 is called 1998. NA – not applicable or not used; MFish – NZ Ministry of Fisheries; NZRLIC – NZ Rock Lobster Industry Council.

Data type	Data source	Begin year	End year
Historical catch rate CR	Annala & King (1983)	1963	1973
CPUE	FSU & CELR	1979	2009
Observer proportions-at-size	MFish	1986	2009
Logbook proportions-at-size	NZRLIC	1994	2009
Tag recovery data	NZRLIC & MFish	1996	2009
Historical MLS regulations	Annala (1983), MFish	1945	2009
Escape gap regulation changes	Annala (1983), MFish	1945	2009
Puerulus settlement	NIWA	1980	2009

Parameters estimated in each model and their priors are provided in Table 42. Fixed parameters and their values are given in Table 43.

CPUE, the historical catch rate, proportions-at-length and tagging data were given relative weights directly by a relative weighting factor. The weights were varied to obtain standard deviations of standardised residuals for each data set that were close to one.

Table 42: Parameters estimated and priors used in basecase assessments for CRA 5. Prior type abbreviations: U – uniform; N – normal; L – lognormal.

	Prior Type	Bounds	Mean	SD	CV
ln(*R0*) (mean recruitment)	U	1–25	–		–
M (natural mortality)	L	0.01–0.35	0.12		0.4
Recruitment deviations	N [1]	-2.3–2.3	0	0.4	
ln(*qCPUE*)	U	-25-0	–		–
ln(*qCR*)	U	-25-2	–		–
ln(*qPuerulus*)	U	-25-0	–		–
Increment at TW=50 (male & female)	U	0.1-20.0	–		–
difference between increment at TW=50 and increment at TW=80 (male & female)	U	0.001-1.000	–		–
shape of growth curve (male & female)	N	0.1-15.0	5.0	0.5	
TW at 50% probability female maturation	U	30–80	–		–
(TW at 95% probability female maturity) – (TW at 50% probability female maturity)	U	5-80	–		–
Relative vulnerability (all sexes and seasons) [2]	U	0-1	–		–
Shape of selectivity left limb (males & females)	U	1–50	–		–
Size at maxim2um selectivity (males & females)	U	30-80	–		–
Size at maximum selectivity females	U	30-80	–		–

[1] Normal in natural log space = lognormal (bounds equivalent to –10 to 10)
[2] Relative vulnerability of males in autumn-winter was fixed at one

Table 43: Fixed values used in base case assessment for CRA 5

	CRA 5
shape parameter for CPUE vs biomass	1
CV of growth increment (male & female)	0.24
minimum std. dev. of growth increment	1.5
Std dev of observation error of increment	1
Std dev of historical catch per day	0.30
Handling mortality	10%
Process error for CPUE	0.25
Year of selectivity change	1993
Current male size limit	54
Current female size limit	60
First year for recruitment deviations	1945
Last year for recruitment deviations	2009
Relative weight for length frequencies	25
Relative weight for CPUE	3
Relative weight for CR	1
Relative weight for puerulus	2
Relative weight for tag-recapture data	0.8

Model projections

Bayesian estimation procedures were used to estimate the uncertainty in model estimates and short-term projections. This procedure was conducted in the following steps:

d) Model parameters were estimated by AD Model Builder™ using maximum likelihood and the prior probabilities. These point estimates are called MPD (mode of the joint posterior) estimates;

e) Samples from the joint posterior distribution of parameters were generated with Markov chain - Monte Carlo (MCMC) simulations using the Hastings-Metropolis algorithm; two million simulations were made, starting from the base case MPD, and 1000 samples were saved. From each sample of the posterior, 5-year projections (2010–2014) were generated with two agreed catch scenarios (Table 44);

f) Future annual recruitment was randomly sampled with replacement from the model's estimated recruitments from 2000–09 (except for the no puerulus sensitivity trial which resampled from 2000–06).

Table 44: Catches (t) used in the five-year projections. Projected catches are based on the current TACC for CRA 5, and the current estimates of recreational, customary and illegal catches.

	Commercial	Recreational	Reported Illegal	Unreported Illegal	Customary
scenario 1	350	156	3	49	10
scenario 2	350	112	3	49	10

Vulnerable biomass in the assessment model was determined by the MLS, selectivity, relative sex and seasonal vulnerability and berried state for mature females. All mature females were assumed to be berried (and not vulnerable to the fishery) in AW and not berried (and vulnerable) in SS.

Base case results suggested that biomass decreased to a low point in 1991, remained low through 1995, then increased (Figure 20). The current vulnerable stock size (AW) is about 3 times the reference biomass and the spawning stock biomass is well above B_{msy} (Table 46). However, projected biomass would decrease at the level of current catches over the next 4 years (Figure 20).

Table 45: Performance indicators used in the CRA 5 stock assessment

Reference points	
Bmin	The lowest beginning AW vulnerable biomass in the series
Bcurrent	Beginning of season AW vulnerable biomass for the year the stock assessment is performed
Bref	Beginning of AW season mean vulnerable biomass for 1979–88
Bproj	Projected beginning of season AW vulnerable biomass (ie, the year of stock assessment plus 4 years)
Bmsy	Beginning of season AW vulnerable biomass associated with MSY, calculated by doing deterministic forward projections with recruitment *R0* and current fishing patterns
MSY	Maximum sustainable yield (sum of AW and SS SL catches) found by searching a across a range of multipliers on F.
Fmult	The multiplier that produced *MSY*
CPUE indicators	
CPUEcurrent	CPUE at *Bcurrent*
CPUEproj	CPUE at *Bproj*
CPUEmsy	CPUE at *Bmsy*
Performance indicators	
Bcurrent / Bmin	ratio of *Bcurrent* to *Bmin*
Bcurrent / Bref	ratio of *Bcurrent* to *Bref*
Bcurrent / Bmsy	ratio of *Bcurrent* to *Bmsy*
Bproj / Bmin	ratio of *Bproj* to *Bmin*
Bproj / Bcurrent	ratio of *Bproj* to *Bcurrent*
Bproj / Bref	ratio of *Bproj* to *Bref*
Bproj / Bmsy	ratio of *Bproj* to *Bmsy*
USLcurrent	The current exploitation rate for SL catch in AW
USLproj	Projected exploitation rate for SL catch in AW
USLproj/USLcurrent	ratio of SL projected exploitation rate to current SL exploitation rate
Probabilities	
P(Bref> Bmsy)	probability *Bref > Bmsy*
P(Bcurrent > Bmin)	probability *Bcurrent > Bmin*
P(Bcurrent > Bref)	probability *Bcurrent > Bref*
P(Bcurrent > Bmsy)	probability *Bcurrent > Bmsy*
P(Bproj > Bmin)	probability *Bproj > Bmin*
P(Bproj > Bref)	probability *Bproj > Bref*
P(Bproj > Bmsy)	probability *Bproj > Bmsy*
P(Bproj > Bcurrent)	probability *Bproj > Bcurrent*
P(USLproj > USLcurrent)	probability SL exploitation rate *proj* > SL exploitation rate *current*
P(SSBcurrent < 0.2 SSB0)	soft limit: probability *SSBcurrent* < 20% *SSB0*
P(SSBproj < 0.2 SSB0)	soft limit: probability *SSBproj* < 20% *SSB0*

A series of MCMC sensitivity trials was also made, including exclusion of puerulus data, using a flat recreational catch vector, fixed M, fast growth found in an exploratory trial, density-dependent growth and estimated shape of the CPUE/biomass relation. The assessment results from the base case and sensitivity trials calculated as a series of agreed indicators (Table 45) are shown in Table 46 for the more aggressive of the two catch scenarios (Scenario 1, Table 44). Indicators from Scenario 2, with lower projected catches, are not reported.

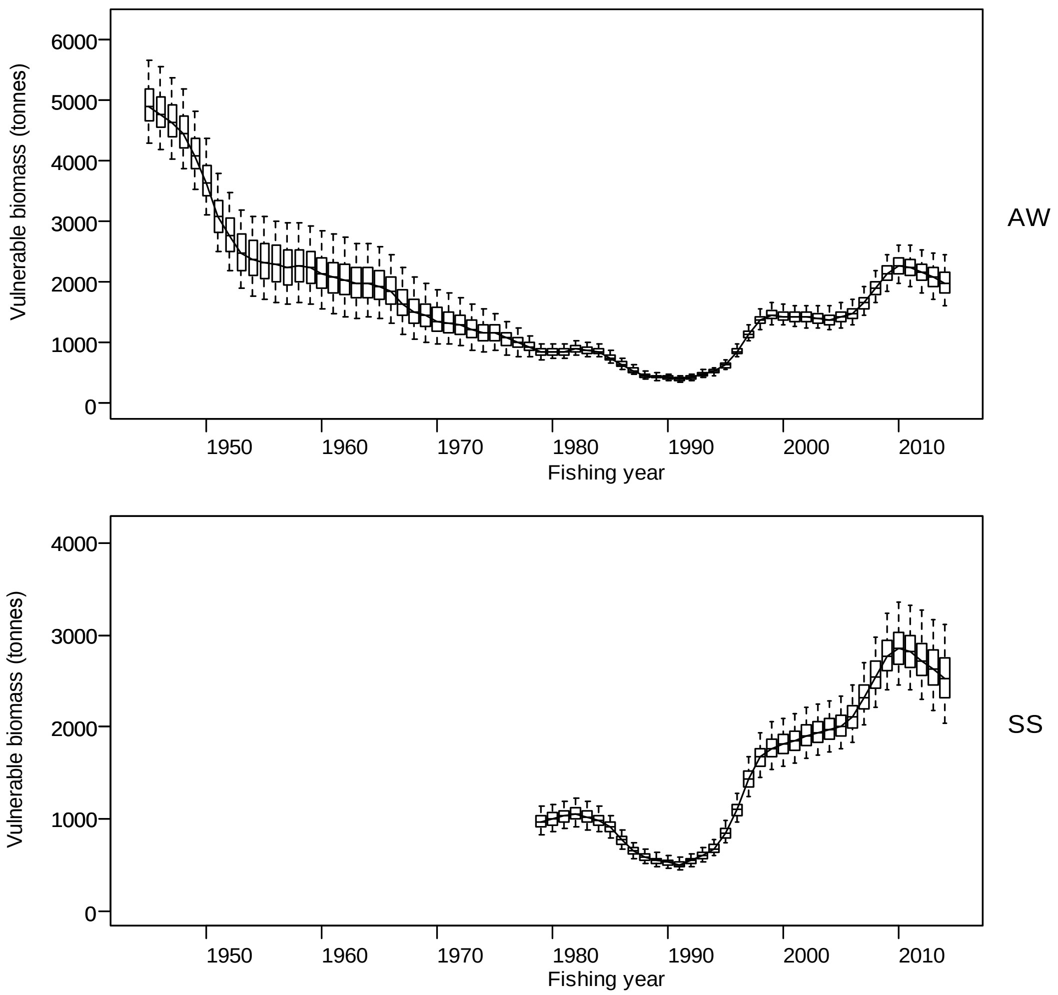


Figure 20: Posterior distributions of the base case McMC biomass vulnerable trajectory. Before 1979 there was a single time step, shown in AW. Projected catches were scenario 1 (Table 43). For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th quantiles.

Indicators based on vulnerable biomass (AW) and *Bmsy*

In the base case and for all trials, the median value for *Bref* was larger than the median for *Bmsy* and the probability of *Bref* being greater than *Bmsy* was at least 57%. In the base case and for all trials, current and projected biomass levels were larger than *Bref* and *Bmsy* reference levels by substantial factors for both catch projection scenarios. Projected biomass decreased in most runs but remained well above the reference levels in the base case and for all trials.

Table 46: Assessment results – medians of indicators described in Table 45 from the base case and sensitivity trials under Scenario 1 catches (Table 44); the lower part of the table shows the probabilities that events are true.

	base	no puerulus	flat rec. catch	fixed M	fast growth	d-d growth	non-linear CPUE
Bmin	404	401	462	338	182	263	492
Bcurr	2,266	2,279	2,633	1,943	800	1,503	1,401
Bref	763	754	867	636	345	536	754
Bproj	1,993	2,482	2,397	1,868	650	1,388	1,092
Bmsy	491	492	480	628	316	527	498
CPUEcurrent	1.61	1.63	1.63	1.66	1.39	1.58	1.50
CPUEproj	1.49	1.90	1.57	1.73	1.06	1.55	0.95
CPUEmsy	0.27	0.28	0.19	0.50	0.29	0.48	0.19
MSY	541	535	567	459	537	510	502
Bcurr/Bmin	5.59	5.68	5.72	5.74	4.41	5.67	2.85
Bcurr/Bref	2.96	3.02	3.05	3.05	2.32	2.79	1.86
Bcurr/Bmsy	4.62	4.62	5.54	3.10	2.53	2.88	2.82
Bproj/Bmin	4.91	6.15	5.15	5.51	3.60	5.23	2.23
Bproj/Bcurr	0.88	1.09	0.91	0.95	0.81	0.92	0.78
Bproj/Bref	2.60	3.27	2.75	2.92	1.89	2.57	1.45
Bproj/Bmsy	4.03	5.01	5.03	2.96	2.07	2.66	2.19
USLcurrent	0.122	0.122	0.101	0.145	0.327	0.184	0.187
USLproj	0.131	0.105	0.104	0.139	0.401	0.188	0.239
USLproj/USLcurrent	1.08	0.86	1.03	0.97	1.23	1.03	1.27
Fmult	5.47	5.41	9.51	2.73	4.05	2.97	3.14
P(Bref>Bmsy)	1.000	1.000	1.000	0.568	0.890	0.570	1.000
P(Bcurr>Bmin)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(Bcurr>Bref)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(Bcurr>Bmsy)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(Bproj>Bmin)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(Bproj>Bcurr)	0.075	0.787	0.092	0.289	0.162	0.093	0.025
P(Bproj>Bref)	1.000	1.000	1.000	1.000	0.979	1.000	0.991
P(Bproj>Bmsy)	1.000	1.000	1.000	1.000	0.986	1.000	1.000
P(USLproj>USLcurr)	0.804	0.110	0.663	0.360	0.794	0.652	0.960
P(SSBcurr<0.2SSB0)	0	0	0	0	0	0	0
P(SSBproj<0.2SSB0)	0	0	0	0	0	0	0

Indicators based on *SSBmsy*

SSBmsy is biomass of mature females associated with B_{MSY}. The historical track of biomass versus fishing intensity is shown in Figure 21. The phase space in the plot shows biomass on the x-axis and fishing intensity on the y-axis. High biomass/low intensity is in the lower right-hand corner, the location of the stock when fishing first began, and low biomass/high intensity is in the upper left-hand corner, in a period when the fishery was largely uncontrolled. Note that fishing patterns include MLS, selectivity and the seasonal catch split and that *Fmsy* varies in each year because fishing patterns change. The reference *SSBmsy* in Figure 21 has been calculated using the 2009 fishing pattern.

In 1945 the fishery was near the lower right-hand corner of the plot, in the high biomass/low fishing the intensity region as expected. It climbed towards the low biomass/high intensity region, reaching highest fishing intensity in 1985 and lowest biomass in 1991. After 1991, the fishery moved quite steadily back towards lower fishing intensity and higher biomass. The current biomass on this scale is near that of 1951, and current fishing intensity is near that of 1952.

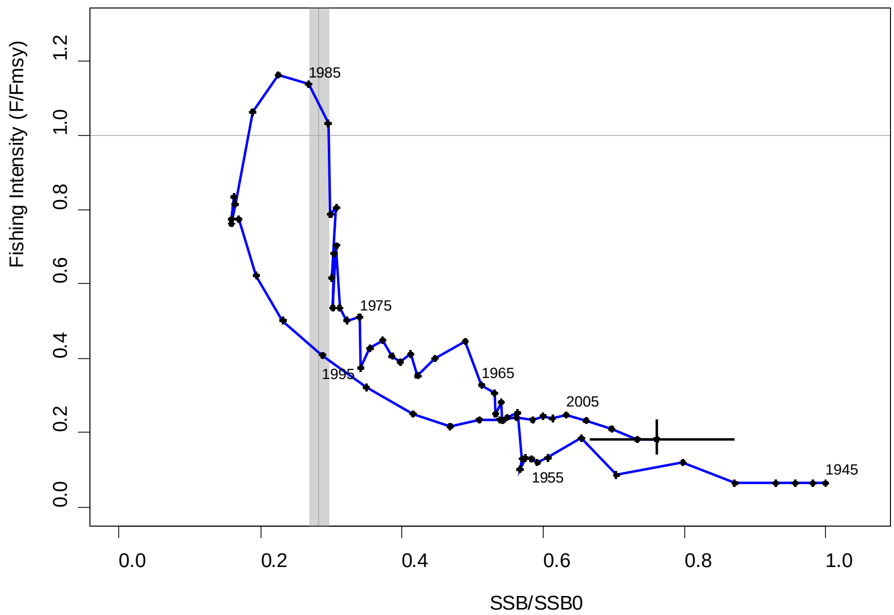


Figure 29: Phase plot that summarises the history of the CRA 5 fishery. The x-axis is the spawning biomass (SSB) as a proportion of B0 (SSB0); the y-axis is the ratio of the fishing intensity (F) relative to Fmsy. Each point is the median of the posterior distributions, and the bars associated with 2009 show the 90% confidence intervals. The vertical reference line shows SSBmsy as a proportion of SSB0, with the grey band indicating the 90% confidence interval. The horizontal reference line is Fmsy.

6.6 CRA 6

The most recent stock assessment for CRA 6 was done in 1996, using catches and abundance indices current up to the 1995–96 fishing year. The status of this stock is uncertain. Catches were less than the TACC 1990–91 to 2004–05, but have been within 10 t of the TACC since then. CPUE showed a declining trend from 1979–80 to 1997–98, but has then increased in two stages to levels higher than seen in the early 1990s. These observations suggest a stable or increasing standing stock after an initial fishing down period. However, size frequency distributions in the lobster catch had not changed when they were examined in the mid 1990s, with a continuing high frequency of large lobsters. Large lobsters would have been expected to disappear from a stock declining under fishing pressure. This apparent discrepancy could be caused by immigration of large lobsters into the area being fished. The models investigated assume a constant level of annual productivity which is independent of the standing stock.

Commercial removals in the 2012–13 fishing year (356 t) were within the range of estimates for MCY (300–380 t), and close to the current TACC (360 t). The current TAC (370 t) lies within the range of the estimated MCY.

Alternative methods have been used to assess the CHI stock. These include a simple depletion analysis presented to the Working Group in previous years and a production model, which appeared to fit the observed data well. Both models assume a constant level of annual productivity which is independent of the standing stock and thus will not be affected by changes to the level of the standing stock. B_0 was estimated by both models to be about 20 000 t.

6.7 CRA 7 and CRA 8

This section describes stock assessments for CRA 7 and CRA 8 conducted in 2012.

Model structure

A two-stock version of the multi-stock length-based model (MSLM) (Haist et al 2009) was fitted to data from CRA 7 and CRA 8: seasonal standardised CPUE from 1979-2011, length frequencies from observer and voluntary (logbook) catch sampling, tag-recapture data and (in preliminary explorations only) puerulus settlement data. The model used an annual time step from 1974 through 1978 and then switched to a seasonal time step with autumn-winter (AW, April through September) and spring-summer (SS) from 1979 through 2011. The model had 93 length bins, 31 for each sex group (males, immature and mature females), each 2 mm TW wide, beginning at left-hand edge 30 mm TW.

Significant catches occurred in the historical series for both CRA 7 and CRA 8 prior to the beginning of the model and the reconstruction assumed the population began from an exploited state. MLS and escape gap regulations in place at the beginning of the reconstruction differed from those currently active. To accommodate these differences, the model incorporated stock-specific time series of MLS regulations by sex and modelled escape gap regulation changes by estimating separate selectivity functions prior to 1993. For the first time, the model was modified to simulate the return of lobsters to the sea in CRA 8, where this practice had become prevalent. Smaller males are retained in preference to larger males, and the model used annual fitted retention curves from 2000 onwards to simulate this in the fishing dynamics. Data and their sources are listed in Table 47.

The assessment assumed that recreational catch was proportional to SS CPUE from 1979 through 2011, that, in 1994, 1996, 2000 and 2001, it was equal to the mean of the 1994, 1996, 2000 and 2001 recreational surveys (see Section 1.2), and that it increased linearly from 20% of the 1979 value in 1945 up to the 1979 value.

Table 47: Data types and sources for the 2012 assessment for CRA 7 and CRA 8. Year codes are from the first 9 months of each fishing year, *viz.* 1998–99 is called 1998. NA – not applicable or not used; MPI – NZ Ministry for primary Industries; NZ RLIC – NZ Rock Lobster Industry Council; FSU: Fisheries Statistics Unit; CELR: catch and effort landing returns; NIWA: National Institute of Water and Atmosphere.

Data type	Data source	CRA 7 Begin year	CRA 7 End year	CRA 8 Begin year	CRA 8 End year
CPUE	FSU & CELR	1979	2011	1979	2011
Observer proportions-at-size	MPI and NZ RLIC	1988	2011	1987	2010
Logbook proportions-at-size	NZ RLIC	not used	not used	1993	2011
Tag recovery data	NZ RLIC & MFish	1965	2008	1966	2011
Historical MLS regulations	Annala (1983), MPI	1974	2011	1974	2011
Escape gap regulation changes	Annala (1983), MPI	1974	2011	1974	2011
Puerulus settlement	NIWA	1990	2011	1980	2011
Retention	NZ RLIC	NA	NA	2000	2011

The initial population in 1974 was assumed to be in equilibrium with an estimated exploitation rate in each stock. Each season, numbers of male, immature female and mature female lobsters in each size class were updated as a result of:

Recruitment: Each year, new recruits to the model were added equally for each sex for each season for each stock, as a normal distribution with a mean size (32 mm) and standard deviation (2 mm), truncated at the smallest size class (30 mm). Recruitment in a specific year was determined by the parameters for base recruitment and parameters for the deviations from base recruitment; all recruitment parameters were stock-specific. The vector of recruitment deviations in natural log space was assumed to be normally distributed with a mean of zero. Recruitment deviations were estimated for 1974 through 2009.

Mortality: Natural, fishing and handling mortalities were applied to each sex category in each size class. Natural mortality was assumed to be constant and independent of sex and length; a common estimated value was used for both stocks. Fishing mortality was determined from observed catch and model biomass in each stock, modified by legal sizes, sex-specific vulnerabilities and selectivity curves in each stock and, for CRA 8, retention curves for 2000 and later. Handling mortality was assumed to be 10% for fish returned to the water. Two fisheries were modelled for each stock: one that operated only on fish above the size limit, excluding berried females (SL fishery – including legal commercial and recreational) and one that did not respect size limits and restrictions on berried females (NSL fishery – all of the illegal fishery plus the Mäori customary fishery). Selectivity and vulnerability functions were otherwise the same for the SL and NSL fisheries. Vulnerability in each stock by sex category and season was estimated relative to males in AW, which were assumed to have the highest vulnerability. Instantaneous fishing mortality rates for each fishery were calculated using Newton-Raphson iteration (four iterations after previous experiments) based on catch and model biomass.

Fishery selectivity: A three-parameter fishery selectivity function was assumed, with parameters for each stock describing the shapes of the ascending and descending limbs and the size at which vulnerability is at a maximum. Changes in regulations over time (for instance, changes in escape gap regulations) were modelled by estimating selectivity in two separate epochs, pre–1993 and 1993–2011. As in previous assessments for the past decade, the descending limb of the selectivity curve was fixed to prevent under-estimation of vulnerability of large lobsters. Estimated selectivity parameters were stock-specific.

Growth and maturation: For each size class and sex category in each stock, a growth transition matrix specified the probability of an individual remaining in the same size class or growing into each of the other size classes. Maturation of females was estimated as a two-parameter logistic curve from the maturity-at-size information in the size frequency data. Estimated growth and maturation parameters were stock-specific.

Movements between stocks: For each year from 1985-2010, the model estimated the proportion of fish of sizes 45-60 mm TW that moved each season from CRA 7 to CRA 8. Mean movement was assumed for all other years. The estimated movement parameters were given an upper bound of 15% in the base case.

Model fitting:
A total negative log likelihood function was minimised using AD Model Builder™. The model was fitted to standardised CPUE and (in explorations only) puerulus settlement data using lognormal likelihood, to proportions-at-length with multinomial likelihood and to tag-recapture data with robust normal likelihood. For the CPUE and puerulus lognormal likelihoods, CVs for each index value were initially set at the standard error from the GLM analysis. Process error was subsequently added to these CVs.

Proportions-at-length, assumed to be representative of the commercial catch, were available (see Table) from observer catch sampling and voluntary logbooks: data were summarised by area/month strata and weighted by the commercial catch taken in each stratum, the number of lobsters measured and the number of days sampled. Size data from each source were fitted separately. Seasonal proportions-at-length summed to one across males, immature and mature females. These data were weighted within the model using the method of Francis (2011).

Experiments (randomisation trials) were conducted to determine whether puerulus settlement data contained a signal with respect to recruitment to the model and, if so, at what lag. These were significant for both stocks, but exploration showed there was no predictive power in the settlement data, and these data were not used further.

In the base case, it was assumed that biomass was proportional to CPUE, that growth was density-dependent, that there is no stock-recruit relationship and that there was migration between CRA 7 and CRA 8, involving fish from 45-60 mm TW. Base case explorations involved experimentally weighting the datasets and inspecting the resulting standard deviations of normalised residuals and medians of absolute residuals, exploring the effect of the start year, experimentally fixing parts of the growth estimation, experimenting with the prior for *M*, experimenting with the upper bound on annual movements and exploring other model options such as CPUE shape. The growth C.V. was fixed after early explorations.

Parameters estimated in the base case and their priors are provided in Table 48. Fixed parameters and their values are given in Table 49.

Table 48: Parameters estimated and priors used in the base case assessments for CRA 7 and CRA 8. Prior type abbreviations: U – uniform; N – normal; L – lognormal.

Parameter	Prior Type	No. of parameters	Bounds	Mean	SD	CV
ln(*R0*) (mean recruitment)	U	2	1–25	–	–	–
M (natural mortality)	L	1	0.01–0.35	0.12	–	0.15
Initial exploitation rate	U	2	0.00–0.99	–	–	–
Recruitment deviations	N [1]	72	-2.3–2.3	0	0.4	
ln(*qCPUE*)	U	2	-25–0	–	–	–
Increment at TW=50 (male & female)	U	4	1–20	–	–	–
ratio of TW=80 increment at TW=50 (male & female)	U	4	0.001–1.000	–	–	–
shape of growth curve (male & female)	U	4	0.1–15.0	–	–	–
TW at 50% probability female maturation	U	2	30–80	–	–	–
difference between TWs at 95% and 50% probability female maturation	U	2	5–60	–	–	–
Relative vulnerability (all sexes and seasons)	U	8	0.01–1.0	–	–	–
Shape of selectivity left limb (males & females)	U	6	1–50	–	–	–
Size at maximum selectivity (males & females)	U	6	30–70	–	–	–
Shape of growth density-dependence	U	2	0–1	–	–	–
Movement parameters	U	26	0.00–0.15	–	–	–

[1] Normal in natural log space = lognormal (bounds equivalent to –10 to 10)

Table 49: Fixed values used in base case assessment for CRA 7 and CRA 8

Value	CRA 7	CRA 8
Shape parameter for CPUE vs biomass	1.0	1.0
Minimum std. dev. of growth increment	0.9	0.9
Std. dev. of observation error of increment	0.5	0.5
Handling mortality	10%	10%
Process error for CPUE	0.25	0.25
Year of selectivity change	1993	1993
Current male size limit (mm TW)	47	54
Current female size limit (mm TW)	49	57
First year for recruitment deviations	1974	1974
Last year for recruitment deviations	2009	2009
Relative weight for length frequencies	1.2	1.2
Relative weight for CPUE	1.4	1.4
Relative weight for tag-recapture data*	0.5	0.5

*for CRA 7 the weight for tag-recapture data was increased by doubling the dataset

Model projections

Bayesian estimation procedures were used to estimate the uncertainty in model estimates and short-term projections. This procedure was conducted in the following steps:

1. Model parameters were estimated by AD Model Builder™ using maximum likelihood and the prior probabilities. The point estimates are called the MPD (mode of the joint posterior) estimates;
2. Samples from the joint posterior distribution of parameters were generated with Markov chain - Monte Carlo (McMC) simulations using the Hastings-Metropolis algorithm; one million simulations were made, starting from the base case MPD, and 1000 samples were saved.
3. From each sample of the posterior, 4-year projections (2012–2015) were generated using the 2011 catches, with annual recruitment randomly sampled from the model's estimated recruitments from 2000-09, and with annual movement set to its mean value.

Performance Indicators and Results

Vulnerable biomass in the assessment model was determined by the MLS, selectivity, relative sex and seasonal vulnerability and berried state for mature females. All mature females were assumed to be berried, not vulnerable to the fishery, in AW and not berried, thus vulnerable, in SS.

Agreed indicators are summarised in Table 50. The WG agreed that *Bmsy* and *SSB* indicators were not useful for CRA 7 because of the high level of out-migration estimated for this stock, and that *Bref* (mean biomass for 1979-85) should replace *Bmsy* for CRA 7. This implied that the soft and hard limits for CRA 7 should be 50% *Bref* and 25% *Bref* respectively.

For CRA 7, base case results (Figure 22 and Table 51) suggested that AW biomass decreased to a low point in 1997, increased to a high in 2009 and since then has decreased again. *Bcurrent* is about 1.25 times *Bref*. Median projected biomass is 25% greater than current biomass at the level of current catches over the next 4 years. Neither current nor projected biomass is anywhere near the soft limit.

For CRA 8, base case results (Figure 23 and Table 52) suggested that AW biomass decreased to a low point in 1990, remained relatively low until 2000, then increased strongly to a high in 2009 and subsequently has decreased but remains relatively high. *Bcurrent* is well above both *Bmsy* and *Bref* (mean biomass for 1979-85). Biomass is projected to decrease by a median of 16% in four years at the current level of catches, but is projected to remain well above both *Bref* and *Bmsy*. Spawning biomass is a high proportion – more than 70% – of the unfished level. Neither current nor projected biomass is anywhere near the soft limit.

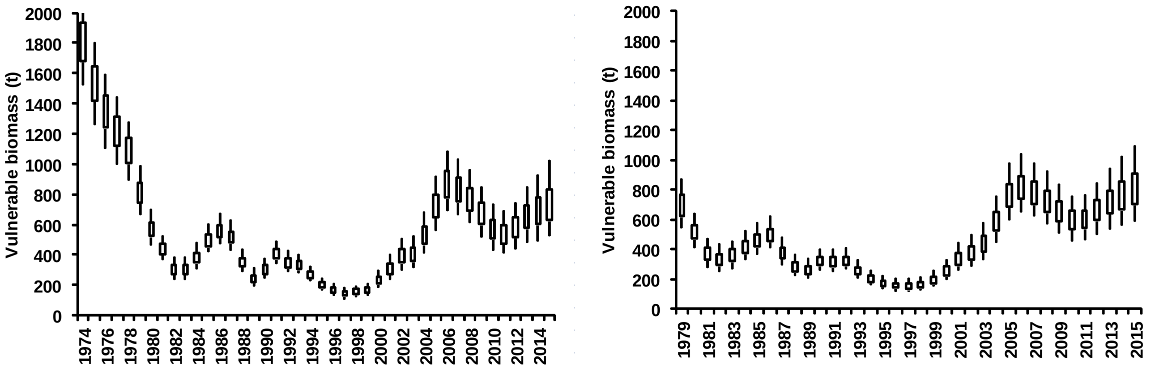


Figure 22: Posterior distributions of the CRA 7 base case McMC vulnerable biomass trajectory. Before 1979 there was a single time step, shown in AW. For each year the box spans the 25th and 75th quantiles and the whiskers span the 5th and 95th quantiles.

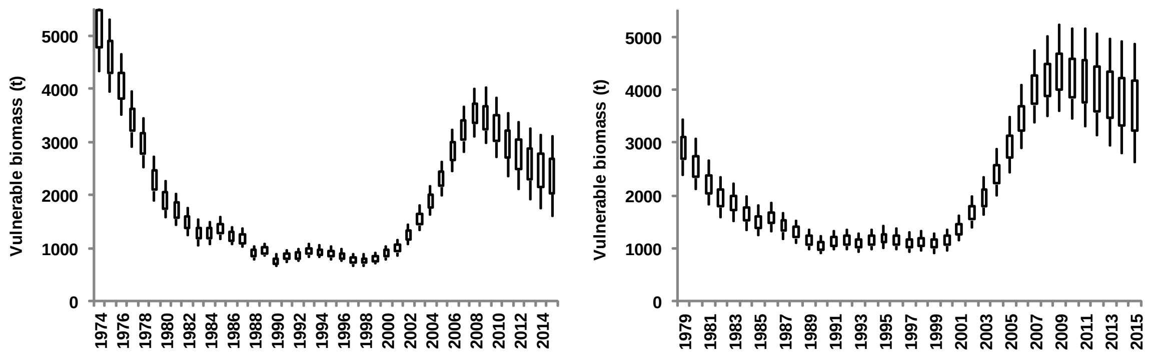


Figure 10: Posterior distributions of the CRA 8 base case McMC vulnerable biomass trajectory. Before 1979 there was a single time step, shown in AW. For each year the box spans the 25th and 75th quantiles and the whiskers span the 5th and 95th quantiles.

Table 50: Performance indicators used in the CRA 7 and CRA 8 stock assessments

Reference points	
Bmin	The lowest beginning AW vulnerable biomass in the series
Bcurrent	Beginning of season AW vulnerable biomass for the year the stock assessment is performed
Bref	Beginning of AW season mean vulnerable biomass for 1979–85
Bproj	Projected beginning of season AW vulnerable biomass (ie, the year of stock assessment plus 4 years)
Bmsy	Beginning of season AW vulnerable biomass associated with MSY, calculated by doing deterministic forward projections with recruitment *R0* and current fishing patterns
MSY	Maximum sustainable yield (sum of AW and SS SL catches) found by searching a across a range of multipliers on *F*.
Fmult	The multiplier that produced *MSY*
SSBcurr	Current spawning stock biomass at start of AW season
SSBproj	Projected spawning stock biomass at start of AW season
SSBmsy	Spawning stock biomass at start of AW season associated with *MSY*
CPUE indicators	
CPUEcurrent	CPUE at *Bcurrent*
CPUEproj	CPUE at *Bproj*
CPUEmsy	CPUE at *Bmsy*
Performance indicators	
Bcurrent / Bmin	ratio of *Bcurrent* to *Bmin*
Bcurrent / Bref	ratio of *Bcurrent* to *Bref*
Bcurrent / Bmsy	ratio of *Bcurrent* to *Bmsy*
Bproj / Bcurrent	ratio of *Bproj* to *Bcurrent*
Bproj / Bref	ratio of *Bproj* to *Bref*
Bproj / Bmsy	ratio of *Bproj* to *Bmsy*
SSBcurr/SSB0	ratio of *SSBcurrent* to *SSB0*
SSBproj/SSB0	ratio of *SSBproj* to *SSB0*
SSBcurr/SSBmsy	ratio of *SSBcurrent* to *SSBmsy*
SSBproj/SSBmsy	ratio of *SSBproj* to *SSBmsy*
SSBproj/SSBcurr	ratio of *SSBproj* to *SSBcurrent*
USLcurrent	The current exploitation rate for SL catch in AW
USLproj	Projected exploitation rate for SL catch in AW
USLproj/USLcurrent	ratio of SL projected exploitation rate to current SL exploitation rate
Probabilities	
P*(Bcurrent > Bmin)*	probability *Bcurrent* > *Bmin*
P*(Bcurrent > Bref)*	probability *Bcurrent* > *Bref*
P*(Bcurrent > Bmsy)*	probability *Bcurrent* > *Bmsy*
P*(Bproj > Bmin)*	probability *Bproj* > *Bmin*
P*(Bproj > Bref)*	probability *Bproj* > *Bref*
P*(Bproj > Bmsy)*	probability *Bproj* > *Bmsy*
P*(Bproj > Bcurrent)*	probability *Bproj* > *Bcurrent*
P*(SSBcurr>SSBmsy)*	probability *SSBcurr>SSBmsy*
P*(SSBproj>SSBmsy)*	probability *SSBproj>SSBmsy*
P*(USLproj>USLcurr)*	probability SL exploitation rate *proj* > SL exploitation rate *current*
P*(SSBcurr<0.2SSB0)*	soft limit CRA 8: probability *SSBcurrent* < 20% *SSB0*
P*(SSBproj<0.2SSB0*	soft limit CRA 8: probability *SSBproj* < 20% *SSB0*
P*(SSBcurr<0.1SSB0)*	hard limit CRA 8: probability *SSBcurrent* < 10% *SSB0*
P*(SSBproj<0.1SSB0)*	hard limit CRA 8: probability *SSBproj* < 10% *SSB0*
P(*Bcurr*<50%*Bref*)	soft limit CRA 7: probability *Bcurr* < 50% *Bref*
P(*Bcurr*<25%*Bref*)	hard limit CRA 7: probability *Bcurr* < 25% *Bref*
P(*Bproj*<50%*Bref*)	soft limit (CRA 7): probability *Bproj* < 50% *Bref*
P(*Bproj*<25%*Bref*)	hard limit (CRA 7):probability *Bproj*< 25% *Bref*

MCMC sensitivity trials were also made:
TwoMs: estimating separate natural mortality for CRA 7 and CRA 8
Moves5% and *Moves25%*: capping seasonal movements at 5% and 25%
FlatRec: using an alternative constant recreational catch vector, not proportional to abundance
FixShape: with growth shape fixed at 2
noDD: with no growth density-dependence

Results from the base case and sensitivity trials are compared in Table 51 for CRA 7 and Table 52 for CRA 8.

Table 51: Assessment results: median and probability indicators for CRA 7 from the base case McMC and sensitivity trials; biomass in tonnes and CPUE in kg/pot. Probabilities involving the *Bref* hard and soft limits were not calculated when the sensitivity trials were done, but are shown for the base case (last four rows).

indicator	base	TwoMs	Moves5%	Moves25%	FlatRec	FixShape	NoDD
Bmin	147.8	155.5	2815.9	127.0	170.7	160.6	151.8
Bcurr	599.5	599.6	8147.0	504.1	659.9	612.4	573.4
Bref	481.7	494.8	6568.7	447.4	528.4	505.4	485.3
Bproj	754.8	727.2	8456.1	659.8	796.8	744.5	717.9
Bmsy	217.4	203.5	5187.6	172.7	215.6	202.5	206.1
MSY	154.1	165.0	461.0	177.9	177.7	174.4	175.1
Fmult	10.1	12.7	15.2	15.2	15.2	15.2	13.2
SSBcurr	99.5	128.1	2373.7	120.3	161.4	166.1	174.4
SSBproj	138.1	155.9	1863.0	142.0	186.6	188.3	192.2
CPUEcurrent	1.0	0.9	0.9	0.8	0.9	0.9	0.9
CPUEproj	1.294	1.183	0.839	1.220	1.178	1.166	1.174
CPUEmsy	0.275	0.225	0.501	0.191	0.223	0.215	0.232
Bcurr/Bmin	4.057	3.863	2.880	3.972	3.874	3.822	3.788
Bcurr/Bref	1.246	1.206	1.237	1.123	1.239	1.210	1.175
Bproj/Bcurr	1.251	1.200	1.028	1.295	1.198	1.200	1.233
Bproj/Bref	1.570	1.461	1.286	1.475	1.497	1.469	1.466
USLcurrent	0.067	0.066	0.004	0.081	0.059	0.064	0.069
USLproj	0.077	0.080	0.007	0.089	0.076	0.078	0.081
USLproj/USLcurrent	1.155	1.227	1.654	1.084	1.301	1.244	1.198
P(*Bcurr*>*Bmin*)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(*Bcurr*>*Bref*)	0.980	0.969	0.989	0.849	0.977	0.955	0.937
P(*Bproj*>*Bmin*)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(*Bproj*>*Bref*)	0.998	0.987	0.875	0.981	0.985	0.972	0.988
P(*Bproj*>*Bcurr*)	0.975	0.926	0.549	0.966	0.894	0.900	0.947
P(*USLproj*>*USLcurr*)	0.811	0.891	0.951	0.686	0.944	0.885	0.830
P(*Bcurr*<*0.5Bref*)	0.000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
P(*Bproj*<*0.5Bref*)	0.000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
P(*Bcurr*<*0.25Bref*)	0.000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
P(*Bproj*<*0.25Bref*)	0.000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Table 52: Assessment results: median and probability indicators for CRA 8 from base case McMC and sensitivity trials; biomass in tonnes and CPUE in kg/pot. [Continued on next page]

indicator	base	TwoMs	Moves5%	Moves25%	FlatRec	FixShape	NoDD
Bmin	734.2	721.7	775.0	722.5	731.0	704.1	964.8
Bcurr	2758.2	2767.3	3013.0	2837.2	2875.1	2761.4	4378.0
Bref	1618.3	1588.7	1677.6	1566.6	1589.5	1598.2	2041.6
Bproj	2303.7	2360.5	2580.1	2482.2	2452.6	2378.2	4176.3
Bmsy	1221.2	1361.4	1203.4	1297.8	1320.8	1328.2	2180.6
MSY	1136.1	1151.2	1146.2	1127.2	1128.7	1122.8	1224.1
Fmult	2.0	1.7	2.3	1.8	2.0	1.7	1.6
SSBcurr	4532.0	4828.0	5458.7	4945.1	4799.6	4512.6	5498.4
SSBproj	4526.0	4994.2	5467.0	5166.1	5024.2	4668.1	5725.7
SSBmsy	2130.4	2723.0	2373.8	2651.3	2604.9	2578.5	3459.1
CPUEcurrent	2.7	2.8	2.9	2.8	2.8	2.8	3.1
CPUEproj	2.004	2.115	2.188	2.230	2.142	2.155	2.817
CPUEmsy	0.896	1.082	0.845	1.024	1.000	1.069	1.353
Bcurr/Bmin	3.712	3.838	3.900	3.924	3.912	3.924	4.519
Bcurr/Bref	1.684	1.751	1.802	1.806	1.804	1.738	2.142
Bcurr/Bmsy	2.247	2.027	2.505	2.175	2.192	2.055	2.000
Bproj/Bcurr	0.843	0.850	0.854	0.865	0.851	0.856	0.942
Bproj/Bref	1.417	1.502	1.544	1.570	1.524	1.483	2.032
Bproj/Bmsy	1.885	1.728	2.144	1.896	1.865	1.763	1.914
SSBcurr/SSB0	0.713	0.660	0.900	0.688	0.688	0.725	0.452
SSBproj/SSB0	0.712	0.685	0.900	0.717	0.721	0.752	0.476
SSBcurr/SSBmsy	2.13	1.77	2.31	1.87	1.84	1.75	1.56
SSBproj/SSBmsy	2.12	1.84	2.32	1.95	1.92	1.81	1.64
SSBproj/SSBcurr	1.000	1.039	1.001	1.046	1.046	1.040	1.045
USLcurrent	0.218	0.218	0.198	0.214	0.211	0.220	0.143
USLproj	0.280	0.274	0.250	0.260	0.276	0.272	0.155

Table 52 [Continued]: Assessment results: median and probability indicators for CRA 8 from base case McMC and sensitivity trials; biomass in tonnes and CPUE in kg/pot.

USLproj/USLcurrent	1.282	1.255	1.266	1.228	1.315	1.244	1.095
P(*Bcurr>Bmin*)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(*Bcurr>Bref*)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(*Bcurr>Bmsy*)	1.000	1.000	1.000	1.000	1.000	1.000	0.998
P(*Bproj>Bmin*)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(*Bproj>Bref*)	0.950	0.977	0.993	0.988	0.981	0.972	1.000
P(*Bproj>Bmsy*)	0.999	0.994	1.000	1.000	0.999	0.998	0.989
P(*Bproj>Bcurr*)	0.063	0.100	0.061	0.096	0.082	0.076	0.293
P(*SSBcurr>SSBmsy*)	1.000	1.000	1.000	1.000	1.000	1.000	0.970
P(*SSBproj>SSBmsy*)	1.000	1.000	1.000	1.000	1.000	1.000	0.985
P(*USLproj>USLcurr*)	0.981	0.946	0.982	0.955	0.973	0.950	0.750
P(*SSBcurr<0.2SSB0*)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
P(*SSBproj<0.2SSB0*)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
P(*SSBcurr<0.1SSB0*)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
P(*SSBproj<0.1SSB0*)	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Indicators based on vulnerable biomass (AW) and *Bmsy*

Except in the *noDD* trial for CRA 8, the median *Bref* was larger than the median *Bmsy*. In all trials, current and projected biomass was larger than *Bref* and *Bmsy* by substantial factors. Projected biomass increased in nearly all runs for CRA 7; it decreased in most runs for CRA 8 but remained well above the reference levels.

Indicators based on *SSBmsy*

The historical track of biomass versus fishing intensity is shown in Figure 24 for the CRA 8 stock. The phase space in the plot shows biomass on the x-axis and fishing intensity on the y-axis. High biomass/low intensity is in the lower right-hand corner, the location of the stock when fishing first began, and low biomass/high intensity is in the upper left-hand corner, in a period when the fishery was largely uncontrolled. *Fmsy* varies among runs because of parameter variations and among years because of variation in fishing patterns, which include MLS, selectivity and the seasonal catch split. The reference *SSBmsy* in Figure 24 was calculated using the 2011 fishing pattern.

Fmsy was calculated with a 50-year projection for each year in each run, with the NSL catch held constant at that year's value, deterministic recruitment at *R0* and a range of multipliers on the SL catch *F*s estimated for year *y*. The *F* (actually separate *F*s for two seasons) that gives *MSY* is *Fmsy* and the multiplier is *Fmult*. Each point on the figure was plotted as the median of the posterior distributions of biomass ratio and fishing intensity ratio.

The silvery trail suggests that the CRA 8 stock was above *Bmsy* and was fished at below *Fmsy* in 1974; that fishing intensity increased and biomass decreased to overfishing and overfished levels; and that biomass has been above *Bmsy* since 2004 and fishing intensity below *Fmsy* since 2000.

No corresponding figure is available for CRA 7 because of the WG's determination that *Bmsy* and *SSB* indicators are not useful for that stock.

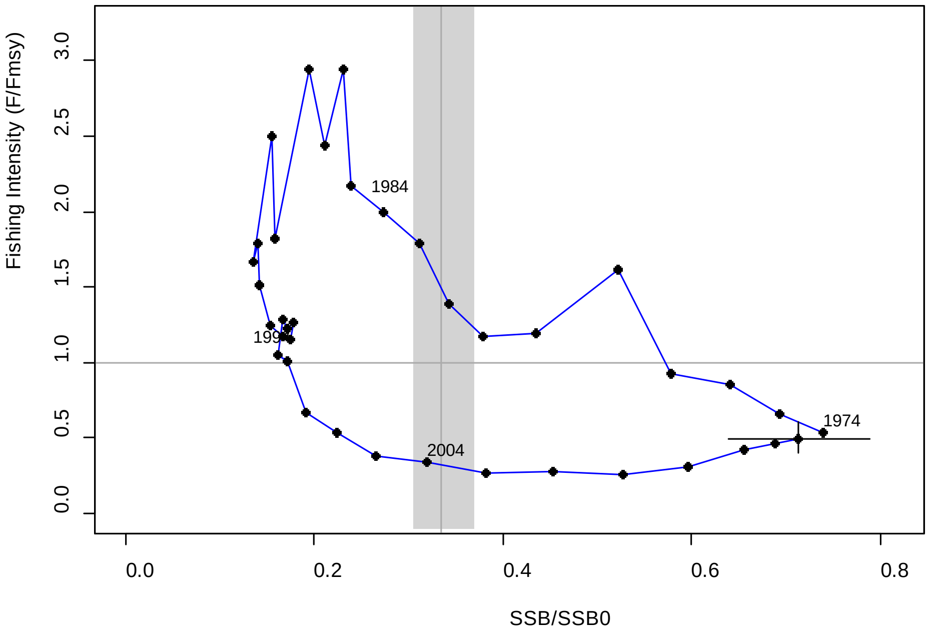


Figure 11: Phase plot that summarises the *SSB* history of the CRA 8 stock. The x-axis is spawning stock biomass *SSB* in each year as a proportion of the unfished spawning stock, *SSB0*. *SSB0* is constant for all years of a run, but varies through the 1000 runs. The y-axis is fishing intensity in each year as a proportion of the fishing intensity (*Fmsy*) that would have given *MSY* under the fishing patterns in that year Each point on the figure shows the median of the posterior distributions of biomass ratio and fishing intensity ratio for one year. The vertical line in the figure is the median (line) and 90% interval (shading) of the posterior distribution of *SSBmsy* ; this ratio was calculated using the fishing pattern in 2011. The horizontal line in the figure is drawn at 1, the fishing intensity associated with *Fmsy*. The bars at the final year of the plot (2011) show the 90% intervals of the posterior distributions of biomass ratio and fishing intensity ratio.

6.8 CRA 9

This section describes work conducted for CRA 9 in 2013 (Breen in prep.).

Model structure

A Fox surplus-production model was fitted to catch and effort data from CRA 9. Annual commercial catch came from the FSU and QMR/ MHR series; recreational catch was assumed to be proportional to standardised spring-summer CPUE (Paul Starr, pers. comm.) and was tuned to the large-scale multi-species survey (National Research Bureau in prep.) in 2011–12 (18 t in 2011). Illegal and customary catch estimates were assumed from information supplied by MPI (both assumed at 1 t for 2012). Annual CPUE was standardised for 1979-2012 (Starr in prep.).

The model was fitted using uniform priors on most parameters (Table 54), but an informed prior on the intrinsic rate of increase was developed.

Table 53: Data types and sources available for the assessment of CRA 9 in 2013. Fishing years are named from the first 9 months, *viz.* 1998–99 is called 1998. NA – not applicable or not used; MPI – NZ Ministry for Primary Industries; NZ RLIC – NZ Rock Lobster Industry Council Ltd.; FSU: Fisheries Statistics Unit; CELR: catch and effort landing returns; NIWA: National Institute of Water and Atmosphere.

Data type	Data source	CRA 9 Begin year	CRA 9 End year
Standardised CPUE	FSU & CELR	1979	2012
Historical CPUE	Annala & King (1963)	1963	1973
Observer proportions-at-size	MPI and NZ RLIC	NA	NA
Logbook proportions-at-size	NZ RLIC	1996	2011
Tag recovery data	NZ RLIC & MFish	1999	2009
Historical MLS regulations	Annala (1983), MPI	NA	NA
Escape gap regulation changes	Annala (1983), MPI	NA	NA
Puerulus settlement	NIWA	NA	NA
Retention	NZ RLIC	NA	NA

Model fitting:

A total negative log-likelihood function was minimised using AD Model Builder™. The model was fitted to the two CPUE series using robust lognormal likelihood and the variance terms were estimated. The model was fitted to the period 1963–2012 and estimated biomass at the beginning of 1963. Parameters estimated in the base case and their priors are provided in Table 54.

Table 54: Parameters estimated and priors used in the base case assessment for CRA 2. Prior type abbreviations: U – uniform; N – normal; L – lognormal.

Parameter	Prior Type	No. of parameters	Bounds	Mean	SD
ln(*K*) (carrying capacity)	U	1	1–25	–	–
Binit (1963 biomass)	U	1	1–25	–	–
r (intrinsic rate of increase)	L	1	0.01–10	2.1	0.25
p (shape parameter)	U	1	0.01–5.0	–	–
ln(*q1*) (catchability for kg/day)	U	1	-20.0–-3.0	–	–
ln(*q2*) (catchability for kg/pot)	U	1	-20.0–-3.0	–	–
sigma1 (for fitting catch/day)	U	1	0.1–2.0	–	–
sigma2 (for fitting catch/pot)	U	1	0.01–2.0	–	–

Bayesian estimation procedures were used to estimate the uncertainty in model estimates and short-term projections. Model parameters were estimated by AD Model Builder™ using maximum likelihood and the prior probability distributions. These estimates are called the MPD (mode of the joint posterior distribution) estimates. Samples from the joint posterior distribution of parameters were generated with Markov chain - Monte Carlo (McMC) simulations using the AD Model Builder Hastings-Metropolis algorithm; five million simulations were made, starting from the base case MPD, and 2500 samples were saved.

Results

Base case results (Figure 25 and Table 55) suggested that AW biomass decreased to a low point in the late 1980s and increased steadily after introduction of the QMS. Estimated current biomass was about 60% of *B0* (where *B0* was assumed equal to carrying capacity, *K*) and 50-60% above *Bmsy*. A phase plot (Figure 26) suggested that the CRA 9 stock was overfished when the QMS was introduced in the early 1990s, then rebuilt steadily to a stock now well above *Bmsy* with current fishing intensity below that associated with *MSY*. Low current fishing intensity is consistent with the numerous large fish observed in logbook sampling.

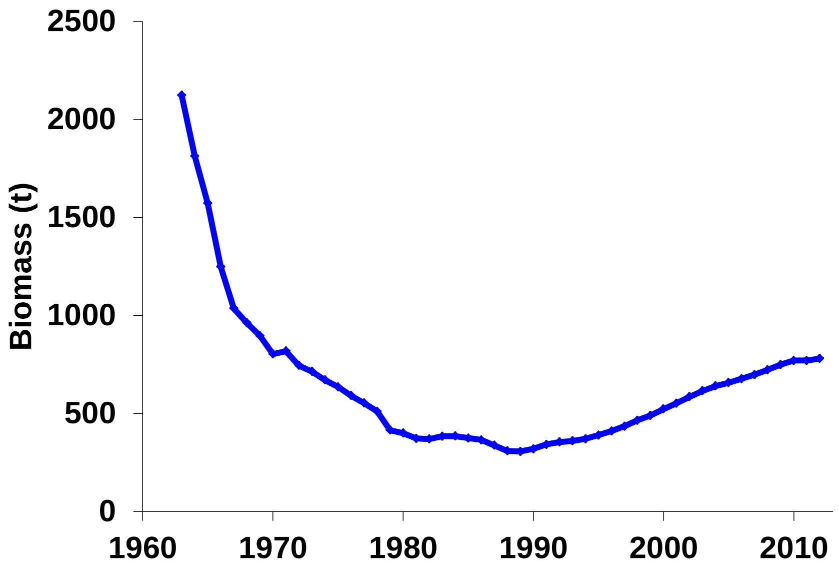


Figure 12: CRA 9 biomass from the base case MPD.

Table 55: CRA 9 surplus production model observation-error fit: summaries of posterior distributions (5th and 95th quantiles, mean and median) of estimated and derived parameters from the McMC, and the MPD estimates. Biomass and yields are shown in t.

	5%	mean	median	95%	MPD
Binit	1139.5	2055.0	4023.0	14405.0	2123.1
K	1130.0	1320.0	1377.7	1830.0	1287.5
r	1.352	1.894	1.921	2.572	1.937
p	0.08	0.11	0.12	0.17	0.12
ln(*q*) for kg/day	-9.940	-9.707	-9.703	-9.452	-9.692
ln(*q*) for kg/pot	-13.17	-12.90	-12.91	-12.70	-12.84
sigma for kg/day	0.113	0.223	0.245	0.451	0.168
sigma for kg/pot	0.147	0.185	0.187	0.236	0.172
B2012	706.4	805.7	831.8	1040.0	780.4
B2012/K	0.540	0.611	0.608	0.662	0.606
Bmin	260	334	344	460	307
Bmsy	441	513	535	704	500
B2012/Bmsy	1.399	1.571	1.564	1.701	1.561
MSY	97.6	101.8	102.2	107.8	100.9
CSP	79.7	85.0	86.1	96.2	85.5

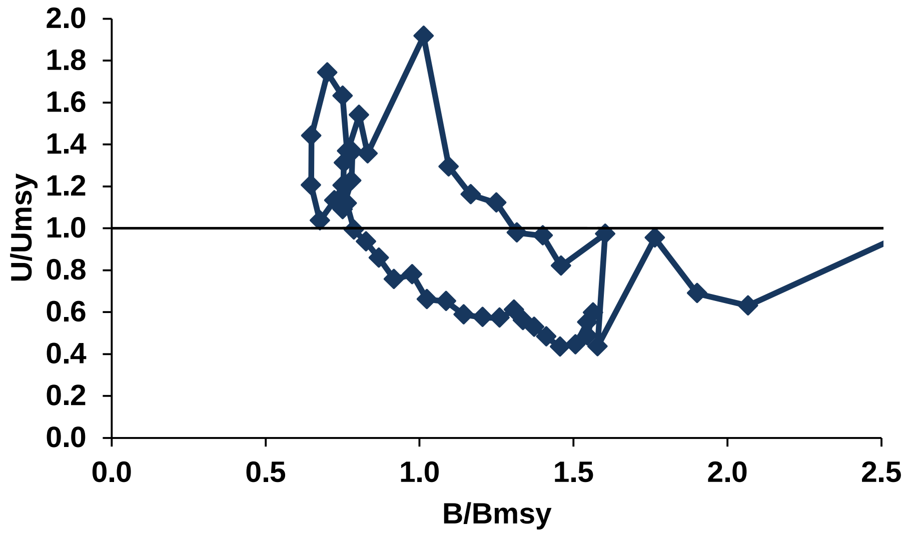


Figure 26: Phase plot of the CRA 9 fishery: the x-axis is the mean of the posterior distribution of biomass as a proportion of *Bmsy*; the y-axis is the mean of the posterior of exploitation rate as a proportion of equilibrium exploitation rate at *Bmsy*; the horizontal line is 1.0 (equilibrium exploitation rate at *Bmsy*). The value above 2.5 on the right is 1967; 2012 is the last point in the string above 1.5; the point at the upper left corner is 1986.

7. STATUS OF THE STOCKS

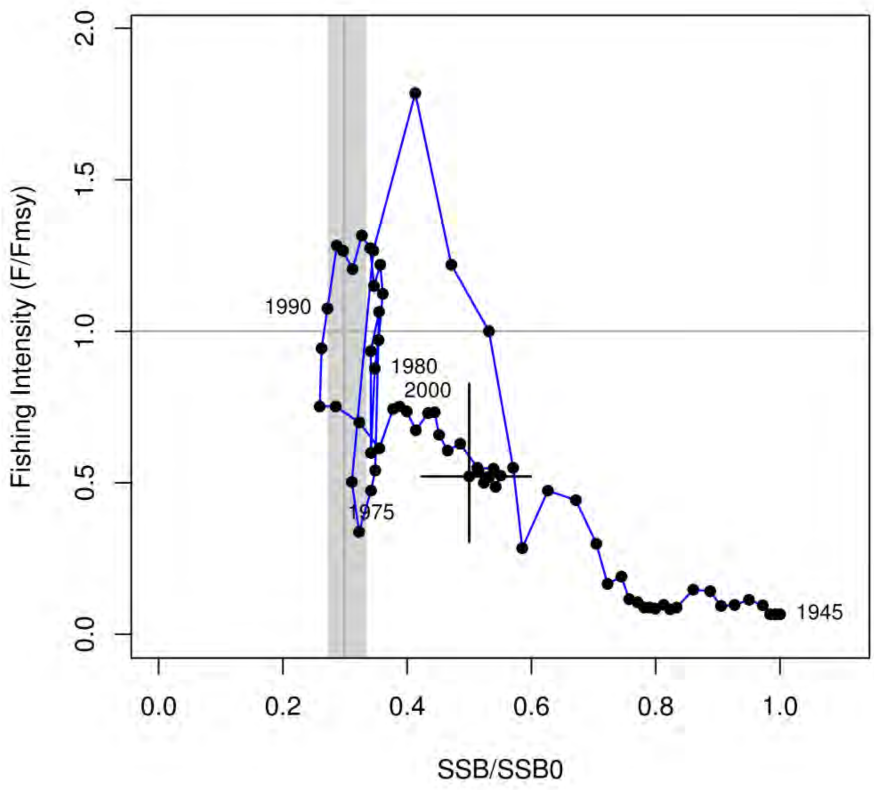
For the purposes of stock assessment and management, rock lobsters are assumed to constitute separate Fishstocks within each CRA quota management area. There is likely to be some degree of relationship and/or exchange between Fishstocks in these CRA areas, either as a result of migration, larval dispersal or both.

7.1 *Jasus edwardsii*

CRA 1 Northland

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Base case and 5 MCMC sensitivities
Reference Points	Target: *Bref*: mean of beginning AW vulnerable biomass for the period 1979–88 Limit: reported against B_{MIN}: minimum AW vulnerable biomass, 1945–2013 Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default)
Status in relation to Target	Virtually Certain (> 99%) $B_{2014} > B_{ref}$
Status in relation to Limits	Exceptionally Unlikely (< 1%) $B_{2014} < B_{min}$ Exceptionally Unlikely (< 1%) B_{2014} < soft and hard limits
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status



Snail trail summary of the CRA 1 base case model. The line tracks the median values for each axis from the MCMC posteriors and the cross marks the 90% credibility interval on both axes for the final model year (2013). The vertical line in the figure is the median (line) and 90% interval (shading) of the posterior distribution of *SSBmsy*. This ratio was calculated using the fishing pattern in 2013. The horizontal line in the figure is drawn at 1, the fishing intensity associated with *Fmsy*.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	AW biomass decreased to a low point in the early-1970s, remained low until the mid-1990s and has increased since then.
Recent Trend in Fishing Intensity or Proxy	Size-limited and non-size-limited exploitation have declined since the early 1990s.
Other Abundance Indices	Catch rates (CR) not fitted (1963-73)
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	4-year forward projections from 2014 under 2013 levels of commercial, customary, non-commercial and illegal catches showed that the stock should increase with > 50% probability. It will remain above B_{ref} with nearly 100% probability.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Exceptionally Unlikely (< 1%) $B_{2017} < B_{min}$ Soft Limit: Exceptionally Unlikely (< 1%) $B_{2017} < 0.2SSB0$ Hard Limit: Exceptionally Unlikely (< 1%) $B_{2017} < 0.1SSB0$
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Exceptionally Unlikely (< 1%)

Assessment Methodology		
Assessment Type	Level 1 Full Quantitative Stock Assessment	
Assessment Method	Bayesian length based model with MCMC posteriors (MLSM, Haist et al. 2009)	
Assessment Dates	Latest assessment: 2014	Next assessment: 2019
Overall assessment quality rank	1 – High quality	
Main data inputs	- CPUE - Length frequency data - Tagging data	1 – High quality 1 – High quality 1 – High quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Latest version of MLSM - Added informed priors to selectivity parameters	
Major Sources of Uncertainty	- Non-commercial catch (the levels of illegal and recreational catches)	

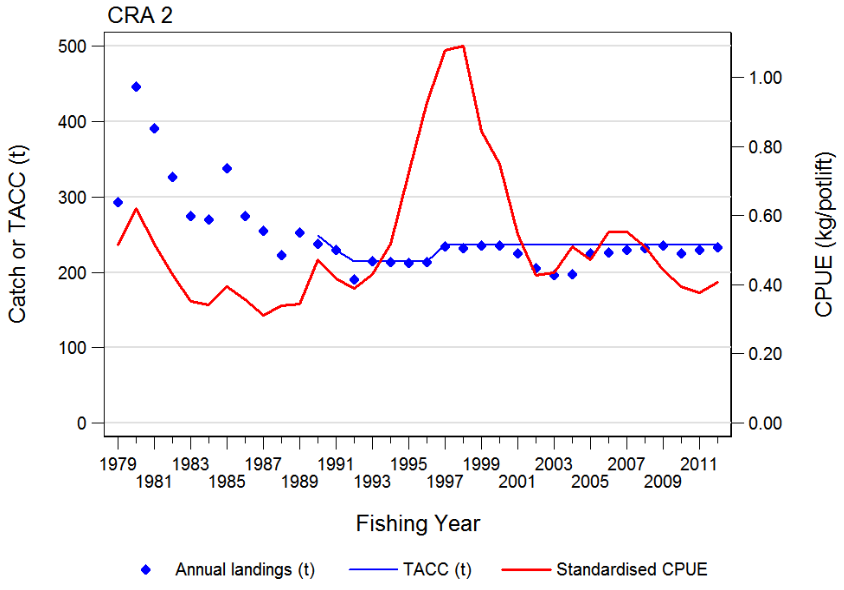
Qualifying Comments
Model could not predict the sex ratios during the spring summer (SS). Spatial heterogeneity of the observations throughout the statistical areas may not be representative of the population.

Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have little direct effect on non-target species.

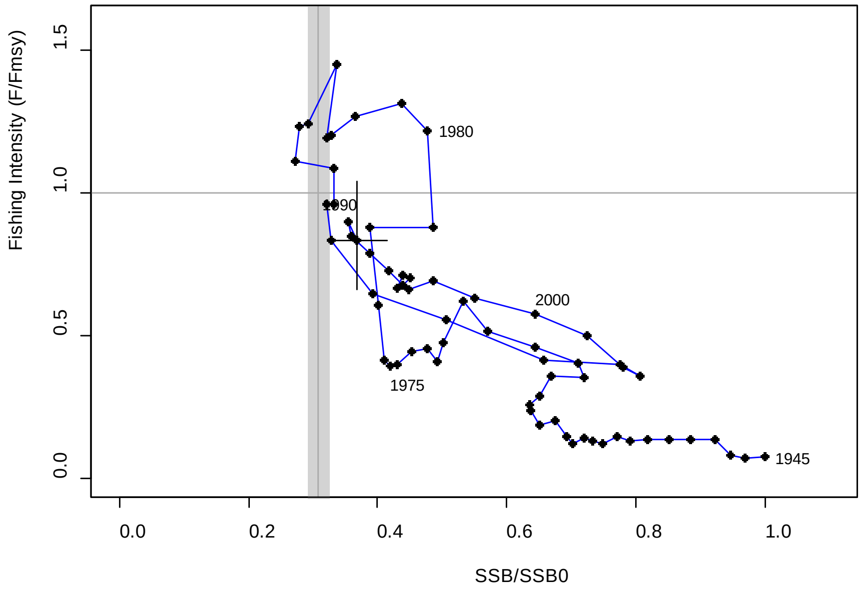
CRA 2 Bay of Plenty

Stock Status	
Year of Most Recent Assessment/Evaluation	2014
Assessment Runs Presented	MP evaluation updated
Reference Points	Target: Not established (reported against B_{MSY} and B_{REF}) B_{REF} : mean of beginning AW vulnerable biomass for the period 1979-81 Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default) Overfishing threshold: F_{MSY}
Status in relation to Target	Biomass in 2013 was 136% of B_{MSY} and 80% of B_{REF} Very Likely (> 90%) to be above B_{MSY} Unlikely (< 40%) to be above B_{REF}
Status in relation to Limits	Exceptionally Unlikely (< 1%) to be below soft and hard limits
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA2 from 1979 to 2012



Phase plot for CRA 2

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has remained at relatively consistent levels after coming down from high levels in the late 1990s; there was a drop in abundance from the mid-2000s to 2011.
Recent Trend in Fishing Intensity or Proxy	Has been less than F_{MSY} since 1989 (see phase plot).
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

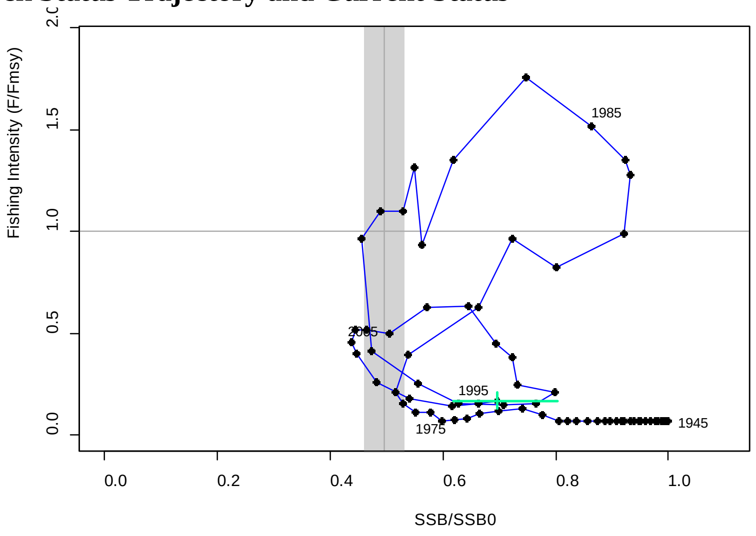
Projections and Prognosis	
Stock Projections or Prognosis	Offset CPUE to Sept 2014 decreased from 0.3668 to 0.3661 kg/potlift which results in no change to the TACC based on the MP rule evaluation.

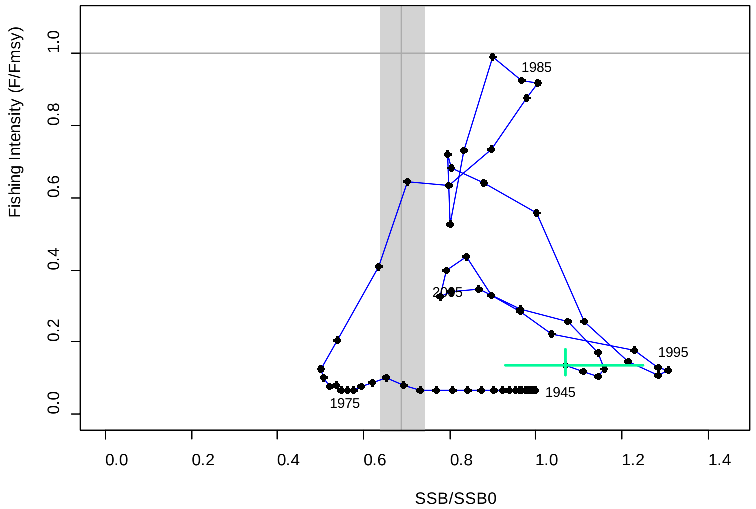
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)	
Probability of Current Catch or TACC causing Overfishing to continue or commence	Unlikely (< 40%)	
Assessment Methodology and Evaluation		
Assessment Type	Level 1 Full Quantitative Stock Assessment (2013)	
Assessment Method	Bayesian length-based model	
Assessment dates	Latest assessment: 2013	Next assessment: 2018?
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- CPUE data 1979-2012 - Length frequency data - Tag-recapture data - Catch rate (CR) data 1963-73	1 – High quality 1 – High quality 1 – High quality 1 – High quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Changes to length frequency weighting regime	
Major Sources of Uncertainty	- Non-commercial catch	
Qualifying Comments		
A management procedure has been developed that may be used to manage the fishery in the future.		
Fishery Interactions		
Potting is the main method of targeting rock lobster and is thought to have little direct effect on non-target species. For all QMAs, the most frequently reported incidental species caught are, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets. However, these comprise less than 10% of the rock lobster catch.		

CRA 3 Gisborne

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Two base case MCMCs and four MCMC sensitivity trials from each base case
Reference Points	Target: no target agreed Reported against B_{MSY}: autumn winter (AW) vulnerable biomass associated with *MSY* (maximum size-limited catch summed across AW and SS) Limit: reported against B_{MIN}: minimum AW vulnerable biomass, 1945–2013 Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default)
Status in relation to Target	Virtually Certain (> 99%) to be above B_{MSY}
Status in relation to Limits	Exceptionally Unlikely (< 1%) to be below B_{MIN} Exceptionally Unlikely (< 1%) to be below soft and hard limits
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

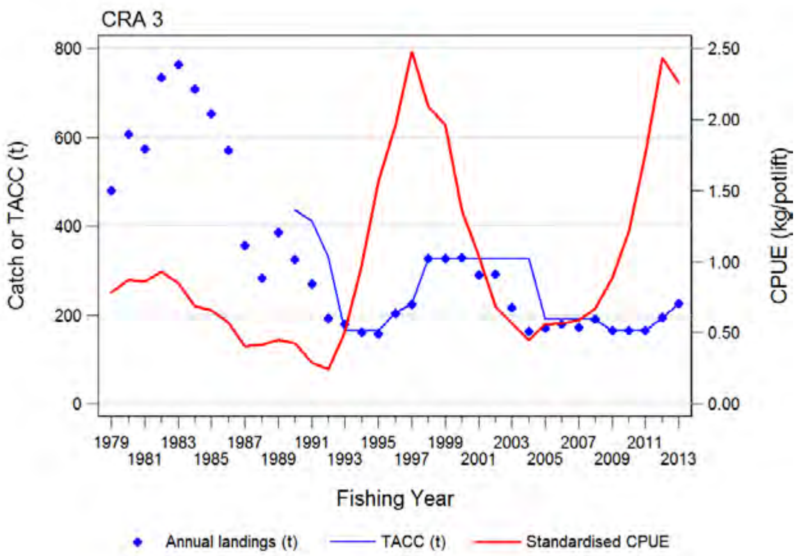
Historical Stock Status Trajectory and Current Status





CRA 3: Snail trails from the two base case MCMCs: fixed growth CV on the left. The vertical line in the figure is the median (line) and 90% interval (shading) of the posterior distribution of *SSBmsy* as a proportion of *SSB0*; this ratio was calculated using the fishing pattern in 2012. The horizontal line in the figure is drawn at 1, the fishing intensity associated with *Fmsy*. The bars at the final year of the plot show the 90% intervals of the posterior distributions of biomass ratio and fishing intensity ratio.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass declined steadily from 1997 to 2003 and then increased strongly after 2009. CPUE shows the same pattern and is now near its 1997 peak.
Recent Trend in Fishing Mortality or Proxy	Size-limited and non-size-limited exploitation have declined since 2002.
Other Abundance Indices	Puerulus not fitted in base case

Trends in Other Relevant Indicators or Variables	 Annual landings, TACC and standardised CPUE for CRA3 from 1979 to 2011

Projections and Prognosis	
Stock Projections or Prognosis	4-year forward projections in 2014 under 2013 levels of commercial, customary, non-commercial and illegal catches showed that the stock would decrease by medians of 16–31%, but would remain well above reference points.
Probability of Current Catch or TACC causing decline below Limits	Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or commence	Unlikely (< 40%)

Assessment Methodology		
Assessment Type	Level 1 Full Quantitative Stock Assessment	
Assessment Method	Bayesian multi-stock length-based model (MLSM, Haist et al. 2009)	
Assessment Dates	Latest assessment: 2014	Next assessment: 2019
Overall assessment quality rank	1 – High quality	
Main data inputs (rank)	- CPUE - Length frequency - Tagging data	1 – High quality 1 – High quality 1 – High quality
Data not used (rank)	- Puerulus not fitted in base case	
Changes to Model Structure and Assumptions	- Latest version of MLSM	
Major Sources of Uncertainty	- Temporal changes in growth rate	

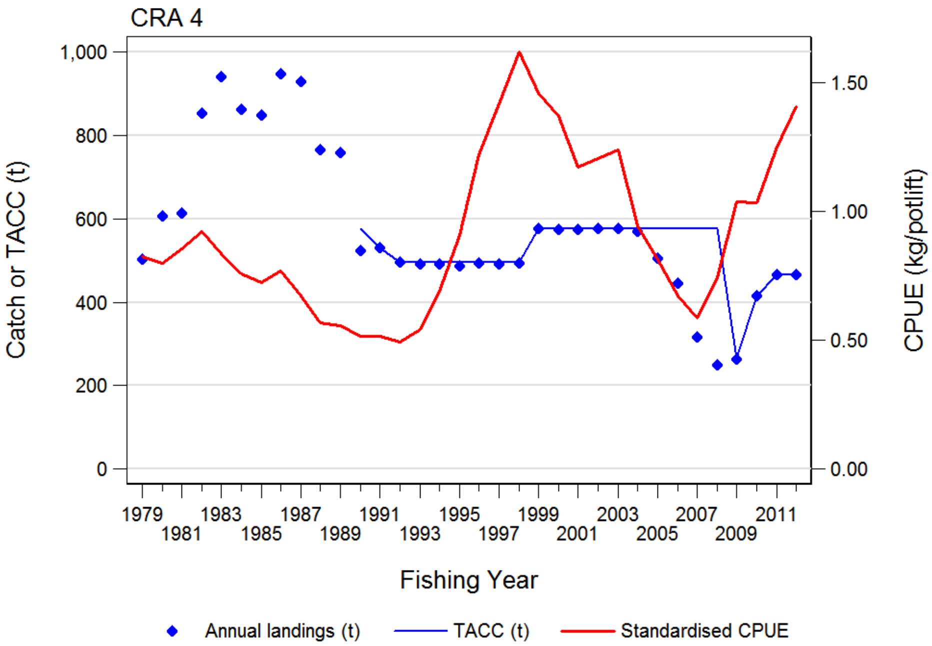
Qualifying Comments
Two base cases presented with different growth model fitting assumptions are presented.

Recent developments in stock status
CPUE increased strongly from 2009 and the current level is near the 1997 peak.
Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have little direct effect on non-target species.

CRA 4 Wellington – Hawkes Bay

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	MP evaluation updated
Reference Point	Target: Not established (reported against B_{REF} and SSB_{MSY}) B_{REF}: mean of beginning AW vulnerable biomass for the period 1979-88 SSB_{MSY}: mature female biomass associated with B_{MSY} Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default) Overfishing threshold: F_{MSY}
Status in relation to Target	CPUE is at a level well above the levels during the reference period. Virtually Certain (> 99%) to be above B_{REF} Very Likely (> 90%) to be above SSB_{MSY}
Status in relation to Limits	Exceptionally Unlikely (< 1%) 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



Annual landings, TACC and standardised CPUE for CRA4 from 1979 to 2012

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has increased since 2007.
Recent Trend in Fishing Intensity or Proxy	-
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Offset CPUE to Sept 2014 decreased from 1.29 to 1.17 kg/potlift which results in no change to the TACC based on the MP rule evaluation.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or commence	Very Unlikely (< 10%)

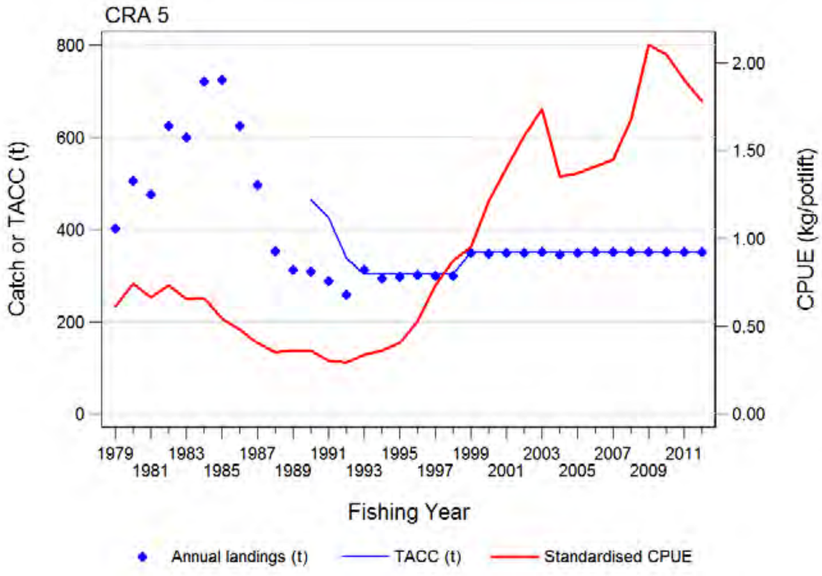
Assessment Methodology		
Assessment Type	Level 1 Full Quantitative Stock Assessment (2011)	
Assessment Method	Bayesian length based model	
Assessment Dates	Latest assessment: 2011	Next assessment: 2016?
Overall assessment quality rank	1- High Quality	
Main data inputs (rank)	CPUE, length frequency, tagging data, puerulus settlement indices	1- High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Addition of fitting to puerulus settlement indices	
Major Sources of Uncertainty	- Level of non-commercial catches, illegal catches, modelling of growth, estimation of productivity, vulnerability of immature females	

Qualifying Comments
A management procedure has been developed that is used to manage the fishery.

Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have little direct effect on non-target species. For all QMAs, the most frequently reported incidental species caught are, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets. However, these comprise less than 10% of the rock lobster catch.

CRA 5 Canterbury - Marlborough

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	MP evaluation updated
Reference Points	Target: Not established (reported against *Bref* and SSB_{MSY}) *Bref*: mean of beginning AW vulnerable biomass for the period 1979-88 SSB_{MSY}: mature female biomass associated with B_{MSY} Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default) Overfishing threshold: F_{MSY}
Status in relation to Target	CPUE is at a level well above the levels during the reference period. Virtually Certain (> 99%) to be above *Bref* Virtually Certain (> 99%) to be above SSB_{MSY}
Status in relation to Limits	Exceptionally Unlikely (< 1%) 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

Annual landings, TACC and standardised CPUE for CRA5 from 1979 to 2012

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has decreased since 2009, the highest level observed in the 33 year series, but remains at high levels.
Recent Trend in Fishing Intensity or Proxy	-
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis		
Stock Projections or Prognosis	Offset CPUE to Sept 2013 decreased from 1.59 to 1.36 kg/potlift which results in a 4% decrease to the TACC based on the MP rule evaluation.	
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Very Unlikely (< 10%)	
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)	
Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model (2010)	
Assessment Method	Bayesian length based model	
Assessment Dates	Latest assessment: 2010	Next assessment: 2014 or 2015?
Overall assessment quality rank	1-High Quality	
Main data inputs (rank)	CPUE, length frequency, tagging data, puerulus data	1-High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Revised growth model - Addition of puerulus data	
Major Sources of Uncertainty	- Level of non-commercial catches, illegal catches, modelling of growth, estimation of productivity	

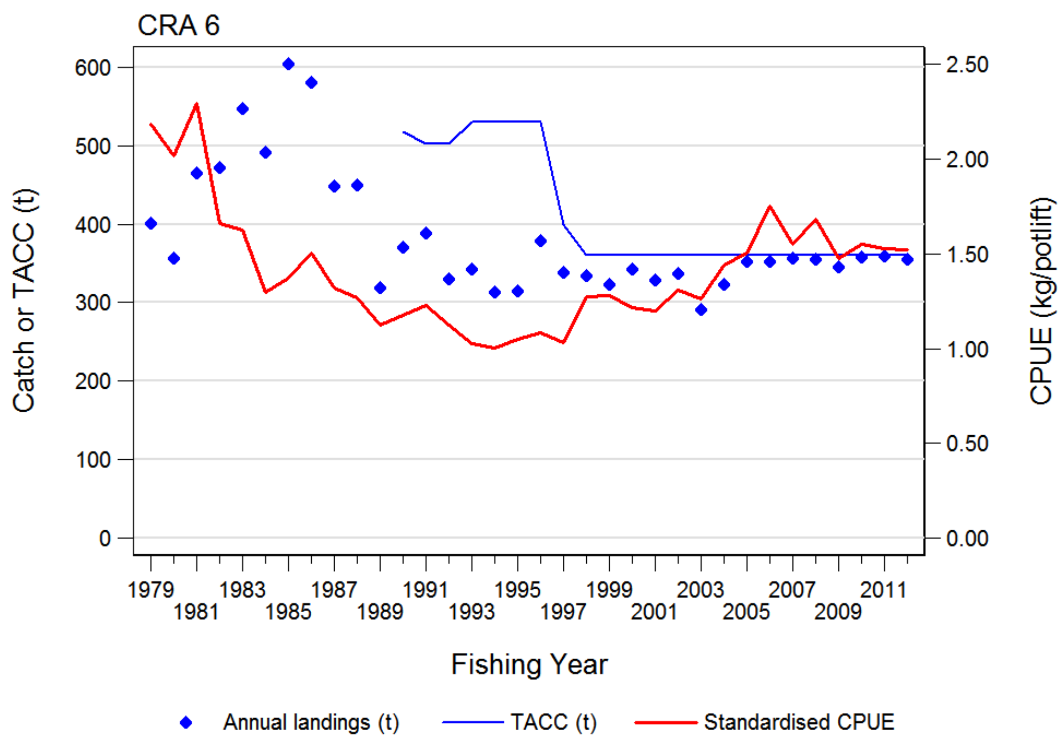
Qualifying Comments
A management procedure has been developed that is used to manage the fishery.

Recent developments in stock status
CPUE dropped in 2010 and 2011 from 2009, the highest point in the series.
Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have very little direct effect on non-target species. For all QMAs, the most frequently reported incidental species caught are, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets. However, these generally comprise less than 10% of the rock lobster catch.

CRA 6 Chatham Islands

Stock Status	
Year of Most Recent Assessment/Evaluation	1996
Assessment Runs Presented	Base case
Reference Points	Target: Not established Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default) Overfishing threshold: F_{MSY}
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



Annual landings, TACC and standardised CPUE for CRA6 from 1979 to 2012

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has been steady for the last 4 years.

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 or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown	
Probability of Current Catch or TACC causing Overfishing to continue or commence	Unknown	
Assessment Methodology and Evaluation		
Assessment Type	Level 1 Quantitative Assessment model (1996)	
Assessment Method	Production model	
Assessment dates	1996	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	CPUE	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	Catch rates are 50% higher than when the production model was fitted in 1996.	

Qualifying Comments
-

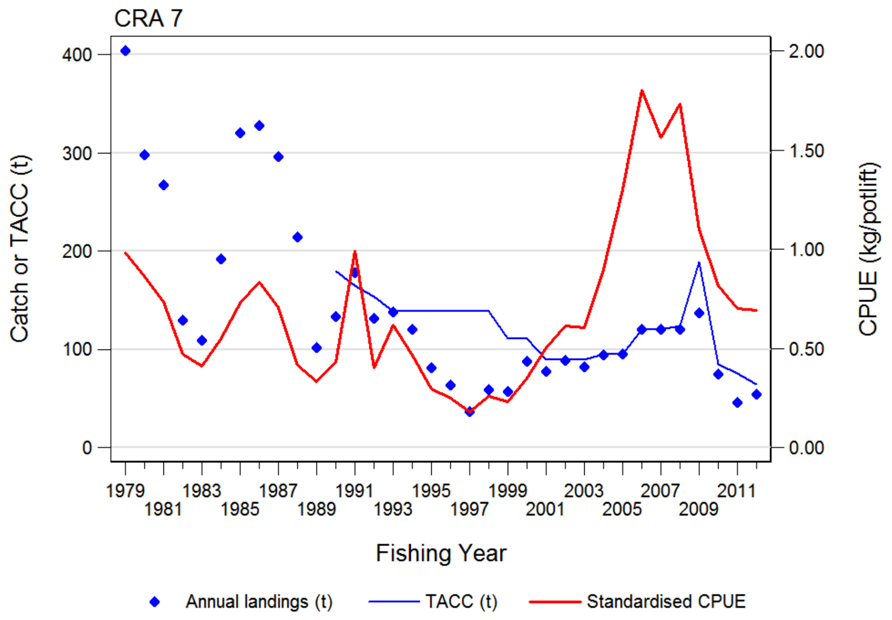
Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have little direct effect on non-target species. For all QMAs, the most frequently reported incidental species caught are, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets. However, these comprise less than 10% of the rock lobster catch.

CRA 7 Otago

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	MP evaluation updated
Reference Point	Target: Not established (reported against B_{REF}) B_{REF}: mean of beginning AW vulnerable biomass for the period 1979-81 SSB_{MSY}: the RLFAWG considered that this reference point is not meaningful, given the high level of estimated out-migration from CRA 7 Soft limit: ½*B_{REF} (default) Hard limit: ¼*B_{REF} (default) Overfishing threshold: F_{MSY}
Status in relation to Target	CPUE is at a level similar to the levels during the reference period. About as Likely as Not (40-60%) to be above B_{REF}
Status in relation to Limits	Unlikely (< 40%) to be below soft or hard limits

Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA 7 from 1979 to 2012

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass levels have decreased since the mid 2000s to a level similar to the reference period
Recent Trend in Fishing Intensity or Proxy	-
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The offset CPUE to Sept 2013 increased from 1.36 to 2.30 kg/potlift which results in a TAC increase from 66 t to 98 t based on the MP rule evaluation.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unlikely (< 40%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%)

Assessment Methodology		
Assessment Type	Level 1 Full Quantitative Stock Assessment (2012)	
Assessment Method	Bayesian length based model	
Assessment Dates	Latest assessment: 2012	Next assessment: 2017?
Overall assessment quality rank	1- High Quality	
Main data inputs (rank)	CPUE, length frequency, tagging data	1- High Quality
Data not used (rank)	N/A	

Changes to Model Structure and Assumptions	Average movement used for years without movement estimated; Francis (2011) weights for composition data; change in tag recapture likelihood; density-dependent growth
Major Sources of Uncertainty	Level of non-commercial catches, illegal catches, modelling of growth, estimation of productivity, vulnerability of immature females

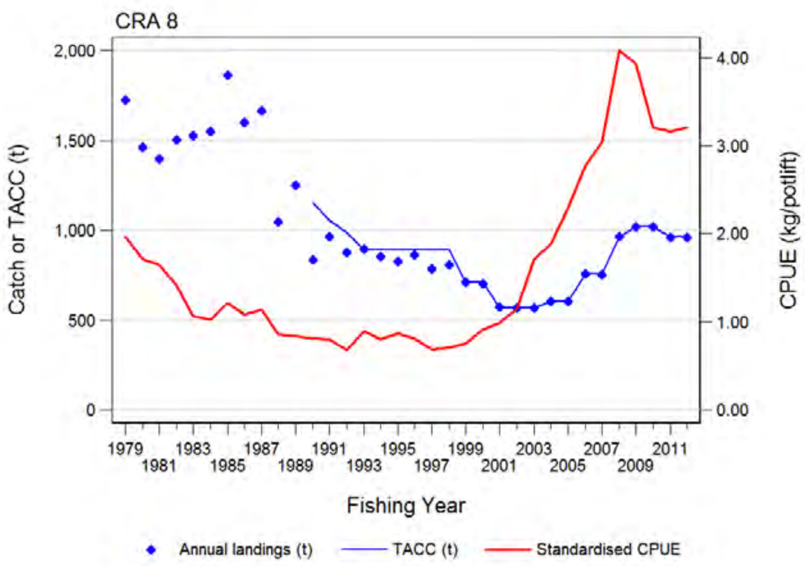
Qualifying Comments
A management procedure has been developed that is used to manage the fishery

Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have little direct effect on non-target species. For all QMAs, the most frequently reported incidental species caught are, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets. However, these comprise less than 10% of the rock lobster catch.

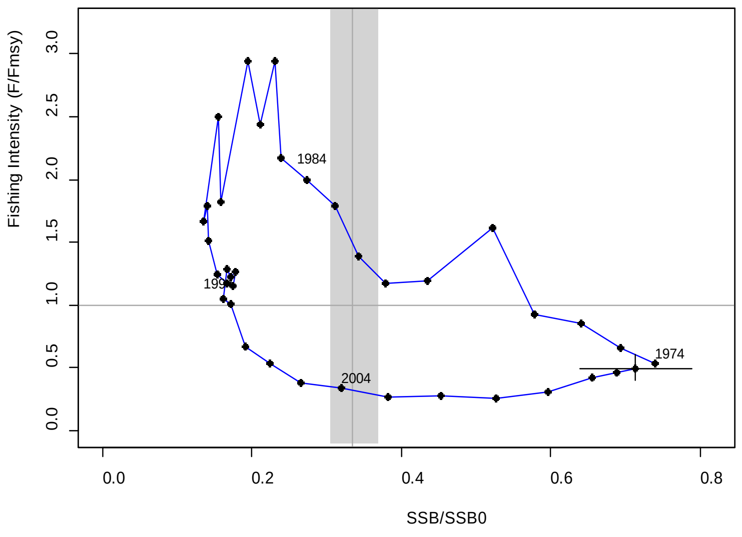
CRA 8 Southern

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	MP evaluation updated
Reference Point	Target: Not established (reported against B_{REF} and SSB_{MSY}) B_{REF}: mean of beginning AW vulnerable biomass for the period 1979-81 SSB_{MSY}: mature female biomass associated with B_{MSY} Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default) Overfishing threshold: F_{MSY}
Status in relation to Target	CPUE is at a level well above the levels during the reference period Very Likely (> 90%) to be above B_{REF}
Status in relation to Limits	Exceptionally Unlikely (< 1%) 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



Annual landings, TACC and standardised CPUE for CRA 8 from 1979 to 2012



Phase plot that summarises the history of the CRA 8 fishery. The x-axis is the spawning biomass (*SSB*) as a proportion of SSB_0; the y-axis is the ratio of the fishing intensity (*F*) relative to F_{MSY}. Each point is the median of the posterior distributions, and the bars associated with 2010 show the 90% confidence intervals. The vertical reference lines shows SSB_{MSY} as a proportion of SSB_0 (with the grey band indicating the 90% confidence interval), the default soft limit: ½ SSB_{MSY} and the default hard limit: ¼ SSB_{MSY}. The horizontal reference line is F_{MSY}.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass decreased to low levels in the 1990s, but has since increased to levels well above those in the reference period.
Recent Trend in Fishing Intensity or Proxy	-
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The offset CPUE to Sept 2014 decreased from 3.38 to 3.36 kg/potlift which results in no change to the TACC based on the MP rule evaluation.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 Full Quantitative Stock Assessment (2012)	
Assessment Method	Bayesian length based model	
Assessment Dates	Latest assessment: 2012	Next assessment: 2017?
Overall assessment quality rank	1- High Quality	
Main data inputs (rank)	CPUE, length frequency, tagging data	1- High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Francis (2011) weights for composition data; change in tag recapture likelihood; density-dependent growth	

Major Sources of Uncertainty	- Level of non-commercial catches, illegal catches, modelling of growth, estimation of productivity, vulnerability of immature females

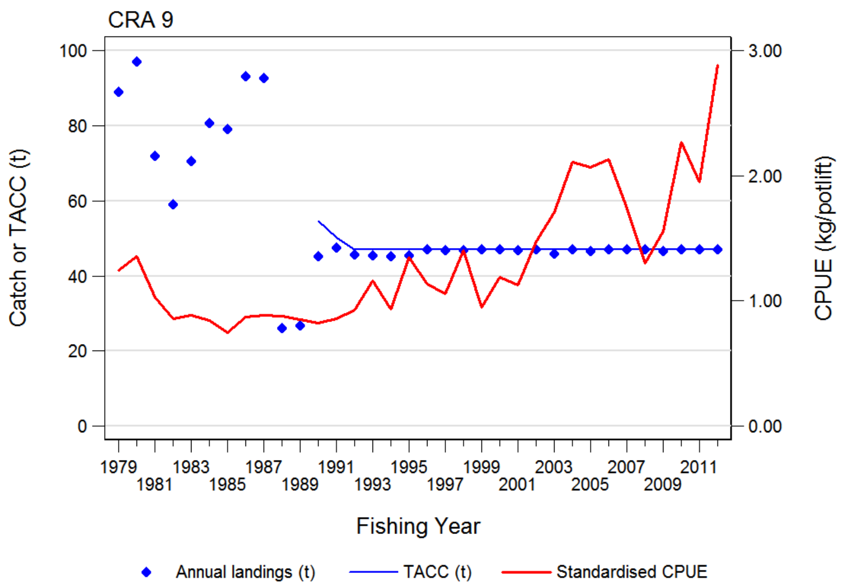
Qualifying Comments
A management procedure has been developed that is used to manage the fishery.

Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have little direct effect on non-target species. For all QMAs, the most frequently reported incidental species caught are, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets. However, these comprise less than 10% of the rock lobster catch.

CRA 9 Westland-Taranaki

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	MP evaluation updated
Reference Points	Target: Not established (reported against B_{MSY}) Soft limit: 20% K (default) Hard limit: 10% K (default) Overfishing threshold: F_{MSY}
Status in relation to Target	Biomass in 2012 was 150% of B_{MSY}; Very Likely (> 90%) to be above B_{MSY}
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



Annual landings, TACC and standardised CPUE for CRA9 from 1979 to 2012.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Estimated biomass has risen steadily since the early 1990s.
Recent Trend in Fishing Intensity or Proxy	The exploitation rate in 2012 was estimated to be 12%.
Other Abundance Indices	High proportion of very large fish in logbook size frequencies
Trends in Other Relevant	

Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The offset CPUE to Sept 2014 decreased from 3.14 to 2.095kg/potlift which results in a decrease to the TACC to 46 t based on the MP rule evaluation.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) to drop below either the soft or hard limits at current catch levels
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model (but used to build an operating model rather than an assessment)	
Assessment Method	Bayesian surplus-production model	
Assessment Dates	Latest assessment: 2013	Next assessment: Unknown
Overall quality assessment rank	1 - High Quality	
Main data inputs (rank)	Catch and CPUE	1 - High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	Catch and CPUE data from small number of participants	

Qualifying Comments
Not a true assessment; the production model was used as an operating model for Management Procedure Evaluations.

Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have little direct effect on non-target species. For all QMAs, the most frequently reported incidental species caught are, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets. However, these comprise less than 10% of the rock lobster catch.

7.2 *Sagmariasus verreauxi*, PHC stock

The status of this stock is unknown.

8. FOR FURTHER INFORMATION

Adey, J. M., I. P. Smith, R.J.A. Atkinson, I.D. Tuck & A.C. Taylor (2008). "'Ghost fishing' of target and non-target species by Norway lobster *Nephrops norvegicus* creels." Marine Ecology-Progress Series 366: 119-127.

Andrew, N. & M. Francis, Eds. (2003). The living Reef: the ecology of New Zealand's Living Reef. Nelson, Craig Potton Publishing.

Annala, J.H. 1983: New Zealand rock lobsters: biology and fisheries. *Fisheries Research Division Occasional Publication 42*. 35 p.

Annala, J.H. & King, M.R. 1983: The 1963–73 New Zealand rock lobster landings by statistical area. *Fisheries Research Division Occasional Publication, Data Series 11*. 20 p.

Annala, J.H. & Sullivan K.J. 1996: Report from the Mid-Year Fishery Assessment Plenary, November 1996: stock assessments and yield estimates. 30 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Babcock, R. C., S. Kelly, N.T. Shears, J.W. Walker & T.J. Willis (1999). "Changes in community structure in temperate marine reserves." Marine Ecology-Progress Series 189: 125-134.

Bell, M., 2012. Shag interactions with commercial rock lobster pot and trap fishing methods in the Chatham Islands. Wildlife Management International Limited for the Department of Conservation Contract 4342 (INT2011-02 Shag interactions with commercial pot and trap fishing methods in New Zealand). p. 24.

Bell, M. & D. Bell (2000). "Census of three shag species in the Chatham Islands." Notornis 47(3): 148-153.

Bentley, N., Breen, P.A. & Starr, P.J. 2003. Design and evaluation of a revised management decision rule for red rock lobster fisheries (*Jasus edwardsii*) in CRA 7 and CRA 8. *New Zealand Fishery Assessment Report 2003/30*. 44 p.

Bentley, N. & Starr, P.J. 2001: An evaluation of the stock structure of New Zealand rock lobster. *New Zealand Fisheries Assessment Report 2001/48*. 22 p.

Bentley, N., Starr, P.J., Walker, N. & Breen, P.A. 2005: Catch and effort data for New Zealand rock lobster stock fisheries. *New Zealand Fisheries Assessment Report 2005/49*. 49 p.

Booth, J. (1979). "North Cape - a 'nursery area' for the packhorse rock lobster, *Jasus verreauxi* (Decapoda: Palinuridae)." New Zealand journal of Marine & Freshwater Research 13(4): 521-528.

Booth, J. (1986). "Rock lobsters of New Zealand." Dive New Zealand October.

Booth, J.D. & Breen, P.A. 1992: Stock structure in the New Zealand red rock lobster, *Jasus edwardsii*. New Zealand Fisheries Assessment Research Document 92/20. 35 p.

Booth, J.D., McKenzie, A., Forman, J.S. & Stotter, D.R. 2007: Settlement indices for 2003 for the red rock lobster (*Jasus edwardsii*), and investigations into correlations between settlement and subsequent stock abundance. *New Zealand Fisheries Assessment Report 2007/42*. 48 p.

Booth, J.D., Robinson, M. & Starr, P.J. 1994: Recent research into New Zealand rock lobsters, and a review of recent rock lobster catch and effort data. New Zealand Fisheries Assessment Research Document 94/7. 56 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 97/7. 16 p.

Bradford, E. 1998: Harvest estimates from the 1996 national marine recreational fishing surveys. New Zealand Fisheries Assessment Research Document 98/16. 27 p.

Breen, P. (2005). Managing the effects of fishing on the environment what does it mean for the rock lobster (*Jasus edwardsii*) fishery? New Zealand Fisheries Assessment Report 2005/73. New Zealand Fisheries Assessment Report 2005L73.45 p.: 45.

Breen, P.A. (2014). CRA 9 management procedure evaluations. New Zealand Fisheries Assessment Report 2014/20. 72 p.

Breen, P.A., Starr, P.J. & Kim, S.W. (2005): A medium-term research plan for red rock lobsters (*Jasus edwardsii*). *New Zealand Fisheries Assessment Report 2005/54*. 52 p.

Breen, P.A.; Starr, P.J.; Haist, V. (2009): New Zealand decision rules and management procedures for rock lobsters (*Jasus edwardsii*). *New Zealand Fisheries Assessment Report 2009/43.* 18 p

Breen, P.A., V. Haist, P.J. Starr & T.H. Kendrick (2009). The 2008 stock assessment of rock lobsters (*Jasus edwardsii*) in CRA 3. *New Zealand Fisheries Assessment Report 2009/23.* 54 p.

Breen, P.A., V. Haist & P.J. Starr. (2007). Stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 7 and CRA 8 in 2006, using a new multi-stock length-based model (MSLM). Final Research Report - CRA2006-01 Objective 4 - unpublished manuscript available from the Ministry of Fisheries, Wellington, New Zealand

Breen, P.A.; Haist, V.; Starr, P.J.; Pomarede, M. (2012). The 2011 stock assessment and management procedure development for red rock lobsters (*Jasus edwardsii*) in CRA 4. New Zealand Fisheries Assessment Report 2012/09. 98 p

Breen, P.A., Kim, S.W., Haist, V. & Starr, P.J. (2006): The 2005 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 4. *New Zealand Fisheries Assessment Report 2006/17*. 133 p.

Breen, P.A., Kendrick, T.H., Starr, P.J. & Maunder, M. (1994): Results of the implementation of the Rock Lobster Decision Rule in 1994. New Zealand Fisheries Assessment Research Working Group Report 94/3. 17 p.

Brock, D., T. Saunders, & T.M. Ward (2003). Development and assessment of methods to reduce predation of 'pot caught' southern rock lobster (*Jasus edwardsii*) by Maori octopus (*Octopus maorum*). Project No. 1998/150. SARDI Aquatic Sciences Publication No. RD03/0063: 87p.

Casement, D. & I. Svane (1999). Direct Effects of Rock Lobster Pots on Temperate Shallow Rocky Reefs in South Australia: a study report to the South Australian Rock Lobster Industry. South Australian Research & Development Institute: 26.

Chiswell, S.M., Wilkin, J., Booth, J.D. & Stanton, B. 2003: Trans-Tasman Sea larval transport: is Australia a source for New Zealand rock lobsters? *Marine Ecology Progress Series.*247: 173-182.

Department of Fisheries Western Australia (2007). Application to the Department of Environment and Water resources on the Western rock lobster fishery: Against the Guidelines for the Ecologically Sustainable Management of Fisheries - 2007: 97.

Edgar, G. & N. Barrett (1999). "Effects of the declaration of marine reserves on Tasmanian reef fishes, invertebrates and plants." Journal of Experimental Marine Biology and Ecology 242: 107-144.

Eno, N., D. Macdonald, J.A. Kinnear, S. Amos, C. J. Chapman, R. A. Clark, F. S. Bunker & C. Munro (2001). "Effects of crustacean traps on benthic fauna." ICES Journal of Marine Science 58(1): 11-20.

Fiordland Marine Guardians (2008). Beneath the reflections: a user's guide to the Fiordland (Ta moana o atawhenua) marine area, Unpublished report available at http://www.fmg.org.nz/fiordland-user-guide/index.html: 136p.

Forman, J. S.; McKenzie, A.; Stotter, D. R. (2011). Settlement indices for 2009 for the red rock lobster (*Jasus edwardsii*). *New Zealand Fisheries Assessment Report 2011/15*.

Forman J., McKenzie, A., Stotter, D. (2013). Settlement indices for 2011 for the red rock lobster (*Jasus edwardsii*) 2013/32. 32p.

Forman, J.S.; McKenzie, A.; Stotter, D.R. (2014). Settlement indices for 2012 for the red rock lobster (*Jasus edwardsii*). New Zealand Fisheries Assessment Report. 2014/47. 56 p.

Francis, R.I.C.C. 1999: Moving towards B_{MSY}. New Zealand Fisheries Assessment Research Document 1999/2. 23 p.

Freeman, D.J. 2008: The ecology of spiny lobsters (*Jasus edwardsii*) on fished and unfished reefs. PhD thesis, University of Auckland. 306 p.

Haist, V., P.A. Breen, S.W. Kim & P.J. Starr. 2005: Stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 3 in 2004. *New Zealand Fisheries Assessment Report 2005/38*. 126 p.

Haist, V., Breen, P.A. & Starr, P.J. 2009: A new multi-stock length-based assessment model for New Zealand rock lobsters (*Jasus edwardsii*) *New Zealand Journal of Marine and Freshwater Research* 43(1): 355-371.

Haist, V., P.A. Breen, P.J. Starr & T.H. Kendrick. 2011. The 2010 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 5, and development of an operational management procedure. New Zealand Fisheries Assessment Report 2011/12. 68 pp.

Haist, V.; Starr, P.J.; Breen, P.A. (2013). The 2012 stock assessment of red rock lobsters (Jasus edwardsii) in CRA 7 and CRA 8, and review of management procedures. New Zealand Fisheries Assessment Report 2013/60. 90 p.

Kensler, K. (1967). "The distribution of spiny lobsters in New Zealand waters (Crustacea: Decapoda: Palinuridae).." New Zealand Journal of Marine and Freshwater Research 1: 412-420.

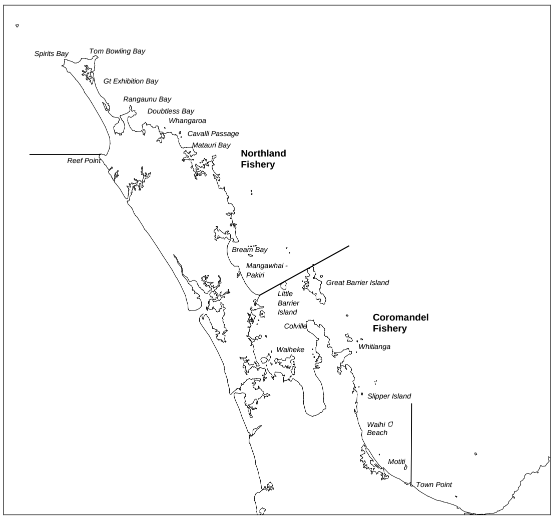
Kim, S.W., N. Bentley, P.J. Starr & P.A. Breen. 2004: Assessment of red rock lobsters (*Jasus edwardsii*) in CRA 4 and CRA 5 in 2003. *New Zealand Fisheries Assessment Report 2004/8.* 165 p.

King, K., Clarke, M., 1984. The food of rig (Mustelus lenticulatus) and the relationship of feeding to reproduction and condition in Golden Bay. New Zealand Journal of Marine and Freshwater Research 18, 29-42.

Langlois, T., M. Anderson, R.C. Babcock & S. Kato (2005). "Marine reserves demonstrate trophic interactions across habitats " Oecologia 147(1): 134-140.
Langlois, T. J., M. J. Anderson, M. Brock & G. Murman (2006). "Importance of rock lobster size-structure for trophic interactions: choice of soft-sediment bivalve prey." Marine Biology 149(3): 447-454.
Mann, K. and P. Breen (1972). "The relation between lobster abundance, sea urchins and kelp beds." Journal of the Fisheries Research Board of Canada 29(5): 603-605
Maunder, M.N. & Starr, P.J. 1995: Rock lobster standardised CPUE analysis. New Zealand Fisheries Assessment Research Document 95/11. 28 p.
Ministry of Fisheries 2006: Report from the Mid-Year Fishery Assessment Plenary, November 2006: stock assessments and yield estimates. 59 p. (Unpublished report held in NIWA Greta Point library, Wellington.)
Ministry of Fisheries 2008: Report from the Mid-Year Fishery Assessment Plenary, November 2008: stock assessments and yield estimates. 156 p. (Unpublished report held in NIWA Greta Point library, Wellington.)
Parrish, F. & T. Kazama (1992). "Evaluation of ghost fishing in the Hawaiian lobster fishery." Fishery Bulletin 90(4): 720-725.
Pike, R. (1969). A case study in research: Crayfish. Fisheries and New Zealand: Sigma Print Ltd.
Shears, N. & R. Babcock (2003). "Continuing trophic cascade effects after 25 years of no-take marine reserve protection." Marine Ecology Progress Series 246: 1-16.
Sheldon, W. & R. Dow (1975). "Trap contributions to losses in the American lobster fishery." Fishery Bulletin 73(2): 449-451.
Sim, D. & R. Powlesland (1995). "Recoveries of Black Shags (*Phalacrorax carbo)* banded in the Wairarapa, New Zealand." Notornis 42: 23-26.
Starr, P.J. (2012). Standardised CPUE analysis exploration: using the rock lobster voluntary logbook and observer catch sampling programmes. New Zealand Fisheries Assessment Report 2012/34. 77 p.
Starr, P.J. (2014). Rock lobster catch and effort data: summaries and CPUE standardisations, 1979–80 to 2012–13. New Zealand Fisheries Assessment Report 2014/28. 110 p.
Starr, P.J., Bentley, N., Breen, P.A. & Kim, S.W. (2003): Assessment of red rock lobsters (*Jasus edwardsii*) in CRA 1 and CRA 2 in 2002. *New Zealand Fisheries Assessment Report 2003/41.* 119 p.
Starr, P.J., P.A. Breen, T.H. Kendrick & V. Haist. (2009). Model and data used for the 2008 stock assessment of rock lobsters (*Jasus edwardsii*) in CRA 3. *New Zealand Fisheries Assessment Report 2009*/22. 62 p.
Starr, P.J., P.A. Breen, V. Haist & T.H. Kendrick. (2011). Data for the 2010 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 5. New Zealand Fisheries Assessment Report 2011/13. 41 pp.
Starr, P.J.; Breen, P.A.; Haist, V.; Pomarede, M. (2012). Data for the 2011 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 4. New Zealand Fisheries Assessment Report 2012/08. 48 p.
Starr, P.J.; Haist, V.; Breen, P.A. (2013). Data for the 2012 stock assessment of red rock lobsters (*Jasus edwardsii*) in CRA 7 and CRA 8. New Zealand Fisheries Assessment Report 2013/59. 43 p.
Starr, P.J.; Breen, P.A.; Edwards, C.T.T.; Haist, V. (2014a). Data for the 2013 stock assessment of red rock lobsters (Jasus edwardsii) in CRA 2. New Zealand Fisheries Assessment Report 2014/18. 54 p.
Starr, P.J.; Haist, V.; Breen, P.A.; Edwards, C.T.T.E. (2014b). The 2013 stock assessment of red rock lobsters (Jasus edwardsii) in CRA 2 and development of management procedures. New Zealand Fisheries Assessment Report 2014/19. 76 p.
Sullivan, K.J. & O'Brien, C.J. (Comps.) 2002: Report from the Mid-Year Fishery Assessment Plenary, November 2002: stock assessments and yield estimates. 45 p. (Unpublished report held in NIWA Greta Point library, Wellington.)
Sullivan, K.J. (Comp.) 2003: Report from the Mid-Year Fishery Assessment Plenary, November 2003: stock assessments and yield estimates. 47 p. (Unpublished report held in NIWA Greta Point library, Wellington.)
Sullivan, K.J., Smith, N.W.McL. & Waugh, S. (Comps.) 2005: Report from the Mid-Year Fishery Assessment Plenary, November 2003: stock assessments and yield estimates. 62 p. (Unpublished report held in NIWA Greta Point library, Wellington.)
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 97/15. 43 p.
Vignaux, M., & Kendrick, T.H. 1998: CPUE analyses for rock lobster substocks and QMAs to 1997. New Zealand Fisheries Assessment Research Document 98/19. 24 p.
Williams, B. & I. Dean (1989). "Timing of locomotor activity in the New Zealand rock lobster, *Jasus edwardsii* " New Zealand Journal of Marine and Freshwater Research 23(2): 215-224.

SCALLOPS NORTHLAND (SCA 1)

(*Pecten novaezelandiae*)
Kuakua, Tipa



1. FISHERY SUMMARY

Northland scallops (SCA 1) were introduced into the Quota Management System (QMS) on 1 April 1997. The Northland TAC is 75 t, comprised of a TACC of 40 t, allowances of 7.5 t for recreational and customary fisheries, and an allowance of 20 t for other sources of mortality (Table 1; all values in meatweight).

Table 1: Total Allowable Commercial Catch (TACC, t) declared for SCA 1 since introduction into the QMS.

Year	TAC	Customary	Recreational	Other Mortality	TACC
1996 - present	75	7.5	7.5	20	40

1.1 Commercial fisheries

SCA 1 is a regionally important commercial fishery situated between Reef Point Ahipara, on the west coast, to Cape Rodney on the east coast. Fishing is conducted within discrete beds in Spirits Bay, Tom Bowling Bay, Great Exhibition Bay, Rangaunu Bay, Doubtless Bay, Stevenson's Island, the Cavalli Passage, Bream Bay, and the coast between Mangawhai and Pakiri Beach. All commercial fishing is by dredge, with fishers preferring self-tipping "box" dredges (up to 2.4 m wide, fitted with a rigid tooth bar on the leading bottom edge) to the "ring bag" designs used in Challenger and Chatham Island fisheries. The fishing year for SCA 1 is from 1 April to 31 March. The Northland commercial scallop season runs from 15 July to 14 February. The minimum legal size (MLS) is 100 mm.

Between 1980–81 and 2009–10, landings varied more than 10-fold from 80 t to over 1600 t (greenweight). There has been a gradual decline in landings since 2005–06, with very low landings of 1 and 2 t in 2010–11 and 2011–12. There was no fishing in 2012–13, as voluntarily agreed by members of the Northland Scallop Enhancement Company (NSEC) (representative of the SCA 1 commercial scallop fishing industry) and only 86kg caught in 2013-14

SCA 1 is managed under the QMS using individual transferable quotas (ITQ) that are proportions of the Total Allowable Commercial Catch (TACC). Catch limits and landings from the Northland fishery are shown in Table 2. SCA 1 is gazetted on the Second Schedule of the Fisheries Act 1996 which specifies that, for certain "highly variable" stocks, the Annual Catch Entitlement

(ACE) can be increased within a fishing season. The TACC is not changed by this process and the ACE reverts to the "base" level of the TACC at the end of each season.

Table 2: Catch limits and landings (t meatweight or greenweight) from the Northland fishery since 1980. Data before 1986 are from Fisheries Statistics Unit (FSU) forms. Landed catch figures come from Quota Management Returns (QMRs), Monthly Harvest Returns (MHRs) forms, and from the landed section of Catch Effort and Landing Returns (CELRs), whereas estimated catch figures come from the effort section of CELRs and are pro-rated to sum to the total CELR landed greenweight. Catch limits for 1996 were specified on permits as meatweights, and, since 1997, were specified as a formal TACC in meatweight (Green1 assumes the gazetted meatweight recovery conversion factor of 12.5% and probably overestimates the actual greenweight taken in most years). In seasons starting in 1999 and 2000, voluntary catch limits were set at 40 and 30 t, respectively. *, split by area not available; –, no catch limits set, or no reported catch (Spirits).

			Landings (t)					
	Catch limits (t)		QMR/ MHR		CELR and FSU	Scaled estimated catch (t green)		
Fishing year	Meat	Green[1]	Meat	Meat	Green	Whangarei	Far North	Spirits
1980–81	–	–	–	–	238	*	*	*
1981–82	–	–	–	–	560	*	*	*
1982–83	–	–	–	–	790	*	*	*
1983–84	–	–	–	–	1 171	78	1 093	–
1984–85	–	–	–	–	541	183	358	–
1985–86	–	–	–	–	343	214	129	–
1986–87	–	–	–	–	675	583	92	–
1987–88	–	–	–	–	1 625	985	640	–
1988–89	–	–	–	–	1 121	1 071	50	–
1989–90	–	–	–	–	781	131	650	–
1990–91	–	–	–	–	519	341	178	–
1991–92	–	–	–	168	854	599	255	–
1992–93	–	–	–	166	741	447	294	–
1993–94	–	–	–	110	862	75	787	1
1994–95	–	–	–	186	1 634	429	1 064	142
1995–96	–	–	–	209	1 469	160	810	499
1996–97	188	1 504	–	152	954	55	387	512
1997–98	188	1 504	–	144	877	22	378	477
1998–99	106	848	28	29	233	0	102	130
1999–00	106	785	22	20	132	0	109	23
2000–01	60	444	15	16	128	0	88	40
2001–02	40	320	38	37	291	14	143	134
2002–03	40	320	40	42	296	42	145	109
2003–04	40	320	38	38	309	11	228	70
2004–05	40	320	40	37	319	206	77	37
2005–06	70	560	69	68	560	559	1	0
2006–07	70	560	53	50	405	404	1	0
2007–08	40	320	33	32	242	9	197	35
2008–09	40	320	25	25	197	0	171	26
2009–10	40	320	10	10	80	0	80	0
2010–11	40	320	1	1	8	0	8	0
2011–12	40	320	2	2	16	0	16	0
2012–13	40	320	0	0	0	0	0	0
2013-14	40	320	0.01	0.01	0.086	0.086	0	0

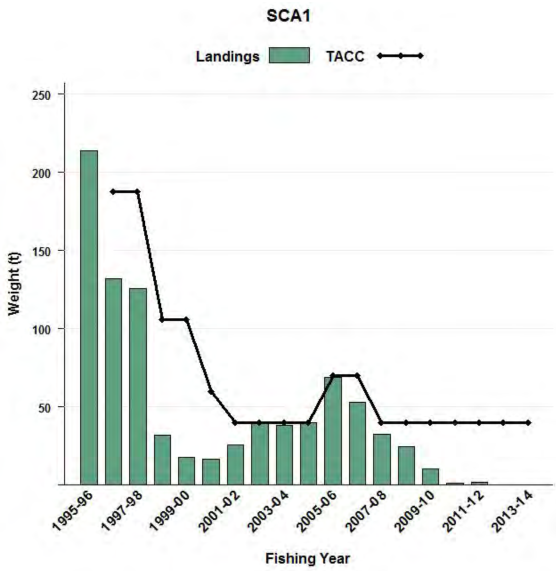


Figure 1: Landings and catch limits for SCA 1 (Northland) from 1997–98 to 2012–14. TACC refers to the base TACC and any inseason increase in Annual Catch Entitlement and 'Weight' refers to meat weight.

1.2 Recreational fisheries

There is a strong non-commercial (recreational and Maori customary) interest in scallops in suitable areas throughout the Northland fishery, mostly in enclosed bays and harbours. Scallops are usually taken by diving using snorkel or scuba, although the use of small dredges is also common practice. In some areas, especially in harbours, scallops can be taken by hand from the shallow subtidal and even the low intertidal zones (on spring tides) and, in storm events, scallops can be cast onto lee beaches in large numbers. One of the management tools used in the northern scallop fishery is the spatial separation of commercial and amateur fisheries through the closure of harbours and enclosed waters to commercial dredging. There remain, however, areas of contention and conflict, some of which have been addressed using additional voluntary or regulated closures. Regulations governing the recreational harvest of scallops from SCA 1 include a minimum legal size of 100 mm shell length and a restricted daily harvest (bag limit) of 20 per person. A change to the recreational fishing regulations in 2005, allowed divers operating from a vessel to take scallops for up to two nominated safety people on board the vessel, in addition to the catch limits for the divers. Until 2006, the recreational scallop season ran from 15 July to 14 February, but in 2007 the season was changed to run from 1 September to 31 March.

Estimates of the recreational scallop harvest from SCA 1 are shown in Table 3. The annual recreational harvest level is likely to vary substantially through time.

Table 3: Estimates of the recreational harvest of scallops from SCA 1. Number, number of scallops; green, greenweight; meat, meatweight (assuming 12.5% recovery of meat weight from green weight).

Year	Area	Survey method	Number	CV	Green (t)	Meat (t)	Reference
2011–12	SCA 1	Panel survey	148 905	0.36	16	2	Wynne-Jones et al (in press)

1.3 Customary fisheries

Limited quantitative information on the level of customary take is available from the Ministry for Primary Industries (MPI) (Table 4).

Table 4: Ministry for Primary Industries records of customary harvest of scallops (reported as numbers or greenweight, or units unspecified) taken from the Northland scallop fishery, 2003–04 to 2008–09. –, no data.

SCA1	Quantity approved, by unit type			Actual quantity harvested, by unit type		
Fishing year	Weight (kg)	Number	Unspecified	Weight (kg)	Number	Unspecified
2006–07	–	1650	–	–	1650	–
2007–08	–	1780	–	–	1780	–
2008–09	120	–	300	220	–	300
2009-10	–	1200	8250	–	1200	4872
2010-11	100	–	11400	–	–	6163
2011-12	130	600	7700	130	480	1740
2012-13	80	2950	4050	80	2640	340
2013-14	8	–	–	8	–	–

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 other sources of mortality for Northland scallops. The box dredges in use in the Northland commercial fishery have been found to be considerably more efficient than ring-bag or Keta-Ami dredges. However, research conducted in the Coromandel scallop fishery showed that scallops encountered by box had modest reductions in growth rate, compared with scallops collected by divers, and quite high mortality (about 20–30% mortality but potentially as high as 50% for scallops that are returned to the water; i.e. those just under the MLS of 100 mm). Stochastic modelling suggested that, of the three dredge designs tested, box dredges would generate the greatest yield-per-recruit and catch rates. The incidental mortality caused by dredging substantially changed the shape of yield-per-recruit curves for Coromandel scallops, causing generally asymptotic curves to become domed, and decreasing estimates of F_{max} and $F_{0.1}$. More recent field experiments and modelling suggest that dredging reduces habitat heterogeneity, increases juvenile mortality, makes yield-per-recruit curves even more domed, and decreases estimates of F_{max} and $F_{0.1}$ even further.

2. BIOLOGY

Pecten novaezelandiae is one of several species of “fan shell” bivalve molluscs found in New Zealand waters. Others include queen scallops and some smaller species of the genus *Chlamys*. *P. novaezelandiae* is endemic to New Zealand, but is very closely related to the Australian species *P. fumatus* and *P. modestus*. Scallops of various taxonomic groups are found in all oceans and support many fisheries world-wide; most scallop populations undergo large fluctuations.

Scallops are found in a variety of coastal habitats, but particularly in semi-enclosed areas where circulating currents are thought to retain larvae. After the planktonic larval phase and a relatively mobile phase as very small juveniles, scallops are largely sessile and move actively mainly in response to predators. They may, however, be moved considerable distances by currents and storms and are sometimes thrown up in large numbers on beaches.

Scallops are functional hermaphrodites, and become sexually mature at a size of about 70 mm shell length. They are extremely fecund and may spawn several times each year. Fertilisation is external and larval development lasts for about 3 weeks. Initial settlement occurs when the larva attaches via a byssus thread to filamentous material or dead shells on or close to the seabed. The major settlement of spat in northern fisheries usually takes place in early January. After growth to about 5 mm, the byssus is detached and, after a highly mobile phase as a small juvenile, the young scallop takes up the relatively sedentary adult mode of life.

The very high fecundity of this species and likely variability in the mortality of larvae and pre-recruits leads to great variability in annual recruitment. This, combined with variable mortality and growth of adults, leads to scallop populations being highly variable from one year to the next, especially in areas of rapid growth where the fishery may be supported by only one or two year classes. This variability is characteristic of scallop populations world-wide, and often occurs independently of fishing pressure.

Little detailed information is available on the growth and natural mortality of Northland scallops, although the few tag returns from Northland indicate that growth rates in Bream Bay are similar to those in the nearby Coromandel fishery (see the chapter for SCA CS). The large average size of scallops in the northern parts of the Northland fishery and the consistent lack of small animals there suggests that growth rates may be high in the far north.

3. STOCKS AND AREAS

Scallops inhabit waters of up to about 60 m deep (apparently up to 85 m at the Chatham Islands), but are more common in depths of 10 to 50 m on substrates of shell gravel, sand or, in some cases, silt. Scallops are typically patchily distributed at a range of spatial scales; some of the beds are persistent and others are ephemeral. The extent to which the various beds or populations are reproductively or functionally separate is not known. It is currently assumed for management purposes that the Northland stock is separate from the adjacent Coromandel stock, from the various west coast harbours stocks and also from the Golden Bay, Tasman Bay, Marlborough Sounds, Stewart Island and Chatham Island stocks.

4. STOCK ASSESSMENT

Northland scallops are managed using a TACC of 40 t meatweight which can be augmented with additional ACE based on the results from a preseason biomass survey and the subsequent Current Annual Yield (CAY) estimates, using $F_{0.1}$ as a reference point. The last biomass survey conducted in SCA 1 was in 2007.

4.1 Estimates of fishery parameters and abundance

Over all of SCA 1, estimated fishing mortality on scallops 100 mm or more was in the range F_{est} = 0.33–0.78 y^{-1} (mean F_{est} = 0.572 y^{-1}) between 1997–98 and 2003–04, but was lower in the period 2005–07 (mean F_{est} = 0.203 y^{-1}) (Table 5). The level of fishing mortality in more recent years is unknown because of the lack of surveys to estimate biomass. There is no known stock-recruit relationship for Northland scallops.

CPUE is not usually presented for this fishery because it is not considered to be a reliable index of abundance (Cryer 2001b). However, recent Management Strategy Evaluation (MSE) modelling suggested at the potential for CPUE to be used as a basis for some management strategies (Haist & Middleton 2010). This may or may not apply to the Northland scallop fishery.

In the absence of survey estimates of abundance in recent years, CPUE indices in 2011 were generated for SCA 1 based on the available data for the period 1991–2011 (Hartill & Williams 2014). Almost all commercial fishing during this period has taken place in three statistical reporting areas, but none of these areas has been fished continuously; in any given year, fishers tend to select the most productive area(s). A stock-wide CPUE index, produced by combining data from the different areas, suggests that the abundance of scallops throughout SCA 1 declined in the late 1990’s, and then steadily increased substantially until 2005–06, after which there has been a steady decline; such an index, however, must be regarded with caution. The limitations of CPUE as an index of abundance are well understood, but are particularly severe for sedentary species like scallops. The nature of the relationship between CPUE and abundance is unclear, but is likely to be hyperstable.

Since 2012, the SCA 1 commercial scallop fishing industry (represented by NSEC, the Northland Scallop Enhancement Company Ltd.) have worked with NIWA to conduct industry surveys using standardised dredge tows in core areas of SCA 1. Preliminary analysis by NIWA suggests scallop abundance in the areas surveyed (Bream Bay and Rangaunu Bay) in 2012 and 2013 was low compared with most of the 2005–07 survey estimates. In 2014 the 2014 industry survey of Bream Bay suggested a slightly higher biomass in the surveyed areas than in 2012 and 2013; at the time of writing (6 November 2014), the 2014 industry survey of Rangaunu Bay had not been conducted.

4.2 Biomass estimates

Virgin biomass, B_0, and the biomass that will support the maximum sustainable yield, B_{MSY}, have not been estimated and are probably not appropriate reference points for a stock with highly variable recruitment and growth such as scallops.

There were reasonably regular assessments of Northland scallops between 1992 and 2007 (Table 5 and Table 6), in support of a CAY management strategy. Assessments are based on pre-season biomass surveys conducted by diving and/or dredging. Composite dive-dredge surveys were conducted annually from 1992 to 1997, except in 1993 when only divers were used. From 1998, surveys were conducted using dredges only. The Northland fishery was not surveyed in 1999, 2000, 2004, or 2008–12. Where dredges have been used, absolute biomass must be estimated by correcting for the efficiency of the particular dredges used. Previously, estimates were corrected for dredge efficiency using scalars (multipliers) which were estimated by directly comparing dredge counts with diver counts in experimental areas (e.g., Cryer & Parkinson 1999). However, different vessels were used in the most recent surveys and no trials were conducted on the efficiency of the particular dredges used. Estimating start-of-season biomass (Table 5) and yield is, therefore, difficult and contains unmeasurable as well as measurable uncertainty. For some years, the highest recorded estimate of dredge efficiency has been used, but more recent surveys have had a range of corrections applied from no correction (the most conservative) to the historical average across all studies (the least conservative). A new model for estimating scallop dredge efficiency in SCA CSis now available, (Bian et al 2012), but has not yet been used as yet to re-analyse the historical survey time series for SCA 1.

Table 5: Estimated start of season abundance and biomass of scallops of 100 mm or more shell length in the Northland fishery from 1997 to 2007 using historical average dredge efficiency; for each year, the catch (reported on the 'Landed' section of CELRs), exploitation rate (catch to biomass ratio), and the estimated fishing mortality (F_{est}) are also given. F_{est} was estimated by iteration using the Baranov catch equation where t = 7/12 and M = 0.50 spread evenly through the year. Abundance and biomass estimates are mean values up to and including 2003, and median values from 2005, when the analytical methodology for producing the estimates was modified. This, together with changes to survey coverage each year, make direct comparisons among years difficult. –, no data. There were no surveys in 1999, 2000, 2004, or 2008–11.

Year	Abundance		Biomass				Exploitation rate	F_{est}
	(millions)	C.V.	(t green)	C.V.	(t meat)	C.V.	(catch/biomass)	≥100 mm
1997	34.9	0.22	3520	0.22	475	0.22	0.27	0.62
1998	13.9	0.13	1547	0.13	209	0.13	0.15	0.33
1999	–	–	–	–	–	–	–	–
2000	–	–	–	–	–	–	–	–
2001	8.9	0.27	871	0.27	118	0.27	0.32	0.78
2002	13.2	0.19	1426	0.19	193	0.19	0.21	0.46
2003	9.3	0.19	1031	0.19	139	0.19	0.28	0.66
2004	–	–	–	–	–	–	–	–
2005	51.3	0.72	5565	0.70	753	0.71	0.09	0.19
2006	66.6	0.45	7280	0.43	984	0.44	0.05	0.11
2007	15.1	0.47	1637	0.45	208	0.46	0.14	0.31

Biomass estimates at the time of the survey for the Northland fishery are shown in Table 6. These estimates are calculated using historical average dredge efficiency for scallops 95 mm or more in shell length. Estimates of current biomass for the Northland fishery are not available (the last biomass survey of the Northland fishery was in 2007), and there are no estimates of reference biomass with which to compare historical estimates of biomass. A substantial increase in biomass was observed between 2003 and 2006, which resulted in the 2006 biomass estimate being the highest recorded for Northland. In 2005 and 2006, estimates of biomass were considerably higher than those in 2003 for some beds (notably Bream Bay), but similar or lower in others. There appeared to have been a “shift” in biomass away from the Far North and towards Bream Bay and Mangawhai/Pakiri Beach. This was the “reverse” of the shift towards the Far North that occurred in the early 1990s. However, the 2007 survey results suggested that the biomass in Bream Bay and Mangawhai/Pakiri had declined markedly since 2006, and, consequently, the overall fishery biomass was far lower in 2007 than in previous years. The beds in Rangaunu Bay seem more consistent between years, although the 2007 biomass estimate was the highest on record. The biomass in Spirits/Tom Bowling Bays was higher in 2007 than 2006 but was low compared with historical levels.

Table 6: Estimated recruited biomass (t greenweight) of scallops of 95 mm or more shell length at the time of the surveys in various component beds of the Northland scallop fishery from 1992 to 2007, assuming historical average dredge efficiency. – indicates no survey in a given year; there have been no surveys of SCA 1 since 2007. Estimates of biomass given for 1993 are probably negatively biased, especially for Rangaunu Bay (*), by the restriction of diving to depths under 30 m, and all estimates before 1996 are negatively biased by the lack of surveys in Spirits Bay (†). Totals also include biomass from less important beds at Mangawhai, Pakiri, around the Cavalli Passage, in Great Exhibition Bay, and Tom Bowling Bay when these were surveyed. Commercial landings in each year for comparison can be seen in Table 1, wherein “Far North” landings come from beds described here as “Whangaroa”, “Doubtless”, and “Rangaunu”.

						Biomass (t)
	Bream Bay	Whangaroa	Doubtless	Rangaunu	Spirits Bay	Total
1992	1 733	–	78	766	–	3 092 †
1993	569	172	77	170 *	–	1 094 *
1994	428	66	133	871	–	1 611 †
1995	363	239	103	941	–	1 984 †
1996	239	128	32	870	3 361	5 098
1997	580	117	50	1 038	1 513	3 974
1998	18	45	37	852	608	1 654
1999	–	–	–	–	–	–
2000	–	–	–	–	–	–
2001	110	8	0	721	604	1 451
2002	553	10	–	1 027	1 094	2 900
2003	86	33	3	667	836	1 554
2004	–	–	–	–	–	–
2005	2 945	–	–	719	861	4 676
2006	5 315	–	–	1 275	261	7 539
2007	795	–	–	1 391	432	2 694

Substantial uncertainty stemming from assumptions about the dredge efficiency during the surveys, rates of growth and natural mortality between the survey and the start of the fishing season, and predicting the average recovery of meatweight from greenweight remain in these stock assessments. A new model of scallop dredge efficiency (Bian et al 2012) has helped to reduce this uncertainty, as should future research projects aimed at collecting more data on scallop growth and mortality. Managing the fisheries based on the number of recruited scallops at the start of the season as opposed to recruited biomass (the current approach) could remove the uncertainty associated with converting estimated numbers of scallops to estimated meatweight.

Diver surveys of scallops were conducted in June 2006 and June–July 2007 at selected scallop beds in Northland recreational fishing areas (Williams et al 2008, Williams 2009). For the four small beds (total area of 4.35 km^2) surveyed, start-of-season biomass of scallops over 100 mm shell length was estimated to be 49.7 t greenweight (CV of 23%) or 6.2 t meatweight in 2006, and 42 t greenweight (CV of 25%) or 5 t meatweight (CV of 29%) in 2007.

4.3 Yield estimates and projections

MCY has not been estimated for Northland scallops and would probably be close to zero.

Yield estimates are generally calculated using reference rates of fishing mortality applied in some way to an estimate of current or reference biomass. Cryer & Parkinson (2006) reviewed reference rates of fishing mortality and summarised modelling studies by Cryer & Parkinson (1997) and Cryer et al (2004). The Ministry for Primary Industries' Shellfish Working Group recommend $F_{0.1}$ as the most appropriate reference rate (target) of fishing mortality for scallops.

Management of Northland scallops is based on a CAY approach. Since 1998, in years when biomass surveys have been conducted, catch limits have been adjusted in line with estimated start-of-season recruited biomass and an estimate of CAY made using the Baranov catch equation:

$$CAY = \frac{F_{ref}}{F_{ref}+M}\left(1 - e^{-(F_{ref}+M)t}\right)B_{beg}$$

where t = 7/12 years, F_{ref} is a reference fishing mortality ($F_{0.1}$) and B_{beg} is the estimated start-of-season (15 July) recruited biomass (scallops of 90 mm or more shell length). Natural mortality is assumed to act in tandem with fishing mortality for the first 7 months of the fishing season, the length of the current Northland commercial scallop season. B_{beg} is estimated assuming historical average dredge efficiency at length, average growth (from previous tagging studies), M = 0.5 spread evenly through the year, and historical average recovery of meatweight from greenweight. Because of the uncertainty over biomass estimates, growth, and mortality in a given year, and appropriate reference rates of fishing mortality, yield estimates must be treated with caution.

Modelling studies for Coromandel scallops (Cryer & Morrison 1997, Cryer et al 2004) indicate that $F_{0.1}$ is sensitive not only to the direct incidental effects of fishing (reduced growth and increased mortality on essentially adult scallops), but also to indirect incidental effects (such as additional juvenile mortality related to reduced habitat heterogeneity in dredged areas). Cryer & Morrison's (1997) yield-per-recruit model for the Coromandel fishery was modified to incorporate growth parameters more suited to the Northland fishery and estimate reference fishing mortality rates. Including direct incidental effects of fishing only, and for an assumed rate of natural mortality of M = 0.50, $F_{0.1}$ was estimated as $F_{0.1}$ = 0.943 y^{-1} (reported by Cryer et al 2004, as 7/12 * $F_{0.1}$ = 0.550) for SCA 1, but estimates of $F_{0.1}$ including direct and indirect incidental effects of fishing were not estimated.

Consequently, the most recent CAY estimates were derived in 2007 (the year of the last biomass survey) for one scenario only:

CAY including direct effects on adults

By including only the direct incidental effects of fishing on scallops, Cryer et al (2004) derived an estimate of $F_{0.1}$ = 0.943 y^{-1} (reported by Cryer et al, 2004, as 7/12 * $F_{0.1}$ = 0.550). Using this value and the 2007 start of season biomass estimates (median projected values), CAY for 2007–08 was estimated to be 609 t greenweight or 77 t meatweight.

These estimates of CAY would have a CV at least as large as that of the estimate of start-of-season recruited biomass (50–51%), are sensitive to assumptions about dredge efficiency, growth, and expected recovery of meatweight from greenweight, and relate to the surveyed beds only. The sensitivity of these yield estimates to excluding areas of low density has not been calculated, but excluding stations with scallop density less than 0.02 m^{-2} and 0.04 m^{-2} reduced the fishery-wide time of survey biomass estimate by 95 and 100%, respectively. It should be noted that these low-density exclusions were calculated before correcting for average historical dredge efficiency, so these estimates are conservative. However, even if corrections for dredge efficiency were applied and no exclusions were made, the density of scallops 100 mm or more was low in all areas of the fishery surveyed in 2007. There is also additional uncertainty associated with using a point estimate of $F_{0.1}$ (i.e., variance associated with the point estimate of $F_{0.1}$ was not incorporated in the analysis).

4.4 Other yield estimates and stock assessment results

The estimation of Provisional Yield (PY) is no longer accepted as appropriate, and assessments since 1998 have used a CAY approach.

5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This is a new section that was reviewed by the Aquatic Environment Working Group for the November 2013 Fisheries Assessment Plenary. A broader summary of information on a range of issues related to the environmental effects of fishing and aspects of the marine environment and biodiversity of relevance to fish and fisheries is available in the Aquatic Environment & Biodiversity Annual Review (http://www.mpi.govt.nz/Default.aspx?TabId=126&id=2122) (Ministry for Primary Industries 2013).

5.1 Role in the ecosystem

Scallops (*Pecten novaezelandiae*) are subtidal, benthic, epifaunal, sedentary, bivalve molluscs, which have a pelagic larval dispersal phase. They are found patchily distributed at a range of scales in particular soft sediment habitats in inshore waters of depths generally to 50 m and exceptionally up to 85 m. They exhibit relatively fast growth, high mortality, and variable recruitment. The rates of these processes probably vary in relation to environmental conditions (e.g., temperature, water flow, turbidity, salinity), ecological resources (e.g., food, oxygen, habitat), and with intra- and inter-specific interactions (e.g., competition, predation, parasitism, mutualism), and the combination of these factors determines the species distribution and abundance (Begon et al 1990). Scallops are considered to be a key component of the inshore coastal ecosystem, acting both as consumers of primary producers and as prey for many predators; the scallops themselves can also provide structural habitat for other epifauna (e.g., sponges, ascidians, algae).

5.1.1 Trophic interactions

Scallops are active suspension feeders, consuming phytoplankton and other suspended material (benthic microalgae and detritus) as their food source (Macdonald et al 2006). Their diet is the same as, or similar to, that of many other suspension-feeding taxa, including other bivalves such as oysters, clams, and mussels.

Scallops are prey to a range of invertebrate and fish predators, whose dominance varies spatially. Across all areas, reported invertebrate predators of scallops include starfish (*Astropecten polyacanthus*, *Coscinasterias calamaria*, *Luidia varia*), octopus (*Pinnoctopus cordiformis*), and hermit crabs (*Pagurus novaezelandiae*), and suspected invertebrate predators include various carnivorous gastropods (e.g., *Cominella adspersa* and *Alcithoe arabica*); reported fish predators of scallops include snapper (*Pagrus auratus*), tarakihi (*Nemadactylus macropterus*), and blue cod (*Parapercis colias*), and suspected fish predators include eagle rays (*Myliobatis tenuicaudatus*) and stingrays (*Dasyatis* sp.) (Morton & Miller 1968, Bull 1976, Morrison 1998, Nesbit 1999). Predation varies with scallop size, with small scallops being generally more susceptible to a larger range of predators.

5.2 Incidental catch (fish and invertebrates)

A range of non-target fish and invertebrate species are caught and discarded by dredge fisheries for *P. novaezelandiae* scallops. No data are available on the level or effect of this incidental catch (bycatch) and discarding by the fisheries. Bycatch data are available, however, from various dredge surveys of the scallop stocks, and the bycatch of the fisheries is likely to be similar to that of the survey tows conducted in areas that support commercial fishing.

Species or groups that have been caught as incidental catch in the box dredges and ring-bag dredges used in surveys of commercial scallop (*P. novaezelandiae*) fishery areas in New Zealand are shown in Table 7. Catch composition varies among the different fishery locations and through time.

In the Coromandel scallop stock (SCACS), a photographic approach was used in the 2006 dredge survey to provisionally examine bycatch groups (Tuck et al 2006), but a more quantitative and comprehensive study was conducted using bycatch data collected in the 2009 dredge survey (Williams et al 2010), with survey catches quantified by volume of different component categories. Over the whole 2009 survey, scallops formed the largest live component of the total catch volume (26%), followed by assorted seaweed (11%), starfish (4%), other live bivalves (4%), coralline turfing algae (1%) plus other live components not exceeding 0.5%. Dead shell (identifiable and hash) formed the largest overall component (45%), and rock, sand, and gravel formed 8%. Categories considered to be sensitive to dredging were caught relatively rarely. Data on the bycatch of the 2010 and 2012 surveys of SCA CS were also collected but not analysed; those data have been loaded to the MPI database 'scallop' for potential future analysis (Williams & Parkinson 2010, Williams et al 2013b).

In the Northland scallop stock (SCA 1), analysis of historical survey bycatch from a localised deep area within Spirits Bay showed an unusually high abundance and species richness of sponges (Cryer et al 2000), and led to the voluntary and subsequent regulated closure of that area to commercial fishing.

In the Southern scallop stock (SCA 7), data on the bycatch of the 1994–2013 surveys have been collected but not analysed, except for preliminary estimation of the 1998–2013 bycatch trajectories (Williams et al. 2013a).

Table 7: Species or groups categorised by bycatch type caught as incidental catch in dredge surveys of commercial scallop (*P. novaezelandiae*) fishery areas in New Zealand.

Type	Species or groups
habitat formers	sponges, tubeworms, coralline algae (turf, maerl), bryozoa
starfish	*Astropecten*, *Coscinasterias*, cushion stars, carpet stars
bivalves	dog cockles, horse mussels, oysters, green-lipped mussels, *Tawera*
other invertebrates	anemones, crabs, gastropods, polychaetes, octopus, rock lobster
Fish	gobie, gurnard, John dory, lemon sole, pufferfish, red cod, sand eel, snake eel, stargazer, yellowbelly flounder
seaweed	*Ecklonia,* other brown algae, green algae, red algae
Shell	whole shells, shell hash
substrate	mud, sand, gravel, rock
Other	rubbish

5.3 Incidental catch (seabirds, mammals, and protected fish)
There is no known bycatch of seabirds, mammals or protected fish species from *P. novaezelandiae* scallop fisheries.

5.4 Benthic interactions
It is well known that fishing with mobile bottom contact gears such as dredges has impacts on benthic populations, communities, and their habitats (e.g., see Kaiser et al 2006, Rice 2006). The effects are not uniform, but depend on at least: "the specific features of the seafloor habitats,

including the natural disturbance regime; the species present; the type of gear used, the methods and timing of deployment of the gear, and the frequency with which a site is impacted by specific gears; and the history of human activities, especially past fishing, in the area of concern" (Department of Fisheries and Oceans 2006). The effects of scallop dredging on the benthos are relatively well-studied, and include several New Zealand studies carried out in areas of the northern fisheries (SCA 1 and SCA CS) (Thrush et al 1995, Thrush et al 1998, Cryer et al 2000, Tuck et al 2009, Tuck & Hewitt 2012) and the Golden/Tasman Bay region of the southern (SCA 7) fishery (Tuck et al 2011). The results of these studies are summarised in the Aquatic Environment & Biodiversity Annual Review (Ministry for Primary Industries 2012), and are consistent with the global literature: generally, with increasing fishing intensity there are decreases in the density and diversity of benthic communities and, especially, the density of emergent epifauna that provide structured habitat for other fauna.

5.5 Other considerations

5.5.1 Spawning disruption

Scallop spawning occurs mainly during spring and summer (Bull 1976, Williams & Babcock 2004). Scallop fishing also occurs during these seasons, and is particularly targeted in areas with scallops in good condition (reproductively mature adults ready to spawn). Fishing also concentrates on high density beds of scallops, which are disproportionately more important for fertilisation success during spawning (Williams 2005). Fishing, therefore, may disrupt spawning by physically disturbing scallops that are either caught and retained (removal), caught and released, not caught but directly contacted by the dredge, or not caught but indirectly affected by the effects of dredging (e.g., suspended sediments).

5.5.2 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 2012) although work is currently underway to define one. Certain features of the habitats which scallops are associated with are known to influence scallop productivity by affecting the recruitment, growth and mortality of scallops, and therefore may in the future be useful in terms of identifying HPSFM. Scallop larval settlement requires the presence of fine filamentous emergent epifauna on the seabed, such as tubeworms, hydroids, and filamentous algae, hence the successful use of synthetic mesh spatbags held in the water column as a method for collecting scallop spat. Survival of juveniles has been shown to vary with habitat complexity, being greater in more complex habitats (with more emergent epifauna) than in more homogeneous areas (Talman et al 2004). The availability of suspended microalgae and detritus affects growth and condition (Macdonald et al 2006). Suspended sediments can reduce rates of respiration and growth, the latter by 'diluting' the food available; scallops regulate ingestion by reducing clearance rates rather than increasing pseudofaeces production. Laboratory studies have demonstrated that suspended sediments disrupt feeding, decrease growth and increase mortality in scallops (Stevens 1987, Cranford & Gordon 1992, Nicholls et al 2003).

6. STOCK STATUS

Stock Structure Assumptions

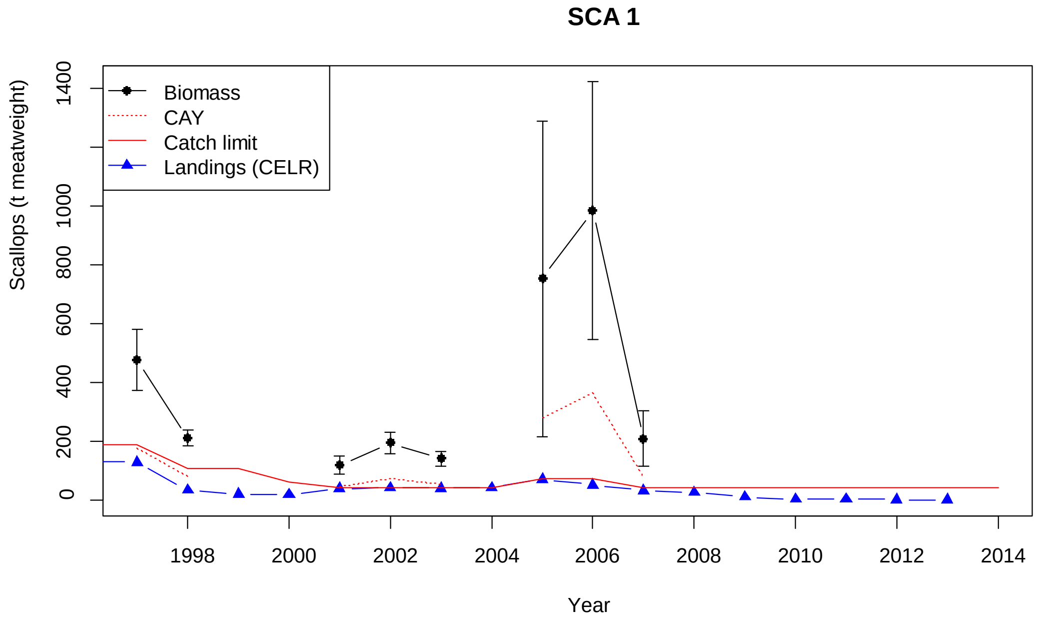
The stock structure of scallops in New Zealand waters is uncertain. For the purposes of the SCA 1assessments, SCA 1 is assumed to be a single biological stock, although the extent to which the various beds or populations are separate reproductively or functionally is not known.

- **Northland scallops, SCA 1**

Stock Status	
Year of Most Recent Assessment	2007
Assessment Runs Presented	Estimate of CAY for 2007
Reference Points	Target: Fishing mortality at or below $F_{0.1}$

	($F_{0.1}$ = 0.943 y^{-1} including direct incidental effects of fishing only) Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	Unlikely (< 40%) to be at or below the target (in 2007–13, F_{est} = 0.145 y^{-1}). There was very limited fishing in 2010–11 and 2011–12, no fishing in 2012–13 and very limited fishing in 2013-14.
Status in relation to Limits	Unknown
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring because literally no commercial fishing is taking place

Historical Stock Status Trajectory and Current Status



Recruited biomass (scallops 100 mm or more shell length), CAY (includes direct effects of fishing on adult scallops), catch limits, and reported landings (from CELRs) in t meatweight for the SCA 1 fishery since 1997.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The recent (2008 to 2014) trend in biomass is unknown. Industry surveys of core fisheries areas (Bream Bay and Rangaunu Bay) in 2012 and 2013 suggest scallop abundance in those areas was low compared with estimates from the 2005–07 surveys. The 2014 industry survey of Bream Bay suggested a slightly higher biomass than in 2012 and 2013; no survey of Rangaunu Bay had been conducted by early November 2014
Recent Trend in Fishing Intensity or Proxy	F_{est} cannot be estimated for this fishery for recent years. Catches in 2010–11 2011–12 were the lowest on record. There was no fishing in 2012–13 and essentially no fishing in 2013-14.
Other Abundance Indices	CPUE is not a reliable index of abundance (Cryer 2001b).
Trends in Other Relevant Indicator or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Stock projections are not available.
Probability of Current Catch	

causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current TACC causing Biomass to remain below or to decline below Limits	Very Likely (> 90%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Likely (< -90%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2: Partial quantitative stock assessment	
Assessment Method	Biomass surveys and CAY management strategy	
Assessment Dates	Latest assessment: 2007	Next assessment: Unknown
Overall Assessment Quality Rank	1 – High Quality	
Main data inputs (rank)	Biomass survey: 2007	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	Current model has been in use since 2005	
Major Sources of Uncertainty	- dredge efficiency during the survey - growth rates and natural mortality between the survey and the start of the fishing season - predicting the average recovery of meatweight from greenweight - the extent to which dredging causes incidental mortality and affects recruitment	

Qualifying Comments
In the Northland fishery some scallop beds are persistent and others are ephemeral. The extent to which the various beds or populations are reproductively or functionally separate is not known. This fishery is managed with a CAY management strategy with a base TACC. However, the management strategy currently resembles a constant catch strategy because there have been no surveys since 2007.

Fishery Interactions
A bycatch survey was conducted in the Coromandel fishery in 2009 under project SCA2007-01B. The results are summarised below and may or may not be relevant to the Northland scallop fishery. Bycatch composition Live components • Scallops 26% • Seaweed 11% • Starfish 4% • Other bivalves 4% • Coralline turf 1% Dead components

- Dead shell 45%
- Rock and gravel 8%

Bycatch data were also collected during the 2010 and 2012 surveys of SCA CS; the data were loaded to the MPI database "*scallop*" for use in future work.

6. FOR FURTHER INFORMATION

Begon, M; Harper, J L; Townsend, C R (1990). Ecology: Individuals, Populations and Communities. Blackwell Science, Cambridge. 945 p.

Bian, R; Williams, J R; Smith, M; Tuck, I D (2011). Modelling dredge efficiency for scallop fisheries in northeastern New Zealand. Final Research Report for Ministry of Fisheries project SAP200913. (Unpublished report held by Ministry for Primary Industries).

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. 81p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Boyd R O; Reilly J L (2002). 1999/2000 National marine recreational fishing survey: harvest estimates. Final Research Report for Ministry of Fisheries project REC98/03. 28 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Bradford E (1997). Estimated recreational catches from Ministry of Fisheries North region marine recreational fishing surveys, 1993-94. New Zealand Fisheries Assessment Research Document 97/7. 16 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. 27 p. (Unpublished report held in NIWA library, Wellington.)

Bull M F (1991). New Zealand. pp. 853–859 in Shumway S.E. (Ed) Scallops: biology, ecology and aquaculture. *Developments in Aquaculture & Fisheries Science*, 21. Elsevier. Amsterdam. 1095p.

Bull, M F (1976). Aspects of the biology of the New Zealand scallop, Pecten novaezelandiae Reeve 1853, in the Marlborough Sounds. Unpublished PhD thesis. Victoria University of Wellington, New Zealand. 175 p.

Cranford, P J; Gordon, D C (1992). The influence of dilute clay suspensions on sea scallop (*Placopecten magellanicus*) feeding activity and tissue growth. *Netherlands Journal of Sea Research* 30: 107-120.

Cryer M (1994). Estimating CAY for northern commercial scallop fisheries: a technique based on estimates of biomass and catch from the Whitianga bed. New Zealand Fisheries Assessment Research Document 1994/18. 21p. (Unpublished report held in NIWA library, Wellington.)

Cryer M (2001a). Coromandel scallop stock assessment for 1999. *New Zealand Fisheries Assessment Report* 2001/9. 18p.

Cryer M (2001b). An appraisal of an in-season depletion method of estimating biomass and yield in the Coromandel scallop fishery. *New Zealand Fisheries Assessment Report* 2001/8. 28p.

Cryer M (2002). Northland and Coromandel scallop stock assessments for 2001. New Zealand Fisheries Assessment Report 2002/60. 21p.

Cryer, M; Davies, N M; Morrison, M (2004). Collateral damage in scallop fisheries: translating "statistics" into management advice. Presentation and working document for Shellfish Fishery Assessment Working Group, March 2004. p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cryer M; Morrison M (1997). Yield per recruit in northern commercial scallop fisheries: inferences from an individual-based population model and experimental estimates of incidental impacts on growth and survival. Final Research Report for Ministry of Fisheries project AKSC03. 67p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cryer, M; O'Shea, S; Gordon, D P; Kelly, M; Drury, J D; Morrison, M A; Hill, A; Saunders, H; Shankar, U; Wilkinson, M; Foster, G (2000). Distribution and structure of benthic invertebrate communities between North Cape and Cape Reinga. Final Research Report by NIWA for Ministry of Fisheries Research Project ENV9805 Objectives 1–4. p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cryer M; Parkinson D M (1999). Dredge surveys and sampling of commercial landings in the Northland and Coromandel scallop fisheries, May 1998. NIWA Technical Report 69. 63p.

Cryer M; Parkinson D M (2001). Dredge surveys of scallops in the Northland and Coromandel scallop fisheries, April–May 2001. Working Document for Ministry of Fisheries Shellfish Fishery Assessment Working Group Meeting June 2001. 40p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cryer M; Parkinson D M (2002). Dredge surveys of scallops in the Northland and Coromandel scallop fisheries, 2001. *New Zealand Fisheries Assessment Report* 2002/61. 25p.

Cryer M; Parkinson D M (2004). Dredge survey and stock assessment for the Northland scallop fishery, 2003. Final Research Report to Ministry of Fisheries on Project SCA2002/02. 34p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cryer M; Parkinson D M (2006). Biomass surveys and stock assessments for the Coromandel and Northland scallop fisheries, 2005. New Zealand Fisheries Assessment Report. 2006/34. 54p.

Department of Fisheries and Oceans (2006). Impacts of trawl gear and scallop dredges on benthic habitats, populations and communities. *DFO Canadian Science Advisory Secretariat Science Advisory Report 2006/025*: 13 p.

Haist V; Middleton D (2010) Management Strategy Evaluation for Coromandel Scallop, April 2010. Seafood Industry Council Report. 54p (Unpublished report held by the Ministry for Primary Industries).

Hartill, B; Williams, J R (2014). Characterisation of the Northland scallop fishery (SCA 1), 1989–90 to 2010–11. *New Zealand Fisheries Assessment Report 2014/26*. 43 p.

Kaiser, M J; Clarke, K R; Hinz, H; Austen, M C V; Somerfield, P J; Karakassis, I (2006). Global analysis of the response and recovery of benthic biota to fishing. *Marine Ecology Progress Series 311*: 1–14.

Macdonald, B A; Bricelj, M; Shumway, S E (2006). Physiology: Energy Aquisition and Utilisation. *In*: Shumway, S.E.; Parsons, G.J. (eds.) Scallops: Biology, Ecology and Aquaculture, pp. 417–492. *Developments in aquaculture and fisheries science*. Elsevier, Amsterdam.

Ministry for Primary Industries (2013). Fisheries Assessment Plenary, May 2013: stock assessments and yield estimates. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1357 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.

Morrison M A (1998). Population dynamics of the scallop, *Pecten novaezelandiae*, in the Hauraki Gulf. Unpublished PhD thesis, University of Auckland, Auckland, New Zealand. 157p.

Morton, J E; Miller, M C (1968). The New Zealand sea shore. Collins, Auckland, New Zealand. 638 p.

Nesbit, G J (1999). Reseeding and hatchery potential of *Pecten novaezelandiae* and effects of recreational harvesting. Unpublished MSc thesis. University of Auckland, New Zealand. 145 p.

Nicholls, P; Hewitt, J; Halliday, J (2003). Effects of suspended sediment concentrations on suspension and deposit feeding marine macrofauna. NIWA Client Report HAM2003-077 prepared for Auckland Regional Council (NIWA Project ARC03267). August. 43 p. ARC Technical Publication No. 211.

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.

Stevens, P M (1987). Response of excised gill tissue from the New Zealand scallop *Pecten novaezelandiae* to suspended silt. *New Zealand Journal of Marine and Freshwater Research 21*: 605-614.

Talman, S G; Norkko, A; Thrush, S F; Hewitt, J E (2004). Habitat structure and the survival of juvenile scallops *Pecten novaezelandiae*: comparing predation in habitats with varying complexity. *Marine Ecology Progress Series 269*: 197–207.

Thrush, S F; Hewitt, J E; Cummings, V J; Dayton, P K (1995). The impact of habitat disturbance by scallop dredging on marine benthic communities: what can be predicted from the results of experiments? *Marine Ecology Progress Series 129*: 141–150.

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.

Tuck, I; Hewitt, J; Handley, S; Willis, T; Carter, M; Hadfield, M; Gorman, R; Cairney, D; Brown, S; Palmer, A (2011). Assessing the effects of fishing on soft sediment habitat, fauna and processes. Progress Report for Ministry of Fisheries project BEN2007-01. 30 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Tuck, I.; Parkinson, D.; Dey, K.; Oldman, J.; Wadhwa, S. (2006). Information on benthic impacts in support of the Coromandel Scallops Fishery Plan. Final Research Report prepared by NIWA for Ministry of Fisheries Research Project ZBD2005-15 Objective 1-6. p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Tuck, I D; Drury, J; Kelly, M; Gerring, P (2009). Designing a programme to monitor the recovery of the benthic community between North Cape and Cape Reinga. Final Research Report by NIWA for Ministry of Fisheries Research Project ENV2005-23. x p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Tuck, I D; Hewitt, J E (2012). Monitoring change in benthic communities in Spirits Bay. Final Research Report by NIWA for Ministry of Fisheries research project BEN200901. 51 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Williams J R (2005). Reproductive ecology of the scallop, *Pecten novaezelandiae*. Unpublished PhD thesis, University of Auckland, Auckland, New Zealand. 134p.

Williams J R (2007). Biomass surveys and stock assessments for the Coromandel and Northland scallop fisheries, 2007. *New Zealand Fisheries Assessment Report* 2008/35. 41p

Williams J R (2008). Abundance of scallops (*Pecten novaezelandiae*) in Northland and Coromandel recreational fishing areas, 2007. Final draft New Zealand Fisheries Assessment Report for Ministry of Fisheries project SCA2006/03. 23p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Williams, J R (2009). Abundance of scallops (*Pecten novaezelandiae*) in Northland and Coromandel recreational fishing areas, 2007. New Zealand Fisheries Assessment Report 2009/62. 22p.

Williams J R; Babcock R C (2004a). Patterns of reproduction and spawning behaviour for scallops, *Pecten novaezelandiae*, in northeastern New Zealand. *Journal of Shellfish Research* 23: 318.

Williams J R; Babcock R C (2004b). Comparison of multiple techniques to evaluate reproductive variability in a marine bivalve: application to the scallop *Pecten novaezelandiae*. Marine and Freshwater Research *55*: 457–468.

Williams J R; Babcock R C (2005). Assessment of size at maturity and gonad index methods for the scallop *Pecten novaezelandiae*. *New Zealand Journal of Marine and Freshwater Research* 39: 851–864.

Williams, J R; Hartill, B; Bian, R; Williams, C L (2014). Review of the Southern scallop fishery (SCA 7). *New Zealand Fisheries Assessment Report 2014/07*. 71 p.

Williams, J R; Parkinson, D M (2010). Biomass survey and stock assessment for the Coromandel scallop fishery, 2010. *New Zealand Fisheries Assessment Report 2010/37*. 30 p.

Williams, J R; Parkinson, D M; Bian, R (2013b). Biomass survey and yield calculation for the Coromandel scallop fishery, 2012. *New Zealand Fisheries Assessment Report 2013/18*: 57 p.

Williams, J R; Parkinson, D M; Tuck, I D (2010). Biomass survey and stock assessment for the Coromandel scallop fishery, 2009. *New Zealand Fisheries Assessment Report 2010/33*. 40 p.

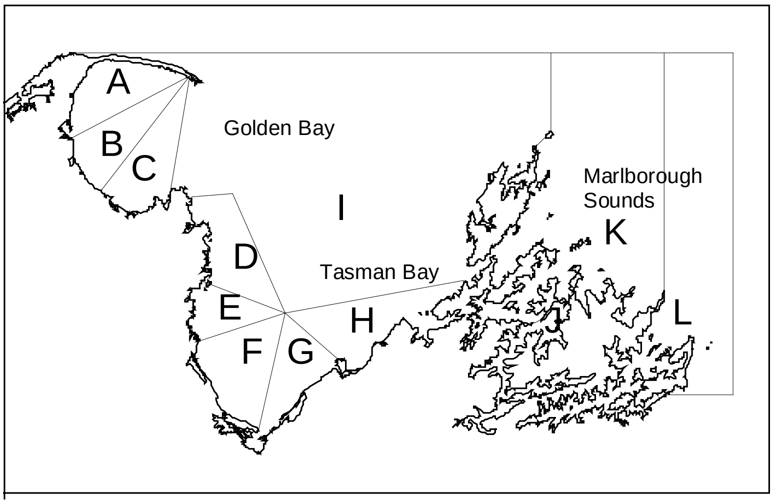
Williams J R; Tuck I D; Carbines G D (2008). Abundance of scallops (*Pecten novaezelandiae*) in Northland and Coromandel recreational fishing areas, 2006. *New Zealand Fisheries Assessment Report* 2008/34

Williams J R; Tuck I D; Parkinson D M (2007). Biomass surveys and stock assessments for the Coromandel and Northland scallop fisheries, 2006. *New Zealand Fisheries Assessment Report* 2007/24.

Wynne-Jones, J; Heinemann, A; Gray, A; Hill, L (in press). NZ recreational marine fishing survey 2011-2012. Draft New Zealand Fisheries Assessment Report by National Research Bureau Ltd. 69 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

SCALLOPS Nelson/Marlborough (SCA 7)

(*Pecten novaezelandiae*)
Kuakua



1. FISHERY SUMMARY

The Nelson/Marlborough scallop fishery (SCA 7) is spread over the three regions of Golden Bay, Tasman Bay, and the Marlborough Sounds. The fishery was introduced into a modified form of the Quota Management system (QMS) in 1992 and in 1995 an annual TACC was set at 720 t. In 2002 the TACC was increased to 747 t and a TAC set with allowances made for customary and recreational fishing (Table 1). In 2014 the TAC was reduced to 520due to consistently declining biomass for the past 10 years

Table 1: Total Allowable Commercial Catch (TACC, t) declared for SCA 7 since introduction into the QMS in 1992.

Year	TAC	Customary	Recreational	Other Mortality	TACC
1995–2002	–	–	–	–	720
2002–2012	827	40	40	0	747
2013 to present	520	40	40	40	400

1.1 Commercial fisheries

The commercial catch history for this fishery is quite variable with landings reaching an all time peak of 1244 tonnes in 1975. At this time there were 216 licensed vessels involved in the fishery and the minimum legal size (MLS) was 100 mm. After 1975 the fishery rapidly declined, and in 1981 and 1982 it was closed.

The fishery re-opened in 1983 with only 48 licences being issued and each vessel being allocated a defined, and equal, catch limit on an annual basis. In the same year the Ministry of Fisheries initiated a scallop enhancement programme in Golden and Tasman Bays and in 1989 a rotational fishing management strategy together with a reduction in the MLS to 90mm was also introduced in these two regions. The rotational fishing strategy worked such that the Golden and Tasman Bay regions were subdivided into 3 and 6 catch and effort reporting sectors respectively. Each year, several of the sectors in each region were opened to commercial fishing, and at the end of the season the fished sectors were reseeded and then closed to commercial fishing for at least 2 years. The new MLS of 90mm was also introduced into the Marlborough Sounds in 1989 but no enhancement or rotational fishing management strategy has ever been undertaken in this region. The Marlborough Sounds is divided into 2 catch and effort reporting sectors and the remaining portion of Golden and Tasman Bay became the final catch and effort reporting sector for SCA 7, giving 12 sectors overall.

In 1992, the SCA 7 fishery was introduced into a modified form of the Quota Management System (QMS) with an annual harvest limit of 640 t (12 t to each of the 48 licence holders, plus 64 t to Maori) initially allocated as ITQ. Provision was also made for any additional quota in excess of the 640 t to be allocated to the Crown for lease, with preference being given to existing quota holders. In October 1995, legislation was passed in which annual quotas were determined as a fixed proportion of the TACC rather than being allocated as a fixed tonnage. This provided for greater flexibility in changing the TACC. A statutory Enhancement Plan was also introduced at this time, to provide for ongoing enhancement of the fishery. The legislation was modified to enable a transition towards the enhancement programme being implemented by the Challenger Scallop Enhancement Company (CSEC) rather than the Ministry of Fisheries. In 1996, because of the rotational fishing and stock enhancement management strategy being used to manage the stocks in SCA7, the fishery was placed on the Third Schedule to the Fisheries Act 1996, and was, therefore, able to have an alternative TAC set under section 14 of the Act. Over the last 10years the rotational fishing and stock enhancement management strategy has not been strictly adhered to and the protocol of closing entire sectors to commercial fishing on an annual rotational basis is no longer practiced, with parts of all sectors being fished wherever scallops are available. In recent years reseeding activity has also reduced due to lack of adequate funds being available

Annual dredge surveys, used to estimate biomass levels and population size structures for each sector within SCA7, are conducted before each season begins. This approach enables the fishery to concentrate in areas where scallops are predominantly above the minimum legal size, and reduces disturbance in areas where most of the population is sub-legal.

Separate catch limits are set each year (by CSEC in consultation with MPI) for the Tasman/Golden Bays and the Marlborough Sounds regions of the fishery. Catch limits for Golden/Tasman Bays are based on direct results from the biomass surveys and the actual commercial catch is set by CSEC each year within the TACC limits. For the Marlborough Sounds, where there is no enhancement or rotational fishing plan, catch limits are formally set each year in consultation between MPI, CSEC and other relevant stakeholders. The catch limits that are set are based on estimates of Current Annual Yield calculated from the biomass survey results. In 2014 an alternative yield was also estimated by applying a target exploitation rate to the projected biomass.

Overall commercial catch is set based on knowledge of:

- the biomass in the three regions,
- any adverse effects of fishing on the marine environment being avoided, remedied or mitigated,
- providing for an allowance for non-commercial fishing,
- a biotoxin monitoring programme being maintained, and
- the ratio of legal to non-legal sized fish that are above pre-set levels.

Reported landings (meatweight) from the Challenger scallop fishery are listed in Tables 2 and 3. The fishing year applicable to this fishery is from 1 April to 31 March. Commercial fishing usually occurs from August to December, although opening and closing dates may differ between years.

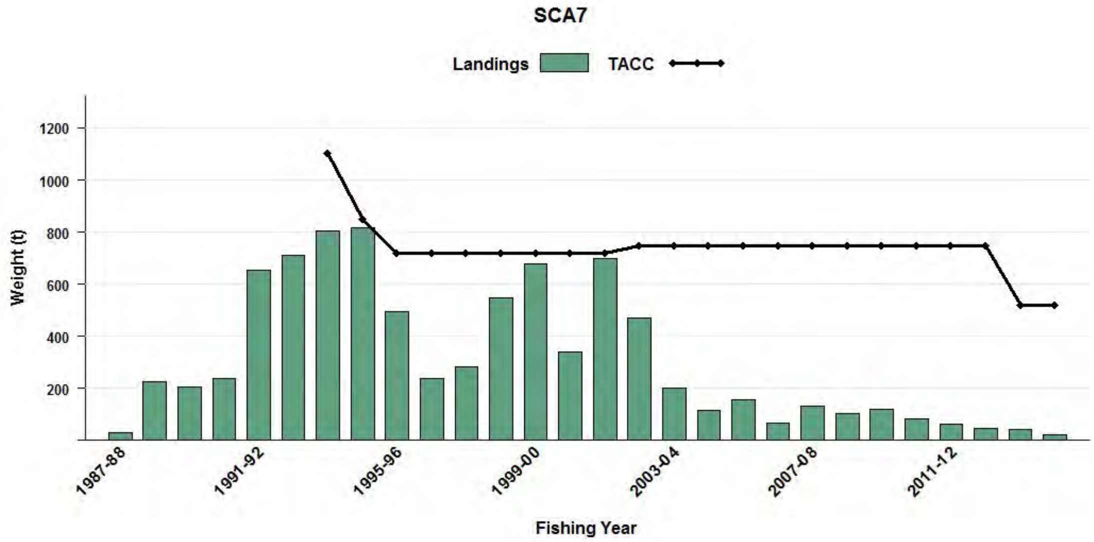


Figure 1: Historical landings and TACC for SCA7 (Nelson Marlborough).

Table 2: Reported landings (t, meatweight) of scallops from SCA 7 from 1959–60 to 1982–83. The fishery was closed for the 1981–82 and 1982–83 scallop fishing years. Landings are presented by region (GB, Golden Bay; TB, Tasman Bay; MS, Marlborough Sounds) and total, except before 1977 when landings were reported by the Golden Bay and Tasman Bay combined area (Gold/Tas). Data source: King & McKoy (1984).

Year	Gold/Tas	GB	TB	MS	Total
1959–60	1	–	–	0	1
1960–61	4	–	–	2	7
1961–62	19	–	–	0	19
1962–63	24	–	–	< 0.01	24
1963–64	105	–	–	2	107
1964–65	108	–	–	2	110
1965–66	44	–	–	< 0.5	44
1966–67	23	–	–	8	32
1967–68	16	–	–	7	23
1968–69	1	–	–	8	9
1969–70	72	–	–	6	78
1970–71	73	–	–	7	80
1971–72	206	–	–	10	215
1972–73	190	–	–	46	236
1973–74	193	–	–	127	320
1974–75	597	–	–	36	632
1975–76	1172	–	–	73	1244
1976–77	589	–	–	79	668
1977–78	–	342	168	63	574
1978–79	–	86	4	76	166
1979–80	–	32	30	40	101
1980–81	–	0	14	27	41
1981–82	–	–	–	–	–
1982–83	–	–	–	–	–

Table 3: Catch limits and reported landings (t, meatweight) of scallops from SCA 7 since 1983–84. The fishery was closed for the 1981–82 and 1982–83 scallop fishing years, and was subsequently managed under a rotationally enhanced regime. Two catch limits are presented: TACC, Total Allowable Commercial Catch; MSCL, Marlborough Sounds catch limit (a subset of the TACC, or a subset of the Annual Allowable Catch in 1994–95). Landings data come from the following sources: FSU, Fisheries Statistics Unit; MHR, Monthly Harvest Returns (Quota Harvest Returns before October 2001); CELR, Catch Effort Landing Returns; CSEC, Challenger Scallop Enhancement Company. Landings are also presented by region (GB, Golden Bay; TB, Tasman Bay; MS, Marlborough Sounds) and best total (believed to be the most accurate record) for the SCA 7 fishstock. –, no data.

	Catch limits		Landings				Landings by region and best total				
Year	TACC	MSCL	FSU	MHR	CELR	CSEC	GB	TB	MS	Best total	Source
1983–84	–	–	225	–	–	–	< 0.5	164	61	225	FSU
1984–85	–	–	367	–	–	–	45	184	138	367	FSU
1985–86	–	–	245	–	–	–	43	102	100	245	FSU
1986–87	–	–	355	–	–	–	208	30	117	355	FSU
1987–88	–	–	219	29	–	–	113	1	105	219	FSU
1988–89	–	–	222	228	–	–	127	23	72	222	FSU
1989–90	–	–	–	205	125	–	68	42	95	205	Shumway & Parsons (2006)
1990–91	–	–	–	237	228	–	154	8	66	228	CELR
1991–92	–	–	–	655	659	–	629	9	20	659	CELR
1992–93	–	–	–	712	674	–	269	247	157	674	CELR
1993–94	*1 100	–	–	805	798	–	208	461	129	798	CELR
1994–95	*850	70	–	815	825	–	415	394	16	825	CELR
1995–96	720	73	–	496	479	–	319	92	67	479	CELR
1996–97	#720	61	–	238	224	231	123	47	61	231	CSEC
1997–98	#720	58	–	284	265	299	239	2	58	299	CSEC
1998–99	#720	120	–	549	511	548	353	78	117	548	CSEC
1999–00	720	50	–	678	644	676	514	155	7	676	CSEC
2000–01	720	50	–	338	343	338	303	19	16	338	CSEC
2001–02	720	76	–	697	715	717	660	32	25	717	CSEC
2002–03	747	–	–	469	469	471	370	39	62	471	CSEC
2003–04	747	–	–	202	209	206	28	107	71	206	CSEC
2004–05	747	–	–	117	112	118	20	47	51	118	CSEC
2005–06	747	–	–	158	156	156	35	5	116	157	CSEC
2006–07	747	–	–	67	66	68	26	0	43	68	CSEC
2007–08	747	–	–	134	183	134	128	0	6	134	CSEC
2008–09	747	–	–	103	137	104	76	0	28	104	CSEC
2009–10	747	–	–	120	120	–	19	0	101	120	CELR
2010–11	747	–	–	85	85	–	10	0	74	85	CELR
2011–12	747	–	–	62	61	–	1	0	60	61	CELR
2012–13	747	–	–	48	48	–	0	0	48	48	CELR
2013-14	520	48	–	43		–	0	0	43	43	CELR
2014-15	520	28	–	^18	22	–	0	0	22	22	CELR

*Annual Allowable Catch (AAC); TACCs came into force 1 October 1995.
#Initial industry controlled catch limit was 350 t in 1996-97, 310 t in 1997-98, and 450 t in 1998-99.
^ not all catch data available at the time of writing this report

1.2 Recreational fisheries

Recreational fishers harvest scallops from SCA 7 by dredge and by diving. The recreational fishing season runs from 15 July to 14 February. In October 1995 the recreational bag limit was increased from 20 to 50 scallops, and the minimum legal size was reduced from 100 mm to 90 mm, as part of the statutory enhancement programme agreement. Recreational fishers have access to both the wild and enhanced scallop populations, and are not subject to the area closures experienced by the commercial fishery. Each year the commercial and recreational sectors jointly review the prospects for the recreational fishery based on pre-season abundance and yield estimates from CSEC dredge surveys. Following those discussions a number of non-commercial areas are routinely established to supplement the various regulatory closures, which apply to the commercial fishery only.

Estimates of annual recreational scallop harvest from SCA 7 are shown in Table 4; note the estimates provided by telephone diary surveys are no longer considered reliable for various reasons (for more information, see Ministry for Primary Industries 2013: pp 1101-1105 of the snapper section of the Fisheries Assessment Plenary 2013). The estimates from a creel survey in 2003–04 (Cole et al. 2006) and a panel survey in 2011–12 (Wynne-Jones et al. in press) equate to about 7–18% of the commercial harvest in the areas surveyed in those years.

Table 3: Estimates of the annual recreational harvest of scallops from SCA 7. Number, number of scallops; meat, meatweight (assuming 12.5% recovery of meat weight from green weight). GB/TB, Golden Bay/Tasman Bay. The estimates provided by telephone diary surveys are no longer considered reliable for various reasons. The 2011–12 estimate assumes a 12.5% recovery of meat from greenweight; note the panel survey was still under review at the time this report was written, but appears to provide plausible results.

Year	Area	Survey method	Number	CV	Meat (t)	Reference
1992–93	SCA 7	Telephone diary	1 680 000	0.15	22	Teirney et al. (1997)
1996	SCA 7	Telephone diary	1 456 000	0.21	19	Bradford (1998)
1999–00	SCA 7	Telephone diary	3 391 000	0.20	44	Boyd and Reilly (2002)
2000–01	SCA 7	Telephone diary	2 867 000	0.14	37	Boyd et al. (2004)
2003–04	GB/TB	Creel survey	860 000	0.05	9	Cole et al. (2006)
2011–12	SCA 7	Panel survey	796 164	0.23	11	Wynne-Jones et al. (in press)

1.3 Customary fisheries
Scallops were undoubtedly used traditionally as food by Maori, although quantitative information on the level of customary take is not available.

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

1.5 Other sources of fishing mortality
The extent of other sources of fishing mortality is unknown. Incidental mortality of scallops caused by ring-bag dredging is unknown for the Challenger fishery, although studies conducted in the Coromandel fishery showed that mortality was quite high (about 20–30% mortality for scallops that are returned to the water. i.e. just under the MLS of 90 mm) for scallops encountered by box dredges. Stochastic modelling suggested that the incidental mortality caused by dredging substantially changed the shape of yield-per-recruit curves for Coromandel scallops, causing generally asymptotic curves to become domed, and decreasing estimates of F_{MAX} and $F_{0.1}$. Other field experiments and modelling suggest that dredging reduces habitat heterogeneity, increases juvenile mortality, makes yield-per-recruit curves even more domed, and decreases estimates of F_{MAX} and $F_{0.1}$ even further. Incidental mortality of scallops may also result from bottom trawling, although the extent of this is unknown. Observational monitoring of *P. novaezelandiae* spat released in the first three years of enhancement (1984–86) in Golden Bay suggested spat survival was higher in areas closed to trawling (Bradford-Grieve et al. 1994).

2. BIOLOGY

Pecten novaezelandiae is a functional hermaphrodite that breeds generally in early summer (although partial spawning can occur from at least August to February). Most scallops mature by the end of their first year, but they contribute little to the spawning pool until the end of their second year. Year 1 scallops contain about 500 000 eggs, whereas year 4 and 5 scallops can contain over 40 million. Scallop veliger larvae spend about three weeks in the plankton. They then attach to algae or some other filamentous material with fine byssus threads. When the spat reach about 5 mm they detach and take up the free-living habit of adults, usually lying in depressions on the seabed and often covered by a layer of silt. Although adult scallops can swim, they appear to move very little (based on underwater observations, the recovery of tagged scallops, and the persistence of morphological differences between adjacent sub-populations).

The relatively high fecundity, and likely variability in the mortality of larvae and pre-recruits, could lead to high variability in natural annual recruitment. This variability is a characteristic of scallop populations worldwide.

All references to "shell length" in this report refer to the maximum linear dimension of the shell, in an anterior-posterior axis. Scallops in the outer Pelorus Sound grew to a shell length of about 60 mm in one year, and can reach 100 mm in two years. This is typical of the pattern of growth that occurs under the rotational fishing strategy in Tasman and Golden Bays as well. Growth slows during the winter, and was found to vary between years (it is probably influenced by water temperature, food availability, and scallop density). Growth rings form on the shell during winter, but also at other times, precluding the use of ring counts as accurate indicators of age. Experience with enhanced stocks in Tasman and Golden Bay has indicated that scallops generally attain a shell length of 90 mm in just under two years, although, in conditions where food is limiting, almost three years may be required to reach this size.

From studies of the ratio of live to dead scallops and the breakdown of the shell hinge in dead scallops, Bull (1976) estimated the annual natural mortality rate for two populations of adult scallops in the Marlborough Sounds (Forsyth Bay and North West Bay in Pelorus Sound) to be 23% (M = 0.26) and 39% (M = 0.49). From a tagging study conducted in Golden and Tasman Bays from 1991 to 1992, Bull & Drummond (1994) estimated the mortality of 0+ and 1+ scallops to be about 38% (M = 0.21) per year, and the mortality of 2+ scallops to be 66% (M = 0.46). These studies suggest that average natural mortality in the Challenger fishery is quite high (Table 5), and most previous stock assessments have assumed $M = 0.5\ y^{-1}$ (instantaneous rate). Incidences of large-scale die-off in localised areas have been observed (e.g., mortality associated with storms in 1998).

Table 5: Estimates of biological parameters

		Estimates	Source
1. Natural mortality, M		M	
Pelorus Sound		0.26, 0.49	Bull (1976)
Golden & Tasman Bays		0+ & 1+, 0.21	Bull & Drummond (1994)
Golden & Tasman Bays		2+, 0.46	Bull & Drummond (1994)
2. Growth			
Age-length relationship	Age (y)	SL (mm)	
Pelorus Sound	1	60	Bull (1976)
Pelorus Sound	2	97	Bull (1976)
Pelorus Sound	3	105	Bull (1976)
Pelorus Sound	4	111	Bull (1976)
von Bertalanffy parameters	L_∞	K	
	144	0.40	Data of Bull (1976), analysed by Breen (1995)

3. STOCKS AND AREAS

Scallops inhabit waters of up to about 60 m deep (apparently up to 85 m at the Chatham Islands), but are more common in depths of 10 to 50 m on substrates of shell gravel, sand or, in some cases, silt. Scallops are typically patchily distributed at a range of spatial scales; some of the beds are persistent and others are ephemeral. The extent to which the various beds or populations are reproductively or functionally separate is not known. Whether or not scallops in Tasman Bay and Golden Bay constituted a single genetic stock before enhancement began, is unknown. Enhancement in the Marlborough Sounds has been limited, but could have contributed towards homogenising stocks. Water movements eastward through Cook Strait could have enabled a degree of genetic mixing between Tasman/Golden Bay and Marlborough Sounds stocks before any enhancement began. It is currently assumed for management that the SCA 7 stock is made up of three individual substocks (Golden Bay, Tasman Bay, and Marlborough Sounds) that are separate from the Northland and Coromandel stocks and from the various west coast harbours, Stewart Island and Chatham Island areas.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

Scallop abundance and biomass in the main commercial scallop beds in the Challenger fishery have been estimated annually since 1994 using a two-phase stratified random dredge survey (Table 6), although no second-phase sampling has been conducted in the 2009–14 surveys. In 2013 only the Marlborough Sounds region was surveyed but all three regions (Golden Bay, Tasman Bay and Marlborough Sounds) were surveyed in 2014. Surveys since 1998 are essentially comparable, in that they used the same fishing gear and covered quite similar areas. Earlier surveys covered smaller areas, although these would generally have included the areas of main recruited scallop densities.

Surveys up to 1995 used the “MAF” dredge, while from 1997 the “CSEC” dredge was used. In 1996, both dredges were used, with data from the CSEC dredge being used for the biomass analysis. The efficiencies of the two dredges at a single site in each of Golden Bay, Tasman Bay, and the Marlborough Sounds were not significantly different. The mean efficiency at these sites (based on a comparison of diver and dredge transects) were 0.58, 0.66, and 0.85, respectively.

The estimated efficiency of the ring-bag dredge used in the SCA 7 survey is based on limited data from two studies (Cranfield et al. 1996, Handley et al. 2004), which we assume are representative of the average efficiency of the dredge for all areas of the stock. Using these data, a non-parametric resampling with replacement (bootstrapping) method was used by Tuck & Brown (2008) to estimate dredge efficiency for SCA 7, and that method has been applied in the workup of SCA 7 survey data since 2008. This ‘bootstrapping’ method, that better accounts for uncertainty in the biomass, abundance estimates, was originally developed and used by Cryer & Parkinson (2006) to estimate dredge efficiency for SCA 1 and SCA CS, but has been shown to result in a positive bias on the estimated biomass relative to a preferred model-based method of estimating dredge efficiency (Bian et al. 2012). The bootstrapping method was used in the current SCA 7 survey analysis because it was considered there are too few data to apply the model-based method.

To examine the potential difference in dredge efficiency estimated by the two different approaches (bootstrapping versus the model-based), comparisons were made of the dredge efficiency curves generated by each approach. The curves estimated the dredge efficiency of box dredges used on silt substrates at 20 m depth in SCA CS (i.e. for conditions thought to be the most similar to those in the Marlborough Sounds beds) for scallops of different lengths. For the 90–100 mm length range (that is most influential on the estimated biomass), preliminary estimates of dredge efficiency from the bootstrapping method were 20% lower than those estimated by the model-based method. Potential underestimation of dredge efficiency by 20% using the bootstrapping method would result in a 20% positive bias on the SCA 7 biomass estimates. Adjusting for this potential bias would reduce the Marlborough Sounds 2014 start of season biomass estimate from 125 t (‘standard estimate’) to 100 t (‘adjusted estimate’).

Table 6 shows the absolute estimates and CVs, from dredge surveys, of recruited numbers, greenweight and meatweight of scallops 90mm or more in shell length in Golden and Tasman Bays and the Marlborough Sounds. These estimates are calculated using dredge efficiency that is calculated using the bootstrapping method mentioned above and are “time of survey” estimates. All data prior to 2008, the data when the bootstrapping method superseded the previous simple scalar approach, have been reanalysed using dredge efficiency calculated using the bootstrapping method as described by Tuck & Brown (2008). The estimates use a recruit size of ≥ 90 mm (the commercial size limit) up to 1995. A yield per recruit analysis in 1995 indicated that 89 mm was the optimal harvest size, so from 1996 to 2000, recruit estimates were calculated using 89mm (although harvesters and processors continued to take only scallops ≥ 90 mm, the minimum legal size). From 2001 onwards a recruit size of ≥ 90 mm was again used.

Table 6: Absolute estimates and CVs of recruited numbers of scallops 90 mm or more shell length (RecN, millions), recruited greenweight (RecG, t), and recruited meatweight (MtWt, t) in Golden Bay, Tasman Bay, the Marlborough Sounds, and for the SCA 7 fishery total, from dredge surveys in May-June of each year. Golden Bay and Tasman Bay were not surveyed in 2013. Values in this table were derived by reanalysing the historical survey data using a revised analytical procedure described by Tuck & Brown (2008) to better account for uncertainty in the time of survey biomass estimates. These estimates do not include Croisilles Harbour in Tasman Bay. – value not estimated. [Figure continued on next page].

Year						Golden Bay
	RecN	RecN CV	RecG	RecG CV	MtWt	MtWt CV
1997	40.1	0.24	3 471	0.25	437	0.29
1998	55.7	0.18	4 605	0.19	584	0.24
1999	60.4	0.20	5 323	0.20	673	0.25
2000	87.8	0.18	6 896	0.18	872	0.24
2001	151.5	0.22	11 510	0.21	1 456	0.26
2002	106.6	0.18	8 326	0.18	1 053	0.24
2003	28.9	0.18	2 269	0.17	287	0.23
2004	5.6	0.20	432	0.20	55	0.25
2005	10.9	0.20	871	0.20	110	0.25
2006	10.3	0.20	858	0.20	109	0.25
2007	55.6	0.20	4 411	0.20	557	0.24
2008	27.0	0.20	2 198	0.20	278	0.25
2009	13.6	0.23	1061	0.23	146	0.23
2010	6.5	0.25	510	0.24	–	–
2011	1.5	0.35	120	0.36	–	–
2012	0.8	0.42	64	0.42	–	–
2013					–	–
2014	2.9	0.26	252	0.26	–	–

Year						Tasman Bay
	RecN	RecN CV	RecG	RecG CV	MtWt	MtWt CV
1997	3.1	0.25	245	0.25	31	0.29
1998	66.2	0.19	5 108	0.18	645	0.23
1999	55.3	0.21	4 724	0.21	602	0.27
2000	36.3	0.18	3 027	0.18	386	0.23
2001	37.8	0.18	2 977	0.18	378	0.23
2002	55.3	0.18	4 272	0.18	544	0.23
2003	67.9	0.18	5 192	0.18	661	0.23
2004	31.8	0.18	2 386	0.18	304	0.24
2005	13.1	0.19	1 012	0.19	129	0.23
2006	2.4	0.19	186	0.19	24	0.23
2007	1.6	0.22	131	0.22	17	0.27
2008	0.8	0.32	58	0.32	7	0.35
2009	1.1	0.32	88	0.31	11	0.31
2010	1.6	0.26	125	0.26	–	–
2011	0.7	0.36	63	0.36	–	–
2012	0.5	0.39	42	0.40	–	–
2013					–	–
2014	3.6	0.30	304	0.28	–	–

For comparability with previous years, the 2012 estimates do not include the 2012 survey strata 8 or 19 in the previously unsurveyed outer (deeper) region of Golden and Tasman Bays.

Table 6 [Continued]: Absolute estimates and CVs of recruited numbers of scallops 90 mm or more shell length (RecN, millions), recruited greenweight (RecG, t), and recruited meatweight (MtWt, t) in Golden Bay, Tasman Bay, the Marlborough Sounds, and for the SCA 7 fishery total, from dredge surveys in May-June of each year. Values in this table were derived by reanalysing the historical survey data using a revised analytical procedure described by Tuck & Brown (2008) to better account for uncertainty in the time of survey biomass estimates. These estimates do not include Croisilles Harbour in Tasman Bay. – value not estimated.

Year	Marlborough Sounds					
	RecN	RecN CV	RecG	RecG CV	MtWt	MtWt CV
1997	9.0	0.23	781	0.24	99	0.29
1998	20.8	0.25	1 731	0.25	220	0.29
1999	11.6	0.18	969	0.19	123	0.23
2000	11.4	0.19	962	0.19	122	0.24
2001	14.0	0.20	1 124	0.20	143	0.24
2002	24.8	0.21	2 048	0.22	260	0.26
2003	16.6	0.21	1 325	0.21	168	0.26
2004	14.5	0.19	1 120	0.19	142	0.24
2005	21.6	0.20	1 690	0.20	214	0.25
2006	13.6	0.22	1 041	0.22	132	0.27
2007	16.7	0.23	1 326	0.23	169	0.28
2008	19.8	0.21	1 611	0.21	205	0.26
2009	28.6	0.23	2 321	0.24	281	0.24
2010	19.8	0.19	1 606	0.19	–	–
2011	19.1	0.20	1 615	0.21	–	–
2012	10.1	0.21	885	0.22	–	–
2013	15.6	0.20	1265	0.21	–	–
2014	10.9	0.20	886	0.21	–	–

Year	SCA 7 fishery total					
	RecN	RecN CV	RecG	RecG CV	MtWt	MtWt CV
1997	52.1	0.22	4 497	0.23	568	0.26
1998	142.7	0.17	11 444	0.18	1 450	0.20
1999	127.2	0.18	11 016	0.19	1 399	0.21
2000	135.5	0.17	10 885	0.17	1 380	0.20
2001	203.3	0.20	15 611	0.19	1 977	0.22
2002	186.7	0.17	14 646	0.18	1 857	0.20
2003	113.3	0.17	8 786	0.17	1 116	0.19
2004	51.9	0.17	3 937	0.17	501	0.20
2005	45.7	0.18	3 574	0.18	453	0.20
2006	26.3	0.19	2 085	0.19	264	0.22
2007	74.0	0.19	5 868	0.19	742	0.22
2008	47.6	0.19	3 867	0.19	490	0.22
2009	43.4	0.19	3 489	0.19	444	0.19
2010	27.9	0.18	2 254	0.18	–	–
2011	21.3	0.20	1 796	0.20	–	–
2012	11.5	0.20	1 006	0.21	–	–
2013	15.6	0.20	1265	0.21	–	–
2014	17.4	0.20	1439	0.20	–	–

For comparability with previous years, the 2012 estimates do not include the 2012 survey strata 8 or 19 in the previously unsurveyed deeper region of Golden and Tasman Bays.

This fishery operates with a feedback loop that checks the reliability of the biomass survey. At the end of each commercial season, landings from each sector fished are compared with the survey biomass estimates for the sector.

4.2 Biomass estimates

Virgin biomass, B_0, and the biomass that will support the maximum sustainable yield, B_{MSY}, have not been estimated and are probably not appropriate reference points for a stock with highly variable recruitment and growth such as scallops.

Start of season (nominally 1 September) absolute recruited biomass is estimated each year from a pre-season dredge survey, which is usually conducted in May. Estimates were derived by reanalysing the historical survey data using dredge efficiency calculated using the bootstrapping method as described by Tuck & Brown (2008) to better account for uncertainty in the start of season biomass estimates (Table 7). In 2013 the Golden Bay and Tasman Bay regions were not surveyed.

Table 7: Projected recruited biomass (and c.v.) of scallops (90 mm or longer shell length) at the nominal start of season (1 September) in the survey years, 1997 to present. Golden Bay and Tasman Bay were not surveyed in 2013. Estimates were derived using the revised analytical procedure described by Tuck & Brown (2008). For each year, the catch (reported on the 'Landed' section of CELRs) and exploitation rate (catch to recruited biomass ratio) are also given. Biomass and catch are in t meatweight.

Year	Golden Bay				Tasman Bay			
	Biomass	c.v.	Catch	Catch/Biomass	Biomass	c.v.	Catch	Catch/Biomass
1997	432	0.26	239	0.55	38	0.27	2	0.05
1998	659	0.22	353	0.54	847	0.25	78	0.09
1999	642	0.24	514	0.80	626	0.25	155	0.25
2000	1236	0.21	303	0.25	606	0.23	19	0.03
2001	1640	0.24	660	0.40	945	0.25	32	0.03
2002	1186	0.22	370	0.31	1225	0.25	39	0.03
2003	354	0.22	28	0.08	1110	0.24	107	0.10
2004	79	0.23	20	0.25	468	0.22	47	0.10
2005	132	0.21	35	0.27	169	0.21	5	0.03
2006	265	0.25	26	0.10	43	0.24	0	0.00
2007	636	0.23	128	0.20	32	0.28	0	0.00
2008	313	0.22	76	0.24	15	0.31	0	0.00
2009	278	0.21	19	0.07	14	0.31	0	0.00
2010	78	0.27	10	0.13	15	0.27	0	0.00
2011	20	0.3	1	0.05	8	0.36	0	0.00
2012	9	0.39	0.2	0.02	5	0.42	0	0.00
2013			0	0.00			0	0.00
2014	33.4	0.25	0	0.00	37.3	0.28	0	0.00

Year	Marl. Sounds				SCA 7 Total			
	Biomass	c.v.	Catch	Catch/Biomass	Biomass	c.v.	Catch	Catch/Biomass
1997	98	0.26	58	0.59	572	0.20	299	0.52
1998	228	0.29	117	0.51	1737	0.17	548	0.32
1999	132	0.24	7	0.05	1404	0.19	676	0.48
2000	143	0.22	16	0.11	1969	0.17	338	0.17
2001	185	0.23	25	0.14	2798	0.18	717	0.26
2002	378	0.24	62	0.16	2787	0.18	471	0.17
2003	232	0.24	71	0.31	1692	0.18	206	0.12
2004	246	0.24	51	0.21	797	0.17	118	0.15
2005	370	0.25	116	0.31	675	0.18	157	0.23
2006	272	0.26	43	0.16	580	0.21	68	0.12
2007	273	0.27	6	0.02	940	0.19	134	0.14
2008	270	0.23	28	0.10	597	0.18	104	0.17
2009	396	0.22	101	0.26	690	0.18	120	0.17
2010	228	0.19	74	0.32	321	0.19	85	0.26
2011	221	0.19	60	0.27	248	0.18	61	0.25
2012	120	0.22	48	0.40	131	0.21	48	0.37
2013	184	0.19	43	0.23	184	0.19	43	0.23
2014	125	0.20	22	0.18	196	0.19	22	0.11

For comparability with previous years, the 2012 estimates do not include the 2012 survey strata 8 or 19 in the previously unsurveyed outer (deeper) region of Golden and Tasman Bays, nor stratum 16 (Croisilles Harbour)

In addition to estimates of absolute biomass, the biomass at different commercial threshold ('critical') densities (in the range 0–0.2 scallops m^{-2}) is also estimated each year.

Figure 2 shows the trends in estimated recruited biomass, plotted by region and for the overall SCA7 stock, since 1998. In Golden Bay, biomass increased from 1999 to reach a peak in 2001, but rapidly decreased to 2004; biomass increased again to reach a second, smaller peak in 2007, but subsequently decreased and has remained at very low levels from 2011 to 2014. In Tasman Bay there was a similar large increase and decrease in biomass that occurred with slightly later timing: biomass increased in Tasman Bay from 2000 to reach a peak in 2002–03, but subsequently decreased and remained at very low levels from 2006 to 2014. In Marlborough Sounds, biomass generally followed an increasing trend from 1999 to 2009 (albeit with evidence of a peak in 2002), and a decreasing trend from 2009 to 2014.

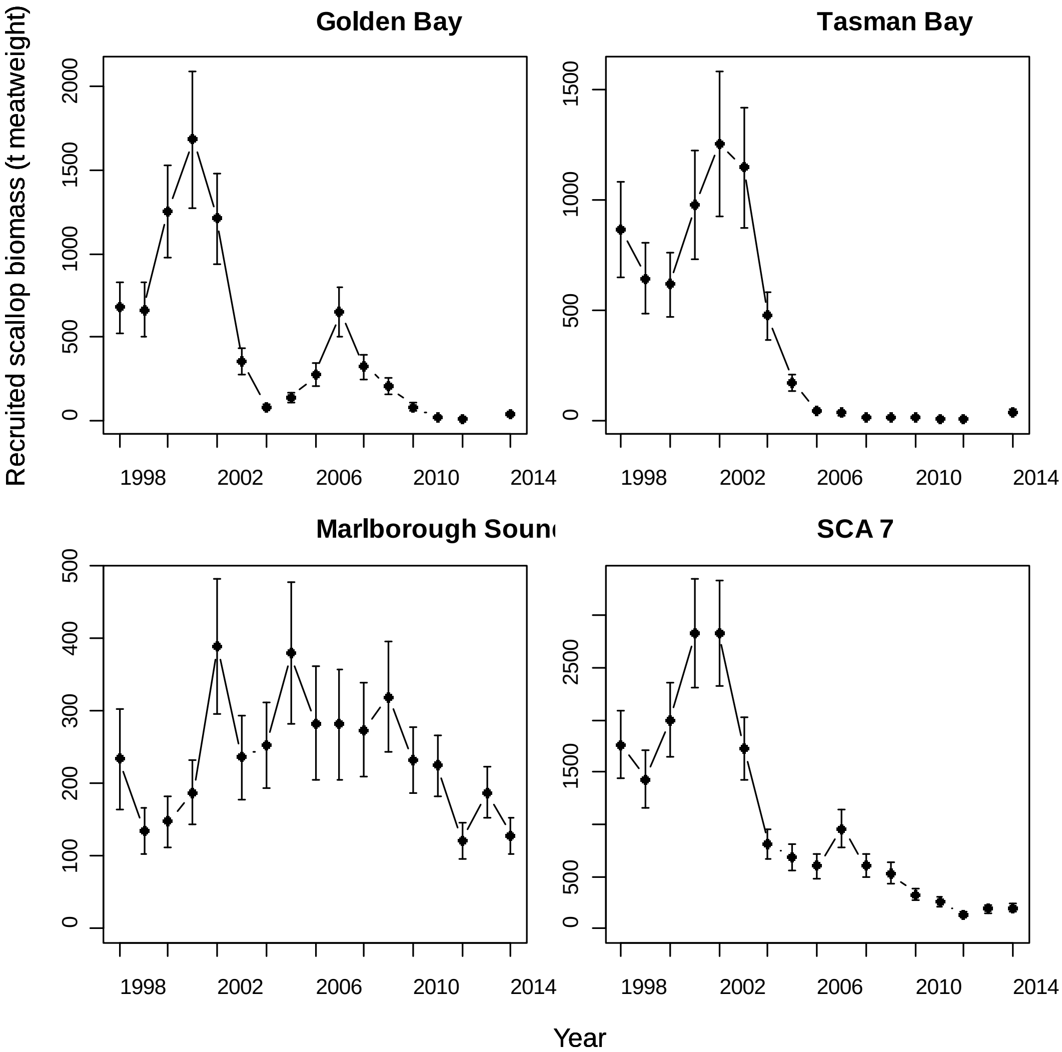


Figure 2: Trends in start of season recruited scallop biomass (t meatweight) by region and for the total SCA 7 stock, 1998–2014. Values are the estimated mean and CV of the projected recruited biomass. Note: Golden and Tasman Bays were not surveyed in 2013

4.3 Yield estimates and projections

MCY has not been estimated for SCA 7 scallops because it is not thought to be a reasonable management approach for highly fluctuating stocks such as scallops. Catch limits for Golden/Tasman Bays are based on direct results from the biomass surveys and the actual commercial catch is set by CSEC each year within the TACC limits (subject to approval by the Minister).

For the Marlborough Sounds, where there is no enhancement or rotational fishing plan catch limits are set based on estimates of Current Annual Yield calculated from the biomass survey results. In 2014 an alternative yield was also estimated by applying a target exploitation rate of 22% to the projected biomass.CAY was calculated using Method 1(Ministry for Primary Industries 2012):

$$CAY = \left(1 - e^{-(F_{ref})}\right) B_{beg}$$

where B_{beg} is the projected (i.e., 1 September) recruited meatweight biomass estimate and F_{ref} is $F_{0.1}$. This equation is appropriate where fishing occurs over a short period of the year.

The projected absolute recruited biomass estimate for the Marlborough Sounds at the start of the 2014 season (nominally 1 September) was an estimated 125 t meatweight (standard estimate) with a CV of 20% (Williams & Bian 2012). In 2014 research was undertaken to determine if, when using the bootstrapping approach to estimate dredge efficiency, there was the potential for any bias to occur in the dredge efficiency estimates. The research suggested there is a potential to underestimate the dredge efficiency by 20%. This underestimation would result in a positive bias of 20% in the estimates of biomass. Adjusting for this potential 20% bias reduces the 2014 start of season biomass estimates for the Marlborough Sounds, from 125t to 100t (adjusted estimate). Using the standard and adjusted biomass estimates and the reference points $F_{0.1}$ of 0.553 (assumed M = 0.4) and $F_{0.1}$ of 0.63 (assumed M = 0.5) the following CAY estimates (in tonnes meatweight) were calculated for SCA 7:

		$F_{0.1}$ = 0.55	$F_{0.1}$ = 0.63	E=0.22	
B_{beg} =	125 t	53t	58t	27t	Standard estimate
B_{beg} =	100t	42t	47t	22t	Adjusted estimate

These estimates of CAY would have a CV at least as large as that of the estimate of start-of-season recruited biomass, are sensitive to assumptions about dredge efficiency, growth, expected recovery of meatweight from greenweight, and relate to the surveyed beds only. The level of risk to the putative Marlborough Sounds scallop substock of fishing at the estimated CAY level has not been determined.

Due to uncertainty in the reliability of the $F_{0.1}$ values used to esimate CAY, the Shellfish Working Group (2014) recommended using an annual exploitation rate to estimate appropriate yield for the Marlborough Sounds stocks. An empirical exploitation rate of 22% of the biomass was recommended based on an analysis of the biomass trends relative to rates of exploitation in the Marlborough Sounds, over the last 14 years. The analysis suggested that during the period of increasing biomass, from 1999 to 2008, exploitation rate was on average at a level of 22%. However, during the period 2009-2014, when biomass was observed to be declining, the exploitation rate was higher at an average of 31% (Figure 3). This suggested that, at the broad spatial scale of the 7KK-7LL sectors combined, fishing at an exploitation rate of 22% tends to result in increasing biomass (avoids biomass declines). This approach of determining an appropriate target reference point for the fishery as the exploitation rate that avoids biomass declines is used in scallop fisheries in Atlantic Canada (Smith & Hubley 2012). Expressing each of the two estimates of CAY, derived from using F_{ref} = 0.55 or 0.63, as a proportion of the recruited scallop biomass equates to ‘target’ fishery removal exploitation rates (*E*, catch divided by recruited biomass) of E = 0.42 and 0.47, respectively

The estimate of yield, using an exploitation rate of 22%, is 27t and 22t for the Standard and Adjusted estimates of biomass respectively. More conservative yield estimates when compared to estimates using the CAY approach.

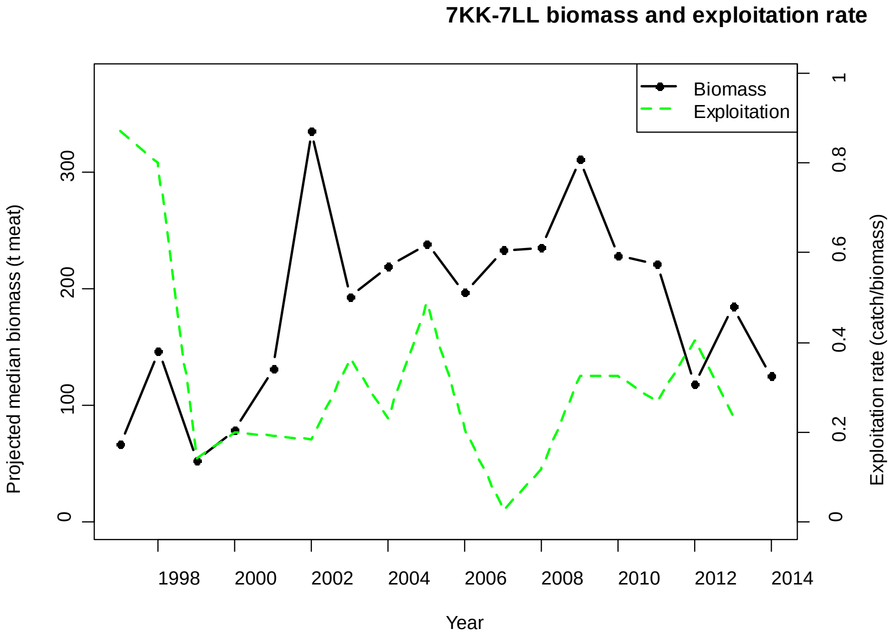


Figure 3: Trends in biomass and exploitation rate for the combined areas surveyed in sectors 7KK and 7LL in the Marlborough Sounds, 1997-2014.

4.4 Other yield estimates and stock assessment results

A simulation modelling study of the Challenger scallop fishery examined the effects of catch limits, exploitation rate limits, rotational fishing, and enhancement (Breen & Kendrick 1997). The results suggested that constant catch strategies are not safe, but constant exploitation rate strategies are safe, if the maximum rate is appropriate. Rotational fishing appears to be highly stabilising, even without enhancement; collapses occurred only when the short rotational periods are combined with high intensity. Three-year rotation appears to be safer than two-year rotation. Enhancement appears to improve safety, catch, and biomass, and slightly reduces the population variability. The conclusions from this study underpinned the agreed rotational and enhancement management framework for the fishery. However, the theory of rotational fishing assumes that scallops, and habitats important for scallops, are distributed approximately evenly among the areas (sectors) to be fished rotationally; this is probably an invalid assumption for the SCA 7 fishery sectors.

$F_{0.1}$ was estimated for the Challenger fishery from a yield per recruit analysis using a size at recruitment of 90 mm and assumed values of M of 0.40 and 0.50 (Breen & Kendrick 1999). $F_{0.1}$ was 0.553 and 0.631, respectively[1]. For similar values of minimum size and natural mortality, Cryer (1999) estimated $F_{0.1}$ to be 0.469 and 0.508 in the northern scallop fishery. Consequently, $F_{0.1}$ for the Challenger fishery is assumed to be in the range 0.47 to 0.63[2].

Scallop meatweight recovery (meatweight divided by greenweight) is variable among areas, years, and weeks within the fishing season but in general appears to be highest from scallops in parts of Golden Bay (e.g., sector A) and lowest from those in Tasman Bay (e.g., sector D). Using data on the commercial landings of recruited scallops in the period 1996–2008, the mean annual meatweight recovery was 13.8% for Golden Bay, 11.8% for Tasman Bay, and 13.2% for the Marlborough Sounds. An analysis of meatweight recovery data at the time of the survey and during the fishing season for the years 1996–2007 showed meatweight recovery measured at the time of the survey could not be used to predict meatweight recovery during the fishing season.

[1] The F values reported by Breen & Kendrick (1999) are instantaneous Fs.

[2] The F values reported by Cryer (1999) are not instantaneous Fs.

5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This is a new section that was reviewed by the Aquatic Environment Working Group for the November 2013 Fishery Assessment Plenary. A broader summary of information on a range of issues related to the environmental effects of fishing and aspects of the marine environment and biodiversity of relevance to fish and fisheries is available in the Aquatic Environment & Biodiversity Annual Review (http://www.mpi.govt.nz/Default.aspx?TabId=126&id=2122) (Ministry for Primary Industries 2013).

5.1 Role in the ecosystem

Scallops (*Pecten novaezelandiae*) are subtidal, benthic, epifaunal, sedentary, bivalve molluscs, which have a pelagic larval dispersal phase. They are found patchily distributed at a range of scales in particular soft sediment habitats in inshore waters of depths generally to 50 m and exceptionally up to 85 m. They exhibit relatively fast growth, high mortality, and variable recruitment. The rates of these processes probably vary in relation to environmental conditions (e.g., temperature, water flow, turbidity, salinity), ecological resources (e.g., food, oxygen, habitat), and with intra- and inter-specific interactions (e.g., competition, predation, parasitism, mutualism), and the combination of these factors determines the species distribution and abundance (Begon et al 1990). Scallops are considered to be a key component of the inshore coastal ecosystem, acting both as consumers of primary producers and as prey for many predators; the scallops themselves can also provide structural habitat for other epifauna (e.g., sponges, ascidians, algae).

5.1.1 Trophic interactions

Scallops are active suspension feeders, consuming phytoplankton and other suspended material (benthic microalgae and detritus) as their food source (Macdonald et al 2006). Their diet is the same as, or similar to, that of many other suspension-feeding taxa, including other bivalves such as oysters, clams, and mussels.

Scallops are prey to a range of invertebrate and fish predators, whose dominance varies spatially. Across all areas, reported invertebrate predators of scallops include starfish (*Astropecten polyacanthus*, *Coscinasterias calamaria*, *Luidia varia*), octopus (*Pinnoctopus cordiformis*), and hermit crabs (*Pagurus novaezelandiae*), and suspected invertebrate predators include various carnivorous gastropods (e.g., *Cominella adspersa* and *Alcithoe arabica*); reported fish predators of scallops include snapper (*Pagrus auratus*), tarakihi (*Nemadactylus macropterus*), and blue cod (*Parapercis colias*), and suspected fish predators include eagle rays (*Myliobatis tenuicaudatus*) and stingrays (*Dasyatis* sp.) (Morton & Miller 1968, Bull 1976, Morrison 1998, Nesbit 1999). Predation varies with scallop size, with small scallops being generally more susceptible to a larger range of predators.

5.2 Incidental catch (fish and invertebrates)

A range of non-target fish and invertebrate species are caught and discarded by dredge fisheries for *P. novaezelandiae* scallops. No data are available on the level or effect of this incidental catch (bycatch) and discarding by the fisheries. Bycatch data are available, however, from various dredge surveys of the scallop stocks, and the bycatch of the fisheries is likely to be similar to that of the survey tows conducted in areas that support commercial fishing.

Species or groups that have been caught as incidental catch in the box dredges and ring-bag dredges used in surveys of commercial scallop (*P. novaezelandiae*) fishery areas in New Zealand are shown in Table 8. Catch composition varies among the different fishery locations and through time.

In the Coromandel scallop stock (SCACS), a photographic approach was used in the 2006 dredge survey to provisionally examine bycatch groups (Tuck et al 2006), but a more quantitative and comprehensive study was conducted using bycatch data collected in the 2009 dredge survey

(Williams et al 2010), with survey catches quantified by volume of different component categories. Over the whole 2009 survey, scallops formed the largest live component of the total catch volume (26%), followed by assorted seaweed (11%), starfish (4%), other live bivalves (4%), coralline turfing algae (1%) plus other live components not exceeding 0.5%. Dead shell (identifiable and hash) formed the largest overall component (45%), and rock, sand, and gravel formed 8%. Categories considered to be sensitive to dredging were caught relatively rarely. Data on the bycatch of the 2010 and 2012 surveys of SCA CS were also collected but not analysed; those data have been loaded to the MPI database 'scallop' for potential future analysis (Williams & Parkinson 2010, Williams et al 2013b).

In the Northland scallop stock (SCA 1), analysis of historical survey bycatch from a localised deep area within Spirits Bay showed an unusually high abundance and species richness of sponges (Cryer et al 2000), and led to the voluntary and subsequent regulated closure of that area to commercial fishing.

In the Southern scallop stock (SCA 7), data on the bycatch of the 1994–2013 surveys have been collected but not analysed, except for preliminary estimation of the 1998–2013 bycatch trajectories (Williams et al 2013a).

Table 8: Species or groups categorised by bycatch type caught as incidental catch in dredge surveys of commercial scallop (*P. novaezelandiae*) fishery areas in New Zealand.

Type	Species or groups
habitat formers	sponges, tubeworms, coralline algae (turf, maerl), bryozoa
starfish	*Astropecten*, *Coscinasterias*, cushion stars, carpet stars
bivalves	dog cockles, horse mussels, oysters, green-lipped mussels, *Tawera*
other invertebrates	anemones, crabs, gastropods, polychaetes, octopus, rock lobster
fish	gobie, gurnard, John dory, lemon sole, pufferfish, red cod, sand eel, snake eel, stargazer, yellowbelly flounder
seaweed	*Ecklonia,* other brown algae, green algae, red algae
shell	whole shells, shell hash
substrate	mud, sand, gravel, rock
other	Rubbish

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

There is no known bycatch of seabirds, mammals or protected fish species from *P. novaezelandiae* scallop fisheries.

5.4 Benthic interactions

It is well known that fishing with mobile bottom contact gears such as dredges has impacts on benthic populations, communities, and their habitats (e.g., see Kaiser et al 2006, Rice 2006). The effects are not uniform, but depend on at least: "the specific features of the seafloor habitats, including the natural disturbance regime; the species present; the type of gear used, the methods and timing of deployment of the gear, and the frequency with which a site is impacted by specific gears; and the history of human activities, especially past fishing, in the area of concern" (Department of Fisheries and Oceans 2006). The effects of scallop dredging on the benthos are relatively well-studied, and include several New Zealand studies carried out in areas of the northern fisheries (SCA 1 and SCA CS) (Thrush et al 1995, Thrush et al 1998, Cryer et al 2000, Tuck et al 2009, Tuck & Hewitt 2012) and the Golden/Tasman Bay region of the southern (SCA 7) fishery (Tuck et al 2011). The results of these studies are summarised in the Aquatic Environment & Biodiversity Annual Review (Ministry for Primary Industries 2012), and are consistent with the global literature: generally, with increasing fishing intensity there are decreases in the density and diversity of benthic communities and, especially, the density of emergent epifauna that provide structured habitat for other fauna.

5.5 Other considerations

5.5.1 Spawning disruption

Scallop spawning occurs mainly during spring and summer (Bull 1976, Williams & Babcock 2004). Scallop fishing also occurs during these seasons, and is particularly targeted in areas with scallops in good condition (reproductively mature adults ready to spawn). Fishing also concentrates on high density beds of scallops, which are disproportionately more important for fertilisation success during spawning (Williams 2005). Fishing, therefore, may disrupt spawning by physically disturbing scallops that are either caught and retained (removal), caught and released, not caught but directly contacted by the dredge, or not caught but indirectly affected by the effects of dredging (e.g., suspended sediments).

5.5.2 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 2012) although work is currently underway to define one. Certain features of the habitats which scallops are associated with are known to influence scallop productivity by affecting the recruitment, growth and mortality of scallops, and therefore may in the future be useful in terms of identifying HPSFM. Scallop larval settlement requires the presence of fine filamentous emergent epifauna on the seabed, such as tubeworms, hydroids, and filamentous algae, hence the successful use of synthetic mesh spatbags held in the water column as a method for collecting scallop spat. Survival of juveniles has been shown to vary with habitat complexity, being greater in more complex habitats (with more emergent epifauna) than in more homogeneous areas (Talman et al 2004). The availability of suspended microalgae and detritus affects growth and condition (Macdonald et al 2006). Suspended sediments can reduce rates of respiration and growth, the latter by ‘diluting’ the food available; scallops regulate ingestion by reducing clearance rates rather than increasing pseudofaeces production. Laboratory studies have demonstrated that suspended sediments disrupt feeding, decrease growth and increase mortality in scallops (Stevens 1987, Cranford & Gordon 1992, Nicholls et al 2003).

6. STATUS OF THE STOCKS

Stock Structure Assumptions

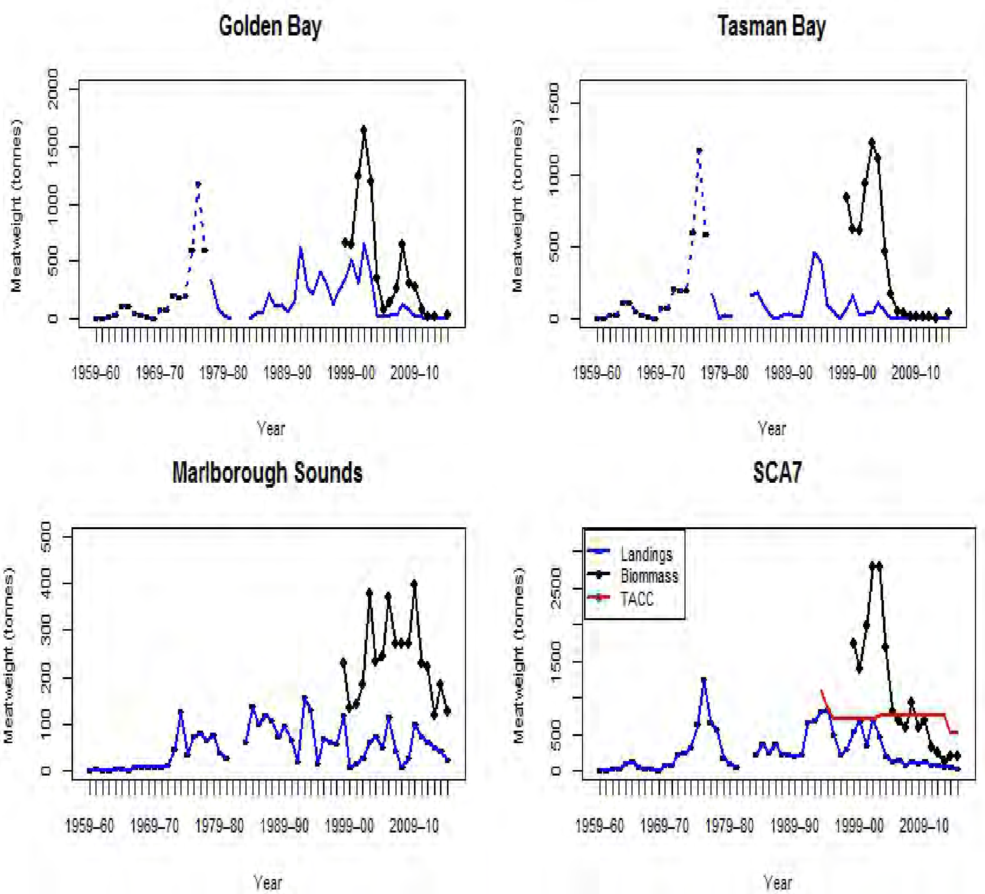
The stock structure of scallops in New Zealand waters is uncertain. For the purposes of this assessment and due to the different management regimes, Golden Bay, Tasman Bay and Marlborough Sounds are assumed to be individual and separate substocks of SCA 7.

- **Challenger scallops, SCA 7**

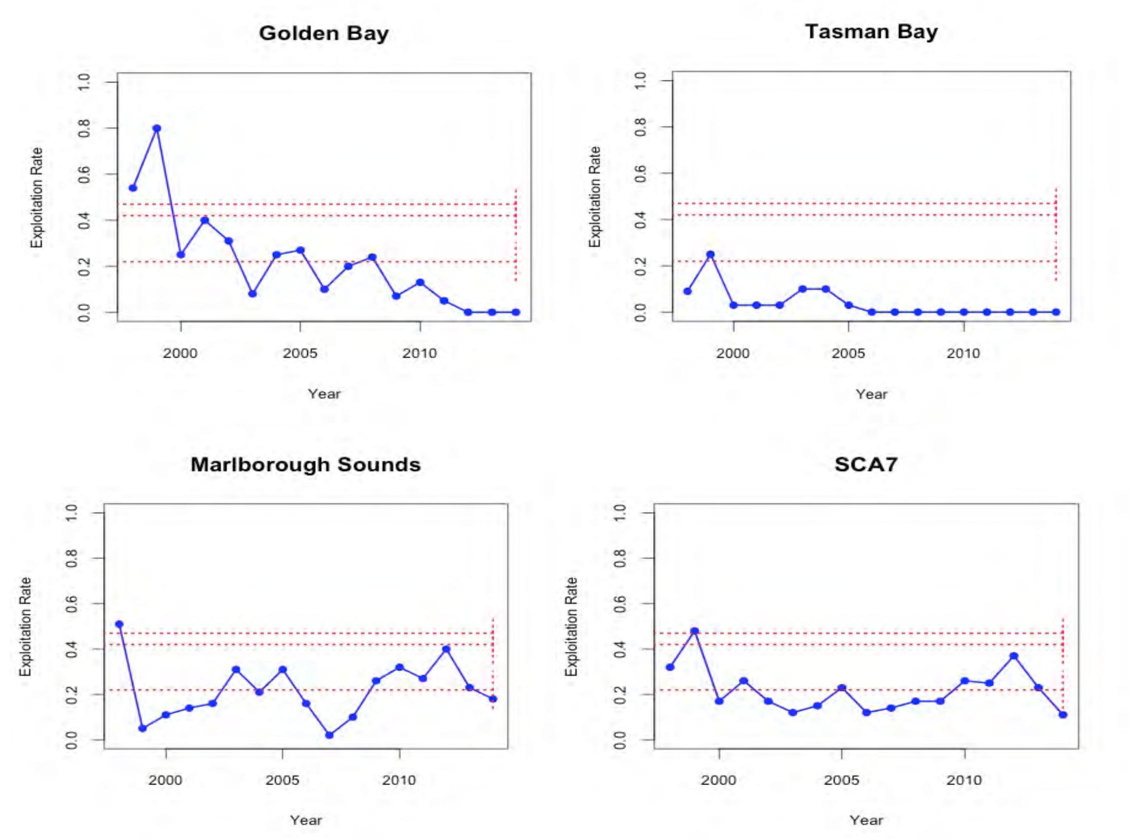
Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Marlborough Sounds: CAY estimated using two approaches. Yield also estimated using an agreed exploitation rate of 22%. Golden Bay and Tasman Bay: Estimates of biomass
Reference Points	Marlborough Sounds Target: Fishing mortality at or below $F_{0.1}$ ($F_{0.1}$ = 0.553 y^{-1} or 0.631 y^{-1} if M = 0.4 and 0.5, respectively) or, at or below an exploitation rate of 22% No targets have been set for Golden Bay or Tasman Bay All Regions: Soft Limit: 20% B_0

	Hard Limit: 10% B_0 Overfishing threshold: F_{MSY} or the equivalent exploitation rate
Status in relation to Target	Marlborough Sounds: About as Likely as Not (40-60%) to be at or below F_{target} Golden/Tasman Bays: Very Unlikely (< 40%) to be at or below F_{target}
Status in relation to Limits	Marlborough Sounds: Unknown Golden/Tasman Bays: Very Likely (> 90%) to be below the soft limit Likely (> 60%) to be below the hard limit
Status in relation to Overfishing	Marlborough Sounds: About as Likely as Not (40-60%) to be occurring Golden Bay and Tasman Bay: Unknown, due to lack of information about recreational catch

Historical Stock Status Trajectory and Current Status



Recruited (scallops 90 mm or more shell length) mean biomass estimates (solid black line), TACC (solid red line), and reported landings (solid blue line) in t meatweight for the three regions of the fishery and the overall SCA 7 stock since 1959 (landings before 1977 from Golden and Tasman Bays were reported as combined values from the two bays, shown as a dotted blue line). Estimates of biomass from surveys before 1998 are not presented because the surveys did not cover the full extent of the SCA 7 fishery. Scale differs between plots. Note the fishery was closed for the 1981–82 and 1982–83 scallop fishing years.



Exploitation rate (catch divided by biomass) trends for recruited scallops by region and for the overall SCA 7 stock (solid blue lines). Horizontal lines show three 'Target' exploitation rates. The lower line is E=0.22. The top and middle lines are exploitation of 0.42 (middle dotted red line) and 0.47 (upper dotted red line) representing two estimates of CAY expressed as proportions of the recruited biomass. The two estimates of CAY were calculated retrospectively for all areas using target fishing mortalities of $F_{0.1}$ = 0.553 and 0.631 based on assumed natural mortality rates of M = 0.4 and M = 0.5, respectively.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Marlborough Sounds: Biomass has being overall been declining since 2009. In 2014 biomass was lower than the 2013 estimate but slightly higher than in 2012. Golden of Tasman Bays: No surveys were conducted in 2013 because of expected low abundance in these regions. In 2014 biomass may have increased slightly from the 2012 estimates. In all three substocks of SCA 7, estimated recruited scallop biomass generally increased from the late 1990s to reach peak levels around 2001–02. Since then there has been an overall decline in biomass in all three regions, with Golden and Tasman Bays at very low levels.
Recent Trend in Fishing Intensity or Proxy	In Golden Bay, the commercial exploitation rate (catch to biomass ratio) on scallops 90 mm or more was high in the period 1998–99 (54–80%), followed by a decreasing trend with fluctuation from 2000. In Tasman Bay, the peak commercial exploitation rate in the time series was 25% in 1999, but otherwise has been relatively low. No fishing has occurred in Tasman Bay since 2005. In the Marlborough Sounds, the commercial exploitation rate

	was 51% in 1998 but dropped to 5.5% in 1999, followed by a general increase to reach about 31% in 2005. Exploitation in the Marlborough Sounds subsequently decreased to only 2% in 2007–08, increased to 40% in 2012–13 and dropped to 18% in the 2014-15 fishing year.
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Stock projections are not available. The 2014 survey suggested little sign of juvenile recruitment in Golden or Tasman Bays and a possible slight increase in the number of juveniles in the Marlborough Sounds. The low numbers of pre-recruit scallops (89 mm or smaller) in Golden Bay and Tasman Bay at the time of the 2014 survey suggests recruitment to the fishable biomass in those areas over the next two years is likely to be minimal.
Probability of Current Catch causing Biomass to remain below or to decline below Limits	Unknown for current catch, because recreational catch levels have not been quantified
Probability of TACC causing Biomass to remain below or to decline below Limits	Virtually Certain (> 99%) for the current TACC
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Virtually Certain (> 99%) for the current TACC

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial quantitative stock assessment	
Assessment Method	Biomass surveys and CAY and Exploitation rate management strategy	
Assessment Dates	Latest assessment: 2014	Next assessment: 2015
Overall Assessment Quality Rank	1 – High Quality	
Main data inputs (rank)	Biomass survey: 2014	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	None since the 2008 assessment when the survey workup methodology was revised. CAY model for Marlborough Sounds has been in use since 1997.	
Major Sources of Uncertainty	These include assumptions about: dredge efficiency during the survey, growth rates and natural mortality between the survey and the start of the season, predicting the average recovery of meatweight from greenweight and the extent to which dredging causes incidental mortality and affects recruitment.	
Qualifying Comments		
The extent to which the various beds or populations are reproductively or functionally separate is not known. The Golden Bay and Tasman Bay regions of SCA 7 operate under a fishing plan that involves enhancement and rotational fishing, although these activities have been minimal in recent years. Recent work for MPI includes a review of factors affecting the SCA 7 fishery (Williams et al		

2013), and modelling of the effects of scallop spat enhancement on scallop catches in Golden Bay and Tasman Bay (Tuck & Williams 2012). The cause of the major declines in the scallop populations of Golden Bay and Tasman Bay is unknown, but a comparison of landings in relation to the CAY at the broad scale of the three substocks within SCA 7 suggest the downturn is probably exacerbated by factors other than simply the magnitude of direct removals of scallops by fishing. It has been recognised, however, that the estimates of the target fishing mortality $F_{0.1}$ used to calculate CAY may be too high. Nevertheless, declines in stocks of other shellfish (oysters, mussels) have also been observed. In addition to direct fishing mortality, a combination of other anthropogenic (e.g., land-based influences, indirect effects of fishing) and natural (e.g., oceanographic) drivers may have affected the productivity of the SCA 7 fishery. To address the system complexity, NIWA have been engaging with fishery endusers to inform the development of an ecosystem model, working towards an ecosystem approach to fisheries management (EAFM) for Golden and Tasman Bays, with a view to potentially restoring sustainable fisheries production in the long term. A review of information on drivers of shellfish fisheries production in Golden and Tasman Bays and knowledge gaps was coordinated by NIWA and presented to stakeholder workshops in 2012 and 2013 (NIWA in prep).
Fishery Interactions
Bycatch data are collected routinely during the annual surveys. Bycatch can include dredge oysters, green-lipped mussels, and a range of other benthic invertebrates. The bycatch of the fishery is likely to be similar to that of the survey.

6. FOR FURTHER INFORMATION

Arbuckle, M; Drummond, K (1999). Evolution of self-governance within a harvesting system governed by Individual Transferable Quota. Paper prepared for the FishRights99 Conference. (Unpublished report held by the Ministry for Primary Industries).

Begon, M; Harper, J L; Townsend, C R (1990). Ecology: Individuals, Populations and Communities. Blackwell Science, Cambridge. 945 p.

Boyd, R O; Reilly, J L (2002). 1999/2000 National marine recreational fishing survey: harvest estimates. 84 p. (Unpublished report held by Ministry for Primary Industries, Wellington).

Boyd, R O; Gowing, L; Reilly, J L (2004). 2000-2001 National marine recreational fishing survey: diary results and harvest estimates. 81 p. (Unpublished report held by Ministry for Primary Industries, Wellington).

Bradford, E (1998). Harvest estimates from the 1996 national marine recreational fishing surveys. *New Zealand Fisheries Assessment Research Document* 98/16. 27 p. (Unpublished report by Ministry for Primary Industries, Wellington.)

Breen, P A (1995). Report on the MLS implications for Challenger scallops. 21 p. (Unpublished report held by Ministry for Primary Industries, Wellington).

Breen, P A (2000). Survey of scallops and oysters in Golden Bay, Tasman Bay and the Marlborough Sounds in May-June 2000. Unpublished report prepared for Challenger Scallop Enhancement Co. (NIWA Client Report WLG00/52).

Breen, P A; Kendrick, T H (1997). A model to evaluate fishing strategies for the Challenger scallop fishery. Unpublished report prepared for Challenger Scallop Enhancement Co. (NIWA Client Report WLG97/36).

Breen, P A; Kendrick, T H (1999). Survey of scallops and oysters in Golden Bay, Tasman Bay and the Marlborough Sounds in June 1999. Unpublished report prepared for Challenger Scallop Enhancement Co. by NIWA.

Bull, M F (1976). Aspects of the biology of the New Zealand scallop, *Pecten novaezelandiae* Reeve 1853, in the Marlborough Sounds. Ph.D thesis, Victoria University of Wellington. 175 p.

Bull, M F; Drummond, K L (1994). Report on Tasman Bay and Golden Bay scallop mortality trials. Central Fisheries Region Internal Report No. 24. 17 p. (Unpublished report held by Ministry for Primary Industries.)

Cole, R; Horn, P L; Davey, N; Bradley, A (2006). An estimate of the recreational catch of scallops and dredge oysters in the Golden bay and Tasman bay sections of the Southern Scallop Fishery (SCA 7) for the 2003–04 fishing season. *New Zealand Fisheries Assessment Report 2006/10*. 26 p.

Cranford, P J; Gordon, D C (1992). The influence of dilute clay suspensions on sea scallop (*Placopecten magellanicus*) feeding activity and tissue growth. *Netherlands Journal of Sea Research 30*: 107-120.

Cranfield, J; Michael, K; Doonan, I (1996). Biomass of scallops in Golden Bay, Tasman Bay and the Marlborough Sounds, 1996. Unpublished report prepared for Challenger Scallop Enhancement Co. (NIWA Client Report 1996/14-WN).

Cranfield, J; Michael, K; Doonan, I (1997). Biomass of scallops in Golden Bay, Tasman Bay, and the Marlborough Sounds, 1996. Unpublished report prepared for Challenger Scallop Enhancement Co. (NIWA Client Report WLG97/27).

Cryer, M (1999). Coromandel and Northland scallop stock assessment for 1998. New Zealand Fishery Assessment Research Document 99/37. 14 p. (Unpublished document held by NIWA library, Wellington.)

Cryer, M; O'Shea, S; Gordon, D P; Kelly, M; Drury, J D; Morrison, M A; Hill, A; Saunders, H; Shankar, U; Wilkinson, M; Foster, G (2000). Distribution and structure of benthic invertebrate communities between North Cape and Cape Reinga. Final Research Report by NIWA for Ministry of Fisheries Research Project ENV9805 Objectives 1–4. p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Department of Fisheries and Oceans (2006). Impacts of trawl gear and scallop dredges on benthic habitats, populations and communities. *DFO Canadian Science Advisory Secretariat Science Advisory Report 2006/025*: 13 p.

Doonan, I J; McKoy, J L; Bull, M F; Stead, D H (1985). Scallop surveys in the Nelson and Marlborough regions, 1960–82. N.Z. Fisheries Research Division Occasional Publication: Data Series No. 18.

Drummond, K (1994). Estimates of abundance and yield for the southern scallop fishery in the 1994 season. Unpublished report, MAF Fisheries Central Region, Nelson. (Unpublished report held by Ministry for Primary Industries.)

Horn, P L (2001). Survey of scallops and oysters in Golden Bay, Tasman Bay, and the Marlborough Sounds, in May 2001. Draft N.Z. Fisheries Assessment Report. 32 p. (Unpublished report held by Ministry for Primary Industries.)

Kaiser, M J; Clarke, K R; Hinz, H; Austen, M C V; Somerfield, P J; Karakassis, I (2006). Global analysis of the response and recovery of benthic biota to fishing. *Marine Ecology Progress Series 311*: 1–14.

Macdonald, B A; Bricelj, M; Shumway, S E (2006). Physiology: Energy Aquisition and Utilisation. *In*: Shumway, S.E.; Parsons, G.J. (eds.) Scallops: Biology, Ecology and Aquaculture, pp. 417–492. *Developments in aquaculture and fisheries science*. Elsevier, Amsterdam.

Ministry for Primary Industries (2013). Fisheries Assessment Plenary, May 2013: stock assessments and yield estimates. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1357 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.

Morrison, M.A. (1998). Population dynamics and exploitation of scallops, *Pecten novaezelandiae*, in the Hauraki Gulf. Unpublished PhD thesis. University of Auckland, New Zealand. 157 p.

Morton, J E; Miller, M C (1968). The New Zealand sea shore. Collins, Auckland, New Zealand. 638 p.

Nesbit, G J (1999). Reseeding and hatchery potential of *Pecten novaezelandiae* and effects of recreational harvesting. Unpublished MSc thesis. University of Auckland, New Zealand. 145 p.

Nicholls, P; Hewitt, J; Halliday, J (2003). Effects of suspended sediment concentrations on suspension and deposit feeding marine macrofauna. NIWA Client Report HAM2003-077 prepared for Auckland Regional Council (NIWA Project ARC03267). August. 43 p. ARC Technical Publication No. 211.

Osborne, T A (1998). Biomass of scallops in Golden Bay, Tasman Bay and the Marlborough Sounds, 1998. Unpublished report prepared for Challenger Scallop Enhancement Co. by Osborne Research Co. Ltd.

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.

Stevens, P M (1987). Response of excised gill tissue from the New Zealand scallop *Pecten novaezelandiae* to suspended silt. *New Zealand Journal of Marine and Freshwater Research 21*: 605-614.

Talman, S G; Norkko, A; Thrush, S F; Hewitt, J E (2004). Habitat structure and the survival of juvenile scallops *Pecten novaezelandiae*: comparing predation in habitats with varying complexity. *Marine Ecology Progress Series 269*: 197–207.

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 97/15. 43 p. (Unpublished report held in NIWA library, Wellington.)

Thrush, S F; Hewitt, J E; Cummings, V J; Dayton, P K (1995). The impact of habitat disturbance by scallop dredging on marine benthic communities: what can be predicted from the results of experiments? *Marine Ecology Progress Series 129*: 141–150.

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.

Tuck, I D; Drury, J; Kelly, M; Gerring, P (2009). Designing a programme to monitor the recovery of the benthic community between North Cape and Cape Reinga. Final Research Report by NIWA for Ministry of Fisheries Research Project ENV2005-23. x p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Tuck, I; Brown, S (2008). Survey of scallops and oysters in Golden Bay, Tasman Bay, and the Marlborough Sounds, 2008. NIWA Client Report: NEL2008-022. (Unpublished report held by NIWA Auckland.). 37 p.

Tuck, I D; Hewitt, J E (2012). Monitoring change in benthic communities in Spirits Bay. Final Research Report by NIWA for Ministry of Fisheries research project BEN200901. 51 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Tuck, I; Hewitt, J; Handley, S; Willis, T; Carter, M; Hadfield, M; Gorman, R; Cairney, D; Brown, S; Palmer, A (2011). Assessing the effects of fishing on soft sediment habitat, fauna and processes. Progress Report for Ministry of Fisheries project BEN2007-01. 30 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Tuck, I; Parkinson, D; Dey, K; Oldman, J; Wadhwa, S (2006). Information on benthic impacts in support of the Coromandel Scallops Fishery Plan. Final Research Report prepared by NIWA for Ministry of Fisheries Research Project ZBD2005-15 Objective 1-6. p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Tuck, I D; Williams, J R (2012). Effects of scallop spat enhancement on scallop catches in Golden Bay and Tasman Bay. Final Research Report for Ministry for Primary Industries project SAP200914. 31 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Vignaux, M; Michael, K; Doonan, I; Cranfield, J; Breen, P (1995). Biomass of scallops in Golden Bay, Tasman Bay and the Marlborough Sounds, 1995. Unpublished report prepared for Challenger Scallop Enhancement Co. by MAF Fisheries Marine Research.

Williams, J R (2005). Reproductive ecology of the scallop *Pecten novaezelandiae*. Unpublished PhD thesis. University of Auckland, New Zealand. 134 p.

Williams, J R; Babcock, R C (2004). Comparison of multiple techniques to evaluate reproductive variability in a marine bivalve: application to the scallop *Pecten novaezelandiae*. *Marine and Freshwater Research 55*: 457–468.

Williams, J R; Bian, R (2012). Survey of scallops and oysters in Golden Bay, Tasman Bay, and the Marlborough Sounds, 2012. NIWA Client Report AKL2012-032 prepared for Challenger Scallop Enhancement Company Ltd. NIWA Project: CSE12301. 65 p. (Unpublished report held by NIWA, Auckland.)

Williams, J R; Bian, R; Brown, S (2009). Survey of scallops and oysters in Golden Bay, Tasman Bay, and the Marlborough Sounds, 2009. NIWA Client Report: NEL2009-024. (Unpublished report held by NIWA Auckland.). 37 p.

Williams, J R; Hartill, B; Bian, R; Williams, C L (2013). Review of the Southern scallop fishery (SCA 7). Draft New Zealand Fisheries Assessment Report report for project SCA200704, submitted to MPI in November 2013. 66 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Williams, J R; Michael K; Bian, R (2010). Survey of scallops and oysters in Golden Bay, Tasman Bay, and the Marlborough Sounds, 2010. NIWA Client Report: WLG2010-052. (Unpublished report held by NIWA Auckland.). 60 p.

Williams, J R; Michael, K (2011). Survey of scallops and oysters in Golden Bay, Tasman Bay, and the Marlborough Sounds, 2011. NIWA Client Report: AKL2011-026. (Unpublished report held by NIWA Auckland.). 64 p.

Williams, J R; Parkinson, D M (2010). Biomass survey and stock assessment for the Coromandel scallop fishery, 2010. *New Zealand Fisheries Assessment Report 2010/37*. 30 p.

Williams, J R; Parkinson, D M; Bian, R (2013b). Biomass survey and yield calculation for the Coromandel scallop fishery, 2012. *New Zealand Fisheries Assessment Report 2013/18*: 57 p.

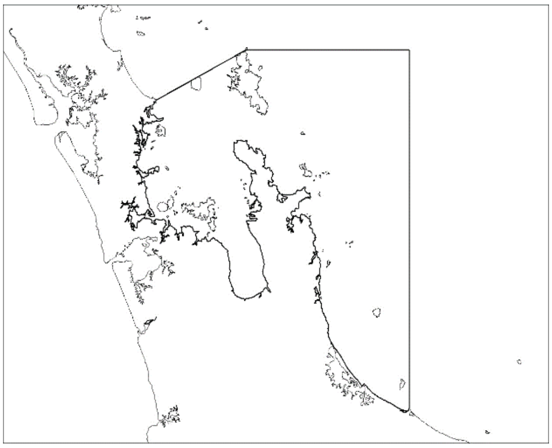
Williams, J R; Parkinson, D M; Tuck, I D (2010). Biomass survey and stock assessment for the Coromandel scallop fishery, 2009. *New Zealand Fisheries Assessment Report 2010/33*. 40 p.

Williams, J R; Tuck, I D; Hartill, B H; Bian, R (in prep) Review of the Southern scallop fishery (SCA 7). Draft FAR for Ministry for Primary Industry projects SCA200704 and SAP200914.

Wynne-Jones, J; Heinemann, A; Gray, A; Hill, L (in review). NZ recreational marine fishing survey 2011-2012. Draft New Zealand Fisheries Assessment Report by National Research Bureau Ltd. 69 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

SCALLOPS COROMANDEL (SCA CS)

(*Pecten novaezelandiae*)
Kuakua, Tipa



1. FISHERY SUMMARY

The Coromandel scallop fishery is a regionally important commercial fishery and runs in the area between Cape Rodney, Leigh in the north and Town Point near Tauranga in the south. Coromandel scallops (SCA CS) were introduced into the QMS on 1 April 2002, with a TAC of 48 t; following a review of the TAC in 2012–13 (Ministry for Primary Industries 2013a), on 1 April 2013 the TAC was changed to 131 t, comprising a TACC of 100 t, allowances of 10 t for recreational and customary fisheries, and an allowance of 11 t for other sources of mortality (Table 1; values all in meatweight (muscle plus attached roe).

Table 1: Total Allowable Commercial Catch (TACC, t) declared for SCA CS since introduction into the QMS.

Year	TAC	Customary	Recreational	Other Mortality	TACC
2002 to 2012	48	7.5	7.5	11	22
2013	131	10	10	11	100

1.1 Commercial fisheries

Commercial fishing is conducted within a number of discrete beds around Little Barrier Island, east of Waiheke Island (though not in recent years), at Colville, north of Whitianga (to the west and south of the Mercury Islands), and in the Bay of Plenty (principally off Waihi, and around Motiti and Slipper Islands). In 2011, fishers discovered that a large area of the Hauraki Gulf contained good densities of large scallops, which supported a large proportion of the fishing during from 2011 to 2013. This new, deeper (45–50 m water depth) region of the fishery lies mainly within statistical reporting area 2W and a smaller portion in 2S, and was surveyed for the first time in 2012. All commercial fishing is by dredge, with fishers preferring self-tipping “box” dredges (1.5–2.4 m wide, fitted with a rigid tooth bar on the leading bottom edge) to the “ring bag” designs used in the Challenger and Chatham Island fisheries. The fishing year applicable to this fishery is from 1 April to 31 March. The Coromandel commercial scallop fishing season runs from 15 July to 21 December each year.

A wide variety of effort controls and daily catch limits have been imposed in the past, but since 1992 the fishery has been limited by explicit seasonal catch limits specified in meatweight (adductor muscle with roe attached), together with some additional controls on dredge size, fishing hours and non-fishing days. Catch and catch rates from the Coromandel fishery are variable both within and among years, a characteristic typical of scallop fisheries worldwide.

Catch rates typically decline as each season progresses, but such declines are highly variable and depletion analysis has not been successfully used to assess start-of-season biomass.

Until the 1994 season, the minimum legal size for scallops taken commercially in northern (Coromandel and Northland) scallop fisheries was 100 mm shell length. From 1995 onwards, a new limit of 90 mm shell length was applied in the Coromandel (but not the Northland) fishery as part of a management plan comprising several new measures. Since 1980 when the fishery was considered to be fully-developed, landings have varied more than 30-fold from less than 6 t to over 188 t (meatweight). The two lowest recorded landings were in 1999 and 2000.

Currently, seven vessels operate in the Coromandel scallop fishery. The fishery is open for five days per week and daily catch limits apply, by agreement of the quota holders. The SCA CS commercial fishing industry is represented by the Coromandel Scallop Fishermen's Association (CSFA). Since 2010, in addition to CELR reporting, CSFA have carried out a logbook program that involves recording fishery data at a fine spatial scale within the broader CELR statistical reporting areas, and fishing has been voluntarily constrained by applying an operational decision rule which specifies an agreed CPUE limit, below which fishing in an area ceases. Meatweight recovery, and the proportion of legal size scallops in the catch, are also monitored and used to determine fishing patterns.

The Coromandel scallop fishery is managed under the QMS using individual transferable quotas (ITQ) that are proportions of the Total Allowable Commercial Catch (TACC). Catch limits and landings from the Coromandel fishery are shown in Table 2. SCA CS is included on Schedule Two of the Fisheries Act 1996 which specifies that, for certain "highly variable" stocks, the total allowable catch can be increased within a fishing season after considering information about the abundance during the current fishing year. The TACC is not permanently changed by this process and the catch limit reverts to the "base" level of the TACC at the end of each season. Requests from the commercial fishers for an increase in ACE has usually been supported by estimates of biomass, resulting from an annual biomass survey, and also require a consultation process with all relevant stakeholders, prior to being implemented

From 1992 up to and including the 2012 fishing year, the base TACC for SCA CS was 22t. In most years annual surveys were conducted (exceptions 2000 and 2011) and an increase in ACE, above the base 22t, was allowed (Table 2). In 2013, the base TACC was raised from 22t to 100t. The purpose of the increase was to reduce management and research costs by reducing the need for the annual survey and consultation processes that were required to support requests for increases in TACC.

Table 2: Catch limits and landings (t meatweight or greenweight) from the Coromandel fishery since 1974. Data before 1986 are from Fisheries Statistics Unit (FSU) forms. Landed catch figures come from Monthly Harvest Return (MHR) forms, Licensed Fish Receiver Return (LFRR) forms, and from the landed section of Catch Effort and Landing Return (CELR) forms, whereas estimated catch figures come from the effort section of CELRs and are pro-rated to sum to the total CELR greenweight. "Hauraki" = 2X and 2W, "Mercury" = 2L and 2K, "Barrier" = 2R, 2S, and 2Q, "Plenty" = 2A–2I. Seasonal catch limits (since 1992) have been specified as ACE or on permits in meatweight (Green[1] assumes the gazetted meatweight recovery conversion factor of 12.5% and probably overestimates the actual greenweight taken in most years). * 1991 landings include about 400 t from Colville; #a large proportion of the 2011, 2012 and 2013 landings were from a relatively deep (45–50 m) area of 2W fished for the first time in 2011; –, no catch limits set, or no reported catch. [Continued on next page]

			Landings (t)						
	Catch limits (t)		MHR	CELR		Scaled estimated catch (t green)			
Season	Meat	Green[1]	Meat	Meat	Green	Hauraki	Mercury	Barrier	Plenty
1974	–	–	–	–	26	0	26	0	0
1975	–	–	–	–	76	0	76	0	0
1976	–	–	–	–	112	0	98	0	14
1977	–	–	–	–	710	0	574	0	136
1978	–	–	–	–	961	164	729	3	65

Table 2 [Continued]:

1979	–	–	–	–	790	282	362	51	91
1980	–	–	–	–	1 005	249	690	23	77
1981	–	–	–	–	1 170	332	743	41	72
1982	–	–	–	–	1 050	687	385	49	80
1983	–	–	–	–	1 553	687	715	120	31
1984	–	–	–	–	1 123	524	525	62	12
1985	–	–	–	–	877	518	277	82	0
1986	–	–	–	–	1 035	135	576	305	19
1987	–	–	–	–	1 431	676	556	136	62
1988	–	–	–	–	1 167	19	911	234	3
1989	–	–	–	–	360	24	253	95	1
1990	–	–	–	–	903	98	691	114	0
1991	–	–	–	–	1 392	*472	822	98	0
1992–93	154	1 232	–	–	901	67	686	68	76
1993–94	132	1 056	–	–	455	11	229	60	149
1994–95	66	528	–	–	323	17	139	48	119
1995–96	86	686	–	79	574	25	323	176	50
1996–97	88	704	–	80	594	25	359	193	18
1997–98	105	840	–	89	679	26	473	165	15
1998–99	110	880	–	37	204	1	199	2	1
1999–00	31	248	–	7	47	0	12	17	18
2000–01	15	123	–	10	70	0	24	2	44
2001–02	22	176	–	20	161	1	63	85	12
2002–03	35	280	32	31	204	0	79	12	112
2003–04	58	464	58	56	451	63	153	13	223
2004–05	78	624	78	78	624	27	333	27	237
2005–06	118	944	119	121	968	21	872	75	0
2006–07	118	944	118	117	934	28	846	60	0
2007–08	108	864	59	59	471	51	373	45	2
2008–09	95	760	71	72	541	12	509	15	5
2009–10	100	800	33	33	267	12	184	71	0
2010–11	100	800	35	35	281	11	110	160	1
2011–12	50	400	50	50	402	#220	160	20	0
2012–13	325	2600	73	73	584	#572	1	11	0
2013–14	100	800	51	68	545	#344	133	68	0
2014-15*	100		32						

*all landing and catch records were not available at the time of writing the report

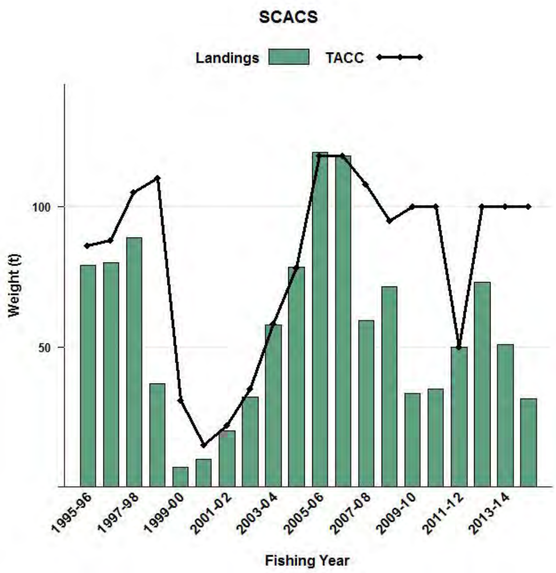


Figure 1: Landings and catch limits for SCACS (Coromandel) from 2002–03 to 2012–13. TACC refers to catch limit, and Weight refers to Meatweight.

1.2 Recreational fisheries

There is a strong non-commercial (recreational and Maori customary) interest in scallops in suitable areas throughout the Coromandel fishery, mostly in enclosed bays and harbours. Scallops are usually taken by diving using snorkel or scuba, although considerable amounts are also taken using small dredges. In some areas, especially in harbours, scallops can be taken by hand from the shallow subtidal and even the low intertidal zones (on spring tides), and, in storm events, scallops can be cast onto lee beaches in large numbers. One management tool for northern scallop fisheries is the general spatial separation of commercial and amateur fisheries through the closure of harbours and enclosed waters to commercial dredging. There remain, however, areas of contention and conflict, some of which have been addressed using additional regulated closures. Regulations governing the recreational harvest of scallops from SCA CS include a minimum legal size of 100 mm shell length and a restricted daily harvest (bag limit) of 20 per person. A change to the recreational fishing regulations in 2005 allowed divers operating from a vessel to take scallops for up to two nominated safety people on board the vessel, in addition to the catch limits for the divers. Until 2006, the recreational scallop season ran from 15 July to 14 February, but in 2007 the season was changed to run from 1 September to 31 March.

Estimates of the recreational scallop harvest from SCA CS are shown in Table 3. A pilot study creel survey was conducted in 2007–08 to assess the feasibility of estimating the recreational catch in that part of the Coromandel scallop fishery from Cape Colville to Hot Water Beach (Holdsworth & Walshe 2009). The study was based on an access point (boat ramp) survey using interviewers to collect catch and effort information from returning fishers, and was conducted from 1 December 2007 to 28 February 2008 (90 days) during the peak of the scallop season. The total estimated harvest during the survey period was 205,400 scallops (CV = 8.6%), with an estimated 23.9 t greenweight harvested (about 3 t meatweight). The estimate of 67 t greenweight (about 8 t meatweight) from a panel survey in 2011–12 (Wynne-Jones et al in press) equates to about 16% of the commercial harvest in the area surveyed in that year. The annual recreational harvest level is likely to vary substantially through time.

Table 3: Estimates of the recreational harvest of scallops from SCA CS. Number, number of scallops; green, greenweight; meat, meatweight (assuming 12.5% recovery of meat weight from green weight). The 2007–08 estimates are for a 90 day period of the summer in a defined area (Coromandel peninsular) within SCA CS only.

Year	Area	Survey method	Number	CV	Green (t)	Meat (t)	Reference
2007–08	Coro. peninsular	Creel survey	205 400	0.09	24	3	Holdsworth and Walshe (2009)
2011–12	SCA CS	Panel survey	605 466	0.27	67	8	Wynne-Jones et al (in review)

1.3 Customary fisheries

Scallops were undoubtedly used traditionally as food by Maori, and some limited quantitative information on recent levels of customary take is available from Ministry for Primary Industries (Table 4).

Table 4: Ministry for Primary Industries records of customary harvest of scallops (reported on customary permits as numbers or greenweight, or units unspecified) taken from the Coromandel scallop fishery, 2003–04 to 2008–09. –, no data.

SCACS	Quantity approved, by unit type					Actual quantity harvested, by unit type				
Fishing year	Bag	BIN	Weight (kg)	Number	Unspecified	Bag	BIN	Weight (kg)	Number	Unspecified
2003–04	–	–	600	200	–	–	–	600	200	–
2004–05	–	–	360	50	150	–	–	360	–	–
2005–06	–	–	3	700	50	–	–	0	–	–
2006–07	–	–	–	290	–	–	–	–	180	–
2007–08	–	–	330	630	–	–	–	285	280	–
2008–09	1	10	370	2390	13550	–	4	82	2090	4476
2009-10	–	1	150	1260	15510	–	202	65	1000	4500
2010-11	–	–	675	1800	19700	–	–	190	1400	6785
2011-12	–	–	310	640	25590	–	–	310	0	10270
2012-13	–	3	250	80	29800	–	200	200	80	14904
2013-14	–	–	–	2390	16830	–	–	–	2090	7055

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

1.5 Other sources of mortality
The box dredges in use in the Coromandel commercial fishery have been found to be considerably more efficient, in the generally sandy conditions prevalent in the fishery, than ring-bag or Keta-Ami dredges. However, scallops encountered by box dredges showed modest reductions in growth rate, compared with scallops collected by divers, and quite high mortality (about 20–30% mortality for scallops that are returned to the water. i.e. just under the MLS of 90 mm). Stochastic modelling suggested that, of the three dredge designs tested, box dredges would generate the greatest yield-per-recruit and catch rates. The incidental mortality caused by dredging substantially changed the shape of yield-per-recruit curves for Coromandel scallops, causing generally asymptotic curves to become domed, and decreasing estimates of F_{max} and $F_{0.1}$. More recent field experiments and modelling suggest that dredging reduces habitat heterogeneity, increases juvenile mortality, makes yield-per-recruit curves even more domed, and decreases estimates of F_{max} and $F_{0.1}$ even further.

2. BIOLOGY

Pecten novaezelandiae is one of several species of “fan shell” bivalve molluscs found in New Zealand waters. Others include queen scallops and some smaller species of the genus *Chlamys*. *P. novaezelandiae* is endemic to New Zealand, but is very closely related to the Australian species *P. fumatus* and *P. modestus*. Scallops of various taxonomic groups are found in all oceans and support many fisheries world-wide; most scallop populations undergo large fluctuations.

Scallops are found in a variety of coastal habitats, but particularly in semi-enclosed areas where circulating currents are thought to retain larvae. After the planktonic larval phase and a relatively mobile phase as very small juveniles, scallops are largely sessile and move actively mainly in response to predators. They may, however, be moved considerable distances by currents and storms and are sometimes thrown up in large numbers on beaches.

Scallops are functional hermaphrodites, and become sexually mature at a size of about 70 mm shell length. They are extremely fecund and may spawn several times each year. Fertilisation is external and larval development lasts for about 3 weeks. Initial settlement occurs when the larva attaches via a byssus thread to filamentous material or dead shells on or close to the seabed. The major settlement of spat in northern fisheries usually takes place in early January. After growth to about 5 mm, the byssus is detached and, after a highly mobile phase as a small juvenile, the young scallop takes up the relatively sedentary adult mode of life.

The very high fecundity of this species, and likely variability in the mortality of larvae and pre-recruits, leads to great variability in annual recruitment. This, combined with variable mortality and growth rate of adults, leads to scallop populations being highly variable from one year to the next, especially in areas of rapid growth where the fishery may be supported by only one or two year classes. This variability is characteristic of scallop populations world-wide, and often occurs independently of fishing pressure.

The growth of scallops within the Coromandel fishery is variable among areas, years, seasons and depths, and probably among substrates. In the Hauraki Gulf scallops have been estimated to grow to 100 mm shell length in 18 months or less, whereas this can take three or more years elsewhere (Table 5). In some years, growth is very slow, whereas in others it is very rapid. There is a steep relationship with depth and scallops in shallow water grow much faster than those in deeper water. This is not a simple relationship, however, as scallops in some very deep beds (e.g., Rangaunu Bay and Spirits Bay in the far north, both deeper than 40 m) appear to grow at least as fast as those in favourable parts of the Coromandel fishery. Food supply undoubtedly plays a role.

A variety of studies suggest that average natural mortality in the Coromandel fishery is quite high at $M = 0.50\ y^{-1}$ (instantaneous rate), and maximum age in unexploited populations is thought to be about 6 or 7 years.

Table 5: Estimates of biological parameters.

Stock	Estimates		Source
1. Natural mortality, *M*			
Motiti Island	0.4–0.5		Walshe 1984
2. Weight = a(length)^b			
	a	b	
Coromandel fishery	0.00042	2.662	Cryer & Parkinson 1999
3. von Bertalanffy parameters			
	L_∞	K	
Motiti Island (1981–82)	140.6	0.378	Walshe 1984
Hauraki Gulf (1982–83)	115.9	1.200	Walshe 1984
Whitianga (1982)	114.7	1.210	Data of L.G. Allen, analysed by Cryer & Parkinson 1999
Whitianga (1983)	108.1	1.197	Data of L.G. Allen, analysed by Cryer & Parkinson 1999
Whitianga (1984)	108.4	0.586	Data of L.G. Allen, analysed by Cryer & Parkinson 1999
Coromandel fishery (1992–97)	108.8	1.366	Cryer & Parkinson 1999
Whitianga mean depth 10.6 m	113.5	1.700	Cryer & Parkinson 1999
Whitianga mean depth 21.1 m	109.0	0.669	Cryer & Parkinson 1999
Whitianga mean depth 29.7 m	110.3	0.588	Cryer & Parkinson 1999

3. STOCKS AND AREAS

Scallops inhabit waters of up to about 60 m deep (apparently up to 85 m at the Chatham Islands), but are more common in depths of 10 to 50 m on substrates of shell gravel, sand or, in some cases, silt. Scallops are typically patchily distributed at a range of spatial scales; some of the beds are persistent and others are ephemeral. The extent to which the various beds or populations are reproductively or functionally separate is not known. It is currently assumed for management that the Northland stock is separate from the adjacent Coromandel stock and from the various west coast harbours, Golden Bay, Tasman Bay, Marlborough Sounds, Stewart Island and Chatham Island areas.

4. STOCK ASSESSMENT

From 1992 to 2010, biomass surveys of selected scallop beds in the fishery have been conducted on an almost annual basis, as a means of estimating stock size and informing management decisions on potential increases in the annual TACC.

In 2011, no survey was conducted; instead, biomass estimates were calculated using estimates of projected biomass generated by projecting the 2010 survey data forward to the start of the 2011 fishing season. The projection approach used a length-based growth transition matrix (based on tag return data) to grow the scallops from the time of the survey (May 2010) to the start of the fishing season the following year (July 2011), correcting for dredge efficiency, and allowing for natural mortality and fishing mortality (catch and incidental mortality). Uncertainty was incorporated during the projection process by bootstrapping (resampling with replacement) from the various data sources (Tuck 2011).

In 2012, a comprehensive survey was conducted that aimed to provide an estimate of abundance representative of the status of the overall SCA CS stock. The survey coverage was more extensive than used previously, with the stratification comprising ‘core’ strata (those surveyed and fished consistently in the past), 'background' strata (areas of lower densities outside the core strata that formed part of the survey coverage in the past), and 'new' strata (those in Hauraki Gulf that had never been surveyed before).

In 2013, the base TACC was raised from 22t to 100t.

4.1 Estimates of fishery parameters and abundance

Fishing mortality has been variable over time in the Coromandel fishery (Table 6).

Standardised CPUE from the statutory catch and effort returns is not considered a reliable index of abundance at the stock level (Cryer 2001b). Recent simulation studies have, however, examined the use of local area CPUE as a basis for some management strategies (Haist & Middleton 2014).

4.2 Biomass estimates

From 1992 to 2012 biomass surveys were conducted almost annually (Table 6 & 7). Average biomass in the absence of fishing, B_0, and the biomass that will support the maximum sustainable yield, B_{MSY}, have not been estimated and are probably not appropriate reference points for a stock with highly variable recruitment and growth such as scallops.

Assessments of current yields were based on pre-season biomass surveys done by diving and/or dredging (Tables 6& 7). Bian et al (2012) modelled the efficiency of box dredges used in northern New Zealand scallop fisheries, and the results suggest the efficiency of these dredges was underestimated previously (2004 to 2010), resulting in overestimation of biomass and yield. The 2012 estimates of abundance and biomass were made using the new parametric model of dredge efficiency (Bian et al 2012) that estimates efficiency with respect to scallop length, water depth, substrate type, and tow termination.

Table 6: Estimated start of season abundance and biomass of scallops of 90 mm or more shell length in the Coromandel fishery since 1998 using historical average dredge efficiency; for each year, the catch (reported on the 'Landed' section of CELRs), exploitation rate (catch to biomass ratio), and the estimated fishing mortality (F_{est}) are also given. F_{est} was estimated by iteration using the Baranov catch equation where t = 5/12 and M = 0.50 spread evenly through the year. Abundance and biomass estimates are mean values up to and including 2003, and median values from 2004, when the analytical methodology for producing the estimates was modified. Note the estimates for 1998–2010 were produced by correcting for dredge efficiency using the method of Cryer & Parkinson (2006), which was replaced by the method of Bian et al (2012) in 2012 (a preliminary version of that method was used in 2011). This, together with changes to survey coverage each year, makes direct comparisons among years difficult. There was no survey in 2000, 2011, 2013 or 2014. The 2011 values are projected estimates generated by projecting forward the 2010 survey data to the start of the 2011 fishing season. Estimates of abundance in numbers (millions) of scallops were not reported in 2011. –, no data.

Year	Abundance		Biomass				Catch	Exploitation rate	F_{est}
	(millions)	CV	(t green)	CV	(t meat)	CV	(t meat)	(catch/biomass)	≥90 mm
1998	35.4	0.16	2702	0.16	365	0.16	31	0.08	0.237
1999	10.3	0.18	752	0.18	102	0.18	7	0.07	0.189
2000	–	–	–	–	–	–	10	–	–
2001	8.3	0.26	577	0.27	78	0.27	20	0.26	0.796
2002	10.3	0.20	768	0.20	104	0.20	31	0.30	0.954
2003	16.0	0.18	1224	0.18	165	0.18	56	0.34	1.131
2004	111.5	0.22	9024	0.21	1131	0.26	78	0.07	0.191
2005	169.3	0.24	14374	0.23	1795	0.27	121	0.07	0.185
2006	143.1	0.21	12302	0.21	1531	0.25	117	0.08	0.212
2007	101.6	0.20	8428	0.20	1061	0.23	59	0.06	0.152
2008	94.0	0.29	6900	0.28	868	0.31	72	0.08	0.232
2009	64.5	0.23	4676	0.22	595	0.24	33	0.06	0.154
2010	58.8	0.20	4442	0.19	540	0.21	35	0.07	0.180
2011	–	–	5426	0.85	658	0.87	50	0.08	0.211
2012	140.0	0.15	11423	0.15	1380	0.18	73	0.05	0.145
2013	–	–	–	–	–	–	–	–	–
2014	–	–	–	–	–	–	–	–	–

The 2012 estimates were produced from a comprehensive survey coverage that included previously unsurveyed areas of the SCA CS stock (e.g., the 40–50 m deep region of Hauraki Gulf, which contained a considerable biomass in 2012).

Discerning trends in the abundance and biomass of recruited scallops is complicated by changes to survey coverage, the establishment of closed areas, and uncertainty about dredge efficiency in any particular year. Time series of abundance and biomass estimates of scallops 90 mm or more shell length are shown in Table 7. It is important to note that these time series were produced by correcting for dredge efficiency using the method of Cryer & Parkinson (2006), so the 2012 values were generated using that same method so that all years are comparable. For 2012, the estimates were generated using data from the 'core' strata only (i.e., the 'background' strata, and 'new' strata in the Hauraki Gulf region, were excluded, the latter because there was no survey from the past; it was surveyed for the first time in 2012).

Estimates around the turn of the century (2000) were consistently at or near the lowest on record leading to the conclusion that the population was, for unknown reasons, at a very low level. In contrast, following reasonable increases in 2003 and, especially, 2004, the abundance and biomass in 2005 were the highest on record and probably higher than in the mid 1980s when not all of the beds were surveyed. This resurgence was strongest in the Mercury region to the north of Whitianga (the mainstay of the fishery), but most beds showed some increase in density. There has been a gradual decline in the overall recruited population since the peak in 2005, but in 2010 this downward trend appeared to have stalled. For the regions usually fished (i.e. for the core strata only, excluding the area in Hauraki Gulf and the 'background' strata) the status of the recruited population in 2012 appears to be fairly similar to that in 2010 (Appendix 8; estimated using Cryer & Parkinson (2006) dredge efficiency method), and again most of the fishable biomass is held in the Mercury beds, but with high densities of recruits in beds at Little Barrier. For the Hauraki Gulf region of the fishery (2W/2S), it is unknown whether the large biomass of scallops surveyed in 2012 is a consistent part of the population, or a product of successful recruitment in recent years.

Table 7: Estimated abundance and biomass of scallops 90 mm or more shell length at the time of surveys in the five main regions of the Coromandel fishery since 1998. Excludes the "new", deep fishery region in Hauraki Gulf, which was fished for the first time in 2011, and surveyed for the first time in 2012 (estimated 148.5 million scallops or 13278 t greenweight biomass). Survey data were analysed using a non-parametric re-sampling with replacement approach to estimation (1000 bootstraps). Note these estimates were produced by correcting for dredge efficiency using the method of Cryer & Parkinson (2006), which has now been replaced by the method of Bian et al (2012). Figures are not necessarily directly comparable among years because of changes to survey coverage. –, no survey in a region or year. The 2001 survey totals include scallops surveyed in 7 km^2 strata at both Kawau (0.5 million, 3 t) and Great Barrier Island (0.8 million, 62 t). [Continued on next page]

Year	Abundance (millions)						Area surveyed
	Barrier	Waiheke	Colville	Mercury	Plenty	Total	(km^2)
1998	2.0	9.0	0.4	21.3	2.2	36.1	341
1999	0.5	0.5	0.0	7.3	2.7	11.2	341
2000	–	–	–	–	–	–	–
2001	7.4	0.4	–	6.9	2.1	18.1	125
2002	1.8	4.0	–	6.6	2.0	14.7	119
2003	2.5	4.0	4.3	12.3	4.9	28.6	130
2004	4.5	9.8	0.4	58.5	8.2	82.6	149
2005	6.2	3.3	3.0	118.8	12.6	145.3	174
2006	5.6	–	10.3	101.6	6.5	125.3	160
2007	4.2	1.3	4.4	59.9	14.3	84.6	175
2008	2.0	–	1.7	56.3	4.8	65.0	144
2009	10.4	–	3.1	31.8	1.3	46.9	144
2010	9.6	0.8	2.6	28.0	3.9	45.6	149
2011	–	–	–	–	–	–	–
2012	7.7	0.4	2.4	22.8	2.9	36.8	180
2013	–	–	–	–	–	–	–
2014	–	–	–	–	–	–	–

Table 7 [Continued]:

Year	Biomass (t green)						Area
	Barrier	Waiheke	Colville	Mercury	Plenty	Total	(km^2)
1998	173	731	30	1 674	205	2 912	341
1999	42	34	1	559	224	873	341
2000	–	–	–	–	–	–	–
2001	554	32	–	525	165	1 362	125
2002	150	289	–	538	163	1 156	119
2003	225	302	387	995	406	2 355	130
2004	348	737	30	4 923	676	6 794	149
2005	544	274	316	10 118	1 058	12 404	174
2006	519	–	1 041	8 731	534	10 902	160
2007	376	96	409	5 498	1 110	7 539	175
2008	166	–	150	4 575	367	5 265	144
2009	823	–	257	2 512	102	3 725	144
2010	764	59	219	2 299	291	3 671	149
2011	–	–	–	–	–	–	–
2012	629	32	250	1 855	225	3 027	180
2013	–	–	–	–	–	–	–
2014	–	–	–	–	–	–	–

Uncertainty stemming from assumptions about dredge efficiency during the surveys, rates of growth and natural mortality between survey and season, and predicting the average recovery of meatweight from greenweight remain in these biomass estimates. A new model of scallop dredge efficiency (Bian et al 2012) has helped to reduce this uncertainty, as should future research projects aimed at collecting more data on scallop growth and mortality. Managing the fisheries based on the number of recruited scallops at the start of the season as opposed to recruited biomass (the current approach) could remove the uncertainty associated with converting estimated numbers of scallops to estimated meatweight.

In the recreational SCA CS fishing areas, diver surveys of scallops were conducted annually in June–July from 2006 to 2010 (Williams et al 2008, Williams 2009a, b, 2012). For the four small beds (total area of 4.64 km^2) surveyed each year, the projected (15 July) biomass of scallops over 100 mm shell length was estimated to be 128 t greenweight (CV of 26%) or 16 t meatweight in 2006, 82 t greenweight (CV of 13%) or 10 t meatweight (CV of 20%) in 2007, and 79 t greenweight (CV of 14%) or 10 t meatweight (CV of 21%) in 2008. Survey stratum boundaries were revised in 2009 to better reflect the extent of the scallop bed at each site, resulting in a slightly reduced total area (3.6 km^2) surveyed; the total projected biomass was estimated to be 50 t greenweight or 6 t meatweight (CVs of 13%) in 2009, and 48 t greenweight or 6 t meatweight (CVs of 13 and 16%) in 2010 (Williams 2012).

4.3 Yield estimates and projections

MCY has not been estimated for Coromandel scallops because of the high natural variation in abundance.

Until 1997, assessments for the Coromandel fishery were based on Provisional Yield (PY, estimated as the lower bound of a 95% confidence distribution for the estimated start-of-season biomass of scallops 100 mm or more shell length). However, experiments and modelling showed this method to be sub-optimal. New estimates of the reference fishing mortality rates $F_{0.1}$, $F_{40\%}$ and F_{max} were made, taking into account experimental estimates of incidental fishing mortality. For assessments since 1998, CAY was estimated using these reference fishing mortality rates, and CAY supplanted PY as a yield estimator. Recent experimentation and modelling of juvenile mortality in relation to habitat heterogeneity suggest that even these more conservative reference fishing mortality rates may be too high.

Yield estimates are generally calculated using reference rates of fishing mortality applied to an estimate of current or reference biomass. Cryer & Parkinson (2006) reviewed reference rates of fishing mortality and summarised modelling studies by Cryer & Parkinson (1997) and Cryer et al (2004). $F_{0.1}$ is used as the target reference rate of fishing mortality for scallops. From 1998 to

2012, catch limits have been adjusted in line with estimated start-of-season recruited biomass and an estimate of CAY made using the Baranov catch equation:

$$CAY = \frac{F_{ref}}{F_{ref} + M}\left(1 - e^{-(F_{ref}+M)t}\right)B_{beg}$$

where t = 5/12 years, F_{ref} is a reference fishing mortality ($F_{0.1}$) and B_{beg} is the estimated start-of-season (15 July) recruited biomass (scallops of 90 mm or more shell length). Natural mortality is assumed to act in tandem with fishing mortality for the first 5 months of the fishing season, the length of the current Coromandel commercial scallop season. B_{beg} is estimated assuming historical average dredge efficiency at length, average growth (from previous tagging studies), M = 0.5 spread evenly through the year, and historical average recovery of meatweight from greenweight. Because of the uncertainty over biomass estimates, growth, and mortality in a given year, and appropriate reference rates of fishing mortality, yield estimates must be treated with caution.

Modelling studies for Coromandel scallops (Cryer & Morrison 1997, Cryer et al 2004) indicate that $F_{0.1}$ is sensitive not only to the direct incidental effects of fishing (reduced growth and increased mortality on adult scallops), but also to indirect incidental effects (such as additional juvenile mortality related to reduced habitat heterogeneity in dredged areas). By including only the direct incidental effects of fishing on scallops, Cryer et al (2004) derived an estimate of $F_{0.1}$ = 1.034 y^{-1} (reported by Cryer et al 2004, as 5/12 * $F_{0.1}$ = 0.431). Cryer et al (2004) also modelled the “feedback” effects of habitat modification by the dredge method on juvenile mortality in scallops. They developed estimates of F_{ref} that incorporated such effects, but had to make assumptions about the duration of what they called the “critical phase” of juvenile growth during which scallops were susceptible to increased mortality. To give some guidance on the possible outcome of including “indirect” (as well as direct) effects on yield estimates, the Cryer et al (2004) estimate of $F_{0.1}$ = 0.658 y^{-1} (reported as 5/12 * $F_{0.1}$ = 0.274) was also applied in calculations of CAY.

For both scenarios, the estimates of CAY would have C.V.s at least as large as those of the estimate of start-of-season recruited biomass, are sensitive to assumptions about dredge efficiency, growth, and expected recovery of meatweight from greenweight, and relate to the surveyed beds only. Further, the second approach which includes indirect incidental effects (putative “habitat effects”) is sensitive to the duration of any habitat-mediated increase in juvenile mortality. There is also additional uncertainty associated with using a point estimate of $F_{0.1}$ (i.e., variance associated with the point estimate of $F_{0.1}$ was not incorporated in the analysis), and the fact that the estimates of $F_{0.1}$ were generated using estimates of dredge efficiency that are different to those used to estimate current biomass; the latter may have resulted in underestimates of yield.

The last biomass survey was undertaken in 2012 and the CAY estimates calculated (tonnes meatweight):

		$F_{0.1}$=0.431	$F_{0.1}$=0.274
B_{beg}	1380t	439t	300t

Regardless of the approach used to estimate CAY, the production of a single ‘best estimate’ of CAY should be treated with caution. For the projections to the 2012 start of season, the 1000 combined greenweight estimates were converted to meatweight (resampling from the meatweight greenweight conversion ratio data).. The median of this meatweight distribution was 1380 tonnes. Using the existing target reference $F_{0.1}$ values for Coromandel scallops, this meatweight distribution was converted into a distribution of CAY estimates and a range of catch limit options were compared with this distribution to provide a decision table (Table 8).

Table 8: Decision table showing probability that a particular catch limit (t meatweight) would exceed reference fishing mortality values, for the Coromandel scallop (SCA CS) 2012–13 fishing year. $F_{0.1}$ (direct effects) represents the probability that the estimate of $F_{0.1}$ = 1.034 incorporating direct incidental mortality effects is exceeded. $F_{0.1}$ (direct & indirect effects) represents the probability that the estimate of $F_{0.1}$ = 0.658 incorporating direct and indirect incidental mortality effects is exceeded. These probabilities were generated from an analysis using estimates of absolute biomass within the surveyed area (i.e., a critical density of 0.00 scallops m^{-2}). [Continued on next page]

Catch limit (t)	F0.1 (direct effects)	F0.1 (direct & indirect effects)
150	0.000	0.000
160	0.000	0.000
170	0.000	0.001
180	0.000	0.002
190	0.000	0.005
200	0.000	0.011
210	0.000	0.018
220	0.000	0.036
230	0.000	0.063
240	0.001	0.109
250	0.001	0.162
260	0.002	0.217
270	0.002	0.285
280	0.007	0.351
290	0.010	0.429
300	0.016	0.510
310	0.020	0.577
320	0.033	0.645
330	0.050	0.706
340	0.070	0.772
350	0.104	0.817
360	0.138	0.850
370	0.179	0.886
380	0.213	0.914
390	0.259	0.933
400	0.306	0.950
410	0.353	0.960
420	0.402	0.974
430	0.460	0.985
440	0.513	0.988

5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was reviewed by the Aquatic Environment Working Group for the November 2013 Fishery Assessment Plenary. A broader summary of information on a range of issues related to the environmental effects of fishing and aspects of the marine environment and biodiversity of relevance to fish and fisheries is available in the Aquatic Environment & Biodiversity Annual Review (http://www.mpi.govt.nz/Default.aspx?TabId=126&id=2122) (Ministry for Primary Industries 2013).

5.1 Role in the ecosystem

Scallops (*Pecten novaezelandiae*) are subtidal, benthic, epifaunal, sedentary, bivalve molluscs, which have a pelagic larval dispersal phase. They are found patchily distributed at a range of scales in particular soft sediment habitats in inshore waters of depths generally to 50 m and exceptionally up to 85 m. They exhibit relatively fast growth, high mortality, and variable recruitment. The rates of these processes probably vary in relation to environmental conditions (e.g., temperature, water flow, turbidity, salinity), ecological resources (e.g., food, oxygen, habitat), and with intra- and inter-specific interactions (e.g., competition, predation, parasitism, mutualism), and the combination of these factors determines the species distribution and abundance (Begon et al 1990). Scallops are considered to be a key component of the inshore coastal ecosystem, acting both as consumers of primary producers and as prey for many predators; the scallops themselves can also provide structural habitat for other epifauna (e.g., sponges, ascidians, algae).

5.1.1 Trophic interactions

Scallops are active suspension feeders, consuming phytoplankton and other suspended material (benthic microalgae and detritus) as their food source (Macdonald et al 2006). Their diet is the same as, or similar to, that of many other suspension feeding taxa, including other bivalves such as oysters, clams, and mussels.

Scallops are prey to a range of invertebrate and fish predators, whose dominance varies spatially. Across all areas, reported invertebrate predators of scallops include starfish (*Astropecten polyacanthus*, *Coscinasterias calamaria*, *Luidia varia*), octopus (*Pinnoctopus cordiformis*), and hermit crabs (*Pagurus novaezelandiae*), and suspected invertebrate predators include various carnivorous gastropods (e.g., *Cominella adspersa* and *Alcithoe arabica*); reported fish predators of scallops include snapper (*Pagrus auratus*), tarakihi (*Nemadactylus macropterus*), and blue cod (*Parapercis colias*), and suspected fish predators include eagle rays (*Myliobatis tenuicaudatus*) and stingrays (*Dasyatis* sp.) (Morton & Miller 1968, Bull 1976, Morrison 1998, Nesbit 1999). Predation varies with scallop size, with small scallops being generally more susceptible to a larger range of predators.

5.2 Incidental catch (fish and invertebrates)

A range of non-target fish and invertebrate species are caught and discarded by dredge fisheries for *P. novaezelandiae* scallops. No data are available on the level or effect of this incidental catch (bycatch) and discarding by the fisheries. Bycatch data are available, however, from various dredge surveys of the scallop stocks, and the bycatch of the fisheries is likely to be similar to that of the survey tows conducted in areas that support commercial fishing.

Species or groups that have been caught as incidental catch in the box dredges and ring-bag dredges used in surveys of commercial scallop (*P. novaezelandiae*) fishery areas in New Zealand are shown in Table 10. Catch composition varies among the different fishery locations and through time.

In the Coromandel scallop stock (SCACS), a photographic approach was used in the 2006 dredge survey to provisionally examine bycatch groups (Tuck et al 2006), but a more quantitative and comprehensive study was conducted using bycatch data collected in the 2009 dredge survey (Williams et al 2010), with survey catches quantified by volume of different component categories. Over the whole 2009 survey, scallops formed the largest live component of the total catch volume (26%), followed by assorted seaweed (11%), starfish (4%), other live bivalves (4%), coralline turfing algae (1%) plus other live components not exceeding 0.5%. Dead shell (identifiable and hash) formed the largest overall component (45%), and rock, sand, and gravel formed 8%. Categories considered to be sensitive to dredging were caught relatively rarely. Data on the bycatch of the 2010 and 2012 surveys of SCA CS were also collected but not analysed; those data have been loaded to the MPI database ‘scallop’ for potential future analysis (Williams & Parkinson 2010, Williams et al 2013b).

In the Northland scallop stock (SCA 1), analysis of historical survey bycatch from a localised deep area within Spirits Bay showed an unusually high abundance and species richness of sponges (Cryer et al 2000), and led to the voluntary and subsequent regulated closure of that area to commercial fishing.

In the Southern scallop stock (SCA 7), data on the bycatch of the 1994–2013 surveys have been collected but not analysed, except for preliminary estimation of the 1998–2013 bycatch trajectories (Williams et al 2013a).

Table 10: Species or groups categorised by bycatch type caught as incidental catch in dredge surveys of commercial scallop (*P. novaezelandiae*) fishery areas in New Zealand.

Type	Species or groups
habitat formers	sponges, tubeworms, coralline algae (turf, maerl), bryozoa
starfish	Astropecten, Coscinasterias, cushion stars, carpet stars
bivalves	dog cockles, horse mussels, oysters, green-lipped mussels, Tawera
other invertebrates	anemones, crabs, gastropods, polychaetes, octopus, rock lobster
fish	gobie, gurnard, John dory, lemon sole, pufferfish, red cod, sand eel, snake eel, stargazer, yellowbelly flounder
seaweed	Ecklonia, other brown algae, green algae, red algae
shell	whole shells, shell hash
substrate	mud, sand, gravel, rock
other	rubbish

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

There is no known bycatch of seabirds, mammals or protected fish species from P. novaezelandiae scallop fisheries.

5.4 Benthic interactions

It is well known that fishing with mobile bottom contact gears such as dredges has impacts on benthic populations, communities, and their habitats (e.g., see Kaiser et al 2006, Rice 2006). The effects are not uniform, but depend on at least: “the specific features of the seafloor habitats, including the natural disturbance regime; the species present; the type of gear used, the methods and timing of deployment of the gear, and the frequency with which a site is impacted by specific gears; and the history of human activities, especially past fishing, in the area of concern” (Department of Fisheries and Oceans 2006). The effects of scallop dredging on the benthos are relatively well-studied, and include several New Zealand studies carried out in areas of the northern fisheries (SCA 1 and SCA CS) (Thrush et al 1995, Thrush et al 1998, Cryer et al 2000, Tuck et al 2009, Tuck & Hewitt 2012) and the Golden/Tasman Bay region of the southern (SCA 7) fishery (Tuck et al 2011). The results of these studies are summarised in the Aquatic Environment & Biodiversity Annual Review (Ministry for Primary Industries 2012), and are consistent with the global literature: generally, with increasing fishing intensity there are decreases in the density and diversity of benthic communities and, especially, the density of emergent epifauna that provide structured habitat for other fauna.

5.5 Other considerations

5.5.1 Spawning disruption

Scallop spawning occurs mainly during spring and summer (Bull 1976, Williams & Babcock 2004). Scallop fishing also occurs during these seasons, and is particularly targeted in areas with scallops in good condition (reproductively mature adults ready to spawn). Fishing also concentrates on high density beds of scallops, which are disproportionately more important for fertilisation success during spawning (Williams 2005). Fishing, therefore, may disrupt spawning by physically disturbing scallops that are either caught and retained (removal), caught and released, not caught but directly contacted by the dredge, or not caught but indirectly affected by the effects of dredging (e.g., suspended sediments).

5.5.2 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 2012) although work is currently underway to define one. Certain features of the habitats which scallops are associated with are known to influence scallop productivity by affecting the recruitment, growth and mortality of scallops, and therefore may in the future be useful in terms of identifying HPSFM. Scallop larval settlement requires the presence of fine filamentous emergent epifauna on the seabed, such as tubeworms, hydroids, and filamentous algae, hence the successful use of synthetic mesh spatbags held in the water column as a method for collecting scallop spat. Survival of juveniles has been shown to vary with habitat complexity, being greater in more complex habitats (with more emergent epifauna) than in more homogeneous areas (Talman et al 2004). The availability of suspended microalgae and detritus affects growth and condition (Macdonald et al 2006). Suspended sediments can reduce rates of respiration and growth, the latter by ‘diluting’ the food available; scallops regulate ingestion by reducing clearance rates rather than increasing pseudofaeces production. Laboratory studies have demonstrated that suspended sediments disrupt feeding, decrease growth and increase mortality in scallops (Stevens 1987, Cranford & Gordon 1992, Nicholls et al 2003).

6. STOCK STATUS

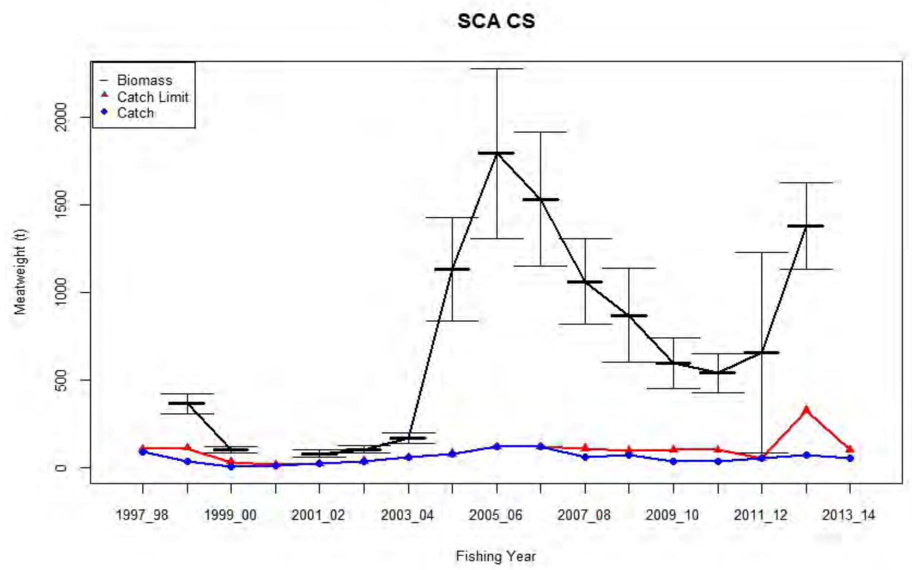
Stock Structure Assumptions

The stock structure of scallops in New Zealand waters is uncertain. For the purposes of this assessment, SCA CS is assumed to be a single biological stock, although the extent to which the various beds or populations are reproductively or functionally separate is not known.

- **Coromandel scallops, SCA CS**

Stock Status	
Year of Most Recent Assessment	2012-13 fishing season
Assessment Runs Presented	Two approaches to estimating CAY
Reference Points	Target: Fishing mortality at or below $F_{0.1}$ ($F_{0.1}$ = 1.034 y^{-1} including direct incidental effects of fishing only, or $F_{0.1}$ = 0.658 y^{-1} including direct and indirect effects of fishing) Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	Very Likely (> 90%) to be below F_{target} (in 2012–13, F_{est} = 0.145 y^{-1}) Unknown for 2013-14
Status in relation to Limits	Unlikely (< 40%) 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



Estimated recruited biomass (scallops 90 mm or more shell length), catch limits, and landings (MHRs) in t meatweight for the SCA CS fishery since 1998. In 2011, no survey was conducted; instead, biomass was estimated by projecting forward from the 2010 survey.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Estimated recruited biomass (t meatweight of scallops ≥ 90 mm shell length) in the core areas of the fishery during 1999–2003 was consistently at or near the lowest on record (78 t meatweight in 2001), but increased to record high levels in 2005 (1795 t) and 2006 (1531 t). There was a trend of decreasing biomass from the peak in 2005 to the 2009 estimate of 595 t. The comprehensive 2012 survey coverage included a large new area of the fishery in Hauraki Gulf, and showed that it held a considerable biomass. It is unknown whether the large biomass of scallops found in 2012 is a consistent part of the population, or a product of successful recruitment in recent years. Including that 'new' area, projected biomass in 2012 was an estimated 1380 t.
Recent Trend in Fishing Intensity or Proxy	At the fishery-wide level, estimated fishing mortality on scallops 90 mm or more was relatively low in the periods 1998–99 and 2004–12 (mean F_{est} = 0.19 y^{-1}).
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Stock projections beyond the start of the 2012 season are not available. Catch, catch rates and growth are highly variable both within and among years. Recruitment is also highly variable between years.
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	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial quantitative stock assessment	
Assessment Method	Biomass surveys and CAY estimate	
Assessment Dates	Latest assessment: 2012	Next assessment: Unknown
Overall Assessment Quality Rank	1 – High Quality	
Main data inputs (rank)	Biomass survey: 2012	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	None since the 2009 assessment.	
Major Sources of Uncertainty	- dredge efficiency during the survey - growth rates and natural mortality between the survey and the start of the season - predicting the average recovery of meatweight from greenweight - the extent to which dredging causes incidental mortality and affects recruitment	

Qualifying Comments
In the Coromandel fishery some scallop beds are persistent and others are ephemeral. The extent to which the various beds or populations are reproductively or functionally separate is not known.
Fishery Interactions
A bycatch survey was conducted in the Coromandel fishery in 2009 under project SCA2007-01B. The results are summarised below. The bycatch of the fishery is likely to be similar to that of the survey. Bycatch composition Live components • Scallops 26% • Seaweed 11% • Starfish 4% • Other bivalves 4% • Coralline turf 1% Dead components • Dead shell 45% • Rock and gravel 8% Bycatch data were also collected during the 2010 and 2012 surveys of SCA CS; the data were loaded to the MPI database "*scallop*" for use in future work.

6. FOR FURTHER INFORMATION

Begon, M; Harper, J L; Townsend, C R (1990). Ecology: Individuals, Populations and Communities. Blackwell Science, Cambridge. 945 p.

Bian, R; Williams, J R; Smith, M; Tuck, I D (2011) Modelling dredge efficiency for scallop fisheries in northeastern New Zealand. Final Research Report for Ministry of Fisheries project SAP200913. (Unpublished report held by Ministry for Primary Industries.)

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. 81 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Boyd, R O; Reilly, J L (2002) 1999/2000 National marine recreational fishing survey: harvest estimates. Final Research Report for Ministry of Fisheries project REC98/03. 28 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Bradford, E (1997) Estimated recreational catches from Ministry of Fisheries North region marine recreational fishing surveys, 1993–94. New Zealand Fisheries Assessment Research Document 97/7. 16 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. 27 p. (Unpublished report held in NIWA library, Wellington.)

Bull, M F (1991a) New Zealand. pp 853–859 in Shumway S.E. (Ed) *Scallops: biology, ecology and aquaculture. Developments in Aquaculture & Fisheries Science*, 21. Elsevier. Amsterdam. 1095p.

Bull, M F (1991b) Report on a survey of the scallop resource at the Chatham Islands 22 April – 5 May 1990. Central Fisheries Region Internal Report No. 16. 29 p.

Bull, M F (1976). Aspects of the biology of the New Zealand scallop, *Pecten novaezelandiae* Reeve 1853, in the Marlborough Sounds. Unpublished PhD thesis. Victoria University of Wellington, New Zealand. 175 p.

Cranford, P J; Gordon, D C (1992). The influence of dilute clay suspensions on sea scallop (*Placopecten magellanicus*) feeding activity and tissue growth. *Netherlands Journal of Sea Research 30*: 107-120.

Cryer, M (1994) Estimating CAY for northern commercial scallop fisheries: a technique based on estimates of biomass and catch from the Whitianga bed. New Zealand Fisheries Assessment Research Document 1994/18. 21 p. (Unpublished report held by NIWA library, Wellington.)

Cryer, M (2001a) Coromandel scallop stock assessment for 1999. *New Zealand Fisheries Assessment Report 2001/9*. 18 p.

Cryer, M (2001b) An appraisal of an in-season depletion method of estimating biomass and yield in the Coromandel scallop fishery. *New Zealand Fisheries Assessment Report 2001/8*. 28 p.

Cryer, M (2002) Northland and Coromandel scallop stock assessments for 2001. *New Zealand Fisheries Assessment Report 2002/60*. 20 p.

Cryer, M; Breen, P A; Kendrick, T H (2003b) Models to evaluate fishing strategies for northern scallop fisheries. Final Research Report for Ministry of Fisheries Research Project MOF2000/03E. 61 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cryer, M; Davies, N M; Morrison, M (2004). Collateral damage in scallop fisheries: translating "statistics" into management advice. Presentation and working document for Shellfish Fishery Assessment Working Group, March 2004. p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cryer, M; Morrison, M (1997) Yield per recruit in northern commercial scallop fisheries: inferences from an individual-based population model and experimental estimates of incidental impacts on growth and survival. Final Research Report for Ministry of Fisheries project AKSC03. 67 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cryer, M; Morrison, M; Davies, N M (2003a) Including incidental effects in fisheries models can have major implications for management advice: an example based on scallop dredging. Submitted to Canadian Journal of Fisheries and Aquatic Sciences, also presented to 2003 meeting of New Zealand Marine Sciences Society.

Cryer, M; O'Shea, S; Gordon, D P; Kelly, M; Drury, J D; Morrison, M A; Hill, A; Saunders, H; Shankar, U; Wilkinson, M; Foster, G (2000). Distribution and structure of benthic invertebrate communities between North Cape and Cape Reinga. Final Research Report by NIWA for Ministry of Fisheries Research Project ENV9805 Objectives 1–4. p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cryer, M; Parkinson, D M (1999) Dredge surveys and sampling of commercial landings in the Northland and Coromandel scallop fisheries, May 1998. *NIWA Technical Report* 69. 63 p.

Cryer, M; Parkinson, D M (2001) Dredge surveys of scallops in the Northland and Coromandel scallop fisheries, April–May 2001. Working Document for Ministry of Fisheries Shellfish Fishery Assessment Working Group Meeting June 2001. 40 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cryer, M; Parkinson, D M (2004a) Dredge survey and stock assessment for the Coromandel scallop fishery, 2003. Final Research Report for Ministry of Fisheries project SCA2002/01. 36p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cryer, M; Parkinson, D M (2004b) Dredge survey and stock assessment for the Coromandel scallop fishery, 2004. Research Progress Report and working document for Shellfish Fishery Assessment Working Group (June 2004), Ministry of Fisheries project SCA2003/01. 36 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cryer, M; Parkinson, D M (2006) Biomass surveys and stock assessments for the Coromandel and Northland scallop fisheries, 2005. *New Zealand Fisheries Assessment Report 2006/34*. 53 p.

Department of Fisheries and Oceans (2006). Impacts of trawl gear and scallop dredges on benthic habitats, populations and communities. *DFO Canadian Science Advisory Secretariat Science Advisory Report 2006/025*: 13 p.

Diggles, B; Chang, H; Smith, P; Uddstrom, M; Zeldis, J (2000) A discolouration syndrome of commercial bivalve molluscs in the waters surrounding the Coromandel Peninsula. Final Research Report for Ministry of Fisheries Project MOF1999/04B. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Haist, V; Middleton, D (2010) Management Strategy Evaluation for Coromandel Scallop, April 2010. Seafood Industry Council Report. 54 p (Unpublished report held by the Seafood New Zealand).

Hancock, D A (1973) The relationship between stock and recruitment in exploited invertebrates. *Rapports et Process Verbeaux de la Reunion du Conseil Intrenationale pour l'Exploration de la Mer* 164: 113–131.

Holdsworth, J C; Walshe, K (2009) Harvest survey from the recreational scallop and rock lobster fisheries in eastern Coromandel, 2007–08. Draft New Zealand Fisheries Assessment Report for Ministry of Fisheries project REC200711. 24p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Kaiser, M J; Clarke, K R; Hinz, H; Austen, M C V; Somerfield, P J; Karakassis, I (2006). Global analysis of the response and recovery of benthic biota to fishing. *Marine Ecology Progress Series 311*: 1–14.

Macdonald, B A; Bricelj, M; Shumway, S E (2006). Physiology: Energy Aquisition and Utilisation. *In*: Shumway, S.E.; Parsons, G.J. (eds.) Scallops: Biology, Ecology and Aquaculture, pp. 417–492. *Developments in aquaculture and fisheries science*. Elsevier, Amsterdam.

Ministry for Primary Industries (2013a). Coromandel scallops (SCA CS): Total Allowable Catch Review Final Advice. Final Advice Paper to the Minister for Primary Industries. 46 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Ministry for Primary Industries (2013b). Fisheries Assessment Plenary, May 2013: stock assessments and yield estimates. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1357 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.

Morrison, M (1998) Population dynamics of the scallop, *Pecten novaezelandiae*, in the Hauraki Gulf. Unpublished PhD thesis, University of Auckland, Auckland, New Zealand. 157 p.

Morton, J E; Miller, M C (1968). The New Zealand sea shore. Collins, Auckland, New Zealand. 638 p.

Nesbit, G J (1999). Reseeding and hatchery potential of *Pecten novaezelandiae* and effects of recreational harvesting. Unpublished MSc thesis. University of Auckland, New Zealand. 145 p.

Nicholls, P; Hewitt, J; Halliday, J (2003). Effects of suspended sediment concentrations on suspension and deposit feeding marine macrofauna. NIWA Client Report HAM2003-077 prepared for Auckland Regional Council (NIWA Project ARC03267). August. 43 p. ARC Technical Publication No. 211.

Orensanz, J M; Parma, A M; Iribarne, O O (1991) Population dynamics and management of natural stocks. Ch. 13 *In*: Shumway, S E (Ed.) *Scallops: biology ecology and aquaculture. Developments in Aquaculture and Fisheries Science*, 21. Elsevier, Amsterdam. 1095 p.

Peterson, C H; Summerson, H C (1992) Basin–scale coherence of population dynamics of an exploited marine invertebrate, the bay scallop: implications of recruitment limitation. *Marine Ecology Progress Series* 90: 257–272.

Peterson, C H; Summerson, H C; Leuttich, R A (1996) Response of Bay scallops to spawner transplants: a test of recruitment limitation. *Marine Ecology Progress Series* 132: 93–107.

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.

Stevens, P M (1987). Response of excised gill tissue from the New Zealand scallop *Pecten novaezelandiae* to suspended silt. *New Zealand Journal of Marine and Freshwater Research 21*: 605-614.

Shumway, S E (Ed.) (1991) *Scallops: biology, ecology and aquaculture. Developments in Aquaculture and Fisheries Science*, 21. Elsevier. Amsterdam. 1095 p.

Shumway, S E; Sandifer, P A (Eds.) (1991) Scallop biology and culture. Selected papers from the 7th International Pectinid Workshop. World Aquaculture Society, Baton Rouge, Louisiana, USA.

Talman, S G; Norkko, A; Thrush, S F; Hewitt, J E (2004) Habitat structure and the survival of juvenile scallops *Pecten novaezelandiae*: comparing predation in habitats with varying complexity. *Marine Ecology Progress Series* 269: 197–207.

Thrush, S F; Hewitt, J E; Cummings, V J; Dayton, P K (1995). The impact of habitat disturbance by scallop dredging on marine benthic communities: what can be predicted from the results of experiments? *Marine Ecology Progress Series 129*: 141–150.

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; Hewitt, J E; Funnell, G A; Cummings, V J; Ellis, J; Schultz, D; Talley, D; Norkko, A (2001) Fishing disturbance and marine biodiversity: the role of habitat structure in simple soft-sediment systems. *Marine Ecology Progress Series* 223: 277–286.

Tuck, I D (2011) Utility of scallop surveys in predicting future year's CAY. Final Research Report for Ministry of Fisheries project SEA2010-11. 29 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Tuck, I D; Drury, J; Kelly, M; Gerring, P (2009). Designing a programme to monitor the recovery of the benthic community between North Cape and Cape Reinga. Final Research Report by NIWA for Ministry of Fisheries Research Project ENV2005-23. x p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Tuck, I D; Hewitt, J E (2012). Monitoring change in benthic communities in Spirits Bay. Final Research Report by NIWA for Ministry of Fisheries research project BEN200901. 51 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Tuck, I; Hewitt, J; Handley, S; Willis, T; Carter, M; Hadfield, M; Gorman, R; Cairney, D; Brown, S; Palmer, A (2011). Assessing the effects of fishing on soft sediment habitat, fauna and processes. Progress Report for Ministry of Fisheries project BEN2007-01. 30 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Tuck, I; Parkinson, D; Dey, K; Oldman, J; Wadhwa, S (2006). Information on benthic impacts in support of the Coromandel Scallops Fishery Plan. Final Research Report prepared by NIWA for Ministry of Fisheries Research Project ZBD2005-15 Objective 1-6. p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Tuck, I D; Williams, J R (2012). Scallop growth. Final Research Report for Ministry of Fisheries project SCA200903. 71 p. (Unpublished report held by Ministry of Fisheries, Wellington.)

Walshe, K A R (1984) A study to determine the optimum number of licences for the Tauranga commercial scallop fishery based on a optimum yield estimate. Unpublished report for Diploma in Business and Administration, Massey University, Palmerston North, New Zealand.

Waller, T R (1991) Evolutionary relationships among commercial scallops (Mollusca: Bivalva: Pectinidae). pp 1–74 in Shumway, S E (Ed.) *Scallops: biology, ecology and aquaculture. Developments in Aquaculture and Fisheries Science*, 21. Elsevier. Amsterdam. 1095 p.

Williams, J R (2005) Reproductive ecology of the scallop, *Pecten novaezelandiae*. Unpublished PhD thesis, University of Auckland, Auckland, New Zealand. 134 p.

Williams, J R (2007) Biomass surveys and stock assessments for the Coromandel and Northland scallop fisheries, 2007. *New Zealand Fisheries Assessment Report 2008/35*. 41 p

Williams, J R (2009a) Abundance of scallops (*Pecten novaezelandiae*) in Coromandel recreational fishing areas, 2008. *New Zealand Fisheries Assessment Report 2009/8*. 18 p.

Williams, J R (2009b) Abundance of scallops (*Pecten novaezelandiae*) in Northland and Coromandel recreational fishing areas, 2007. *New Zealand Fisheries Assessment Report 2009/62*. 22 p.

Williams, J R (2009c) Biomass survey and stock assessment for the Coromandel scallop fishery, 2008. *New Zealand Fisheries Assessment Report 2009/02*. 31 p.

Williams, J R (2012) Abundance of scallops (*Pecten novaezelandiae*) in Coromandel recreational fishing areas, 2009 and 2010. *New Zealand Fisheries Assessment Report 2012/24*. 29 p.

Williams, J R; Babcock, R C (2004a) Patterns of reproduction and spawning behaviour for scallops, *Pecten novaezelandiae*, in north eastern New Zealand. *Journal of Shellfish Research* 23: 318.

Williams, J R; Babcock, R C (2004b) Comparison of multiple techniques to evaluate reproductive variability in a marine bivalve: application to the scallop *Pecten novaezelandiae*. *Marine and Freshwater Research* 55: 457–468.

Williams, J R; Babcock, R C (2005) Assessment of size at maturity and gonad index methods for the scallop *Pecten novaezelandiae*. *New Zealand Journal of Marine and Freshwater Research* 39: 851–864.

Williams, J R; Hartill, B; Bian, R; Tuck, I D (2011) Review of difference between CAY estimates and actual catch for the SCA CS scallop fishery. Final Research Report for Ministry of Fisheries project SAP200910. (Unpublished report held by Ministry for Primary Industries.)

Williams, J R; Hartill, B; Bian, R; Williams, C L (2013a). Review of the Southern scallop fishery (SCA 7). Draft New Zealand Fisheries Assessment Report report for project SCA200704, submitted to MPI in November 2013. 66 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Williams, J R; Parkinson, D M (2010) Biomass survey and stock assessment for the Coromandel scallop fishery, 2010. *New Zealand Fisheries Assessment Report 2010/37*. 30 p.

Williams, J R; Parkinson, D M; Bian, R (2013b). Biomass survey and yield calculation for the Coromandel scallop fishery, 2012. *New Zealand Fisheries Assessment Report 2013/18*: 57 p.

Williams, J R; Parkinson, D M; Tuck, I D (2010) Biomass survey and stock assessment for the Coromandel scallop fishery, 2009. *New Zealand Fisheries Assessment Report 2010/33*. 40 p.

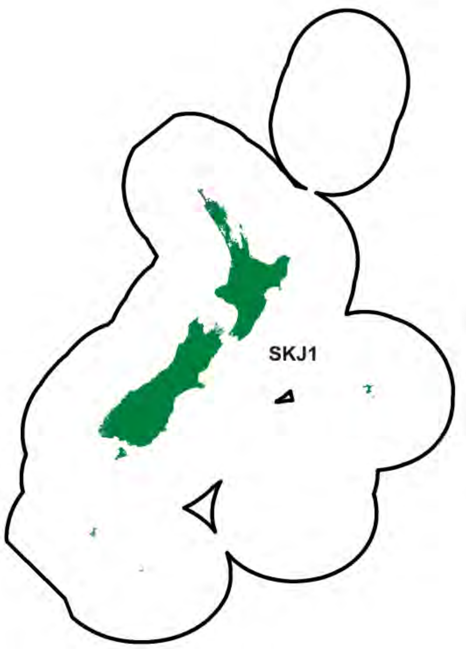
Williams, J R; Tuck, I D; Carbines, G D (2008) Abundance of scallops (*Pecten novaezelandiae*) in Northland and Coromandel recreational fishing areas, 2006. *New Zealand Fisheries Assessment Report 2008/34*. 23 p.

Williams, J R; Tuck, I D; Parkinson, D M (2007) Biomass surveys and stock assessments for the Coromandel and Northland scallop fisheries, 2006. *New Zealand Fisheries Assessment Report 2007/24*. 41 p.

Wynne-Jones, J; Heinemann, A; Gray, A; Hill, L (in review). NZ recreational marine fishing survey 2011-2012. Draft New Zealand Fisheries Assessment Report by National Research Bureau Ltd. 69 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

SKIPJACK TUNA (SKJ)

(Katsuwonus pelamis)
Aku



1. FISHERY SUMMARY

Management of skipjack tuna throughout the Western and Central Pacific Ocean (WCPO) is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). Under this regional convention New Zealand is responsible for ensuring that the management measures applied within New Zealand fisheries waters are compatible with those adopted by the Commission.

1.1 Commercial fisheries

Skipjack was the first commercially exploited tuna in New Zealand waters, with landings beginning in the 1960s in the Taranaki Bight and quickly extending to the Bay of Plenty. The fishery in New Zealand waters has been almost exclusively a purse seine fishery, although minor catches (less than 1%) are taken by other gear types (especially troll). The purse seine fishery for the years 2006 to 2010 was based on a few (5–7 medium sized vessels under 500 GRT) operating on short fishing trips assisted by fixed wing aircraft, acting as spotter planes, in FMA 1, FMA 2 and occasionally FMA 9 during summer months. In addition, during the late 1970s and early 1980s a fleet of US purse seiners seasonally operated in New Zealand waters. During this period total annual catches were about 9000 t. Since 2001, however, New Zealand companies have also operated four large ex-US super seiners which fish for skipjack in the EEZ, on the high seas, and in the EEZs of various Pacific Island countries in equatorial waters.

Domestic landings within the EEZ Between 2001 and 2013 ranged between 3 555t and 13 312 t (Table 1). Catches in the New Zealand EEZ are variable and can approximate 10 000 t in good seasons such as 1999–00, 2003–04, 2004–05, 2006–07, 2007–08, 2010–11, 2011–12 and 2012–13.

Table 1 compares New Zealand landings with total catches from the WCPO stock, while Table 2 shows the catches reported on commercial logsheets and Monthly Harvest Returns. Figure 1 shows historical landings for SKJ fisheries.

Catches from within New Zealand fisheries waters are very small (0.6% average for 2007–2013) compared to those from the greater stock in the WCPO. Catches by New Zealand flagged vessels in the WCPO are larger (0.9% average for 2007–2013).

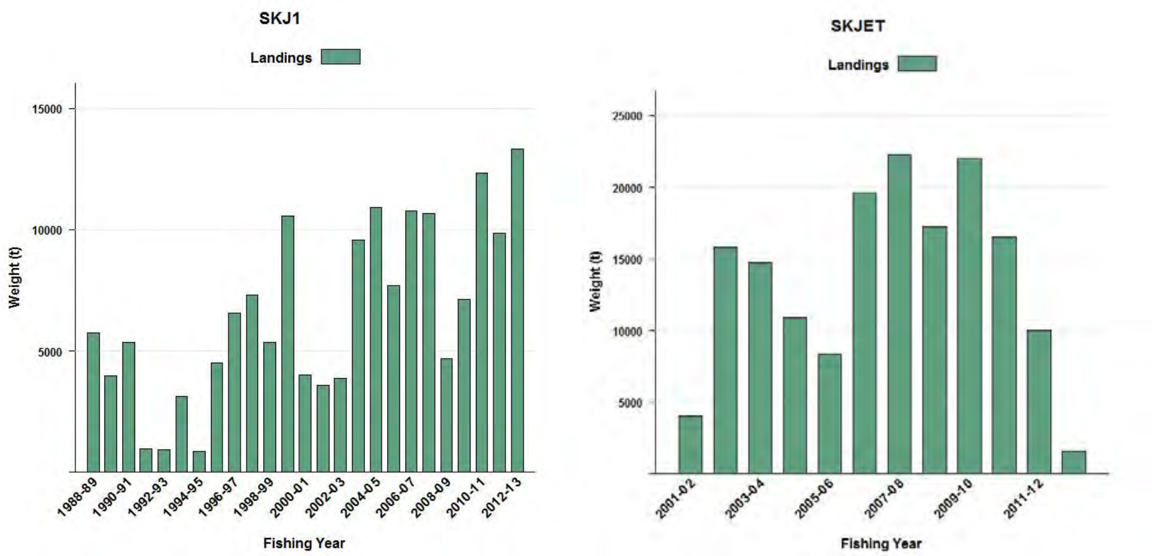


Figure 1: Skipjack purse seine catch from 1988–89 to 2012–13 within New Zealand waters (SKJ 1), and 2001–02 to 2012–13 in the equatorial Pacific by New Zealand vessels.

Table 1: Total New Zealand landings (t) both within and outside the New Zealand EEZ, and total landings from the Western and Central Pacific Ocean (t) of skipjack tuna by calendar year from 2001 to 2013.

	NZ landings (t)			All WCPO Landings
Year	Within NZ fisheries waters	Outside NZ fisheries waters*	Total	Total landings (t)
2001	4 261	4 069	8 330	1 106 302
2002	3 555	15 827	19 382	1 276 919
2003	3 828	14 769	18 597	1 278 420
2004	9 704	10 932	20 636	1 399 138
2005	10 819	8 335	19 154	1 395 737
2006	7 247	19 588	26 835	1 477 438
2007	11 392	22 266	33 659	1 659 557
2008	10 033	17 204	27 237	1 639 651
2009	4 685	21 991	26 676	1 777 598
2010	8 629	16 530	25 153	1 690 145
2011	10 840	9 999	20 839	1 524 599
2012	9 881	8 016	17 897	1 727 773
2013	13 312	10 207	23 520	1 771 822

*Includes some catches taken in the EEZs of other countries under access agreements.
Source: Ministry for Primary Industries Catch, Effort, Landing Returns, High Seas reporting system; OFP (2010); and Anon (2013).

Table 2: Reported commercial catches (t) within New Zealand fishing waters of skipjack by fishing year from catch effort data (mainly purse seine fisheries), and estimated landings from LFRRs (processor records) and Monthly Harvest Returns (MHRs).

Year	Total catches from catch/effort	LFRR	MHR
1988–89	0	5 769	
1989–90	6 627	3 972	
1990–91	7 408	5 371	
1991–92	1 000	988	
1992–93	1 189	946	
1993–94	3 216	3136	
1994–95	1 113	861	
1995–96	4 214	4 520	
1996–97	6 303	6 571	
1997–98	7 325	7 308	
1998–99	5 690	5 347	
1999–00	10 306	10 561	
2000–01	4 342	4 020	
2001–02	3 840	3 487	3 581
2002–03	3 664	2 826	3 868
2003–04	9 892	9 225	9 606
2004–05	10 311	8 301	10 928
2005–06	7 220	7 702	7702
2006–07	10 115	10 761	10 762
2007–08	10 116	10 665	10 665
2008–09	4 384	4 737	4 685
2009–10		8 020	7 141
2010–11		17 764	12 326
2011–12		11 814	9 866
2012–13		14 895	13 334

Skipjack tuna account for the largest proportion of purse seine target sets in New Zealand fishery waters (Figure 2). However, jack mackerel make up the bulk of the catch and skipjack tuna account for only 25% of the landed mass of the domestic purse seine fleet (Figure 3). The skipjack tuna catch occurs on both the east and west coasts of the North Island (Figure 4).

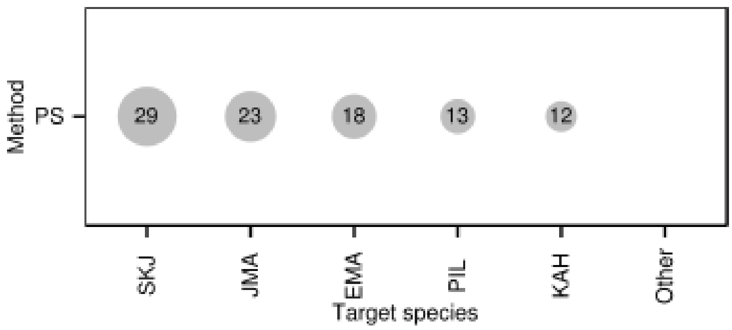


Figure 2: A summary of the proportion of target sets in the domestic purse seine fishery. The area of each circle represents the percentage of the vessel days targeting each species PS = purse seine (Bentley et al 2013).

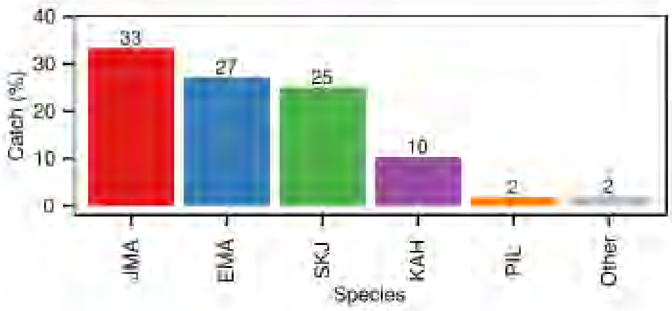


Figure 3: A summary of species composition for all reported domestic purse seine catches. The percentage by weight of each species is calculated for all domestic trips (Bentley et al 2013).

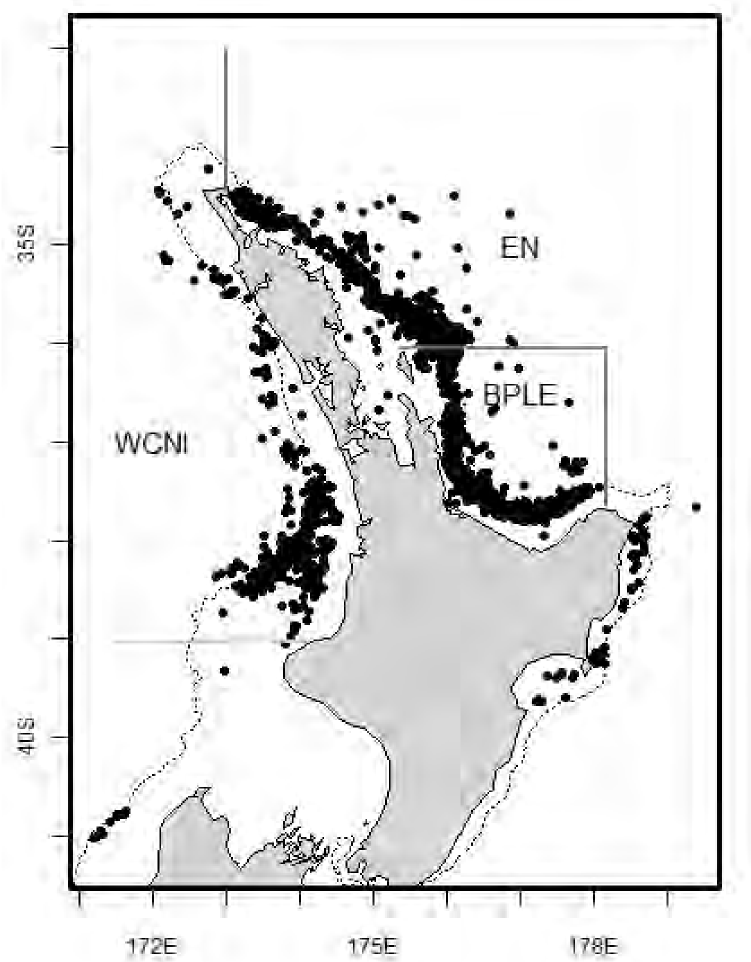


Figure 4: Location of purse-seine sets targeting skipjack tuna from 1999–2000 to 2008–09. The solid grey lines denote the boundaries of the main fishery areas (EN, east Northland, BPLE, Bay of Plenty; WCNI, west coast North Island). The dashed line represents the 200 m depth contour (Langley 2011).

Fishing activity for skipjack tuna by New Zealand flagged vessels outside of New Zealand fishery waters is generally limited to within the 10° S to 5° N latitudinal range (Figure 5). The distribution of fishing activity is largely constrained to areas of international waters ("high seas") and the national waters of those countries for which the fleet has established access arrangements, most notably the EEZs of Tuvalu and Kiribati (Table 3). A limited amount of fishing has also occurred in the waters of Nauru, Solomon Islands, Tokelau, Federal States of Micronesia (FSM) and Marshall Islands although the activity in these areas has either been intermittent or maintained at a low level. Fishing access to a country's national waters is generally negotiated collectively under the auspices of the New Zealand Far Seas Tuna Fishers Association. However, the individual members of the association may decide not to purchase a licence in a specific year (Langley 2011).

There are four main areas of international waters within the western equatorial Pacific. Of these areas, most of the fishing by the New Zealand fleet has been within the area of international waters surrounded by the national waters of Nauru, Kiribati (Gilbert Islands), Tuvalu, Solomon Islands, Papua New Guinea and FSM (the so called "high seas pockets", denoted A2 in Figure 5. The fleet also operates in the narrow strip of international waters between Tuvalu and the Phoenix Islands (Kiribati) (area A3) and intermittently in the eastern area of international waters between the Phoenix Islands and Line Islands (Kiribati) (area A4). Limited fishing has occurred in the international waters between Papua New Guinea and FSM (area A1). Overall, the areas of international waters account for about 30% of the annual level of fishing activity and skipjack tuna catch of the New Zealand fleet operating in the equatorial fishery (Table 3) (Langley 2011).

Total fishing effort (number of sets) was highest in 2002 and was dominated by fishing within Kiribati waters. In the subsequent years, the fishing effort tended to fluctuate about the average level, with higher levels of effort in 2006 and 2009 and lower effort in 2005 and 2007 (Table 3) (Langley 2011).

In the initial years (2002–2005), there was considerable variability in the distribution of fishing effort among the main fishing areas. Fishing effort in Kiribati waters was high in 2002 and 2005 and fishing effort in Tuvalu waters was low in 2003 when a considerable amount of fishing occurred in the waters of FSM. During 2006–2009, the distribution of fishing effort was relatively stable with international waters and the EEZs of Tuvalu and Kiribati each accounting for about 25–35% of the annual fishing effort and 5–15% of the total effort occurring in other areas (Table 3) (Langley 2011).

1.2 Recreational fisheries

Recreational fishers using rod and reel regularly catch skipjack tuna particularly in FMA 1, FMA 2 and FMA 9. They do not comprise part of the voluntary recreational tag and release programme and there is limited information on the size of the recreational catch. Much of the recreational skipjack catch is used as bait. The provisional results of the national survey of amateur harvest in 2011–12 (Large Scale Multi Species Survey) estimated about 41,000 skipjack tuna were kept with an estimated weight of 92 tonne. This is a similar harvest weight to that for albacore tuna in the same survey.

1.3 Customary non-commercial fisheries

There is no information on the customary take, but it is considered to be low.

1.4 Illegal catch

There is no known illegal catch of skipjack tuna.

1.5 Other sources of mortality

Skipjack tuna are occasionally caught as bycatch in the tuna longline fishery in small quantities; because of their low commercial value this bycatch are often discarded.

Table 3: Number of sets conducted by New Zealand flagged purse-seine vessels operating within areas of international waters (IW) and countries EEZ's in the western equatorial Pacific fishery by calendar year. KI denotes Kiribati. Areas of international waters (A1–4) are defined in Figure 5 (Langley 2011).

Area									Year
	2001	2002	2003	2004	2005	2006	2007	2008	2009
IW A1	0	0	50	0	0	0	0	0	0
IW A2	7	58	114	73	52	189	125	163	110
IW A3	7	15	74	37	16	39	43	19	30
IW A4	0	126	3	5	39	29	1	0	48
FSM	0	1	143	0	0	0	0	0	0
Gilbert Is (KI)	43	92	130	122	111	133	90	112	37
Line Is (KI)	0	149	0	0	3	0	27	0	0
Pheonix Is (KI)	12	126	31	44	144	49	62	9	164
Marshall Islands	0	0	4	6	10	0	0	0	0
Nauru	0	0	0	44	30	17	17	21	0
Solomon Islands	0	0	65	77	4	71	2	89	25
Tokelau	0	12	1	0	1	0	0	0	32
Tuvalu	94	187	29	136	81	138	141	169	211
Other	0	5	14	3	1	6	3	1	1
Total	163	771	658	547	492	671	511	583	658
% IW	9	26	37	21	22	38	33	31	29

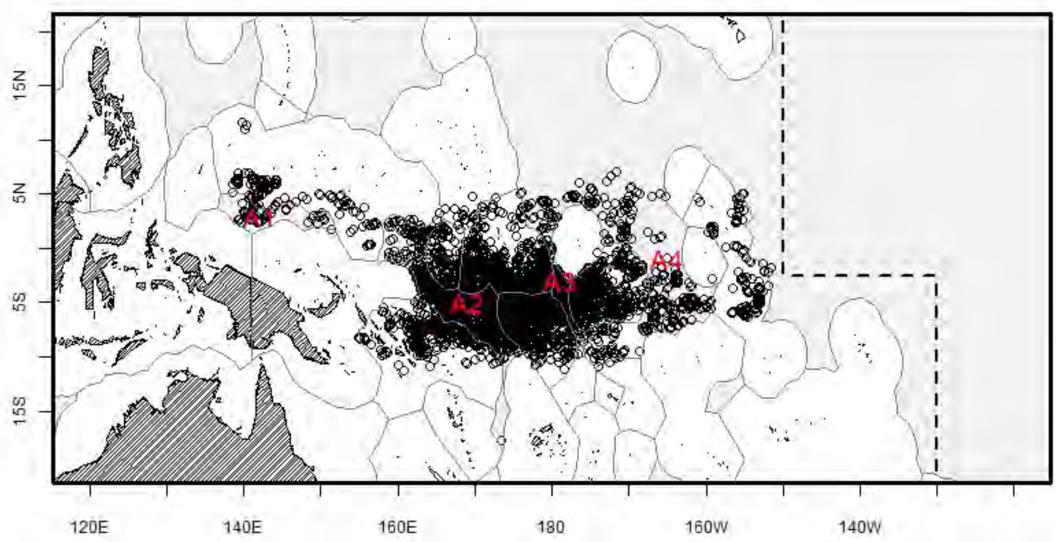


Figure 5: Distribution of purse-seine set locations for New Zealand flagged vessels operating in the equatorial region of the western Pacific Ocean from 2001 to 2009. The red labels (A 1–4) denote the four areas of international waters referred to in the text.

2. BIOLOGY

Skipjack tuna are epi-pelagic opportunistic predators of fish, crustaceans and cephalopods found within the upper few hundred meters of the surface. Individual tagged skipjack tuna are capable of movements of over several thousand nautical miles but also exhibit periods of residency around islands in the central and western Pacific, resulting in some degree of regional fidelity. Skipjack are typically a schooling species with juveniles and adults forming large schools at or near the surface in tropical and warm-temperate waters to at least 40ºS in New Zealand waters. Individuals found in New Zealand waters are mostly juveniles, which also occur more broadly across the Pacific Ocean, in both the northern and southern hemisphere. Adult skipjack reach a maximum size of 34.5 kg and lengths of 108 cm. The maximum reported age is 12 years old although the maximum time at liberty for a tagged skipjack of 4.5 years indicates that skipjack grow rapidly (reach 80 cm by age 4) and probably few fish live beyond 5 years old. Spawning takes place in equatorial waters across the entire Pacific Ocean throughout the year, in tropical waters spawning is almost daily. Recruitment shows a strong positive correlation with periods of El Niño.

Natural mortality is estimated to vary with age, with maximum values at age 1 and declining for older fish. A range of von Bertalanffy growth parameters has been estimated for skipjack in the western and central Pacific Ocean, depending on the area and the size of skipjack studied (Table 4). For skipjack tuna in the Pacific Ocean, the intrinsic rate of increase (k) is inversely related to asymptotic length (L_∞) by a power relationship; both parameters are also weakly correlated with sea surface temperature over the range 12º to 29º C.

Length frequency data were available from the MPI observer programme. In most years, the sampled component of the skipjack tuna purse-seine catch from the main fishery area was dominated by fish in the 40–50 cm (FL) length range (Figure 6). Considerably larger fish were caught in the Bay of Plenty and East Northland fisheries in 2004–05 and in the North Taranaki Bight fishery in 2005–06 and 2006–07. The modal structure in the length composition data indicates that the fishery is principally catching fish of 1–2 years of age (Tanabe et al 2003 estimated that skipjack tuna in the western Pacific reach 45 cm at 1 year and 65 cm at 2 years old) (Langley 2011).

Table 4: The range in L_∞ and k by country or area.

Country/Area	L_∞ (cm)	k
Hawaii	84.6 to 102.0	1.16 to 0.55
Indonesia	79.0 to 80.0	1.10 to 0.95
Japan	144.0	0.185
Papua New Guinea	65.0 to 74.8	0.92 to 0.52
Philippines	72.0 to 84.5	0.70 to 0.51
Taiwan	104.0	0.30 to 0.43
Vanuatu	62.0	1.10
Western Pacific	61.3	1.25
Western tropical Pacific	65.1	1.30

3. STOCKS AND AREAS

Surface-schooling, adult skipjack tuna (over 40 cm fork length, FL) are commonly found in tropical and subtropical waters of the Pacific Ocean.

Skipjack in the western and central Pacific Ocean (WCPO) are considered a single stock for assessment purposes. A substantial amount of information on skipjack movement is available from tagging programmes. In general, skipjack movement is highly variable but is thought to be influenced by large-scale oceanographic variability. In the western Pacific, warm, poleward-flowing currents near northern Japan and southern Australia extend their distribution to 40°N and 40°S. These limits roughly correspond to the 20°C surface isotherm.

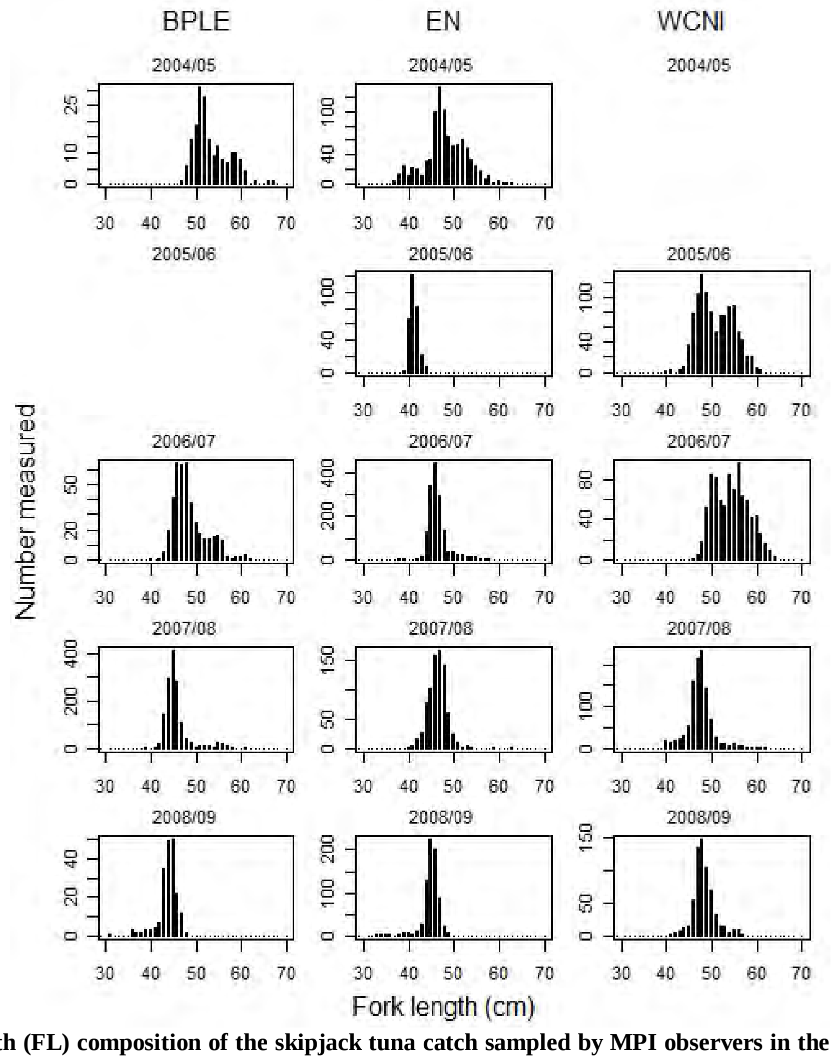


Figure 6: Length (FL) composition of the skipjack tuna catch sampled by MPI observers in the domestic target purse-seine fishery by fishery area (columns) and fishing year (rows) (fishery areas: BPLE, Bay of Plenty; EN, east Northland; WCNI, west coast North Island) (Langley 2011).

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2014 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of the skipjack tuna fishery; a more detailed summary from an issue-by-issue perspective is, or will shortly be, available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed (http://www.mpi.govt.nz/Default.aspx?TabId=126&id=2122) (Ministry for Primary Industries 2013).

4.1 Role in the ecosystem

Skipjack tuna (*Katsuwonus pelamis*) average 45–60 cm length in New Zealand, reaching an upper maximum of around 70 cm (Paul 2000). Skipjack are prey of larger tuna, HMS sharks and billfish.

4.2 Incidental bycatch

4.2.1 Purse seine fishery

4.2.1.1 Protected species bycatch

In the domestic skipjack purse seine fishery observer rates are relatively high. Relative to the skipjack catch (Table 5), observed bycatch is minor and consists mostly of teleosts. Spinetail devil rays (*Mobula japanica*) are the only protected species that have been observed captured by purse seine vessels in New Zealand. Work is underway to develop safe release methods for protected species, including sharks and rays. Overall Jack mackerel and blue mackerel are the most common teleost bycatch by weight but small numbers of large individuals such as striped marlin and mako sharks are also landed (Table 6).

Table 5: Domestic purse seine sets targeting skipjack tuna observed as a percentage of sets made for 2005–2013.

Calendar year	No. sets observed	% sets observed	% SKJ catch
2005	37	4.7	4.5
2006	104	17.6	35.5
2007	77	14.8	25.2
2008	118	27.6	57.3
2009	83	10.4	33.1
2010	109	8.8	15.3
2011	125	11.9	23.8
2012	113	9.5	19.7
2013	112	9.2	19.8

Table 6: Catch composition from six observed purse seine trips targeting skipjack tuna operating within New Zealand fisheries waters in 2011 and 2013 [Continued on next page].

Common name	**Scientific name**	**Observed catch weight (kg)**	**% Catch**
Skipjack tuna	*Katsuwonus pelamis*	4 416 546	98.90
Jack mackerel	*Trachurus* spp.	22 057	0.49
Blue mackerel	*Scomber australasicus*	14 310	0.32
Sunfish	*Mola mola*	4 555	0.10
Spine-tailed devil ray	*Mobula japonica*	2 700	0.06
Striped marlin	*Tetrapturus audax*	1 520	0.03
Frigate tuna	*Auxis thazard*	1 010	0.02
Albacore tuna	*Thunnus alalunga*	679	0.02
Thresher shark	*Alopias vulpinus*	520	0.01
Jellyfish	Scyphozoa	309	0.01
Hammerhead shark	*Sphyrna zygaena*	245	0.01

Table 6 [Continued]: Catch composition from six observed purse seine trips targeting skipjack tuna operating within New Zealand fisheries waters in 2011 and 2013.

Common name	Scientific name	Observed catch weight (kg)	% Catch
Stingray	Dasyatididae	185	<0.01
Mako shark	*Isurus oxyrinchus*	158	<0.01
Swordfish	*Xiphias gladius*	150	<0.01
Frostfish	*Lepidopus caudatus*	102	<0.01
Flying fish	Exocoetidae	84	<0.01
Ray's bream	*Brama brama*	81	<0.01
Bronze whaler shark	*Carcharhinus brachyurus*	80	<0.01
Blue shark	*Prionace glauca*	70	<0.01
Slender tuna	*Allothunnus fallai*	50	<0.01
Snapper	*Pagrus auratus*	23	<0.01
Kahawai	*Arripis trutta*	20	<0.01
Porcupine fish	*Allomycterus jaculiferus*	15	<0.01
Tarakihi	*Nemadactylus macropterus*	15	<0.01
Electric ray	*Torpedo fairchildi*	12	<0.01
Pufferfish	*Sphoeroides pachygaster*	9	<0.01
Octopus	Octopoda	7	<0.01
Squid	Teuthoidea	7	<0.01
Kingfish	*Seriola lalandi*	6	<0.01
Rough skate	*Dipturus nasutus*	4	<0.01
Dolphinfish	*Coryphaena hippurus*	3	<0.01
Paper nautilus	*Argonauta nodosa*	2	<0.01
Pelagic ray	*Pteroplatytrygon violacea*	2	<0.01
John dory	*Zeus faber*	2	<0.01
Leatherjacket	*Parika scaber*	2	<0.01
Porae	*Nemadactylus douglasi*	2	<0.01
Rudderfish	*Centrolophus niger*	2	<0.01
Smooth skate	*Dipturus innominatus*	2	<0.01
Jack mackerel	*Trachurus murphyi*	1	<0.01
Pipefish	Syngnathidae	1	<0.01

5. STOCK ASSESSMENT

Recent stock assessments of the western and central Pacific Ocean stock of skipjack tuna have been undertaken by the Oceanic Fisheries Programme (OFP) of the Secretariat of the Pacific Community (SPC) under contract to WCPFC.

No assessment is possible for skipjack tuna within the New Zealand fisheries waters as the proportion of the greater stock found here is unknown and is likely to vary from year to year.

The skipjack stock assessment was updated by the SPC in 2014 in SC10-SA-WP-0 (Rice et. al. 2014) and reviewed by the WCPFC Scientific Committee (SC10) in August 2014. In addition SC10-SA-IP-01 (Harley et. al. 2014) summarized the major changes to the tropical tuna stock assessments resulting from the recommendations provided in SC8-SA-WP-01 (Independent Review of the 2011 bigeye tuna stock assessment). Also, status quo stochastic projections were provided for skipjack tuna in SC10-SA-WP-06 (Pilling 2014).

Some of the main improvements in the 2014 assessment are:

- Increases in the number of spatial regions to better model the tagging and size data;

- Improved modelling of recruitment to ensure that uncertain estimates do not influence key stock status outcomes; and

- A large amount of new tagging data corrected for differential post-release mortality and other tag losses

The large number of changes since the 2011 assessment (some of which are described above), and the nature of some of these changes, means that full consideration of the impacts of individual changes is not possible. Nevertheless, the report details some of the steps from the 2011 reference case to the 2014 reference case (Run 012_L0W0T0M0). Distinguishing features of the 2014 reference case model include:

- The steepness parameter of the stock recruitment relationship is fixed at 0.8.

- Growth fixed according to 2010 estimates used in the last two assessments.

- The likelihood function weighting of the size data is determined using an effective sample size for each fishing observation of one-twentieth of the actual sample size, with a maximum effective sample size of 50.

- For modelling the tagging data, a mixing period of 1 quarter (including the quarter of release) is applied.

- The last four quarterly recruitments aggregated over regions are assumed to lie on the stock-recruitment curve.

- recruitment curve.

The rationale for these choices, which comprise the key areas of uncertainty for the assessment, is described in detail in the report. We report the results of "one-off" sensitivity models to explore the impact of these choices for the reference case model on the stock assessment results. A sub-set of key, plausible model runs was taken from these sensitivities to include in a structural uncertainty analysis (grid) for consideration in developing management advice.

The main conclusions of the current assessment are consistent with recent assessments presented in 2010 and 2011. The main conclusions are as follows:

i. A fluctuating but consistently high level of recruitment since the early 1970s has supported a robust fishery in all regions. The analysis suggests that the regional declines in spawning potential, in all regions except region 1, are being driven primarily by the fishing impacts.

ii. Although the ratio of exploited to unexploited spawning potential is estimated to have declined, with some fluctuations, throughout the model period, the average total biomass of the last five years is estimated to be above the average total biomass of the first five years of the model.

iii. Latest catches slightly exceed the maximum sustainable yield (MSY).

iv. Fishing mortality for adult and juvenile skipjack tuna is estimated to have increased continuously since the beginning of industrial tuna fishing, but fishing mortality still remains below the level that would result in the MSY.

v. Recent levels of spawning potential are well above the level that will support the MSY.

vi. The estimated 2011 level of spawning potential represents approximately 52% of the unfished level, and is well above the LRP of 20%$SB_{F=0}$ agreed by WCPFC.

vii. Recent levels of spawning potential are in the middle of the range of candidate biomass-related TRPs currently under consideration for skipjack tuna, i.e., 40-60% $SB_{F=0}$.

viii. Stock status conclusions were most sensitive to alternative assumptions regarding steepness and growth. However the main conclusions of the assessment are robust to the range of uncertainty that was explored.

Paper SC10-SA-WP-06 (Pilling 2014) contained status quo stochastic projections for bigeye, skipjack, and yellowfin tunas. The paper outlined an assessment of the potential consequences of recent (2012) fishing conditions on the future biological status of the three tropical tuna stocks, based on the 2014 tropical tuna stock assessments. Projected status in 2032 was reported relative to spawning biomass and fishing mortality reference levels in absolute terms (as a median of the projection outcomes) and in probabilistic terms.

A single assessment model run (the reference case model for each tropical tuna stock) was used as the basis for projecting future stock status. Only uncertainty arising from future recruitment conditions was therefore captured in the results, using two alternative hypotheses: where recruitment was assumed to follow the estimated stock recruitment relationship on average with randomly selected deviates from the period used to estimate the relationship in each stock assessment; or was assumed to be consistent with actual recruitments estimated over the period 2002-2011.

It was exceptionally unlikely (<1%) that the yellowfin stock would fall below the LRP level or that fishing mortality would increase above the F_{MSY} level by 2032, and dependent upon the future recruitment assumption, it was exceptionally unlikely (<1%; long-term recruitment deviate assumption) or very unlikely (<10%; recent recruitment assumption) to fall below SB_{MSY}.

Stock status and trends

There have been significant improvements to the 2014 stock assessment resulting from the implementation of the 2012 bigeye review recommendations. Improvements were made to regional and fisheries structures, CPUE, size, and tagging data inputs, and the MULTIFAN-CL modelling framework. This assessment is also the first since the adoption of a LRP based on the spawning biomass in the absence of fishing (0.2$SB_{F=0}$).

SC10 selected the reference case model as the base case to represent the stock status of skipjack. To characterize uncertainty SC10 chose three additional models based on alternative values of steepness and a longer tag mixing period. Fuller details of the base case and other models are provided in Table SKJ1.

Table 7: Description of the base case and key model chosen for the provision of management advice.

Name	Description
Base Case	JPN PL CPUE for regions 1,2,3, PH PS-Associated CPUE for Region 4, PNG PS-Associated CPUE for region 5. Size data weighted as sample number/20, steepness fixed at 0.8, growth fixed, mixing period of 1 quarter, terminal 4 recruitments not estimated
h_0.65	Steepness=0.65.
h_0.95	Steepness=0.95.
Mix_2qtr	Tag mixing period=2 quarters

Time trends in estimated recruitment, biomass, fishing mortality and depletion are shown in Figures SKJ 1–4.

The estimated maximum sustainable yield (MSY) is 1,532,000 mt which is lower than recent catches.

Fishing mortality has generally been increasing through time, and for the base case $F_{current}$ (2008-11 average) is estimated to be 0.62 times the fishing mortality that will support the MSY. Across the base case and three sensitivity models $F_{current}/F_{MSY}$ ranged from 0.45 to 0.84. This indicates that overfishing is not occurring for the WCPO skipjack tuna stock.

The latest (2011) estimates of spawning biomass are above both the level that will support the MSY (SB_{latest}/SB_{MSY} = 1.81 for the base case and range 1.61 - 2.34 across the four models) and the newly adopted LRP of $0.2SB_{F=0}$ ($SB_{latest}/SB_{F=0}$ = 0.48 for the base case and range 0.46-0.5). These biomass estimates are within the range (0.4-0.6) of depletion levels currently under consideration for a possible TRP.

Future status under status quo projections (assuming 2012 conditions) was robust to assumptions on future recruitment. Under either assumption, spawning biomass remained relatively constant and it is exceptionally unlikely (0%) for the stock to become overfished ($SB_{2032}<0.2SB_{F=0}$) nor for the spawning biomass to fall below SB_{MSY}, and it was exceptionally unlikely (0%) for the stock to become subject to overfishing ($F>F_{MSY}$).

Abundance indices of coastal fisheries in the Pacific coastal waters of Japan show declining trend and level between 2006 and 2013 were half of its level between 1996 and 2005. The migration of skipjack stock to coastal area around Japan, one of the edge areas of skipjack distribution has been diminished since around 2006 possibly due to range contraction of this species in the WCPO, though other reasons cannot be ruled out.

SC10 recommended that the PAW consider the inclusion of fisheries data into the skipjack assessment for the northern and southern margins of the Convention Area.

SC10 recommended further research for range contraction of skipjack should be conducted in the framework of Project 67.

Table 8: Estimates of management quantities for selected stock assessment models (see Table SKJ1 for details). For the purpose of this assessment, “current” is the average over the period 2008–2011 and “latest” is 2011.

	Base case	h=0.65	h=0.95	Mix_2qtr
MSY	1,532,000	1,334,400	1,724,400	1,699,200
C_{latest}/MSY	1.08	1.24	0.96	0.97
$F_{current}/F_{MSY}$	0.62	0.84	0.45	0.53
B_0	6,281,000	6,558,000	6,123,000	7,112,000
$B_{current}$	3,615,213	3,613,290	3,612,585	4,374,786
SB_0	5,940,000	6,202,000	5,791,000	6,699,000
SB_{MSY}	1,683,000	2,021,000	1,393,000	1,928,000
$SB_{F=0}$	6,303,358	6,690,474	6,082,301	7,085,699
$SB_{current}$	3,260,579	3,258,721	3,258,170	3,971,998
SB_{latest}	3,052,995	3,050,692	3,049,508	3,548,468
$SB_{current}/SB_{F=0}$	0.52	0.49	0.54	0.56
$SB_{latest}/SB_{F=0}$	0.48	0.46	0.50	0.50
$SB_{current}/SB_{MSY}$	1.94	1.61	2.34	2.06
SB_{latest}/SB_{MSY}	1.81	1.51	2.19	1.84

Table 9: Comparison of selected WCPO skipjack tuna reference points from the 2010, 2011, and 2014 base case models.

Management quantity	Base Case 2010	Base Case 2011	Base Case 2014
MSY	1,375,600	1,503,600	1,532,000
$F_{current}/F_{MSY}$	0.34	0.37	0.62
$SB_{latest}/SB_{F=0}$	0.48	0.55	0.48

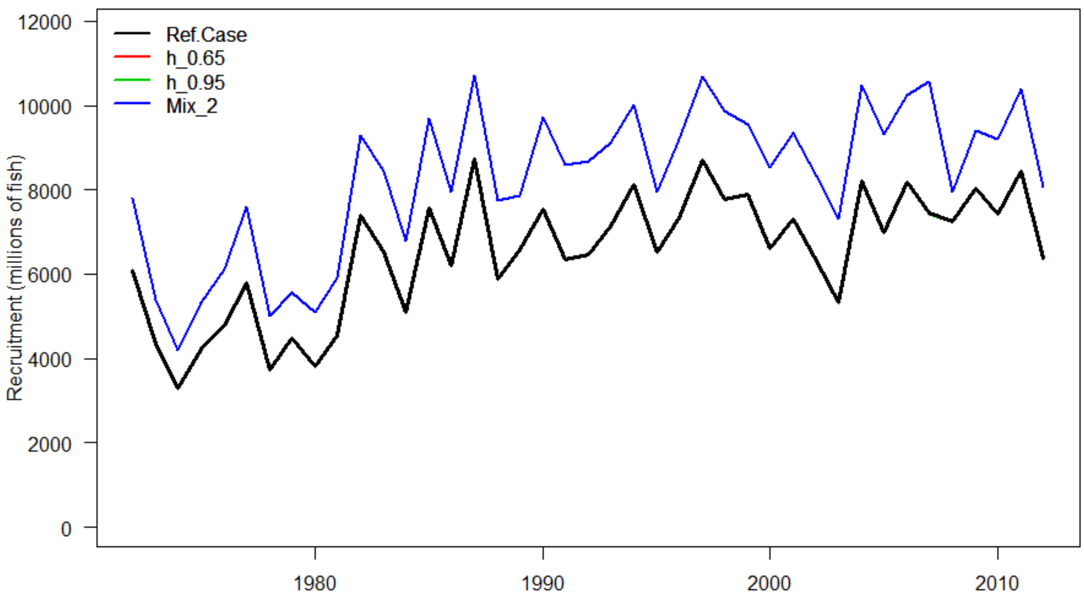


Figure 7: Estimated annual recruitment (millions of fish) for the WCPO obtained from the base case model from the base case model and three additional runs described in Table SKJ1. The model runs with alternative steepness values give the same recruitment estimates.

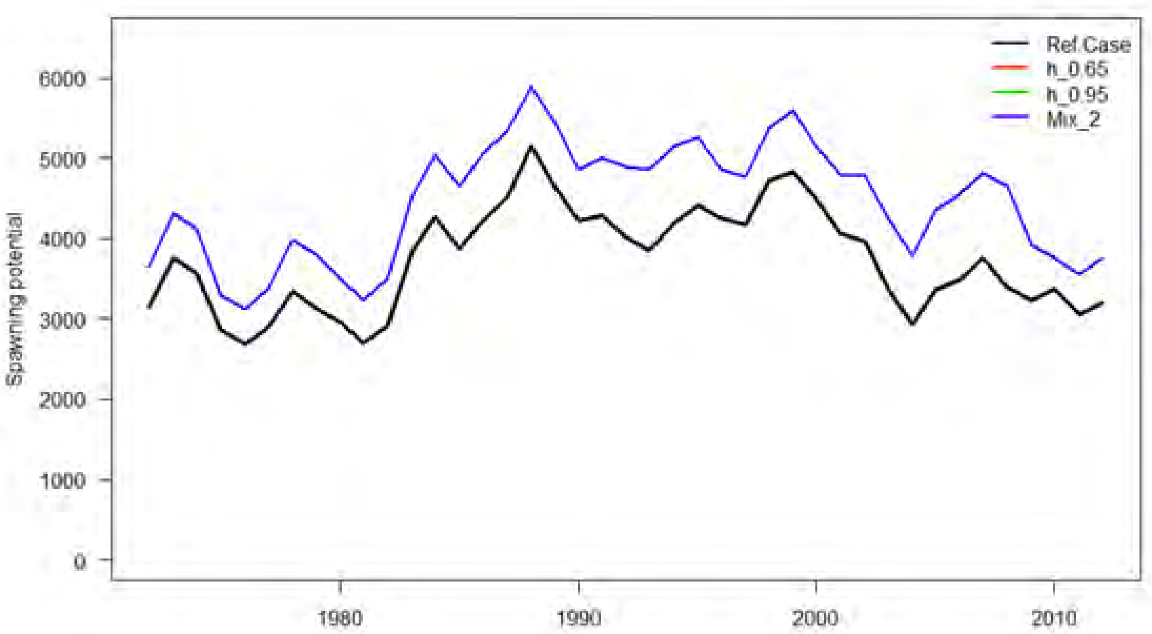


Figure 8: Estimated annual average spawning potential for the WCPO obtained from the base case model and three additional runs described in Table SKJ1. The model runs with alternative steepness values give the same spawning potential estimates.

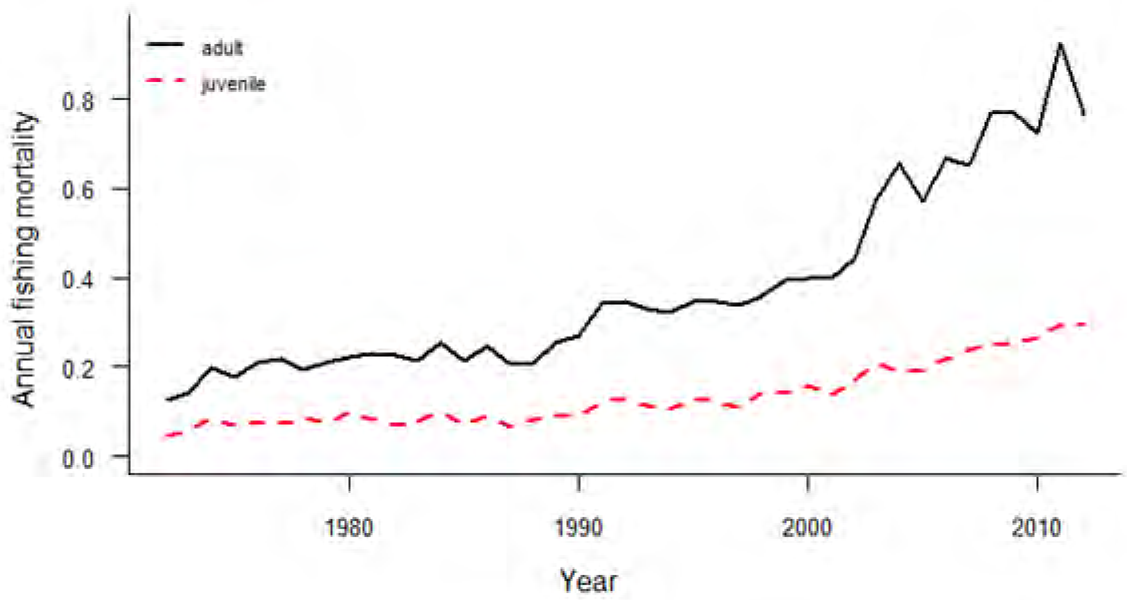


Figure 9: Estimated annual average juvenile and adult fishing mortality for the WCPO obtained from the base case model.

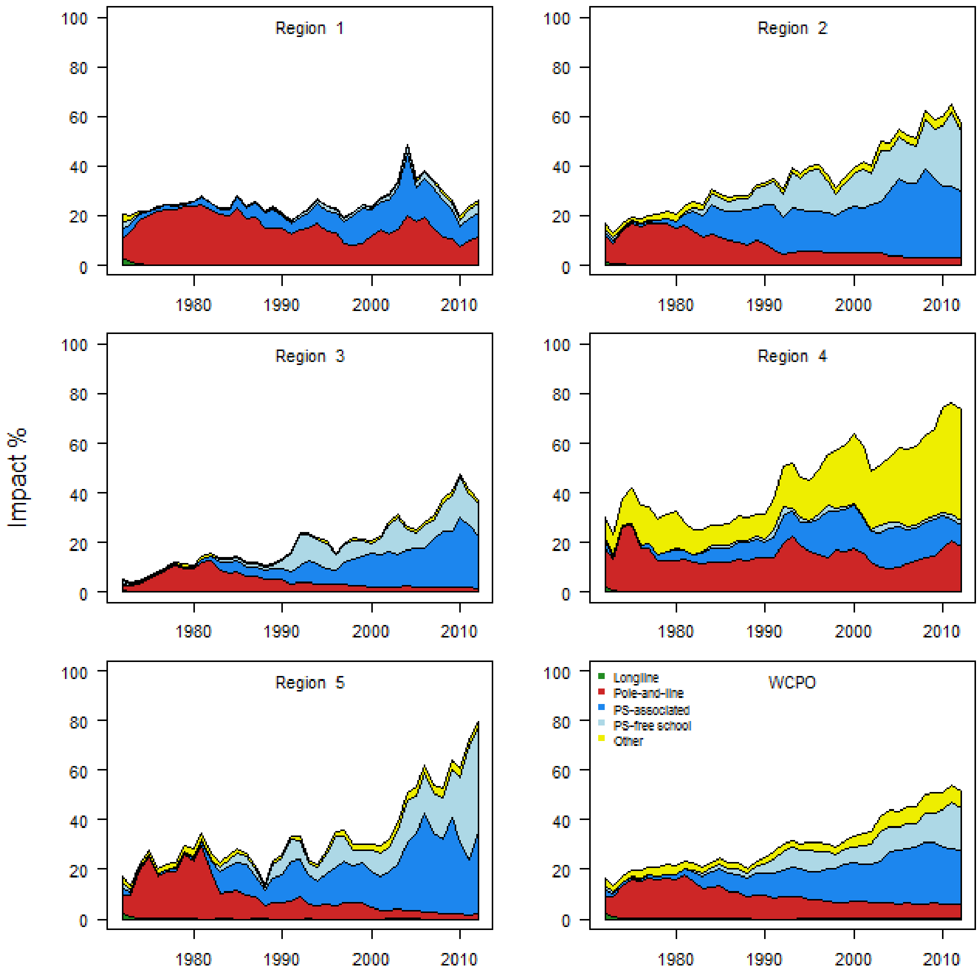
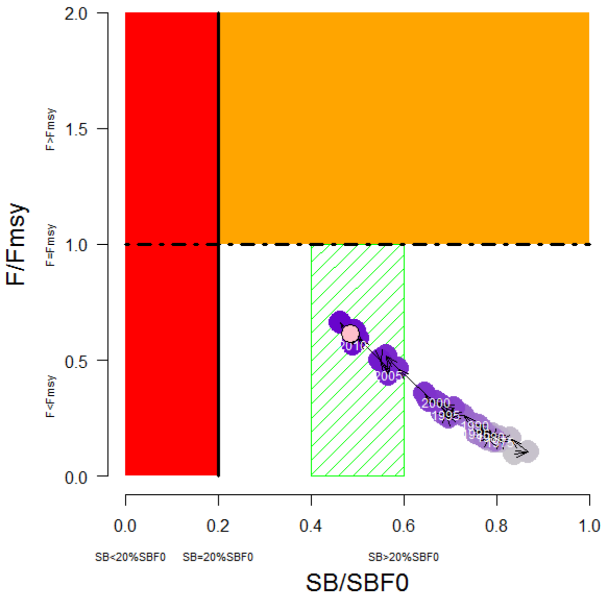


Figure 10: Estimates of reduction in spawning potential due to fishing (fishery impact = $1\text{-}SB_t/SB_{t,F=0}$) by region and for the WCPO attributed to various fishery groups for the base case model. Note: the region 1 Japanese purse-seine fishery was grouped as an associated set fishery in this analysis.



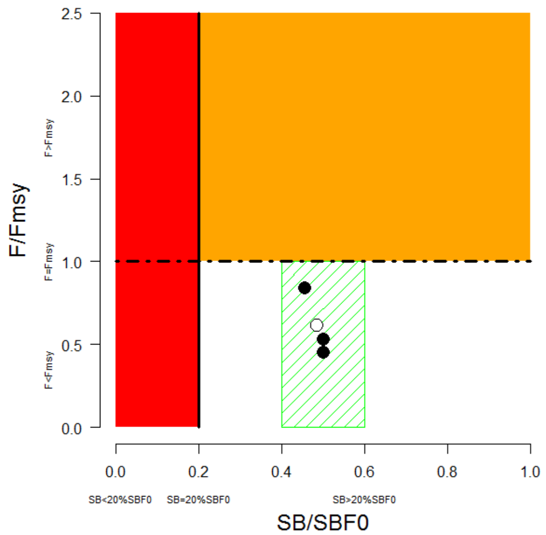


Figure 11: Temporal trend for the base case model (top) and terminal condition for the base case and other sensitivity runs (bottom) in stock status relative to $SB_{F=0}$ (x-axis) and F_{MSY} (y-axis). The red zone represents spawning potential levels lower than the agreed LRP which is marked with the solid black line ($0.2SB_{F=0}$). The orange region is for fishing mortality greater than F_{MSY} ($F=F_{MSY}$; marked with the black dashed line). The lightly shaded green rectangle covering 0.4-0.6$SB_{F=0}$ is the candidate TRPs of 40%, 50% and 60% of unfished spawning stock biomass that WCPFC10 has asked for consideration of a TRP for skipjack. The pink circle (top panel) is $SB_{2012}/SB_{F=0}$ (where $SB_{F=0}$ was the average over the period 2002-2011). The bottom panel includes the base case (white dot) and sensitivity analyses described Table SKJ-1.

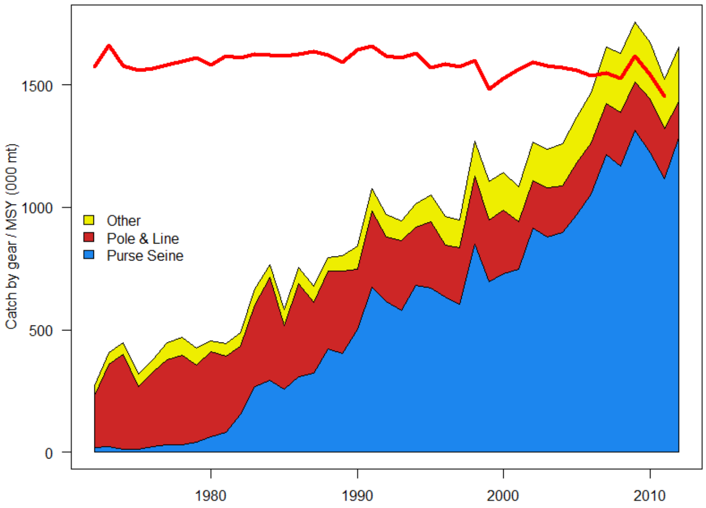


Figure 12: History of annual estimates of MSY compared with catches of three major fisheries for the base case model.

Management advice and implications

Recent catches are slightly above the estimated MSY of 1,532,000 mt. The assessment continues to show that the stock is currently only moderately exploited ($F_{current}/F_{MSY}$ = 0.62) and fishing mortality levels are sustainable. However, the continuing increase in fishing mortality and decline in stock size are recognized.

SC10 advised the WCPFC that there is concern that high catches in the equatorial region could result in range contractions of the stocks, thus reducing skipjack availability to high latitude fisheries.

Fishing is having a significant impact on stock size, especially in the western equatorial region and can be expected to affect catch rates. The stock distribution is also influenced by changes in oceanographic conditions associated with El Niño and La Niña events, which impact on catch rates and stock size. Additional purse-seine effort will yield only modest gains in long-term skipjack catches and may result in a corresponding increase in fishing mortality for bigeye and yellowfin tunas. The management of total effort in the WCPO should recognize this.

The spawning biomass is now around the mid-point of the range of candidate TRPs of 40%, 50%, and 60% of unfished spawning stock biomass that WCPFC10 has asked the SC10 to consider for skipjack. SC10 recommends the commission take action to avoid further increases in fishing mortality and keep the skipjack stock around the current levels, with tighter purse-seine control rules and advocates for the adoption of TRP and harvest control rules.

SC10 recommended that the Commission consider the results of updated projections at WCPFC11, including evaluation of the potential impacts of CMM 2013-01, to determine whether the CMM will achieve its objectives including impacts of the skipjack fishery on bigeye and yellowfin tuna.

5.1 Estimates of fishery parameters and abundance

There are no fishery-independent indices of abundance for the skipjack tuna. Unlike other pelagic tunas, the low selectivity of skipjack tuna to longline gear means that no relative abundance information is available from longline catch per unit effort data. Regional CPUE indices derived from Japanese pole-and-line logsheet data and purse seine associated CPUE for the Philippines and Papua New Guinea fleets are the principal indices of stock abundance incorporated in the WCPO stock assessment. However, the pole-and-line fleet has declined considerably over the last 20 years and there has been a contraction of the spatial distribution of the fishery in the equatorial region. Purse seine catch per unit effort data is difficult to interpret. Returns from a large scale tagging programme undertaken in the early 1990s also provides information on rates of fishing mortality which in turn leads to improved estimates of abundance.

Average fishing mortality rates for juvenile and adult age-classes increased throughout the time series. Since the 1980s, the increase of fishing mortality to the current levels is due to the increase of catches of both juvenile and adult fish beginning at that time from both associated purse seine sets and the mixed gear fisheries in the Philippines and Indonesia. Fishing mortality on intermediate ages (5- 8 quarters) is also increasing through time consistent with the increased fishing mortality from the purse seine fishery.

5.2 Biomass estimates

WCPO spawning potential is estimated to have been relatively stable during the 1970s, before increasing in the early 1980's due to higher recruitment, before declining over the past decade due to fishing. The eastern equatorial region (region 3) remains the region with the greatest spawning potential and the central equatorial region (region 2) is the second largest with the single northern region the third largest. The spawning potential in the western equatorial regions 4 and 5 are similar.

5.3 Yield estimates and projections

No estimates of MCY and CAY are available.

5.4 Other yield estimates and stock assessment results

SC10 achieved consensus to accept and endorse the reference case proposed in the assessment document, and that $SB_{20\%,F=0}$ be used as the LRP for stock status purposes as agreed by WCPFC. There was further discussion about whether to use SB_{latest} or $SB_{current}$ as the terminal spawning biomass for management purposes. The SC agreed to use the most recent information on spawning biomass, SB_{latest} corresponding to 2012. At 0.48 $SB_{F=0}$ SB_{latest} is above the limit reference point.

SC10 also endorsed the use of the candidate biomass-related target reference point (TRP) currently under consideration for skipjack tuna, i.e., 40-60% $SB_{F=0}$. At 0.48 $SB_{F=0}$ SB_{latest} is near the mid-point of the range for the target reference point.

5.5 Other factors

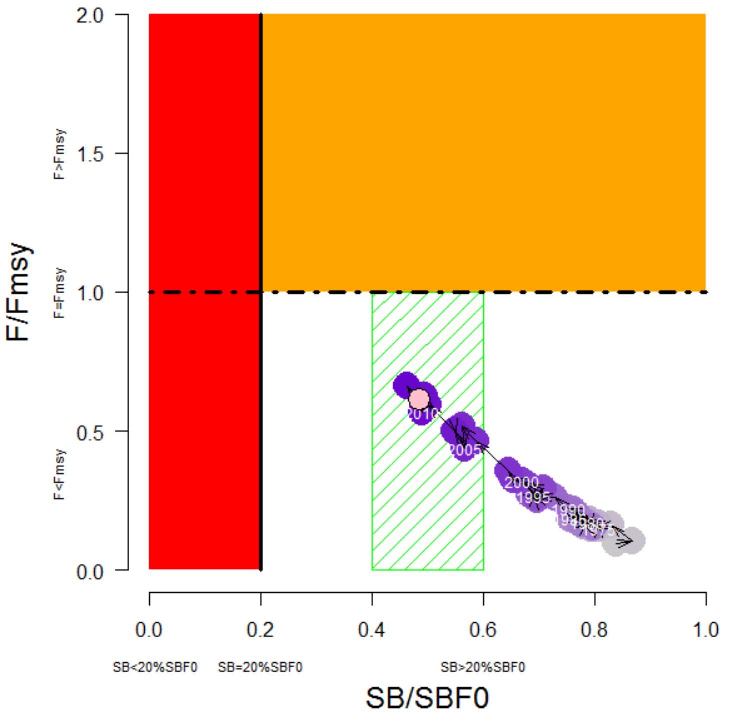
One area of concern with fisheries for skipjack tuna relates to the potential for significant bycatch of juvenile bigeye and yellowfin tunas in the purse seine fishery in equatorial waters. Juveniles of these species occur in mixed schools with skipjack tuna broadly through the equatorial Pacific Ocean, and are vulnerable to the large-scale purse seine fishing when sets are made on floating objects (FADs). The fishery in New Zealand fisheries waters is on single species free schools.

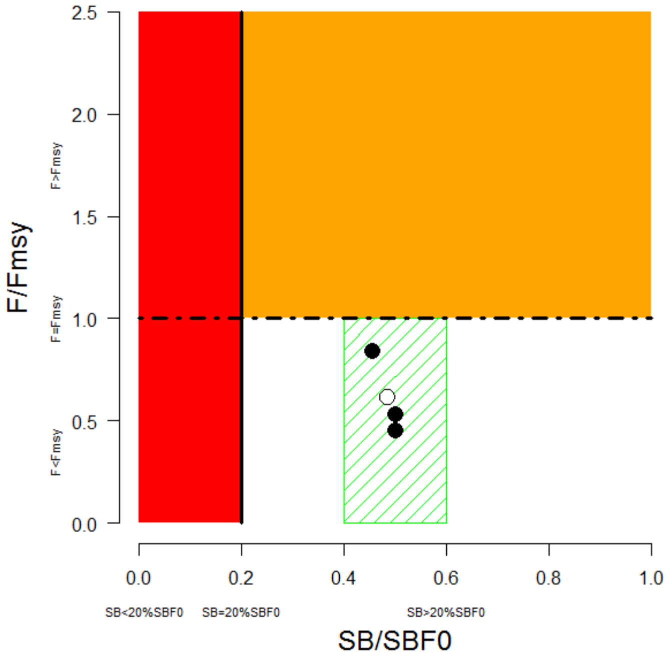
While the skipjack resource within New Zealand waters is considered to represent a component of the wider WCPO stock, the extent of the interaction between the domestic fishery and the fisheries in the equatorial region is unclear. Catches within New Zealand waters vary inter-annually due to prevailing oceanographic conditions. Nonetheless, recent domestic catches have been at or about the highest level recorded from the fishery while the recent total catches from the WCPO have also been the highest on record. A review of domestic purse-seine catch and effort data and associated aerial sightings data from the skipjack tuna fishery did not reveal any temporal trend in the availability of skipjack to the domestic fishery (Langley 2011).

6. STATUS OF THE STOCKS

Stock structure assumptions
Skipjack tuna are considered to be a single stock in the WCPO.

Stock Status	
Year of Most Recent Assessment	A full stock assessment was completed in 2014
Assessment Runs Presented	Base case model and a range of sensitivities
Reference Points	Candidate biomass-related target reference point (TRP) currently under consideration for key tuna species is 40-60% SB_0 Limit reference point of 20% SB_0 established by WCPFC equivalent to the HSS default of 20% SB_0 Hard Limit: Not established by WCPFC; but evaluated using HSS default of 10% SB_0 Overfishing threshold: F_{MSY}
Status in relation to Target	Very Likely (> 90%) to be in the range 40-60% SB_0 and Very Likely (> 90%) that $F < F_{MSY}$
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 Very Unlikely (< 10%) to be occurring
Historical Stock Status Trajectory and Current Status	





Temporal trend for the base case model (top) and terminal condition for the base case and other sensitivity runs (bottom) in stock status relative to $SB_{F=0}$ (x-axis) and F_{MSY} (y-axis). The red zone represents spawning potential levels lower than the agreed LRP which is marked with the solid black line ($0.2SB_{F=0}$). The orange region is for fishing mortality greater than F_{MSY} ($F=F_{MSY}$; marked with the black dashed line). The lightly shaded green rectangle covering $0.4\text{-}0.6SB_{F=0}$ is the candidate TRPs of 40%, 50% and 60% of unfished spawning stock biomass that WCPFC10 has asked for consideration of a TRP for skipjack. The pink circle (top panel) is $SB_{2012}/SB_{F=0}$ (where $SB_{F=0}$ was the average over the period 2002-2011). The bottom panel includes the base case (white dot) and sensitivity analyses described Table SKJ-1.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass increased in the mid 1980s and fluctuated about the higher level over the subsequent period, before declining from 2008 to 2012. Recent depletion level is estimated at 0.52 (i.e. 0.48 of the unfished level).
Recent Trend in Fishing Intensity or Proxy	F is estimated to have remained well below F_{MSY} over the history of the fishery, although the level of fishing mortality has increased considerably over the last 8 years.
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	Recruitment showed an upward shift in the mid-1980s and is estimated to have fluctuated about the higher level since that time. The estimated distribution of recruitment across regions should be interpreted with caution as MULTIFAN-CL can use a combination of movement and regional recruitment to distribute fish.

Projections and Prognosis	
Stock Projections or Prognosis	Projections indicated it is Exceptionally Unlikely (< 1%) that the yellowfin stock would fall below the LRP level or that fishing mortality would increase above the F_{MSY} level by 2032, and dependent upon the future recruitment assumption, it was Exceptionally Unlikely (< 1%) (long-term recruitment deviate assumption) or Very Unlikely (< 10%) (recent recruitment assumption) to fall below SB_{MSY}.

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	Exceptionally Unlikely (< 1%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1: Quantitative Stock assessment	
Assessment Method	The assessment uses the stock assessment model and computer software known as MULTIFAN-CL.	
Assessment Dates	Latest assessment: 2014	Next assessment: 2017
Overall assessment quality rank	1 - High Quality	
Main data inputs	Inputs include improved purse seine catch estimates; reviews of the catch statistics of the component fisheries; standardised CPUE analyses of Japanese pole-and-line operational level catch and effort data; CPUE data for two purse seine fisheries; size data inputs from the purse seine fishery; revised regional structures and fisheries definitions; and preparation of tagging data and reporting rate information.	1 - High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Increases in the number of spatial regions to better model the tagging and size data; - Improved modelling of recruitment to ensure that uncertain estimates do not influence key stock status outcomes; and - A large amount of new tagging data corrected for differential post-release mortality and other tag losses	
Major Sources of Uncertainty	Pole-and-line CPUE data are one of the most important drivers of the skipjack stock assessment; however with the continuing decline of the Japanese pole-and-line fleet particularly in the tropical regions, the ongoing reliance on this fleet to provide a suitable index of skipjack abundance will become increasingly problematic. The current assessment had the greatest update of tagging data in many years and the limited sensitivity analyses demonstrated that key model outputs are lightly sensitive to tagging data assumptions such as the assumed mixing period. Finally, one area of reduced uncertainty in the current assessment has been impact of steepness on the spawning potential reference point.	

Qualifying Comments
-

Fishery Interactions
There is a high level of bycatch of small bigeye and yellowfin tuna in the tropical skipjack purse seine fishery when using Fish Aggregating Devices (FADs). This has increased the catch of bigeye and yellowfin and has contributed to the biomass decline of these two species. Sea turtles also get incidentally captured in purse seine nets and FADs; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure (CMM2008-03). Mortality of whale sharks, basking sharks and whales, which act as FADs and are caught in purse seine nets, is known to occur, but the extent of this is currently unknown.

7. FOR FURTHER INFORMATION

Anon. (2002) Annual Report of the Inter-American Tropical Tuna Commission. I-ATTC, La Jolla, California. 148 p.

Anon. (2008) Commission or the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean: Scientific Committee Summary report. Western and Central Pacific Fisheries Commission, Pohnpei, Federated States of Micronesia. 234 p.

Anon. (2003). Report of the 16th meeting of the Standing Committee on Tuna and Billfish. www.spc.int.

Anon (2013) Tuna fishery yearbook 2012. Western and Central Pacific Fisheries Commission, 154 p.

CMM2008-03 (2008) Conservation and Management measure for sea turtles, for the Western and Central Pacific Ocean. CMM2008-03 of the Western and Central Pacific Fisheries Commission.

Harley, S., N. Davies, J. Rice, S. McKechnie and J. Hampton. 2014. Summary of major changes in the 2014 tropical tuna stock assessments. WCPFC-SC10-2014/SA-IP-01.

Hoyle, S; Kleiber, P; Davies, N; Harley, S; Hampton, J (2010) Stock assessment of skipjack tuna in the Western and Central Pacific Ocean. Report to the Western and Central Pacific Fisheries Commission Scientific Committee WCPFC-SC6-2010/SA-WP-11.

Hoyle, S; Kleiber, P; Davies, N; Langley, A; Hampton, J (2011) Stock assessment of skipjack tuna in the Western and Central Pacific Ocean. Report to the Western and Central Pacific Fisheries Commission Scientific Committee, WCPFC-SC7-2011/SA-WP-04. 103 p.

Langley, A D (2011) Characterisation of the New Zealand fisheries for skipjack tuna *Katsuwonus pelamis* from 2000 to 2009. *New Zealand Fisheries Assessment Report 2011/43*.

Langley, A; Hampton, J (2008) Stock assessment of skipjack tuna in the Western and Central Pacific Ocean. Report to the Western and Central Pacific Fisheries Commission Scientific Committee WCPFC-SC4-2008/SA-WP-04. 74 p.

Langley, A; Hampton, J; Ogura, M (2005) Stock assessment of skipjack tuna in the western and central Pacific Ocean. SC-1 SA-WP-4. First meeting of the WCPFC-Scientific Committee, 8–19 August 2005, Noumea, New Caledonia.

Langley, A; Ogura, M; Hampton, J (2003) Stock assessment of skipjack tuna in the western and central Pacific Ocean, SCTB16 Working Paper SKJ-1. www.spc.int.

Lawson, T A (2008) Western and Central Pacific Fisheries Commission Tuna Fishery Yearbook 2007. Western and Central Pacific Fisheries Commission, Pohnpei, Federated States of Micronesia. 203 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.

OFP (2010) Estimates of annual catches in the WCPFC statistical area. WCPFC-SC6-2010/ST-IP-1. Sixth meeting of the WCPFC-Scientific Committee, 10–19 August 2010, Nuku'alofa, Kingdom of Tonga.

Paul, L J (2000) *New Zealand Fishes: identification, natural history & fisheries*. Auckland, N.Z.: Reed Publishing (NZ) Ltd, 2000.

Pilling, G. M., S. J. Harley, N. Davies, J. Rice and J. Hampton. 2014. Status quo projections for bigeye, skipjack, and yellowfin tunas. WCPFC-SC10/SA-WP-06.

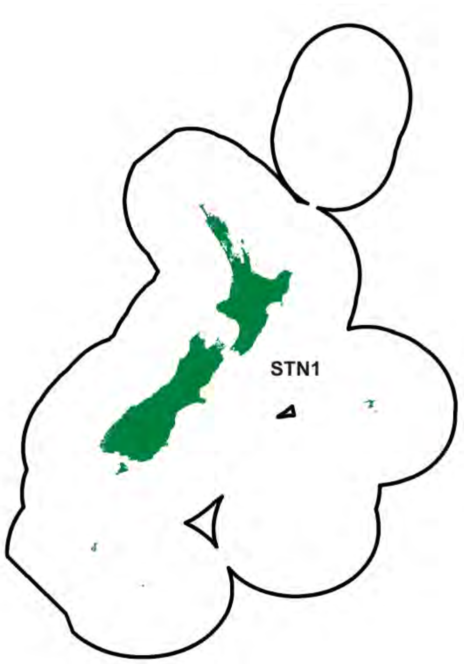
Rice, J. S. Harley, N. Davies, and J. Hampton. 2014. Stock assessment of skipjack tuna in the western and central Pacific Ocean. WCPFC-SC10-2014/SA-WP-05.

Tanabe, T; Kayama, S; Ogura, M (2003) Precise age determination of young to adult skipjack tuna (Katsuwonus pelamis) with validation of otolith daily increment. Working Paper SKJ−8, 16th Meeting of the Standing Committee on Tuna and Billfish, 9−16 July 2003, Mooloolaba, Australia.

Williams, P; Terawasi, P (2011) Overview of tuna fisheries in the western and central Pacific Ocean, including economic conditions – 2010. Unpublished report to the Western and Central Pacific Fisheries Commission, WCPFC-SC7-2011/GN WP-01. 47 p.

SOUTHERN BLUEFIN TUNA (STN)

(*Thunnus maccoyii)*



1. FISHERY SUMMARY

Southern bluefin tuna were introduced into the QMS on 1 October 2004 under a single QMA, STN 1, with allowances for customary and recreational fisheries and other sources of mortality within the TAC and a commercial TACC. The current allowances and the TACC are outlined in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACCS and TAC (all in tonnes) for southern bluefin tuna.

Fishstock	Recreational Allowance (t)	Customary non-commercial Allowance (t)	Other mortality (t)	TACC (t)	TAC (t)
STN 1	8	1	4	817	830

Southern bluefin tuna were added to the Third Schedule of the Fisheries Act 1996 with a TAC set under s14 because a national allocation of southern bluefin tuna for New Zealand has been determined as part of an international agreement. The TAC applies to all New Zealand fisheries waters, and all waters beyond the outer boundary of the exclusive economic zone.

Southern bluefin tuna were also added to the Sixth Schedule of the Fisheries Act 1996 with the provision that:

> "A person who is a New Zealand national fishing against New Zealand's national allocation of southern bluefin tuna may return any southern bluefin tuna to the waters from which it was taken from if –
> (a) that southern bluefin tuna is likely to survive on return; and
> (b) the return takes place as soon as practicable after the southern bluefin tuna is taken".

Management of southern bluefin tuna throughout its range is the responsibility of the Commission for Conservation of Southern Bluefin Tuna (CCSBT) of which New Zealand is a founding member. Current members of the CCSBT also include Australia, Japan, the Republic of Korea, the Fishing Entity of Taiwan and Indonesia. The Republic of South Africa, the European Community, and the Philippines have Cooperating Non-member status. Determination of the global TAC and provision of a national allocation to New Zealand is carried out by the CCSBT.

Management procedure

In 2011, the Commission adopted a management procedure (MP) to set quotas for three year periods based on the latest fisheries indicators from the stock. The MP is designed to rebuild the spawning stock to 20% of the unfished level by 2035 (with 70% certainty). However, the Commission decided not to fully implement the first increase indicated by the operation of the MP in 2011 as there was concern that the TAC may have to be reduced again at the end of the 3 years. Instead the Commission opted for a limited increase in the first three year period. Quotas set for the three years allowed a 1000 t increase in 2012 to 10 449, a further increase in 2013 to 10 949 t and subject to the MP output an increase to 12 449 in 2014.

Table 2: Allocated catches for Members and Cooperating Non-members for 2014.

Member	Effective catch limit (t)
Australia	5193
Fishing Entity of Taiwan	1045
Japan	3403
New Zealand	918
Republic of Korea	1045
Indonesia	750
Cooperating Non-Member	
European Community	10
Philippines	45
South Africa	40*
TOTAL	12,449

* The allocation to South Africa will increase to 150 t if it accedes to the Convention by 31 May of the respective year

At the 20th meeting of CCSBT in October 2013 the TACC was confirmed at 12 449 t for 2014-15 and on the basis of the operation of the management procedure the TACC for 2015 to 2017 was recommended to be set at 14 647 tonnes. The TACC for 2015-16 was also confirmed at this higher figure. At the 21st meeting of CCSBT in October 2014 the TACC was confirmed at 14 647t for 2016-17.

Market and farming reviews

In July 2006, the CCSBT Commission reviewed the results of two joint Australia / Japan reviews: the first was an assessment of the amount of southern bluefin tuna being sold through Japanese markets (referred to as the Market Review), and the second was an assessment of the potential for overcatch from the Australian surface fishery and associated farming operations (referred to as the Farming Review).

The Market Review reported that quantities of southern bluefin tuna sold through the Japanese markets (back to the mid-1980s) were well in excess of the amount reported by Japan as domestic catch or imported from other countries (measured through the Trade Documentation Scheme), i.e., there were large volumes of unreported catch. The Market Review could not determine where the catch came from.

The Farming Review reported that while the catch in numbers from the surface fishery were probably well reported there was scope for biases in reported catch in weight due to two factors: (1) changes in the weight of fish between the time of capture and when the weight sample is taken; and (2) the sample of fish taken to estimate the mean weight of fish in the catch may not be representative (causing either negative or positive biases in the mean weight estimate).

The Farming Review was inconclusive.

While Japan does not accept the findings of the Market review they have acknowledged some illegal catch during the 2005 fishing season and changed how they manage their fishery and in 2006 accepted a cut in their allocated catch to 3000 t down from 6065 t for a minimum of 5 years. Current allocations for all countries are provided in Table 2 above.

The findings of the two reviews have resulted in considerable uncertainty in the southern bluefin tuna science process as even the most fundamental data (e.g., catch history) are not reliable and may be very different from reported catches. Further, many of the indicators of stock status previously relied upon are now under question as they may be biased due to illegal activity.

1.1 Commercial fisheries

The Japanese distant water longline fleet began fishing for southern bluefin tuna in the New Zealand region in the late 1950s and continued after the declaration of New Zealand's EEZ in 1979 under a series of bilateral access agreements until 1995.

The domestic southern bluefin tuna fishery began with exploratory fishing by Watties in 1966 and Ferons Seafoods in 1969. Most of the catch was used for crayfish bait (reported landings began in 1972). During the 1980s the fishery developed further when substantial quantities of southern bluefin tuna were air freighted to Japan. Throughout the 1980s, small vessels handlining and trolling for southern bluefin tuna dominated the domestic fishery. Southern bluefin tuna were landed to a dedicated freezer vessel serving as a mother ship, or, ashore for the fresh chilled market in Japan.

Longlining for southern bluefin tuna was introduced to the domestic fishery in the late 1980s under government encouragement and began in 1988 with the establishment of the New Zealand Japan Tuna Company Ltd. New Zealand owned and operated longliners, mostly smaller than 50 GRT, began fishing in 1991 for southern bluefin tuna (1 vessel). The number of domestic vessels targeting STN expanded throughout the 1990s and early 2000s prior to the introduction of STN into the QMS. Table 3 summarises southern bluefin landings in New Zealand waters since 1972. Figure 1 shows historical landings and TACC values for domestic southern bluefin tuna.

Since 1991 surface longlines have been the predominant gear used to target southern bluefin tuna in the domestic fishery with 96% of all days fished using this method and only 4% using hand line (< 1% used trolling). This represents a major change from the 1980s when most fishing was by hand line.

In the few instances when the New Zealand allocation has been exceeded, the domestic catch limit has been reduced in the following year by an equivalent amount. Table 3 contrasts New Zealand STN catches with those from the entire stock. The low catches relative to other participants in the global fishery are due to New Zealand's limited involvement historically rather than to local availability. Table 4 indicates that throughout most of the 1980s catches of STN up to two thousand tonnes were taken within the New Zealand EEZ.

Data on reported catch of southern bluefin tuna are available from the early 1950s. By 1960 catches had peaked at nearly 80 000 t, most taken on longline by Japan. From the 1960s through the mid 1970s, when Australia was expanding their domestic surface fisheries for southern bluefin tuna, total catches were in the range 40 000 to 60 000 t. From the mid 1970s through the mid 1980s catches were in the range 35 000 to 45 000 t. Catches declined from 33 325 t in 1985 to 13 869 t in 1990 and fluctuated about 15 000 t per year until 2005. However, since 2006 catches have been less than 12 000 t (see Table 4). However, it should be noted that reported total catches are likely to be underestimates, at least after 1989, as they do not incorporate the findings from the Market and Farming Reviews. Despite this uncertainty the catches reported in 2009 (10 941 t) are the lowest estimated global catch for over 50 years.

From 1960 to the 1990s catches by longline declined while surface fishery catches in Australian waters increased to reach its maximum level of 21 512 t in 1982 (equal to the longline catches of Japan). During the 1980s catches by both surface and longline fisheries declined but following dramatic TAC reductions in the late 1980s, catches stabilised. The main difference between gear types is that surface fisheries target juveniles (age-1 to age-3 year olds) while longline fisheries catch older juveniles and adults (age-4 year old up to age-40+). The surface fishery has comprised purse seine and pole-&-line vessels supported by aerial spotter planes that search out surface schools. The Australian surface fisheries prior to 1990 were a mix of pole-&-line and purse seine vessels, and have since the mid-1990s become almost exclusively a purse seine fishery. Whereas prior to 1990, surface fishery catches supplied canneries, since the mid-1990s these vessels catch juveniles for southern bluefin tuna farms where they are “on-grown” for the Japanese fresh fish market. The fisheries of all other members, (including New Zealand) are based on longline.

Analysis of New Zealand catch data shows that most southern bluefin tuna are caught in FMA1, FMA2, FMA5 and FMA7. The northern FMAs (FMA1 and FMA2) that accounted for a small proportion of southern bluefin tuna before 1998 have in recent years accounted for about the same amount of southern bluefin tuna as the southern FMAs (FMA5 and FMA7). This change in spatial distribution of catches can be attributed to the increase in domestic longline effort in the northern waters. Table 5 shows the longline effort targeted at southern bluefin in New Zealand waters by the charter and domestic fleets since 1989. Some of the charter fleet effort in region 5 was directed at other fish species than southern bluefin but most of the effort was targeting STN.

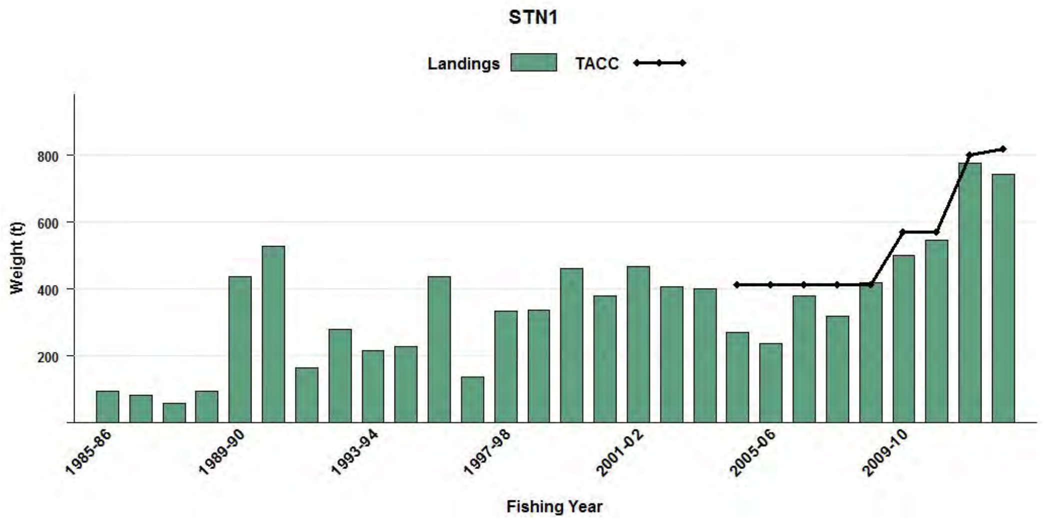


Figure 1: Commercial catch of southern bluefin tuna from 1985-86 to 2012-13 within NZ fishery waters (STN1).

Table 3: Reported domestic[1] and total[2] southern bluefin tuna landings (t) from 1972 to 2013 (calendar year) [continued on next page].

Year	NZ Landings (t)	Total stock (t)	Year	NZ Landings (t)	Total stock (t)
1972	1	51 925	1993	217	14 344
1973	6	41 205	1994	277	13 154
1974	4	46 777	1995	436	13 637
1975	0	32 982	1996	139	16 356
1976	0	42 509	1997	334	16 076
1977	5	42 178	1998	337	17 776
1978	10	35 908	1999	461	19 529
1979	5	38 673	2000	380	15 475
1980	130	45 054	2001	358	16 032
1981	173	45 104	2002	450	15 258
1982	305	42 788	2003	390	14 077
1983	132	42 881	2004	393	13 504
1984	93	37 090	2005	264	16 150
1985	94	33 325	2006	238	11 741
1986	82	28 319	2007	379	10 583
1987	59	25 575	2008	319	11 396

Table 3 [Continued]: Reported domestic[1] and total[2] southern bluefin tuna landings (t) from 1972 to 2013 (calendar year).

Year	NZ Landings (t)	Total stock (t)	Year	NZ Landings (t)	Total stock (t)
1988	94	23 145	2009	419	10 946
1989	437	17 843	2010	501	9 723
1990	529	13 870	2011	547	9 440
1991	164	13 691	2012	776	10 049
1992	279	14 217	2013	756	11 726

[1] Domestic here includes catches from domestic vessels and Japanese vessels operating under charter agreement, i.e. all catch against the New Zealand allocation; [2] These figures are likely underestimates as they do not incorporate the findings from the Market and Farming Reviews
Source: NZ data from Annual Reports on Fisheries, MPI data, NZ Fishing Industry Board Export data and LFRR data; Total stock from www.ccsbt.org.

Table 4: Reported catches or landings (t) of southern bluefin tuna by fleet and Fishing Year. NZ: New Zealand domestic and charter fleet, ET: catches by New Zealand flagged vessels outside these areas, JPNFL: Japanese foreign licensed vessels, LFRR: Estimated landings from Licensed Fish Receiver Returns, and MHR: Monthly Harvest Return Data.

Fish Yr	JPNFL	NZ	Total	LFRR/MHR	NZ ET
1979/80	7 374.7		7 374.7		
1980/81	5 910.8		5 910.8		
1981/82	3 146.6		3 146.6		
1982/83	1 854.7		1 854.7		
1983/84	1 734.7		1 734.7		
1984/85	1 974.9		1 974.9		
1985/86	1 535.7		1 535.7		
1986/87	1 863.1		1 863.1	59.9	
1987/88	1 059.0		1 059.0	94.0	
1988/89	751.1	284.3	1 035.5	437.0	
1989/90	812.4	379.1	1 191.5	529.3	
1990/91	780.5	93.4	873.9	164.6	
1991/92	549.1	248.9	798.1	279.1	
1992/93	232.9	126.6	359.5	216.4	
1993/94	0.0	287.3	287.3	277.0	
1994/95	37.3	358.0	395.2	435.3	
1995/96		141.8	141.8	140.5	
1996/97		331.8	331.8	333.5	
1997/98		330.8	330.8	331.5	
1998/99		438.1	438.1	457.9	
1999/00		378.3	378.3	381.3	
2000/01		366.0	366.0	366.4	
2001/02		468.3	468.3	465.4	
2002/03		405.7	405.7	391.7	0.0
2003/04		399.6	399.6	394.6	0.0
2004/05		272.1	272.1	264.1	0.0
2005/06		237.7	237.7	238.0	0.1
2006/07*		379.1	379.1	379.1	-
2007/08*		318.2	318.2	318.2	-
2008/09*		417.3	417.3	417.5	-
2009/10*		499.5	499.5	499.5	-
2010/11*		547.3	547.3	547.3	-
2011/12*		775.2	775.2	775.2	-
2012/13*		758.2	758.2	758.2	-

* - Southern bluefin tuna landings are not separated into within zone and ET since 2006/07

Table 5: Effort (thousands of hooks) for the charter and domestic fleet by year and CCSBT Region.

	Charter			Domestic[#]		
Calendar Year	**Region 5**	**Region 6**	**Other***	**Region 5**	**Region 6**	**Other***
1989		1596	3.5			
1990	259	1490.6		41.7		
1991	306	1056.5		31.5	49.2	
1992	47.6	1386.8	3	71.7	12.1	
1993	174.1	1125.7	101.4	644.0	108.1	7.7
1994		799.1		122.6	143.3	5.8
1995	27.1	1198.7	13.5	221.5	760.4	26.7
1996				417.9	564.3	11.5
1997	135.2	1098.7		736.4	8.9	17.3
1998	225	616		633.6	314.5	1.2
1999	57.2	955.1		1221.4	382.9	5.5
2000	30.3	757.9		1164.0	454.4	8.5
2001		639.4		1027.6	751.5	1.9
2002		726.4		1358.6	1246.8	13.5
2003	3	866.6		1868.7	1569.1	4.3
2004		1113.5		1154.1	1431.9	1.2
2005	137	498.9		1133.0	153.6	2.4
2006	39.4	562.5		1036.4	122.4	0.9
2007	271.6	1136.1		681.2	19.0	
2008		568.3		527.8	94.0	
2009	66.8	731.0		733.9	165.4	1.3
2010		484.9		1114.9	294.2	1.3
2011		495.9		965.0	196.5	
2012		548.4	3.4	858.1	629.8	
2013	13.2	450.8		910.8	563.0	1.2

* Includes erroneous position data and data without position data

[#] Effort for sets that either targeted or caught southern bluefin tuna

The majority of southern bluefin tuna (86%) are caught in the southern bluefin tuna fishery (Figure 2). However, albacore comprise an equal proportion of the catch (27%) as southern bluefin tuna (Figure 3). Longline fishing effort is distributed along the east coast of the North Island and the south west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the east coast of the North Island targets a range of species including bigeye, swordfish, and southern bluefin tuna (Figure 4).

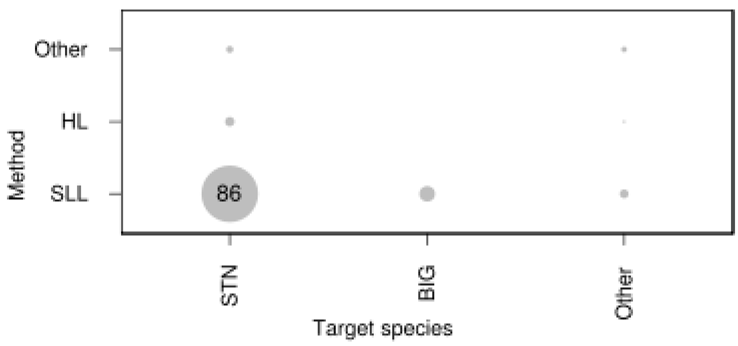


Figure 2: A summary of the proportion of landings of southern bluefin tuna taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bobble is the percentage. SLL = surface longline, HL = hook and line (Bentley et al 2012).

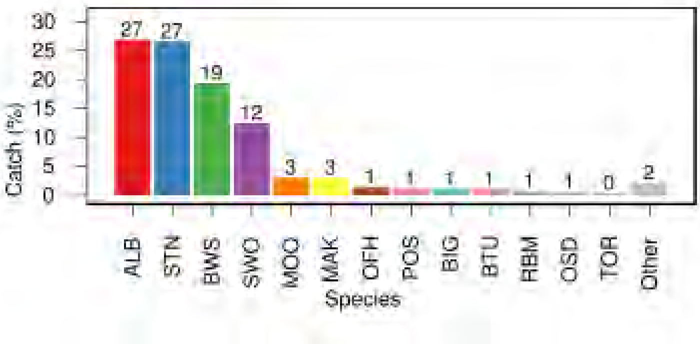


Figure 3: A summary of species composition of the reported southern bluefin tuna target surface longline catch. The percentage by weight of each species is calculated for all surface longline trips targeting southern bluefin tuna (Bentley et al 2012).

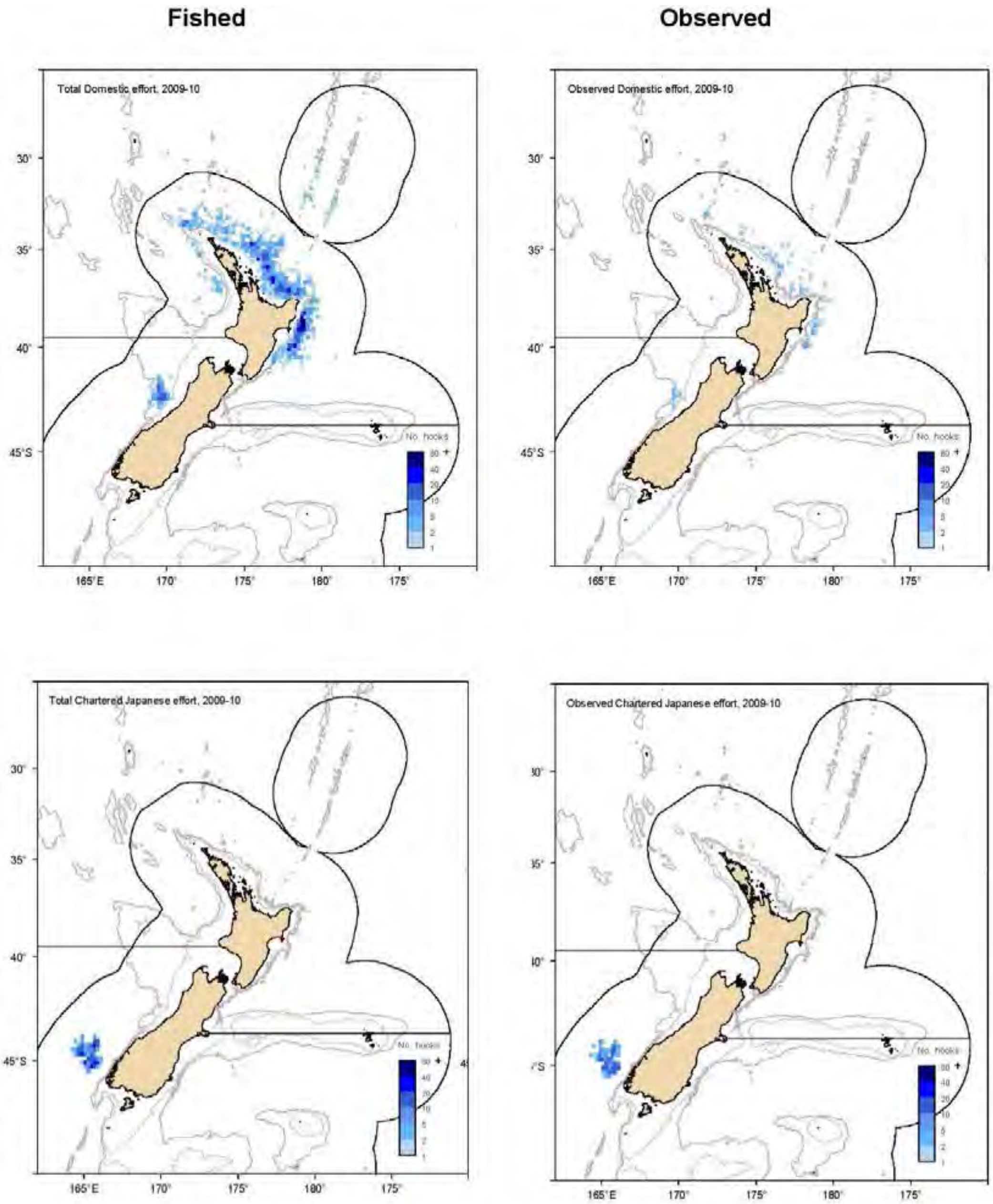


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009-10 fishing year, displaying both fishing effort (left) and observer effort (right).

1.2 Recreational fisheries

Charter vessels based in Milford Sound are known to have targeted southern bluefin tuna historically. Gamefish charter vessels fishing from Greymouth and Westport now take STN as bycatch in the newly developed Pacific bluefin tuna fishery. Estimates of catch based on voluntary charter boat reporting range from 4 025 kg (35 fish) in 2007 to 400 kg (3 fish) in 2008. A further 20 fish (2 171 kg) were released alive, probably after tagging.

The estimate of non-commercial SBT catch as bycatch from the Pacific bluefin tuna game fishery was less than one tonne in 2010. Six fish were reported as non-commercial SBT catch from recreational charter vessels in 2012, and 2 were released alive.

1.3 Customary non-commercial fisheries

An estimate of the current customary catch is not available**.** Given that Maori knew of several oceanic fish species and missionaries reported that Maori regularly fished several miles from shore, it is possible that southern bluefin tuna were part of the catch of Maori prior to European settlement. It is clear that Maori trolled lures (for kahawai) that are very similar to those still used by Tahitian fishermen for small tunas and also used large baited hooks capable of catching large southern bluefin tuna. However, there is no Maori name for southern bluefin tuna, therefore it is uncertain if Maori caught southern bluefin tuna.

1.4 Illegal catch

There is no known illegal catch of southern bluefin tuna by New Zealand vessels in the EEZ or from the high seas. The review of the Japanese Market suggests very large illegal catch from the broader stock historically.

CCSBT has operated a catch documentation scheme since 1 January 2010, with documentation and tagging requirements for all STN, coupled with market-based controls and reporting obligations. Recent actions by individual CCSBT members to improve monitoring, control, and surveillance measures for southern bluefin tuna fisheries are also intended to halt the occurrence of unreported catch.

1.5 Other sources of mortality

Incidental catches of southern bluefin tuna appear to be limited to occasional small catches in trawl and troll fisheries. Small catches of southern bluefin tuna have been reported as non-target catch (< 0.5 t and 2 t respectively), in trawl fisheries for hoki (*Macruronus novaezelandiae*) and arrow squid (*Notodarus* spp.). In addition there have been occasional anecdotal reports of southern bluefin being caught in trawl fisheries for southern blue whiting (*Micromesistius australis*) and jack mackerel (*Trachurus* spp.) in sub-Antarctic waters.

In addition to the limited trawl bycatch there is some discarding and loss (usually as a result of shark damage) before fish are landed that occurs in the longline fishery. The estimated overall incidental mortality rate from observed longline effort is 0.54% of the catch. Discard rates are 0.86% on average from observer data of which approximately 50% are discarded dead. Fish are also lost at the surface in the longline fishery during hauling, 1.47% on average from observer data, of which 95% are thought to escape alive. An allowance of 4 t has been made for other sources of mortality.

2. BIOLOGY

The age at which 50% of southern bluefin are mature is uncertain because of limited sampling of fish on the spawning ground off Java. Recent sampling of the Indonesian catch suggests that 50% age-at-maturity may be as high as 12 years, while interpretations of available data since 1994 have used 8 years and older fish as representing the adult portion of the stock in the population models.

As the growth rate has changed over the course of the fishery (see following section & Table 7) the size-at-maturity depends on when the fish was alive (prior to the 1970s, during the 1970s, or in the period since 1980), as well as which maturity ogive is used. A simple linear interpolation is assumed for the 1970s. Table 6 shows the range of sizes (cm) for southern bluefin tuna aged 8 to 12 years for the two von Bertalanffy growth models used.

Table 6: Differences in southern bluefin tuna size at ages 8 – 12 between the 1960s and 1980s (lengths in cm).

Age	1960s	1980s
8	138.2	147.0
9	144.6	152.7
10	150.2	157.6
11	155.1	161.6
12	159.4	165.0

Radiocarbon dating of otoliths has been used to determine that southern bluefin tuna live beyond 30 years of age and that individuals reaching asymptotic length may be 20 years or older.
The sex ratio of southern bluefin caught by longline in the EEZ has been monitored since 1987. The ratio of males to females is 1.2:1.0, and is statistically significantly different than 1:1.

The parameters of length:weight relationships for southern bluefin tuna based on linear regressions of greenweight versus fork length are in Table 7.

Table 7: Parameters of length/ weight relationship for southern bluefin tuna. *l*n (Weight) = b_1 *l*n(length) – b_0 (Weight in kg, length in cm).

	b_0	B_1
Male	-10.94	3.02
Female	-10.91	3.01
All	-10.93	3.02

The data used include all longline observer data for the period 1987 to 2000 from all vessels in the EEZ (n = 18 994).

CCSBT scientists have used two stanza Von Bertalanffy growth models since 1994:

$$l_t = L_\infty(1 - e^{-k2(t-t0)})(1 + e^{-\beta(t-t0-\alpha)}) / (1 + e^{\beta\alpha})^{-(k2-k1)}$$, where t is age in years.

Table 8: von Bertalanffy growth parameters for southern bluefin tuna.

	L_∞	k_1	k_2	α	β	t_0
1960 von Bertalanffy	187.6	0.47	0.14	0.75	30	0.243
1980 von Bertalanffy	182	0.23	0.18	2.9	30	-0.35

While change in growth in the two periods (pre-1970 and post 1980) is significant and the impact of the change in growth on the results of population models substantial, the differences between the growth curves seem slight. The change in growth rate for juveniles and young adults has been attributed to a density dependent effect of over fishing.

No estimates of F and Z are presented because they are model dependent and because a range of models and modelling approaches are used. Prior to 1995 natural mortality rates were assumed to be constant and M = 0.2 was used. However, the results indicating that asymptotic size was reached at about 20 years and fish older than 30 years were still in the population, suggested that values of M ≥ 0.2 were likely to be too high. Tagging results of juvenile’s ages 1 to 3 years also suggests that M for these fish is high (possibly as high as M = 0.4), while M for fish of intermediate years is unknown. For these reasons M has been considered to be age-specific and represented by various M vectors. In the CCSBT stock assessments, a range of natural mortality vectors are now used.

A conversion factor of 1.15 is used for gilled and gutted southern bluefin tuna.

3. STOCKS AND AREAS

Southern bluefin tuna consist of a single stock primarily distributed between 30ºS and 45ºS, which is only known to spawn in the Indian Ocean south of Java. Adults are broadly distributed in the South Atlantic, Indian and western South Pacific Oceans, especially in temperate latitudes while juveniles occur along the continental shelf of Western and South Australia and in high seas areas of the Indian Ocean. Southern bluefin tuna caught in the New Zealand EEZ appear to represent the easternmost extent of a stock whose centre is in the Indian Ocean.

A large-scale electronic tagging programme, involving most members of the Commission, has been undertaken to provide better information on stock structure. The goal has been to tag smaller fish across the range of the stock. New Zealand has participated in this programme, having deployed 19 implantable tags in small fish in 2007. Fifteen larger STN were tagged with pop-off tags as well, with 12 tags having reported data thus far. Of note, one of the tagged fish moved to the spawning ground south of Indonesia.

Electronic tagging of juvenile STN in the Great Australian Bight showed that for a number of years tagged juveniles were not moving into the Tasman Sea. It was not known whether this was due to unfavourable environmental conditions or range contraction following the decline in the stock. However, in the last couple of years more of these tagged juveniles have been reported in New Zealand catches.

Two sources of information suggest that there may be ‘sub-structure’ within the broader STN stock, in particular the Tasman Sea. Tagging of adult STN within the Australian east coast tuna and billfish fishery suggests that STN may spend most of the years within the broader Tasman Sea region. An analysis of the length and age composition of catches from the New Zealand JV fleet showed that cohorts that were initially strong or weak did not change over time, e.g., if a particular year class was weak (or strong) when it initially recruited to the New Zealand fishery it remained so over time.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2014 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of the southern bluefin tuna longline fishery; a more detailed summary from an issue-by-issue perspective is available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed (http://www.mpi.govt.nz/Default.aspx?TabId=126&id=2122) (Ministry for Primary Industries 2013a).

4.1 Role in the ecosystem

Southern bluefin tuna (*Thunnus maccoyii*) are apex predators, feeding opportunistically on a mixture of fish, crustaceans and squid and juveniles also feed on a variety of zooplankton and micronecton species (Young et al 1997). Southern bluefin tuna are large pelagic predators, so they are likely to have a ‘top down’ effect on the fish, crustaceans and squid they feed on.

4.2 Incidental catch of seabirds, sea turtles and mammals

These capture estimates relate to the southern bluefin target longline fishery only, from the New Zealand EEZ. The capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.2.1 Seabird bycatch

Between 2002–03 and 2012–13, there were 584 observed captures of birds in southern bluefin longline fisheries. Seabird capture rates since 2003 are presented in Figure 5. Capture rates peaked in 2006-07 and 2009-10. Seabird captures were most concentrated off Fiordland and around East Cape (see Table 9 and Figure 6). Bayesian models of varying complexity dependent on data quality have been used to estimate captures across a range of methods (Richard & Abraham 2014). Observed and estimated seabird captures in albacore longline fisheries are provided in Table 10.

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 the notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Risk posed by commercial fishing to seabirds has been assessed via a level 2 method which supports much of the NPOA-Seabirds 2013 risk assessment framework (MPI 2013b). The method used in the level 2 risk assessment arose initially from an expert workshop hosted by the Ministry of Fisheries in 2008. The overall framework is described in Sharp et al. (2011) and has been variously applied and improved in multiple iterations (Waugh et al. 2009, Richard et al. 2011, Richard and Abraham 2013, Richard et al. 2013 and Richard & Abraham in press). The method applies an "exposure-effects" approach where exposure refers to the number of fatalities is calculated from the overlap of seabirds with fishing effort compared with observed captures to estimate the species vulnerability (capture rates per encounter) to each fishery group. This is then compared to the population's productivity, based on population estimates and biological characteristics to yield estimates of population-level risk.

The 2014 iteration of the seabird risk assessment (Richard & Abraham in press) assessed the southern bluefin tuna surface longline target fisheries contribution to the total risk posed by New Zealand commercial fishing to seabirds (see Table 11). These target fisheries contribute 0.651 of PBR_1 to the risk to Southern Buller's albatross and 0.290 of PBR_1 to Gibson's albatross; both species were assessed to be at very high risk from New Zealand commercial fishing. This fishery also contributed 0.230 of PBR_1 to Antipodean albatross, which was assessed to be at high risk from New Zealand commercial fishing (Richard & Abraham in press).

Table 9: Number of observed seabird captures in southern bluefin tuna longline fisheries, 2002–03 to 2012–13, by species and area. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR (from Richard and Abraham (2014) where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for southern bluefin tuna using longline gear but rather the total risk for each seabird species. Other data, version 20140201.

Species	Risk ratio	Fiordland	East Coast North Island	West Coast South Island	Stewart Snares Shelf	Bay of Plenty	Northland and Hauraki	Total
Southern Buller's albatross	Very high	280	14	39		2		335
New Zealand white-capped albatross	Very high	62	3	34	10			109
Campbell black-browed albatross	High	3	13	2		2	3	23
Gibson's albatross	Very high	3	4	2			1	10
Wandering albatrosses	N/A	3	4					7
Antipodean albatross	High		5				1	6
Southern royal albatross	Low	4		1				5
Salvin's albatross	Very high		3			1		4
Southern black-browed albatross	N/A		2					2
Wandering albatross	N/A		1					1
Black-browed albatrosses	N/A		1					1
Light-mantled sooty albatross	Low			1				1
Smaller albatrosses	N/A		1					1
Northern Buller's albatross	High		1					1
Total albatrosses	N/A	355	52	79	10	5	5	506
Grey petrel	Low		35			3	2	40
White-chinned petrel	Medium	20	1		1		1	23
Westland petrel	High	1		5				6
Sooty shearwater	Negligible	1			3			4
Cape petrels	N/A		2					2
Southern giant petrel	N/A		2					2
Seabird - large	N/A	1						1
Total other seabirds	N/A	23	40	5	4	3	3	78

Table 10: Effort, observed and estimated seabird captures in southern bluefin tuna fisheries by fishing year within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). Estimates are based on methods described in Thompson et al (2013) and are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002–03 to 2010–11 and preliminary estimates for 2012–13 are based on data version 20140131.

	Fishing effort			Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	3 513 361	1 133 740	32.3	43	0.038	484	368–664
2003–2004	3 195 071	1 471 964	46.1	70	0.048	375	296–486
2004–2005	1 661 979	734 026	44.2	36	0.049	176	139–223
2005–2006	1 493 418	655 445	43.9	29	0.044	141	109–184
2006–2007	1 938 111	916 660	47.3	111	0.121	229	186–260
2007–2008	1 104 825	375 975	34.0	30	0.08	154	119–193
2008–2009	1 484 438	840 048	56.6	48	0.057	191	151–236
2009–2010	1 559 858	580 395	37.2	112	0.193	379	312–470
2010–2011	1 330 265	567 204	42.6	32	0.056	185	136–269
2011–2012	1 593 754	645 530	40.5	50	0.077	362	255–558
2012–2013†	1 501 647	491 903	32.8	23	0.047	271-	186–442

†Provisional data, model estimates not finalised.

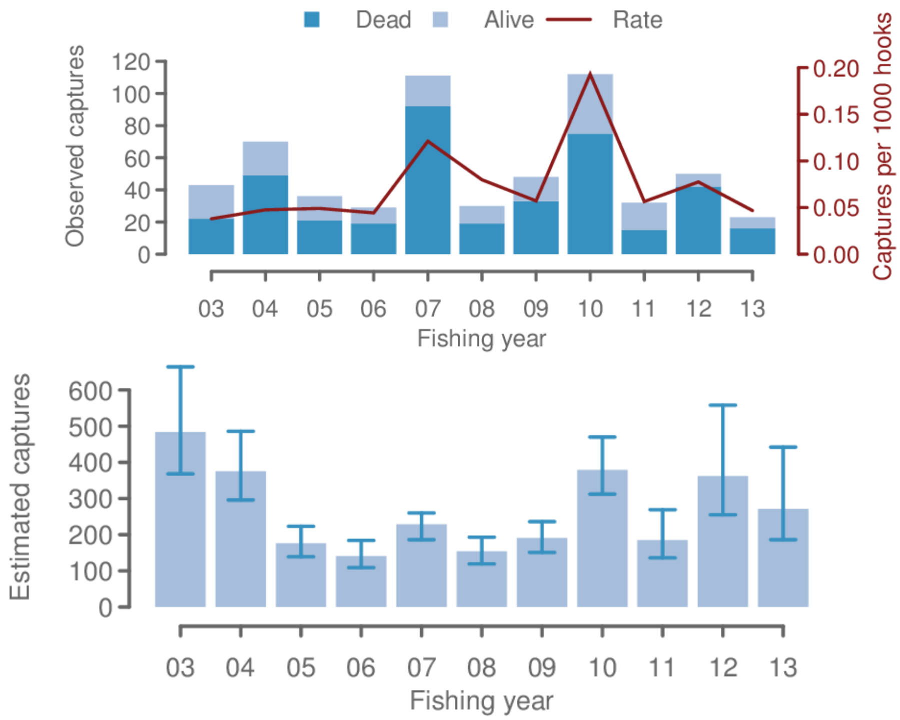


Figure 5: Observed and estimated captures of seabirds in southern bluefin tuna longline fisheries from 2002–03 to 2012–13.

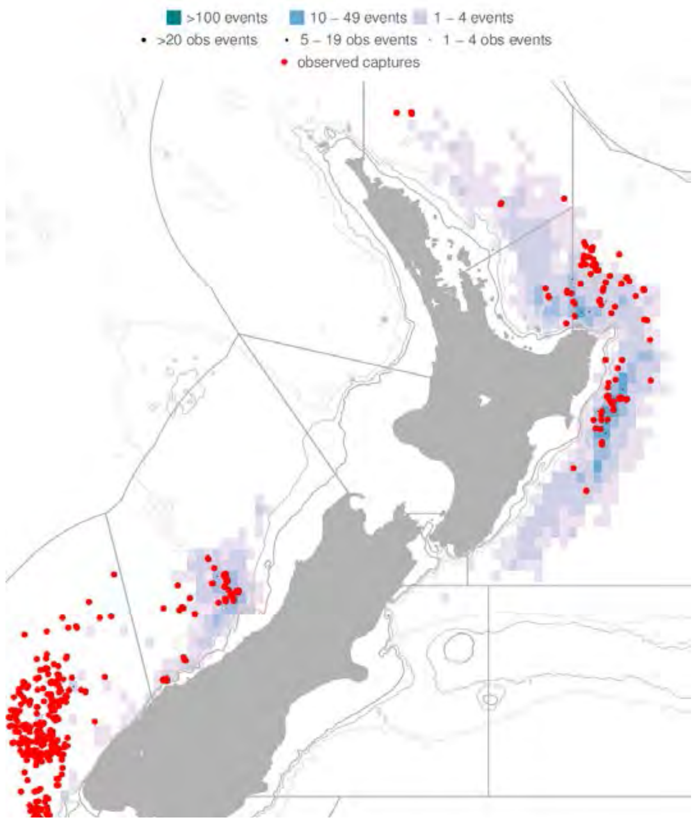


Figure 6: Distribution of fishing effort targeting southern bluefin tuna and observed seabird captures, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 78.7% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

Table 11: Risk ratio of seabirds predicted by the level two risk assessment for the southern bluefin tuna target surface longline fisheries and all fisheries included in the level two risk assessment, 2006–07 to 2012–13, showing seabird species with risk category of very or high, or a medium risk category and risk ratio of at least 1% of the total risk. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR_1 (from Richard and Abraham 2014 where full details of the risk assessment approach can be found). PBR_1 applies a recovery factor of 1.0. Typically a recovery factor of 0.1 to 0.5 is applied (based on the state of the population) to allow for recovery from low population sizes as quickly as possible. This should be considered when interpreting these results. The New Zealand threat classifications are shown (Robertson et al 2013 at http://www.doc.govt.nz/documents/science-and-technical/nztcs4entire.pdf)

	Risk ratio				
Species name	STN target SLL	Total risk from NZ commercial fishing	% of total risk from NZ commercial fishing	Risk category	NZ Threat Classification
Black petrel	0.025	15.095	0.17	Very high	Threatened: Nationally Vulnerable
Salvin's albatross	0.005	3.543	0.15	Very high	Threatened: Nationally Critical
Southern Buller's albatross	0.651	2.823	23.08	Very high	At Risk: Naturally Uncommon
Flesh-footed shearwater	0.013	1.557	0.84	Very high	Threatened: Nationally Vulnerable
Gibson's albatross	0.290	1.245	23.33	Very high	Threatened: Nationally Critical
New Zealand white-capped albatross	0.026	1.096	2.40	Very high	At Risk: Declining
Chatham Island albatross	0.000	0.913	0.00	High	At Risk: Naturally Uncommon
Antipodean albatross	0.230	0.888	25.90	High	Threatened: Nationally Critical
Westland petrel	0.081	0.498	16.28	High	At Risk: Naturally Uncommon
Northern Buller's albatross	0.074	0.336	22.13	High	At Risk: Naturally Uncommon
Campbell black-browed albatross	0.043	0.304	14.17	High	At Risk: Naturally Uncommon
Stewart Island shag	0.000	0.301	0.00	High	Threatened: Nationally Vulnerable
White-chinned petrel	0.006	0.268	2.10	Medium	At Risk: Declining
Northern royal albatross	0.008	0.181	4.39	Medium	At Risk: Naturally Uncommon

4.2.2 Sea turtle bycatch

Between 2002–03 and 2012–13, there were three observed captures of sea turtles in southern bluefin longline fisheries (Tables 12 and 13, Figure 7). Observer recordings documented all sea turtles as captured and released alive. Sea turtle captures for this fishery have only been observed off the east coast of the North Island (Figure 8).

Table 12: Number of observed sea turtle captures in southern bluefin tuna longline fisheries, 2002–03 to 2012–13, by species and area. Data from Thompson et al (2013), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Total
Leatherback turtle	1	1	2
Green turtle	0	1	1
Total	1	2	3

Table 13: Fishing effort and sea turtle captures in southern bluefin tuna longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data see Thompson et al (2013).

	Fishing effort			Observed captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate
2002–2003	3 513 361	1 133 740	32.3	0	0
2003–2004	3 195 071	1 471 964	46.1	0	0
2004–2005	1 661 979	734 026	44.2	0	0
2005–2006	1 493 418	655 445	43.9	0	0
2006–2007	1 938 111	916 660	47.3	0	0
2007–2008	1 104 825	375 975	34.0	0	0
2008–2009	1 484 438	840 048	56.6	0	0
2009–2010	1 559 858	580 395	37.2	0	0
2010–2011	1 330 265	567 204	42.6	3	0.005
2011–2012	1 593 754	645 530	40.5	0	0
2012–2013	1 501 647	491 903	32.8	0	0

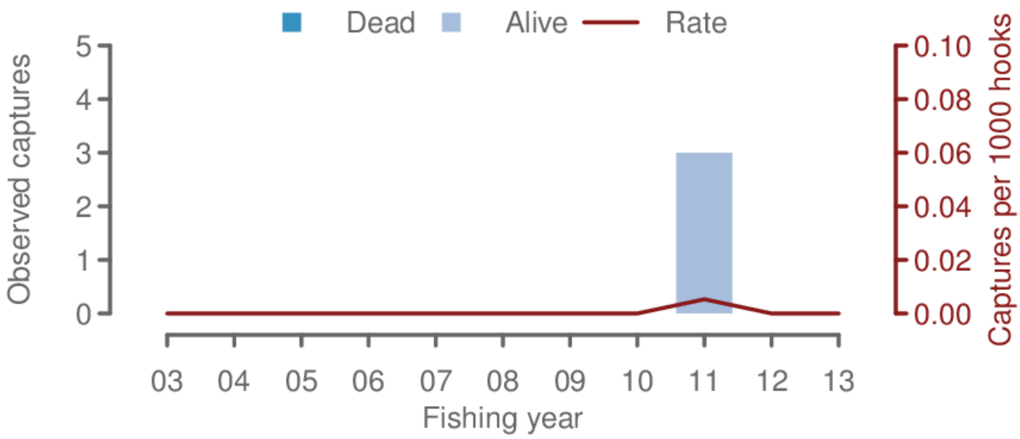


Figure 7: Observed captures of sea turtles in southern bluefin tuna longline fisheries from 2002–03 to 2012–13.

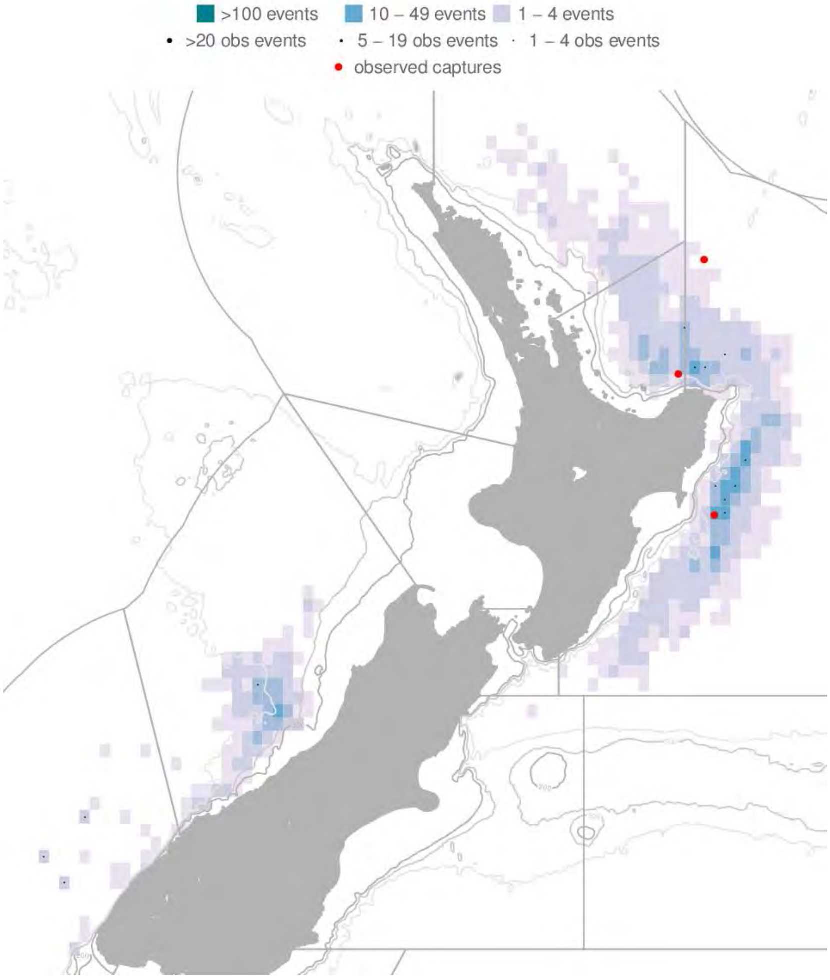


Figure 8: Distribution of fishing effort targeting southern bluefin tuna and observed sea turtle captures, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 78.7% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Cetaceans are dispersed throughout New Zealand waters (Perrin et al 2008). The spatial and temporal overlap of commercial fishing grounds and cetacean foraging areas has resulted in cetacean captures in fishing gear (Abraham and Thompson 2009, 2011).

Between 2002–03 and 2012–13, there were five observed captures of whales and dolphins in southern bluefin longline fisheries (Tables 14 and 15, Figure 9). Observed captures included two long-finned pilot whales and three unidentified cetaceans (Abraham and Thompson 2011). All captured animals recorded were documented as being caught and released alive (Thompson & Abraham 2010), with catches occurring in the east coast of the North Island, west coast of the South Island, Fiordland, and Bay of Plenty (Figure 9). Cetacean capture distributions do not coincide with fishing effort and are more common on the north east coast of the North Island (Figure 10).

Table 14: Number of observed cetacean captures in southern bluefin tuna longline fisheries, 2002–03 to 2012–13, by species and area. Data from Thompson et al (2013), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Fiordland	West Coast South Island	Total
Long-finned pilot whale	0	1	0	1	2
Unidentified cetacean	1	1	1	0	3
Total	1	2	1	1	5

Table 15: Effort and cetacean captures in southern bluefin tuna longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Thompson et al (2013).

	Fishing effort			Observed captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate
2002–2003	3 513 361	1 133 740	32.3	0	0
2003–2004	3 195 071	1 471 964	46.1	3	0.002
2004–2005	1 661 979	734 026	44.2	1	0.001
2005–2006	1 493 418	655 445	43.9	0	0
2006–2007	1 938 111	916 660	47.3	0	0
2007–2008	1 104 825	375 975	34.0	1	0.003
2008–2009	1 484 438	840 048	56.6	0	0
2009–2010	1 559 858	580 395	37.2	0	0
2010–2011	1 330 265	567 204	42.6	0	0
2011–2012	1 593 754	645 530	40.5	0	0
2012–2013	1 501 647	491 903	32.8	0	0

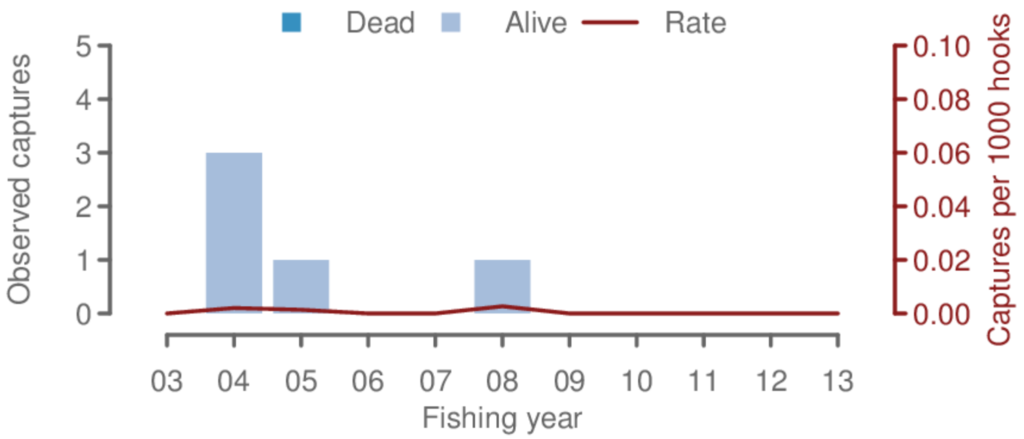


Figure 9: Observed captures of cetaceans in southern bluefin longline fisheries from 2002–03 to 2012–13.

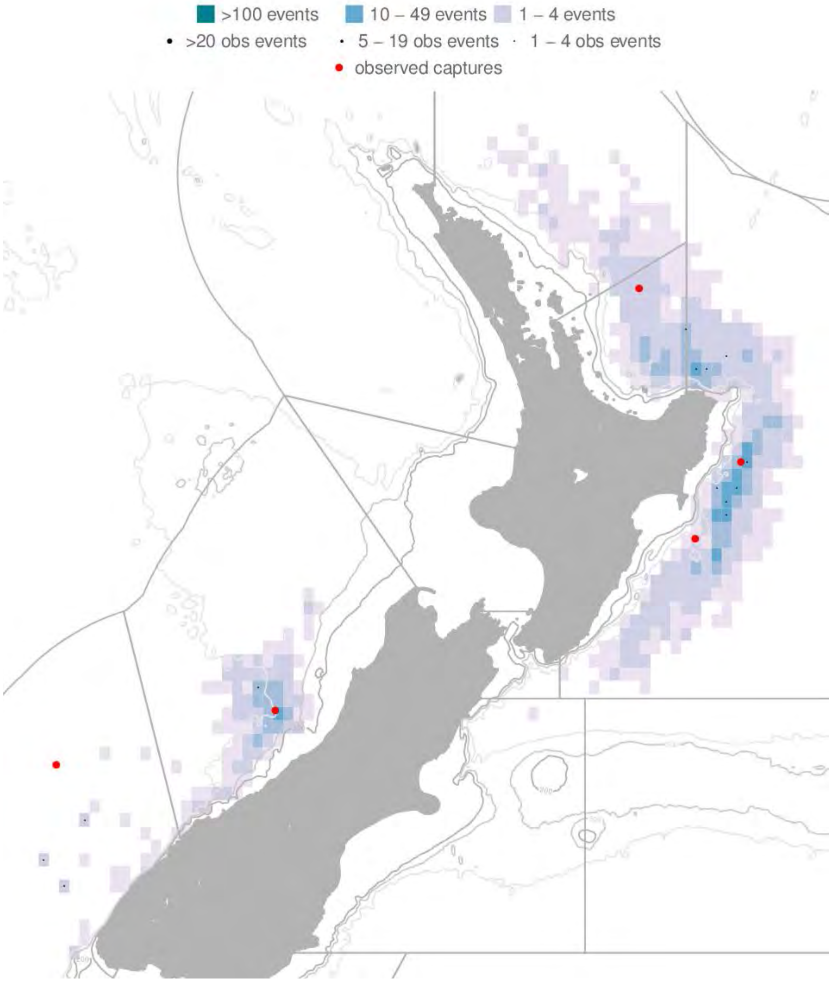


Figure 10: Distribution of fishing effort targeting southern bluefin tuna and observed cetacean captures, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 78.7% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, but are more common in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf, which slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts, around much of the South Island and offshore islands. Captures on longlines occur when the fur seals attempt to feed on the bait and fish catch during hauling. Most New Zealand fur seals are released alive, typically with a hook and short snood or trace still attached.

New Zealand fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty-East Cape area. Estimated numbers range from 127 (95% CI 121–133) in 1998–99 to 25 (14–39) in 2007–08 during southern bluefin tuna fishing by chartered and domestic vessels (Abraham et al 2010) (Tables 16 and 17). These capture rates include animals that are released alive (100% of observed surface longline capture in 2008–09; Thompson & Abraham 2010). Capture rates in 2011–12 and 2012-

13 were higher than they were in the early 2000s (Figure 11). While fur seal captures have occurred throughout the range of this fishery, most have occurred off the Southwest coast of the South Island (Figure 12).

Table 16: Number of observed New Zealand fur seal captures in southern bluefin tuna longline fisheries, 2002–03 to 2012–13, by species and area. Data from Thompson et al (2013), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	Stewart Snares Shelf	West Coast South Island	Total
New Zealand fur seal	9	15	159	4	4	32	223

Table 17: Effort and captures of New Zealand fur seal by fishing year in southern bluefin tuna longline fisheries. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). Data from Thompson et al (2013), retrieved from http://data.dragonfly.co.nz/psc/. Estimates from 2002–03 to 2010–11 and preliminary estimates for 2012–13 are based on data version 20140131.

			Fishing effort	Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	3 513 361	1 133 740	32.3	56	0.049	266	172–381
2003–2004	3 195 071	1 471 964	46.1	40	0.027	121	81–170
2004–2005	1 661 979	734 026	44.2	18	0.025	60	35–91
2005–2006	1 493 418	655 445	43.9	12	0.018	43	21–72
2006–2007	1 938 111	916 660	47.3	10	0.011	30	13–53
2007–2008	1 104 825	375 975	34.0	8	0.021	37	17–64
2008–2009	1 484 438	840 048	56.6	22	0.026	49	27–76
2009–2010	1 559 858	580 395	37.2	19	0.033	73	41–114
2010–2011	1 330 265	567 204	42.6	17	0.030	57	31–90
2011–2012†	1 593 754	645 530	40.5	40	0.062	127	84–179
2012–13	1 501 647	491 903	32.8	21	0.043	98	57–153

†Provisional data, model estimates not finalised.

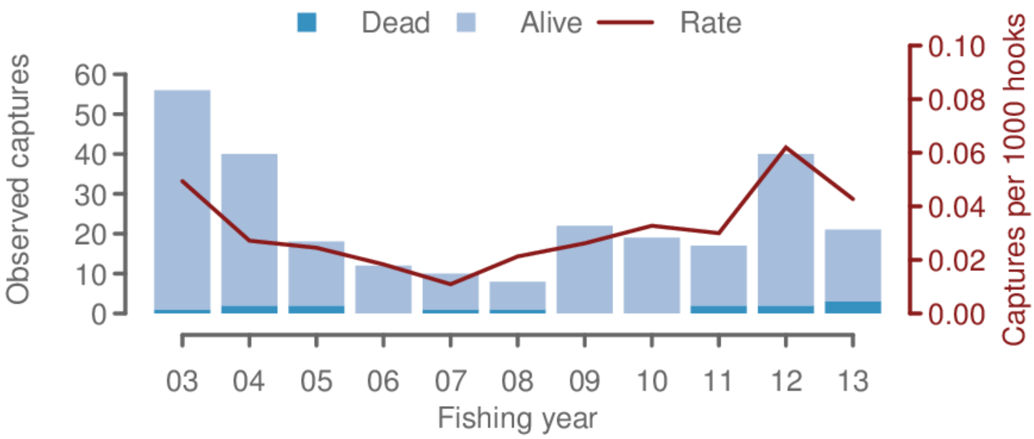


Figure 11: Observed captures of New Zealand fur seal in southern bluefin longline fisheries from 2002–03 to 2012–13.

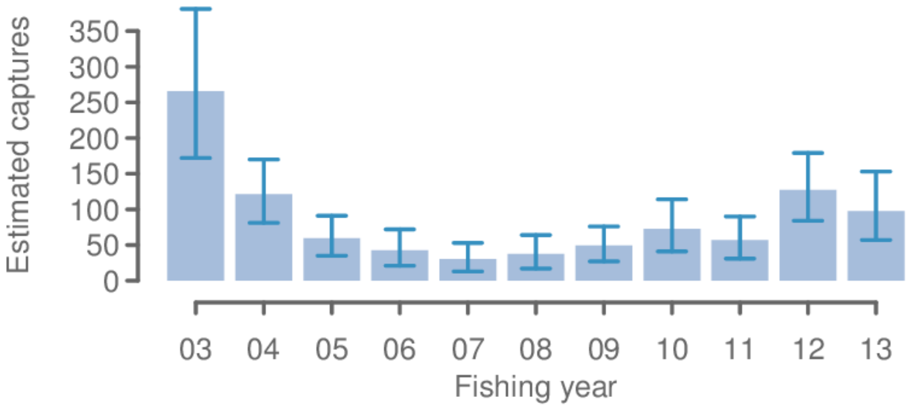


Figure 12: Estimated captures of New Zealand fur seal in southern bluefin longline fisheries from 2002–03 to 2012–13.

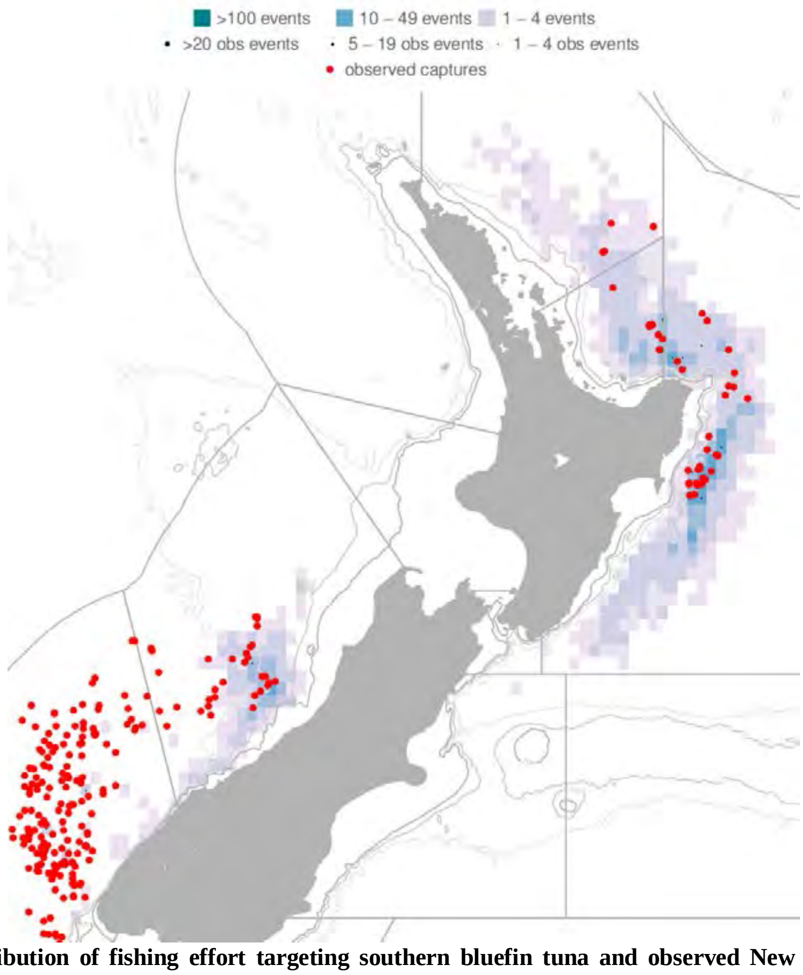


Figure 13: Distribution of fishing effort targeting southern bluefin tuna and observed New Zealand fur seal captures, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 78.7% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3 Incidental fish bycatch

This section summarises fish catches taken in tuna longline sets that either targeted or caught southern bluefin tuna. Numbers of fish observed, and estimated numbers scaled from observer to the commercial fishing effort during the 2009 and 2010 calendar years are shown in Table 17.

Catch per unit effort is also shown in Table 18. The scaled estimates provided for the domestic fleet can be considered less reliable than those of the charter fleet as they are based on lower observer coverage.

Bycatch composition from the charter fleet and the domestic fleet is different. This is likely to be due to differences in waters fished, with the charter fleet mostly operating in southern waters, and the domestic vessels fishing primarily in waters north of about 40°S. Charter vessels fished north of East Cape late in the 2009 season but only fished off the West Coast of the South Island in 2010 and this resulted in a different catch composition in the two years. In both 2009 and 2010, blue shark, Ray’s bream, and albacore were predominant in the catches overall, with these three species making up nearly 70% of the catch. Charter vessels caught mostly blue sharks and Ray’s bream, with blue sharks the most abundant species in the catch in 2009 and Ray’s bream higher in 2010. Blue sharks dominated the catches of the domestic vessels, followed by albacore.

Table 18: Numbers of fish caught reported on commercial catch effort returns (reported), observed, estimated from observer reports and total fishing effort (scaled), and catch per unit effort (CPUE) for fish species caught on longline sets where southern bluefin tuna was either targeted or caught during the 2010 calendar year.

	Charter			New Zealand Domestic		
	Observed	Scaled	CPUE	Observed	Scaled	CPUE
Blue shark	2 024	2 501	5.226	5 062	57 834	46.406
Rays bream	3 295	4 072	8.508	362	4 136	3.319
Albacore tuna	90	111	0.232	1 219	13 927	11.175
Dealfish	882	1 090	2.277	7	80	0.064
Big scale pomfret	349	431	0.901	3	34	0.028
Porbeagle shark	72	89	0.186	279	3 188	2.558
Deepwater	305	377	0.788	0	0	0.000
Swordfish	3	4	0.008	269	3 073	2.466
Lancetfish	3	4	0.008	337	3 850	3.089
Mako shark	11	14	0.028	211	2 411	1.934
Moonfish	76	94	0.196	143	1 634	1.311
Butterfly tuna	15	19	0.039	103	1 177	0.944
Oilfish	2	2	0.005	44	503	0.403
School shark	34	42	0.088	2	23	0.018
Sunfish	7	9	0.018	65	743	0.596
Rudderfish	39	48	0.101	18	206	0.165
Flathead pomfret	56	69	0.145	0	0	0.000
Escolar	0	0	0.000	58	663	0.532
Pelagic stingray	0	0	0.000	8	91	0.073
Thresher shark	7	9	0.018	9	103	0.083
Hoki	0	0	0.000	1	11	0.009
Pacific bluefin	0	0	0.000	2	23	0.018
Skipjack tuna	0	0	0.000	1	11	0.009
Striped marlin	0	0	0.000	1	11	0.009
Yellowfin tuna	0	0	0.000	0	0	0.000

4.4 Benthic interactions
N/A

4.5 Key environmental and ecosystem information gaps
Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

Determination of the status of the southern bluefin tuna stock is undertaken by the CCSBT Scientific Committee (CCSBT-SC). The stock assessment was updated in 2014 for the first time since 2011. The report describes the reconditioning of the SBT operating models and the current estimates of stock status, following initial work for the OMMP meeting. The assessment results are based on the agreed base case and a range of sensitivity scenarios. This is the first stock assessment since the MP was implemented in 2011, and the first stock assessment with the close-kin data formally included.

5.1 Estimates of fishery parameters and abundance

Fishery indicators

As part of the stock assessment, a range of fishery indicators that were independent of any stock assessment model were considered to provide support and/or additional information important to aspects of current stock status. Indicators considered included those relating to recent recruitment, spawning biomass, and vulnerable biomass and were based on catch at age data, CPUE data, and information from various surveys (e.g., aerial sightings and troll surveys).

The summary of indicators in 2014 was as follows:

- The 2014 scientific aerial survey index of relative juvenile (2-4 year old) abundance is the highest value seen in the time series. Between 2010 and 2014 the index has shown more variation but with an increasing trend. The commercial SAPUE index also increased from 2013 to 2014, but to a lesser extent. The trolling survey index for age 1 declined slightly between 2013 and 2014.
- Longline CPUE for the Japanese fleet for ages 6 and 7 increased steadily from 2007 to 2012 but decreased in 2013. The CPUE index values for ages 8-11 decreased slightly and gradually from 2008 to 2011 but have increased in more recent years. The CPUE indices for age 12+ has showed a decline from 2008 to 2010 and then fluctuated around a low level afterward; this is expected given the weak recruitment from 1999 to 2002.
- In 2012-13 and 2013-14 there was a decline in the mean length of SBT on the spawning ground, with a new mode of relatively small/young fish in the Indonesian catch. It remains to be determined whether the catch of smaller fish comes from the spawning ground and whether they are mature.

Length frequencies and CPUE in New Zealand waters

Length frequency data from the charter fleet are shown in Figure 14. Nominal CPUE by fleet across all Regions based on targeted longline effort is provided in Figure 15. Charter CPUE averaged around three STN per 1000 hooks over 1997-2002. Associated with the lack of new recruitment, CPUE declined dramatically in 2003 and stayed at about these historically low levels for five consecutive years until a marked increase in 2008 – 2010 for the Charter fleet. CPUE remained at these higher levels during 2011 – 2013. This increase occurred in the core area of their fishery (e.g., Region 6) and was likely due to the appearance of the smaller fish seen in Figure 14. The domestic fleet mainly operating in area 5 has also experienced increased CPUE from 2008 to 2013.

5.2 Biomass estimates

5.2.1 Spawning biomass

In 2014 the stock remains at a very low state estimated to be 9% of the initial SSB, and below the level to produce maximum sustainable yield (MSY), however there has been some improvement since the 2011 stock assessment and fishing mortality is below the level associated with MSY. B10+ relative to initial is estimated to be 7% which is up from the estimate of 5% in 2011.

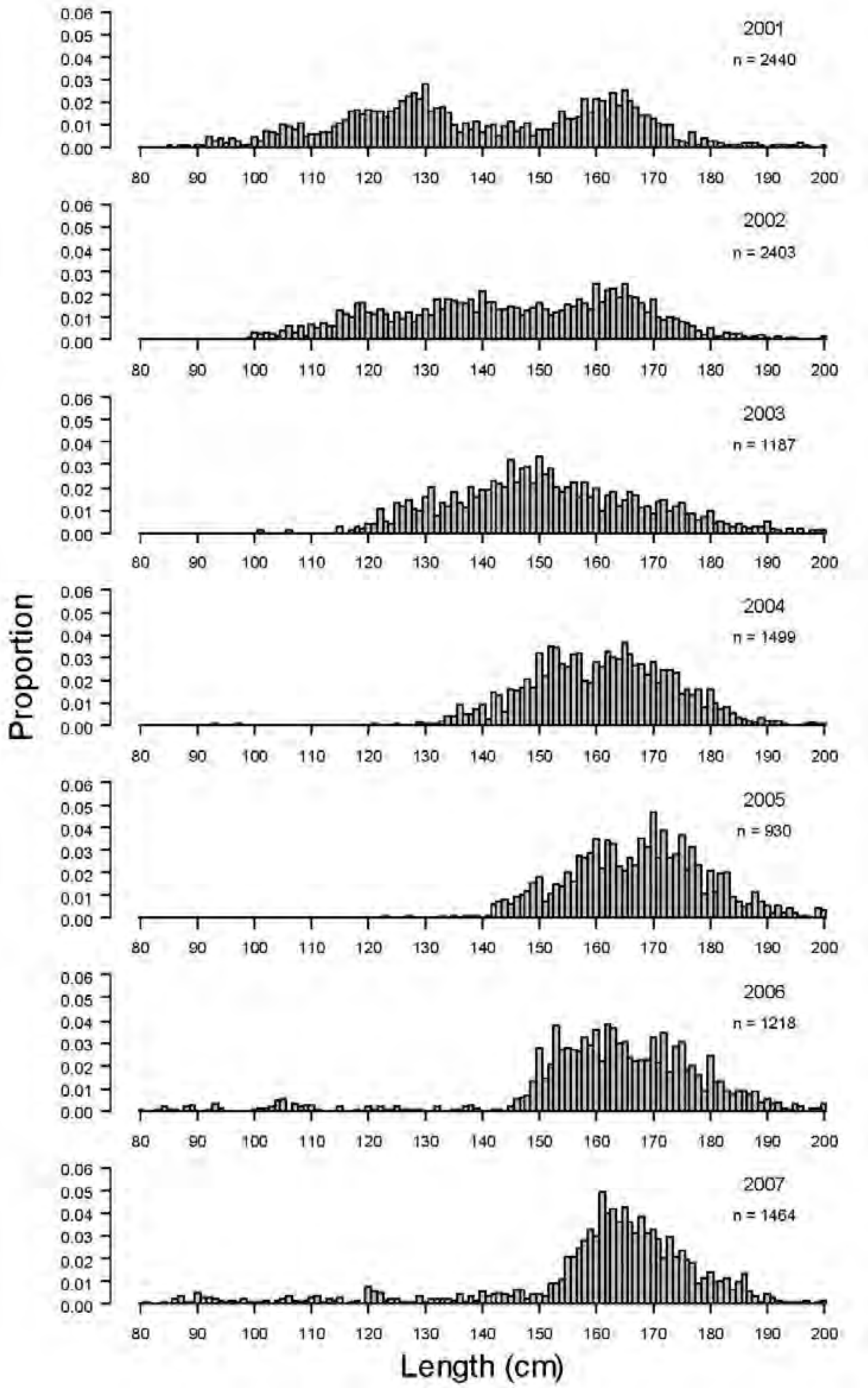


Figure 14: Proportion at length for the Japanese charter fleet operating in New Zealand Fishery waters for 2001 to 2013. Source: CCSBT-ESC/1409/SBT Fisheries New Zealand (2014) [Continued on next page].

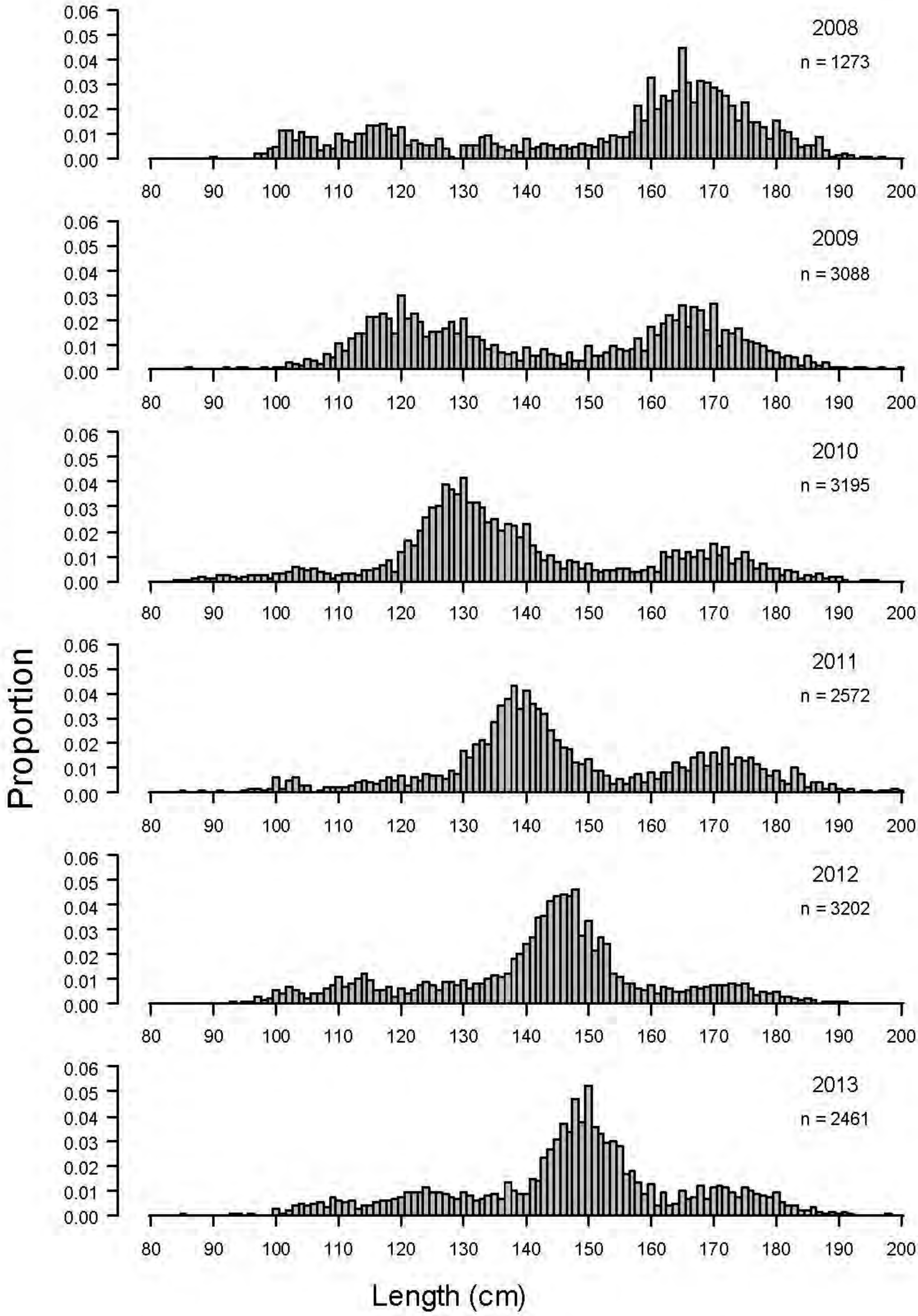


Figure 14 [Continued]: Proportion at length for the Japanese charter fleet operating in New Zealand Fishery waters for 2001 to 2013. Source: CCSBT-ESC/1409/SBT Fisheries New Zealand (2014).

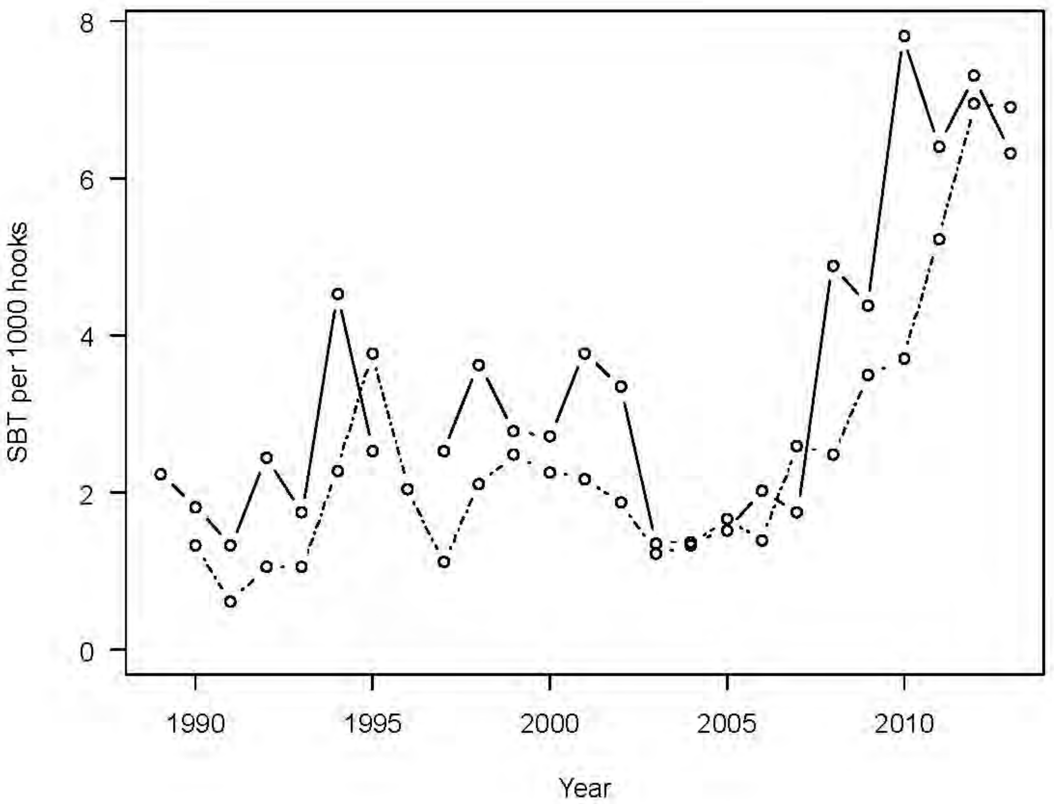


Figure 15: Nominal catch per unit effort (number of STN per thousand hooks) by calendar year for the New Zealand Charter (solid line) and domestic (dashed line) longline fleets operating in New Zealand based only on effort from sets that either targeted or caught southern bluefin tuna. Source: CCSBT-ESC/1409/SBT Fisheries New Zealand (2014).

The estimated trajectory of spawning stock biomass integrated over the grid for the base case over the full time series for the fishery is given in Figure 16. This shows a continuous decline from the late 1950s to the late 1970s, then a short period of stabilisation followed by a further decline from the early 1980s to mid 1990s to a very low level. The spawning stock biomass is estimated to have remained at this low level with relatively small annual variation until the early 2000s. For the more recent period, a decline in the median spawning stock biomass is evident from 2002 through 2012. There is no current evidence of the spawning stock rebuilding, but it is projected to start rebuilding after 2013.

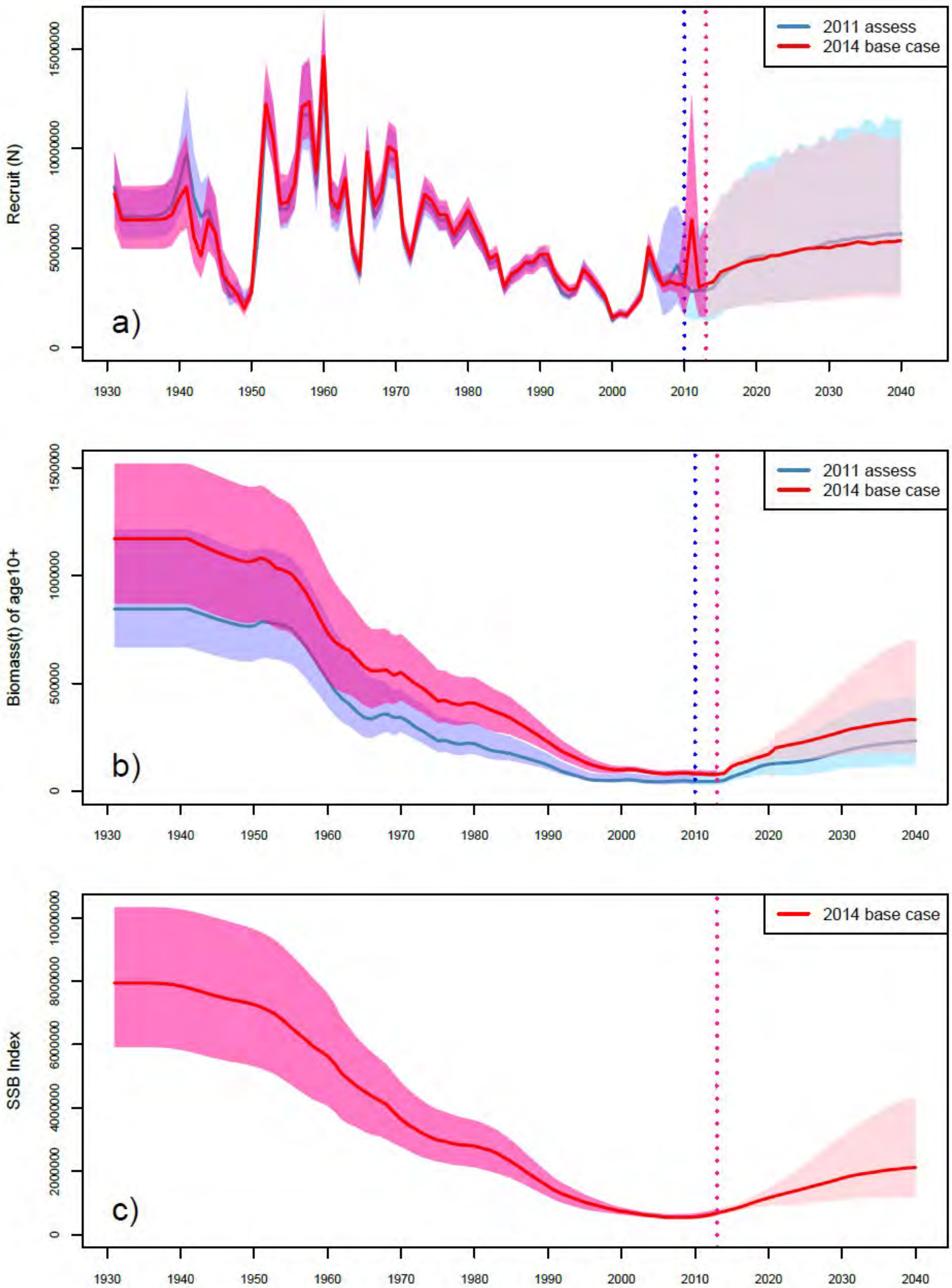


Figure 16: Recruitment and spawning stock biomass for the base case, showing the medians, quartiles and 90th percentiles, together with reference points of 20% of pre-exploitation spawning stock biomass and the spawning stock biomass in 2004 (B_{2004}). Source: Report of the Scientific Committee 2011.

The close-kin genetics project has now been completed, and the inclusion of the close-kin data within the operating model (OM) has been reviewed by the Extended Scientific Committee and approved for inclusion. Both the stand-alone abundance estimator from the close-kin project and the OM with the close-kin data included suggest that the current spawning biomass may be appreciably higher than was previously estimated. Indications in the OM incorporating the close-kin data are that biomass depletion (i.e. Bcurrent/B_0) and also absolute biomass are not as low as previously estimated. However, associated estimates of the probable levels of sustainable yield are very similar. When these two aspects are considered in combination, the indications are that the estimated recent productivity of the resource (upon which TAC advice is based) differs only slightly from previous estimates.

5.2.2 Stock projections

Note that the future catch levels will be set by the Commission based on the output from the Management Procedure. The MP is designed to rebuild the spawning stock to 20% of the unfished level by 2035 (with 70% certainty). The base case achieved the rebuilding target with a slightly greater probability than 70%.

In 2013 the EC requested that the ESC conduct sensitivity analysis of the potential impacts of unaccounted mortalities (UAM) on the assessment of stock status and incorporate this in their advice on exceptional circumstances. In addition, the EC requested that the ESC provide preliminary advice on the impact of unaccounted mortalities on the rebuilding plan for SBT and recommendations beyond the current TAC block (2015-2017). The ESC tested a range of UAM scenarios with the most extreme being an extra catch of 1000 t of large fish plus 1000 t of small fish.

Current stock status estimates appear to be unaffected by the unaccounted mortality scenarios. There are impacts on the projections and rebuilding performance from the unaccounted mortality scenarios. From the analysis of the impacts of unaccounted mortality scenarios on projections the ESC notes that if total mortalities are as large as those considered in the added-catch scenario, then impacts on the rebuilding plan may be substantial. The probability of achieving the rebuilding target by 2035 is reduced to 49%. There is a differential impact from catches of large and small fish; unaccounted catch mortalities of large fish impact directly or early, and impacts from unaccounted small fish catches have a substantial lag-time before the impacts will be observed. The ESC noted that the added catch scenario was potentially plausible given the available data, information and anecdotal market reports. The probability of rebuilding for this scenario was similar to but not worse than the most pessimistic scenario tested in 2011 (upq sensitivity run).

The ESC noted that the current analysis is based on a different reference set, but the equivalent level of performance of the MP to sensitivities was accepted by the EC in 2011.

5.3 Other yield estimates and stock assessment results

In 2012 the preliminary results from the close-kin genetics study were reported at the Scientific Committee of CCSBT (CCSBT-ESC/1208/19). Over 13,000 bluefin caught in the GAB (juveniles) and off Indonesia (mature adults) from 2006 to 2010 were genotyped and 45 Parent-Offspring Pairs (POPs) were detected. When these data were analysed in an independent assessment model the result was that adult abundance was estimated to be higher than the current estimates from the Operating Model used by the Scientific Committee in 2011. The data from the close-kin study have been incorporated into the Operating Model in 2014.

6. STATUS OF THE STOCK

Based on the stock assessment results presented to the ESC in 2014, the following stock status advice for the reference set of operating models was compiled (Table 19). Two measures of the current spawning stock size are presented. The new method used in the operating model is presented as spawning stock biomass (SSB), and is based on a revised spawning potential estimate which has been introduced into the operating model along with incorporation of the close-kin data. The biomass aged 10 and older (B10+) is also presented, because this is the same measure used in previous stock assessments and therefore allows for comparisons.

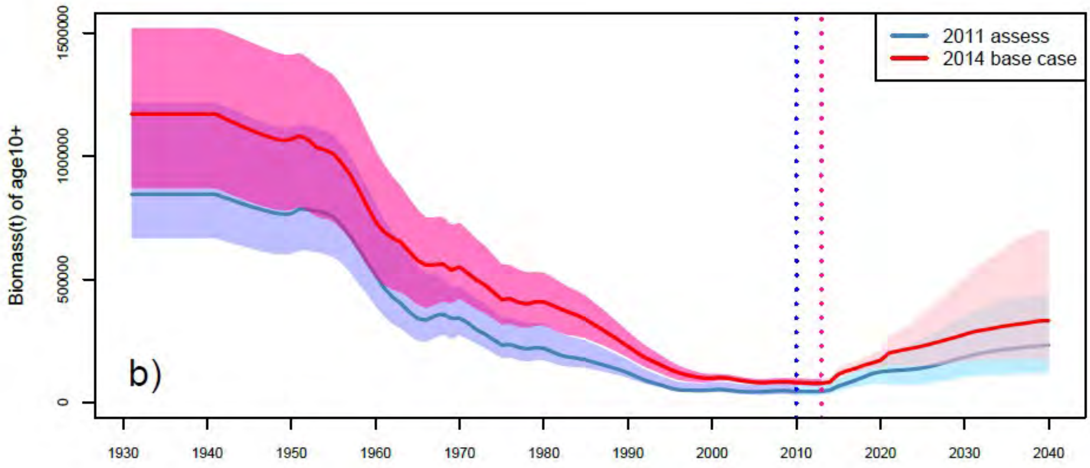
The stock remains at a very low state estimated to be 9% of the initial SSB, and below the level to produce maximum sustainable yield (MSY), however there has been some improvement since the 2011 stock assessment and the fishing mortality rate is below the level associated with MSY. B10+ relative to initial is estimated to be 7% which is up from the estimate of 5% in 2011. The current TAC has been set following the recommendation from the management procedure adopted in 2011.

Table 19: Assessment of southern bluefin tuna stock status in 2014

Southern Bluefin Tuna Summary of 2014 Assessment of Stock Status	
Maximum sustainable yield	33,000t (30,000-36,000)
Reported 2013 catch	11,726 t
Current replacement yield	44,600t (35,500-53,600)
Current (2014) spawner biomass (B10+)	83,000 (75,000-96,000)
Current depletion (Current relative to initial)	
SSB	0.09 (0.08-0.12)
B10+	0.07 (0.06-0.09
Spawner biomass (2014) relative to SSBmsy	0.38 (0.26-0.70)
Fishing mortality (2013) relative to Fmsy	0.66 (0.39-1.00)
Current management measures	Effective catch limit for Members and Cooperating Non-members: 12449t in 2014, and 14647 t /yr for the years 2015-2017.

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Base case model plus a range of sensitivity scenarios
Reference Points	Target: B_{MSY} Soft Limit: Default 20% B_0 Hard Limit: Default 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	Well below B_{MSY}. Spawning stock biomass estimated to be about 38% B_{MSY}. Very Unlikely (< 10%) to be at or above B_{MSY}.
Status in relation to Limits	Very Likely (> 90%) to be below the soft limit About as Likely as Not Likely (40- 60%) 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



Spawning stock biomass for the base case, showing the medians, quartiles and 90th percentiles, together with reference points of 20% of pre-exploitation spawning stock biomass and the spawning stock biomass in 2004 (B_{2004}). Source: Report of the Scientific Committee 2011.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Flat trajectory of SSB
Recent Trend in Fishing Intensity or Proxy	Reduced in last 4 years. Current fishing mortality is below $F_{MSY.}$
Other Abundance Indices	CPUE has been increasing since 2007; juvenile abundance is improved in recent years.
Trends in Other Relevant Indicators or Variables	Recent recruitments are estimated to be well below the levels from 1950-1980, but have improved since the poor recruitments of 1999-2002.

Projections and Prognosis	
Stock Projections or Prognosis	The Management Procedure adopted by the Commission in 2011 should rebuild the SB to 20% SB_0 by 2035 with a 70% probability. The MP was evaluated in 2013 and the increased CPUE and the increased index for the aerial survey resulted in a recommended TAC increase for 2015-17.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Likely (> 60%)
Probability of Current Catch or TACC causing Overfishing to continue or commence	Unlikely (< 40%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1: Quantitative stock assessment	
Assessment Method	Basecase grid of reconditioned CCSBT Operating Model	
Assessment Dates	Latest assessment: 2014	Next assessment: 2017
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	CPUE, catch at age and length frequency data, scientific aerial survey indices, close-kin (C-K) biomass estimate	1 – High Quality

Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	Biomass estimate from the close-kin (C-K) analysis incorporated into the Operating Model	
Major Sources of Uncertainty	CPUE indices: - Historical indices have an unknown bias from misreporting - Fisheries management and operational changes since 2006 mean that recent CPUE series may not be comparable with earlier years - The level of assumed unaccounted mortality may have compromised OM conditioning and achieving the rebuilding target with the agreed probability	

Qualifying Comments
The MP was evaluated in 2013 and resulted in an increase in the TAC for 2015-17 of 2198 t to 14 647 t.

Fishery Interactions
The ERS working group noted interactions reported by observers on seabirds, turtles and sharks but total mortalities of these groups have not been estimated.

7. FOR FURTHER INFORMATION

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. Final Research Report prepared for Ministry of Fisheries project PRO2007/01. (Unpublished report held by the Ministry of Fisheries, Wellington.) 170 pages.

Abraham, E. R., & Thompson, F. N. (2009). Capture of protected species in New Zealand trawl and longline fisheries, 1998–99 to 2006–07. *New Zealand Aquatic Environment and Biodiversity Report No. 32*.

Abraham, E.R.; Thompson, F.N.; Oliver, M.D. (2010). Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report No. 45*. 148 p.

Anon. 2001. Report of the sixth meeting of the scientific committee, Tokyo, Japan, 28–31 August 2001.

Anon. 2004. Report of the Fifth Meeting of the Stock Assessment Group, 6-11 September 2004, Jeju, Republic of Korea

Anon. 2004. Report of the Ninth Meeting of the Scientific Committee, 13-16 September 2004, Jeju, Republic of Korea.

Anon. 2005. Report of the Sixth Meeting of the Stock Assessment Group, 29 August - 3 September 2005, Taipei, Taiwan

Anon. 2005. Report of the Tenth Meeting of the Scientific Committee, 9 September 2005, Narita,Japan.

Anon. 2006. Report of the Seventh Meeting of the Stock Assessment Group, 4-11 September 2004, Tokyo, Japan

Anon. 2006. Report of the Eleventh Meeting of the Scientific Committee, 12-15 September 2006, Tokyo,Japan.

Anon. 2009a. Report of the Operating Model and Management Procedure Technical Meeting, 13-17 July 2009, Seattle, USA

Anon. 2009b. Report of the Fourteenth Meeting of the Scientific Committee, 5-11 September 2009, Busan, Republic of Korea.

Anon. 2011. Report of the Sixteenth Meeting of the Scientific Committee, 19-29 July 2011, Bali, Indonesia.

Anon. 2012. Report of the Seventeenth Meeting of the Scientific Committee, 27-31 August 2012, Tokyo, Japan.

Anon. 2012. Review of National SBT Fisheries for the Scientific Committee - New Zealand. CCSBT-ESC/1208/SBT Fisheries New Zealand

Baird, S.J. (2008). Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in longline fisheries in New Zealand waters, 1994–95 to 2005–06. *New Zealand Aquatic Environment and Biodiversity Report No. 20.* 21 p.

Bentley, N; Langley, A D; Middleton, D A J; Lallemand, P (2013). Fisheries of New Zealand, 1989/90-2011/12. Retrieved from http://fonz.tridentsystems.co.nz. Accessed 11 October 2013.

Best, E. 1929. Fishing methods and devices of the Maori. *Dominion Museum Bulletin* no 12.

Bravington, M., Grewe, P. & Davies, C. 2012: Report of the Close-Kin Project: estimating the absolute spawning stock size of SBT using genetics. CCSBT-ESC/1208/19

Caton, A. (ed.). 1991. Review of aspects of southern bluefin tuna biology, population and fisheries. I-ATTC Special Report 7: 181–350.

Harley, S. J., and Kendrick, T. 2006. Annual Review of National SBT Fisheries for the Scientific Committee. CCSBT-ESC/0609/SBT Fisheries: New Zealand.

Hufflett, C. 2000. Southern bluefin tuna. Unpublished report available from Solander Fisheries, Nelson.

Kalish, J.M.; Johnston, J.M.; Gunn, J.S.; Clear, N.P. 1996. Use of bomb radiocarbon chronometer to determine age of southern bluefin tuna (*Thunnus maccoyii*). *Marine Ecology Progress Series* 143: 1–8.

Leigh, G.M.; Hearn, W.S. 2000. Changes in growth of juvenile southern bluefin tuna (*Thunnus maccoyii*): an analysis of length–frequency data from the Australian fishery. *Marine and Freshwater Researc*h 51: 143–154.

Mattlin, R.H. (1987). New Zealand fur seal, Arctocephalus forsteri, within the New Zealand region. In Croxall, J.P.; Gentry, R.L. Status, biology, and ecology of fur seals: Proceedings of an international symposium and workshop, Cambridge, England, 23–27 April 1984. NOAA Technical Report NMFS-51.

Ministry for Primary Industries (2013a). Aquatic Environment and Biodiversity Annual Review 2013. Compiled by the Fisheries Management Science Team, Ministry for Primary Industries, Wellington, New Zealand. 538 p.

Ministry for Primary Industries (2013b). Nathional Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand Fisheries. Ministry for Primary Industries, Wellington, New Zealand. 59 p.

Murray, T.; Richardson, K.M. 2001. Trends in the New Zealand southern bluefin tuna fishery. CCSBT-SC/0108/SBT Fisheries – New Zealand.

Murray, T.; Richardson, K.; Griggs, L. 2002. New Zealand tuna fisheries, 1991–2000. *N.Z. Draft Fisheries Assessment Report*.

Perrin, W.F.; Wursig, B.; Thewissen, J.G.M., (Eds) (2008): Encyclopedia of marine mammals. Second Edition. Academic Press, San Diego.

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 (2014). Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002-03 to 2011-12. *New Zealand Aquatic Environment and Biodiversity Report*.

Richard, Y., and Abraham, E. R. 2013. Application of Potential Biological Removal methods to seabird populations. New Zealand Aquatic Environment and Biodiversity Report No. 108. 30p.

Richard Y; Abraham, E R (in press). Assessment of the risk of commercial fisheries to New Zealand seabird, 2006-07 to 2012/13. New Zealand Aquatic Environment and Biodiversity Report in press.

Richard, Y., Abraham, E. R., and Filippi, D. 2011. Assessment of the risk to seabird populations from New Zealand commercial fisheries. Final Research Report for projects IPA2009/19 and IPA2009/20. Unpublished report held by the Ministry of Fisheries, Wellington. 137p.

Richard, Y., Abraham, E. R., and Filippi, D. 2013. Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006-07 to 2010-11. New Zealand Aquatic Environment and Biodiversity Report No. 109. 58 + 70p.

Robertson, H.A; Dowding, J.E; Elliot, G.P; Hitchmough, R.A; Miskelly, C.M; O'Donnell, C.F.J; Powlesland, R.G; Sagar, P.M; Scofield, R.P; Taylor, G.A (2013) Conservation stats of New Zealand Birds, 2012. *New Zealand Threat Classification Series 4*. Department of Conservation, Wellington. 22 p.

Rowe, S J (2009) Conservation Services Programme observer report: 1 July 2004 to 30 June 2007. *DOC Marine Conservation Services Series 1*. Department of Conservation, Wellington. 93 p.

Sharp, B., Waugh, S., Walker, N.A, 2011. A risk assessment framework for incidental seabird mortality associated with New Zealand fishing in the New Zealand EEZ., Unpublished report held by the Ministry of Fisheries, Wellington., 39 p.

Strickland, R.R. 1990. Nga tini a Tangaroa, a Maori-English, English-Maori dictionary of fish names. NZ Fisheries Occasional Publication no. 5.

Thompson, F.N.; Abraham, E.R. (2010). 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.

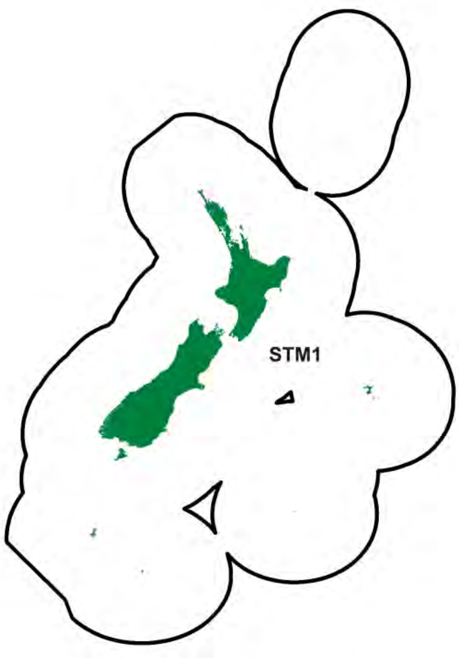
Thompson, F N; Berkenbusch, K; Abraham, E R (2013). Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11. *New Zealand Aquatic Environment and Biodiversity Report No. 105*. 73 p.

Waugh, S., Fillipi, D., Abraham, E., 2009. Ecological Risk Assessment for Seabirds in New Zealand fisheries, Unpublished Final Research Report for the Ministry of Fisheries 58 p.

Young J.W.; Lamb T.D.; Le D.; Bradford R.W.; Whitelaw A.W. (1997). Feeding ecology and interannual variations in diet of southern bluefin tuna, *Thunnus maccoyii*, in relation to coastal and oceanic waters off eastern Tasmania, Australia. *Environmental Biology of Fishes* 50: 275–291, 1997.

STRIPED MARLIN (STM)

(*Kajikia audax*)



1. FISHERY SUMMARY

All marlin species are currently managed outside the Quota Management System.

Management of the striped marlin and other highly migratory pelagic species throughout the western and central Pacific Ocean (WCPO) is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). Under this regional convention, New Zealand is responsible for ensuring that the fisheries management measures applied within New Zealand fisheries waters are compatible with those of the Commission.

At its third annual meeting (2006) the WCPFC passed a Conservation and Management Measure (CMM) (this is a binding measure that all parties must abide by) relating to conservation and management of striped marlin in the southwest Pacific Ocean (www.wcpfc.int). This measure restricts the number of vessels a state can have targeting striped marlin on the high seas. However, this does not apply to those coastal states (including New Zealand) south of 15 degrees south in the Convention Area who have already taken, and continue to take, significant steps to address concerns over the status of striped marlin in the Southwestern Pacific region, through the establishment of a commercial moratorium on the landing of striped marlin caught within waters under their national jurisdiction.

1.1 Commercial fisheries

Most of the commercial striped marlin catch in the southwest Pacific is caught in the tuna surface longline fishery, which started in 1952, and in the New Zealand region in 1956. Since 1980 foreign fishing vessels had to obtain a license to fish in New Zealand's EEZ and were required to provide records of catch and effort. New Zealand domestic vessels commenced fishing with surface longlines in 1989 and the number of vessels and the fishing effort expanded rapidly during the 1990s. Also in 1989, licences were issued to charter up to five Japanese surface longline vessels to fish on behalf of New Zealand companies. Very few striped marlin are caught by other commercial methods, although there are occasional reports of striped marlin caught in purse seine nets.

A three-year billfish moratorium was introduced in October 1987 in response to concerns over the decline in availability of striped marlin to recreational fishers. The moratorium prohibited access to the Auckland Fisheries Management Area (AFMA - Tirua Point to Cape Runaway) by foreign licensed and chartered tuna longline vessels between 1 October and 31 May each year. Licence restrictions required that all billfish, including broadbill swordfish, caught in the AFMA be released. In 1990 the moratorium was renewed for a further three years with some amended conditions and it was reviewed and extended in 1993 for a further year.

Regulations prohibited domestic commercial fishing vessels from retaining billfish caught within the AFMA since 1988. In 1991 these regulations were amended to allow the retention of broadbill swordfish and prohibited the retention of marlin species (striped, blue and black marlin) by commercial fishers in New Zealand fishery waters. These regulations, and government policy changes on the access rights of foreign licensed surface longline vessels, have replaced the billfish moratorium. A billfish memorandum of understanding (MOU) between representatives of commercial fishers and recreational interests provided a framework for discussion and agreement on billfish management measures. This MOU was reviewed annually between 1990 and 1997 and was last signed in 1996.

A review of marlin regulations and management was identified as an issue during the development of the National Fisheries Plan for Highly Migratory Species. The main focus was on the relative benefits of alternative management options for striped marlin including introduction to the Quota Management System and some limited commercial utilisation. At the review meetings in 2013 there was no agreement between sector representatives on alternative management measures for marlin. The Minister decided to retain the moratorium on commercial landings of marlin caught in New Zealand waters.

Estimates of total landings (commercial and recreational) for New Zealand are given in Table 1. Commercial catch of striped marlin reported on Catch Effort Landing Returns (CELRs) and Tuna Longline Catch and Effort Returns (TLCERs) and recreational catches from New Zealand Big Game Fishing Council records are given in Table 1. Figure 1 shows historic landings and longline fishing effort for the STM stocks.

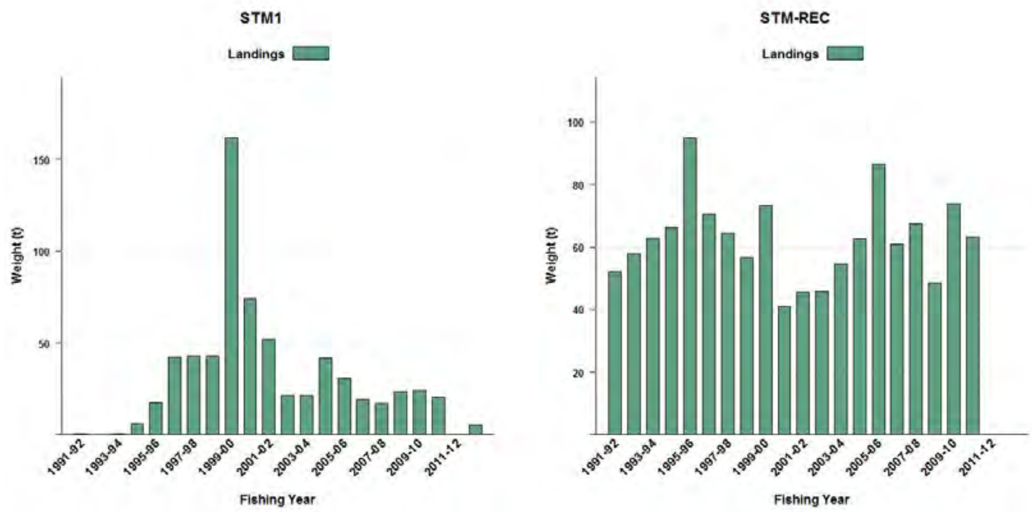


Figure 1: Striped marlin catch between 1991–92 and 2012–13 within New Zealand waters of commercial discards (STM 1) and 1991–92 to 2012–13 for recreational catch (STM-REC). [Figure continued on next page.]

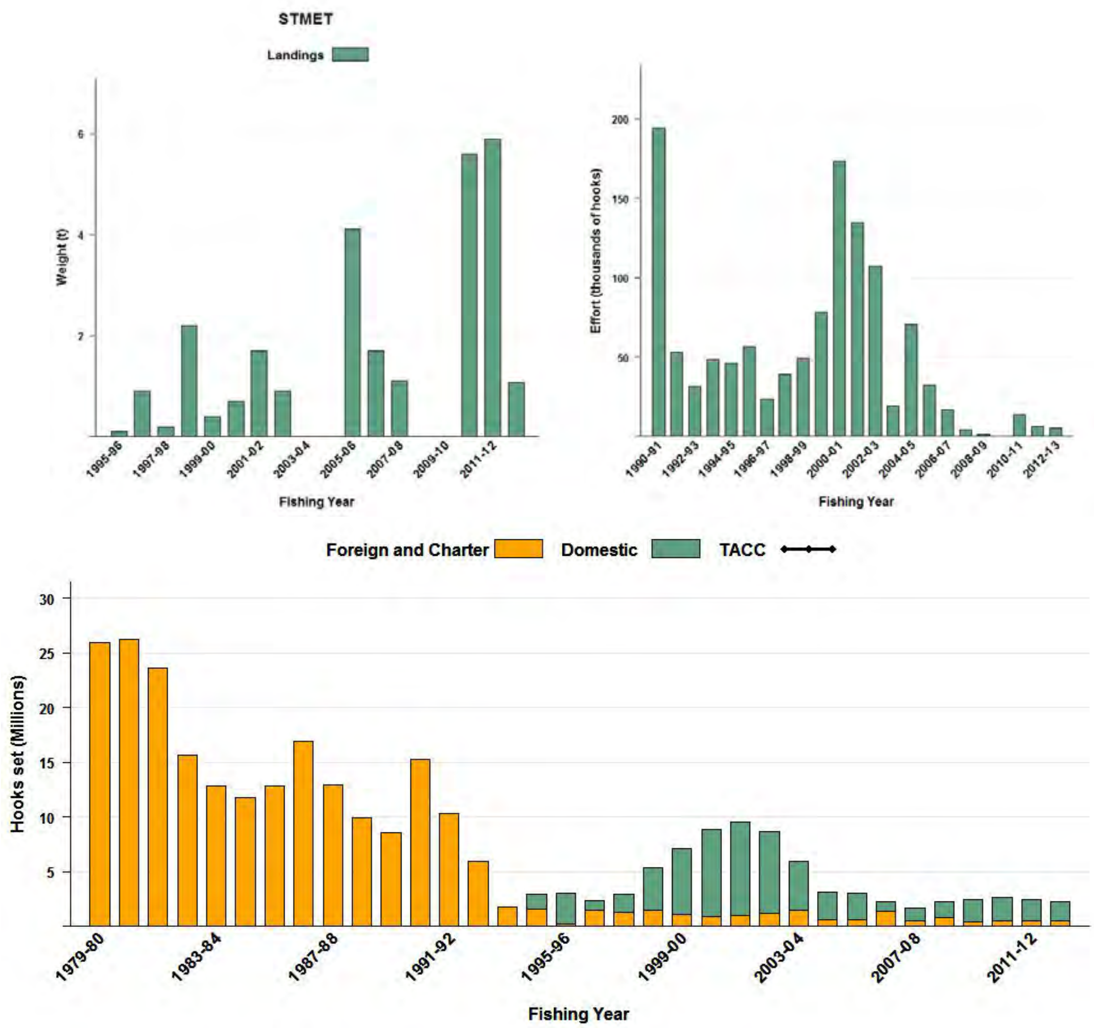


Figure 1 [Continued]: [Top] Striped marlin catch between 1995–96 and 2012–13 on the high seas (STM ET). [Middle] Fishing effort (number of hooks set) for all high seas New Zealand flagged surface longline vessels, and [Bottom] domestic vessels (including effort by foreign vessels chartered by New Zealand fishing companies), from 1990–91 to 2012–13 and 1979–80 to 2012–13, respectively.

Table 1: Commercial landings and discards (number of fish) of striped marlin in the New Zealand EEZ reported by fishing nation (CELRs and TLCERs), and recreational landings and number of fish tagged, by fishing year [Continued on next page].

Fishing	Japan		Korea	Philippine	Australia	Domestic	NZ Recreational		Total
Year	Landed	Discarded	Landed	Discarded	Discarded	Discarded	Landed	Tagged	
1979–80	659						692	17	1 368
1980–81	1 663		46				792	2	2 503
1981–82	2 796		44				704	11	3 555
1982–83	973		32				702	6	1 713
1983–84	1 172		199				543	9	1 923
1984–85	548		160				262		970
1985–86	1 503		19				395	2	1 919
1986–87	1 925		26				226	2	2 179
1987–88	197		100				281	136	714
1988–89	23		30			5	647	408	1 113
1989–90	138					1	463	367	969
1990–91		1				6	532	232	771
1991–92		17				1	519	242	779
1992–93						7	608	386	1 001

Table 1 [Continued]: Commercial landings and discards (number of fish) of striped marlin in the New Zealand EEZ reported by fishing nation (CELRs and TLCERs), and recreational landings and number of fish tagged, by fishing year.

Fishing	Japan		Korea	Philippine	Australia	Domestic	NZ Recreational		Total
Year	Landed	Discarded	Landed	Discarded	Discarded	Discarded	Landed	Tagged	
1993–94						59	663	929	1 651
1994–95						182	910	1 206	2 298
1995–96						456	705	1 104	2 265
1996–97						441	619	1 302	2 362
1997–98						445	543	898	1 886
1998–99						1 642	823	1 541	4 006
1999–00		2				798	398	791	1 989
2000–01						527	422	851	1 800
2001–02						225	430	771	1 426
2002–03		3		7		205	495	671	1 371
2003–04		1				423	592	1 051	2 066
2004–05						258	834	1 348	2 440
2005–06						168	630	923	1 721
2006–07					9	154	688	964	1 806
2007–08		1				208	485	806	1 499
2008–09						241	731	1 058	2 030
2009–10						195	607	858	1 660
2010–11						269	607	731	1 601
2011–12						241	635	663	1 531
2012–13		1				216	744	745	

Total recorded commercial catch was highest in 1981–82 at 2843 fish and 198 t. Following the introduction of the billfish regulations, striped marlin caught on commercial vessels were required to be returned to the sea and few of these fish were recorded on catch/effort returns. In 1995 the Ministry of Fisheries (now MPI) instructed that commercially caught marlin be recorded on TLCERs. However, compliance with this requirement was inconsistent and estimated catches in the tuna longline fishery (calculated by scaling-up observed catches to the entire fleet) are considerably higher than reported catches in fishing years for which these estimates are available. However, the estimates are probably imprecise as MPI observer coverage of the domestic fleet has been low (just below 10% for the years 2007–2010) and has not adequately covered the spatial and temporal distribution of the fishery over summer.

Few striped marlin in the TLCER database were reported south of 42°S and most striped marlin reported by commercial fishers were caught north of 38°S. Historically, Japanese and Korean vessels caught most striped marlin between 31°S and 35°S with a peak at 33°S. The New Zealand domestic fleet caught the majority of their striped marlin in the Bay of Plenty, East Cape area, between 36°S and 37°S.

A significant number of catch records from domestic commercial vessels provide the number of fish caught but not the estimated catch weight. The total weight of striped marlin caught per season was therefore calculated using fisher estimates from TLCER and CELR records plus the number of fish with no weights multiplied by the mean recreational striped marlin weight for that season. Reported total landings and discards (commercial and recreational) and commercial landings from outside the EEZ are shown in Table 2.

Combined landings from within New Zealand fisheries waters are relatively small compared to commercial landings from the greater stock in the southwest Pacific Ocean (8% average for 2002–2006). In New Zealand, striped marlin are landed almost exclusively by the recreational sector, but there are no current estimates of recreational catch from elsewhere in the southwest Pacific.

Table 2: Reported total New Zealand landings and discards (commercial and recreational) (t) and commercial landings from the western and Central Pacific Ocean (WCPO) (t) of striped marlin from 1991 to 2013.

	Commercial		Recreational		EEZ	NZ Commercial	WCPO all
	Landed	Discarded	Landed	Tagged	Total	Outside the EEZ	gears *
1991	0.1	0.5	52	21	73		7 076
1992	0.8	0.1	57.8	21.9	81		6 878
1993	0	0.8	62.8	34.4	99		11 867
1994		5.7	66.3	81.2	153		8 013
1995		17.2	95	100	214	0.1	8 437
1996		42.3	70.6	91.6	204	0.9	6 746
1997		42.9	64.4	127.8	230	0.2	6 027
1998		42.7	56.5	80.9	182	2.2	8 501
1999		161.9	73.2	130.9	345	0.4	7 222
2000		74.1	40.9	72.1	179	0.7	5 644
2001		51.6	45.5	78.7	177	1.7	6 149
2002		21.2	45.8	76.9	144	0.9	5 962
2003		21.1	54.6	65.4	142		6 625
2004		41.7	62.7	105.6	208		6 551
2005		30.7	86.6	131.3	249	3.5	5 611
2006	0.4	19.0	60.8	85.8	166	3.2	5 534
2007	1.2	16.9	67.5	93.4	179	1.9	4 486
2008		22.6	48.6	79.7	152	1.1	5 057
2009		25.3	73.7	104.4	202		3 930
2010		18.6	63.1	79.5	163	5.6	3 530
2011		27.4	51.1	66.6	144	5.9	4 174
2012		24.0	75.9	77.6	153	1.8	4 060
2013		22.8	80.6	76.6	157	1.1	3 684

Source: TLCER and CELRs; NZSFC; Holdsworth (2008a); Holdsworth and Saul (2014);* Anon (2013).

The majority of striped marlin (66%) caught in the New Zealand commercial fisheries are caught as bycatch in the bigeye tuna target surface longline fishery (Figure 2). Striped marlin are not allowed to be retained by commercial fishers in New Zealand fishery waters and as a result do not show up in the reported catch (Figure 3). Longline fishing effort is distributed along the east coast of the North Island and the south west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the east coast of the North Island targets a range of species including bigeye, swordfish, and southern bluefin tuna (Figure 4).

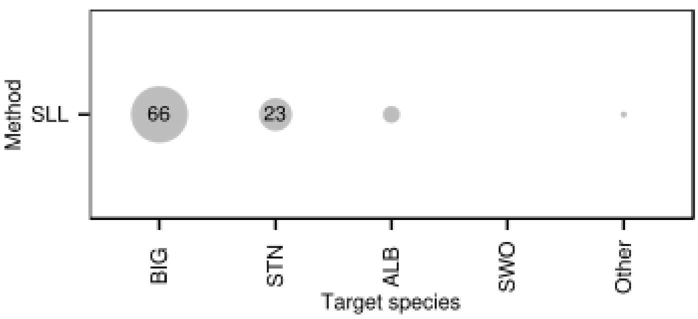


Figure 2: A summary of the proportion of striped marlin taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the circle is the percentage. SLL = surface longline (Bentley et al 2013).

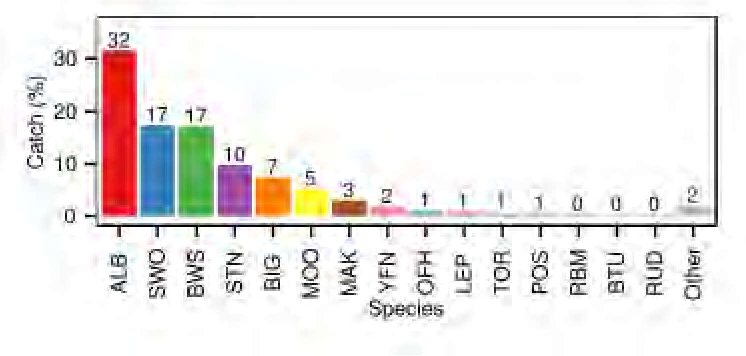


Figure 3: A summary of species composition of the reported surface longline catch. The percentage by weight of each species is calculated for all surface longline trips (Bentley et al 2013).

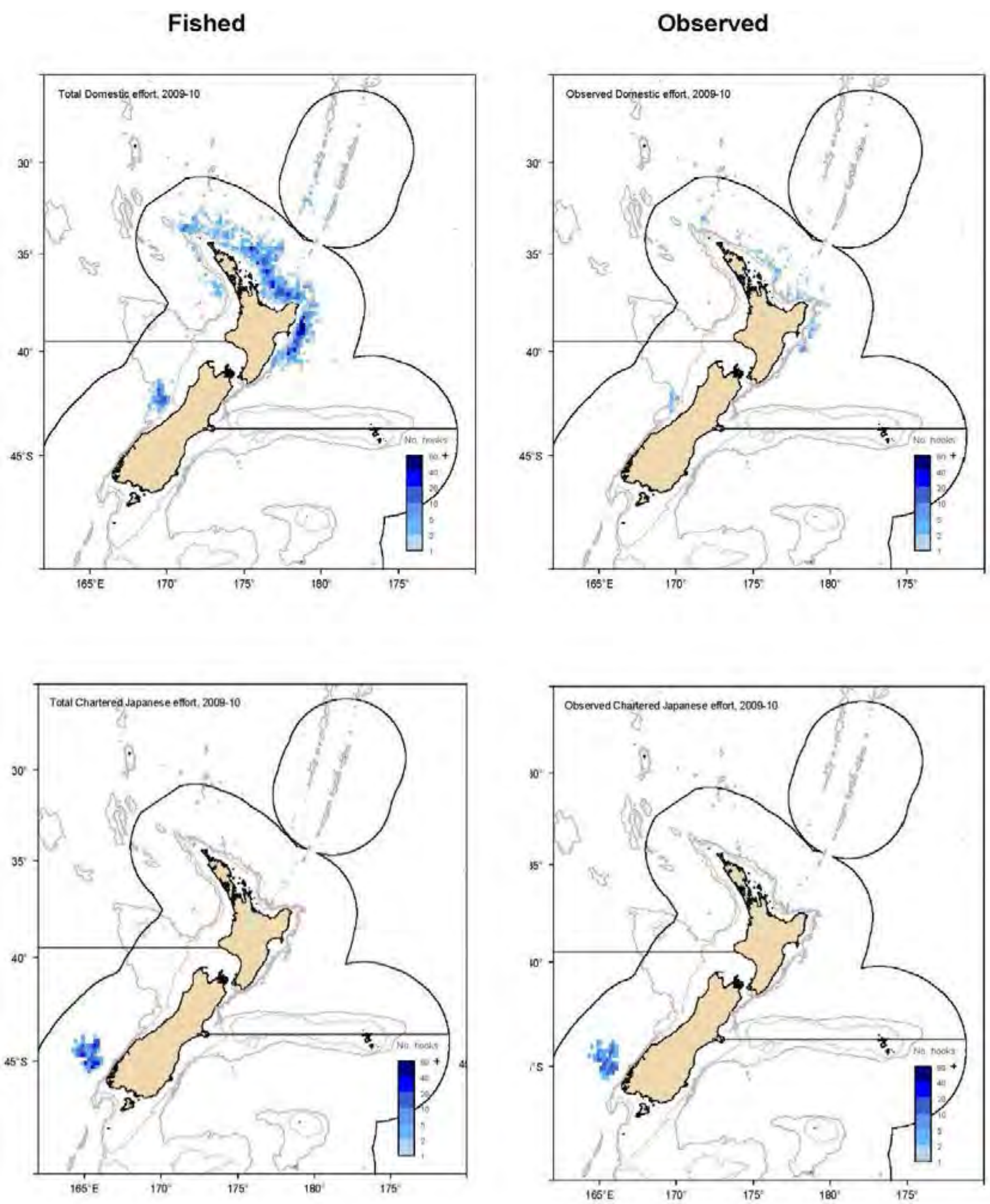


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009–10 fishing year, displaying both fishing effort (left) and observer effort (right).

In the longline fishery 73% of the striped marlin were alive when brought to the side of the vessel for all fleets (Table 3), and almost all were discarded (Table 4) as required by New Zealand legislation.

Table 3: Percentage of striped marlin (including discards) that were alive or dead when arriving at the longline vessel and observed during 2006–07 to 2009–10, by fishing year, fleet and region. Small sample sizes (number observed < 20) were omitted Griggs & Baird (2013).

Year	Fleet	Area	% alive	% dead	Number
2006–07	Total		65.0	35.0	20
2007–08	Total		100.0	0.0	6
2008–09	Total		50.0	50.0	8
2009–10	Domestic	North	72.7	27.3	22
	Total		72.7	27.3	22
Total all strata			69.6	30.4	56

Table 4: Percentage of striped marlin that were retained, or discarded or lost, when observed on a longline vessel during 2006–07 to 2009–10, by fishing year and fleet. Small sample sizes (number observed < 20) omitted Griggs & Baird (2013).

Year	Fleet	% retained	% discarded or lost	Number
2006–07	Total	10.0	90.0	20
2007–08	Total	0.0	100.0	6
2008–09	Total	0.0	100.0	9
2009–10	Domestic	4.3	95.7	23
	Total	4.3	95.7	23

1.2 Recreational fisheries

The striped marlin fishery is an important component of the recreational fishery and tourist industry from late December to May in northern New Zealand. There are approximately 100 recreational charter boats that derive part of their income from marlin fishing and a growing number of private vessels participating in the fishery. Many of the largest fishing clubs in New Zealand target gamefish and are affiliated to the national body, the New Zealand Sport Fishing Council (NZSFC). Clubs provide facilities to weigh fish and keep catch records. The sport fishing season runs from 1 July to 30 June the following year. Almost all striped marlin are caught between January and June in the later half of the season.

In 1988 the NZSFC proposed a voluntary minimum size of 90 kg for striped marlin in order to encourage tag and release. Fish under this size do not count for club or national contests or trophies but most are included in the catch records each fishing season. In 2012–13 the 53 recreational fishing clubs affiliated to NZSFC reported landing 3029 billfish, sharks, kingfish, mahimahi, and tuna, and tagged and released a further 1299 gamefish. In 2012–13, 744 striped marlin were landed and weighed at a club (25% of landed fish in NZSFC records) and 745 were tagged and released (57% of tagged fish in NZSFC records). There is a fairly complete historical database of recreational catch records for each striped marlin caught by the Bay of Islands Swordfish Club and the Whangaroa Big Game Fishing Club going back to the 1920s, when this fishery started.

1.3 Customary non-commercial fisheries

Maori traditionally ate a wide variety of seafood, however, no record of specific marlin fishing methods has been found to date. An estimate of the current customary catch is not available.

1.4 Illegal catch

There is no known illegal catch of striped marlin.

1.5 Other sources of mortality

Some fish that break free from commercial or recreational fishing gear may die due to hook damage or entanglement in trailing line. A high proportion of fish that are caught are released alive by both commercial and recreational fishers. Data collected by MPI Observer Services from the tuna longline fishery suggest that most striped marlin are alive on retrieval (72% of the observed catch). The proportion of striped marlin brought to the boat alive was similar on domestic longliners and foreign and charter vessels. However, post release survival rates are unknown.

Recreational anglers tag and release 50 to 60% of their striped marlin catch. Most of these fish are caught on lures. Reported results from 66 pop-up satellite archival tags (PSATs) deployed on lure caught striped marlin in New Zealand showed a high survival rate following catch and release. The pop-up archival tags are programmed to release from the fish following death. No fish died and sank to the seafloor. One fish was eaten (tag and all) by a lamnid shark about 15 hours after it was tagged and released. A small proportion of other PSAT tags failed to report so the fate of these fish is unknown.

Striped marlin caught on baits in Mexico showed a 26% mortality rate within 5 days of release. Injury was a clear predictor of mortality; 100% of fish that were bleeding from the gill cavity died, 63% of fish hooked deep died, and 9% of those released in good condition died.

2. BIOLOGY

Striped marlin is one of eight species of billfish in the family Istiophoridae. They are epi-pelagic predators in the tropical, subtropical and temperate pelagic ecosystem of the Pacific and Indian Oceans. Juveniles generally stay in warmer waters, while adults move into higher latitudes and temperate water feeding grounds in summer (i.e. the first quarter of the calendar year in the southern hemisphere; the third quarter in the northern hemisphere). The latitudinal range estimated from longline data extends from 45°N to 40°S in the Pacific and from continental Asia to 45°S in the Indian Ocean. Striped marlin are not uniformly distributed, having a number of areas of high abundance. Fish tagged in New Zealand have undergone extensive seasonal migrations within the southwest Pacific but not beyond.

Samples from recreationally caught striped marlin in New Zealand indicate that the most frequent prey items are saury and arrow squid, followed by jack mackerel. However, 28 fish species and 4 cephalopod species have been identified from stomach contents indicating that they are opportunistic predators.

The highest striped marlin catch for the surface longline method is recorded in January–February but striped marlin have been caught in New Zealand fisheries waters in every month, with lowest catches in November and December.

Striped marlin are oviparous and are known to spawn in the Coral Sea between Australia and New Caledonia. Their ovaries start to mature in this region during late September or early October. Spawning peaks in November and December and 60–70% of fish captured at this time are in spawning condition. The minimum size of mature fish in the Coral Sea is recorded at approximately 170 cm lower jaw-fork length (LJFL) and 36 kg. Striped marlin captured in New Zealand are rarely less than 200 cm (LJFL) suggesting that these fish are all mature. Female striped marlin are larger than males on average but sexual dimorphism is not as marked as that seen in blue and black marlin. The sex ratio of striped marlin sampled from the recreational fishery in Northland (n = 61) was 1:1 prior to the introduction of the voluntary minimum size restriction (90 kg). There is no clear evidence of striped marlin reproductive activity in New Zealand waters. The northern edge of the EEZ around the Kermadec Islands extends into subtropical waters. According to historical longline records, in some years there are moderate numbers of striped marlin in this area from October to December. Therefore, striped marlin spawning could occur in this area.

Estimated growth and validated age estimates of striped marlin were derived from fin spine and otolith age estimates from 425 striped marlin collected between 2006 and 2009. Samples came from the Australian commercial longline and recreational fisheries, longline fisheries in Pacific Island countries and 133 samples from the New Zealand recreational fishery. Ages ranged from 130 days to 8 years, in striped marlin ranging in length from 990 mm (about 4 kg) to 2871 mm (about 168 kg) LJFL (Kopf et al 2010). Estimated ages of striped marlin from New Zealand ranged from 2 to 8 years in fish ranging in length from 2000 mm to 2871 mm LJFL. The median age of striped marlin landed in the New Zealand recreational fishery was 4.4 years for females and 3.8 years for males.

Growth for striped marlin in the southwest Pacific is broadly comparable with overseas studies. Melo-Barrera et al (2003) identified between 2 and 11 growth bands from fish sampled in Mexico, and Skillman & Yong (1976) classified up to 12 age groups from length frequency analysis of striped marlin in Hawaii. Recreational catch records kept by the International Game Fish Association (IGFA) list the heaviest striped marlin as 224.1 kg caught in New Zealand in 1975.

Estimates of biological parameters for striped marlin in New Zealand waters are given in Table 5.

Table 5: Estimates of biological parameters.

Parameter	Estimate				Source
1. Natural mortality (M)					
STM	0.49–1.33				Boggs (1989)
STM	0.389–0.818				Hinton & Bayliff (2002)
2. Weight = a (length)^b (Weight in kg, length in mm lower jaw fork length)					
	a	b			
STM	1.012×10^{-10}	3.55		South West Pacific	Kopf et al (2010)
STM males	4.171×10^{-11}	3.67		South West Pacific	
STM females	1.902×10^{-9}	3.16		South West Pacific	
STM males	2.0×10^{-8}	2.88		New Zealand	Kopf et al (2005)
STM females	2.0×10^{-8}	2.90			
3. Von Bertalanffy model parameter estimates					
	k	t_0	L_∞		
STM	0.44	-1.07	2636	South West Pacific	Kopf et al (2010)
STM	0.22	-0.04	3010	New Zealand	Kopf et al (2005)
STM	0.23	-1.6	2210	Mexico	Melo-Barrera et al (2003)
STM male	0.315–0.417	-0.521	2 774–3 144	Hawaii	Skillman & Yong (1976)
STM female	0.686–0.709	0.136	2 887–3 262	Hawaii	Skillman & Yong (1976)

3. STOCKS AND AREAS

Striped marlin are a highly migratory species, and fish caught in the New Zealand fisheries waters are part of a wider stock. The stock structure of striped marlin in the Pacific Ocean is not well understood, but resolving stock structure uncertainties is the focus of current research activities. The two most frequently considered hypotheses are: (1) a single-unit stock in the Pacific, which is supported by the continuous “horseshoe-shaped” distribution of striped marlin; and (2) a two-stock structure, with the stocks separated roughly at the Equator, albeit with some intermixing in the eastern Pacific.

Spawning occurs in water warmer than 24^{o}C, in the southern hemisphere, mainly in November and December. Known spawning areas in the southwest Pacific are in the Coral Sea in the west and in French Polynesia in the east of the region. The southern hemisphere spawning season is out of phase with the north Pacific. Very warm equatorial water in the western Pacific, where striped marlin are seldom caught, may be acting as a natural barrier to stock mixing. However, in the eastern Pacific striped marlin may be found in equatorial waters and three fish tagged in the northern hemisphere were recaptured in the southern hemisphere. The results of mitochondrial DNA analysis are consistent with shallow population structuring within striped marlin in the Pacific.

The New Zealand Gamefish Tagging Programme tagged and released 21 597 striped marlin between 1 July 1975 and 30 June 2013. Of the 87 recaptures reported, 32 have been made outside the EEZ spread across the region from French Polynesia (142°W) to eastern Australia (154°E) and from latitude 2°S to 38°S. There have been no reports of striped marlin tagged in the southwestern Pacific being recaptured elsewhere in the Pacific Ocean. Projects by New Zealand and US researchers using electronic tags have described the movement and habitat preferences of Pacific striped marlin.

Striped marlin are believed to have a preference for sea surface temperatures of 20 to 25°C. Generally striped marlin arrive in New Zealand fisheries waters in January and February, and tag recaptures indicate that most leave the New Zealand EEZ between March and June; although they have been caught by surface longliners in the EEZ in every month. Within the EEZ most striped marlin are caught in FMA 1 and FMA 9.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2014 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of striped marlin but there is no directed fishery for them and the incidental catch sections below reflect the New Zealand longline fishery as a whole and are not specific to this species; a more detailed summary from an issue-by-issue perspective is available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed (http://www.mpi.govt.nz/Default.aspx?TabId=126&id=2122) (Ministry for Primary Industries 2013a).

4.1 Role in the ecosystem

Striped marlin (*Kajikia audax*) are large pelagic predators, so they are likely to have a ‘top down’ effect on the squid, fish and crustaceans they feed on.

4.2 Incidental catch (seabirds, sea turtles and mammals)

The protected species, capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.2.1 Seabird bycatch

Between 2002–03 and 2012–13, there were 818 observed captures of birds across other surface longline target fisheries (those not targeting albacore tuna, bigeye tuna, southern bluefin tuna, pacific bluefin tuna and swordfish). Seabird capture rates since 2003 are presented in Table 6 and Figure 5. Seabird captures were more frequent off the south west coast of the South Island (Figure 6). Bayesian models of varying complexity dependent on data quality have been used to estimate captures across a range of methods (Richard & Abraham 2014). Observed and estimated seabird captures in albacore longline fisheries are provided in Table 7.

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 the notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Risk posed by commercial fishing to seabirds has been assessed via a level 2 method which supports much of the NPOA-Seabirds 2013 risk assessment framework (MPI 2013b). The method used in the level 2 risk assessment arose initially from an expert workshop hosted by the Ministry of Fisheries in 2008. The overall framework is described in Sharp et al. (2011) and has been variously applied and improved in multiple iterations (Waugh et al. 2009, Richard et al. 2011, Richard and Abraham 2013, Richard et al. 2013 and Richard & Abraham in press). The method applies an "exposure-effects" approach where exposure refers to the number of fatalities is calculated from the overlap of seabirds with fishing effort compared with observed captures to estimate the species vulnerability (capture rates per encounter) to each fishery group. This is then compared to the population's productivity, based on population estimates and biological characteristics to yield estimates of population-level risk.

The 2014 iteration of the seabird risk assessment (Richard & Abraham in press) assessed other surface longline target fisheries (those not targeting albacore tuna, bigeye tuna, southern bluefin tuna, pacific bluefin tuna and swordfish) contribution to the total risk posed by New Zealand commercial fishing to seabirds (see Table 8). These target fisheries contribute 0.003 of PBR_1 to the risk to Southern Buller's albatross which was assessed to be at very high risk from New Zealand commercial fishing (Richard & Abraham in press).

Table 6: Number of observed seabird captures in the New Zealand surface longline fisheries, 2002–03 to 2012–13, by species and area. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR (from Richard and Abraham (2013) where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for striped marlin using longline gear but rather the total risk for each seabird species. Other data, version 20130305 [Continued on next page].

Albatross Species	Risk Ratio	Kermadec Islands	Northland and Hauraki	Bay of Plenty	East Coast North Island	Stewart Snares Shelf	Fiordland	West Coast South Island	West Coast North Island	Total
Salvin's	Very high	0	1	2	6	0	0	0	0	9
Southern Buller's	Very high	0	5	2	27	0	280	39	0	353
NZ white-capped	Very high	0	2	0	3	10	62	36	1	114
Northern Buller's	High	0	0	0	1	0	0	0	0	1
Gibson's	High	4	16	0	17	0	6	3	1	47
Antipodean	High	12	10	1	8	0	0	0	1	32
Northern royal	Medium	0	0	1	0	0	0	0	0	1
Southern royal	Medium	0	1	0	0	0	4	1	0	6
Campbell black-browed	Medium	2	10	2	29	0	3	3	1	50
Light-mantled sooty	Very low	0	0	0	0	0	0	1	0	1
Unidentified	N/A	38	2	0	2	0	0	0	1	43
Total	**N/A**	**56**	**47**	**8**	**93**	**10**	**355**	**83**	**5**	**657**

Table 6: Number of observed seabird captures in the New Zealand surface longline fisheries, 2002–03 to 2012–13, by species and area. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR (from Richard and Abraham (2013) where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for striped marlin using longline gear but rather the total risk for each seabird species. Other data, version 20130305

Other seabirds	Risk Ratio	Kermadec Islands	Northland and Hauraki	Bay of Plenty	East Coast North Island	Stewart Snares Shelf	Fiordland	West Coast South Island	West Coast North Island	Total
Black petrel	Very high	1	10	1	0	0	0	0	1	13
Flesh-footed shearwater	Very high	0	0	0	10	0	0	0	2	12
Cape petrel	High	0	0	0	2	0	0	0	0	2
Westland petrel	Medium	0	0	0	2	0	1	6	0	9
White-chinned petrel	Medium	2	3	3	3	1	20	3	3	38
Grey petrel	Medium	3	4	3	38	0	0	0	0	48
Grey-faced petrel	Very low	12	5	1	2	0	0	0	0	20
Sooty shearwater	Very low	1	0	0	8	3	1	0	0	13
Southern giant petrel	-	0	0	2	0	0	0	0	2	0
White-headed petrel	-	2	0	0	0	0	0	0	0	2
Unidentified	N/A	0	1	0	0	0	1	0	0	2
Total	**N/A**	**21**	**23**	**10**	**65**	**4**	**23**	**9**	**8**	**159**

Table 7: Effort, observed and estimated seabird captures by fishing year for the New Zealand surface longline fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures; the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). Estimates are based on methods described in Thompson et al (2013) are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002–03 to 2010–11 20120531 and preliminary estimates for 2012–13 are based on data version 20140131.

	Fishing effort			Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	10 772 188	2 195 152	20.4	115	0.052	2 088	1 613–2 807
2003–2004	7 386 329	1 607 304	21.8	71	0.044	1 395	1 086–1 851
2004–2005	3 679 765	783 812	21.3	41	0.052	617	483–793
2005–2006	3 690 119	705 945	19.1	37	0.052	808	611–1 132
2006–2007	3 739 912	1 040 948	27.8	187	0.18	958	736–1 345
2007–2008	2 246 189	421 900	18.8	37	0.088	524	417–676
2008–2009	3 115 633	937 496	30.1	57	0.061	609	493–766
2009–2010	2 995 264	665 883	22.2	135	0.203	939	749–1 216
2010–2011	3 187 879	674 572	21.2	47	0.07	705	532–964
2011–2012	3 100 277	728 190	23.5	64	0.088	829	617–1 161
2012–2013†	2 862 182	560 333	19.6	27	0.048	783	567–1 144

†Provisional data, model estimates not finalised.

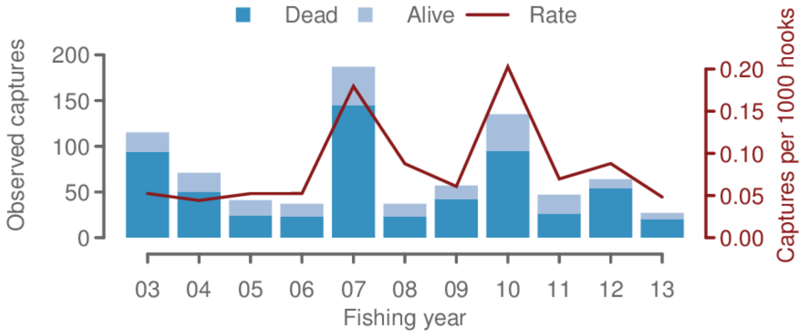


Figure 5: Observed captures of seabirds in the New Zealand surface longline fisheries from 2002–03 to 2012–13.

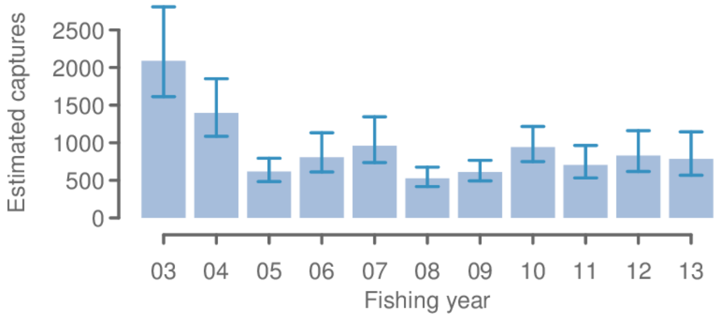


Figure 6: Estimated captures of seabirds in the New Zealand surface longline fisheries from 2002–03 to 2011–12.

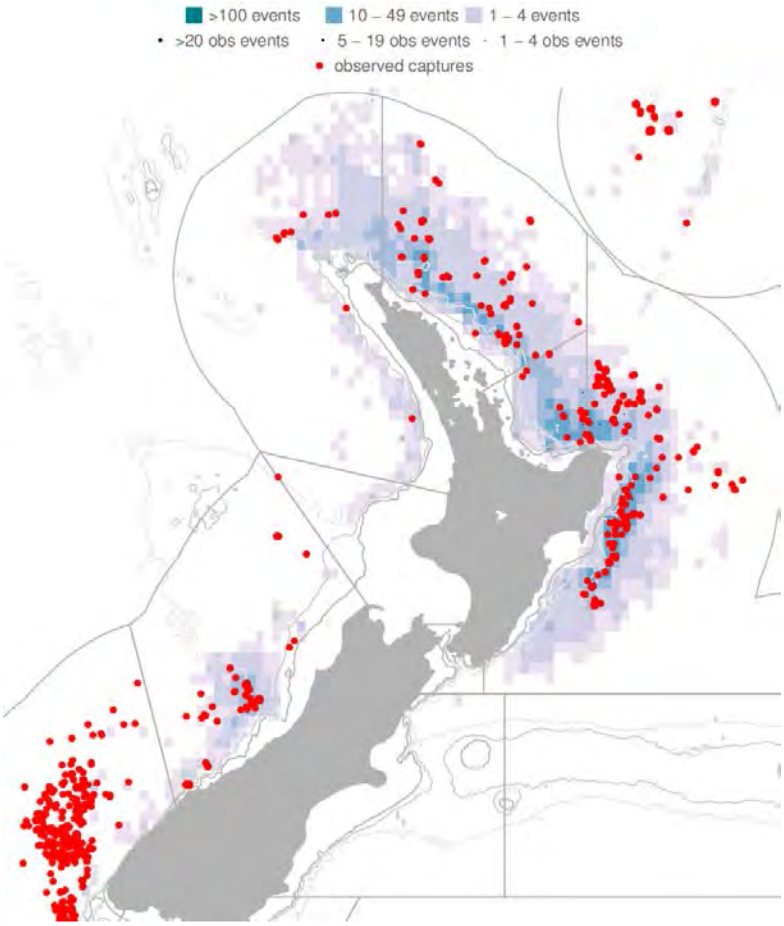


Figure 7: Distribution of fishing effort in the New Zealand surface longline fisheries and observed seabird captures, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 89.4% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

Table 8: Risk ratio of seabirds predicted by the level two risk assessment for the other species target surface longline fisheries (those not targeting albacore tuna, bigeye tuna, southern bluefin tuna, pacific bluefin tuna and swordfish) and all fisheries included in the level two risk assessment, 2006–07 to 2012–13, showing seabird species with risk category of very or high, or a medium risk category and risk ratio of at least 1% of the total risk. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR_1 (from Richard and Abraham 2014 where full details of the risk assessment approach can be found). PBR_1 applies a recovery factor of 1.0. Typically a recovery factor of 0.1 to 0.5 is applied (based on the state of the population) to allow for recovery from low population sizes as quickly as possible. This should be considered when interpreting these results. The New Zealand threat classifications are shown (Robertson et al 2013 at http://www.doc.govt.nz/documents/science-and-technical/nztcs4entire.pdf)

	Risk ratio				
Species name	OTH target SLL	Total risk from NZ commercial fishing	% of total risk from NZ commercial fishing	Risk category	NZ Threat Classification
Black petrel	0.000	15.095	0.00	Very high	Threatened: Nationally Vulnerable
Salvin's albatross	0.000	3.543	0.00	Very high	Threatened: Nationally Critical
Southern Buller's albatross	0.003	2.823	0.10	Very high	At Risk: Naturally Uncommon
Flesh-footed shearwater	0.000	1.557	0.00	Very high	Threatened: Nationally Vulnerable
Gibson's albatross	0.000	1.245	0.00	Very high	Threatened: Nationally Critical
New Zealand white-capped albatross	0.000	1.096	0.01	Very high	At Risk: Declining
Chatham Island albatross	0.000	0.913	0.00	High	At Risk: Naturally Uncommon
Antipodean albatross	0.000	0.888	0.00	High	Threatened: Nationally Critical
Westland petrel	0.000	0.498	0.00	High	At Risk: Naturally Uncommon
Northern Buller's albatross	0.000	0.336	0.13	High	At Risk: Naturally Uncommon
Campbell black-browed albatross	0.000	0.304	0.00	High	At Risk: Naturally Uncommon
Stewart Island shag	0.000	0.301	0.00	High	Threatened: Nationally Vulnerable

4.2.2 Sea turtle bycatch

Between 2002–03 and 2012–13, there were 15 observed captures of sea turtles across all surface longline fisheries (Tables 9 and 10, Figure 8). Observer records documented all but one sea turtle as captured and released alive. Sea turtle capture distributions predominantly occur throughout the east coast of the North Island and Kermadec Island fisheries (Figure 9).

Table 9: Number of observed sea turtle captures in the New Zealand surface longline fisheries, 2002–03 to 2012–13, by species and area. Data from Thompson et al (2013), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Kermadec Islands	West Coast North Island	Total
Leatherback turtle	1	4	3	3	11
Green turtle	0	1	0	0	1
Unknown turtle	0	1	0	2	3
Total	1	6	3	5	15

Table 10: Effort and sea turtle captures in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data see Thompson et al (2013).

	Fishing effort			Observed captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate
2002–2003	10 772 188	2 195 152	20.4	0	0
2003–2004	7 386 329	1 607 304	21.8	1	0.001
2004–2005	3 679 765	783 812	21.3	2	0.003
2005–2006	3 690 119	705 945	19.1	1	0.001
2006–2007	3 739 912	1 040 948	27.8	2	0.002
2007–2008	2 246 189	421 900	18.8	1	0.002
2008–2009	3 115 633	937 496	30.1	2	0.002
2009–2010	2 995 264	665 883	22.2	0	0
2010–2011	3 187 879	674 572	21.2	4	0.006
2011–2012	3 100 277	728 190	23.5	0	0
2012–2013	2 862 182	560 333	19.6	2	0.004

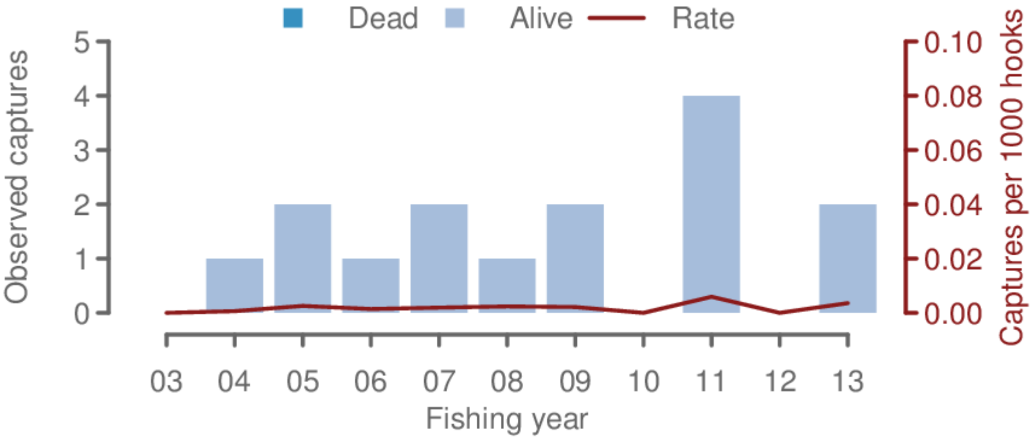


Figure 8: Observed captures of sea turtles in the New Zealand surface longline fisheries from 2002–03 to 2012–13.

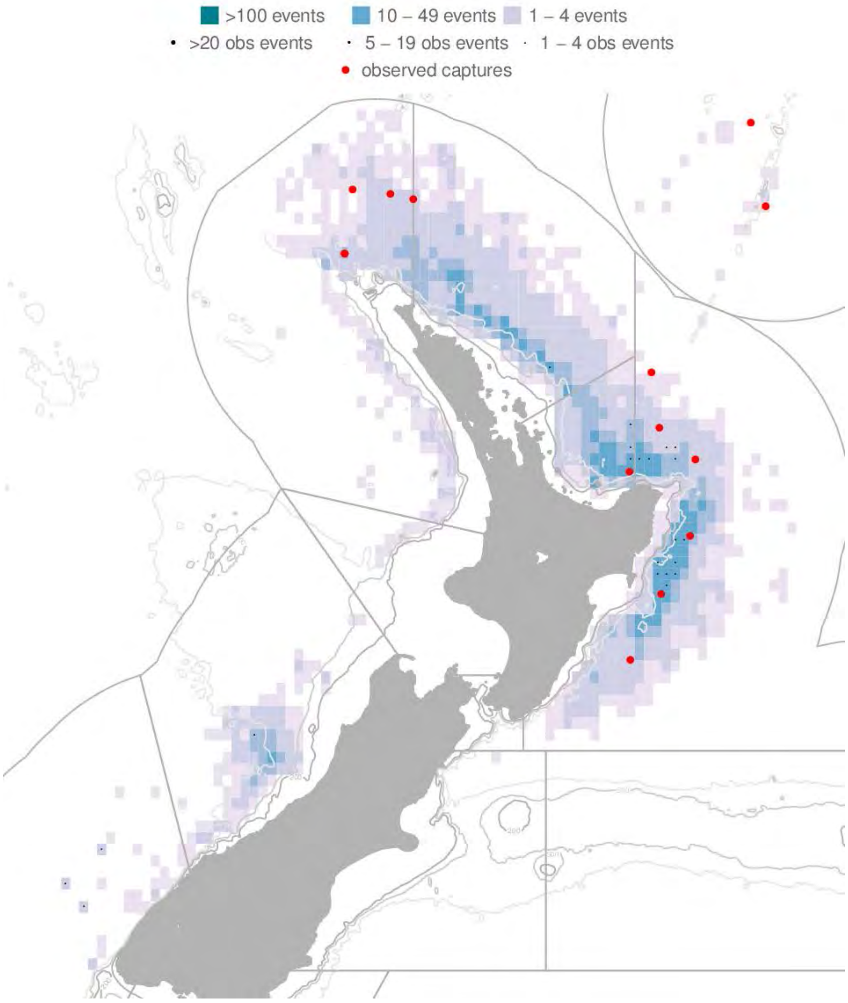


Figure 9: Distribution of fishing effort in the New Zealand surface longline fisheries and observed sea turtle captures, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 89.4% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Cetaceans are dispersed throughout New Zealand waters (Perrin et al 2008). The spatial and temporal overlap of commercial fishing grounds and cetacean foraging areas has resulted in cetacean captures in fishing gear (Abraham & Thompson 2009, 2011).

Between 2002–03 and 2012–13, there were seven observed captures of whales and dolphins in surface longline fisheries. Observed captures included 5 unidentified cetaceans and 2 long-finned Pilot whales (Tables 11 and 12, Figure 10) (Thompson et al 2013). All captured animals recorded were documented as being caught and released alive (Thompson et al 2013). Cetacean capture distributions are more frequent off the east coast of the North Island (Figure 11).

Table 11: Number of observed cetacean captures in the New Zealand surface longline fisheries, 2002–03 to 2012–13, by species and area. Data from Thompson et al (2013), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	West Coast North Island	West Coast South Island	Total
Long-finned pilot whale	0	1	0	0	0	1	2
Unidentified cetacean	1	1	1	1	1	0	5
Total	1	2	1	1	1	1	7

Table 12: Effort and captures of cetaceans in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Thompson et al (2013).

	Fishing effort			Observed captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate
2002–2003	10 772 188	2 195 152	20.4	1	0
2003–2004	7 386 329	1 607 304	21.8	4	0.002
2004–2005	3 679 765	783 812	21.3	1	0.001
2005–2006	3 690 119	705 945	19.1	0	0
2006–2007	3 739 912	1 040 948	27.8	0	0
2007–2008	2 246 189	421 900	18.8	1	0.002
2008–2009	3 115 633	937 496	30.1	0	0
2009–2010	2 995 264	665 883	22.2	0	0
2010–2011	3 187 879	674 572	21.2	0	0
2011–2012	3 100 277	728 190	23.5	0	0
2012–2013	2 862 182	560 333	19.6	0	0

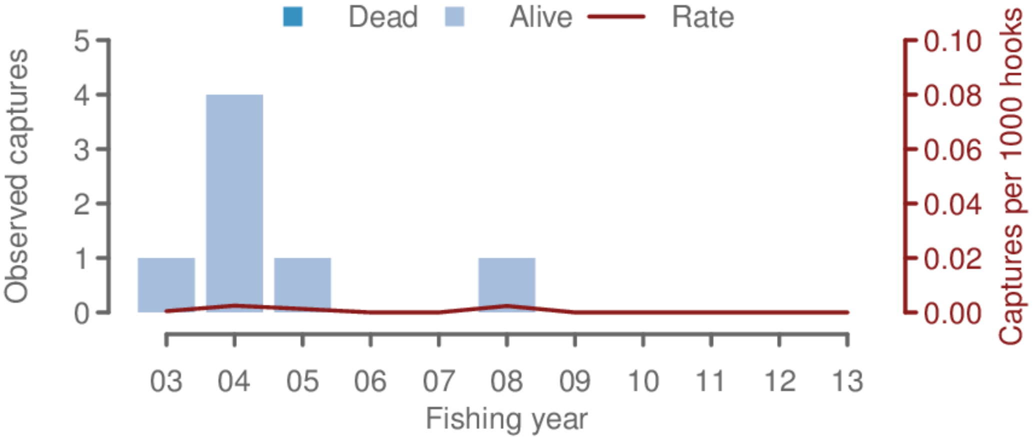


Figure 10: Observed captures of cetaceans in the New Zealand surface longline fisheries from 2002–03 to 2012–13.

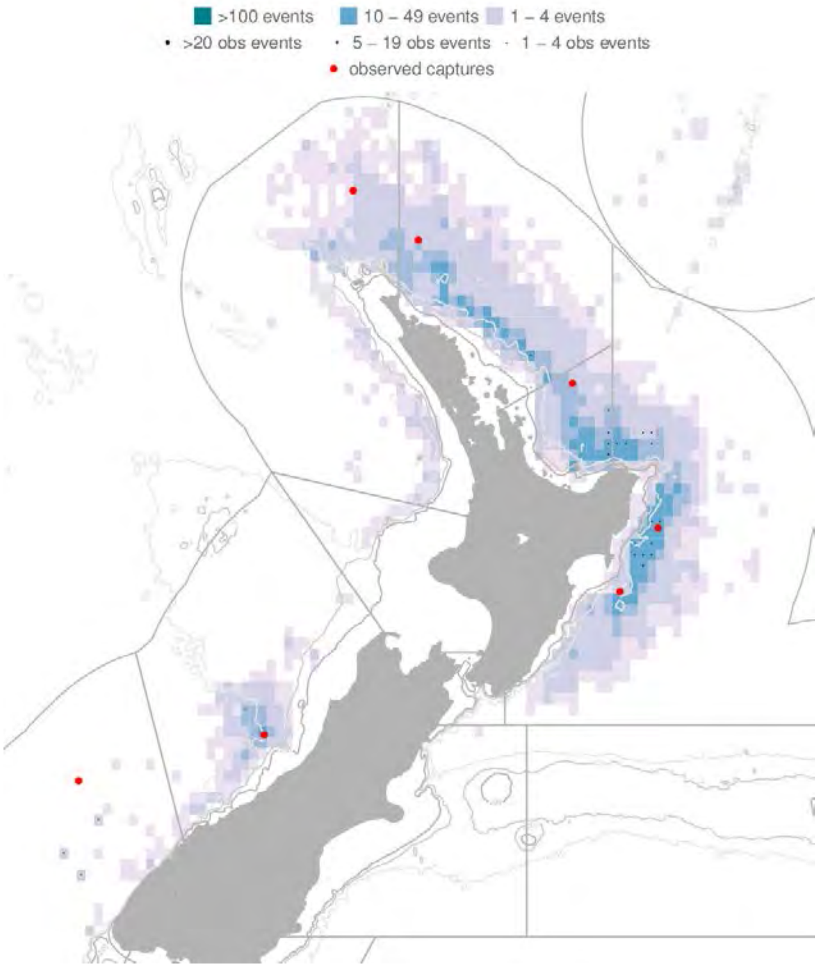


Figure 11: Distribution of fishing effort in the New Zealand surface longline fisheries and observed cetacean captures, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 89.4% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, especially in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf, which slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts, around much of the South Island and offshore islands. Captures on longlines occur when the fur seals attempt to feed on the bait and fish catch during hauling. Most New Zealand fur seals are released alive, typically with a hook and short snood or trace still attached.

New Zealand fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty-East Cape area when the animals have attempted to take bait or fish from the line as it is hauled. These capture rates include animals that are released alive (100% of observed surface longline capture in 2008–09; Thompson & Abraham 2010). Capture rates in 2011–12 and 2012-13 were higher than they were in the early 2000s (Figures 12 and 13). While fur seal captures have occurred throughout the range of this fishery most New Zealand captures have occurred off the Southwest coast of the South Island (Figure 14). Between 2002–03 and 2012–13, there were 267 observed captures of New Zealand fur seal in surface longline fisheries (Tables 13 and 14).

Table 13: Number of observed New Zealand fur seal captures in the New Zealand surface longline fisheries, 2002–03 to 2012–13, by species and area. Data from Thompson et al. (2013), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	Stewart Snares Shelf	West Coast North Island	West Coast South Island	Total
New Zealand fur seal	11	33	179	4	4	2	34	267

Table 14: Effort and captures of New Zealand fur seal in the New Zealand surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). Data from Thompson et al (2013), retrieved from http://data.dragonfly.co.nz/psc/. Estimates from 2002–03 to 2010–11 and preliminary estimates for 2012–13 are based on data version 20140131.

	Fishing effort			Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	10 772 188	2 195 152	20.4	56	0.026	299	199–428
2003–2004	7 386 329	1 607 304	21.8	40	0.025	134	90–188
2004–2005	3 679 765	783 812	21.3	20	0.026	66	38–99
2005–2006	3 690 119	705 945	19.1	12	0.017	47	23–79
2006–2007	3 739 912	1 040 948	27.8	10	0.010	32	14–55
2007–2008	2 246 189	421 900	18.8	10	0.024	40	19–68
2008–2009	3 115 633	937 496	30.1	22	0.023	53	29–81
2009–2010	2 995 264	665 883	22.2	19	0.029	77	43–121
2010–2011	3 187 879	674 572	21.2	17	0.025	64	35–101
2011–2012	3 100 277	728 190	23.5	40	0.055	140	92–198
2012–2013†	2 862 182	560 333	19.6	21	0.037	110	65–171

†Provisional data, model estimates not finalised.

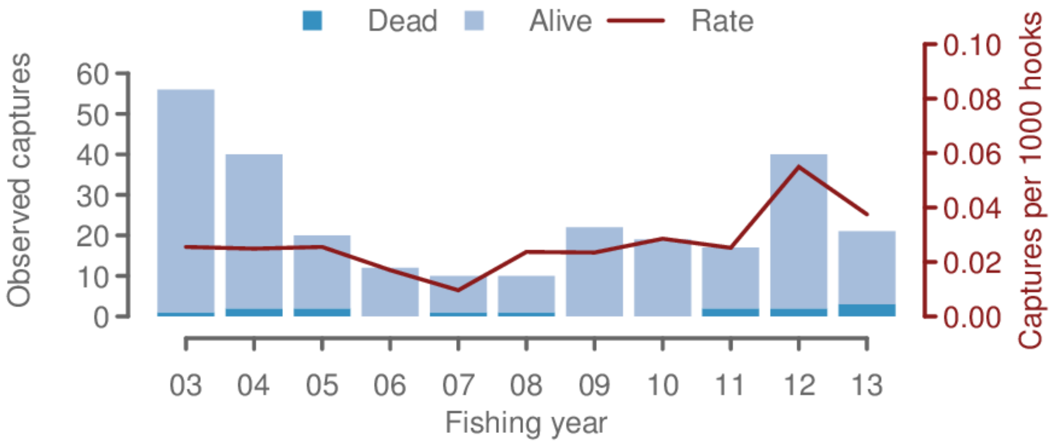


Figure 12: Observed captures of New Zealand fur seal in the New Zealand surface longline fisheries from 2002–03 to 2012–13.

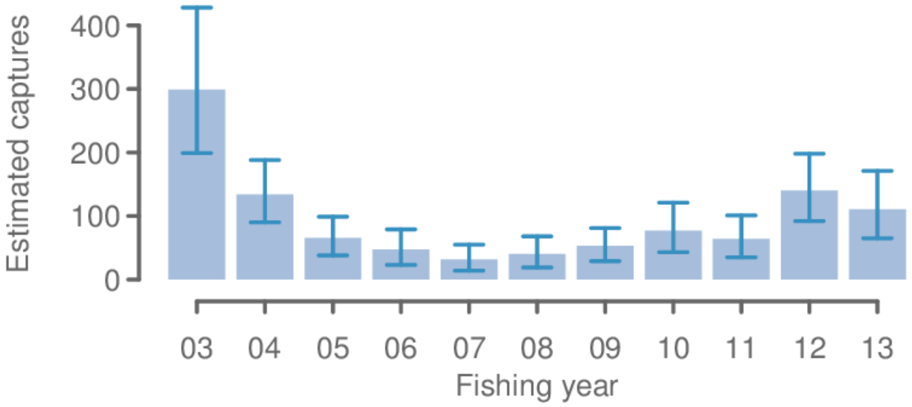


Figure 13: Estimated captures of New Zealand fur seal in the New Zealand surface longline fisheries from 2002–03 to 2012–13.

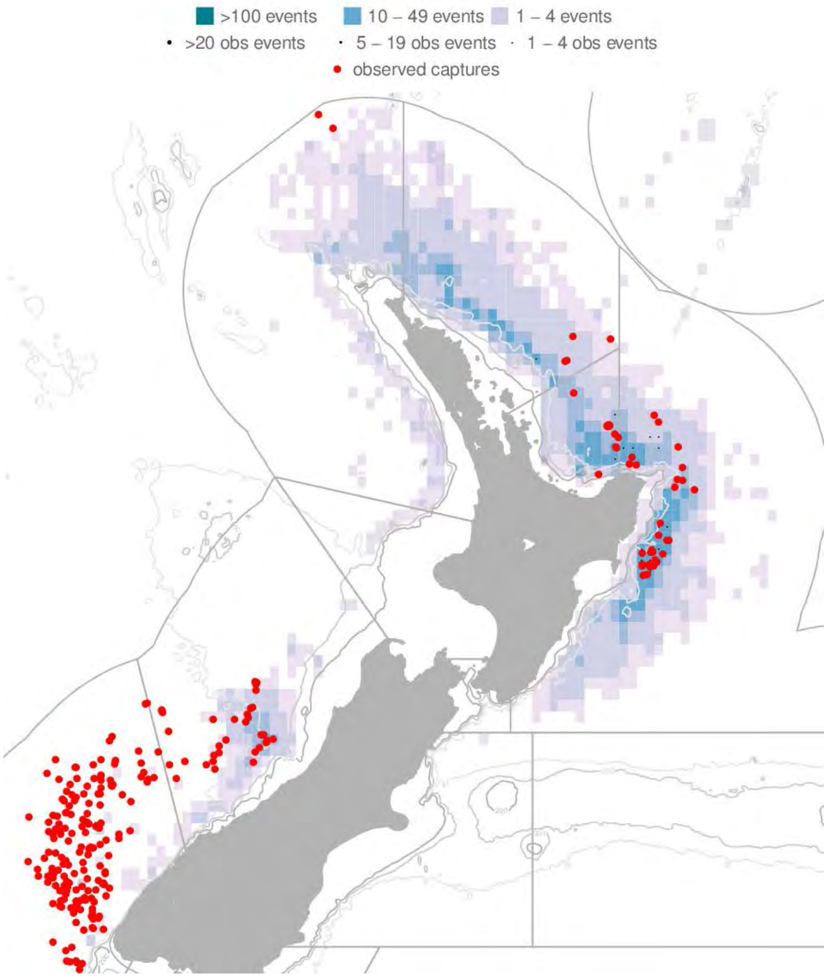


Figure 14: Distribution of fishing effort in the New Zealand surface longline fisheries and observed New Zealand fur seal captures, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 89.4% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3 Incidental fish bycatch

Observer records indicate that a wide range of species are landed by the longline fleets in New Zealand fishery waters. Blue sharks are the most commonly landed species (by number), followed by Ray's bream (Table 15). Southern bluefin tuna and albacore tuna are the only target species that occur in the top five of the frequency of occurrence.

Table 15: Total estimated catch (numbers of fish) of common bycatch species in the New Zealand longline fishery as estimated from observer data from 2009 to 2013. Also provided is the percentage of these species retained (2013 data only) and the percentage of fish that were alive when discarded, N/A (none discarded).

Species	2010	2011	2012	2013	% retained (2013)	discards % alive (2013)
Blue shark	66113	53432	132925	158736	45.2	97.4
Lancetfish	43425	37305	7866	19172	0.1	37.6
Rays bream	20041	18453	19918	13568	97.4	4.2
Porbeagle shark	4679	9929	7019	9805	34.0	79.8
Mako shark	4490	9770	3902	3981	35.5	84.9
Moonfish	5398	3418	2363	2470	99.0	0.0
Escolar	1539	6602	2181	2088	30.2	76.3
Sunfish	3148	3773	3265	1937	2.7	100.0
Pelagic stingray	1983	4090	712	1199	1.0	97.0
Butterfly tuna	1158	909	713	1030	48.1	11.1
Deepwater dogfish	377	548	647	743	1.2	88.5
Oilfish	886	1747	509	386	26.5	72.2
Rudderfish	326	338	491	362	13.0	80.0
Thresher shark	209	349	246	256	33.3	75.0
Skipjack tuna	91	255	123	240	100.0	N/A
Dealfish	1160	223	372	237	1.7	25.1
Striped marlin	471	175	124	182	0.0	44.4
Big scale pomfret	505	139	108	67	88.2	100.0
School shark	62	49	477	21	100.0	N/A

4.4 Benthic interactions

N/A

4.5 Key environmental and ecosystem information gaps

Cryptic mortality is unknown at present.

Observer coverage in the New Zealand fleet has historically not been spatially or temporally representative of the fishing effort. However in 2013 the observer effort was re-structured to rectify this by planning observer deployment to correspond with recent spatial and temporal trends in fishing effort.

5. STOCK ASSESSMENT

With the establishment of WCPFC in 2004, the Scientific Committee of the Western and Central Pacific Fisheries Commission (WCPFC) will review stock assessments of striped marlin in the western and central Pacific Ocean stock.

In 2012, scientists from Australia and the Secretariat of the Pacific Community (SPC) collaborated on an assessment for striped marlin in the southwest Pacific Ocean (further details can be found in Davies et al (2012). This was the second attempt to carry out an assessment for this stock and contained many improvements from the previous assessment.

Excerpts from the stock assessment are provided below, as are several figures and tables regarding stock status that reflect the model runs selected by SC for the determination of current stock status and the provision of management advice. This assessment is supported by several other analyses which are documented separately, but should be considered when reviewing this assessment as they underpin many of the fundamental inputs to the models. These include standardised CPUE analyses of aggregate Japanese and Taiwanese longline catch and effort data; standardised CPUE analyses of operational catch and effort data for the Australian longline fishery; standardized CPUE for the recreational fisheries in Australia and New Zealand (Holdsworth & Kendrick 2012), and new biological estimates for growth, the length-weight relationship, and maturity at age (Kopf 2009, 2011). The assessment includes a series of model runs describing stepwise changes from the 2006 assessment model (bcase06) to develop a new "reference case" model (Ref.case), and then a series of "one-off" sensitivity models that represent a single change from the Ref.case model run. A sub-set of key model runs was taken from the sensitivities that represent a set of plausible model runs, and these were included in a structural uncertainty analysis (grid) for consideration in developing management advice.

Besides updating the input data to December 2011, the main developments to the inputs compared to the 2006 assessment included:

a) Japanese longline catches for 1952–2011 revised downwards by approximately 50%;
b) Nine revised and new standardised CPUE time series (with temporal CVs) derived from:
    - aggregate catch-effort data for Japanese and Taiwanese longline fisheries;
    - operational catch-effort data for the Australian longline fishery;
    - operational catch-effort data for the Australian and New Zealand recreational fisheries, and
c) Size composition data for the Australian recreational fishery.

The main developments to model structural assumptions were to: fix steepness at 0.8; fix growth at the published estimates; estimate spline selectivities for the main longline fisheries; estimate logistic selectivity for the Australian recreational fishery; include time-variant precision in fitting the model to standardized CPUE indices; and remove conflict among the CPUE indices by taking only the Japanese longline index in model area 2 as being representative for the Ref.case.

The primary factors causing the differences between the 2006 and 2012 assessments are:

- The approximately 50% reduction in Japanese longline catches over the entire model time period;
- The faster growth rates;
- Steepness fixed at 0.8 rather than estimated (0.546);
- Selectivities for the major longline fisheries use cubic splines, and are not constrained to be asymptotic;
- Removing conflict among the CPUE indices by separating conflicting indices into different models.

Together these changes produce an estimated absolute biomass that is around 30% lower than the 2006 base case and MSY is estimated to be 20% lower. Current biomass levels are higher relative to the MSY reference point levels.

The main conclusions of the 2012 assessment undertaken by SPC (Davies et al 2012) and reviewed by the WCPFC Scientific Committee in August 2012 are as follows:

a) "The decreasing trend in recruitment estimated in the 2006 assessment remains a feature of the current assessment, particularly during the first 20 years. It is concurrent with large declines in catch and CPUE in the Japanese longline fishery in area 2. Recruitment over the latter 40 years of the model period declines slightly.

b) Estimates of absolute biomass were sensitive to assumptions about selectivity and to conflicts among the standardized CPUE time series. The reference case model (Ref.case) estimated selectivity functions that decrease with age for the main longline fisheries that achieved the best fit to the size data. The CPUE time series for the Japanese longline fishery in area 2 was selected for fitting the Ref.case model because this time series was considered to be the most representative of changes in overall population relative to abundance. Alternative options for selectivity assumptions and the CPUE time series included in the model fit were explored in sensitivity and structural uncertainty analyses, and are presented as the key model runs.

c) Estimates of equilibrium yield and the associated reference points are highly sensitive to the assumed values of natural mortality and, to a lesser extent, steepness in the stock-recruitment relationship. Estimates of stock status are therefore uncertain with respect to these assumptions.

d) If one considers the recruitment estimates since 1970 to be more plausible and representative of the overall productivity of the striped marlin stock than estimates of earlier recruitments, the results of the 'msy_recent' analysis could be used for formulating management advice. Under this productivity assumption *MSY* was 16% lower than the grid median value, but the general conclusions regarding stock status were similar.

e) Total and spawning biomass are estimated to have declined to at least 50% of their initial levels by 1970, with more gradual declines since then in both total biomass ($B_{current}/B_0$ = 36%) and spawning biomass ($SB_{current}/SB_0$ = 29%).

f) When the non-equilibrium nature of recent recruitment is taken into account, we can estimate the level of depletion that has occurred. It is estimated that, for the period 2007–2010, spawning potential is at 43% of the level predicted to exist in the absence of fishing, and for 2011 is at 46%.

g) The attribution of depletion to various fisheries or groups of fisheries indicates that the Japanese longline fisheries have impacted the population for the longest period, but this has declined to low levels since 1990. Most of the recent impacts are attributed to the 'Other' group of longline fisheries in areas 1 and 4, and to a lesser extent the 'Other' and Australian fisheries in areas 2 and 3.

h) Recent catches are 20% below the *MSY* level of 2182 mt. In contrast, the 'msy-recent' analysis calculates *MSY* to be 1839 mt, which places current catches 5% below this alternative *MSY* level. Based on these results, we conclude that current levels of catch are below MSY but are approaching MSY at the recent [low] levels of recruitment estimated for the last four decades.

i) Fishing mortality for adult and juvenile striped marlin is estimated to have increased continuously since the beginning of industrial tuna fishing. Apart from those model runs that assumed lower natural mortality or steepness, $F_{current}/F_{MSY}$ was estimated to be lower than 1. For the grid median, this ratio is estimated at 0.58. Based on these results, we conclude that overfishing is not occurring in the striped marlin stock.

j) The reference points that predict the status of the stock under equilibrium conditions at current F are $B_{Fcurrent}/B_{MSY}$ and $SB_{Fcurrent}/SB_{MSY}$. The model predicts that at equilibrium the biomass and spawning biomass would increase to 129% and 144%, respectively, of the level that supports *MSY*. This is equivalent to 39% of virgin spawning biomass. Current stock status compared to these reference points indicates that the current total and spawning biomass are close to the associated MSY levels ($B_{current}/B_{MSY}$ = 0.96 and $SB_{current}/SB_{MSY}$ = 1.09) based on the medians from the structural uncertainty grid. The structural uncertainty analysis indicates a 50% probability that $SB_{current}<SB_{MSY}$, and 6 of the 10 key model runs indicate the ratio to be < 1. Based on these results above, and the recent trend in spawning biomass, we conclude that striped marlin is approaching an overfished state."

The Scientific Committee selected the reference case model from the assessment to characterize stock status and selected several key sensitivity runs to characterize uncertainty in trends in abundance and stock status (Figures 15–19 and Tables 16 and 17). It was noted that the use of the reference case and key sensitivities selected by the Scientific Committee in 2012 (Table 3) leads to slightly different conclusions in terms of stock status compared to that based on the uncertainty grid used in the assessment. The reference case and five of the six other key sensitivity runs estimated $F_{current}/F_{MSY}$ to be less than one indicating that overfishing is unlikely to be occurring. However, when considering $SB_{current}/SB_{MSY}$, the reference case and four of the six other key sensitivity runs are estimated to be less than one, indicating evidence that the stock may be overfished.

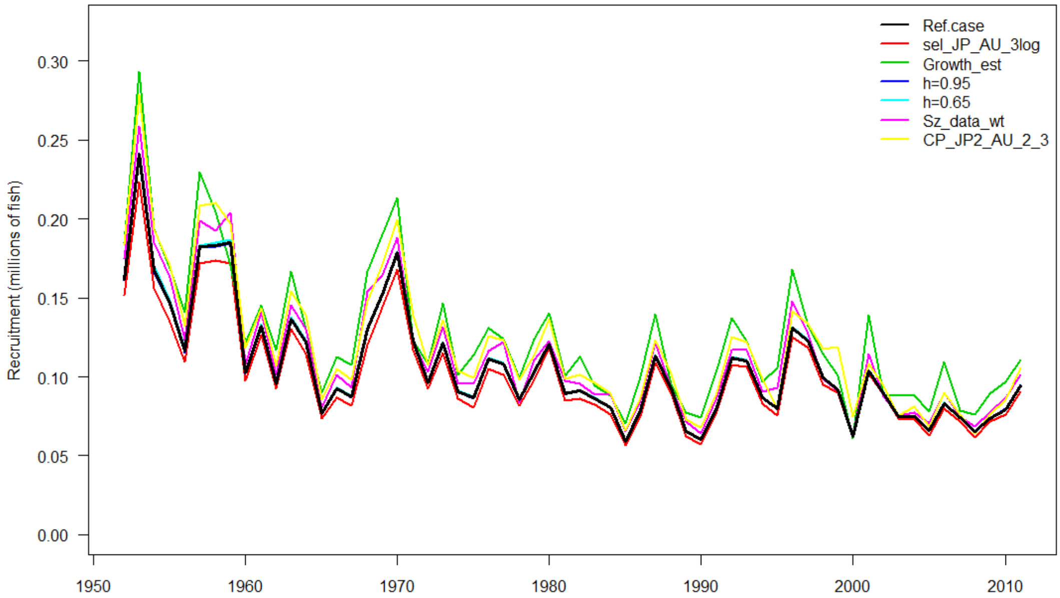


Figure 15: Estimated annual recruitment (millions of fish) for the southwest Pacific Ocean striped marlin obtained from the Ref.case model (black line) and the six plausible key model runs.

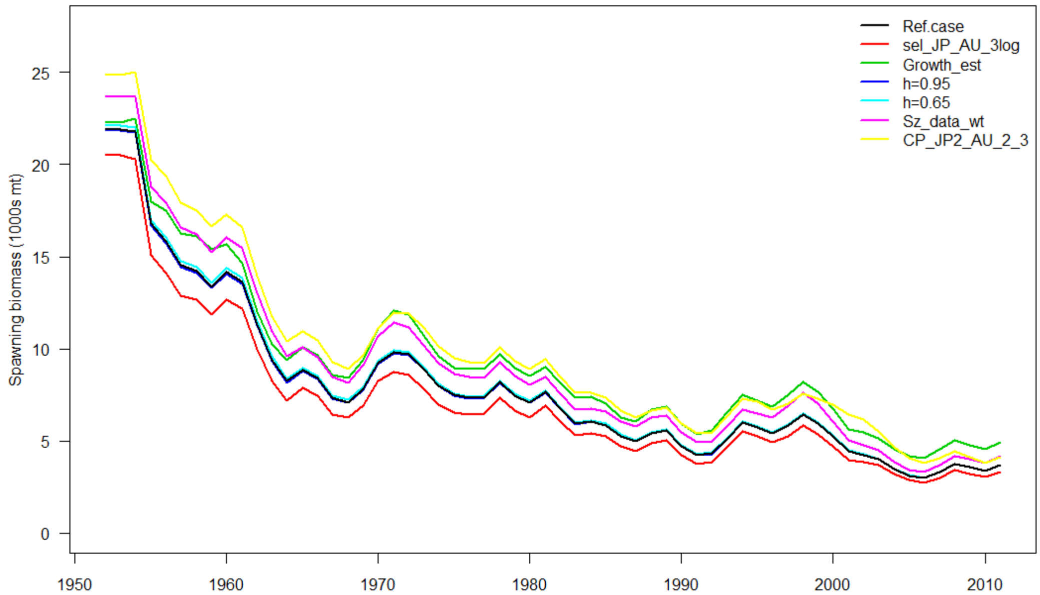


Figure 16: Estimated average annual average spawning potential for the southwest Pacific Ocean striped marlin obtained from the Ref.case model (black line) and the six plausible key model runs.

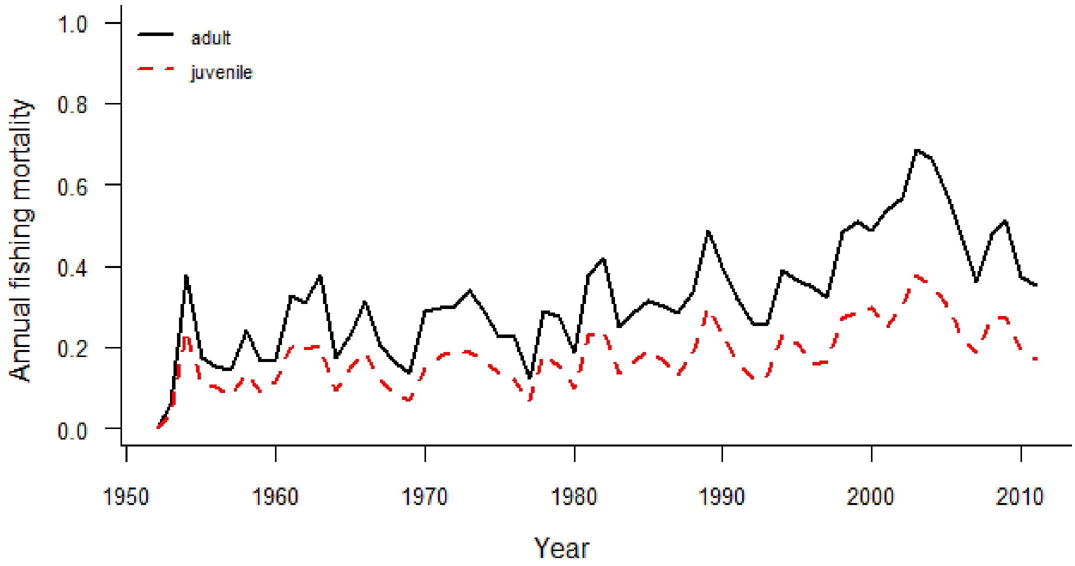


Figure 17: Estimated annual average juvenile and adult fishing mortality for the southwest Pacific Ocean striped marlin obtained from the Ref.case model.

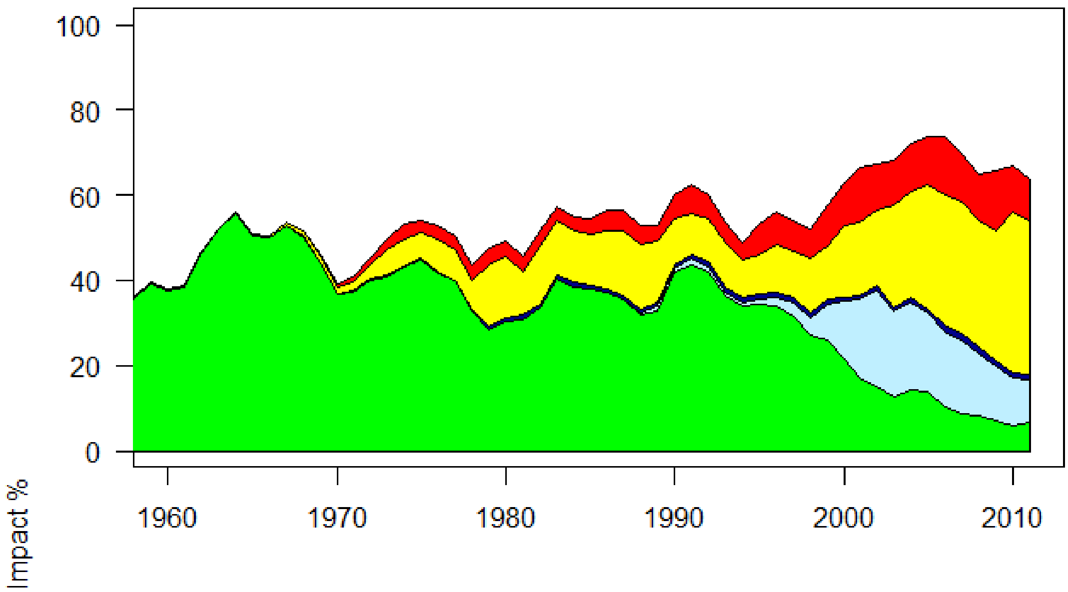


Figure 18: Estimates of reduction in spawning potential due to fishing (fishery impact = 1-SBt/SB$_{tF=0}$) for the southwest Pacific Ocean striped marlin attributed to various fishery groups (Ref.case model). Green = Japanese longline fisheries in sub-areas 1 to 4 and Taiwanese longline fishery in sub-area 4; Light blue = Australian and New Zealand longline fisheries; Dark blue = Australian and New Zealand recreational fisheries; Yellow = all longline fisheries in sub-areas 1 and 4 excluding Taiwanese in sub-area 4 and excluding Japanese; Red = all longline fisheries in sub-areas 2 and 3 excluding Japanese, Australian and New Zealand.

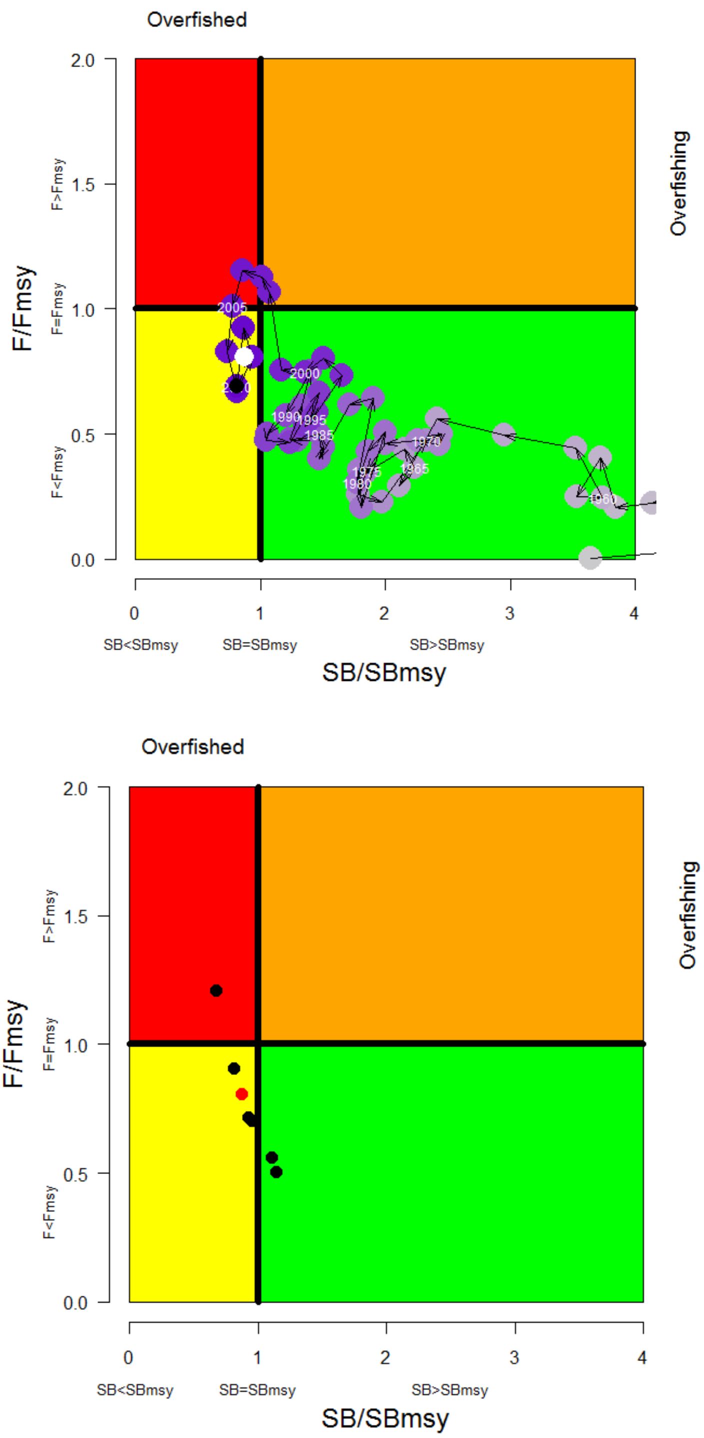


Figure 19: Temporal trend in annual stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the Ref.case (top) and $F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for the Ref.case (red circle) and the six plausible key model runs. See Table 15 to determine the individual model runs.

Table 16. Estimates of management quantities for selected stock assessment models from the 2012 Ref.case model and the six plausible key model runs. For the purpose of this assessment, "current" is the average over the period 2007–2010 and "latest" is 2011.

	Ref.case	sel_JP_AU_3log	CP_JP2_AU_2_3	h=0.65	h=0.95	Growth_est	Sz_data_wt
$C_{current}$	1 758	1 753	1 785	1 759	1 759	1 707	1 764
C_{latest}	1 522	1 523	1 512	1 522	1 522	1 476	1 521
MSY	2 081	2 017	2 256	1 914	2 276	2 182	2 179
$C_{current}/MSY$	0.85	0.87	0.79	0.92	0.77	0.78	0.81
C_{latest}/MSY	0.73	0.76	0.67	0.80	0.67	0.68	0.70
F_{mult}	1.24	1.10	1.39	0.83	1.98	1.79	1.42
$F_{current}/F_{MSY}$	0.81	0.91	0.72	1.21	0.51	0.56	0.71
SB_0	15,130	14,530	16,590	16,790	14,220	15,360	16,000
SB_{MSY}/SB_0	0.27	0.27	0.27	0.32	0.22	0.28	0.26
$SB_{current}/SB_0$	0.24	0.22	0.25	0.21	0.25	0.31	0.25
SB_{latest}/SB_0	0.24	0.23	0.25	0.22	0.26	0.32	0.26
$SB_{current}/SB_{MSY}$	0.87	0.81	0.92	0.67	1.14	1.11	0.95
SB_{latest}/SB_{MSY}	0.90	0.84	0.92	0.70	1.19	1.14	1.00
$SB_{curr}/SB_{curr_{F=0}}$	0.34	0.32	0.37	0.34	0.34	0.44	0.37
$SB_{latest}/SB_{latest_{F=0}}$	0.37	0.34	0.39	0.37	0.37	0.46	0.40
Steepness (h)	0.80	0.80	0.80	0.65	0.95	0.80	0.80

Table 17: Comparison of southwest Pacific Ocean striped marlin reference points from the 2012 reference case model and the range of the seven models in Table 15; the 2006 base case model (steepness estimated as 0.51). ***NA*** **= not available.**

Management quantity	2012 assessment Ref.case (uncertainty)	2006 assessment Base case
Most recent catch	1758 mt (2011)	1412 mt (2004)
MSY	2081 mt (1914 – 2276)	2610 mt
$F_{current}/F_{MSY}$	0.81 (0.51–1.21)	1.25
$B_{current}/B_{MSY}$	0.83 (0.70–0.99)	0.70
$SB_{current}/SB_{MSY}$	0.87 (0.67–1.14)	0.68
$Y_{Fcurrent}/MSY$	0.99 (0.93–1.00)	0.99
$B_{current}/B_{current,\ F=0}$	0.46 (0.44–0.53)	0.53
$SB_{current}/SB_{current,\ F=0}$	0.34 (0.32–0.44)	*NA*

Commercial catch and effort returns in New Zealand

The commercial TLCER data are compromised by the failure of many vessels to report their catch of striped marlin which they are required to release. Since 2000 the standardised series of positive catches shows some promise as an index of relative abundance.

The non-zero model explained almost 25% of the variance in log catch, largely by standardising for changes in the core fleet and in the month fished, both of which are predicted to have improved observed catches over the study period. No measure of effort entered the model.

Log(number STM per set) = fishing year + vessel + month

Positive catches usually comprise a single fish and rarely more than two fish per set. There is thus little contrast in catch rate in positive sets, but the standardised series suggests an overall decline in abundance (Figure 18). The fit of positive catches to the lognormal assumption is poor and is improved slightly by assuming an inverse Gaussian error distribution. The effect of the alternative error distribution on the annual indices is to steepen the decline slightly in recent years. The series is based on recorded catches and has large error bars around each point due to the small number of records.

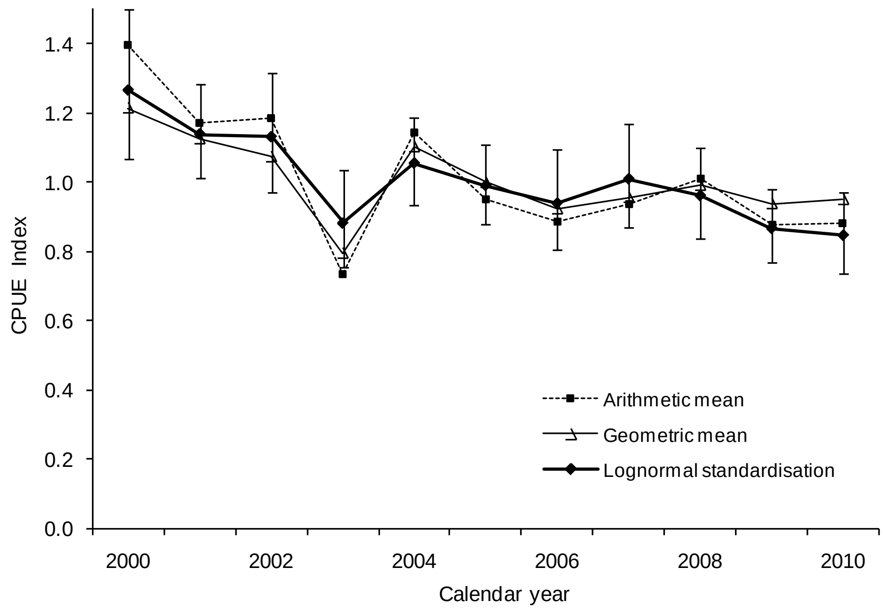


Figure 18: Unstandardised commercial logbook CPUE (annual geometric mean number of STM per set), the year effects from the model of non-zero catches (± 2 s.e.).

These CPUE analyses are done on the data that were groomed and submitted to WCPFC. In respect of some potential explanatory variables these datasets are not complete, and there is some potential to improve the analyses in future with dedicated data extracts. The shortened time series of commercial data used reflects the period for which we have confidence that striped marlin were being reported, however, there is some potential to extend that series back a little further in time for the positive catches only.

Observer logbook data

The observer database is limited in its coverage of the striped marlin which is largely a bycatch of bigeye tuna and swordfish target fisheries from the northern part of the EEZ, because observer effort is focused on the charter fleet that fishes further south for southern bluefin tuna.

The final non-zero model of observer logbook data explained 30% of the variance in catch rate. Fishing year was forced as the first variable and explained most of the variance in catch (16%). Sea surface temperature entered the model as the second most important variable explaining an additional 5% of the variance and it was followed by longitude, buoy-line length and longline length, each adding little additional explanatory power.

The final model form was as follows:

Log(number STM per set) = fishing year + temperature + longitude + buoy-line length + longline length

The effect of standardisation is marked because of the unbalanced nature of the dataset that the model attempts to account for. The standardised series is smoother than the unstandardised with most of the anomalous peaks being removed. The first two years in the series was comprised entirely of sets in cool water which the model accounts for by lifting the standardised CPUE in those years relative to the unstandardised model, but the error around each point is large and the overall trend is essentially flat (Figure 20).

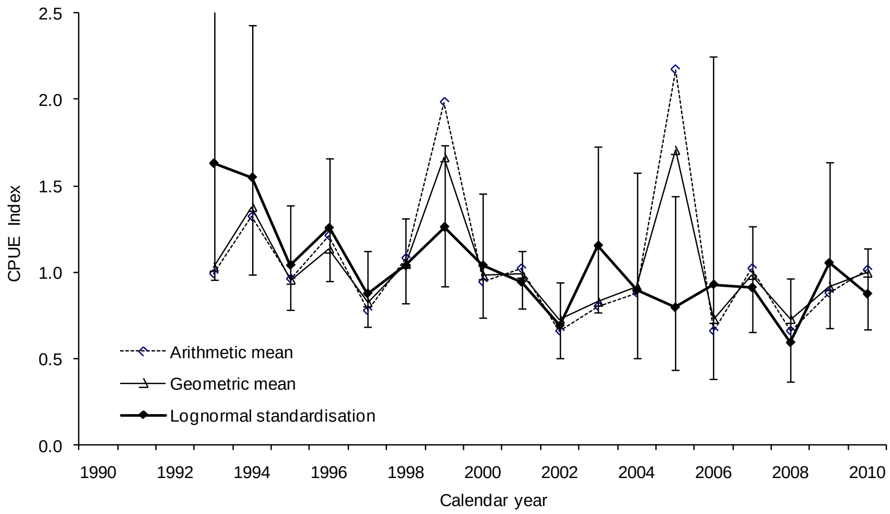


Figure 20: Unstandardised observer logbook CPUE (arithmetic and geometric mean numbers of STM per set) and the year effects from the lognormal model of catch rates in successful sets (± 2 s.e.).

Recreational charter boat data

A time series of data was collected using annual postal surveys of East Northland gamefish charter skippers. They provided striped marlin catch and effort information giving an average catch per vessel day fished over the whole season. Since 2006–07 more detailed daily catch and effort information has been collected from all regions with the billfish logbook programme. A subset of these data from east northland charter vessels extends the existing data series. Survey responses were trimmed to include vessels with six or more years of data and a range of factors were investigated using GLMs. Fine scale spatial and environmental variables are not available for most earlier years and were not offered to the model. A negative binomial model was fitted to all data including zero catches.

The final model form was as follows:

~ fishing year + poly(log(days fished), 3) + vessel + area

The standardization effect of the model was a tendency to reduce the index in the early years and lift the index since the late 1990s (Figure 21). The main driver for this was the effort term which shows a large and consistent trend toward fewer days fished by charter boats in East Northland between 1982 and 2009. The vessel effect pushed the index back down as a number of new high performing vessels entered the fishery in the mid-2000s.

Recreational charter CPUE increased in the late 1970s followed by three very poor years in the mid-1980s (Figure 21). Charter CPUE was high again in the mid-1990s and above avera in the mid-2000s. CPUE over the last four years has been relatively poor. While these data are informative on recreational fishing success in east Northland care should be taken making more general assumptions because of the relatively small area where this fishery operates.

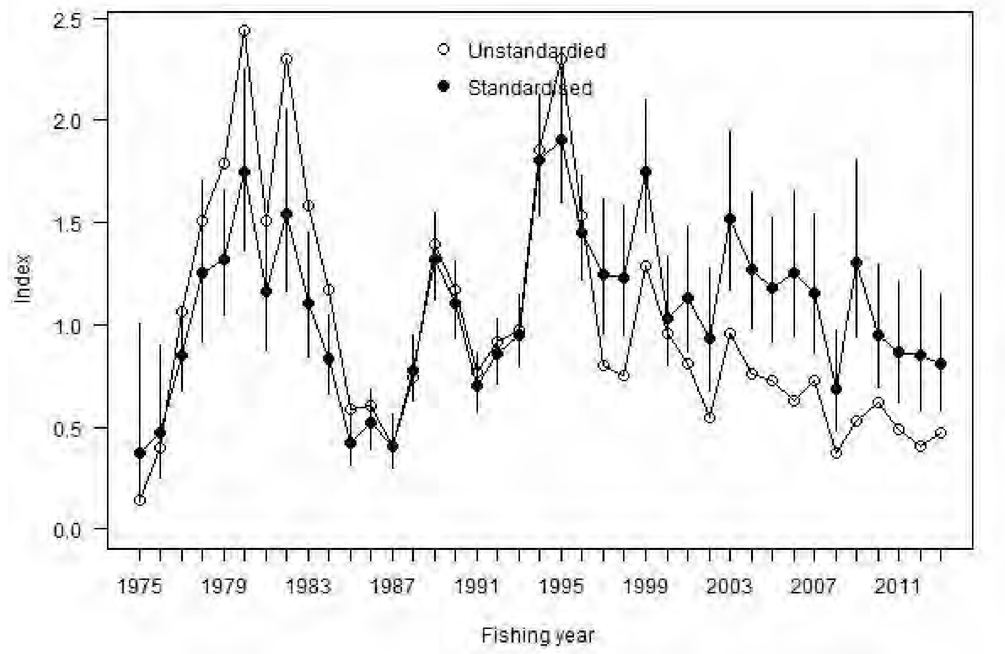


Figure 21: Overall standardization effect of the model of recreational charter boat catch. The unstandardised index is based on the geometric mean of the catch per strata and is not adjusted for effort.

Comparison of models

The standardised series of observed non-zero commercial catches shows considerable interannual variance due to the small number of records, but does not disagree with the better estimated series for the core longline vessels reporting in commercial catch reporting, in describing a flat or maybe slightly declining trajectory over the last decade (Figure 22). There is also considerable interannual variability in the standardised series from the recreational charter fishery but trends are similar to the non-zero commercial and observer time series with high CPUE in the mid-1990s, a peak in 1999 and a declining trend over the last decade (Figure 22).

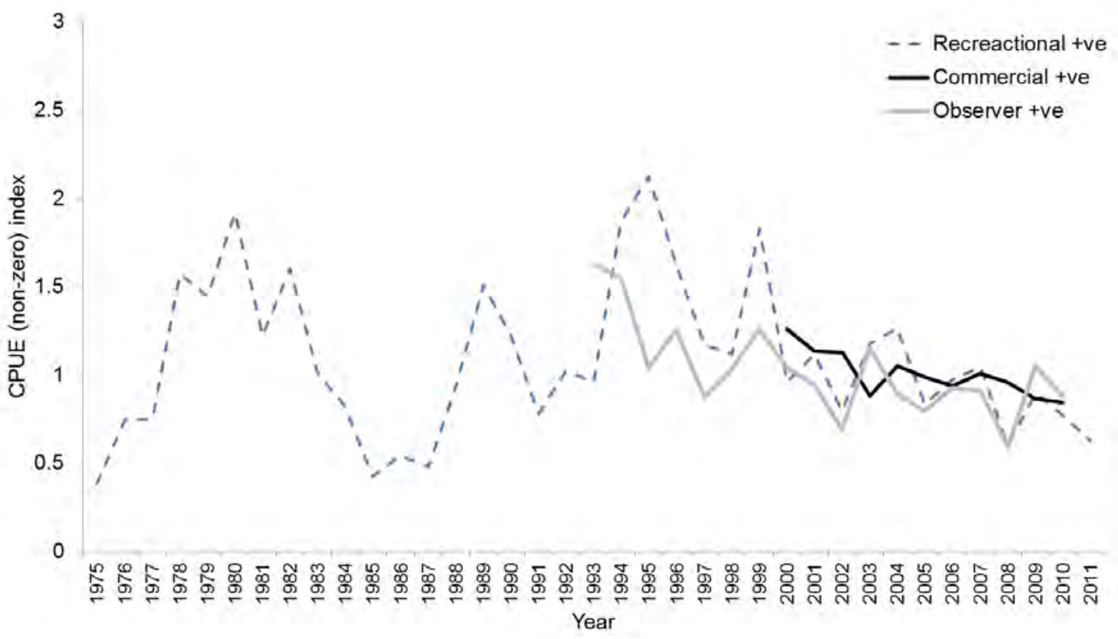


Figure 22: Comparison of standardised CPUE from the non-zero models of recreational charter vessel records with non-zero models of commercial and observer logbook records.

All the New Zealand CPUE data sets suffer from a limited spatial scale and limited numbers of records. There are some quite large changes in availability from year to year which appear in all indices. These may be indicative of changes in abundance or recruitment in some part of the south western Pacific stock but the scale may be amplified by annual variability in oceanographic conditions.

5.1 Biomass and yield estimates

No estimates of biomass or yield are available for New Zealand.

5.2 Other factors

Given that New Zealand fishers encounter some of the largest striped marlin in the Pacific, the abundance of fish found within New Zealand fisheries waters will be very sensitive to the status of the stock. In addition, environmental factors may also influence availability. The average size of striped marlin in the recreational fishery has declined over the last 80 years. Individual weights were averaged from published catch records in sport fishing club year books (Figure 23).

A commercial marlin fishery was started in waters north of New Zealand in 1956 by Japanese surface longline vessels. Mean fish weight has declined since then and there is more inter-annual variability. There have been changes to recreational fishing methods in the area fished over this time. The most significant change was in the late 1980s when there was a switch from trolled baits to artificial lures. Over the last 15 years more than half the weights have been estimated following tag and release.

In 2006–07 the Ministry of Fisheries instigated a billfish logbook programme to capture fine scale temporal and spatial information along with marlin catch and effort. Data collection expanded to include private vessels in all areas, including Bay of Plenty, West Coast North Island and the Three Kings.

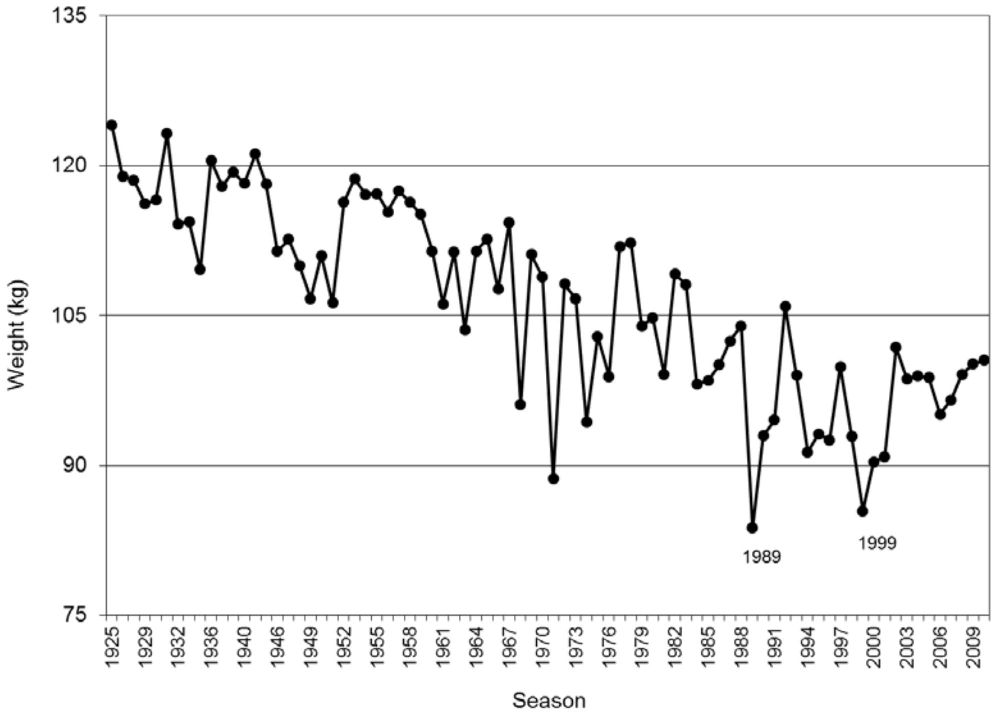


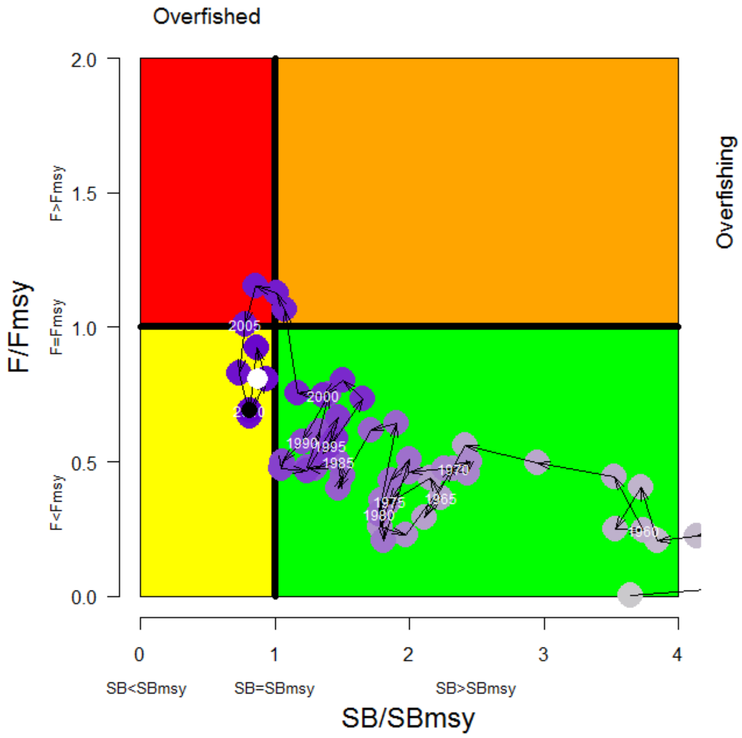
Figure 23: The mean annual weight of striped marlin (landed and tagged) caught in New Zealand fishery waters by recreational fishers by season from club records.

6. STATUS OF THE STOCK

Stock structure assumptions
Western and Central Pacific Ocean.
All biomass in this table refers to spawning biomass (SB)

Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	Reference case (ref.case) and five sensitivity runs
Reference Points	Target: $SB > SB_{MSY}$ and $F < F_{MSY}$ Soft Limit: Not established by WCPFC but evaluated using HSS default of 20% SB_0 Hard Limit: Not established by WCPFC but evaluated using HSS default of 10% SB_0 Overfishing threshold: F_{MSY}
Status in relation to Target	About as Likely as Not (40-60%) that SB is at or above SB_{MSY} Likely (> 60%) that F is at or below F_{MSY}
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Unlikely (< 40%) to be below
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status



Temporal trend in annual stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the Ref.case

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Stock biomass declined rapidly through the 1960s, but the stock decline has been more gradual from 1970 through to 2011.
Recent Trend in Fishing	Overall fishing mortality has shown a slow but continuous

Intensity or Proxy	decrease from since 2004.	
Other Abundance Indices	Recruitment is variable but has declined by 50% since the 1950s.	
Trends in Other Relevant Indicator or Variables	-	
Projections and Prognosis		
Stock Projections or Prognosis	The stock is Likely to decline without management intervention	
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 commence	Unlikely (< 40%)	
Assessment Methodology and Evaluation		
Assessment Type	Level 1: Quantitative Stock assessment	
Assessment Method	MULTIFAN-CL	
Assessment Dates	Latest assessment: 2012	Next assessment: 2017
Overall assessment quality rank	1 - High Quality	
Main data inputs (rank)	**a)** Japanese longline catches for 1952–2011 revised downwards by approximately 50%;	1 - High Quality
	b) Nine revised and new standardised CPUE time series (with temporal CVs) derived from: • aggregate catch-effort data for Japanese and Taiwanese longline fisheries; • operational catch-effort data for the Australian longline fishery; • operational catch-effort data for the Australian and New Zealand recreational fisheries, and	1 - High Quality
	c) Size composition data for the Australian recreational fishery.	1 - High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	Catch estimated from the most recent years is uncertain as some catch has still not been reported. There are high levels of uncertainty regarding recruitment estimates and the resulting estimates of steepness.	

Qualifying Comments
At a 2012 ISC Billfish Working Group a meta-analysis was presented that included a) a review of all known estimates of striped marlin steepness including the 2006 WCPFC assessment of southwest Pacific striped marlin; b) a description of the analytical methods used; and c) a description of the data. The point estimate of steepness from the meta-analysis was M = 0.38 with a credible range of 0.3 to 0.5. Based on the results of this meta-analysis, SPC considered that the southwest Pacific striped marlin model runs where M was set to be 0.2 and 0.6 should

have a low weight as they are probably outside the plausible range of natural mortality rates.
Fishery Interactions
Interactions with protected species are known to occur in the longline fisheries of the South Pacific, particularly south of 25°S. Seabird bycatch mitigation measures are required in the New Zealand and Australian EEZs and through the WCPFC Conservation and Management Measure (CMM2007-04). Sea turtles are also captured incidentally in longline gear; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure (CMM2008-03). Shark bycatch is common in longline fisheries and largely unavoidable; this is being managed through New Zealand domestic legislation and to a limited extent through Conservation and Management Measure (CMM2010-07).

7. FOR FURTHER INFORMATION

Abraham, E R; Thompson, F N (2009) Capture of protected species in New Zealand trawl and longline fisheries, 1998–99 to 2006–07. *New Zealand Aquatic Environment and Biodiversity Report No. 32*.

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. Final Research Report prepared for Ministry of Fisheries project PRO2007/01. (Unpublished report held by the Ministry for Primary Industries, Wellington.) 170 pages.

Abraham, E R; Thompson, F N; Oliver, M D (2010) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report No. 45*. 148 p.

Anon (2013) Tuna fishery yearbook 2012. Western and Central Pacific Fisheries Commission, 154 p.

Baird, S J (2008) Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in longline fisheries in New Zealand waters, 1994–95 to 2005–06. *New Zealand Aquatic Environment and Biodiversity Report No. 20.* 21 p.

Bentley, N; Langley, A D; Middleton, D A J; Lallemand, P (2013). Fisheries of New Zealand, 1989/90-2011/12. Retrieved from http://fonz.tridentsystems.co.nz. Accessed 21 November 2013.

Boggs, C H (1989) Vital rate statistics for billfish stock assessment. Proceedings of the second international billfish symposium, Kailua-Kona, Hawaii, 1988 Part 165–177.

Bromhead, D; Pepperell, J; Wise, B; Findlay, J (2004) Striped marlin: biology and fisheries. Bureau of Rural Sciences. Canberra.

CMM2010-07 (2010) Conservation and Management measure for sharks, for the Western and Central Pacific Ocean. CMM2010-07 of the Western and Central Pacific Fisheries Commission.

Collette, B B; McDowell, J R; Graves, J E (2006) Phylogeny of recent billfishes (Xiphioidei). *Bulletin of Marine Science* 79:455–468.

Domeier, M L; Dewar, H; Nasby-Lucas, N (2003) Post-release mortality rate of striped marlin caught with recreational tackle. *Marine and Freshwater Research* 54, 435–445.

Davies, N; Hoyle, S; Hampton, J. (2012) Stock assessment of striped marlin (*Kajikia audax*) in the southwest Pacific Ocean. Report to the Western and Central Pacific Fisheries Commission Scientific Committee. WCPFC-SC8-2012/SA-WP-05. 84 p. (www.wcpfc.int).

Francis, M P; Griggs, L H; Baird, S J (2004) Fish bycatch in New Zealand tuna longline fisheries, 1998–99 to 1999–2000. *New Zealand Fisheries Assessment Report 2004/22*. 62 p.

Graves, J E; McDowell, J R (2003) Stock structure of the world's istiophorid billfishes: a genetic perspective. *Marine and Freshwater Research* 54, 287–298.

Griggs, L H; Baird, S J (2013). Fish bycatch in New Zealand tuna longline fisheries 2006–07 to 2009–10. *New Zealand Fisheries Assessment Report 2013/13*. 71 p.

Hanamoto, E (1977) Fishery Oceanography of Striped Marlin Part 2 Spawning Activity of the Fish in the Southern Coral Sea. SO - *Nippon Suisan Gakkaishi-Bulletin of the Japanese Society of Scientific Fisheries*. 43(11). 1977 (RECD 1978). 1279–1286.

Hinton, M G; Bayliff, W H (2002) Status of striped marlin in the eastern Pacific Ocean in 2001 and outlook for 2002. BBRG-1: Working group paper for the 15th meeting of the Standing Committee on Tuna and Billfish, Honolulu, Hawaii.

Hinton, M G; Maunder, M N (2003). Status of striped marlin in the eastern Pacific Ocean in 2002 and outlook for 2003–2004. Inter-American Tropical Tuna Commission 4.

Holdsworth, J; Kendrick, T H (2012) Characterisation and Catch Per Unit Effort of Striped Marlin in New Zealand. WCPFC-SC8-2012/ SA-IP-08. (www.wcpfc.int).

Holdsworth, J; Saul, P (2003) New Zealand billfish and gamefish tagging, 2001–02. *New Zealand Fisheries Assessment Report 2003/15*. 39 p.

Holdsworth, J; Saul, P (2007) New Zealand billfish and gamefish tagging, 2005–06. *New Zealand Fisheries Assessment Report 2007/02*. 29 p.

Holdsworth, J; Saul, P (2008) New Zealand billfish and gamefish tagging, 2006–07. *New Zealand Fisheries Assessment Report 2008/28*. 27 p.

Holdsworth, J; Saul, P (2013). New Zealand striped marlin recreational catch and effort 2011–12 and 2012–13. *New Zealand Fisheries Assessment Report 2013/67*. 29 p.

Holdsworth, J; Saul, P (2014) New Zealand billfish and gamefish tagging, 2012–13. *New Zealand Fisheries Assessment Report 2014/11*. 26 p.

Holdsworth, J; Saul, P; Browne, G (2003) Factors affecting striped marlin catch rate in the New Zealand recreational fishery. *Marine and Freshwater Research* 54, 473–481.

Holdsworth, J; Saul, P; van der Straten, K M (2007) Striped marlin fisheries in New Zealand. *New Zealand Fisheries Assessment Report 2007/32*. 37 p.

Holdsworth, J C; Sippel, T J; Block, B A (2009) Near real time satellite tracking of striped marlin (*Kajikia audax*) movements in the Pacific Ocean. *Marine Biology* Volume 156, 505–514.

Kopf, R K; Davie, P S (2009) Population biology and habitat preferences of striped marlin, *Kajikia audax* in eastern Australia and southwest Pacific Ocean. Australian Fisheries Management Authority and Fisheries Research and Development Corporation, Final Report. Project number 2006/816.

Kopf, R K; Davie, P S; Holdsworth, J C (2005) Size trends and population characteristics of striped marlin, *Tetrapturus audax*, in the New Zealand recreational fishery. *New Zealand Journal of Marine and Freshwater Research, 2005, Vol. 39*: 1145–1156.

Kopf, R K; Drew, K; Humphreys Jr., R L (2010). Age estimation of billfishes (Kajikia spp.) using fin spine cross-sections: the need for an international code of practice. *Aquatic Living Resources* 23:13–23.

Langley, A; Molony, B; Bromhead, D; Yokawa, K; Wise, B (2007) Stock assessment of striped marlin (*Tetrapturus audax*) in the southwest Pacific Ocean. WCPFC-SC SA WP-6 (www.wcpfc.int).

Mattlin, R H (1987) New Zealand fur seal, *Arctocephalus forsteri*, within the New Zealand region. In Croxall, J.P.; Gentry, R.L. Status, biology, and ecology of fur seals: Proceedings of an international symposium and workshop, Cambridge, England, 23–27 April 1984. NOAA Technical Report NMFS-51.

Melo-Barrera, F N; Uraga-Felix, R; Velazquez-Quinonez, C (2003) Growth and length-weight relationship of the striped marlin in Cabo San Lucas, Baja California Sur, Mexico. *Ciencias Marinas* 29(3), 305–313.

Ministry for Primary Industries (2013a). Aquatic Environment and Biodiversity Annual Review 2013. Compiled by the Fisheries Management Science Team, Ministry for Primary Industries, Wellington, New Zealand. 538 p.

Ministry for Primary Industries (2013b). Nathional Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand Fisheries. Ministry for Primary Industries, Wellington, New Zealand. 59 p.

Molony, B (2005) Summary of the biology, ecology and stock status of billfishes in the WCPFC, with a review of major variables influencing longline fishery performance. WCPFC Scientific Committee Working Paper SC1-EB-WP-2. www.spc.int.

Nakamura, I (1985) FAO species catalogue, Billfishes of the world. An annotated and illustrated catalogue of marlins, sailfishes, spearfishes and swordfishes known to date, Rome 5.

Ortiz, M; Prince, E; Serafy, J; Holts, D; Davy, K; Pepperell, J; Lowery, M; Holdsworth, J. (2003) A global overview of the major constituent-based billfish tagging programs and their results since 1954. *Marine and Freshwater Research* 54, 489–508.

Perrin, W F; Wursig, B; Thewissen, J G M (Eds.) (2008) *Encyclopedia of marine mammals*. Second Edition. Academic Press, San Diego.

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 (2014). Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002-03 to 2011-12. *New Zealand Aquatic Environment and Biodiversity Report*.

Richard, Y., and Abraham, E. R. 2013. Application of Potential Biological Removal methods to seabird populations. New Zealand Aquatic Environment and Biodiversity Report No. 108. 30p.

Richard Y; Abraham, E R (in press). Assessment of the risk of commercial fisheries to New Zealand seabird, 2006-07 to 2012/13. New Zealand Aquatic Environment and Biodiversity Report in press.

Richard, Y., Abraham, E. R., and Filippi, D. 2011. Assessment of the risk to seabird populations from New Zealand commercial fisheries. Final Research Report for projects IPA2009/19 and IPA2009/20. Unpublished report held by the Ministry of Fisheries, Wellington. 137p.

Richard, Y., Abraham, E. R., and Filippi, D. 2013. Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006-07 to 2010-11. New Zealand Aquatic Environment and Biodiversity Report No. 109. 58 + 70p.

Robertson, H.A; Dowding, J.E; Elliot, G.P; Hitchmough, R.A; Miskelly, C.M; O'Donnell, C.F.J; Powlesland, R.G; Sagar, P.M; Scofield, R.P; Taylor, G.A (2013) Conservation stats of New Zealand Birds, 2012. *New Zealand Threat Classification Series 4*. Department of Conservation, Wellington. 22 p.

Rowe, S J (2009) Conservation Services Programme observer report: 1 July 2004 to 30 June 2007. *DOC Marine Conservation Services Series 1*. Department of Conservation, Wellington. 93 p.

Sharp, B., Waugh, S., Walker, N.A, 2011. A risk assessment framework for incidental seabird mortality associated with New Zealand fishing in the New Zealand EEZ., Unpublished report held by the Ministry of Fisheries, Wellington., 39 p.

Sippel, T J; Davie, P S., Holdsworth, J C; Block, B A (2007) Striped marlin (*Tetrapturus audax*) movements and habitat utilization during a summer and autumn in the Southwest Pacific Ocean. *Fisheries Oceanography 16*: 459–472.

Sippel, T; Holdsworth, J; Dennis, T; Montgomery, J (2011) Investigating Behaviour and Population Dynamics of Striped Marlin (*Kajikia audax*) from the Southwest Pacific Ocean with Satellite Tags. *PLoS ONE 6(6)*: e21087. doi: 10.1371/ journal.pone.0021087.

Skillman, R A; Yong, M Y Y (1976) Von Bertalanffy Growth Curves for Striped Marlin *Tetrapturus audax* and Blue Marlin *Makaira nigricans* in the Central North Pacific Ocean. SO - *Fishery Bulletin* 74(3), 553–566.

Suzuki, Z (1989) Catch and fishing effort relationships for striped marlin, blue marlin, and black marlin in the Pacific Ocean, 1952 to 1985. Proceedings of the second international billfish symposium, Kailua-Kona, Hawaii, 1988 Part 165–177.

Thompson, F N; Abraham, E R (2010) 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.

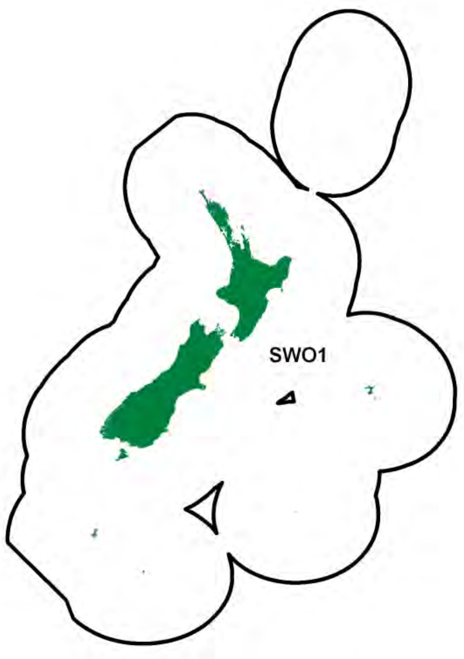
Thompson, F N; Berkenbusch, K; Abraham, E R (2013). Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11. *New Zealand Aquatic Environment and Biodiversity Report No. 105*. 73 p.

Ueyanagi, S; Wares, P G (1975) Synopsis of biological data on striped marlin, *Tetrapturus audax* (Philippi, 1887). In: Shomura, R.S. and Williams, F., (Eds.) Proceedings of the international billfish symposium, Kailua-Kona, Hawaii, 9–12 August 1972, Part 3. Species synopses. 132–159.

Waugh, S., Fillipi, D., Abraham, E., 2009. Ecological Risk Assessment for Seabirds in New Zealand fisheries, Unpublished Final Research Report for the Ministry of Fisheries 58 p.

SWORDFISH (SWO)

(*Xiphias gladius*)



1. FISHERY SUMMARY

Swordfish were introduced into the QMS on 1 October 2004 under a single QMA, SWO 1, with allowances, TACC, and TAC in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACC and TAC (all in tonnes) for swordfish.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other mortality	TACC	TAC
SWO 1	20	10	4	885	919

Swordfish were added to the Third Schedule of the 1996 Fisheries Act with a TAC set under s14 because swordfish is a highly migratory species and it is not possible to estimate MSY for the part of the stock that is found within New Zealand fisheries waters.

Swordfish were also added to the Sixth Schedule of the 1996 Fisheries Act with the provision that:

> "A commercial fisher may return any swordfish to the waters from which it was taken from if –
> (a) that swordfish is likely to survive on return; and
> (b) the return takes place as soon as practicable after the swordfish is taken; and
> (c) that swordfish has a lower jaw to fork length of less than 1.25m."

Management of swordfish throughout the western and central Pacific Ocean (WCPO) is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). At its sixth annual meeting (2009) the WCPFC passed a Conservation and Management Measure (CMM) (this is a binding measure that all parties must abide by) relating to conservation and management of swordfish in the southwest Pacific Ocean (www.wcpfc.int/). This measure restricts the number of vessels fishing for swordfish and sets catch limits in the convention area south of 20 degrees south.

1.1 Commercial fisheries

Annual swordfish catches throughout the Pacific have been increasing, with catches in the Western and Central Pacific increasing to 20 000 t in 2012 (Williams and Terawasi 2013). The swordfish catch from the southwest Pacific has averaged about 12% of the Pacific Ocean total in recent years. In New Zealand, swordfish are caught throughout the year in oceanic waters, primarily by pelagic longlines in areas where the bottom depth exceeds 1000 m.

Swordfish are either targeted or caught in the tuna longline fishery as a bycatch when targeting bigeye and to a lesser extent when targeting southern bluefin tuna. Swordfish can be caught in most FMAs and adjacent high seas areas although most catches are from waters north of 40ºS. Swordfish catch by domestic vessels increased rapidly from 1994–95 to peak at 1100 t in 2000–01. Since 2000–01 swordfish catches declined in each year coinciding with the decline in effort in the surface longline fishery, until 2005–06 when they increased again (Table 2). This increase is attributed to the development of a target fishery, which was, in part, initiated by the arrival of several surface longline vessels from Australia. Most of the catch is from FMA 1, FMA 2 and FMA 9. Figure 1 shows historical landings and TACCs and longline effort for SWO stocks.

Swordfish are processed at sea and the processed weight of the catch is converted to a greenweight using approved conversion factors. TLCER, CELR and LFRR data are provided for comparative purposes in Table 2 for the domestic fleet (New Zealand owned and operated vessels and chartered longline vessels).

Before the start of the domestic longline fishery in 1990–91, distant water longline fleets were granted foreign license access to fish for southern bluefin and bigeye tuna (Japan) and albacore (Korea). Swordfish catches for the Japanese fleet are given in Table 2 (Japan). The swordfish bycatch by the Japanese foreign licensed fishery averaged 388 t per year between 1979–80 and 1992–93 with a maximum catch of 761 t in 1980–81. Most of the Japanese swordfish catch (85%) was from FMA 2 and FMA 9. Korean catches were only small (0 to 7 t per year) and were mostly (79%) from FMA 9 and FMA 10.

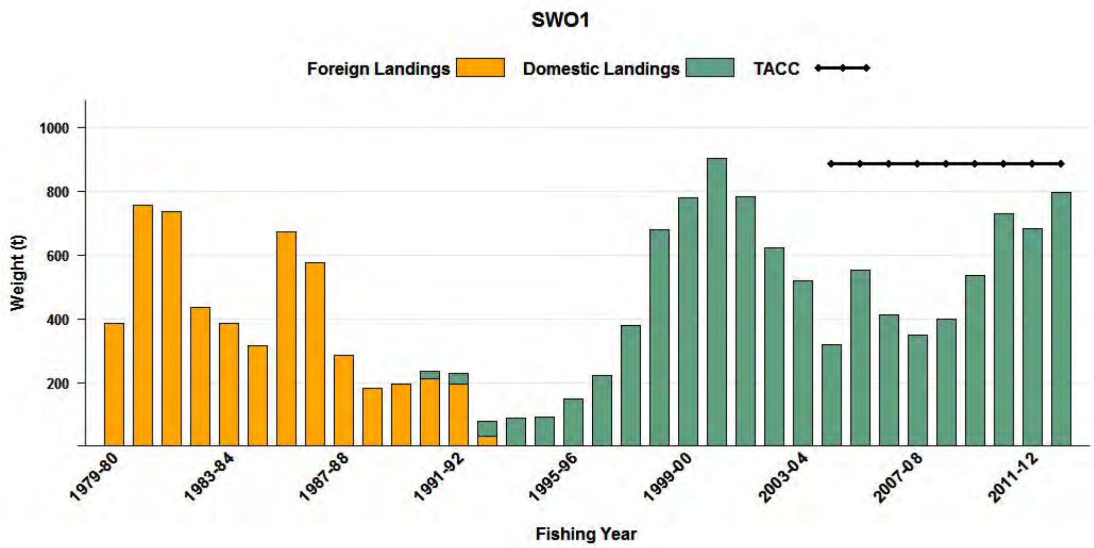


Figure 1: Swordfish catch by foreign licensed and New Zealand vessels from 1979–80 to 2012–13 New Zealand fishery waters (SWO 1). [Figure continued on next page].

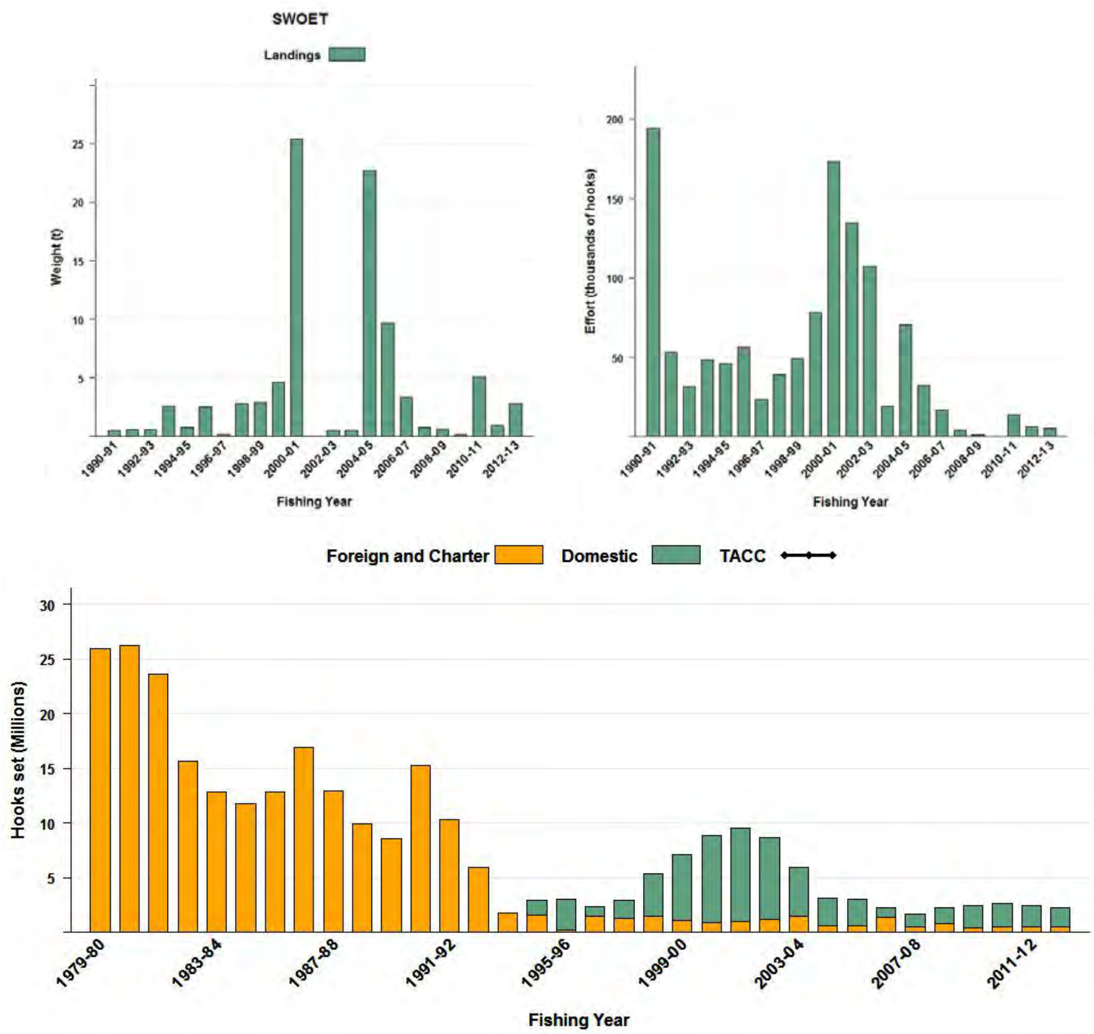


Figure 1 [Continued]: [Top] Swordfish catch by New Zealand vessels fishing on the high seas from 1990–91 to 2012–13. [Middle] Fishing effort (number of hooks set) for all New Zealand vessels fishing on the high seas; and [Bottom] fishing effort (number of hooks set) within New Zealand fishery waters for domestic and foreign vessels (including foreign charter vessels) from 1979–80 to 2012–13.

Table 2: Reported catches (t) of *X. gladius* by fishing year (from TLCER and CELR data) for the New Zealand domestic and chartered vessel fleet 1990-91 to 2012-13 and Japanese foreign licensed fleet 1979–80 to 2012–13; with annual totals from LFRR and MHR data from 2001–02 to present [Continued on next page].

	SWO 1 (all FMAs)				
Year	Japan	NZ/MHR	Total	LFRR	NZ ET
1979–80	386		386		
1980–81	756.1		756.1		
1981–82	734.6		734.6		
1982–83	436.1		436.1		
1983–84	384.8		384.8		
1984–85	316.1		316.1		
1985–86	673.6		673.6		
1986–87	575.5		575.5		
1987–88	286.2		286.2		
1988–89	181.1		181.1		
1989–90	194.3		194.3		
1990–91	211.9	21.9	233.8	41	0.5
1991–92	194.5	33.5	228	32	0.6
1992–93	31.1	46.8	77.9	79	0.6
1993–94		88.2	88.2	102	2.6
1994–95		91.4	91.4	102	0.8
1995–96		148.6	148.6	187	2.5

Table 2 [Continued]: Reported catches (t) of *X. gladius* by fishing year (from TLCER and CELR data) for the New Zealand domestic and chartered vessel fleet 1990-91 to 2012-13 and Japanese foreign licensed fleet 1979–80 to 2012–13; with annual totals from LFRR and MHR data from 2001–02 to present.

	SWO 1 (all FMAs)				
Year	Japan	NZ/MHR	Total	LFRR	NZ ET
1996–97		223.3	223.3	283	0.2
1997–98		379.7	379.7	534	2.8
1998–99		679.1	679.1	965	2.9
1999–00		778	778	976	4.6
2000–01		901.4	901.4	1 022	25.4
2001–02		945	783.9	958.8	
2002–03		673	622.0	670.1	0.5
2003–04		545	519.4	555.2	0.5
2004–05		344	320.7	344.7	22.7
2005–06		560.9	548.3	558.9	9.7
2006–07		412.7	412.7	425.8	3.3
2007–08		350.1	350.1	351.4	0.7
2008–09		398.7	398.7	393.9	0.6
2009–10		536.5	536.5	533.4	0.1
2010–11		729.6	729.6	739	5.1
2011–12		688.1	688.1	686.4	0.9
2012–13		796.8	796.8	788.4	2.8

The majority of swordfish are caught in the bigeye target surface longline fishery (64%) (Figure 2), however, across all longline fisheries swordfish make up 17% of the catch by weight (Figure 3). Longline fishing effort is distributed along the east coast of the North Island and the south west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the east coast of the North Island targets a range of species including bigeye, swordfish, and southern bluefin tuna (Figure 4).

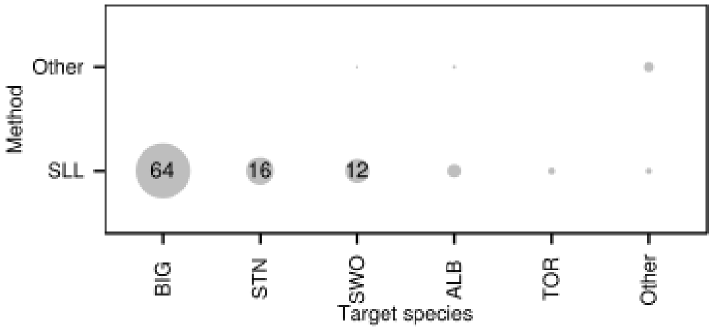


Figure 2: A summary of the proportion of landings of swordfish taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the circle is the percentage. SLL = surface longline (Bentley et al 2013).

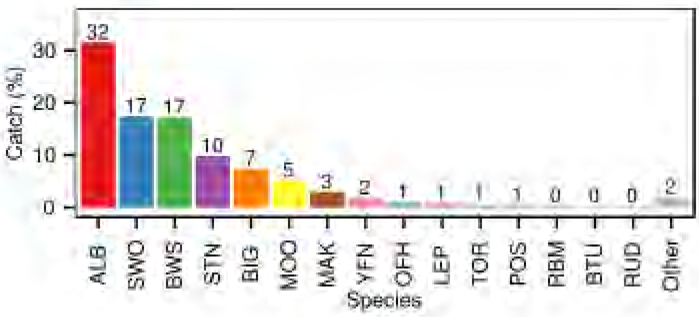


Figure 3: A summary of species composition of the reported surface longline catch. The percentage by weight of each species is calculated for all surface longline trips (Bentley et al 2013).

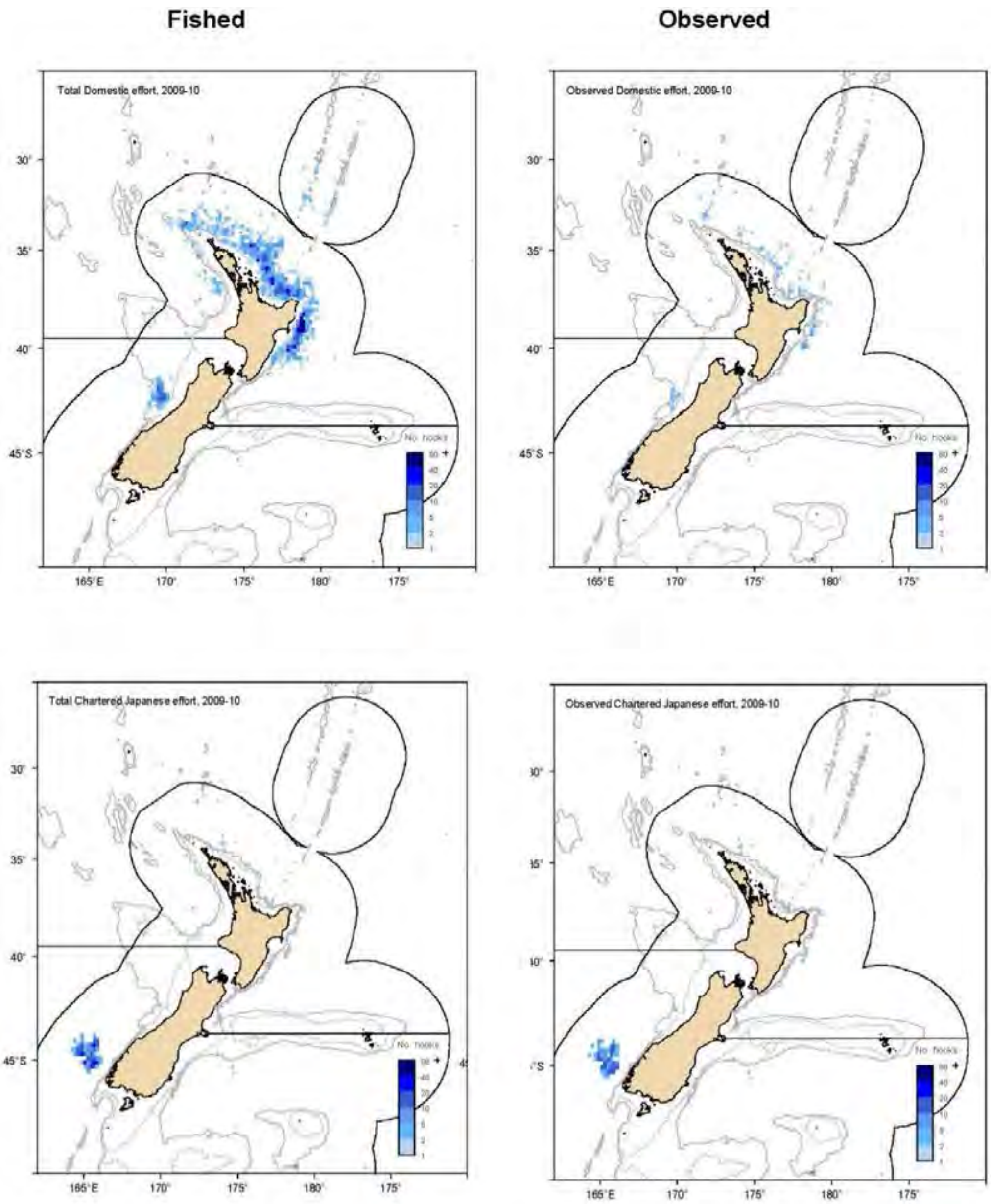


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009–10 fishing year, displaying both fishing effort (left) and observer effort (right).

Across all fleets in the longline fishery, 30.9% of the swordfish were alive when brought to the side of the vessel (Table 3). The domestic fleets retain around 90–99% of their swordfish catch, while the foreign charter fleet retain 99–100% of the swordfish catch, the Australian fleet that fished in New Zealand waters in 2006–07 retained most (94.8%) of their swordfish (Table 4).

Table 3: Percentage of swordfish (including discards) that were alive or dead when arriving at the longline vessel and observed during 2006–07 to 2009–10, by fishing year, fleet and region. Small sample sizes (number observed < 20) were omitted Griggs & Baird (2013).

Year	Fleet	Area	% alive	% dead	Number
2006–07	Australia	North	42.8	57.2	325
	Charter	North	58.9	41.1	90
		South	61.9	38.1	21
	Domestic	North	27.3	72.7	355
	Total		**38.2**	**61.8**	**791**
2007–08	Domestic	North	25.1	74.9	495
	Total		**25.3**	**74.7**	**498**
2008–09	Charter	North	97.0	3.0	33
	Domestic	North	26.0	74.0	416
	Total		**31.6**	**68.4**	**455**
2009–10	Domestic	North	23.2	76.8	448
	Total		**23.7**	**76.3**	**452**
Total all strata			**30.9**	**69.1**	**2 196**

Table 4: Percentage of swordfish that were retained, or discarded or lost, when observed on a longline vessel during 2006–07 to 2009–10, by fishing year and fleet. Small sample sizes (number observed < 20) omitted Griggs & Baird (2013).

Year	Fleet	% retained	% discarded or lost	Number
2006–07	Australia	94.8	5.2	326
	Charter	99.1	0.9	115
	Domestic	93.2	6.8	355
	Total	**94.7**	**5.3**	**796**
2007–08	Charter	100.0	0.0	3
	Domestic	91.5	8.5	496
	Total	**91.6**	**8.4**	**499**
2008–09	Charter	100.0	0.0	43
	Domestic	97.1	2.9	418
	Total	**97.4**	**2.6**	**461**
2009–10	Charter	100.0	0.0	3
	Domestic	94.3	5.7	454
	Total	**94.3**	**5.7**	**457**
Total all strata		**94.5**	**5.5**	**2 213**

1.2 Recreational fisheries

Swordfish are targeted by some recreational sport fishers with the annual recreational landed catch increasing over the last four years to 55 fish in 2012-13. There is renewed recreational interest in swordfish using deep drifted baits during the day rather than drifting or slow trolling at night. There has also been an increase in the number of swordfish tagged and released with 43 tagged by recreational fishers and 7 by commercial fishers in 2012–13.

1.3 Customary non-commercial fisheries

An estimate of the current customary catch is not available, but it is considered to be low.

1.4 Illegal catch

Prior to QMS introduction in 2004 it was illegal to target swordfish but analyses of CPUE data suggest targeting did occur. These catches were generally still reported (although as bycatch), so estimates of total annual catch were not affected.

1.5 Other sources of mortality

The estimated overall incidental mortality rate from observed longline effort is 0.44% of the catch. Discard rates from observer data are 0.7% on average, of which approximately 60% are discarded dead (usually small fish, or as a result of shark damage). Fish are also lost at the surface in the longline fishery, from observer data, 0.21% on average. Approximately 20% of those fish are also dead. Swordfish have occasionally been observed as a bycatch in the skipjack tuna purse seine fishery and in trawl fisheries for jack mackerel and hoki.

2. BIOLOGY

Swordfish (*Xiphias gladius* Linnaeus, 1758) are an epi- and mesopelagic highly migratory species found in all tropical and temperate oceans and large seas. Based on longline catches, swordfish range from 50ºN to 45ºS in the western Pacific Ocean and from 45ºN to 35ºS in the eastern Pacific Ocean.

Growth rates have been estimated for Pacific Ocean swordfish caught off Taiwan. Estimates of growth rate indicate rapid growth with fish reaching about 1 m in lower jaw to fork length during the first year. Growth rate slows progressively with age. Females grow significantly faster than males. Asymptotic length for males is 213 cm while asymptotic length for females is about 300 cm. The maximum age observed in Taiwanese samples was 10 years for males and 12 years for females. The maximum size reported for a swordfish is 445 cm total length (includes the bill and furthest extension of the tail) and about 540 kg.

A number of studies of swordfish growth have been undertaken in Australia and New Zealand (Young and Drake 2004; Young et al 2003; Young et al 2008). The results are generally consistent within the two areas, with maximum ages of 18 and 15 years, respectively. It is likely that swordfish attain a maximum age of 20 years. Given the lack of observations of swordfish in New Zealand with ripe or running ripe gonad condition, age-at-maturity was defined on the basis of the Australian estimates of length-at-50% maturity for males and females of 101 and 221 cm, respectively. Using the growth curves estimated for New Zealand swordfish, this corresponds to ages at 50% maturity for males and females of 1 and 10 years, respectively.

In the New Zealand EEZ swordfish size varies markedly with latitude, with larger swordfish (and hence fewer males) caught south of 40ºS. Average size of both males and females is larger in the southern region compared to the north: 228 and 158.4 cm for males, and 231.9 and 175 cm for females, respectively. Average length (lower jaw to fork length) of swordfish caught in the EEZ has been relatively stable since 1991, averaging 196.6 cm for the Japanese charter fleet and 163.9 cm for the domestic owned and operated fleet based on limited observer data. Overall the average size over all fleets since 1991 is 178.3 cm, however, this will be largely representative of the charter fleet. Males are substantially smaller than females with most males smaller than 189 cm (77%) and most females (51%) larger than 189 cm for all fleets. From 1987 to 2005 the average sex ratio of longline-caught swordfish in the EEZ was 1:3.15 (male:female).

A relationship between lower jaw-fork length and weight has been estimated for swordfish from observer records (n = 2 835): weight (kg) = (3.8787×10^{-6}) length$^{3.24}$.

Spawning takes place in the tropical waters of the western Pacific Ocean and to a lesser extent the equatorial waters of the central Pacific Ocean.

Swordfish are serial batch spawners, perhaps spawning as frequently as every few days over several months. Eggs are spawned in the upper layers of the tropical ocean and, like the protracted larval phase, are pelagic. Depending on fish size, swordfish egg production is estimated to range from 1 to 29 million eggs per year (for 68 – 272 kg females respectively).

Little information on mortality rate is available, but *M* has been estimated elsewhere in the Pacific to be 0.22 yr^{-1}. This value is consistent with the maximum estimated ages for swordfish in Australia and New Zealand.

3. STOCKS AND AREAS

Swordfish found in the New Zealand EEZ are part of a much larger stock that spawns in the tropical central to western Pacific Ocean. They are highly migratory and their residence time in the EEZ and adjacent waters is unknown. In the Pacific Ocean swordfish occur from 50ºN to 45ºS in the western Pacific Ocean and from 45ºN to 35ºS in the eastern Pacific Ocean. Swordfish are visual predators with a wide temperature tolerance. Extensive diel vertical migrations have been observed for swordfish in the Atlantic and Pacific Oceans from waters deeper than 600 m to the surface and across large temperature gradients (e.g., from 8º to 27ºC) in a few hours. Swordfish are found at or near the surface, at night. Within the EEZ most swordfish are caught in FMA 1, FMA 2, and FMA 9 when sea surface temperatures are 17º to 19ºC.

Stock structure is uncertain and recent genetic studies have indicated that there may be multiple Pacific Ocean stocks. There is limited information on swordfish movement from conventional tagging studies. From a release sample of 327 swordfish tagged in the New Zealand EEZ as part of the New Zealand gamefish tagging programme, three have been recaptured. Two small fish were tagged by commercial fishers one 120 nautical miles north of New Zealand and the other 80 nautical miles north east of East Cape. Both were recaptured after extended periods at liberty, 8 and 10 years respectively, and had grown to sizes consistent with being sexually mature. Despite the long liberty period the recapture positions were not far (less than 130 nautical miles) from the release locations. In February 2012 a recreational angler recaptured a 130 kg swordfish he personally had tagged from the same boat and same location 8 months previously. Although the apparent net movement is limited, little can be inferred from this information in relation to swordfish stock structure or migration in, and around, New Zealand waters.

From a release sample of 672 fish tagged in the Australian EEZ, eight recaptures have been reported. Although some fish tagged in east Australian waters have moved large distances (e.g., 893 nautical miles), none were recaptured outside of the Australian EEZ, or have crossed the Tasman Sea into the New Zealand EEZ. Nineteen pop-off satellite archival tags have been deployed on swordfish in New Zealand with the aim of tracking fish over the spring spawning period. The eight longer term tracks (4 to 8 months) show fish moving into sub-tropical waters in spring and returning to the New Zealand EEZ or adjacent waters in summer. Data from satellite tagged swordfish in New Zealand, Australia and the Cook Islands was used to describe the stock structure in the south-west Pacific region in the 2013 stock assessment model.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2014 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of the swordfish longline fishery; a more detailed summary from an issue-by-issue perspective is available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed (http://www.mpi.govt.nz/Default.aspx?TabId=126&id=2122) (Ministry for Primary Industries 2013).

4.1 Role in the ecosystem

Swordfish (*Xiphias gladius*) are large pelagic predators, so they are likely to have a 'top down' effect on the squid, fish and crustaceans they feed on.

4.2 Incidental catch of seabirds, sea turtles and mammals

These capture estimates relate to the swordfish target longline fishery only, from the New Zealand EEZ. The capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.2.1 Seabird bycatch

Between 2002–03 and 2012–13, there were 87 observed captures of seabirds in swordfish longline fisheries. Seabird capture rates since 2003 are presented in Figure 5. Peaks in observed capture rate were seen in 2006-07 and 2009-10. The seabird capture locations are predominantly within the northern area of New Zealand's EEZ (see Table 5 and Figure 6). The high number of captures in 2007 (Figure 5) are anomalous and are the result of an Australian vessel fishing in the EEZ with inappropriate mitigation gear, this issue has since been resolved. Bayesian models of varying complexity dependent on data quality have been used to estimate captures across a range of methods (Richard & Abraham 2014). Observed and estimated seabird captures in albacore longline fisheries are provided in Table 6.

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 the notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Risk posed by commercial fishing to seabirds has been assessed via a level 2 method which supports much of the NPOA-Seabirds 2013 risk assessment framework (MPI 2013b). The method used in the level 2 risk assessment arose initially from an expert workshop hosted by the Ministry of Fisheries in 2008. The overall framework is described in Sharp et al. (2011) and has been variously applied and improved in multiple iterations (Waugh et al. 2009, Richard et al. 2011, Richard and Abraham 2013, Richard et al. 2013 and Richard & Abraham in press). The method applies an "exposure-effects" approach where exposure refers to the number of fatalities is calculated from the overlap of seabirds with fishing effort compared with observed captures to estimate the species vulnerability (capture rates per encounter) to each fishery group. This is then compared to the population's productivity, based on population estimates and biological characteristics to yield estimates of population-level risk.

The 2014 iteration of the seabird risk assessment (Richard & Abraham in press) assessed the swordfish target fishery contribution to the total risk posed by New Zealand commercial fishing to seabirds (see Table 7). This target fishery contributed 0.441 of PBR_1 to the risk to Gibson's albatross which was assessed to be at very high risk from New Zealand commercial fishing. This fishery also contributed 0.232 of PBR_1 to Antipodean albatross, which was assessed to be at high risk from NZ commercial fishing (Richard & Abraham in press).

Table 5: Number of observed seabird captures in swordfish longline fisheries, 2002–03 to 2012–13, by species and area. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR (from Richard and Abraham (2014) where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for swordfish using longline gear but rather the total risk for each seabird species. Other data, version 20140201.

Species	Risk ratio	Kermadec Islands	Northland and Hauraki	West Coast South Island	East Coast North Island	West Coast North Island	Total
Albatrosses	N/A	33					33
Antipodean albatross	High	12	3				15
Gibson's albatross	Very high	4	5	1			10
Antipodean and Gibson's albatross	N/A	5					5
Campbell black-browed albatross	High		2	1			3
New Zealand white-capped albatross	Very high			2		1	3
Black-browed albatrosses	N/A	2					2
Southern Buller's albatross	Very high				1		1
Total albatrosses	**N/A**	**56**	**10**	**4**	**1**	**1**	**72**
White-chinned petrel	Medium	2		3			5
Grey petrel	Low	3					3
Black petrel	Very high		1			1	2
Grey-faced petrel	Negligible	1	1				2
Flesh-footed shearwater	Very high				1		1
Sooty shearwater	Negligible	1					1
Westland petrel	High			1			1
Total other seabirds	**N/A**	**7**	**2**	**4**	**1**	**1**	**15**

Table 6: Effort, observed and estimated seabird captures by fishing year for the swordfish fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). Estimates are based on methods described in Thompson et al (2013) and are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002–03 to 2011–12 and preliminary estimates for 2012–13 are based on data version 20140131.

	Fishing effort			Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	N/A	0	N/A	0	N/A	0	0–3
2003–2004	0	0	N/A	0	N/A	0	0–0
2004–2005	132 503	11 553	8.7	2	0.173	52	27–95
2005–2006	228 305	4 800	2.1	2	0.417	173	69–416
2006–2007	210 175	40 138	19.1	71	1.769	283	156–610
2007–2008	125 330	21 630	17.3	1	0.046	74	36–139
2008–2009	41 700	3 990	9.6	0	0	16	4–51
2009–2010	137 840	500	0.4	3	6	90	42–196
2010–2011	177 248	18 638	10.5	0	0	68	30–155
2011–2012	195 400	43 450	22.2	7	0.161	86	34–223
2012–2013†	316 390	8 250	2.6	1	0.121	175	75–396

†Provisional data, model estimates not finalised.

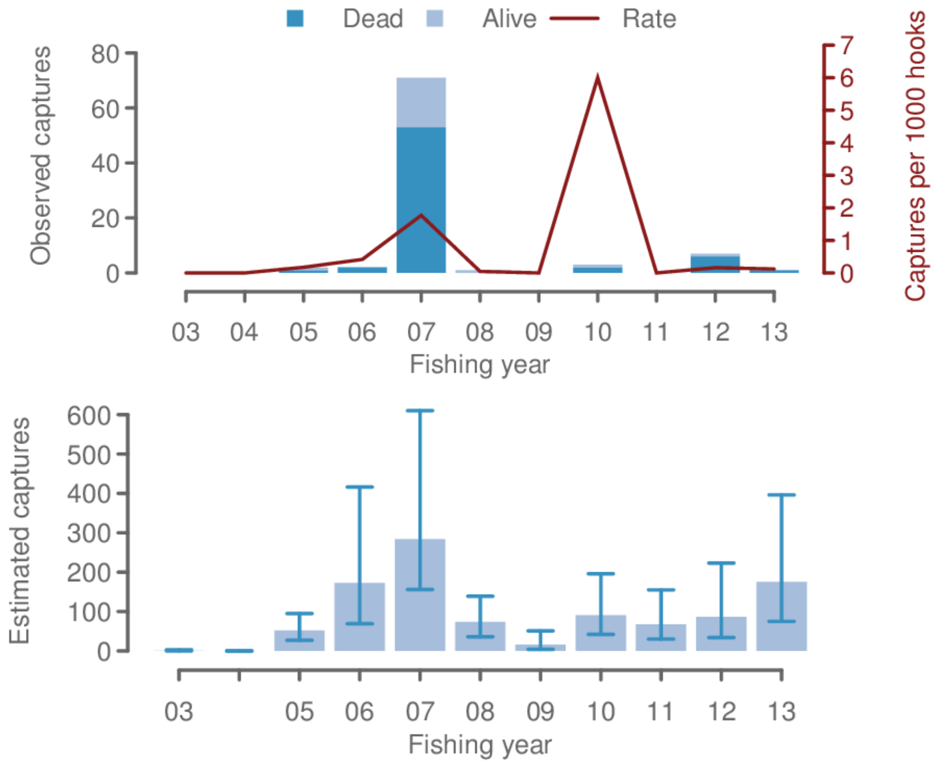


Figure 5: Observed captures and estimated captures of seabirds in swordfish longline fisheries from 2002–03 to 2012–13.

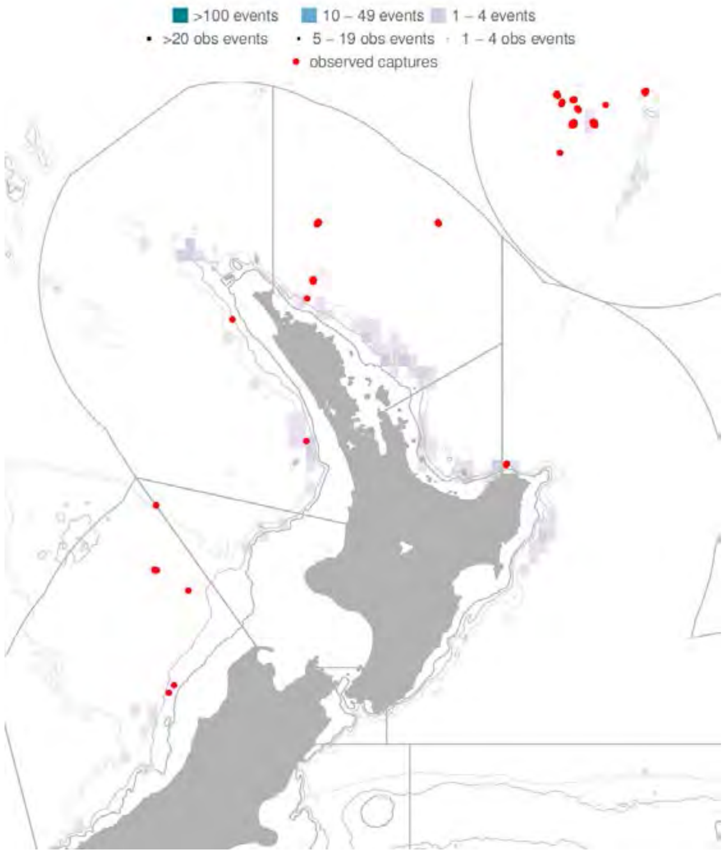


Figure 6: Distribution of fishing effort targeting swordfish and observed seabird captures, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 36.6% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

Table 7: Risk ratio of seabirds predicted by the level two risk assessment for the swordfish target surface longline fisheries and all fisheries included in the level two risk assessment, 2006–07 to 2012–13, showing seabird species with risk category of very or high, or a medium risk category and risk ratio of at least 1% of the total risk. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR_1 (from Richard and Abraham 2014 where full details of the risk assessment approach can be found). PBR_1 applies a recovery factor of 1.0. Typically a recovery factor of 0.1 to 0.5 is applied (based on the state of the population) to allow for recovery from low population sizes as quickly as possible. This should be considered when interpreting these results. The New Zealand threat classifications are shown (Robertson et al 2013 at http://www.doc.govt.nz/documents/science-and-technical/nztcs4entire.pdf)

Species name	Risk ratio SWO target SLL	Total risk from NZ commercial fishing	% of total risk from NZ commercial fishing	Risk category	NZ Threat Classification
Black petrel	0.088	15.095	0.58	Very high	Threatened: Nationally Vulnerable
Salvin's albatross	0.002	3.543	0.06	Very high	Threatened: Nationally Critical
Southern Buller's albatross	0.011	2.823	0.39	Very high	At Risk: Naturally Uncommon
Flesh-footed shearwater	0.005	1.557	0.29	Very high	Threatened: Nationally Vulnerable
Gibson's albatross	0.441	1.245	35.43	Very high	Threatened: Nationally Critical
New Zealand white-capped albatross	0.003	1.096	0.26	Very high	At Risk: Declining
Chatham Island albatross	0.000	0.913	0.00	High	At Risk: Naturally Uncommon
Antipodean albatross	0.232	0.888	26.10	High	Threatened: Nationally Critical
Westland petrel	0.024	0.498	4.85	High	At Risk: Naturally Uncommon
Northern Buller's albatross	0.007	0.336	2.18	High	At Risk: Naturally Uncommon
Campbell black-browed albatross	0.009	0.304	2.95	High	At Risk: Naturally Uncommon
Stewart Island shag	0.000	0.301	0.00	High	Threatened: Nationally Vulnerable
White-chinned petrel	0.004	0.268	1.34	Medium	At Risk: Declining

4.2.2 Sea turtle bycatch

Between 2002–03 and 2012–13, there were two observed captures of sea turtles in swordfish longline fisheries (Table 9 and Figure 7). Observer recordings documented all sea turtles as captured and released alive. Sea turtle captures for this fishery have only been observed in the Kermadec Islands fishing area (Table 8 and Figure 8).

Table 7: Number of observed sea turtle captures in swordfish longline fisheries, 2002–03 to 2012–13, by species and area. Data from Thompson et al (2013), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Kermadec Islands	Total
Leatherback turtle	2	2

Table 8: Fishing effort and sea turtle captures in swordfish longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data see Thompson et al (2013).

	Fishing effort			Observed captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate
2002–2003	N/A	0	N/A	0	N/A
2003–2004	0	0	N/A	0	N/A
2004–2005	132 503	11 553	8.7	0	0
2005–2006	228 305	4 800	2.1	0	0
2006–2007	210 175	40 138	19.1	1	0.025
2007–2008	125 330	21 630	17.3	1	0.046
2008–2009	41 700	3 990	9.6	0	0
2009–2010	137 840	500	0.4	0	0
2010–2011	177 248	18 638	10.5	0	0
2011–2012	195 400	43 450	22.2	0	0
2012–2013	316 390	8 250	2.6	0	0

Figure 7: Observed captures of sea turtles in swordfish longline fisheries from 2002–03 to 2012–13.

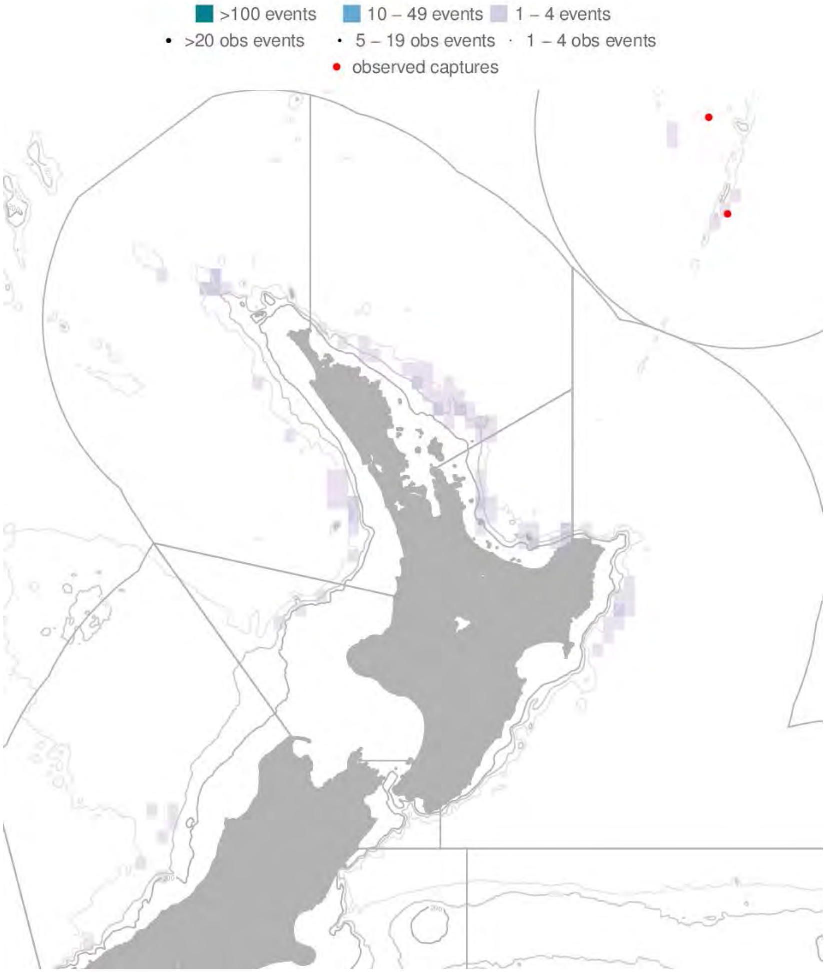


Figure 8: Distribution of fishing effort targeting swordfish and observed sea turtle captures, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 36.6% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Between 2002–03 and 2012–13, there were no observed captures of whales or dolphins in swordfish longline fisheries (Table 10 and Figure 9).

4.2.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, but are more common in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf, which slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts, around much of the South Island and offshore islands. Captures on longlines occur when the fur seals attempt to feed on the bait and fish catch during hauling. Most New Zealand fur seals are released alive, typically with a hook and short snood or trace still attached.

Table 10: Effort and cetacean captures in swordfish longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Thompson et al (2013).

	Fishing effort			Observed captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate
2002–2003	N/A	0	N/A	0	N/A
2003–2004	0	0	N/A	0	N/A
2004–2005	132 503	11 553	8.7	0	0
2005–2006	228 305	4 800	2.1	0	0
2006–2007	210 175	40 138	19.1	0	0
2007–2008	125 330	21 630	17.3	0	0
2008–2009	41 700	3 990	9.6	0	0
2009–2010	137 840	500	0.4	0	0
2010–2011	177 248	18 638	10.5	0	0
2011–2012	195 400	43 450	22.2	0	0
2012–13	316 390	8 250	2.6	0	0

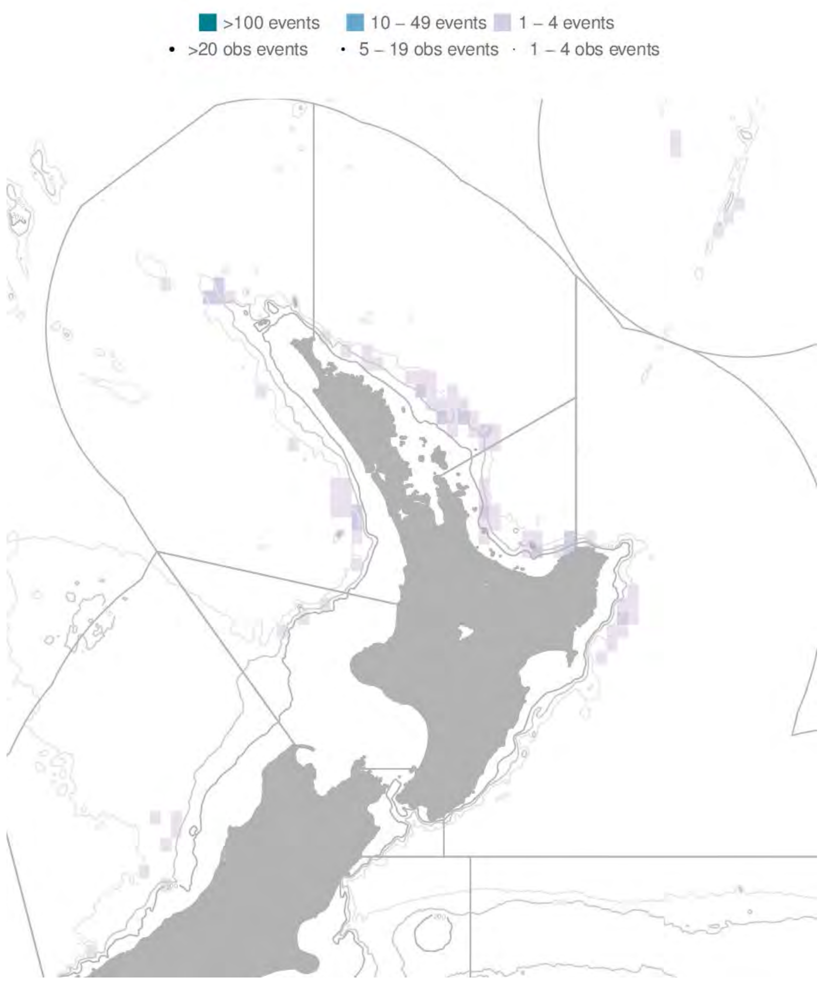


Figure 9: Distribution of fishing effort targeting swordfish, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 36.6% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

Between 2002–03 and 2012–13, there were two observed captures of New Zealand fur seals in swordfish longline fisheries (Table 11 and 12, Figures 10 and 11). These captures include animals that are released alive (Thompson et al 2013).

Table 11: Number of observed New Zealand fur seal captures in swordfish longline fisheries, 2002–03 to 2012–13, by species and area. Data from Thompson et al (2013), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

	Bay of Plenty	East Coast North Island	Total
New Zealand fur seal	1	1	2

Table 12: Effort and captures of New Zealand fur seal in swordfish longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). Estimates are based on methods described in Thompson et al (2013) are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002–03 to 2011–12 and preliminary estimates for 2012–13 are based on data version 20140131.

	Fishing effort			Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	N/A	0	N/A	0	N/A	0	0–0
2003–2004	0	0	N/A	0	N/A	0	0–0
2004–2005	132 503	11 553	8.7	2	0.173	2	0–5
2005–2006	228 305	4 800	2.1	0	0	2	0–5
2006–2007	210 175	40 138	19.1	0	0	0	0–1
2007–2008	125 330	21 630	17.3	0	0	1	0–3
2008–2009	41 700	3 990	9.6	0	0	0	0–2
2009–2010	137 840	500	0.4	0	0	1	0–3
2010–2011	177 248	18 638	10.5	0	0	2	0–5
2011–2012	195 400	43 450	22.2	0	0	6	1–12
2012–2013†	316 390	8 250	2.6	0	0	8	2–16

†Provisional data, model estimates not finalised.

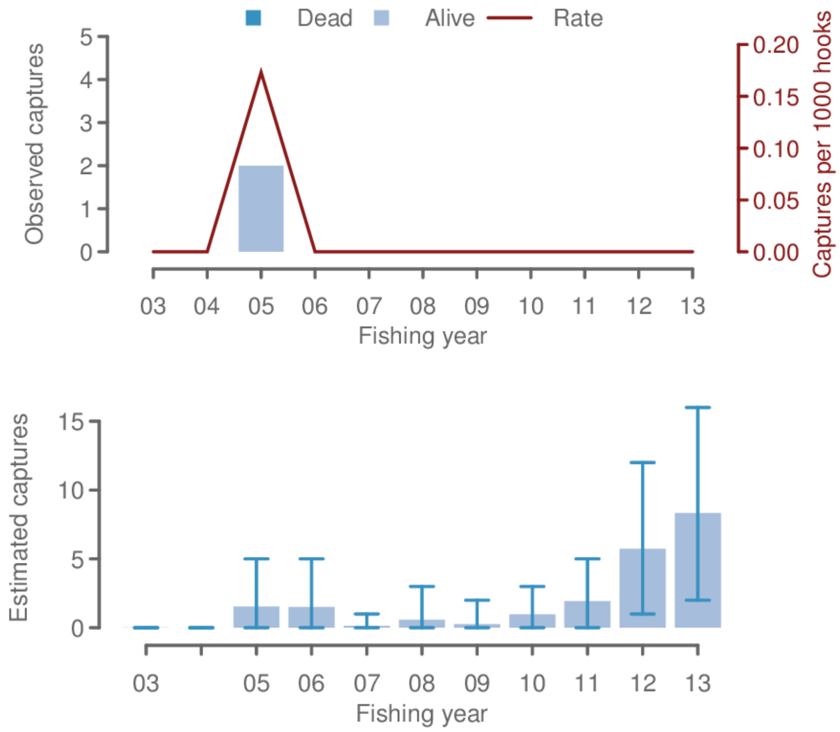


Figure 10: Observed and estimated captures of New Zealand fur seal in swordfish longline fisheries from 2002–03 to 2012–13.

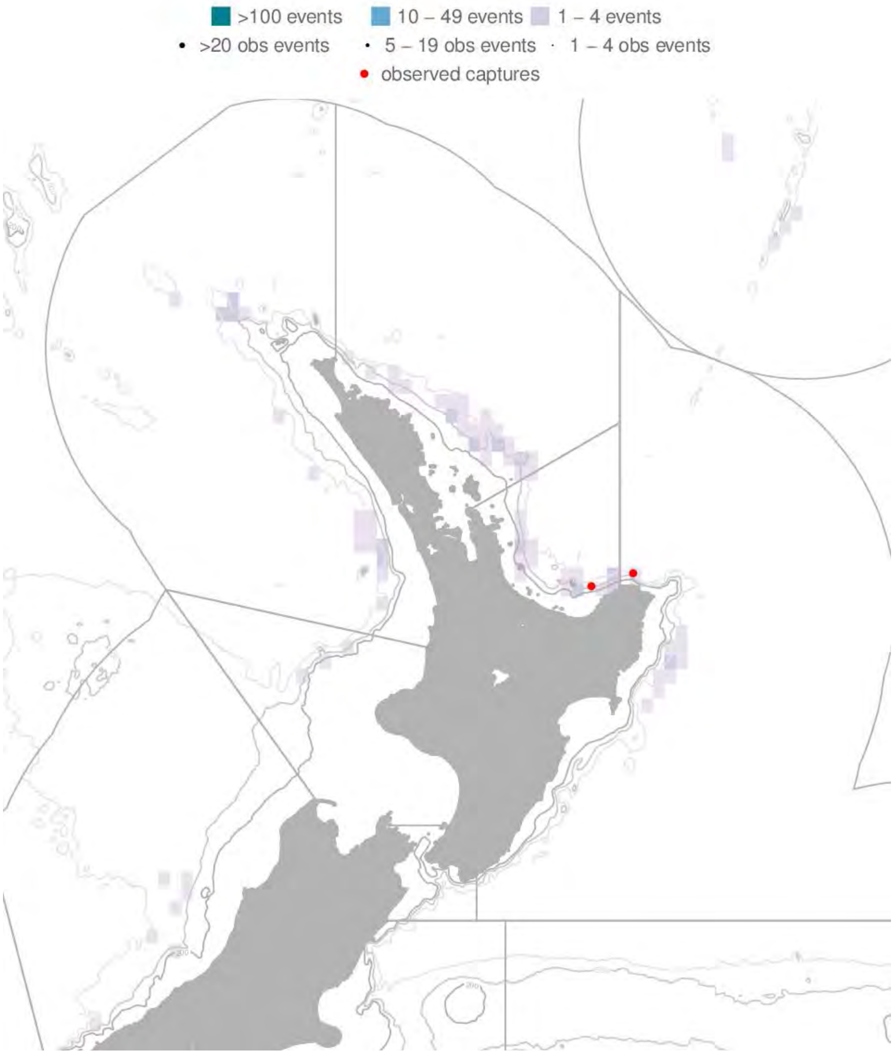


Figure 11: Distribution of fishing effort targeting swordfish and observed New Zealand fur seal captures, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 36.6% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3 Incidental fish bycatch

Observer records indicate that a wide range of species are landed by the longline fleets in New Zealand fishery waters. Blue sharks are the most commonly landed species (by number), followed by Ray’s bream (Table 13). Southern bluefin tuna and albacore tuna are the only target species that occur in the top five of the frequency of occurrence.

Table 13: Total estimated catch (numbers of fish) of common bycatch species in the New Zealand longline fishery as estimated from observer data from 2009 to 2013. Also provided is the percentage of these species retained (2013 data only) and the percentage of fish that were alive when discarded, N/A (none discarded).

Species	2010	2011	2012	2013	% retained (2013)	discards % alive (2013)
Blue shark	66113	53432	132925	158736	45.2	97.4
Lancetfish	43425	37305	7866	19172	0.1	37.6
Rays bream	20041	18453	19918	13568	97.4	4.2
Porbeagle shark	4679	9929	7019	9805	34.0	79.8
Mako shark	4490	9770	3902	3981	35.5	84.9
Moonfish	5398	3418	2363	2470	99.0	0.0
Escolar	1539	6602	2181	2088	30.2	76.3
Sunfish	3148	3773	3265	1937	2.7	100.0
Pelagic stingray	1983	4090	712	1199	1.0	97.0
Butterfly tuna	1158	909	713	1030	48.1	11.1
Deepwater dogfish	377	548	647	743	1.2	88.5
Oilfish	886	1747	509	386	26.5	72.2
Rudderfish	326	338	491	362	13.0	80.0
Thresher shark	209	349	246	256	33.3	75.0
Skipjack tuna	91	255	123	240	100.0	N/A
Dealfish	1160	223	372	237	1.7	25.1
Striped marlin	471	175	124	182	0.0	44.4
Big scale pomfret	505	139	108	67	88.2	100.0
School shark	62	49	477	21	100.0	N/A

4.4 Benthic interactions
N/A

4.5 Key environmental and ecosystem information gaps
Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

With the establishment of WCPFC in 2004, stock assessments of the western and central Pacific Ocean stock of swordfish are reviewed by the WCPFC. Unlike the major tuna stocks, in the short-term, development of a regional assessment for swordfish is to be undertaken by collaboration among interested members.

Davies et al. (2013) undertook a stock assessment for swordfish (*Xiphias gladius*) in the Southwest Pacific. This was presented to the Western and Central Pacific Fisheries Commission Scientific Committee in 2013 and is summarised as follows:

The main developments from previous assessments were to model structural assumptions as follows: assume two model regions, that are biologically connected, this was based on the results of recent electronic tagging programmes; relaxing assumptions such as the relative recruitment to each region; fixing steepness at 0.8; and estimating spline and non-decreasing selectivities for the main longline fisheries. A new statistical assumption was to include time-variant precision in fitting the model to standardized CPUE indices. The model was highly sensitive to the assumption about growth. The full uncertainty grid was presented (Figure 12). Two equally plausible growth schedules were modelled.

The main conclusions of the assessment are:

a) The relatively steep decline in biomass over the period 1997 to 2011 over all key model runs, despite the no concurrent temporal change in recruitment, is a notable feature of the current assessment. It is concurrent with large increases in catch particularly in region 2, and declines in CPUE and median fish sizes in the main fisheries. The recent increase in the AU_1 CPUE index is best described by the Ref.case model for which the faster Hawaiian schedule is made; whereas no increase is predicted when the slower Australian schedule is assumed.
b) Estimates of absolute biomass and equilibrium yield were sensitive to including the NZ_2 standardized CPUE time series in the model fit (key model run cpopt_TW_NZ). The recent declines in the Ref.case model indices for region 2 appear to be consistent with declines in median size over the same period, whereas the NZ_2 index is in conflict with this trend, and is derived from a limited spatial distribution. On this basis, the cpopt_TW_NZ model is considered unreliable, or at least highly uncertain, and this model estimate is excluded from the ranges of the key model runs provided in this section below.
c) The key source of uncertainty in this assessment is the assumed growth/maturity/mortality at age schedule. Estimates of stock status are highly uncertain with respect to this assumption. Across the full uncertainty grid, where the Hawaiian schedule was assumed, the probability of $F_{current}/F_{MSY}$ being greater than 1 was less than 2%, while where the slower Australian schedule was assumed, this increased to 51%.
d) Total and spawning biomass are estimated to have declined most notably since the late 1990s, with more gradual declines before that time. Current levels of total biomass $B_{current}/B_0$ = 44 – 68 % and spawning biomass $SB_{current}/SB_0$ = 27 - 55% (range of key model runs).
e) When the non-equilibrium nature of recent recruitment is taken into account, we can estimate the level of depletion that has occurred. It is estimated that, for the current period, spawning potential is at 26 - 60% (range of key model runs) of the level predicted to exist in the absence of fishing while assuming the historical estimated annual recruitments.
f) Recent catches are between 82% of the MSY level and 102% above the MSY level of between 5299 and 12,730 mt (range of key model runs). Within this range,
g) Based on these results, it was concluded that under the Hawaiian growth schedule current catches are around the MSY level, while under the Australian growth schedule current levels of catch are above the MSY level.
h) Fishing mortality for adult and juvenile swordfish is estimated to have increased sharply in the mid-1990s following the significant increases in catches at that time. $F_{current}/F_{MSY}$ was estimated to be between 0.33 and 1.77 (range of key model runs). Within this range:

    i. assuming the Hawaiian schedule produces estimates between 0.40 to 0.70, while,

ii. assuming the Australian schedule produces estimates that are between 1.06 to 1.77.

i) Based on these results, it was concluded that under the Hawaiian schedule overfishing is not occurring, while under the Australian schedule overfishing is occurring.

The Scientific Committee of the Western and Central Pacific Fisheries Commission made the following conclusion regarding the stock status:

- "*The South Pacific swordfish assessment was highly sensitive to growth assumptions. Two different growth models, one from Australia (GA) and the other from Hawaii (GH), were included in alternative model runs. The Scientific Committee could not decide which of these two assumptions was more reliable. Assessment runs using the GA growth data indicated that overfishing was occurring but that the stock was not in an overfished state. Assessment runs using the GH growth data indicate that no overfishing is occurring and that the stock is not in an overfished state.*
- *Although the median of the uncertainty grid indicates that overfishing (Fcurrent/FMSY = 0.74) was not occurring those sensitivity runs that used the GA growth and maturity schedule indicate that overfishing may be occurring (grid range 5th–95th percentiles: 0.51-2.02). Recent preliminary findings from tagging data indicate that this alternative growth schedule (GA) warrants further consideration. Estimates of stock status are highly uncertain with respect to this assumption. The equivalent grid range of Fcurrent/FMSY for the Hawaiian schedule (GH) is 0.25 – 0.97. Across the uncertainty grid of 378 runs, where the Hawaii schedule was assumed, the probability of Fcurrent/FMSY being greater than 1.0 was less than 3%, while when the slower Australian schedule was assumed, 54% of runs estimated the stock to be experiencing overfishing.*"

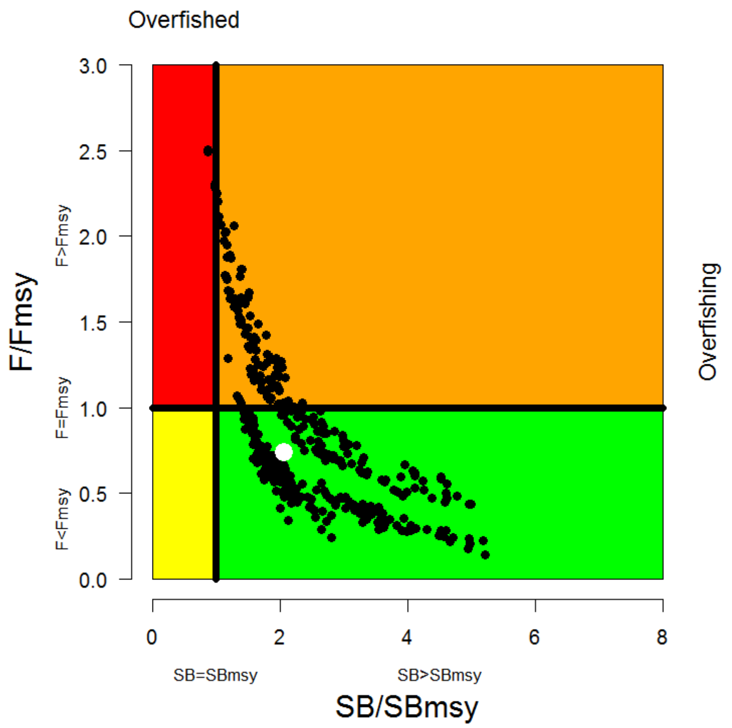


Figure 12: $F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for the median of the selected uncertainty grid (white circle) and the individual uncertainty grid runs.

5.1 Catch per unit effort indices (CPUE)

Catch per unit effort (CPUE) indices for swordfish (*Xiphias gladius*) in the New Zealand surface longline fishery were updated to include fishery data from the five years since the previous analysis, for use as relative abundance indices in a revised south Pacific-wide swordfish stock assessment model being assembled by the Western and Central Pacific Fisheries Commission (WCPFC) (Anderson *et al.* 2013).

Examination of changes in the fishery data (including the use of light sticks, depth of the longline, and timing of fishing around hours of darkness and with respect to the fullness of the moon) showed that targeting of swordfish has effectively been increasing over time, particularly since 2004 when targeting became legal after the introduction of swordfish into the Quota Management System (QMS).

Generalised Additive Models (GAMs) assuming a quasi-poisson error distribution were applied to commercial catch-effort data and remote-sensed environmental variables to produce three alternative CPUE series: **all-data**, based on data from 1993 to 2012 and all vessels in the fishery; **core-vessel**, based on a core set of vessels and the more recent fishery, 1998 to 2012; and **late-series**, based on the core set of vessels and the period subsequent to the introduction of swordfish into the QMS, i.e., 2005 to 2012.

Each model showed an increase in CPUE as the fraction of the longline soak-time occurring in darkness increased. Recorded target species in the all-data model, and rate of light stick usage in the late-series model were also significant.

The indices of the updated models followed a similar temporal pattern to each other and to those of the earlier analyses for the overlapping years, indicating a decline in CPUE between 1993 and 2004, followed by a small increase to 2007. For the subsequent period, 2004 to 2012, the revised models all showed a continuation of this increasing CPUE, reaching a level higher than that of any previous year in the series.

Although it was suspected that changes in operational procedures affecting swordfish catch rates were at least partly responsible for the recent increase in CPUE, it was not possible to determine whether these changes were sufficiently accounted for by the model variables and therefore to have confidence in the use of the year-effects as relative abundance indices.

5.2 Other factors

Other fleets also fish the stock fished in the New Zealand EEZ and the impact of current regional catches on the stock are unknown. It is often assumed that swordfish, particularly large swordfish, may have long residence times which may make them vulnerable to over fishing. Recent Australian research suggests that swordfish CPUE has declined in areas that have been fished the longest and that vessels have maintained high catch rates by travelling further each season, suggesting that serial depletion may be occurring.

6. STATUS OF THE STOCKS

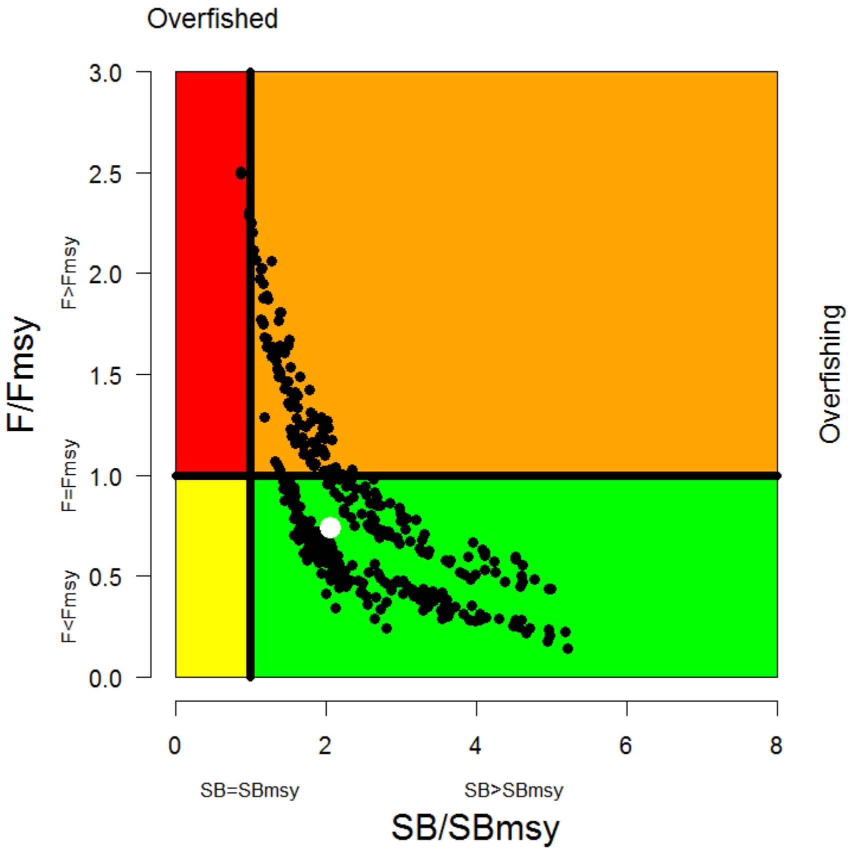
Stock structure assumptions

Swordfish taken in New Zealand are part of larger southwest and south-central Pacific stocks; the evaluation below refers to the assessment of the southwest portion of that stock.

Stock Status	
Year of Most Recent Assessment	A full stock assessment was conducted in 2013

Assessment Runs Presented	Full uncertainty grid
Reference Points	Target: $B > B_{MSY}$ and $F < F_{MSY}$ Soft Limit: Not established by WCPFC but evaluated using HSS default of 20% SB_0 Hard Limit: Not established by WCPFC but evaluated using HSS default of 10% SB_0 Overfishing threshold: F_{MSY}
Status in relation to Target	Likely (> 60%) that B is at or above B_{MSY} and Likely (> 60%) that F < F_{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	Overfishing is About as Likely as Not (40-60%) to be occurring

Historical Stock Status Trajectory and Current Status



$F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for the median of the selected uncertainty grid (white circle) and the individual uncertainty grid runs.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Following a period of continuous decline, the southwest Pacific swordfish biomass has recently increased.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality increased substantially from 1995 to present.
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	Recruitment trends have fluctuated without trend from 1950 to present.

Projections and Prognosis		
Stock Projections or Prognosis	Projections based on the model that used Hawaii growth predict further increases in stock size at current fishing mortality levels. However, using the Australian growth the stock is About as Likely as Not to decline.	
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	About as Likely as Not (40-60%)	
Assessment Methodology and Evaluation		
Assessment Type	Level 1: Full Quantitative Stock Assessment	
Assessment Method	The assessment uses the stock assessment model and computer software known as MULTIFAN-CL.	
Assessment Dates	Latest assessment: 2013	Next assessment: 2016
Overall assessment quality rank	1 - High Quality	
Main data inputs (rank)	Commercial catch and effort data, CPUE, catch-at-age	1 - High Quality
Data not used (rank)		
Changes to Model Structure and Assumptions	Major changes from the 2006 assessment include: • assumes two model regions • relaxing assumptions such as the relative recruitment to each region • fixing steepness at 0.8 • estimating spline and non-decreasing selectivities for the main longline fisheries • A new statistical assumption to include time-variant precision in fitting the model to standardized CPUE indices	
Major Sources of Uncertainty	• Targeting and learned behaviour in the last decade make the CPUE data from many fleets (including New Zealand) unreliable as indices of abundance • Assumed growth schedule	

Qualifying Comments
-

Fishery Interactions
Interactions with protected species are known to occur in the longline fisheries of the South Pacific, particularly south of 25°S. Seabird bycatch mitigation measures are required in the New Zealand and Australian EEZs and through the WCPFC Conservation and Management Measure (CMM2012-07). Sea turtles also get incidentally captured in longline gear; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure (CMM2008-03). Shark bycatch is common in longline fisheries and largely unavoidable; this is being managed through New Zealand domestic legislation and to a limited extent through Conservation and Management Measure (CMM2010-07).

7. FOR FURTHER INFORMATION

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. Final Research Report prepared for Ministry of Fisheries project PRO2007/01. (Unpublished report held by the Ministry for Primary Industries, Wellington.) 170 p.

Abraham, E R; Thompson, F N; Oliver, M D (2010) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report No. 45.* 148 p.

Anderson, O.F.; Doonan, I.J.; Griggs, L.H.; Sutton, P. J. H.; Wei, F. (2013). Standardised CPUE indices for swordfish (*Xiphias gladius*) from the New Zealand tuna longline fishery, 1993 to 2012. New Zealand Fisheries Assessment Report 2013/XX. XX p.

Baird, S J (2008) Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in longline fisheries in New Zealand waters, 1994–95 to 2005–06. *New Zealand Aquatic Environment and Biodiversity Report No. 20.* 21 p.

Bentley, N.; Langley, A.D.; Middleton, D.A.J.; Lallemand, P. (2013) Fisheries of New Zealand, 1989/90-2011/12. Retrieved from http://fonz.tridentsystems.co.nz, *07 November 2013*.

Bigelow, K A; Boggs, C H; He, X (1999) Environmental effects on swordfish and blue shark catch rates in the US North Pacific longline fishery. *Fishery Oceanography* 8: 178–198.

Campbell, R A; Taylor, N A (2000) Data and biological parameter specifications for a spatially structured operating model for broadbill swordfish and bigeye tuna in the south-west Pacific. FRDC 99/107 Milestone Report.

Carey, F G; Robison, B H (1981) Daily patterns in the activities of swordfish, *Xiphias gladius*, observed by acoustic telemetry. *Fishery Bulletin* 79: 277–292.

Carocci, F; Majkowski, J (1996) Pacific tunas and billfishes, atlas of commercial catches. FAO, Rome, 9 p, 28 maps.

CMM2010-07 (2010) Conservation and Management measure for sharks, for the Western and Central Pacific Ocean. CMM2010-07 of the Western and Central Pacific Fisheries Commission.

Davies, N; Bian, R; Kolody, D; Campbell, R (2008) CASAL stock assessment for South-West-Central Pacific broadbill swordfish 1952–2007. Working Paper SA-WP-7 to WCPFC SC4, held 11–22 August 2008, Port Moresby PNG. 80 p.

Davies, N; Campbell, R; Kolody, D (2006) CASAL Stock Assessment for South-West Pacific Broadbill Swordfish 1952–2004. WCPFC-SC 2; ME WP-4.

Davies, N M; Griggs, L; Unwin, M (2005) Information available for developing a stock assessment for New Zealand swordfish (*Xiphias gladius*). Final Research Report for New Zealand Ministry of Fisheries project SWO2003/01, Specific Objective 4. 26 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Davies, N., Pilling, G., Harley, S. and Hampton, J. (2013) Stock assessment of swordfish (*Xiphias gladius*) in the southwest Pacific ocean. Unpublished report to the Western and Central Pacific Fisheries Commission Scientific Committee, WCPFC-SC9-2013/SA-WP-05. 79p.

Evans, K; Abascal, F; Kolody, D; Sippel, T; Holdsworth, J; Maru, P (2014) The horizontal and vertical dynamics of swordfish in the South Pacific Ocean. *Journal of Experimental Marine Biology and Ecology* 450: 55–67.

Griggs, L (2005) Historical and biological data summaries for swordfish (*Xiphias gladius*). Final Research Report for New Zealand Ministry of Fisheries project SWO2003/01, Specific Objectives 1 and 2. 27 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Griggs, L H; Baird, S J (2013). Fish bycatch in New Zealand tuna longline fisheries 2006–07 to 2009–10. *New Zealand Fisheries Assessment Report 2013/13*. 71 p.

Griggs, L; Davies, N M (2007) Biological data summaries for swordfish (*Ziphias gladius*). *New Zealand Fisheries Assessment Report* 2007/17. 59 p.

Griggs, L; Francis, M; Ó Maolagáin, C (2005) Growth rate, age at maturity, longevity and natural mortality rate of swordfish (*Xiphias gladius*). *New Zealand Fisheries Assessment Report* 2005/56. 29 p.

Holdsworth, J C; Saul, P J (2001) New Zealand billfish and gamefish tagging, 2004–05. *New Zealand Fisheries Assessment Report 2006/18*. 28 p.

Holdsworth, J C; Sippel, T J; Saul, P J (2010) Movement of Broadbill Swordfish from New Zealand Tagged with Pop-up Satellite Archival Tags. *New Zealand Fisheries Assessment Report 2010/4.* 34 p.

Kolody, D; Campbell, R; Davies, N (2006a) Multifan-CL Stock Assessment for South-West Pacific Broadbill Swordfish 1952–2004. WCPFC-SC2; ME WP-3.

Kolody, D; Campbell, R; Davies, N (2008) A Multifan-CL Stock Assessment of South-Western-Central Pacific Swordfish 1952–2007. Working Paper SA-WP-6 to WCPFC SC4, held 11–22 August 2008, Port Moresby PNG. 89 p.

Kolody, D; Davies, N; Campbell, R (2006b) SW Pacific Swordfish Stock Status Summary from multiple assessment models. WCPFC-SC2; SA WP-7.

Mattlin, R H (1987) New Zealand fur seal, *Arctocephalus forsteri*, within the New Zealand region. In Croxall, J P; Gentry, R L Status, biology, and ecology of fur seals: Proceedings of an international symposium and workshop, Cambridge, England, 23–27 April 1984. NOAA Technical Report NMFS-51.

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.

Nakamura, I (1985) Billfishes of the world, an annotated and illustrated catalogue of marlins, sailfishes, spearfishes and swordfishes known to date. FAO Fisheries Synopsis 125(5) iv + 65 p.

Nishikawa, Y; Honma, M; Ueyanagi, S; Kikawa, S. (1985) Average distributions of larvae of oceanic species of scomboid fishes, 1956–1981. Far Seas Fisheries Research Laboratory S series 12, 99 p.

Punt, A E; Campbell, R A; Smith, A D M. (2001) Evaluating empirical indicators and reference points for fisheries management: application to the broadbill swordfish fishery off eastern Australia. *Marine and Freshwater Research* 52: 819–832.

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 (2014). Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002-03 to 2011-12. *New Zealand Aquatic Environment and Biodiversity Report*.

Richard, Y., and Abraham, E. R. 2013. Application of Potential Biological Removal methods to seabird populations. New Zealand Aquatic Environment and Biodiversity Report No. 108. 30p.

Richard Y; Abraham, E R (in press). Assessment of the risk of commercial fisheries to New Zealand seabird, 2006-07 to 2012/13. New Zealand Aquatic Environment and Biodiversity Report in press.

Richard, Y., Abraham, E. R., and Filippi, D. 2011. Assessment of the risk to seabird populations from New Zealand commercial fisheries. Final Research Report for projects IPA2009/19 and IPA2009/20. Unpublished report held by the Ministry of Fisheries, Wellington. 137p.

Richard, Y., Abraham, E. R., and Filippi, D. 2013. Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006-07 to 2010-11. New Zealand Aquatic Environment and Biodiversity Report No. 109. 58 + 70p.

Robertson, H.A; Dowding, J.E; Elliot, G.P; Hitchmough, R.A; Miskelly, C.M; O'Donnell, C.F.J; Powlesland, R.G; Sagar, P.M; Scofield, R.P; Taylor, G.A (2013) Conservation stats of New Zealand Birds, 2012. *New Zealand Threat Classification Series 4*. Department of Conservation, Wellington. 22 p.

Rowe, S J (2009) Conservation Services Programme observer report: 1 July 2004 to 30 June 2007. *DOC Marine Conservation Services Series 1*. Department of Conservation, Wellington. 93 p.

Sharp, B., Waugh, S., Walker, N.A, 2011. A risk assessment framework for incidental seabird mortality associated with New Zealand fishing in the New Zealand EEZ., Unpublished report held by the Ministry of Fisheries, Wellington., 39 p.

Stone, H H; Dixon, L K (2001) A comparison of catches of swordfish, *Xiphias gladius*, and other pelagic species from Canadian longline gear configured with alternating monofilament and multifilament nylon gangions. *Fishery Bulletin* 99: 210–216. 2002–03 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report No. 61.* 37 p.

Sun, C-L; Wang, S-P; Yeh S-Z (2002) Age and growth of the swordfish (*Xiphias gladius* L.) in the waters around Taiwan determined from anal-fin rays. *Fishery Bulletin* 100: 822–835.

Thompson, F N; Abraham, E R (2010) Estimation of fur seal (Arctocephalus forsteri) bycatch in New Zealand trawl fisheries, Commission Scientific Committee, WCPFC-SC9-2013/GN WP-1

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.

Unwin, M; Richardson, K; Uddstrom, M; Griggs, L (2005) Standardised CPUE indices for swordfish (*Xiphias gladius*) from the tuna longline fishery 1992–93 to 2003–04 using environmental variables. Final Research Report for New Zealand Ministry of Fisheries project SWO2003/01, specific Objective 3. 26 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Ward, P; Elscot, S (2000) Broadbill swordfish, status of world fisheries. Bureau of Rural Sciences, Canberra, 208 p.

Waugh, S., Fillipi, D., Abraham, E., 2009. Ecological Risk Assessment for Seabirds in New Zealand fisheries, Unpublished Final Research Report for the Ministry of Fisheries 58 p.

Williams, P and Terawasi, P, (2013). Overview of tuna fisheries in the western and central Pacific Ocean, including economic conditions – 2012. Unpublished report to the Western and Central Pacific Fisheries

Yabe, H; Ueyanagi, S; Kikawa, S; Watanabe, H (1959) Study of the life history of the sword-fish, *Xiphias gladius* Linneaeus. N*ankai Regional Fisheries Research Laboratory Report* 10: 107–150.

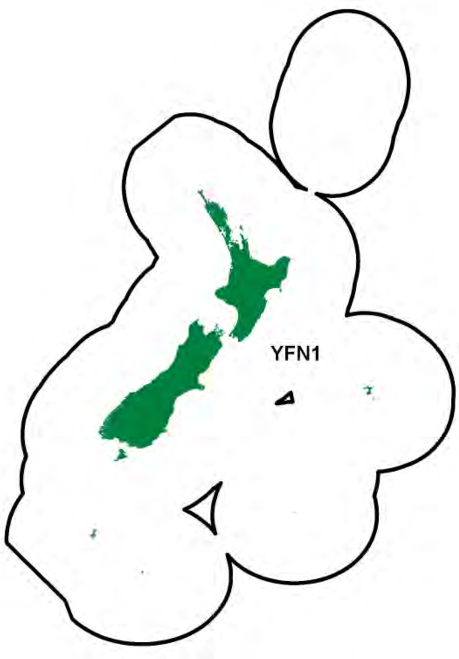
Young, J W; Drake, A (2004) Age and growth of broadbill swordfish (*Xiphias gladius*) from Australian waters. FRDC Project 2001/014. Final Report. 121 pp.

Young. J., Drake. A., Brickhill, M. and Farley, J., Carter, T. (2003) Reproductive dynamics of broadbill swordfish, *Xiphias gladius*, in the domestic longline fishery off eastern Australia. *Mar. Freshwat. Res*. 54:315-332

Young, J; Humphreys, R; Uchiyama, J; Clear, N (2008). Comparison of maturity and swordfish from Hawaiian and Australian waters. Unpublished report to the Western and Central Pacific Fisheries Commission Scientific Committee, WCPFC-SC4-2008/BI-IP-2.

YELLOWFIN TUNA (YFN)

(Thunnus albacares)



1. FISHERY SUMMARY

Yellowfin tuna were introduced into the QMS on 1 October 2004 under a single QMA, YFN 1, with allowances, TACC, and TAC in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACC and TAC (all in tonnes) for yellowfin tuna.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other mortality	TACC	TAC
YFN 1	60	30	5	263	358

Yellowfin tuna were added to the Third Schedule of the 1996 Fisheries Act with a TAC set under s14 because yellowfin tuna is a highly migratory species and it is not possible to estimate MSY for the part of the stock that is found within New Zealand fisheries waters.

Management of the yellowfin stock throughout the Western and Central Pacific Ocean (WCPO) is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). Under this regional convention New Zealand is responsible for ensuring that the management measures applied within New Zealand fisheries waters are compatible with those of the Commission.

At its second annual meeting (2005) the WCPFC passed a Conservation and Management Measure (CMM) (this is a binding measure that all parties must abide by throughout the convention area including EEZs) relating to conservation and management of tunas. Key aspects of this resolution were presented in the 2006 Plenary document. That measure was reviewed by the Scientific Committee (SC) and further recommendations were made such that at its third annual meeting (2006) the WCPFC passed an additional CMM relating to conservation and management of yellowfin tuna (http://www.wcpfc.int/). A further measure CMM2008-01 was agreed to in December 2009, the aim of which was to:

- “Ensure through the implementation of compatible measures for the high seas and EEZs that bigeye and yellowfin tuna stocks are maintained at levels capable of producing their maximum sustainable yield; as qualified by relevant environmental and economic factors including the special requirements of developing States in the Convention area as expressed by Article 5 of the Convention.

- Achieve, through the implementation of a package of measures, over a three-year period commencing in 2009, a minimum of 30% reduction in bigeye tuna fishing mortality from the annual average during the period 2001–2004 or 2004;
- Ensure that there is no increase in fishing mortality for yellowfin tuna beyond the annual average during the period 2001–2004 average or 2004; and
- Adopt a package of measures that shall be reviewed annually and adjusted as necessary by the Commission taking account of the scientific advice available at the time as well as the implementation of the measures. In addition, this review shall include any adjustments required by Commission decisions regarding management objectives and reference points."

This measure is large and detailed with numerous exemptions and provisions. Despite this, effort reductions are being attempted through seasonal FAD closures, high seas area closures (in high seas pockets) for the purse seine fleets, and longline effort reductions as well as other methods. At the 2009 meeting the Scientific Committee recommended that this measure would need to be strengthened if it was to achieve its objectives.

1.1 Commercial fisheries

Most of the commercial catch of yellowfin takes place in the equatorial Western Pacific Ocean (WPO) where they are taken primarily by purse seine and longline. Commercial catches by distant water Asian longliners of yellowfin tuna, in New Zealand waters, began in 1962. Catches through the 1960s averaged 283 t. Yellowfin were not a target species for these fleets and catches remained small and seasonal. Domestic tuna longline vessels began targeting bigeye tuna in 1990–91 in northern waters of FMA 1, FMA 2 and FMA 9 (Table 2). Catches of yellowfin have increased with increasing longline effort, but as yellowfin availability fluctuates dramatically between years, catches have been variable. In addition, small catches of yellowfin are made by pole-and-line fishing (about 4 t per year) and also by trolling (about 14 t per year). Figure 1 shows historic landings and longline fishing effort for YFN stocks.

Catches from within New Zealand fisheries waters are very small (0.07% average for 2000–2011) compared to those from the greater stock in the WCPO (Table 3). In contrast to New Zealand, where yellowfin are taken almost exclusively by longline, 50% of the WCPO catches of yellowfin tuna are taken by purse seine and other surface gears (e.g., ring-nets and pole-and-line).

Table 2: Reported catches or landings (t) of yellowfin tuna by fleet and Fishing Year. NZ: New Zealand domestic and charter fleet, ET: catches outside these areas from New Zealand flagged longline vessels, JPNFL: Japanese foreign licensed vessels, KORFL: foreign licensed vessels from the Republic of Korea. LFRR: Estimated landings from Licensed Fish Receiver Returns and MHR: Monthly Harvest Return Data from 2001–02 onwards [Continued on next page].

	YFN 1 (all FMAs)					
Fishing Year	JPNFL	KORFL	NZ/MHR	Total	LFRR	NZ ET
1979–80	10.1			10.1		
1980–81	79.1	29.9		109		
1981–82	89.4	6.7		96.1		
1982–83	22.4	6.6		29		
1983–84	46.1	12.8		58.9		
1984–85	21.3	64.5		85.8		
1985–86	92.5	3.3		95.8		
1986–87	124.8	29		153.8		
1987–88	35.2	37.3		72.5		
1988–89	11.5	1.8		13.3	19	
1989–90	29.1		4.3	33.4	6.3	
1990–91	7.4		10.7	18.1	19.9	
1991–92	0.2		16.1	16.3	11.8	
1992–93			10.1	10.1	69.7	0.2
1993–94			50.5	50.5	114.4	1.5
1994–95			122.2	122.2	193.4	0.3

Table 2 [Continued]: Reported catches or landings (t) of yellowfin tuna by fleet and Fishing Year. NZ: New Zealand domestic and charter fleet, ET: catches outside these areas from New Zealand flagged longline vessels, JPNFL: Japanese foreign licensed vessels, KORFL: foreign licensed vessels from the Republic of Korea. LFRR: Estimated landings from Licensed Fish Receiver Returns and MHR: Monthly Harvest Return Data from 2001–02 onwards.

1995–96	251.6	251.6	156.7	7.4
1996–97	144.1	144.1	105.3	0.2
1997–98	93.6	93.6	174.7	2.3
1998–99	136.1	136.1	100.6	0.3
1999–00	77.8	77.8	168	2.1
2000–01	123.5	123.5	62.5	3.1
2001–02	64.5	56.7	61.9	1.9
2002–03	41.8	39.7	42.1	2.1
2003–04	57.7	21.1	21.4	36.6
2004–05	42.0	36.1	41.4	6.0
2005–06	9.3	9.2	8.8	0.1
2006–07	18.8	17.3	19.7	1.0
2007–08	22.2	22.4	22.3	0.2
2008–09	5.4	43.6	43.3	3 200
2009–10	6.2	6.2	48.2	1 264
2010–11	2.8	2.8	234.8	818
2011–12	2.2	2.3	742.6	966
2012–13	0.6	0.6	249.1	1 042

Table 3: Reported total New Zealand within EEZ landings, catch made by New Zealand vessels outside New Zealand fishery waters (NZ ET)* and WCPO landings (t) of yellowfin tuna from 1991 to 2013.

Year	NZ landings (t)	WCPO landings (t)	Year	NZ landings (t)	NZ ET landings (t)	WCPO landings (t)
1991	6	403 152	2001	138	955	492 971
1992	20	413 882	2002	25	3 531	463 860
1993	34	351 556	2003	38	3 646	517 362
1994	53	391 108	2004	20	2 658	513 200
1995	141	381 423	2005	36	2 486	545 391
1996	198	351 762	2006	14	2 679	493 261
1997	143	457 984	2007	25	2 329	500 120
1998	127	550 299	2008	12	3 200	580 241
1999	154	479 090	2009	3	1 264	529 426
2000	107	523 956	2010	6	818	542 438
			2011	3	966	518 611
			2012	2	1 042	639 912
			2013	1	837	529 437

Source: Ministry of Fisheries Licensed Fish Receiver Reports, Solander Fisheries Ltd, Anon. 2006, Williams & Terawasi 2011; WCPO landings sourced from WCPFC Yearbook 2012 (Anon 2013).

*New Zealand purse seine vessels operating in tropical regions catch moderate levels of yellowfin tuna when fishing around Fish Aggregating Devices (FADs) and on free schools. These catches are only estimates of catch based on analysis of observer data across all fleets rather than specific data for New Zealand vessels. In addition, catches of juvenile bigeye and yellowfin tuna are often combined on catch effort returns due to difficulties in differentiating the catch.

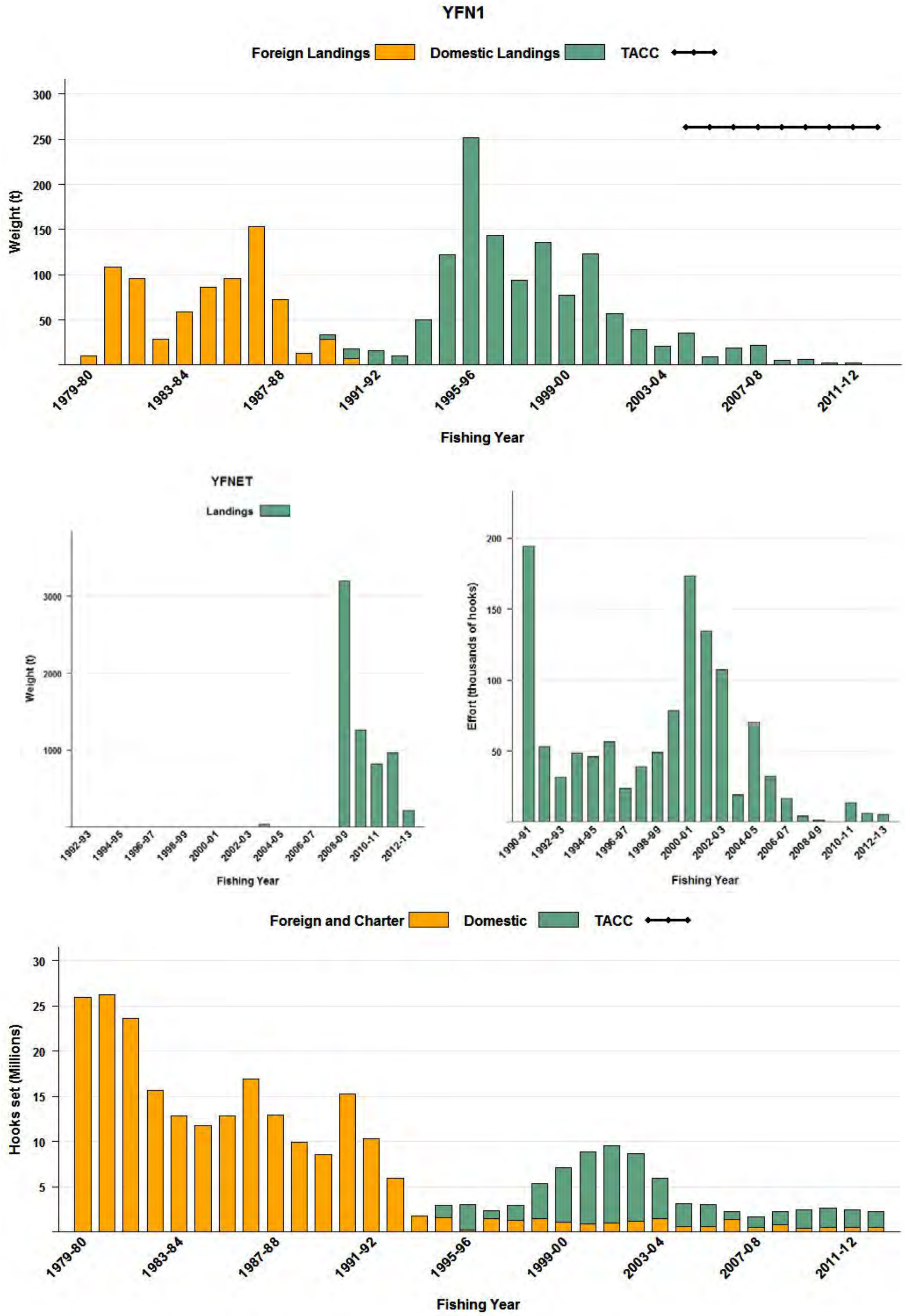


Figure 1: [Top] Yellowfin catch by foreign licensed and New Zealand vessels from 1979–80 to 2012–13 within New Zealand waters (YFN 1), and [middle] 1992–93 to 2012–13 on the high seas (YFN ET). [Middle] Fishing effort (number of hooks set) for all high seas New Zealand flagged surface longline vessels from 1990–91 to 2012–13. [Bottom] Yellowfin effort by domestic vessels (including effort by foreign vessels chartered by New Zealand fishing companies) from 1979–80 to 2011–12.

The majority of yellowfin tuna are caught in the bigeye tuna surface longline fishery (67%) (Figure 2), however, across all longline fisheries albacore make up the bulk of the catch (33%) and yellowfin tuna make up only 2% of the catch (Figure 3). Longline fishing effort is distributed along the east coast of the North Island and the south west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the east coast of the North Island targets a range of species including bigeye, swordfish, and southern bluefin tuna (Figure 4).

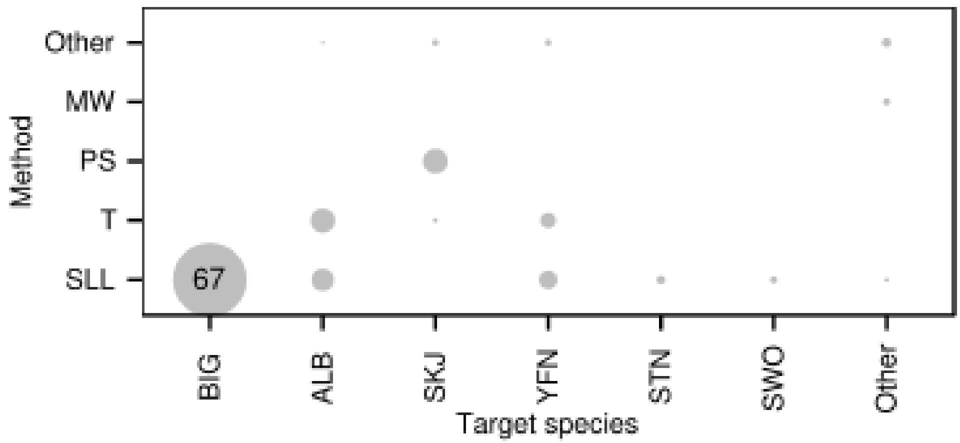


Figure 2: A summary of the proportion of landings of yellowfin tuna taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the circle is the percentage. SLL = surface longline, T = trawl, PS = purse seine, MW = mid-water trawl (Bentley et al 2013).

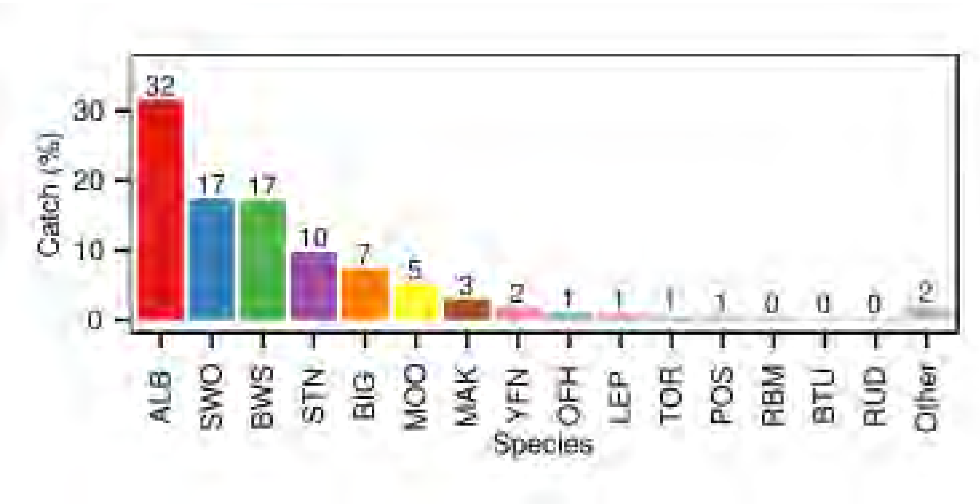


Figure 3: A summary of species composition of the reported surface longline catch. The percentage by weight of each species is calculated for all surface longline trips (Bentley et al. 2013).

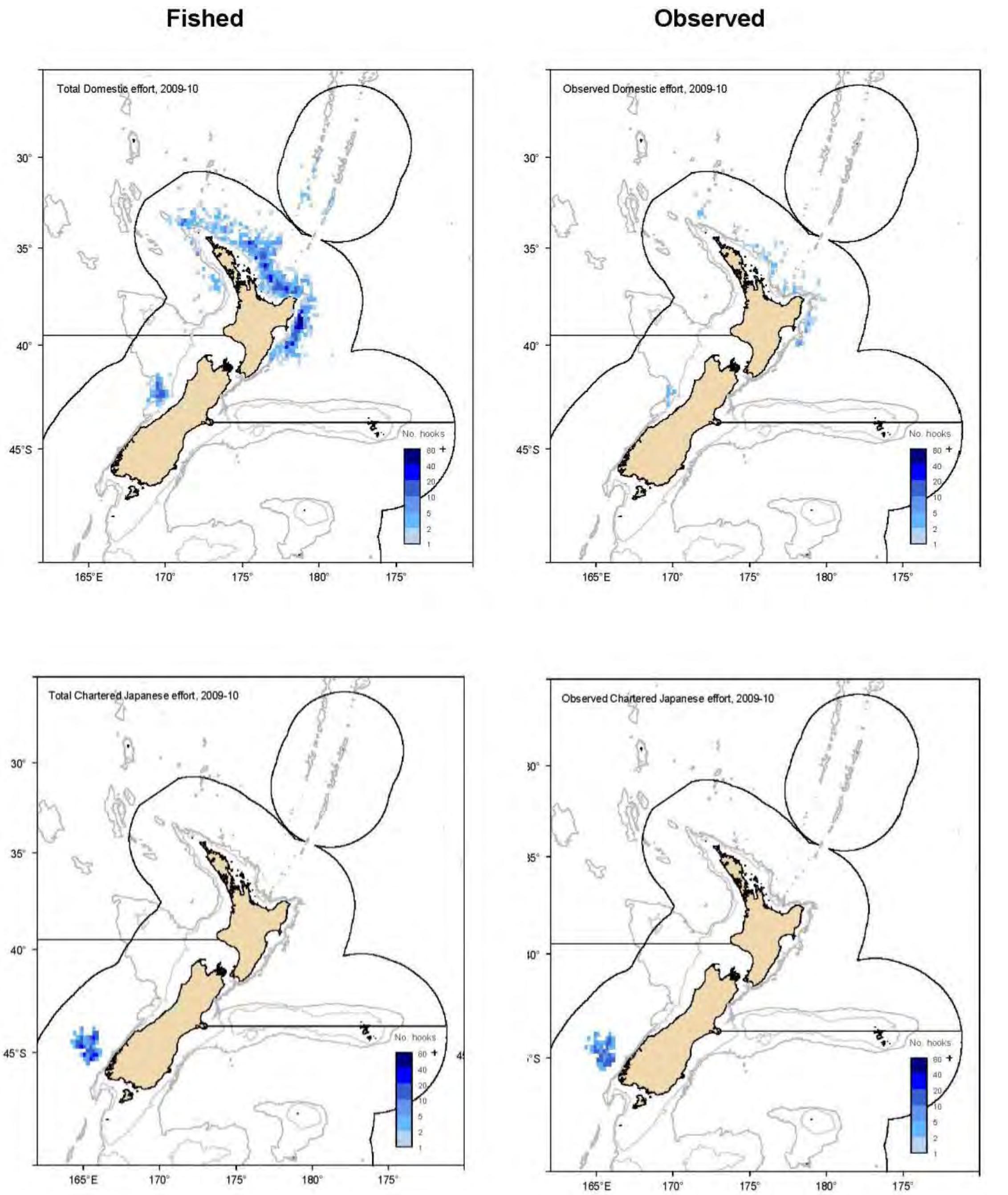


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009–10 fishing year, displaying both fishing effort (left) and observer effort (right).

Across all fleets in the longline fishery 79.4% of the yellowfin tuna were alive when brought to the side of the vessel (Table 4). The domestic fleets retain between 78 and 100% of their yellowfin tuna catch (Table 5).

Table 4: Percentage of yellowfin tuna (including discards) that were alive or dead when arriving at the longline vessel and observed during 2006–07 to 2009–10, by fishing year, fleet and region. Small sample sizes (number observed < 20) were omitted Griggs & Baird (2013).

Year	Fleet	Area	% alive	% dead	Number
2006–07	Domestic	North	75.0	25.0	28
	Total		**78.3**	**21.7**	**46**
2007–08	Domestic	North	75.8	24.2	33
	Total		**75.8**	**24.2**	**33**
2008–09	**Total**		**88.9**	**11.1**	**9**
2009–10	**Total**		**88.9**	**11.1**	**9**
Total all strata			**79.4**	**20.6**	**97**

Table 5: Percentage yellowfin that were retained, or discarded or lost, when observed on a longline vessel during 2006–07 to 2009–10, by fishing year and fleet. Small sample sizes (number observed < 20) omitted Griggs & Baird (2013).

Year	Fleet	% retained	% discarded or lost	Number
Total all strata		**71.0**	**29.0**	**617**
2006–07	Domestic	78.6	21.4	28
	Total	**80.4**	**19.6**	**46**
2007–08	Domestic	90.9	9.1	33
	Total	**90.9**	**9.1**	**33**
2008–09	**Total**	**100.0**	**0.0**	**9**
2009–10	**Total**	**100.0**	**0.0**	**9**
Total all strata		**87.6**	**12.4**	**97**

1.2 Recreational fisheries

Recreational fishers used to make regular catches of yellowfin tuna particularly during summer months and especially in FMA 1 and FMA 2 where the recreational fishery targeted yellowfin as far south as the Wairarapa coast.

While the magnitude of the recreational catch is unknown catches weighed at sport fishing clubs have dropped from over 1000 fish per year in the 1990s to an average of 30 per year in the last 3 years.

1.3 Customary non-commercial fisheries

An estimate of the current customary catch is not available.

1.4 Illegal catch

There is no known illegal catch of yellowfin tuna in the EEZ. Estimates of illegal catch are not available, but are probably insignificant.

1.5 Other sources of mortality

The estimated overall incidental mortality rate from observed longline effort is 0.22% of the catch. Discard rates are 0.92% on average from observer data of which approximately 25% are discarded dead (usually because of shark damage). Fish are also lost at the surface in the longline fishery, 0.16% on average from observer data, of which 95% are reported as escaping alive.

2. BIOLOGY

Yellowfin tuna are epi-pelagic opportunistic predators of fish, crustaceans and cephalopods. Yellowfin tuna are found from the surface to depths where low oxygen levels are limiting (about 250 m in the tropics but probably deeper in temperate waters). Individuals found in New Zealand waters are mostly adults that are distributed in the tropical and temperate waters of the western and central Pacific Ocean. Adults reach a maximum size of 200 kg and length of 239 cm. First maturity is reached at 60 to 80 cm (1 to 2 years old), and the size at 50% maturity is estimated to be 105 cm. The maximum reported age is 8 years. Spawning takes place at the surface at night mostly within 10º of the equator when temperatures exceed 24ºC. Spawning takes place throughout the year but the main spawning season is November to April. Yellowfin are serial spawners, spawning every few days throughout the peak of the season.

Natural mortality is assumed to vary with age. A range of von Bertalanffy growth parameters has been estimated for yellowfin in the Pacific Ocean depending on area (Table 6).

Table 6: von Bertalanffy growth parameters for yellowfin tuna by country or area.

Country/Area	L_∞ (cm)	K	t_0
Philippines	148.0	0.420	
Mexico	162.0	0.660	
Western tropical Pacific	166.0	0.250	
Japan	169.0	0.564	
Mexico	173.0	0.660	
Hawaii	190.0	0.454	
Japan	191.0	0.327	-1.02

Females predominate in the longline catch of yellowfin tuna in the in the New Zealand EEZ (0.75 males:females).

3. STOCKS AND AREAS

Yellowfin tuna in New Zealand waters are part of the western and central Pacific Ocean stock that is distributed throughout the North and South Pacific Ocean west of about 150ºW.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2014 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of yellowfin tuna but there is no directed fishery for them and the incidental catch sections below reflect the New Zealand longline fishery as a whole and are not specific to this species; a more detailed summary from an issue-by-issue perspective is available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed (http://www.mpi.govt.nz/Default.aspx?TabId=126&id=2122) (Ministry for Primary Industries 2013a).

4.1 Role in the ecosystem

Yellowfin tuna (*Thunnus albacares*) are epi-pelagic opportunistic predators of fish, crustaceans and cephalopods generally found within the upper few hundred meters of the ocean. Yellowfin tuna are large pelagic predators, so they are likely to have a ‘top down’ effect on the fish, crustaceans and squid they feed on.

4.2 Incidental catch (seabirds, sea turtles and mammals)

The protected species, capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.2.1 Seabird bycatch

Between 2002–03 and 2012–13, there were 818 observed captures of birds across other surface longline target fisheries (those not targeting albacore tuna, bigeye tuna, southern bluefin tuna, pacific bluefin tuna and swordfish). Seabird capture rates since 2003 are presented in Table 7 and Figure 5. Seabird captures were more frequent off the south west coast of the South Island (Figure 6). Bayesian models of varying complexity dependent on data quality have been used to estimate captures across a range of methods (Richard & Abraham 2014). Observed and estimated seabird captures in albacore longline fisheries are provided in Table 8.

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 the notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Risk posed by commercial fishing to seabirds has been assessed via a level 2 method which supports much of the NPOA-Seabirds 2013 risk assessment framework (MPI 2013b). The method used in the level 2 risk assessment arose initially from an expert workshop hosted by the Ministry of Fisheries in 2008. The overall framework is described in Sharp et al. (2011) and has been variously applied and improved in multiple iterations (Waugh et al. 2009, Richard et al. 2011, Richard and Abraham 2013, Richard et al. 2013 and Richard & Abraham in press). The method applies an “exposure-effects” approach where exposure refers to the number of fatalities is calculated from the overlap of seabirds with fishing effort compared with observed captures to estimate the species vulnerability (capture rates per encounter) to each fishery group. This is then compared to the population’s productivity, based on population estimates and biological characteristics to yield estimates of population-level risk.

The 2014 iteration of the seabird risk assessment (Richard & Abraham in press) assessed other surface longline target fisheries (those not targeting albacore tuna, bigeye tuna, southern bluefin tuna, pacific bluefin tuna and swordfish) contribution to the total risk posed by New Zealand commercial fishing to seabirds (see Table 9). These target fisheries contribute 0.003 of PBR_1 to the risk to Southern Buller’s albatross which was assessed to be at very high risk from New Zealand commercial fishing (Richard & Abraham in press).

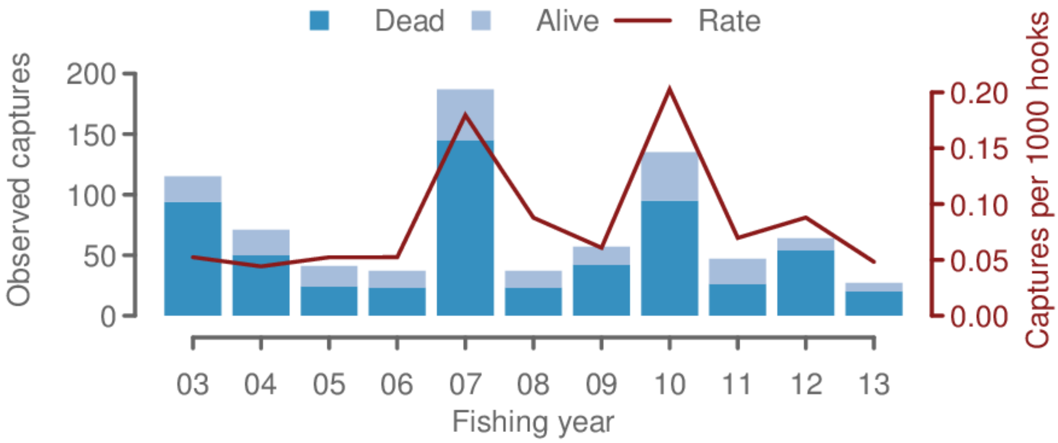
Table 7: Number of observed seabird captures in the New Zealand surface longline fisheries, 2002–03 to 2012–13, by species and area. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR (from Richard and Abraham (2013) where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for porbeagle shark using longline gear but rather the total risk for each seabird species. Other data, version 20130305.

Albatross Species	Risk Ratio	Kermadec Islands	Northland and Hauraki	Bay of Plenty	East Coast North Island	Stewart Snares Shelf	Fiordland	West Coast South Island	West Coast North Island	Total
Salvin's	Very high	0	1	2	6	0	0	0	0	9
Southern Buller's	Very high	0	5	2	27	0	280	39	0	353
NZ white-capped	Very high	0	2	0	3	10	62	36	1	114
Northern Buller's	High	0	0	0	1	0	0	0	0	1
Gibson's	High	4	16	0	17	0	6	3	1	47
Antipodean	High	12	10	1	8	0	0	0	1	32
Northern royal	Medium	0	0	1	0	0	0	0	0	1
Southern royal	Medium	0	1	0	0	0	4	1	0	6
Campbell black-browed	Medium	2	10	2	29	0	3	3	1	50
Light-mantled sooty	Very low	0	0	0	0	0	0	1	0	1
Unidentified	N/A	38	2	0	2	0	0	0	1	43
Total	**N/A**	**56**	**47**	**8**	**93**	**10**	**355**	**83**	**5**	**657**
Other seabirds										
	Risk Ratio	Kermadec Islands	Northland and Hauraki	Bay of Plenty	East Coast North Island	Stewart Snares Shelf	Fiordland	West Coast South Island	West Coast North Island	Total
Black petrel	Very high	1	10	1	0	0	0	0	1	13
Flesh-footed shearwater	Very high	0	0	0	10	0	0	0	2	12
Cape petrel	High	0	0	0	2	0	0	0	0	2
Westland petrel	Medium	0	0	0	2	0	1	6	0	9
White-chinned petrel	Medium	2	3	3	3	1	20	3	3	38
Grey petrel	Medium	3	4	3	38	0	0	0	0	48
Grey-faced petrel	Very low	12	5	1	2	0	0	0	0	20
Sooty shearwater	Very low	1	0	0	8	3	1	0	0	13
Southern giant petrel	-	0	0	2	0	0	0	0	2	0
White-headed petrel	-	2	0	0	0	0	0	0	0	2
Unidentified	N/A	0	1	0	0	0	1	0	0	2
Total	**N/A**	**21**	**23**	**10**	**65**	**4**	**23**	**9**	**8**	**159**

Table 8: Effort, observed and estimated seabird captures by fishing year for the New Zealand surface longline fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures; the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). Estimates are based on methods described in Thompson et al (2013) and are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002–03 to 2011–12 and preliminary estimates for 2012–13 are based on data version 20140131.

	Fishing effort			Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	10 772 188	2 195 152	20.4	115	0.052	2 088	1 613–2 807
2003–2004	7 386 329	1 607 304	21.8	71	0.044	1 395	1 086–1 851
2004–2005	3 679 765	783 812	21.3	41	0.052	617	483–793
2005–2006	3 690 119	705 945	19.1	37	0.052	808	611–1 132
2006–2007	3 739 912	1 040 948	27.8	187	0.18	958	736–1 345
2007–2008	2 246 189	421 900	18.8	37	0.088	524	417–676
2008–2009	3 115 633	937 496	30.1	57	0.061	609	493–766
2009–2010	2 995 264	665 883	22.2	135	0.203	939	749–1 216
2010–2011	3 187 879	674 572	21.2	47	0.07	705	532–964
2011–2012	3 100 277	728 190	23.5	64	0.088	829	617–1 161
2012–2013†	2 862 182	560 333	19.6	27	0.048	783	567–1 144

†Provisional data, model estimates not finalised.



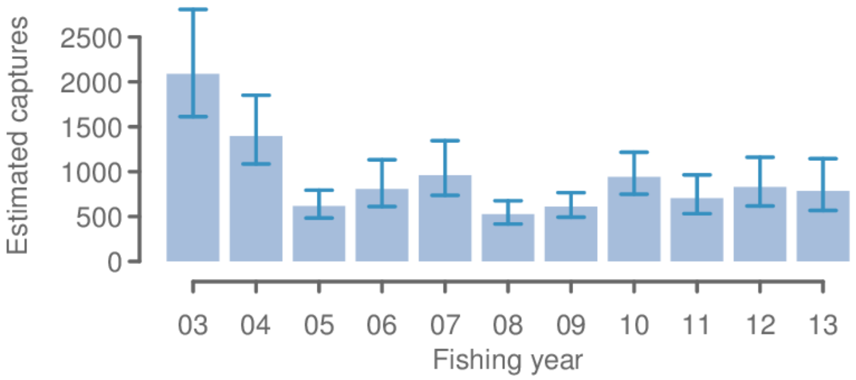


Figure 5: Observed and estimated captures of seabirds in the New Zealand surface longline fisheries from 2002–03 to 2012–13.

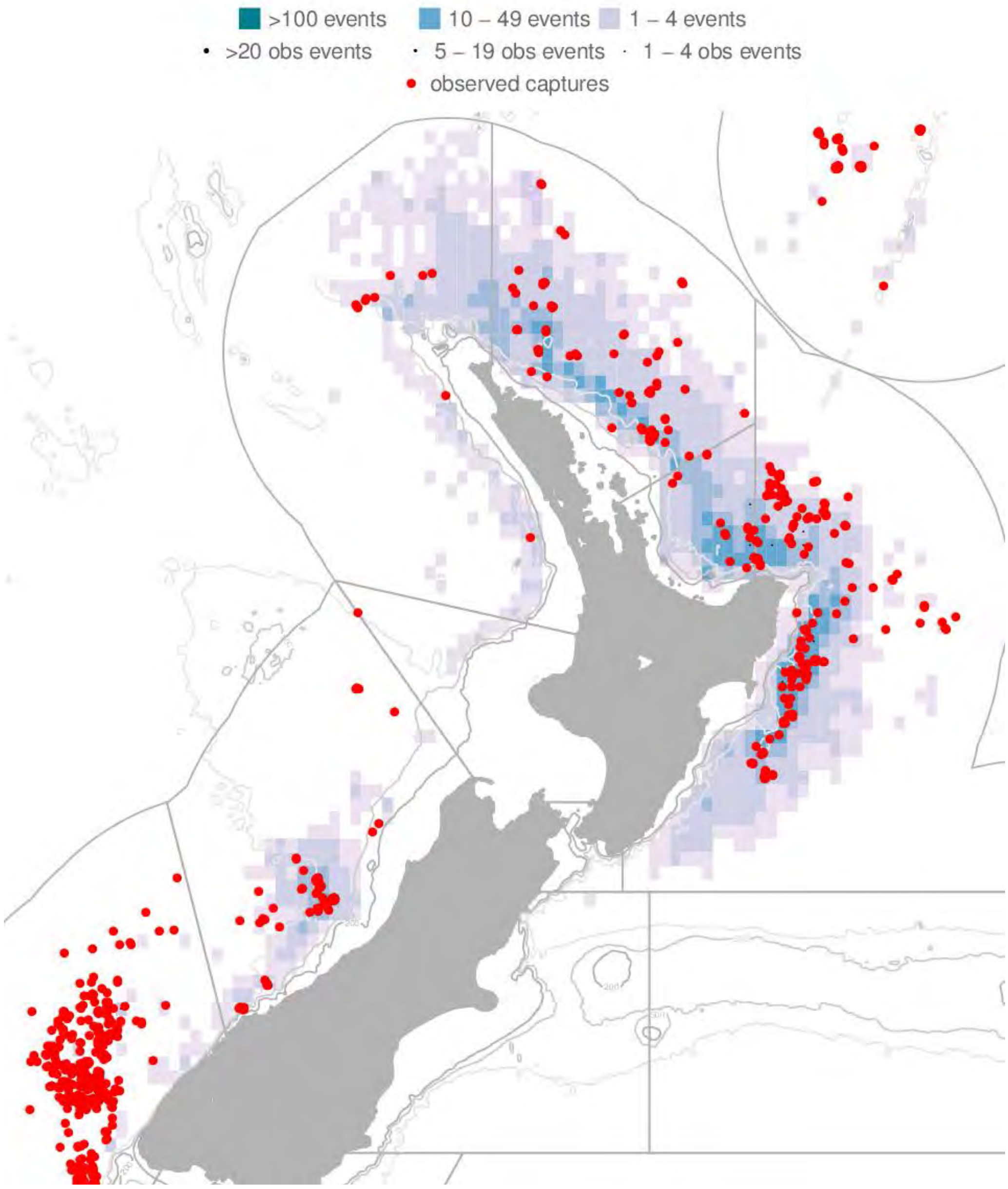


Figure 6: Distribution of fishing effort in the New Zealand surface longline fisheries and observed seabird captures, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 89.4% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

Table 9: Risk ratio of seabirds predicted by the level two risk assessment for the other species target surface longline fisheries (those not targeting albacore tuna, bigeye tuna, southern bluefin tuna, pacific bluefin tuna and swordfish) and all fisheries included in the level two risk assessment, 2006–07 to 2012–13, showing seabird species with risk category of very or high, or a medium risk category and risk ratio of at least 1% of the total risk. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR_1 (from Richard and Abraham 2014 where full details of the risk assessment approach can be found). PBR_1 applies a recovery factor of 1.0. Typically a recovery factor of 0.1 to 0.5 is applied (based on the state of the population) to allow for recovery from low population sizes as quickly as possible. This should be considered when interpreting these results. The New Zealand threat classifications are shown (Robertson et al 2013 at http://www.doc.govt.nz/documents/science-and-technical/nztcs4entire.pdf)

	Risk ratio				
Species name	OTH SLL target	Total risk from NZ commercial fishing	% of total risk from NZ commercial fishing	Risk category	NZ Threat Classification
Black petrel	0.000	15.095	0.00	Very high	Threatened: Nationally Vulnerable
Salvin's albatross	0.000	3.543	0.00	Very high	Threatened: Nationally Critical
Southern Buller's albatross	0.003	2.823	0.10	Very high	At Risk: Naturally Uncommon
Flesh-footed shearwater	0.000	1.557	0.00	Very high	Threatened: Nationally Vulnerable
Gibson's albatross	0.000	1.245	0.00	Very high	Threatened: Nationally Critical
New Zealand white-capped albatross	0.000	1.096	0.01	Very high	At Risk: Declining
Chatham Island albatross	0.000	0.913	0.00	High	At Risk: Naturally Uncommon
Antipodean albatross	0.000	0.888	0.00	High	Threatened: Nationally Critical
Westland petrel	0.000	0.498	0.00	High	At Risk: Naturally Uncommon
Northern Buller's albatross	0.000	0.336	0.13	High	At Risk: Naturally Uncommon
Campbell black-browed albatross	0.000	0.304	0.00	High	At Risk: Naturally Uncommon
Stewart Island shag	0.000	0.301	0.00	High	Threatened: Nationally Vulnerable

4.2.2 Sea turtle bycatch

Between 2002–03 and 2012–13, there were 15 observed captures of sea turtles across all surface longline fisheries (Tables 10 and 11, Figure 7). Observer records documented all but one sea turtle as captured and released alive. Sea turtle capture distributions predominantly occur throughout the east coast of the North Island and Kermadec Island fisheries (Figure 8).

Table 10: Number of observed sea turtle captures in the New Zealand surface longline fisheries, 2002–03 to 2012–13, by species and area. Data from Thompson et al (2013), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Kermadec Islands	West Coast North Island	Total
Leatherback turtle	1	4	3	3	11
Green turtle	0	1	0	0	1
Unknown turtle	0	1	0	2	3
Total	1	6	3	5	15

Table 11: Effort and sea turtle captures in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data see Thompson et al (2013).

			Fishing effort	Observed captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate
2002–2003	10 772 188	2 195 152	20.4	0	0
2003–2004	7 386 329	1 607 304	21.8	1	0.001
2004–2005	3 679 765	783 812	21.3	2	0.003
2005–2006	3 690 119	705 945	19.1	1	0.001
2006–2007	3 739 912	1 040 948	27.8	2	0.002
2007–2008	2 246 189	421 900	18.8	1	0.002
2008–2009	3 115 633	937 496	30.1	2	0.002
2009–2010	2 995 264	665 883	22.2	0	0
2010–2011	3 187 879	674 572	21.2	4	0.006
2011–2012	3 100 277	728 190	23.5	0	0
2012–2013	2 862 182	560 333	19.6	2	0.004

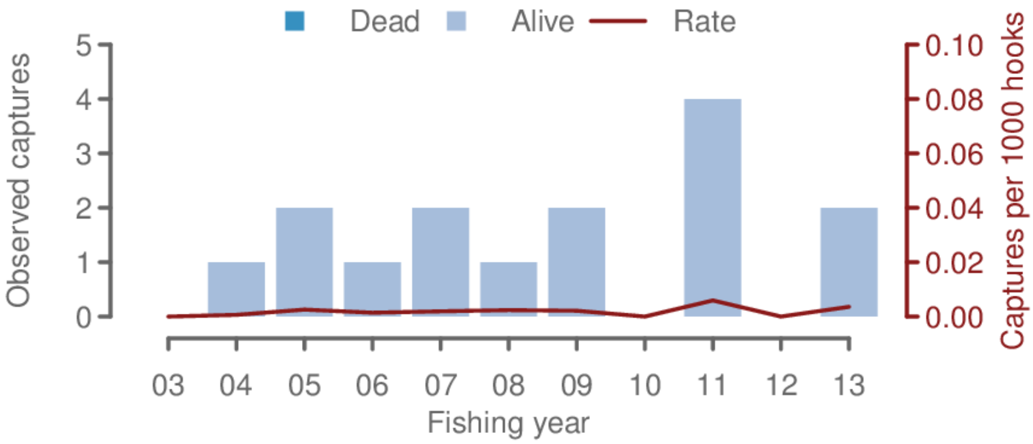


Figure 7: Observed captures of sea turtles in the New Zealand surface longline fisheries from 2002–03 to 2012–13.

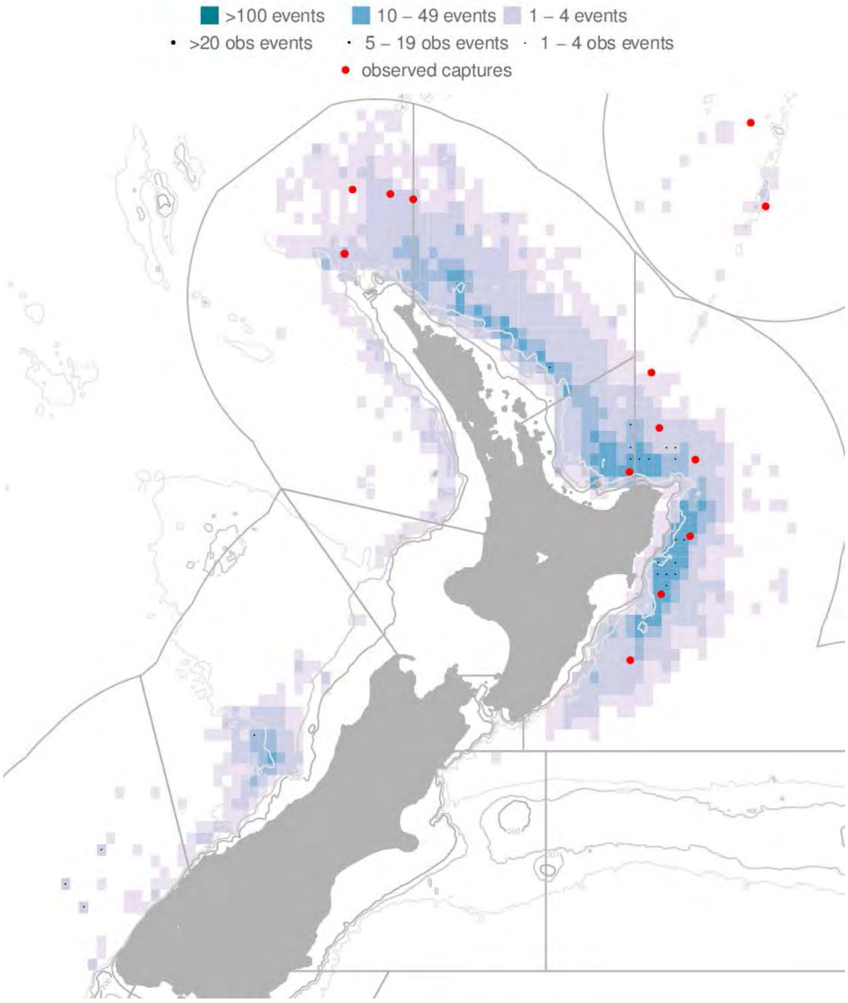


Figure 8: Distribution of fishing effort in the New Zealand surface longline fisheries and observed sea turtle captures, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 89.4% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Cetaceans are dispersed throughout New Zealand waters (Perrin et al 2008). The spatial and temporal overlap of commercial fishing grounds and cetacean foraging areas has resulted in cetacean captures in fishing gear (Abraham & Thompson 2009, 2011).

Between 2002–03 and 2012–13, there were seven observed captures of whales and dolphins in surface longline fisheries. Observed captures included 5 unidentified cetaceans and 2 long-finned Pilot whales (Tables 12 and 13, Figure 9) (Thompson et al 2013). All captured animals recorded were documented as being caught and released alive (Thompson et al 2013). Cetacean capture distributions are more frequent off the east coast of the North Island (Figure 10).

Table 12: Number of observed cetacean captures in the New Zealand surface longline fisheries, 2002–03 to 2012–13, by species and area. Data from Thompson et al (2013), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

Species	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	West Coast North Island	West Coast South Island	Total
Long-finned pilot whale	0	1	0	0	0	1	2
Unidentified cetacean	1	1	1	1	1	0	5
Total	1	2	1	1	1	1	7

Table 13: Effort and captures of cetaceans in surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). For more information on the methods used to prepare the data, see Thompson et al (2013).

	Fishing effort			Observed captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate
2002–2003	10 772 188	2 195 152	20.4	1	0
2003–2004	7 386 329	1 607 304	21.8	4	0.002
2004–2005	3 679 765	783 812	21.3	1	0.001
2005–2006	3 690 119	705 945	19.1	0	0
2006–2007	3 739 912	1 040 948	27.8	0	0
2007–2008	2 246 189	421 900	18.8	1	0.002
2008–2009	3 115 633	937 496	30.1	0	0
2009–2010	2 995 264	665 883	22.2	0	0
2010–2011	3 187 879	674 572	21.2	0	0
2011–2012	3 100 277	728 190	23.5	0	0
2012–2013	2 862 182	560 333	19.6	0	0

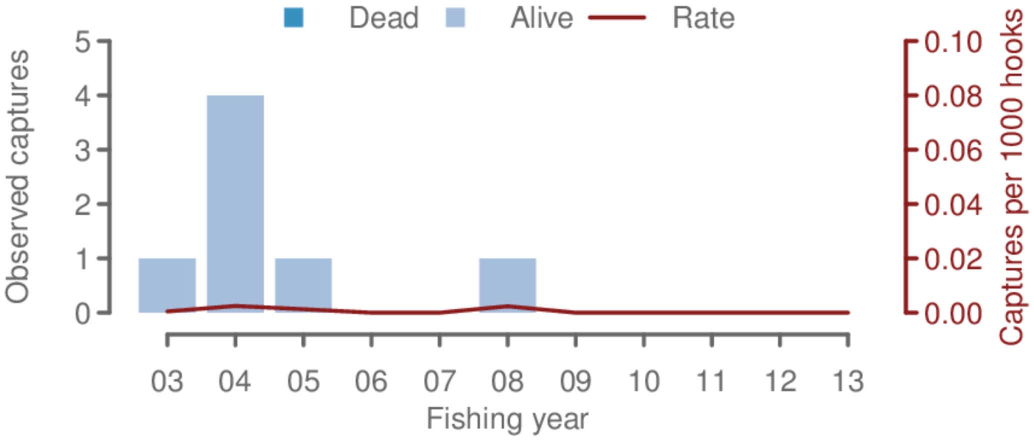


Figure 9: Observed captures of cetaceans in the New Zealand surface longline fisheries from 2002–03 to 2012–13.

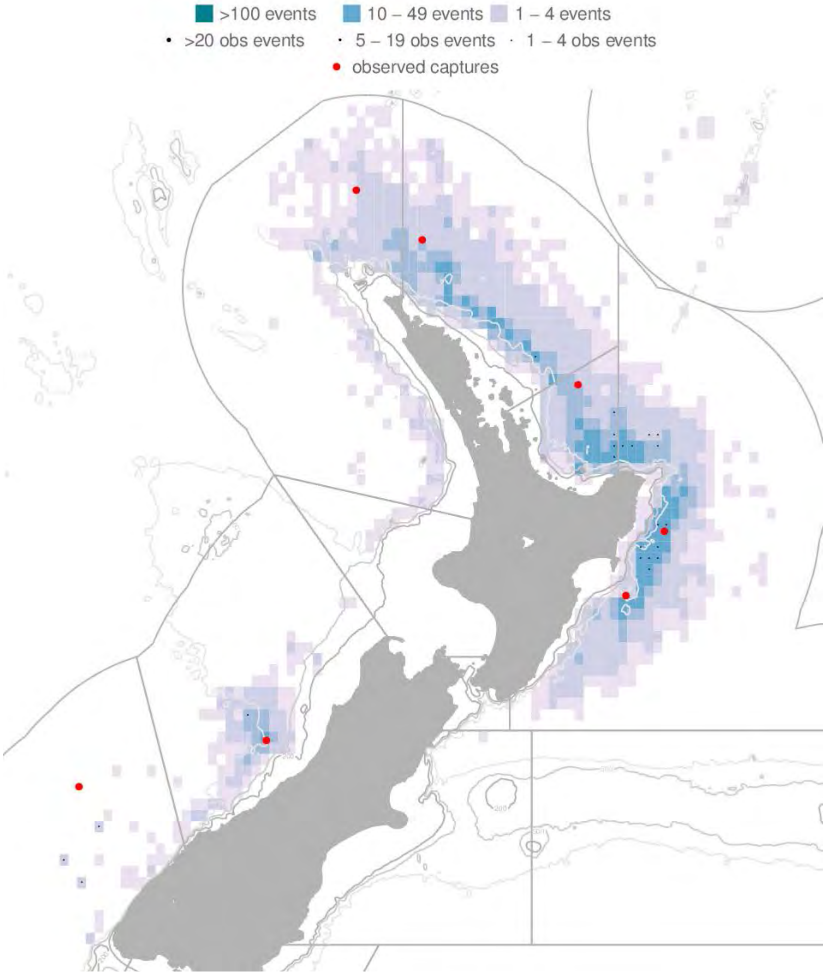


Figure 10: Distribution of fishing effort in the New Zealand surface longline fisheries and observed cetacean captures, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 89.4% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, especially in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf, which slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts, around much of the South Island and offshore islands. Captures on longlines occur when the fur seals attempt to feed on the bait and fish catch during hauling. Most New Zealand fur seals are released alive, typically with a hook and short snood or trace still attached.

New Zealand fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty-East Cape area when the animals have attempted to take bait or fish from the line as it is hauled. These capture rates include animals that are released alive (100% of observed surface longline capture in 2008–09; Thompson & Abraham 2010). Capture rates in 2011–12 and 2012-13 were higher than they were in the early 2000s (Figures 11 and 12). While fur seal captures have occurred throughout the range of this fishery most New Zealand captures have occurred off the Southwest coast of the

South Island (Figure 13). Between 2002–03 and 2012–13, there were 267 observed captures of New Zealand fur seal in surface longline fisheries (Tables 14 and 15).

Table 14: Number of observed New Zealand fur seal captures in the New Zealand surface longline fisheries, 2002–03 to 2012–13, by species and area. Data from Thompson et al (2013), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	Stewart Snares Shelf	West Coast North Island	West Coast South Island	Total
New Zealand fur seal	11	33	179	4	4	2	34	267

Table 15: Effort and captures of New Zealand fur seal in the New Zealand surface longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). Estimates are based on methods described in Thompson et al (2013) are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002–03 to 2011–12 and preliminary estimates for 2012–13 are based on data version 20140131.

	Fishing effort			Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	10 772 188	2 195 152	20.4	56	0.026	299	199–428
2003–2004	7 386 329	1 607 304	21.8	40	0.025	134	90–188
2004–2005	3 679 765	783 812	21.3	20	0.026	66	38–99
2005–2006	3 690 119	705 945	19.1	12	0.017	47	23–79
2006–2007	3 739 912	1 040 948	27.8	10	0.010	32	14–55
2007–2008	2 246 189	421 900	18.8	10	0.024	40	19–68
2008–2009	3 115 633	937 496	30.1	22	0.023	53	29–81
2009–2010	2 995 264	665 883	22.2	19	0.029	77	43–121
2010–2011	3 187 879	674 572	21.2	17	0.025	64	35–101
2011–2012	3 100 277	728 190	23.5	40	0.055	140	92–198
2012–2013†	2 862 182	560 333	19.6	21	0.037	110	65–171

†Provisional data, model estimates not finalised.

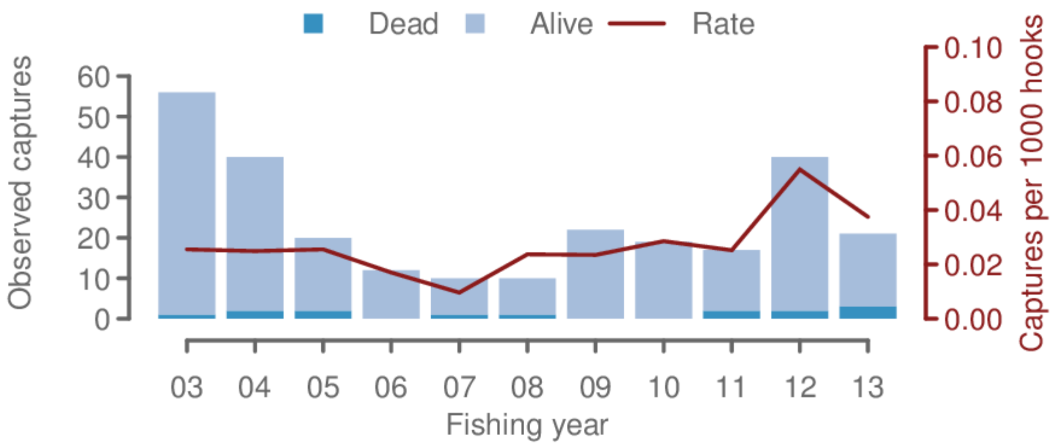


Figure 11: Observed captures of New Zealand fur seal in the New Zealand surface longline fisheries from 2002–03 to 2012–13.

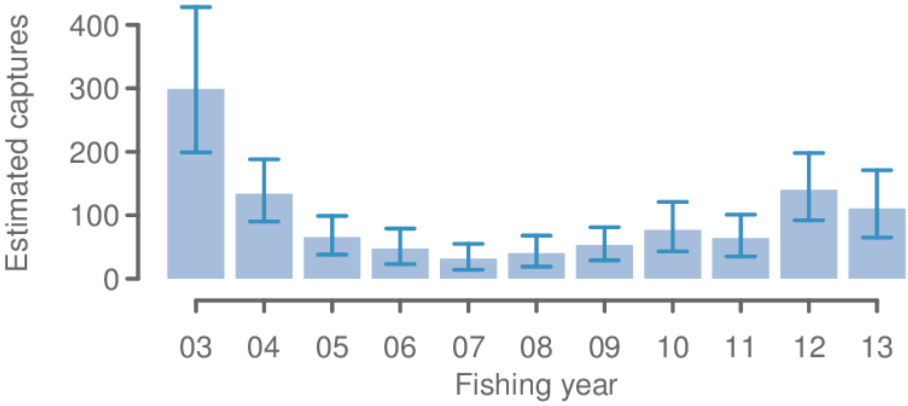


Figure 12: Estimated captures of New Zealand fur seal in the New Zealand surface longline fisheries from 2002–03 to 2012–13.

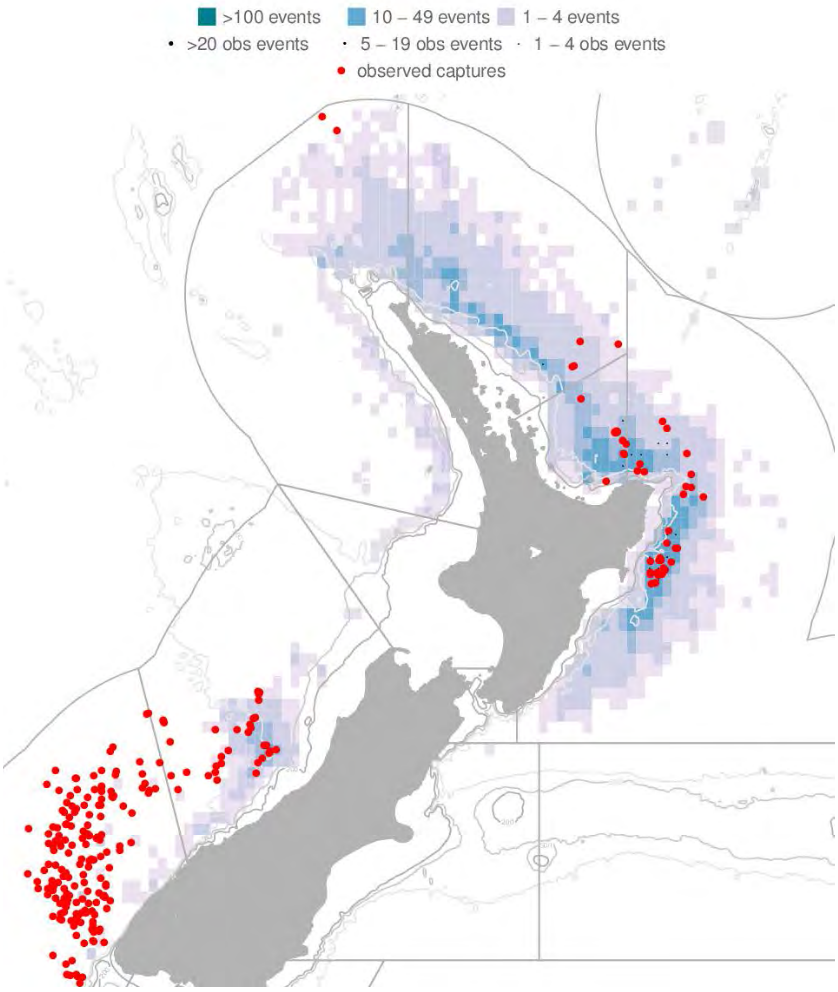


Figure 13: Distribution of fishing effort in the New Zealand surface longline fisheries and observed New Zealand fur seal captures, 2002–03 to 2012–13. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. In this case, 89.4% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.3 Incidental fish bycatch
Observer records indicate that a wide range of species are landed by the longline fleets in New Zealand fishery waters. Blue sharks are the most commonly landed species (by number), followed by Ray's bream (Table 16). Southern bluefin tuna and albacore tuna are the only target species that occur in the top five of the frequency of occurrence.

Table 16: Total estimated catch (numbers of fish) of common bycatch species in the New Zealand longline fishery as estimated from observer data from 2009 to 2013. Also provided is the percentage of these species retained (2013 data only) and the percentage of fish that were alive when discarded, N/A (none discarded).

Species	2010	2011	2012	2013	% retained (2013)	discards % alive (2013)
Blue shark	66113	53432	132925	158736	45.2	97.4
Lancetfish	43425	37305	7866	19172	0.1	37.6
Rays bream	20041	18453	19918	13568	97.4	4.2
Porbeagle shark	4679	9929	7019	9805	34.0	79.8
Mako shark	4490	9770	3902	3981	35.5	84.9
Moonfish	5398	3418	2363	2470	99.0	0.0
Escolar	1539	6602	2181	2088	30.2	76.3
Sunfish	3148	3773	3265	1937	2.7	100.0
Pelagic stingray	1983	4090	712	1199	1.0	97.0
Butterfly tuna	1158	909	713	1030	48.1	11.1
Deepwater dogfish	377	548	647	743	1.2	88.5
Oilfish	886	1747	509	386	26.5	72.2
Rudderfish	326	338	491	362	13.0	80.0
Thresher shark	209	349	246	256	33.3	75.0
Skipjack tuna	91	255	123	240	100.0	N/A
Dealfish	1160	223	372	237	1.7	25.1
Striped marlin	471	175	124	182	0.0	44.4
Big scale pomfret	505	139	108	67	88.2	100.0
School shark	62	49	477	21	100.0	N/A

4.4 Benthic interactions
N/A

4.5 Key environmental and ecosystem information gaps
Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

With the establishment of WCPFC in 2004, stock assessments of the WCPO stock of yellowfin tuna are undertaken by the Oceanic Fisheries Programme (OFP) of Secretariat of the Pacific Community (SPC) under contract to WCPFC.

No assessment is possible for yellowfin within the New Zealand EEZ as the proportion of the stock found within New Zealand fisheries waters is unknown and likely varies from year to year.

The yellowfin stock assessment was updated by the SPC in 2014 in SC10-SA-WP-04 (Davies et. al. 2014) and reviewed by the WCPFC Scientific Committee (SC10) in August 2014. In addition SC10-SA-IP-01 (Harley et. al. 2014) summarized the major changes to the tropical tuna stock assessments resulting from the recommendations provided in SC8-SA-WP-01 (Independent Review of the 2011 bigeye tuna stock assessment). Also, status quo stochastic projections were provided for yellowfin tuna in SC10-SA-WP-06 (Pilling 2014).

The following is a summary of the 2014 yellowfin stock assessment as agreed by the WCPFC Scientific Committee (SC10) in August 2014.

Some of the main improvements in the 2014 assessment are:

- Increases in the number of spatial regions to better model the tagging and size data;
- Inclusion of catch estimates from Vietnam and some Japanese coastal longline data previously not included;
- The use of operational longline data for multiple fleets to better address the contraction of the Japanese fleet and general changes over time in targeting practices;
- Improved modelling of recruitment to ensure that uncertain estimates do not influence key stock status outcomes; and
- A large amount of new tagging data corrected for differential post-release mortality and other tag losses

The large number of changes since the 2011 assessment (some of which are described above), and the nature of some of these changes, means that full consideration of the impacts of individual changes is not possible. Nevertheless, the report details some of the steps from the 2011 reference case (LLcpueOP_TWcpueR6_PTTP) to the 2014 reference case (run37 – Ref.Case). Distinguishing features of the 2014 reference case model include:

- The steepness parameter of the stock recruitment relationship is fixed at 0.8.
- Long-term average recruitment is defined for the period 1965-2011.
- Natural mortality at age is fixed according to an external analysis in which it is assumed that the natural mortality rate of females increases with the onset of reproductive maturity.
- The likelihood function weighting of the size data is determined using an effective sample size for each fishing observation of one-twentieth of the actual sample size, with a maximum effective sample size of 50.
- For modelling the tagging data, a mixing period of 2 quarters (including the quarter of release) is applied.
- The last four quarterly recruitments aggregated over regions are assumed to lie on the stock-recruitment curve.

The rationale for these choices, which comprise the key areas of uncertainty for the assessment, is described in detail in the report. We report the results of “one-off” sensitivity models to explore the impact of these choices for the reference case model on the stock assessment results. A sub-set of key, plausible model runs was taken from these sensitivities to include in a structural uncertainty analysis (grid) for consideration in developing management advice.

The main conclusions of the current assessment are consistent with recent assessments presented in 2009 and 2011. The main conclusions are as follows

1. The new regional structure appears to work well for yellowfin, and in combination with other modelling and data improvements, provides a more informative assessment than in the past.

2. Spatially-aggregated recruitment is estimated to decline in the early part of the assessment, but there is no persistent trend post-1965.

3. There appears to be confounding between the estimates of regional recruitment distribution and movement such that certain regions have very low recruitments. While adding complexity to the recruitment process of age 1 fish, this did not add to the uncertainty over the range of runs considered in this assessment.

4. Latest catches marginally exceed the maximum sustainable yield (MSY).

5. Recent levels of fishing mortality are most likely below the level that will support the MSY.

6. Recent levels of spawning potential are most likely above (based on 2008-11 average and based on 2012) the level which will support the MSY.

7. Recent levels of spawning potential are most likely above (based on 2008-11 average and based on 2012) the LRP of 20%$SB_{F=0}$ agreed by WCPFC.

8. Recent levels of spawning potential are most likely higher (by 1%, based on 2008-11 average) and lower than (by 2% based on 2012) the candidate biomass-related TRPs currently under consideration for skipjack tuna, i.e., 40-60%$SB_{F=0}$.

9. Stock status conclusions were most sensitive to alternative assumptions regarding the modelling of tagging data, assumed steepness and natural mortality. However the main conclusions of the assessment are robust to the range of uncertainty that was explored.

Paper SC10-SA-WP-06 (Pilling 2014) contained status quo stochastic projections for bigeye, skipjack, and yellowfin tunas. The paper outlined an assessment of the potential consequences of recent (2012) fishing conditions on the future biological status of the three tropical tuna stocks, based on the 2014 tropical tuna stock assessments. Projected status in 2032 was reported relative to spawning biomass and fishing mortality reference levels in absolute terms (as a median of the projection outcomes) and in probabilistic terms.

A single assessment model run (the reference case model for each tropical tuna stock) was used as the basis for projecting future stock status. Only uncertainty arising from future recruitment conditions was therefore captured in the results, using two alternative hypotheses: where recruitment was assumed to follow the estimated stock recruitment relationship on average with randomly selected deviates from the period used to estimate the relationship in each stock assessment; or was assumed to be consistent with actual recruitments estimated over the period 2002-2011.

Under 2012 conditions, stochastic projection results indicated that for yellowfin tuna it was exceptionally unlikely (<1%) that the yellowfin stock would fall below the LRP level or that fishing mortality would increase above the F_{MSY} level by 2032, and dependent upon the future recruitment assumption, it was exceptionally unlikely (<1%; long-term recruitment deviate assumption) or very unlikely (<10%; recent recruitment assumption) to fall below SB_{MSY}.

Stock status and trends

There have been significant improvements to the 2014 stock assessment resulting from the implementation of the 2012 bigeye review recommendations which apply equally to yellowfin tuna. Improvements were made to regional and fisheries structures, Catch estimates, CPUE, and tagging data inputs, and the MULTIFAN-CL modelling framework. This assessment is also the first since the adoption of a LRP based on the spawning biomass in the absence of fishing ($0.2SB_{F=0}$).

SC10 selected the reference case which had an assumed steepness of 0.8 to represent the stock status of yellowfin. To characterize uncertainty in the assessment, SC10 chose 3 additional models based on alternate values of steepness and tagging mixing period. Fuller details of the base case and other models are provided in Table 17.

Table 17: Description of the base case and key model chosen for the provision of management advice.

Name	Description
Base Case	JP longline CPUE for regions 1 and 2, all flags longline for regions 3 to 7, and all flags longline nominal for regions 8 and 9; with purse-seine CPUE for PH-ID in region 7 and all flags in region 8. Size data weighted as the number of samples divided by 20, steepness fixed at 0.8, M fixed, tag mixing period of 2 quarters, and fixed natural mortality.
h_0.65	Steepness=0.65.
h_0.95	Steepness=0.95.
Mix_1qtr	Tag mixing period=1 quarter

Time trends in estimated recruitment, biomass, fishing mortality and depletion are shown in Figures 14-17.

High levels of fishing mortality on juveniles have been recorded in region 7 (Figure 19). Stock depletion levels are higher in the equatorial regions than elsewhere, refer Figure 17.

The estimated MSY of 586,400 mt is within the range of previous assessments and model quantities are generally similar with these earlier assessments. This is due largely to the consistent information on declining relative abundance provided by the longline CPUE indices and the large amount of tagging data input to the model.

The dramatic decline in the MSY in the 1970's follows the increased development of those fisheries that catch younger yellowfin, principally the small-fish fisheries in the west equatorial region (Figure 20).

Fishing mortality has generally been increasing through time, and for the reference case $F_{current}$ (2008-11 average) is estimated to be 0.72 times the fishing mortality that will support the MSY. Across the four models (base case and three sensitivity models) $F_{current}/F_{MSY}$ ranged from 0.58 to 0.90. This indicates that overfishing is not occurring for the WCPO yellowfin tuna stock, however latest catches are close to or exceed the MSY by up to 13% (Table 18 and Figure 18).

The latest (2012) estimates of spawning biomass are above both the level that will support the *MSY* (SB_{latest}/SB_{MSY} = 1.24 for the base case and range 1.05-1.51 across the four models) and the newly adopted LRP of $0.2SB_{F=0}$ ($SB_{latest}/SB_{F=0}$ = 0.38 for the base case and range 0.35-0.40.

Table 18: Estimates of management quantities for selected stock assessment models (see Table YFT1 for details). For the purpose of this assessment, "current" is the average over the period 2008–2011 and "latest" is 2012.

	Ref.Case	Mix_1	h_0.65	h_0.95
MSY (mt)	586400	526400	527200	642800
C_{latest}/MSY	1.02	1.12	1.13	0.93
$F_{current}/F_{MSY}$	0.72	0.87	0.9	0.58
B_0	4319000	3862000	4475000	4221000
$B_{current}$	1994655	1597536	1996179	1995224
SB_0	2467000	2202000	2557000	2411000
SB_{MSY}	728300	648000	859600	594500
$SB_{F=0}$	2368557	2206510	2556733	2255523
$SB_{current}$	998622	746743	999474	998914
SB_{latest}	899496	770210	899362	898389
$SB_{current}/SB_{F=0}$	0.42	0.34	0.39	0.44
$SB_{latest}/SB_{F=0}$	0.38	0.35	0.35	0.4
$SB_{current}/SB_{MSY}$	1.37	1.15	1.16	1.68
SB_{latest}/SB_{MSY}	1.24	1.19	1.05	1.51

Table 19: Comparison of selected WCPO yellowfin tuna reference points from the 2009, 2011, and 2014 base case models.

Management quantity	Ref.case-2009	Ref.case-2011	Ref.case-2014
MSY	636,800	538,800	586,400
$F_{current}/F_{MSY}$	0.58	0.77	0.72
$SB_{latest}/SB_{F=0}$	0.50	0.44	0.38

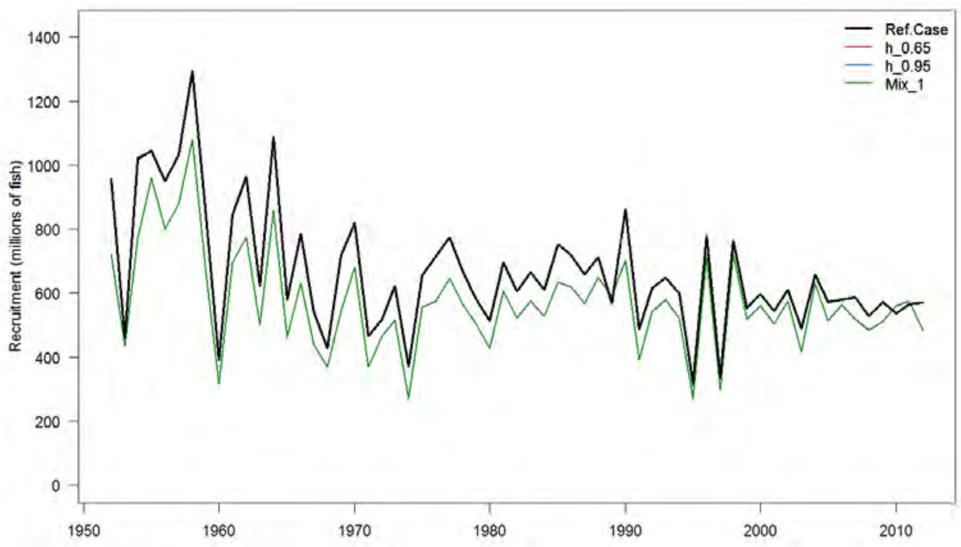


Figure 14: Estimated annual average recruitment for the WCPO obtained from the base case model and three additional runs described in Table YFT1. The model runs with alternative steepness values give the same recruitment estimates.

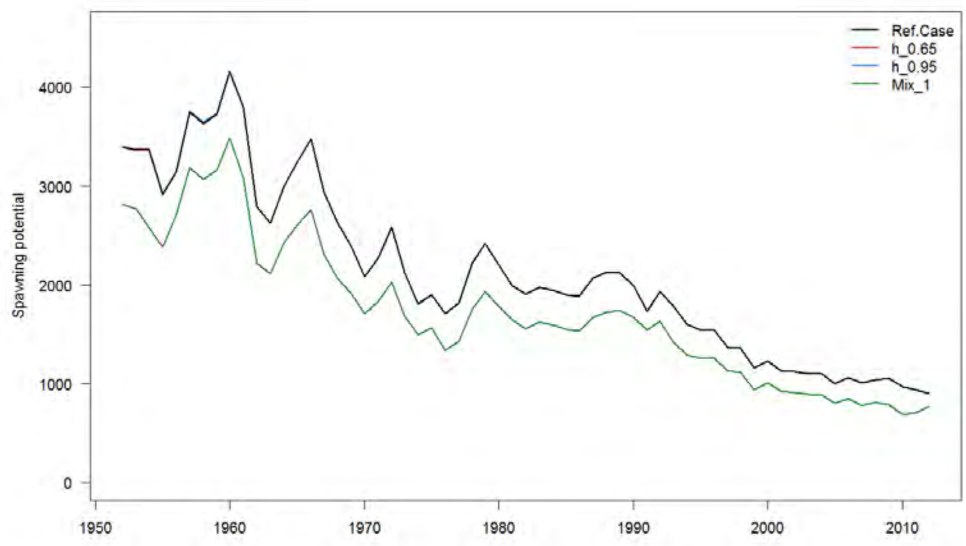


Figure 15: Estimated annual average spawning potential for the WCPO obtained from the base case model and three additional runs described in Table YFT1. The model runs with alternative steepness values give the same recruitment estimates.

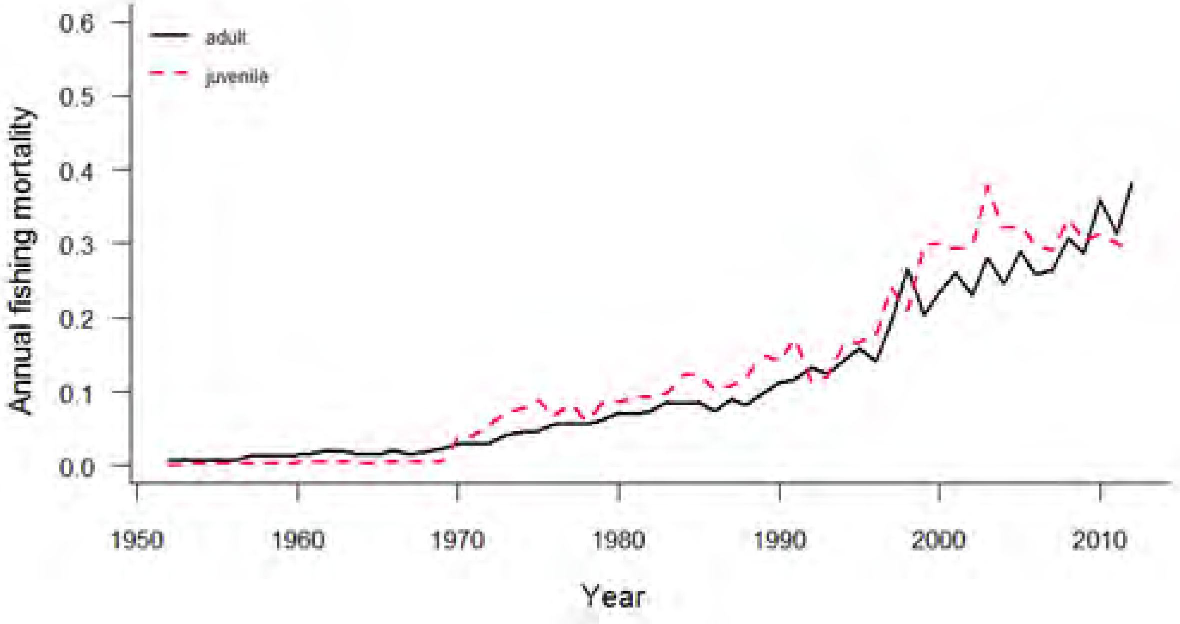


Figure 16: Estimated annual average juvenile and adult fishing mortality for the WCPO obtained from the base case model.

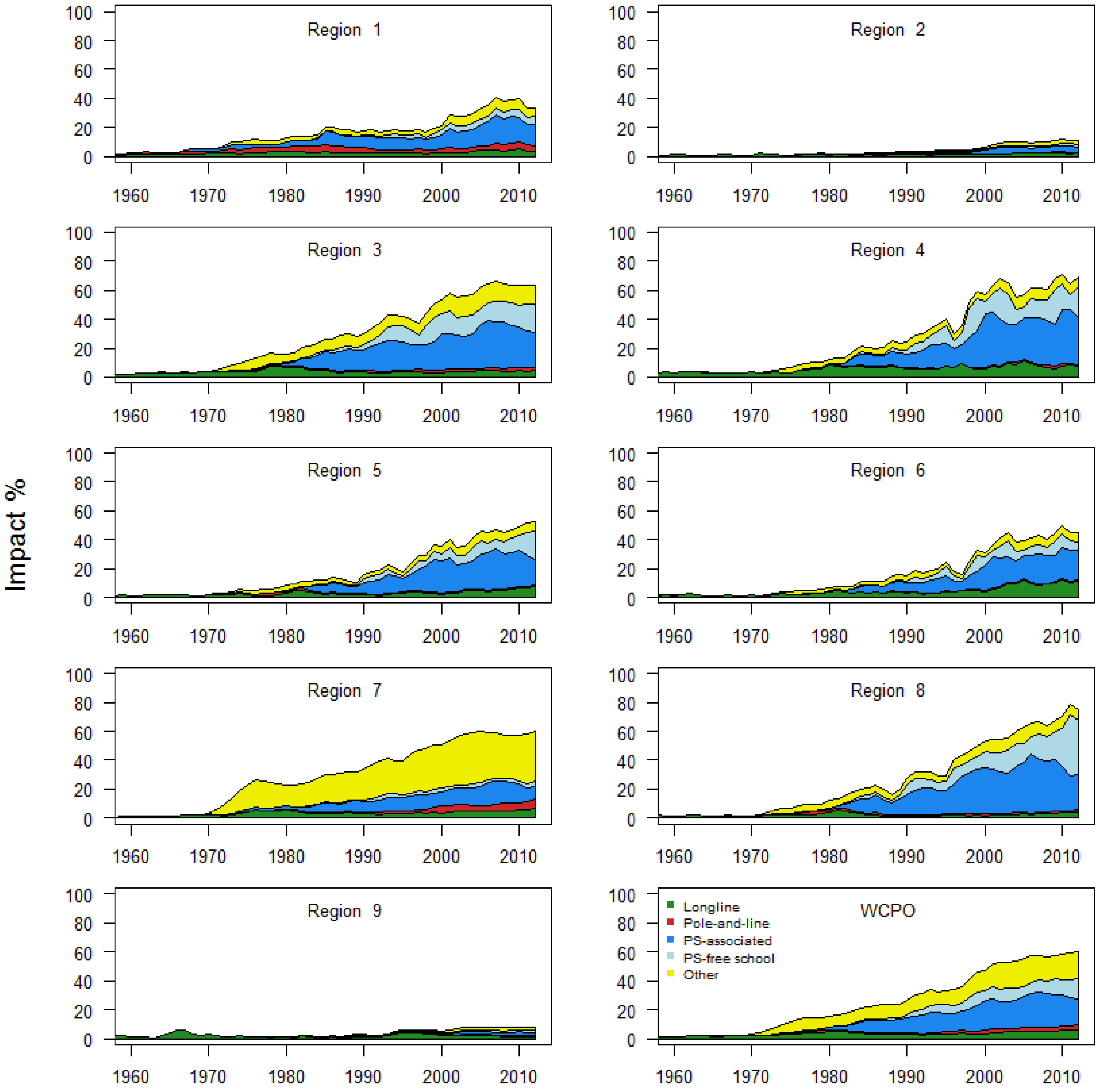


Figure 17: Estimates of reduction in spawning potential due to fishing (fishery impact = 1-$SB_t/SB_{t,F=0}$) by region and for the WCPO attributed to various fishery groups for the base case model.

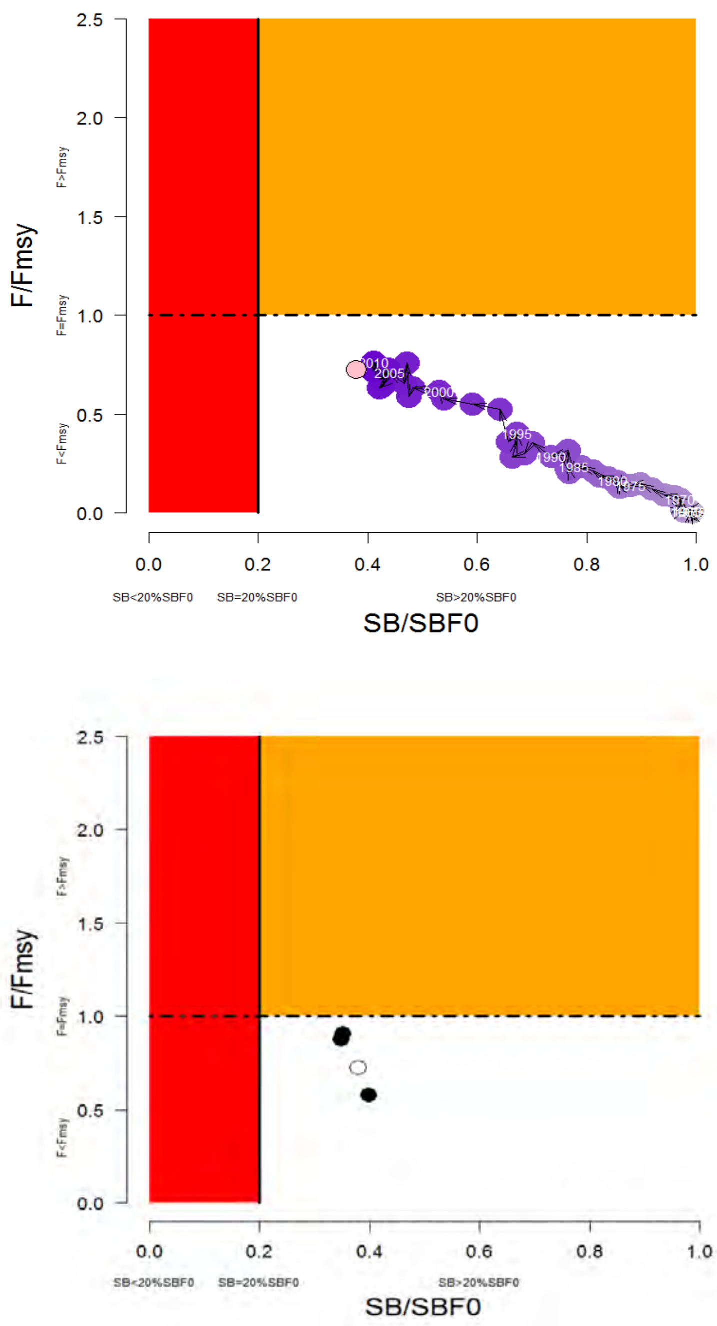


Figure 18: Temporal trend for the base case model (top) and terminal condition for the base case and other sensitivity runs (bottom) in stock status relative to $SB_{F=0}$ (x-axis) and F_{MSY} (y-axis). The red zone represents spawning potential levels lower than the agreed LRP which is marked with the solid black line ($0.2SB_{F=0}$). The orange region is for fishing mortality greater than F_{MSY} ($F=F_{MSY}$; marked with the black dashed line). The pink circle (top panel) is $SB_{2012}/SB_{F=0}$ (where $SB_{F=0}$ was the average over the period 2002-2011). The bottom panel includes the base case (white dot) and sensitivity analyses described Table YFT-1.

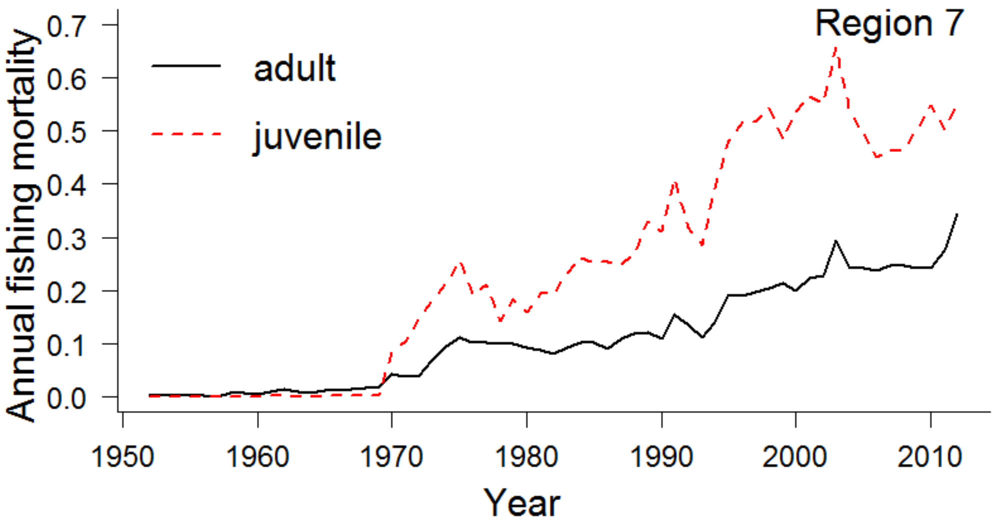


Figure 19: Estimated annual average juvenile and adult fishing mortality for the region 7 of the assessment obtained from the base case model.

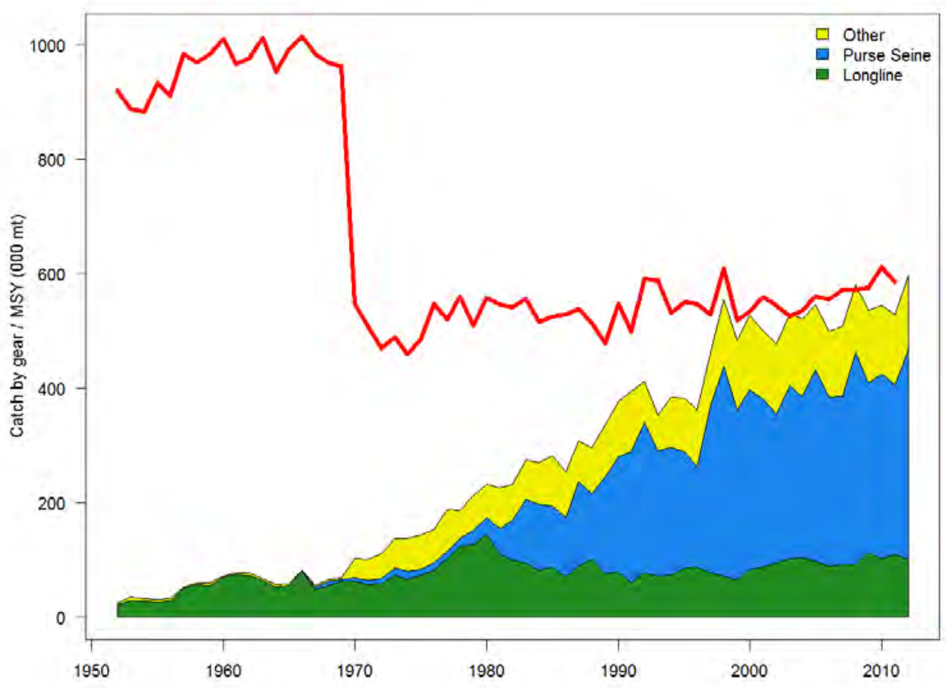


Figure 20: History of annual estimates of MSY compared with catches of three major fisheries for the base case model.

Management Advice and Implications

The WCPO yellowfin spawning biomass is above the biomass-based LRP WCPFC adopted, $0.2SB_{F=0}$, and overall fishing mortality appears to be below F_{MSY}. It is highly likely that stock is not experiencing overfishing and is not in an overfished state.

Latest (2012) catches (612,797mt (SC10-GW-WP-01)) of WCPO yellowfin tuna marginally exceed the MSY (586,400mt).

Future status under status quo projections (assuming 2012 conditions) depends upon assumptions on future recruitment. When spawner-recruitment relationship conditions are assumed, spawning biomass is predicted to increase and the stock is exceptionally unlikely (0%) to become overfished (SB_{2032}<$0.2SB_{F=0}$) or to fall below SB_{MSY}, nor to become subject to overfishing ($F>F_{MSY}$). If recent (2002-2011) actual recruitments are assumed, spawning biomass will remain relatively constant, and the stock is exceptionally unlikely (0%) to become overfished or to become subject to overfishing, and it was very unlikely (2%) that the spawning biomass would fall below SB_{MSY}.

The SC also noted that levels of fishing mortality and depletion differ between regions, and that fishery impact was highest in the tropical region (regions 3, 4, 7, 8 in the stock assessment model). The WCPFC could consider measures to reduce fishing mortality from fisheries that take juveniles, with the goal to increase to maximum fishery yields and reduce any further impacts on the spawning potential for this stock in the tropical regions.

WCPFC could consider a spatial management approach in reducing fishing mortality for yellowfin.

The SC recommend that the catch of WCPO yellowfin should not be increased from 2012 levels which exceeded MSY and measures should be implemented to maintain current spawning biomass levels until the Commission can agree an appropriate TRP.

5.1 Estimates of fishery parameters and abundance

There are no fishery-independent indices of abundance for the yellowfin tuna stock. Relative abundance information is available from standardized indices of longline catch per unit effort data. Returns from large scale tagging programmes undertaken in the early 1990s and 2000s also provide information on rates of fishing mortality which in turn leads to improved estimates of abundance.

5.2 Biomass estimates

These estimates apply to the WCPO portion of the stock or an area that is approximately equivalent to the waters west of 150°W. The stock assessment results and conclusions of the 2014 assessment show $SB_{current}$ / SB_{MSY} estimated at 1.37 over the period 2008-2011. Spawning biomass for the WCPO is estimated to have declined to about 38% of its initial level by 2012.

5.3 Yield estimates and projections

No estimates of MCY and CAY are available.

5.4 Other yield estimates and stock assessment results

SC10 achieved consensus to accept and endorse the reference case proposed in the assessment document, and that $SB_{20\%,F=0}$ be used as the LRP for stock status purposes as agreed by WCPFC. There was further discussion about whether to use SB_{latest} or $SB_{current}$ as the terminal spawning biomass for management purposes. The SC agreed to use the most recent information on spawning biomass, SB_{latest} corresponding to 2012. At 0.38 $SB_{F=0}$ SB_{latest} is above the limit reference point.

SC10 also endorsed the use of the candidate biomass-related target reference point (TRP) currently under consideration for skipjack tuna, i.e., 40-60% $SB_{F=0}$. At 0.38 $SB_{F=0}$ SB_{latest} is slightly below the target reference point.

5.5 Other factors

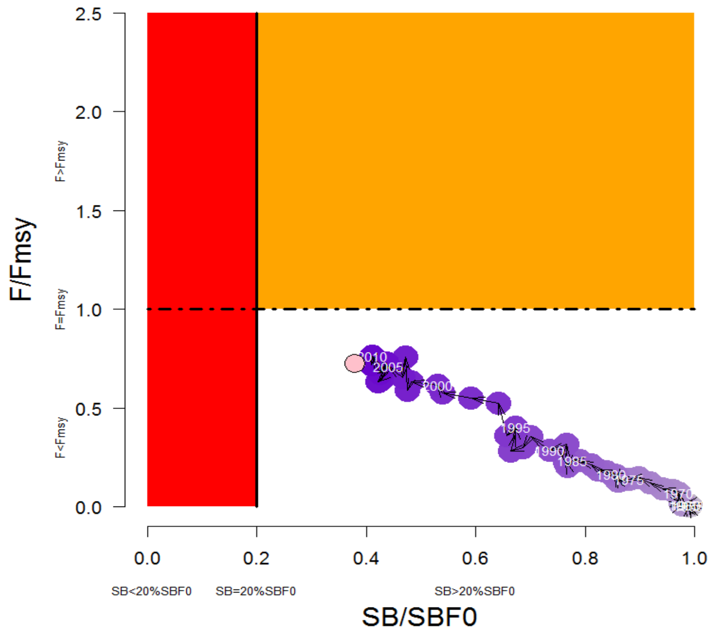
It is thought that large numbers of small yellowfin tuna are taken in surface fisheries in Indonesia and the Philippines. There are considerable uncertainties in the exact catches and these lead to uncertainties in the assessment. Programmes are in place to improve the collection of catch statistics in these fisheries.

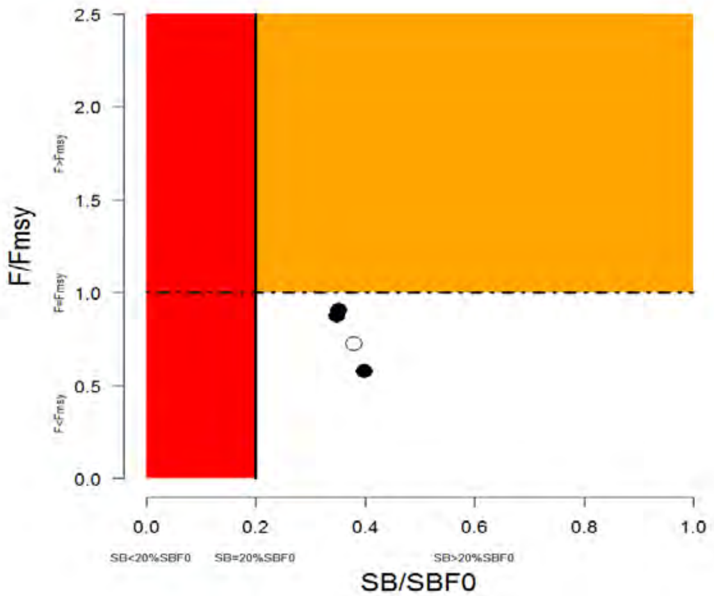
6. STATUS OF THE STOCKS

Stock structure assumptions
Western and Central Pacific Ocean

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Base case model and a range of sensitivities
Reference Points	Candidate biomass-related target reference point (TRP) currently under consideration for key tuna species is 40-60% SB_0 Limit reference point of 20% SB_0 established by WCPFC equivalent to the HSS default of 20% SB_0 Hard Limit: Not established by WCPFC; but evaluated using HSS default of 10% SB_0 Overfishing threshold: F_{MSY}
Status in relation to Target	Recent levels of spawning biomass are About as Likely as Not (40-60%) to be at or above the lower end of the range of 40-60% SB_0 (based on both the 2008-11 average and the 2012 estimate). Likely (> 60%) that $F < F_{MSY}$
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	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status





Temporal trend for the base case model (top) and terminal condition for the base case and other sensitivity runs (bottom) in stock status relative to $SB_{F=0}$ (x-axis) and F_{MSY} (y-axis). The red zone represents spawning potential levels lower than the agreed LRP which is marked with the solid black line ($0.2SB_{F=0}$). The orange region is for fishing mortality greater than F_{MSY} ($F=F_{MSY}$; marked with the black dashed line). The pink circle (top panel) is $SB_{2012}/SB_{F=0}$ (where $SB_{F=0}$ was the average over the period 2002-2011). The bottom panel includes the base case (white dot) and sensitivity analyses described Table YFT-1.

Fishery and Stock Trends	
Recent trend in Biomass or Proxy	Biomass has been reduced steadily over time reaching a level of about 38% of unexploited biomass in 2012. However, depletion is higher in the equatorial region 4 where recent depletion levels are approximately 0.31 for spawning biomass (a 69% reduction from the unexploited level) and 0.24 in region 8.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality has increased over time but is estimated to be lower than F_{MSY} in all cases
Other Abundance Indices	-

Trends in Other Relevant Indicator or Variables	Spatially-aggregated recruitment is estimated to have declined in the early part of the assessment, but there is no persistent trend post-1965. The analysis suggests that the substantial declines in spawning potential are being driven primarily by the fishing impacts rather than long-term declines in recruitment. However, recent recruitment is estimated to be slightly lower than the long-term average (by approximately 6%).

Projections and Prognosis	
Stock Projections or Prognosis	Stochastic projection results indicated that for yellowfin tuna it was Exceptionally Unlikely (< 1%) that the yellowfin stock would fall below the LRP level or that fishing mortality would increase above the F_{MSY} level by 2032.
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 commence	Exceptionally Unlikely (< 1%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1: Quantitative Stock assessment	
Assessment Method	The assessment uses the stock assessment model and computer software known as MULTIFAN-CL.	
Assessment Dates	Latest assessment: 2014	Next assessment: Unknown
Overall assessment quality rank	1 - High Quality	
Main data inputs (rank)	This assessment includes improved purse seine catch estimates; reviews of the catch statistics of the component fisheries; standardised CPUE analyses of operational level catch and effort data; size data inputs from the purse seine and longline fisheries; revised regional structures and fisheries definitions; preparation of tagging data and reporting rate information	1 - High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Changes to the data from the 2011 assessment included: - Increases in the number of spatial regions to better model the tagging and size data; - Inclusion of catch estimates from Vietnam and some Japanese coastal longline data previously not included; - The use of operational longline data for multiple fleets to better address the contraction of the Japanese fleet and general changes over time in targeting practices; - Improved modelling of recruitment to ensure that uncertain	

	estimates do not influence key stock status outcomes; and - A large amount of new tagging data corrected for differential post-release mortality and other tag losses
Major Sources of Uncertainty	Estimated recruitments appear to be uncertain for the terminal time period (2012) as was indicated by the retrospective analyses, with the final recruitment estimate in each retrospective model altering as more data were added. The values of absolute abundance differ among the assessments due to a number of factors including changes in model structure, assumptions, input data and the MULTIFAN-CL software.

Qualifying Comments
-

Fishery Interactions
Interactions with protected species are known to occur in the longline fisheries of the South Pacific, particularly south of 25°S. Seabird bycatch mitigation measures are required in the New Zealand, Australian EEZ's and through the WCPFC Conservation and Management Measure (CMM2007-04). Sea turtles also get incidentally captured in longline gear; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure (CMM2008-03). Shark bycatch is common in longline fisheries and largely unavoidable; this is being managed through New Zealand domestic legislation and to a limited extent through Conservation and Management Measure (CMM2010-07).

7. FOR FURTHER INFORMATION

Abraham, E R; Thompson, F N (2009) Capture of protected species in New Zealand trawl and longline fisheries, 1998–99 to 2006–07. *New Zealand Aquatic Environment and Biodiversity Report No. 32*.

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. Final Research Report prepared for Ministry of Fisheries project PRO2007/01. (Unpublished report held by the Ministry for Primary Industries, Wellington.) 170 p.

Abraham, E R; Thompson, F N; Oliver, M D (2010) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report No. 45*. 148 p.

Anon. (2002) Annual Report of the Inter-American Tropical Tuna Commission. IATTC, La Jolla, California. 148 p.

Anon. (2006) The Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean. Scientific Committee Second regular session, 7–18 August 2006, Manila, Philippines. Kolonia Pohnpei. 252 p.

Anon. (2007) Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean: Scientific Committee Summary report. Western and Central Pacific Fisheries Commission, Pohnpei, Federated States of Micronesia. 244 p.

Anon (2013) Tuna fishery yearbook 2012. Western and Central Pacific Fisheries Commission, 154 p.

Anon (2003). Report of the 16th meeting of the Standing Committee on Tuna and Billfish. www.spc.int.

Baird, S J (2008) Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in longline fisheries in New Zealand waters, 1994–95 to 2005–06. *New Zealand Aquatic Environment and Biodiversity Report No. 20.* 21 p.

Bentley, N; Langley, A D; Middleton, D A J; Lallemand, P (2013) Fisheries of New Zealand, 1989/90-2011/12. Retrieved from http://fonz.tridentsystems.co.nz, *12 November 2013*.

CMM2010-07 (2010) Conservation and Management measure for sharks, for the Western and Central Pacific Ocean. CMM2010-07 of the Western and Central Pacific Fisheries Commission.

Davies, N. S. Harley, J. Hampton and S. McKechnie. 2014. Stock assessment of yellowfin tuna in the western and central Pacific Ocean Rev 1. WCPFC-SC10-2014/SA-WP-4.

Griggs, L H; Baird, S J (2013). Fish bycatch in New Zealand tuna longline fisheries 2006–07 to 2009–10. *New Zealand Fisheries Assessment Report 2013/13*. 71 p.

Hampton, J; Kleiber, P; Langley, A; Hiramatsu, K (2004) Stock assessment of yellowfin tuna in the western and central Pacific Ocean, SCTB17 Working Paper SA–1. www.spc.int.

Hampton, J; Kleiber, P; Langley, A; Takeuchi, Y; Ichinokawa, M (2005) Stock assessment of yellowfin tuna in the western and central Pacific Ocean. SC-1 SA-WP-1. First meeting of the WCPFC-Scientific Committee, 8–19 August 2005, Noumea, New Caledonia.

Hampton, J; Langley, A; Harley, S; Kleiber, P; Takeuchi, Y; Ichinokawa, M (2005) Estimates of sustainable catch and effort levels for target species and the impacts on stocks of potential management measures. SC-1 SA-WP-10. First meeting of the WCPFC-Scientific Committee, 8–19 August 2005, Noumea, New Caledonia.

Hampton, J; Langley, A; Kleiber, P (2006) Stock assessment of yellowfin tuna in the western and central Pacific Ocean, including an assessment of management options. WCPFC-SC2-2006/SA WP-1 . Second meeting of the WCPFC-Scientific Committee, 7-18 August 2006, Manila, Philippines. (www.wcpfc.org/).

Harley, S., N. Davies, J. Rice, S. McKechnie and J. Hampton. 2014. Summary of major changes in the 2014 tropical tuna stock assessments. WCPFC-SC10-2014/SA-IP-01.

Holdsworth, J; Saul, P (2003) New Zealand billfish and gamefish tagging 2001–02. *New Zealand Fisheries Assessment Report 2003/15*, 39 p.

Itano, D G (2000) The reproductive biology of yellowfin tuna (*Thunnus albacares*) in Hawaiian waters and the western tropical Pacific Ocean. SOEST Publication 00-01, University of Hawaii, 69 p.

Koido, T; Suzuki, Z (1989) Main spawning season of yellowfin tuna, *Thunnus albacares*, in the western tropical Pacific Ocean based on gonad index. *Bulletin of the Far Seas Fisheries Research Laboratory* 26: 153–163.

Langley, A; Harley, S; Hoyle, S; Davies, N; Hampton, J; Kleiber, P (2009) Stock assessment of yellowfin tuna in the western and central Pacific Ocean. Report to the Western and Central Pacific Fisheries Commission Scientific Committee WCPFC-SC5-2009/SA-WP-03. 120 p.

Langley, A; Hoyle, S; Hampton, J (2011) Stock assessment of yellowfin tuna in the western and central Pacific Ocean. Report to the Western and Central Pacific Fisheries Commission Scientific Committee WCPFC-SC7-2011/SA-WP-03. 134 p.

Mattlin, R H (1987) New Zealand fur seal, *Arctocephalus forsteri*, within the New Zealand region. In Croxall, J.P.; Gentry, R.L. Status, biology, and ecology of fur seals: Proceedings of an international symposium and workshop, Cambridge, England, 23–27 April 1984. NOAA Technical Report NMFS-51.

Ministry for Primary Industries (2013a). Aquatic Environment and Biodiversity Annual Review 2013. Compiled by the Fisheries Management Science Team, Ministry for Primary Industries, Wellington, New Zealand. 538 p.

Ministry for Primary Industries (2013b). Nathional Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand Fisheries. Ministry for Primary Industries, Wellington, New Zealand. 59 p.

Perrin, W F; Wursig, B; Thewissen, J G M (Eds.) (2008) *Encyclopedia of marine mammals.* Second Edition. Academic Press, San Diego.

Pilling, G. M., S. J. Harley, N. Davies, J. Rice and J. Hampton. 2014. Status quo projections for bigeye, skipjack, and yellowfin tunas. WCPFC-SC10/SA-WP-06.

Richard, Y; Abraham, E R (2013). Risk of commercial fisheries to New Zealand seabird populations. *New Zealand Aquatic Environment and Biodiversity Report No. 109.* 58p.

Richard Y; Abraham, E R (2014). Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002-03 to 2011-12. *New Zealand Aquatic Environment and Biodiversity Report*.

Richard, Y., and Abraham, E. R. 2013. Application of Potential Biological Removal methods to seabird populations. New Zealand Aquatic Environment and Biodiversity Report No. 108. 30p.

Richard Y; Abraham, E R (in press). Assessment of the risk of commercial fisheries to New Zealand seabird, 2006-07 to 2012/13. New Zealand Aquatic Environment and Biodiversity Report in press.

Richard, Y., Abraham, E. R., and Filippi, D. 2011. Assessment of the risk to seabird populations from New Zealand commercial fisheries. Final Research Report for projects IPA2009/19 and IPA2009/20. Unpublished report held by the Ministry of Fisheries, Wellington. 137p.

Richard, Y., Abraham, E. R., and Filippi, D. 2013. Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006-07 to 2010-11. New Zealand Aquatic Environment and Biodiversity Report No. 109. 58 + 70p.

Robertson, H.A; Dowding, J.E; Elliot, G.P; Hitchmough, R.A; Miskelly, C.M; O'Donnell, C.F.J; Powlesland, R.G; Sagar, P.M; Scofield, R.P; Taylor, G.A (2013) Conservation stats of New Zealand Birds, 2012. *New Zealand Threat Classification Series 4*. Department of Conservation, Wellington. 22 p.

Rowe, S J (2009) Conservation Services Programme observer report: 1 July 2004 to 30 June 2007. *DOC Marine Conservation Services Series 1*. Department of Conservation, Wellington. 93 p.

Sharp, B., Waugh, S., Walker, N.A, 2011. A risk assessment framework for incidental seabird mortality associated with New Zealand fishing in the New Zealand EEZ., Unpublished report held by the Ministry of Fisheries, Wellington., 39 p.

Thompson, F N; Abraham, E R (2010) 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; 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*. 73p.

Waugh, S., Fillipi, D., Abraham, E., 2009. Ecological Risk Assessment for Seabirds in New Zealand fisheries, Unpublished Final Research Report for the Ministry of Fisheries 58 p.

Williams, P; Terawasi, P (2011) Overview of the tuna fisheries in the western and central Pacific Ocean, including economic conditions – 2010. Report to the Western and Central Pacific Fisheries Commission Scientific Committee WCPFC-SC7-2011/GN-WP-01. 51 p.

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