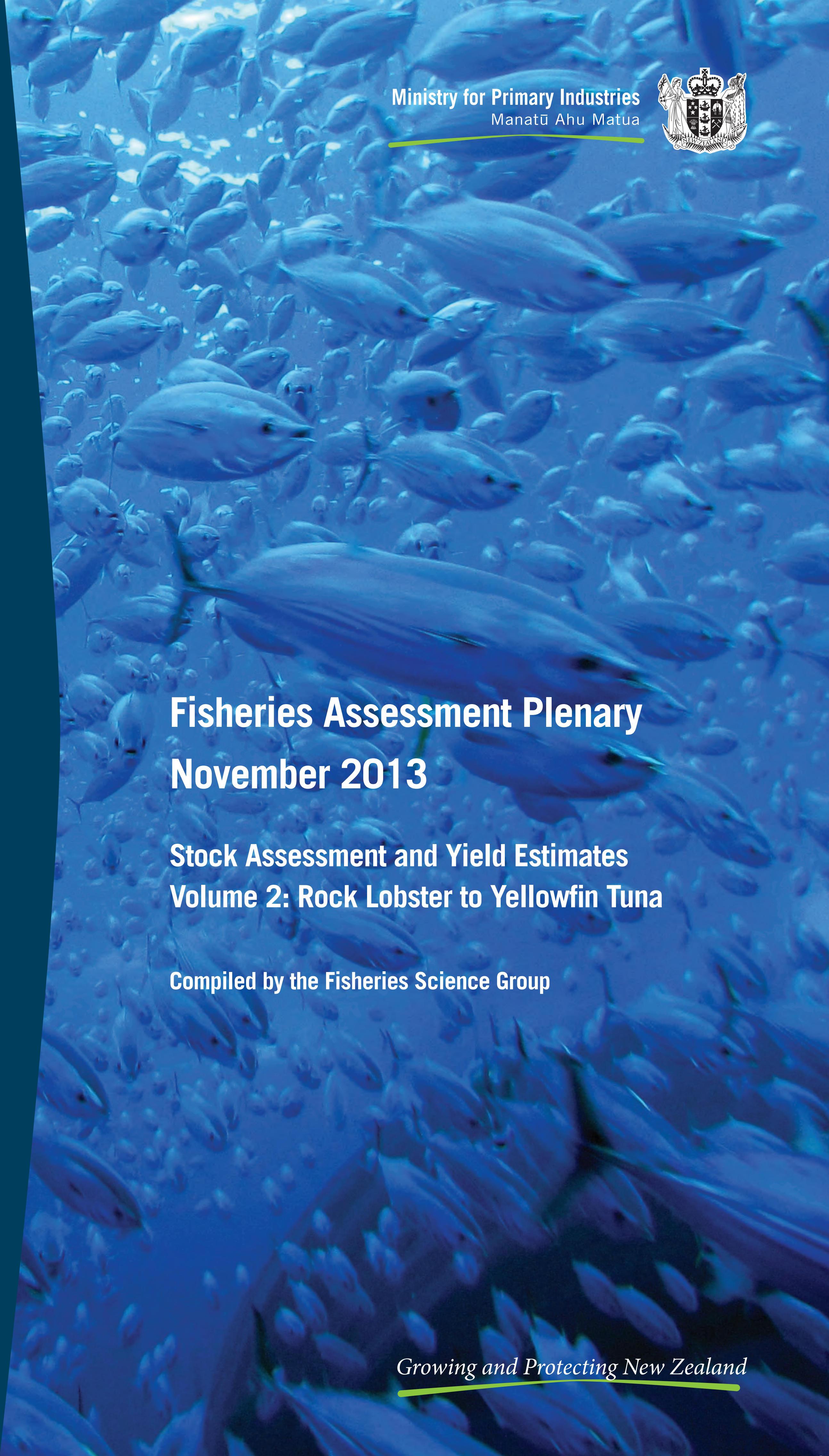

Ministry for Primary Industries
Manatū Ahu Matua

Fisheries Assessment Plenary November 2013

Stock Assessment and Yield Estimates Volume 2: Rock Lobster to Yellowfin Tuna

Compiled by the Fisheries Science Group

Growing and Protecting New Zealand

The New Zealand Government Ministry for Primary Industries
Fisheries Science Group

Fisheries Assessment Plenary

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Stock Assessments and Yield Estimates

Volume 2: Rock Lobster to Yellowfin Tuna

ISBN 978-0-478-42310-5 (print)
ISBN 978-0-478-42309-9 (online)

Compiled and published by:
Fisheries Science Group
Ministry for Primary Industries
Pastoral House, 25 The Terrace
PO Box 2526, Wellington 6140
New Zealand

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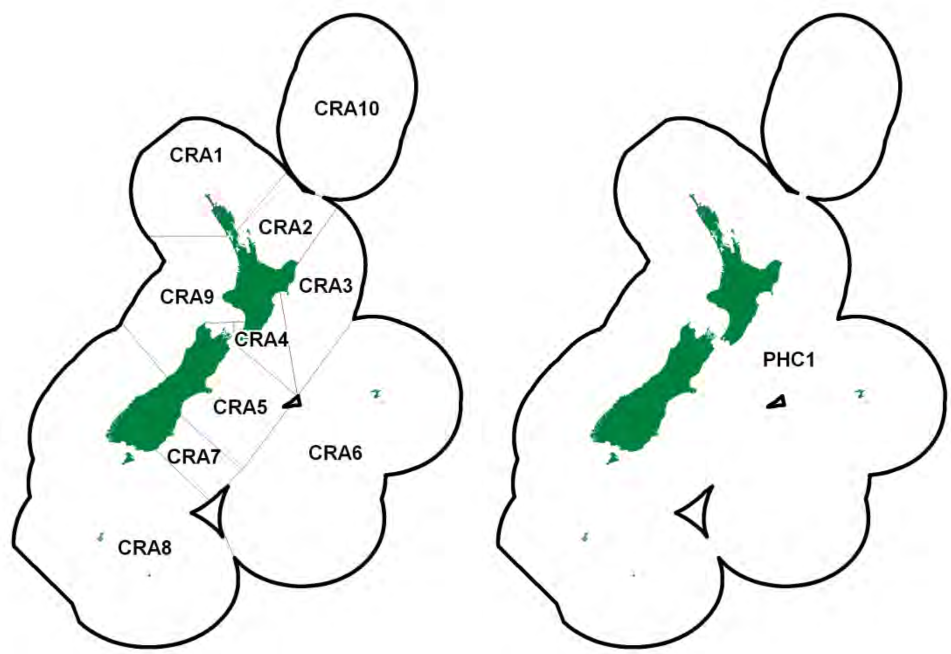
Cover design: Ministry for Primary Industries
Cover image: Courtesy of Dave Itano

Preferred citation

Ministry for Primary Industries (2013). Fisheries Assessment Plenary, Volume 2, November 2013: stock assessments and yield estimates. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 611 p.

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 five 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 five QMAs which use this methodology are CRA 3, CRA 4, CRA 5, CRA 7 and CRA 8 (see Section 4 for a detailed discussion of each rule). MPs are currently (in 2013) being evaluated for both CRA 2 and CRA 9. CRA 1 relies on formal stock assessments to make changes in catch limits, but was last assessed in 2001. Neither CRA 6 nor CRA 9 have used formal stock assessments 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 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	Unspecified	Not applicable	1991, 1992, 1993
CRA 2 (Bay of Plenty)	Formal stock assessment[1]	Unspecified[1]	Not applicable[1]	1991, 1992, 1997
CRA 3 (Gisborne)	Management procedure (MP)	5 years	2010	1991, 1992, 1993, 1996, 1997, 1998, 2005, 2009, 2012, 2013
CRA 4 (Wellington/Hawkes Bay)	Management procedure (MP)	5 years	2007 [2]	1991, 1992, 1999, 2009, 2010, 2011 , 2013
CRA 5 (Canterbury/Marlborough)	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
CRA 8 (Southern)	Management procedure (MP)	5 years	1996	1991, 1992, 1993, 1999, 2001, 2004, 2006, 2008, 2009, 2011
CRA 9 (Westland, Taranaki)	Not assessed[1]	Unspecified[1]	Not applicable[1]	1991, 1992
CRA 10 (Kermadec	Not assessed	Unspecified	Not applicable	–
PHC 1 (all NZ)	Not assessed	Unspecified	Not applicable	1991, 1992

[1] CRA 2 is being assessed in 2013 and both CRA 2 and CRA 9 are evaluating management procedures for implementation in April 2014
[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 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 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 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 CRA 8 has been 60 mm TW since mid-1992. For CRA 8, the female MLS has been 57 mm TW since 1990. The male MLS has been 54 mm TW since 1988, except in CRA 7 (MLS described above) and 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 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. In 2002, the closed season was shortened further and CRA 3 remained closed to commercial fishers only in May (May has been closed to commercial operators in CRA 3 since 1993). From 2014, the May closure will no longer apply. 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 2008-09.

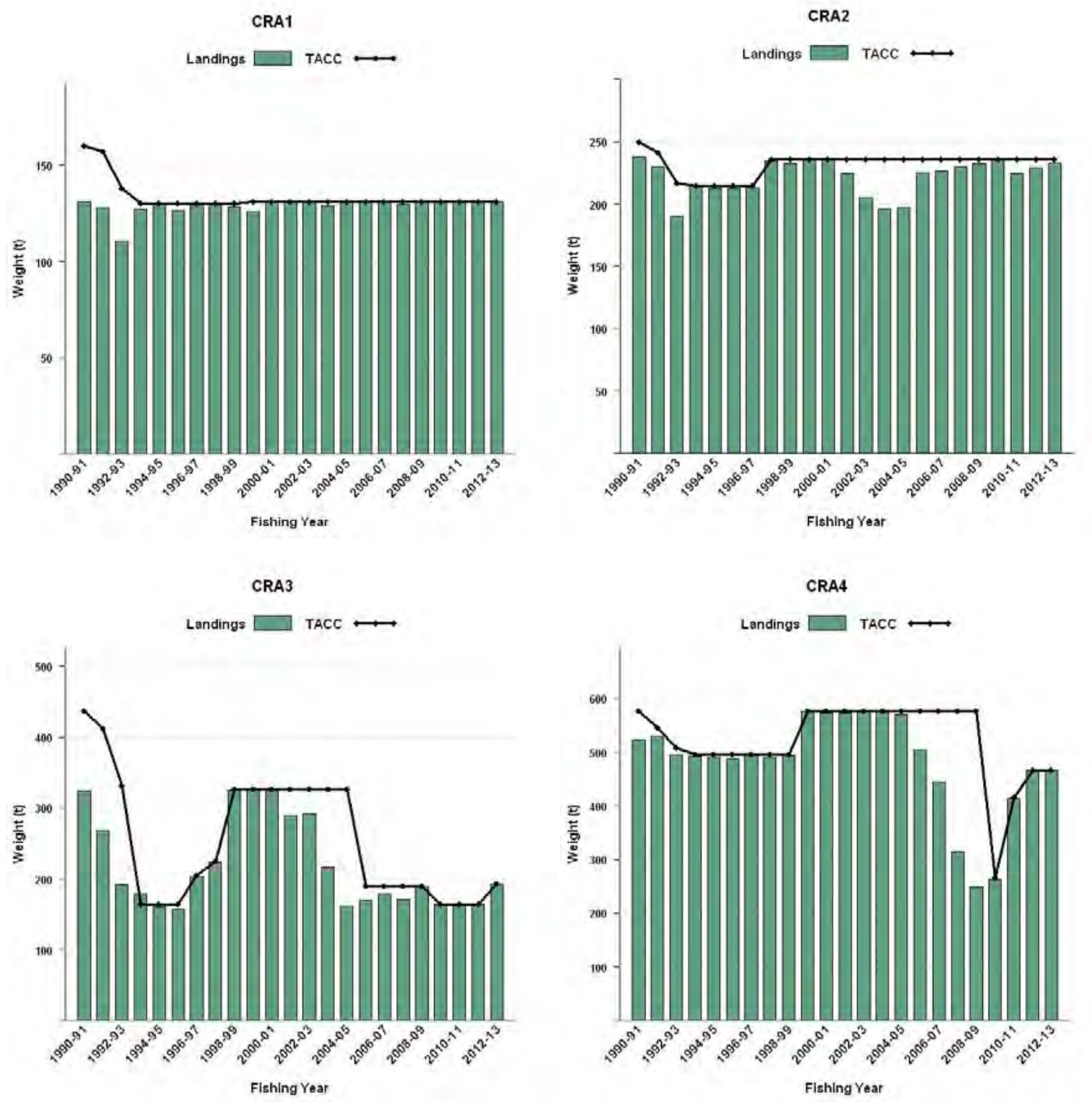


Figure 1: Historical landings and TACC for the 9 main CRA stocks and PHC 1. [Figure continued on next page].

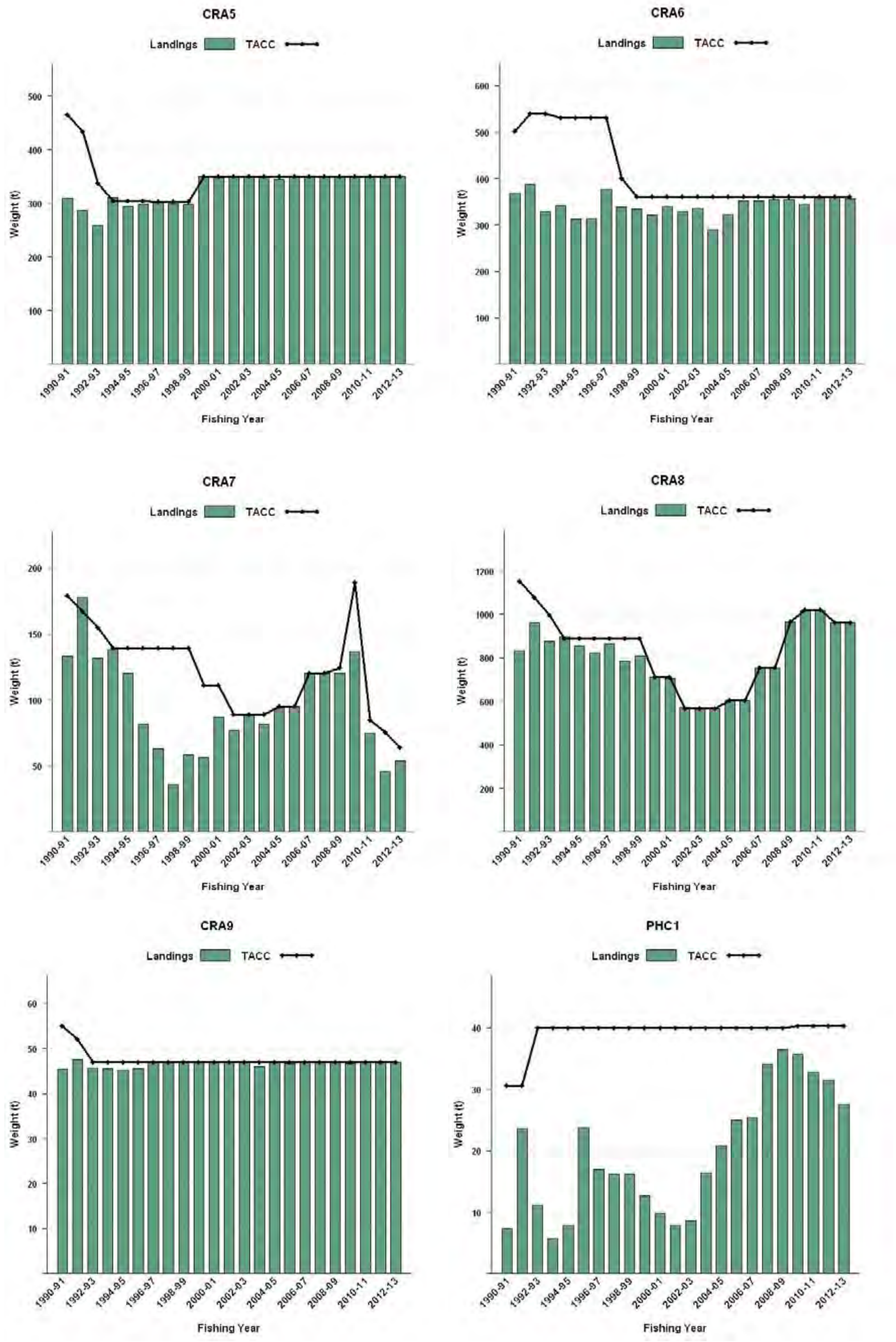


Figure 1 [Continued]: Historical landings and TACC for the 9 main CRA stocks and PHC 1.

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; N/A: 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	146.8	–	229.7	229.4	–	268.8	397.7	–	530.5	529.8	–
1992–93	110.5	137.4	–	190.3	214.6	–	191.5	327.5	–	495.7	495.7	–
1993–94	127.4	130.5	–	214.9	214.6	–	179.5	163.7	–	492.0	495.7	–
1994–95	130.0	130.5	–	212.8	214.6	–	160.7	163.7	–	490.4	495.7	–
1995–96	126.7	130.5	–	212.5	214.6	–	156.9	163.7	–	487.2	495.7	–
1996–97	129.4	130.5	–	213.2	214.6	–	203.5	204.7	–	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	131.1	–	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	–	226.7	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	771.0
2008–09	131.0	131.1	–	232.3	236.1	452.6	189.8	190.0	319.0	249.4	577.0	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	–	233.0	236.1	452.6	193.3	193.3	322.3	466.3	466.9	661.9
2013–14		131.1	–		236.1	452.6		225.5	354.5		499.7	694.7

	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	518.2	–	133.4	179.4	–	834.5	1152.4	–
1991–92	287.4	426.8	–	388.3	503.0	–	177.7	164.7	–	962.7	1054.6	–
1992–93	258.8	336.9	–	329.4	503.0	–	131.6	153.1	–	876.5	986.8	–
1993–94	311.0	303.2	–	341.8	530.6	–	138.1	138.7	–	896.1	888.1	–
1994–95	293.9	303.2	–	312.5	530.6	–	120.3	138.7	–	855.6	888.1	–
1995–96	297.6	303.2	–	315.3	530.6	–	81.3	138.7	–	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	359.1	360.0	370.0	45.7	75.7	95.7	961.2	962.0	1053.0
2012–13	350.0	350.0	467.0	355.6	360.0	370.0	53.8	63.9	83.9	960.8	962.0	1053.0
2013–14		350.0	467.0		360.0	370.0		44.0	64.0		962.0	1053.0

Fishing Year	CRA 9 Catch	CRA 9 TACC	CRA 9 TAC	Total Catch[1]	Total TACC[1]	Total TAC[1]
1990–91	45.3	54.7	–	2907.4	3793.0	–
1991–92	47.5	50.2	–	3020.9	3502.9	–
1992–93	45.7	47.0	–	2629.9	3201.9	–
1993–94	45.5	47.0	–	2746.2	2912.1	–
1994–95	45.2	47.0	–	2621.5	2912.1	–
1995–96	45.4	47.0	–	2548.6	2912.1	–
1996–97	46.9	47.0	–	2690.5	2953.1	–
1997–98	46.7	47.0	–	2584.2	2864.1	1312.0
1998–99	46.9	47.0	–	2726.0	2926.8	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	–	2604.8	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	–	2752.5	2792.8	3393.2
2012–13	47.0	47.0	–	2790.7	2810.3	3410.7
2013–14		47.0	–		2855.4	3455.8

[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 2012–13. Sources of data: from 1979–80 to 1988–89 from the QMS-held FSU data; from 1989–90 to 2012–13 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 (2013) 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	0.822	0.516	0.787	0.823	0.615	2.188	0.981	1.969	1.248
1980–81	0.987	0.620	0.873	0.798	0.748	2.017	0.863	1.711	1.357
1981–82	0.928	0.516	0.862	0.854	0.666	2.297	0.734	1.645	1.029
1982–83	1.004	0.430	0.931	0.920	0.734	1.659	0.473	1.408	0.859
1983–84	0.952	0.352	0.851	0.836	0.656	1.627	0.409	1.062	0.885
1984–85	0.884	0.341	0.689	0.758	0.664	1.299	0.548	1.027	0.844
1985–86	0.825	0.395	0.658	0.724	0.545	1.371	0.731	1.215	0.750
1986–87	0.807	0.357	0.572	0.769	0.481	1.504	0.836	1.080	0.869
1987–88	0.755	0.312	0.406	0.672	0.403	1.322	0.705	1.136	0.885
1988–89	0.662	0.339	0.418	0.566	0.352	1.267	0.414	0.851	0.880
1989–90	0.690	0.345	0.454	0.557	0.374	1.125	0.334	0.835	–
1990–91	0.600	0.472	0.431	0.513	0.363	1.177	0.430	0.812	0.824
1991–92	0.685	0.417	0.290	0.514	0.301	1.227	0.993	0.796	0.858
1992–93	0.603	0.389	0.245	0.494	0.296	1.122	0.400	0.675	0.930
1993–94	0.665	0.429	0.504	0.540	0.358	1.029	0.618	0.897	1.164
1994–95	0.849	0.516	0.988	0.690	0.375	1.004	0.464	0.799	0.935
1995–96	1.176	0.724	1.573	0.907	0.447	1.047	0.294	0.862	1.351
1996–97	0.998	0.927	1.971	1.219	0.604	1.081	0.250	0.807	1.138
1997–98	0.972	1.077	2.496	1.418	0.854	1.035	0.180	0.690	1.057
1998–99	1.067	1.089	2.104	1.617	1.096	1.276	0.260	0.706	1.405
1999–00	0.897	0.845	1.971	1.459	1.119	1.278	0.228	0.754	0.949
2000–01	1.153	0.750	1.370	1.367	1.318	1.217	0.350	0.915	1.187
2001–02	1.197	0.544	1.042	1.170	1.502	1.199	0.505	0.987	1.126
2002–03	1.123	0.427	0.689	1.203	1.571	1.308	0.612	1.150	1.473
2003–04	1.061	0.434	0.567	1.239	1.632	1.261	0.602	1.714	1.713
2004–05	1.339	0.509	0.454	0.944	1.441	1.441	0.897	1.880	2.114
2005–06	1.365	0.473	0.562	0.811	1.351	1.502	1.302	2.291	2.067
2006–07	1.710	0.551	0.567	0.672	1.439	1.754	1.802	2.775	2.132
2007–08	1.776	0.553	0.589	0.587	1.493	1.549	1.565	3.041	1.745
2008–09	1.726	0.510	0.675	0.741	1.582	1.685	1.734	4.076	1.299
2009–10	1.721	0.441	0.890	1.036	1.926	1.474	1.099	3.927	1.556
2010–11	1.521	0.394	1.216	1.032	1.901	1.550	0.814	3.208	2.270
2011–12	1.505	0.376	1.762	1.249	1.871	1.527	0.701	3.159	1.950
2012–13	1.678	0.406	2.445	1.405	1.906	1.525	0.692	3.207	2.888

Problems with rock lobster commercial catch and effort data

There are two types of data on the 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 may show 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 2013). 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 in prep.). 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 (2013).

Descriptions of Fisheries

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

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 presently has the lowest CPUE of all nine CRA QMAs, and has been below 0.5 kg/potlift for 7 of the most recent 12 fishing years.

CRA 2 extends from Bream Bay, south of Whangarei, to East Cape at the easternmost end of the Bay of Plenty (Figure 2). This QMA includes the Hauraki Gulf, both sides of the Coromandel and all of the Bay of Plenty. Commercial fishing is primarily confined to the Bay of Plenty, extending to East Cape, and the eastern side of the Coromandel Peninsula. There is also commercial fishing around Great Barrier Island.

A TAC was first set for CRA 2 in 1997–98 when the TACC was raised in response to the strong increase in abundance observed in the latter half of the 1990s (Table 2). The TAC and TACC have remained unchanged for this QMA since that year. Commercial landings have remained close to the 236 t TACC, except for a period of about three years in the early 2000s when catches dropped near to or below 200 t (Table 2).

In the 2011–12 fishing year there were 35 vessels operating in CRA 2, a total that has been relatively constant since the mid-1990s (Starr 2013).

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

Trends in CPUE 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. Both CRA 3 and CRA 4 are now approaching the high levels observed in the late 1990s. The 2012–13 CRA 3 CPUE is the second highest in the series, very closely approaching the peak in 1997–98. CRA 4 has not yet reached such a high level, but CPUE in this QMA exceeds 1.4 kg/potlift in 2012–13. CRA 5 has remained high throughout the 2000s (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 1.8 kg/potlift in 2006–07, the highest value since the mid-1990s.

Jasus edwardsii, CRA 7 and CRA 8

Catch rates are low in CRA 7 compared with those in CRA 8. 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 34 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. Both these QMAs showed almost no change between 2011–12 and 2012–13.

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 2004–05, with CPUE exceeding 2 kg/potlift. CPUE dropped to a low of 1.3 kg/potlift in 2008–09 but has since risen to 2.9 kg/potlift in 2012–13 (Table 2).

Jasus edwardsii CPUE by statistical area

Table 3 shows the CPUE for the most recent six years within each CRA QMA for each rock lobster statistical area reported on the CELR forms (Figure 2). The values of CPUE and the trends in the fisheries vary within and between CRA areas.

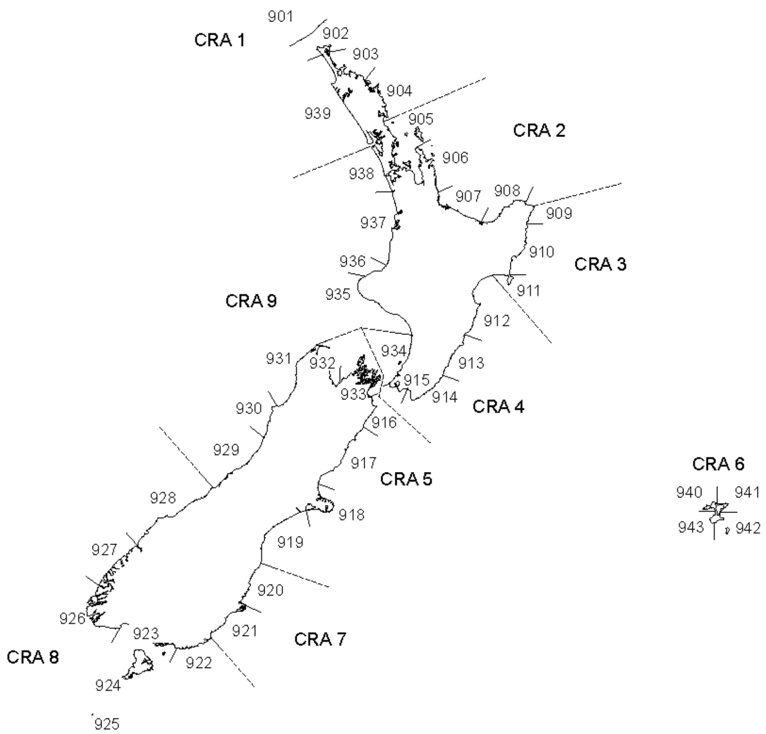


Figure 2: Rock lobster statistical areas as reported on CELR forms.

Table 3: 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	07/08	08/09	09/10	10/11	11/12	12/13	CRA	Stat Area	07/08	08/09	09/10	10/11	11/12	12/13
1	901	3.53	3.88	3.64	2.95	2.77	2.58	6	940	1.36	1.42	1.13	1.37	1.32	1.68
1	902	2.16	2.16	2.36	1.84	1.39	1.45	6	941	1.10	1.35	1.18	1.33	1.32	1.57
1	903	1.39	0.99	1.07	0.86	0.76	1.38	6	942	1.92	1.64	1.67	1.37	1.61	1.48
1	904	0.62	–	–	–	0.46	0.54	6	943	1.34	1.53	1.25	1.49	1.49	1.83
1	939	1.08	1.23	2.15	1.43	1.89	2.98	7	920	1.20	2.37	0.98	0.67	0.69	0.64
2	905	0.56	0.60	0.51	0.40	0.37	0.43	7	921	2.12	2.57	1.84	1.11	0.62	0.65
2	906	0.54	0.45	0.39	0.38	0.35	0.37	8	922	–	–	–	–	–	–
2	907	0.64	0.83	0.70	0.61	0.57	0.51	8	923	2.60	3.77	–	–	–	–
2	908	0.43	0.49	0.45	0.42	0.47	0.44	8	924	3.46	4.08	4.26	3.61	4.05	3.88
3	909	1.02	1.10	1.13	1.29	1.52	–	8	925	4.15	–	–	–	–	2.69
3	910	0.60	0.75	0.94	1.18	1.43	1.81	8	926	2.73	3.33	2.77	2.77	3.33	3.19
3	911	0.48	0.57	0.73	1.02	1.69	2.34	8	927	3.33	3.86	3.95	2.33	2.47	3.68
4	912	0.62	0.69	0.73	0.76	0.87	0.88	8	928	4.58	6.23	5.45	4.40	4.57	5.02
4	913	0.74	0.81	1.10	1.23	1.58	1.93	9	929	–	–	–	–	–	–
4	914	0.43	0.55	1.08	1.08	1.32	1.59	9	930	–	–	–	–	–	–
4	915	0.80	0.84	1.30	0.94	1.31	1.37	9	931	2.26	–	–	2.86	–	–
4	934	0.90	–	–	–	2.04	–	9	935	1.63	3.37	1.45	2.68	3.23	6.77
5	916	2.14	2.33	2.23	2.32	2.15	1.37	9	936	1.78	–	–	–	–	–
5	917	1.37	1.47	2.25	2.38	2.75	2.64	9	937	–	–	–	–	–	–
5	918	–	1.82	–	–	–	–	9	938	–	–	–	–	–	–
5	919	–	–	–	–	–	–								
5	932	–	–	–	–	–	–								
5	933	0.73	0.76	0.74	0.76	0.72	0.73								

Sagmariasus verreauxi, PHC stock

QMS reported landings of the PHC stock halved between 1998–99 and 2001–02 and were below 30 t/year to 2007–08 (Table 4). Landings have exceeded 30 t/year since 2007–08.

Table 4: Reported landings and TACC for *Sagmariasus verreauxi* 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			

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

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 provided estimates in numbers of fish captured and used mean weights of rock lobster obtained from fish measured at boat ramps to convert the estimates to captures by weight.

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.).

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

The harvest estimates provided by these 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 and 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 [1]	1945	2001	47.19	Ramped from 1945; constant from 1979	10	Constant from 1945
CRA 2 [6]	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 [2]	1945	2007	20.0	Constant from 1945	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	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 (2003); [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 (in prep)

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 and CRA 2 [1]	Mean of 1994 and 1996 recreational survey estimates in numbers X 1994/96 SS mean weight from catch sampling	MPI Compliance estimate
CRA 2	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]	By WG agreement	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	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 (2003); [2] Breen et al (2009); [3] see Section 5; [4] Starr et al (2011); [5] Breen et al (2007)

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. The panel members were contacted regularly about their fishing activities and catch information was collected using standardised phone interviews.

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 2 and CRA 9 recreational catch

Recreational catch estimates were required for the 2013 CRA 2 assessment and the 2013 CRA 9 Management Procedure evaluation. The RLFAWG agreed to use an approach consistent with that used in 2010 for CRA 5, in 2011 for CRA 4 and in 2012 for CRA 7 and CRA 8, allowing recreational catch to vary with abundance, as reflected by the spring-summer standardised CPUE index series. Recreational catches in CRA 2 and CRA 9 were calculated by year using the algorithm documented in Equation 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 2 and CRA 9. '–': not used.

Category	CRA 2	CRA 9
Catch estimates in numbers		
1994	142 000	–
1996	223 000	–
2011	58 500	15 500
Derived values		
1994/1996 SS mean weight (kg)	0.672	–
1994 catch estimate (t)	95.424	–
1996 catch estimate (t)	149.856	–
2011 mean weight (kg) [1]	0.701	1.16
2011 catch estimate (t)	40.86	17.96
Reconstructed catch in 1979 (t)	75.72	10.19
20% of 1979 catch (t)	15.14	2.04
Maximum Section 111 catch (t)	1.37	2.26
Estimate of 2012–13 charter boat catches (t)	1.18	–

[1]Hartill (NIWA, pers.comm.)

This algorithm is similar to that adopted by the RLFAWG for the 2011 CRA 4 and the 2012 CRA 7 and CRA 8 stock assessments, which bases the scaling on the standardised SS CPUE for each QMA. This was done in acknowledgement that the recreational fisheries in these QMAs are spread over a large part of each QMA rather than being concentrated in one statistical area (as was assumed for the CRA 5 assessment).

Equation 1

$$^{q}W_{y} = {}^{q}w_{y}\ {}^{q}N_{y}$$
$$^{\mathrm{CRA2}}S \ = \left({}^{\mathrm{CRA2}}W_{94} \big/ {}^{\mathrm{CRA2}}CPUE_{94} + {}^{\mathrm{CRA2}}W_{96} \big/ {}^{\mathrm{CRA2}}CPUE_{96} + {}^{\mathrm{CRA2}}W_{11} \big/ {}^{\mathrm{CRA2}}CPUE_{11} \right) \big/ 3$$
$$^{\mathrm{CRA9}}S \ = {}^{\mathrm{CRA9}}W_{11} \big/ {}^{\mathrm{CRA9}}CPUE_{11}$$
$$^{q}\hat{W}_{i} = {}^{q}S * {}^{q}CPUE_{i} \ \text{ if } i >= 1979$$
$$^{q}\hat{W}_{1945} = 0.2 * {}^{q}\hat{W}_{1979}$$
$$^{q}\hat{W}_{i} = {}^{q}\hat{W}_{i-1} + \frac{({}^{q}\hat{W}_{1979} - {}^{q}\hat{W}_{1945})}{(1979-1945)} \ \text{ if } i > 1945 \,\&\, i < 1979$$

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

For CRA 2, the resulting recreational catch trajectory (Figure 3) reflects the low abundances in the 1980s and the early 1990s, followed by a strong increase in the mid to late 1990s and a subsequent drop from which there has been no increase. The largest annual catches after 1979–80 were estimated to be near to or greater than 140 t from 1996–97 to 1999–00. Since then recreational catches are estimated to have dropped below 100 t/year, with the most recent year (2012–13) estimated to be 58 t, which includes the additional Section 111 landings (see following Section) and estimated recreational charter catches. CRA 9 recreational catches reflect recent increases in CPUE in this QMA, nearly doubling the long-term average of 11 t/year to 20 t/year from 2004–05. An error was found in the National Panel survey area designations for CRA 9, resulting in a decrease between the recreational catch estimates used when evaluating the MPE and the corrected estimates. Although this resulted in a 26% drop in estimated total CRA 9 recreational catch, the drop in the total catch used in the MPE was only 2%, after commercial, illegal and customary catches were added.

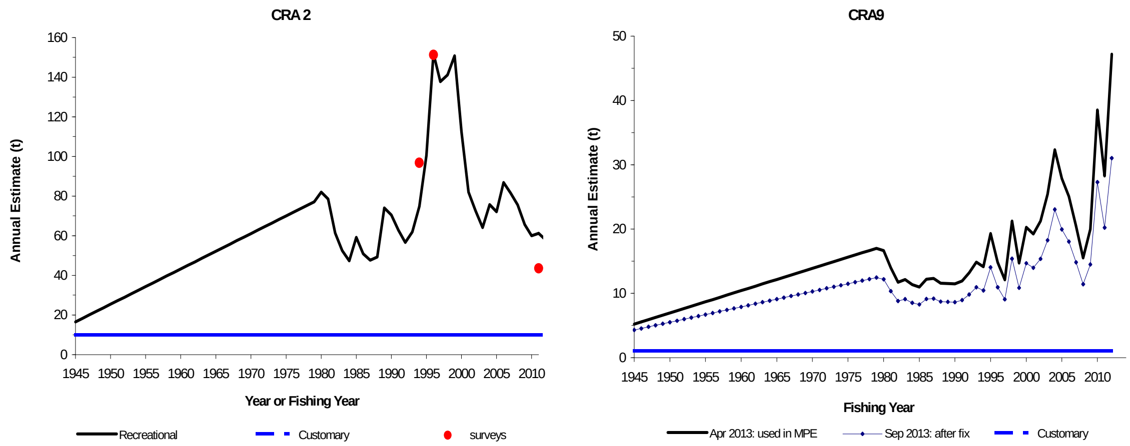


Figure 3. Recreational (grey) and customary (blue) catch trajectories (kg) for the 2013 stock assessment of CRA 2 [left panel] and Management Procedure Evaluation of CRA 9 [right panel]. Section 111 catches have been added to each recreational catch trajectory. Recreational catches were made proportional to the standardised SS CPUE after 1979, scaled to the mean catch weight estimated from the relevant recreational diary surveys. CRA 9 recreational catches are shown before and after an error in the area assignments were fixed (see text).

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	–	–	–	–	–	–	–	–
1999–00	–	–	–	–	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	4 828	473	80	14 913	1 899
2012–13	4 208	1 189	2 576	5 831	7 214	1 027	93	15 827	1 847
Maximum	5 016	1 370	2 576	5 831	7 214	1 027	1 688	15 827	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 stock assessment, 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 a 10 tonne constant customary catch estimate for CRA 2.

Given this information, the 2013 CRA 2 stock assessment used constant catch levels of 10 t/year to represent the customary catches (Table 6; Figure 3). Table 6 presents the customary catch estimates used in all recent rock lobster stock assessments and Table 7 present 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																		

MPI has provided estimates of current and historical illegal catches for the CRA 2 stock assessment, as well as an estimate 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 88 tonne estimate of illegal catch is used in the upcoming CRA 2 stock assessment and sensitivity analyses are carried out with half of the illegal catch estimate (i.e. 44 tonnes).

Given this advice from MPI, the CRA 2 stock assessment used constant illegal catches of 88 t/year to fill in the missing years between 2002 to 2012 (Table 10).

Illegal catch estimates prior to 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.

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.

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	–

1.8 Time series of mortalities

Plots of rock lobster catches from 1945 are presented in Figure 4. Commercial catches prior to 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 easily 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.

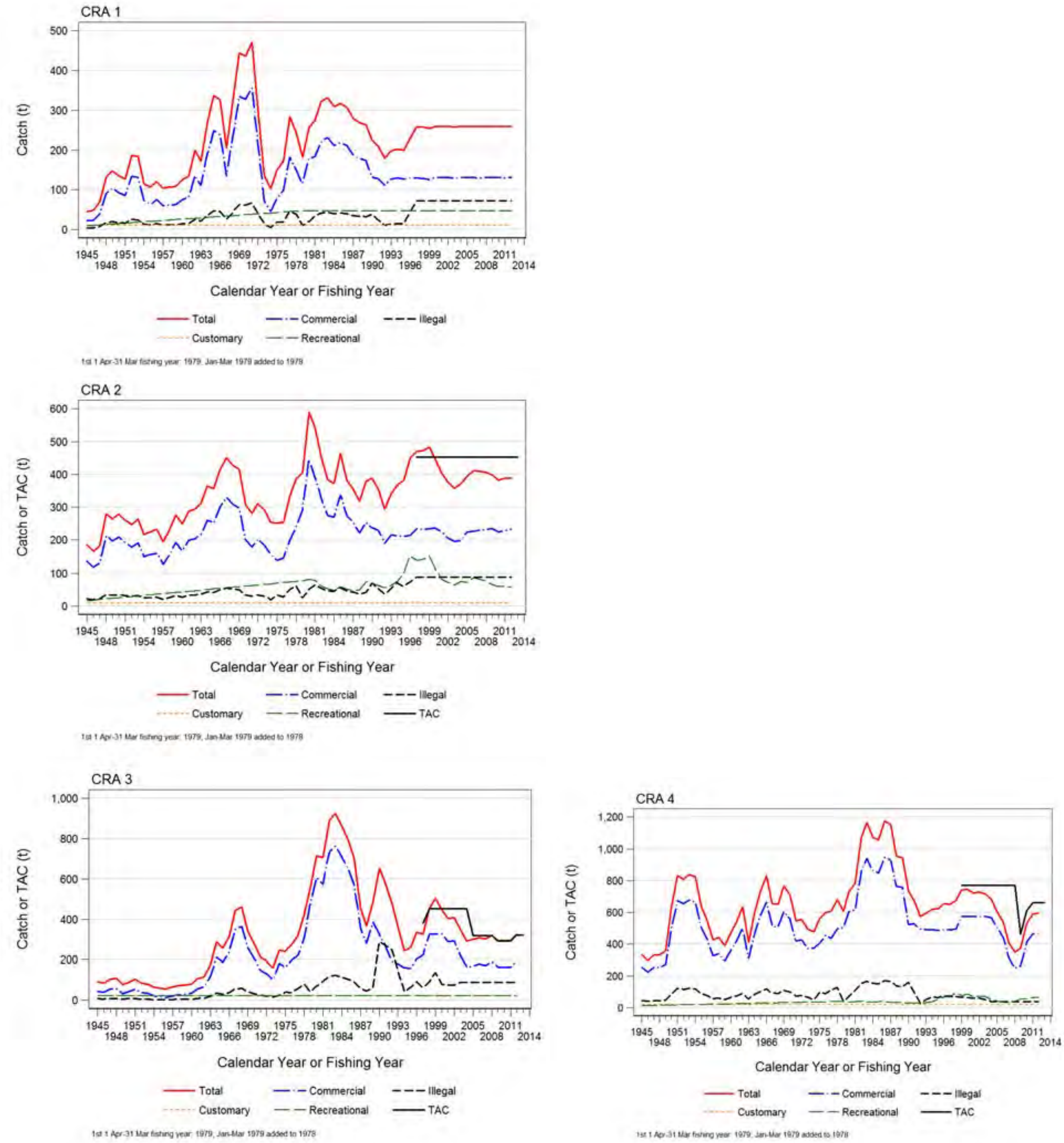


Figure 4: Catch trajectories (t) from 1945 to 2011 and TACs (if in place) from the year of establishment to 2012 for CRA 1 to CRA 9, showing current best estimates for commercial, recreational, customary and illegal categories. Also shown is the sum of these four catch categories. Note that calendar 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. [Figure continued on next page].

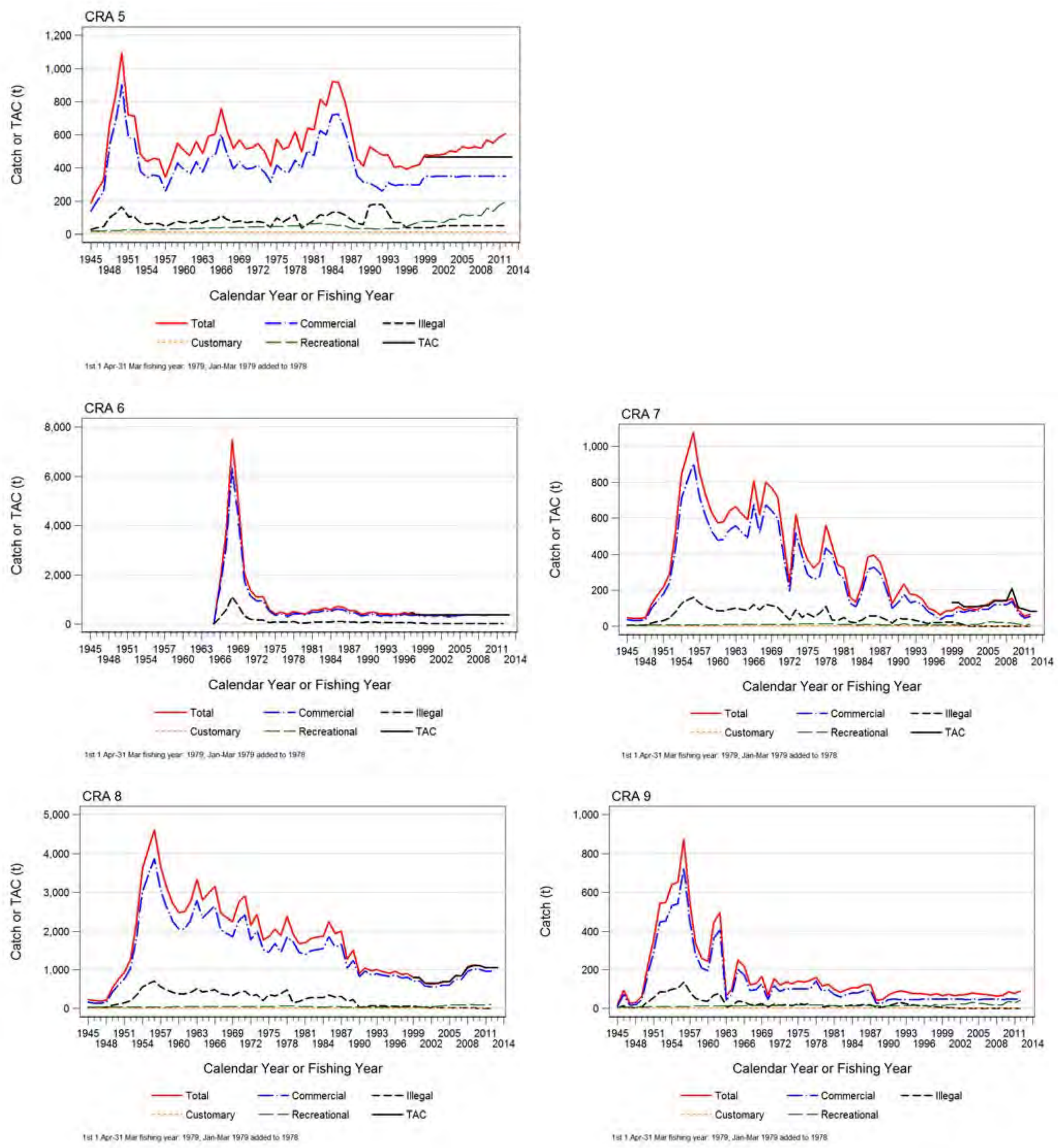


Figure 4 [Continued]: Catch trajectories (t) from 1945 to 2011 and TACs (if in place) from the year of establishment to 2012 for CRA 1 to CRA 9.

Table 12: Values used for some biological parameters.

1. Natural mortality (M) [1]

Area	Both Sexes
CRA 1, 2 ,3, 4, 5	0.12
NSS	0.12

[1] This value has been used as the mean of an informative prior; M was estimated as a parameter of the model.

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, 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 catch of the puerulus from each collector are used as the basis for producing a standardised index of settlement (Forman et al 2013). 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	Jackson Bay	Wharf (JAC001)	1999–Present	5
		Jackson Head (JAC002)	1999–2006	3

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

	Gisborne CRA 3	Napier CRA 4	Castlepoint CRA 4	Kaikoura CRA 5	Moeraki CRA 7	Halfmoon Bay CRA 8	Jackson Bay CRA8
1979	-	0.84	-	-	-	-	-
1980	-	1.52	-	-	-	-	-
1981	-	2.05	-	1.17	-	8.06	-
1982	-	1	-	0.02	-	0.38	-
1983	-	1.24	1.43	0.74	-	4.5	-
1984	-	0.41	1.37	0.24	-	0.38	-
1985	-	0.19	0.88	0.34	-	0.00	-
1986	-	-	0.51	0.11	-	0.11	-
1987	-	-	1.72	1.18	-	1.61	-
1988	-	1.5	0.99	0.52	-	0.2	-
1989	-	1.08	1.55	0.86	-	0.54	-
1990	-	1.14	0.95	0.28	-	0.44	-
1991	1.67	2.27	1.98	5.71	0.00	0.84	-
1992	2.41	2.41	2.46	6.57	0.15	0.62	-
1993	2.05	1.91	1.49	3.31	0.00	0.00	-
1994	3.13	1.43	0.95	0.9	0.00	1.11	-
1995	1.22	1.06	0.9	1.05	0.12	0.32	-
1996	1.14	1.69	1.33	0.79	1.13	0.32	-
1997	1.18	1.3	1.16	1.63	0.67	0.53	-
1998	1.62	1.1	1.7	2.2	0.66	0.27	-
1999	0.11	0.29	0.35	1.49	0.14	0.24	0.61
2000	1.06	0.66	0.5	1.3	3.88	1.2	0.62
2001	1.28	1.33	0.77	0.48	2.42	1.71	0.73
2002	1.24	1.18	0.73	1.26	0.95	1.31	2.37
2003	2.47	1.34	0.77	5.31	7.42	3.5	1.25
2004	0.86	1.06	0.66	1.82	0.45	0.15	0.27
2005	2.79	1.29	1.18	2.37	0.11	0.00	2.72
2006	0.41	0.59	0.65	1.98	0.06	0.13	0.62
2007	0.35	1.04	0.9	1.3	0.04	0.45	0.35
2008	0.77	0.59	0.9	2.51	0.09	0.09	0.27
2009	1.17	0.76	0.93	0.5	0.52	0.96	0.21
2010	0.62	1.31	1.63	2.03	1.43	1.7	3.77
2011	0.25	0.36	0.9	0.47	0.93	0.13	3.49
2012	0.67	0.79	0.66	1.67	0.86	0.21	10.54

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 3, CRA 4, CRA 5, CRA 7 and CRA 8 management procedures (MP) for the 2014–15 fishing year, based on CPUE data extracted in early November 2013 and standardised as described below. Revised management procedures for CRA 7 and CRA 8 were implemented in 2013 and are new to this section of the Report. New MPs have been developed for CRA 2 and CRA 9 in 2013, and may be used to set catch limits for the 2013–14 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 2012 to 30 September 2013 to produce a proposed a TAC or TACC (depending on the rule) for the fishing year, which begins on 1 April 2014 and extends to 31 March 2015.

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.

4.3 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. 1A $$TAC'_{y+1} = 275\left(\frac{I_y + 3}{4}\right)^3$$ **for** $0 < I_y \le 1$ **and**

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

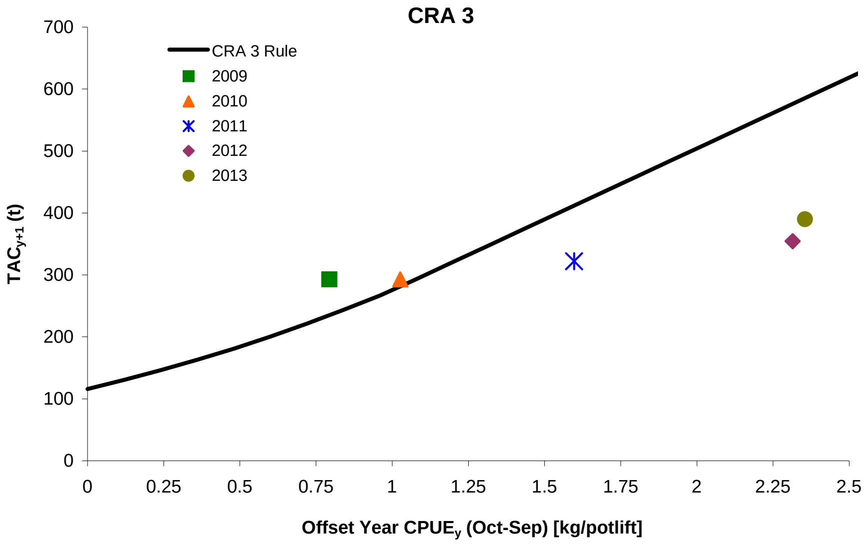


Figure 5: The CRA 3 management procedure, showing the provisional TAC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACs resulting from the rule evaluations performed in 2009 through 2013 for the 2010–11, 2011–12, 2012–13, 2013-14 and 2014–15 fishing years.

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 5, 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. The standardised offset-year CPUE for 2008–09 was 0.794 kg/pot. Because this was greater than the 0.75 kg/potlift threshold and less than the 1.08 kg/potlift threshold, the 2010–11 TAC remained at the conditional initial fixed TAC of 293 t. The TACC was determined by subtracting non-commercial allowances of 129 t, to obtain 164 t (Table 15). In November 2011, standardised offset-year CPUE was 1.597 kg/potlift, above the upper threshold of 1.08 kg/potlift, so the fixed initial TAC expired. The provisional TAC was 411.74 t; this was a greater increase than the maximum of 10%, so the TAC was increased by 10% to 322.3 t.

Table 15: History of the CRA 3 management procedure and proposed TAC limit in the 2014-15 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 (proposed)	2.355	389.95	–	–

In November 2012, the standardised offset-year CPUE was 2.314 kg/potlift. The TAC was determined by the harvest control rule equation 2B, which evaluated to a TAC of 576.20 t. This was a greater increase than the maximum increase of 10%, so the TAC could increase only by 10% to 354.53 t, which the Minister rounded down to 354.5 t. In November 2013, the standardised offset-year CPUE was 2.355 kg/potlift. The TAC was determined by the harvest control rule equation 2B, which evaluated to a TAC of 585.54 t. This was a greater increase than the maximum increase of 10%, so the TAC could increase only by 10% to 389.95 t.

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:

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 “L” destination code using the “B4” data preparation procedure

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

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

Figure 6 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 3A); between a CPUE of 0.5 and 0.9 kg/potlift, the TACC increases linearly with CPUE to a plateau of 467 tonnes (Equation 3B), which extends to a CPUE of 1.3 kg/potlift (Equation 3C). 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 3D).

Eq. 2A $TACC'_{y+1} = 0$ **for** $I_y \le 0.5$

Eq. 2B $TACC'_{y+1} = \left(\frac{467}{0.9-0.5}\right)\left(I_y - 0.5\right)$ **for** $0.5 < I_y \le 0.9$

Eq. 2C $TACC'_{y+1} = 467$ **for** $0.9 < I_y \le 1.3$

Eq. 2D $TACC'_{y+1} = 467\left(1.07^{\mathrm{int}\left(\left(I_y-1.3\right)/0.1\right)+1}\right)$ **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 input CPUE for 2010-11 was 1.194, giving a TACC of 466.9 t and a TAC of 661.9 t when the non-commercial allowances of 195 t were added (Table 16). For 2013–14, the rule generated a proposed TACC of 499.69 t. In November 2013, the standardised offset-year CPUE was 1.293 kg/potlift. The rule generated a proposed TACC of 467 t for 2014–15, a drop of 33 t compared with 2013–14.

Table 16: History of the CRA 4 management procedure and proposed limit to the commercial fishery in the 2014–15 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 (proposed)	1.293	467.0	–	–

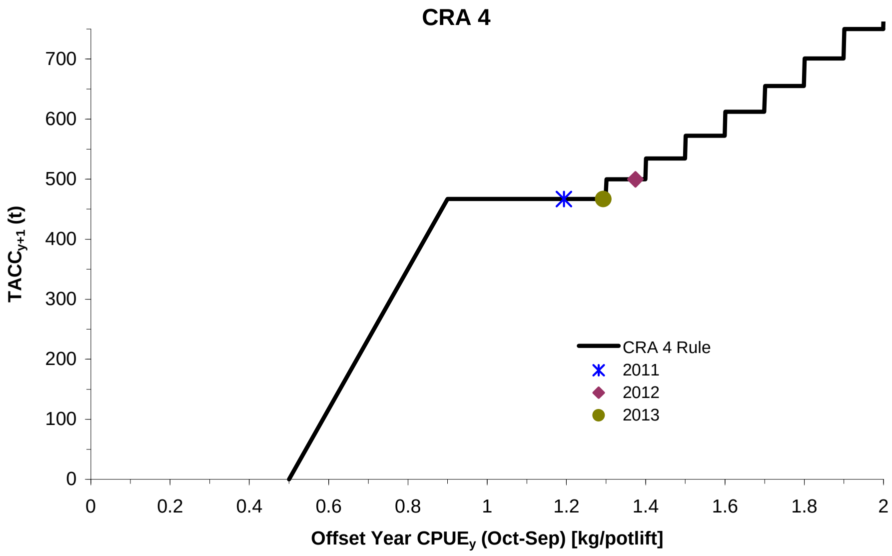


Figure 6: The CRA 4 management procedure, showing the TACC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACCs resulting from the rule evaluations performed in 2011, 2012 and 2013 for the 2012–13, 2013–14 and 2014–15 fishing years.

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 7 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 4A); between a CPUE of 0.3 and 1.4 kg/potlift, the TACC increases linearly with CPUE to a plateau of 350 tonnes (Equation 4B), which extends to a CPUE of 2.0 kg/potlift (Equation 4C). 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 4D).

Eq. 3A $TACC'_{y+1} = 0$ **for** $I_y \le 0.3$

Eq. 3B $TACC'_{y+1} = \left(\frac{350}{1.4-0.3}\right)\left(I_y - 0.3\right)$ **for** $0.3 < I_y \le 1.4$

Eq. 3C $TACC'_{y+1} = 350$ **for** $1.4 < I_y \le 2.0$

Eq. 3D $TACC'_{y+1} = 350\left(1.05^{\mathrm{int}\left(\left(I_y-2.0\right)/0.2\right)+1}\right)$ **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.

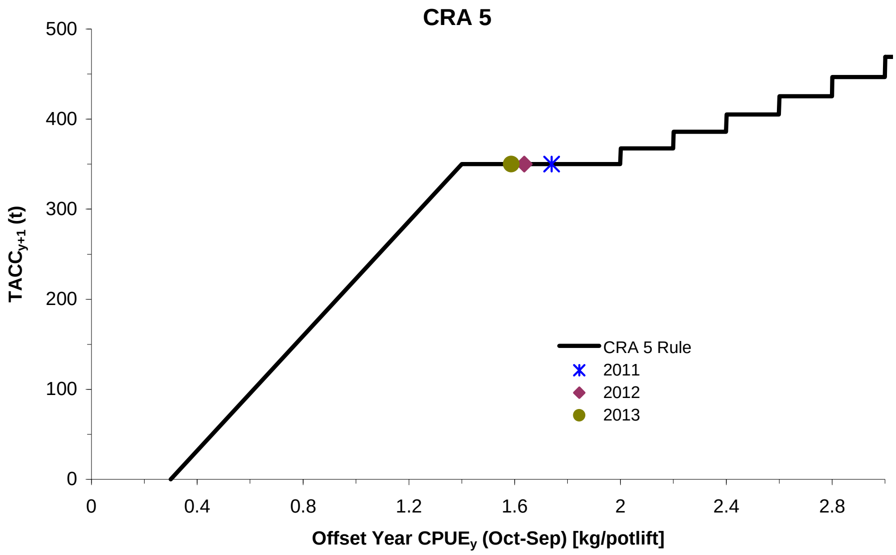


Figure 7: The CRA 5 management procedure, showing the TACC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACCs resulting from the rule evaluations performed in 2011, 2012 and 2013 for the 2012–13, 2013-14 and 2014–15 fishing years.

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 17). In November 2013, the standardised offset-year CPUE was 1.587 kg/potlift. The rule generated a proposed TACC of 350 t for 2014–15, unchanged from 2013–14 because the CPUE lies on the rule plateau (Figure 7).

Table 17: History of the CRA 5 management procedure and proposed limit to the commercial fishery in the 2014–15 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 (proposed)	1.587	350	–	–

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 18. In 2013 the Minister adopted rule 39, for which the specific parameter values are also shown in Table 18. 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. 4A $TACC_{y+1} = 0$ **for** $I_y < par5$

Eq. 4B $TACC_{y+1} = par2\dfrac{I_y - par5}{par3 - par5}$ **for** $par5 < I_y < par3$

Eq. 4C $TACC_{y+1} = par2$ **for** $par3 \le I_y \le par4$

Eq. 4D $TACC_{y+1} = par2\left(1 + 0.5\dfrac{I_y - par4}{par6 - par4}\right)$ **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 18: 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

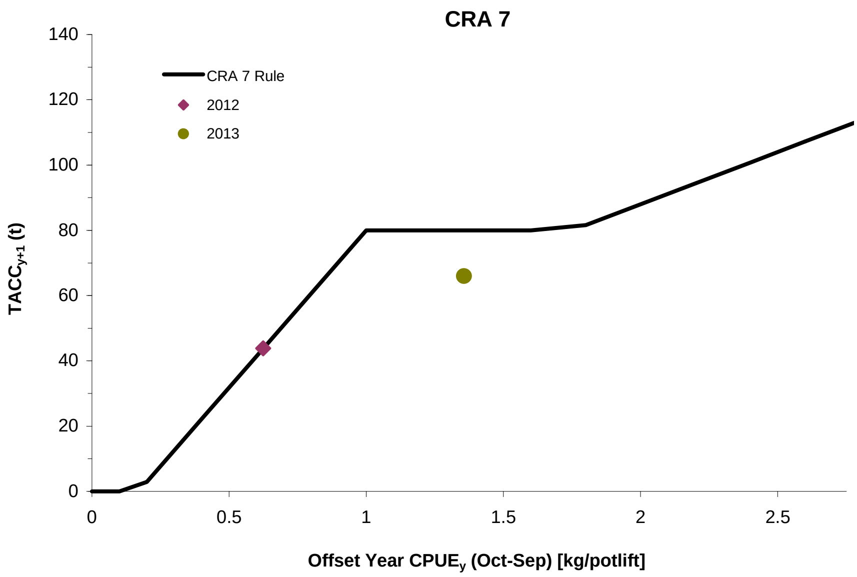


Figure 8: The CRA 7 management procedure, showing the TACC as a function of offset year CPUE, and showing TACCs resulting from the rule evaluations performed in 2012 and 2013 for the 2013-14 and 2014–15 fishing years.

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 19). CPUE doubled in 2012–13 to 1.356 kg/potlift, resulting in a provisional TACC of 80 t. But this would be a larger increase than the 50% maximum allowed by the rule. The TACC resulting from the management procedure is 1.5 times the current value of 44.0 t, or 66.0 t. The TAC would be 86.0 t if the 2013 non-commercial allowances of 20 t were added.

Table 19: History of the CRA 7 management procedure and proposed limit to the commercial fishery in the 2014–15 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 (proposed)	1.356	66	–	–

4.6 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 9. 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. 5A $$TACC_{y+1} = 0 \quad \textbf{for } I_y < par5$$

Eq. 5B $$TACC_{y+1} = par2 \frac{I_y - par5}{par3 - par5} \quad \textbf{for } par5 < I_y < par3$$

Eq. 5C $$TACC_{y+1} = par2 \quad \textbf{for } par3 \le I_y \le par4$$

Eq. 5D $$TACC_{y+1} = par2 \left(1 + 0.5 \frac{I_y - par4}{par6 - par4}\right) \quad \textbf{for } I_y > par4$$

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 21). 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 is below the minimum change threshold of 5% and consequently there is no proposed increase for 2014–15.

Table 20: 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

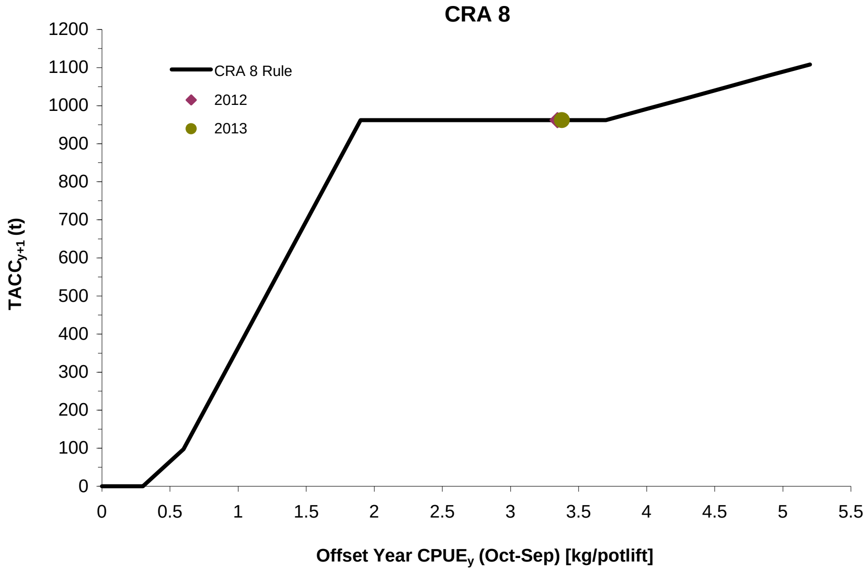


Figure 9: The new Rule 13 CRA 8 management procedure, showing TACCs resulting from the rule evaluations performed in 2012 and 2013 for the 2013-14 and 2014–15 fishing years.

Table 21: History of the new CRA 8 management procedure and proposed limit to the commercial fishery in the 2014–15 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 (proposed)	3.377	–	962	–	–

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 reports the assessment for CRA 1 conducted in 2002.

Model structure

The size-based model used in 2001, which was fully described by Breen et al (2002), has been revised and improved for the 2002 assessment. The model is fitted to two series of catch rate indices from different periods, to size frequency and tagging data. There are no settlement data for CRA 1.

An important structural feature of the model is the division of the year into two seasons (autumn-winter: April to September, and spring-summer: October to March). This captures more accurately several biological processes: a) season- and sex-specific moult patterns; b) possible differential vulnerability of both sexes between each other and between the two seasons; and c) a reduction in the vulnerability of mature females in the autumn-winter season because of their egg-bearing status. The seasonal structure is important to incorporate because several fisheries have changed from predominantly spring/summer fisheries to autumn/winter fisheries which catch mostly male lobsters.

Significant catches occurred in the early part of the time series for CRA 1. Different regulations existed at this time and pots were not required to have escape gaps. We therefore incorporated historical information for CRA 1: a time series of sex-specific MLS regulations, time series of catch per day estimates for the 1960s and early 1970s, and some early size frequency data, including market sampling data. These data and their sources are listed in Table 22. It was possible to estimate recruitment deviations beginning in 1960.

Major changes made to the 2002 model were:

- The CV of the expected growth increment was changed to a sex-specific parameter.
- The catch dynamics were changed to operate in two parts during each 6-month period so that proportions-at-length could be calculated from the mid-season length structure. The dynamics of the SL and NSL fisheries (fisheries respecting or not respecting the size limit) were both improved by doing this.

The initial population in 1945 is 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 are added equally for each sex and both seasons, into the smallest size classes, beginning with the autumn-winter season. The proportion of individuals entering each size class is modelled as a normal distribution with a mean size (32 mm) and standard deviation (2 mm), and is truncated at the smallest size class (30 mm). The magnitude of recruitment in a specific year is determined by the parameter for base recruitment and (except for the early years) a parameter representing the deviation from base recruitment. The vector of recruitment deviations is assumed to be normally distributed with a mean of zero. The years for which recruitment deviations were estimated were 1960 to 2001.

b) **Mortality**. Natural, fishing and handling mortalities are applied to each sex category (male, immature female and mature female) in each size class. Natural mortality is estimated, but assumed to be constant and independent of sex category and length. Fishing mortality is determined from observed catch and model biomass, modified by legal sizes, sex-specific vulnerabilities and selectivity curves. Fisheries that respect size limits (SL fisheries − legal commercial and recreational) are differentiated from those which do not (NSL fisheries − part of the illegal fishery plus the Mäori traditional fishery). It is assumed that size limits and the prohibition of taking of berried females apply only to the SL fisheries. Otherwise, the selectivity and vulnerability functions are the same for the SL and NSL fisheries. Relative vulnerability is calculated by assuming that the males in the spring-summer season have the highest vulnerability and that the vulnerability of all other sex categories by season are equal to or less than the spring-summer males. Mature females have no legal vulnerability in the autumn-winter, when all are assumed to be ovigerous. The annual rate of SL fishing mortality is calculated as the ratio of catch to the SL biomass, where catch includes both the legal catch and the portion of NSL catch taken from the SL biomass. SL biomass is defined as the weight of males and females in the size classes above the MLS limits, adjusted for their relative vulnerability as defined above. Handling mortality rate is assumed to be proportional to legal fishing mortality at 10% of all lobsters that are released.

c) **Fishery selectivity curves**. A three-parameter fishery selectivity function is assumed, with parameters describing increasing vulnerability from the initial size class to a maximum, followed by decreasing vulnerability. The three parameters describe the shapes of the ascending and descending limbs and the size at which vulnerability is maximum. Changes in regulation over time (for instance, changes in escape gap regulations) can be modelled by estimating separate selectivity parameters appropriate to each period of the fishery (but in these assessments, only one selectivity period was estimated in the base cases).

d) **Growth and maturity**. For each size class and sex category in a season, a transition matrix specifies the probability of an individual remaining in the same size class or growing into each of the other size classes. Maturity for females is 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 indices estimated by season from the 1979–80 to 2001–02 fishing years. The model was also fitted to an additional seasonal catch rate index based on daily catch and effort data for the period 1963 to 1973 (Annala & King 1983). A lognormal error structure was assumed and a catchability constant (q) was calculated analytically for each CPUE series.

The model was fitted to size data taken from commercial pots. These data were available either from research sampling conducted on commercial vessels or from voluntary logbooks maintained by rock lobster fishers in CRA 1. Estimates of the seasonal size frequency were obtained by collating data that had been 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. A fundamental assumption is that the size frequency data are representative of the commercial lobster catch. The size proportions within each season summed to one across all three sex categories: males, immature females, and mature females. This provides the model with seasonal estimates of the relative proportion by sex category in the catch.

Market sampling data were also used in the fitting procedure. These data are available only as carapace lengths from males and females, without maturity information. The carapace lengths were converted to tail width, and the model made predictions for the size classes beginning at one size class above the MLS.

A summary of the data used in each assessment, the data sources and the applicable years are provided in Table 22.

Table 22: Data types and sources for the 2002 assessment s for CRA 1. 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 – Rock Lobster Industry Council.

Data type	Data source	Begin year	End year
Historical catch rate	Annala & King (1983)	1963	1973
CPUE	FSU & CELR	1979	2002
Historical proportions-at-size	Various	1974	1978
Observer proportions-at-size	MFish	1990	2002
Logbook proportions-at-size	NZRLIC	1993	2002
Historical tag recovery data	MFish various	1975	1986
Current tag recovery data	NZRLIC & MFish	1996	2002
Historical MLS regulations	Annala (1983)	1945	2002
Escape gap regulation changes	Annala (1983)	1945	2002

Table 23. Fixed parameters and their values are given in Table 24. CPUE, the historical catch rate, the priors and the tagging data were weighted directly by a relative weighting factor. We varied the weights to obtain standard deviations of standardised residuals for each data set that were close to one.

Table 23: Parameters estimated and priors used in basecase assessments for CRA 1. Prior type abbreviations: U – uniform; N – normal; L – lognormal.

	Prior Type	Bounds	Mean	CV
Log R_0 (ln mean recruitment)	U	1–50	–	–
M (natural mortality)	L	0.01–0.35	0.12	0.4
Recruitment deviations	N [1]	-2.3–2.3	0	0.4
Increment at TW=50 (male & female)	U	1–8	–	–
Increment at TW=80 (male & female)	U	-10–3	–	–
CV of growth increment (male & female)	U	0.01–1.0	–	–
Minimum standard deviation of growth	U	0.01–5.0	–	–
TW at 50% probability female maturity	U	30–80	–	–
(TW at 95% probability female maturity) – (TW at 50% probability female maturity)	U	0–60	–	–
Relative vulnerability: males autumn-winter [2]	U	0–1	–	–
Relative vulnerability: immature females autumn-winter	U	0–1	–	–
Relative vulnerability: immature and mature females spring-summer	U	0–1	–	–
Relative vulnerability: mature females autumn-winter	U	0–1	–	–
Shape of ascending limb of vulnerability ogive	U	1–50	–	–
Size at maximum selectivity males	N	10–80	54	2.0
Size at maximum selectivity females	N	10–80	60	2.0
Variance of descending limb of vulnerability ogive (males & females)[3]	U	1–250	–	–

[1] Normal in logspace = lognormal (bounds equivalent to –10 to 10)
[2] Relative vulnerability of males in spring-summer was fixed at one
[3] Fixed at 200 in basecase assessment.

Table 24: Fixed parameter values used in base case assessment for CRA 1.

	CRA 1
Std dev of observation error of increment	2
Historical catch per day CV	0.30
Maximum exploitation rate	90%
Current male size limit	54
Current female size limit	60
First year for recruitment deviations	1960
Last year for recruitment deviations	2001
Relative weight for length frequencies	50
Relative weight for CPUE	1
Relative weight for CR	0.6
Relative weight for tag-recapture data	0.5

Model projections

Bayesian estimation procedures were used to estimate uncertainty in model estimates of current biomass, and in future projections. This procedure was conducted in the following steps:

a) Model parameters were estimated using maximum likelihood and the prior probabilities. These point estimates represent the mode of the joint posterior distributions of the parameters, and are called the MPD estimates;

b) Samples from the joint posterior distribution of parameters were generated using the Markov chain – Monte Carlo procedure (MCMC) using the Hastings-Metropolis algorithm;

c) For each sample of the posterior, 5-year projections (encompassing the 2002–03 to 2006–07 fishing years) were generated by assuming the catches indicated in Table 25. Future annual recruitment was randomly sampled with replacement from the model's estimated recruitments from the period 1989–1998;

d) A marginal posterior distribution was found for each quantity of interest by integrating the product of the likelihood and the priors over all model parameters; the posterior distribution was described by the mean, median, and 5th and 95th percentiles.

Table 25: Catches (t) used in the five-year projections. Projected catches are based on the current TACC for CRA 1, and the current estimates of recreational, customary and illegal catches.

Population modelled	Commercial	Recreational	Reported Illegal	Unreported Illegal	Customary
CRA 1	129.2	47.2	0	72	10

Performance indicators

The 2001 Plenary agreed to use a number of performance indicators as measures of the stock status for CRA 1. These performance indicators were calculated using the current catch levels. The RLFAWG did not consider that virgin biomass or B_{MSY} were appropriate reference points, given the difficulty of accurately estimating these quantities. Therefore the assessment used performance indicators based on biomass levels for the ten years 1979 to 1988. This is the earliest period for which we have CPUE data and the base case fit suggested that biomass was relatively stable during this period. The Plenary agreed that this was an appropriate reference biomass level. Biomass increased in the mid 1990s to higher levels than this reference level.

1. $BVULN_{02}/BVULN_{79-88}$
2. $BVULN_{07}/BVULN_{02}$
3. $BVULN_{07}/BVULN_{79-88}$
4. $UNSL_{02,AW}$
5. $USL_{02,AW}$
6. $UNSL_{06,AW}$
7. $USL_{06,AW}$

The vulnerable biomass in the assessment model is determined by four factors:
- MLS for male and female lobsters
- Length-based selectivity function
- Relative seasonal vulnerability of males and mature and immature females (parameters of the model)
- Berried state for mature females

Current vulnerable biomass, $BVULN_{02}$, is defined as the beginning season vulnerable biomass on 1 April 2002, the beginning of the autumn-winter season for the 2002–03 fishing season. Similarly, projected vulnerable biomass $BVULN_{07}$ is defined as the beginning season vulnerable biomass on 1 April 2007, the beginning of the autumn-winter season for the 2007–2008 fishing season. Vulnerable biomass was also calculated for the reference period: $BVULN_{79-88}$ is defined as the mean of beginning AW vulnerable biomass from 1979 through 1988.

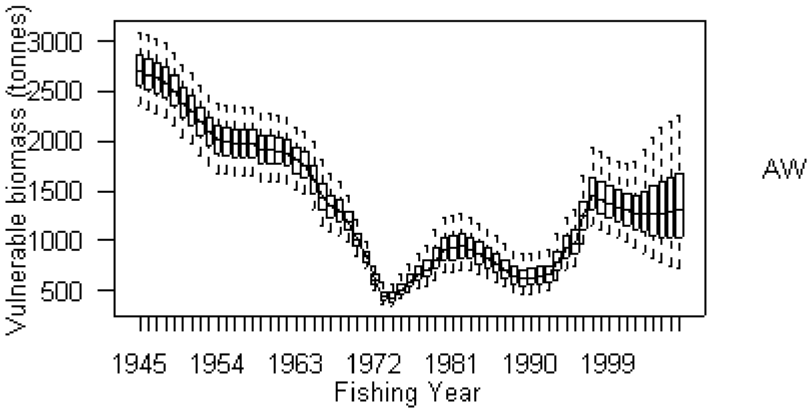
$USL_{02,AW}$ is the exploitation rate for catch taken from the SL vulnerable biomass in the autumn-winter season of 2002–03, and $USL_{06,AW}$ is the exploitation rate for catch taken from the SL vulnerable biomass in the autumn-winter season of 2006–07, the last year of projections. $UNSL_{02,AW}$ and $UNSL_{06,AW}$ are similarly defined except that they describe the exploitation rate for catch taken from the NSL vulnerable biomass.

Stock assessment results: *Jasus edwardsii*, CRA 1

The base case assessment for CRA 1 was obtained by making the standard deviations of standardised residuals from all data sets close to 1 by adjusting the relative weights for each data set. The fit to the data was acceptable, with some systematic problems in fitting the seasonal pattern of CPUE and some large residuals in the fits to proportions-at-length, perhaps caused by the poor quality of these data.

Base case results suggested that biomass decreased to a low point in 1973, increased through the early 1980s, declined again until the early 1990s (but not as low as in 1973), increased strongly in the late 1990s and then declined slightly (Figure 10). Exploitation rate peaked in the early 1970s near 30% for the spring-summer fishery, and are currently in the 7–12% range (Table 26).

A series of sensitivity trials suggested that the results were robust to these trials (based on MPD estimates), except that when the relative weight for CPUE was doubled, the model estimated a high *M* and very high biomass. A set of retrospective analyses on the MPD fits showed little effect of removing data one year at a time, beginning with the most recent year of data.



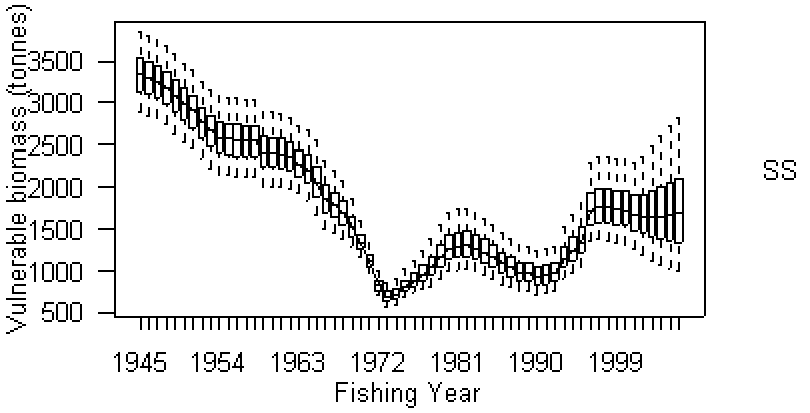


Figure 10: CRA 1: posterior trajectories of vulnerable biomass, for the AW (top) and SS (bottom) seasons, from the CRA 1 base case MCMC simulations. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.

Table 26: Summary statistics for performance indicators from posterior distributions from CRA 1. Biomass indicators are shown in t.

	Basecase				Estimate male SS vulnerability				Estimate descending limb variance of vulnerability ogive			
Indicator	0.05	median	mean	0.95	0.05	median	mean	0.95	0.05	median	mean	0.95
$BALL_{79-88}$	1 741	2 057	2 091	2 542	1 618	1 903	1 949	2 414	2 014	2 560	2 638	3 534
$BRECT_{79-88}$	1 029	1 278	1 304	1 652	959	1 190	1 218	1 570	1 307	1 775	1 832	2 558
$BVULN_{79-88}$	642	834	852	1 121	593	768	793	1 071	623	821	845	1 153
$BALL_{02}$	2 274	2 995	3 082	4 155	2 159	2 788	2 880	3 905	2 894	3 981	4 131	5 844
$BRECT_{02}$	1 594	2 050	2 089	2 715	1 514	1 932	1 980	2 619	2 144	2 961	3 067	4 311
$BVULN_{02}$	929	1 276	1 308	1 792	859	1 182	1 221	1 720	891	1 227	1 272	1 798
$BALL_{07}$	2 007	3 113	3 209	4 771	1 840	2 868	2 969	4 448	2 686	4 208	4 361	6 643
$BRECT_{07}$	1 268	2 087	2 170	3 355	1 172	1 944	2 025	3 171	1 877	3 099	3 231	5 040
$BVULN_{07}$	725	1 320	1 382	2 269	646	1 204	1 266	2 123	768	1 305	1 379	2 242
$UNSL_{02}$ (%)	1.7	2.5	2.5	3.3	1.8	2.6	2.7	3.5	1.7	2.4	2.4	3.3
USL_{02} (%)	7.4	10.4	10.6	14.3	7.8	11.2	11.4	15.4	7.3	10.7	10.8	14.7
$UNSL_{06}$ (%)	1.5	2.4	2.5	3.8	1.6	2.6	2.7	4.2	1.4	2.3	2.4	3.6
USL_{06} (%)	6.2	10.3	10.9	17.4	6.6	11.3	11.9	19.3	6.2	10.3	10.8	16.8
$BVULN_{02}/BVULN_{79-88}$ (%)	131	152	153	182	131	152	154	184	128	149	151	183
$BVULN_{07}/BVULN_{02}$ (%)	67	101	105	157	64	98	103	158	73	102	108	161
$BVULN_{07}/BVULN_{79-88}$ (%)	94	156	162	250	91	152	160	250	103	156	163	249

A sensitivity trial that was evaluated using the MCMC procedure involved changing the assumption that male spring-summer vulnerability is 1 and that the other sex/season vulnerabilities are less than or equal to this value. In this sensitivity trial, the assumption was changed to make the autumn-winter vulnerability for males highest and with the other vulnerabilities relatively less. These results are similar to the base case results. The exploitation rates estimated in this sensitivity trial are very similar to the exploitation rates estimated by the base case.

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 27.

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 27: 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 27) 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 28. Fixed parameters and their values are given in Table 29.

Table 28: 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 29: 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:

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 Hastings-Metropolis algorithm; five 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 (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 30. 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 11 and Table 31) 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*.

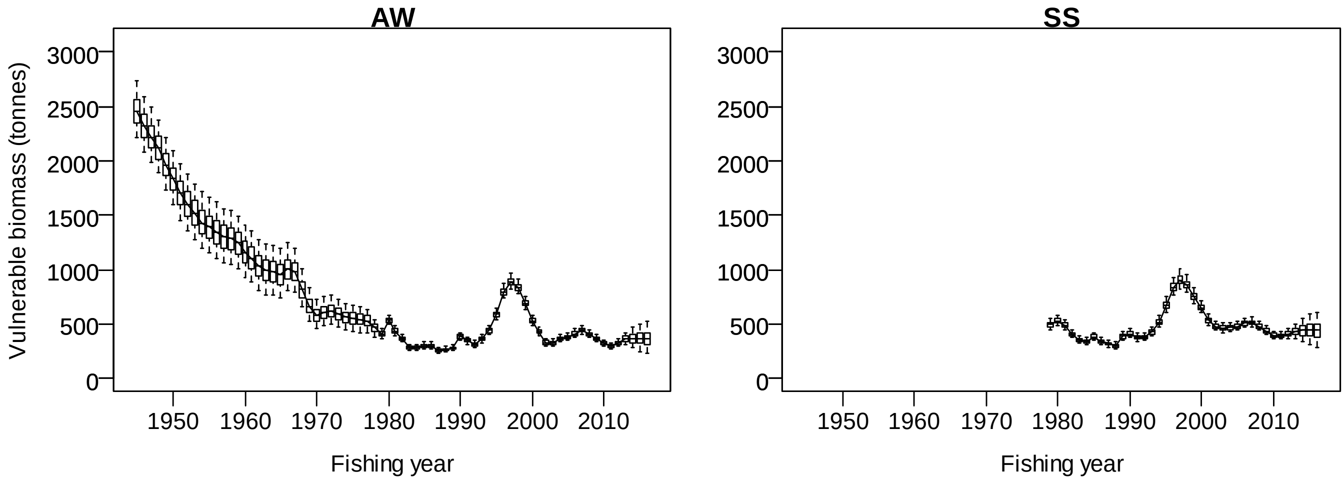


Figure 11: Posterior distributions of the CRA 2 base case McMC vulnerable biomass trajectory by season. Before 1979 there was a single time step, shown in AW. For each year the box spans the 25th and 75th quantiles and the whiskers span the 5th and 95th quantiles.

Table 30: Performance indicators used in the CRA 2 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 1979–81
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*
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*

Reference points

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 31.

Table 31: 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

indicator	basecase	CPUE pow3	CPUE pow5	Old LFs	untrunc LFs	noDD	HiRec
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.

Indicators based on *SSBmsy*

The historical track of biomass versus fishing intensity is shown in Figure 12. 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*.

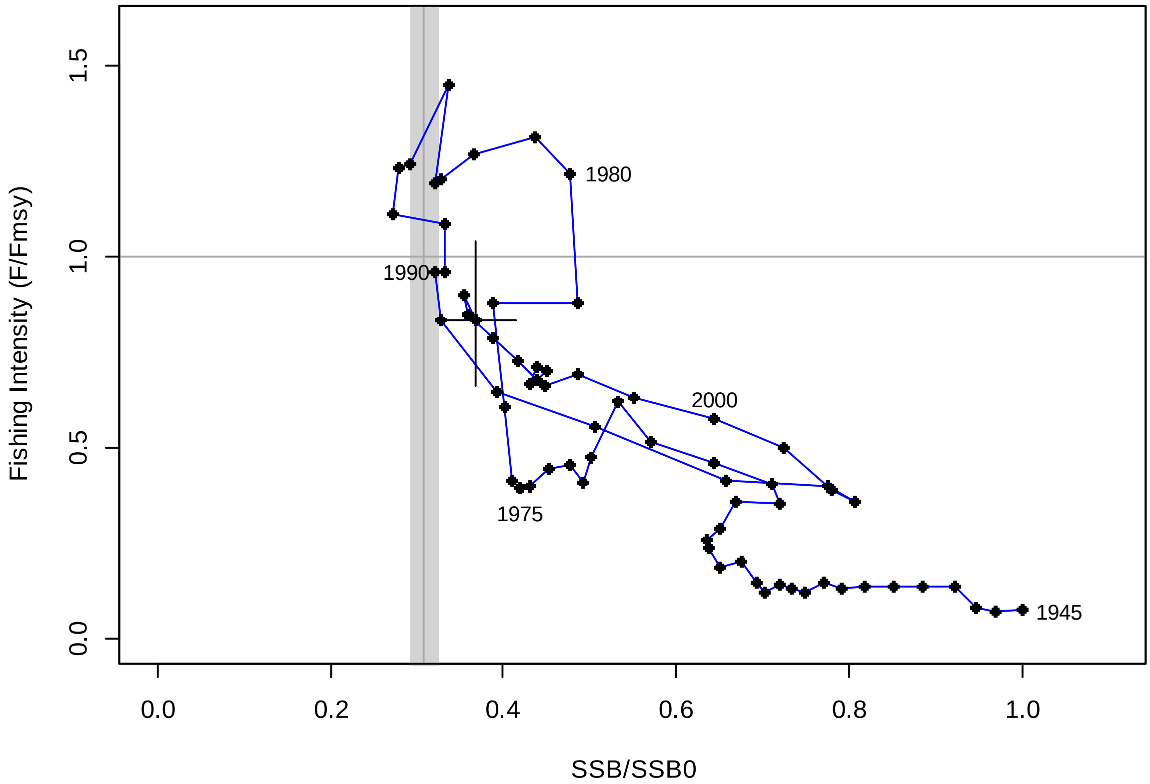


Figure 12: Phase plot that summarises the *SSB* history of the CRA 2 stock. The x-axis is spawning stock biomass *SSB* in each year as a proportion of the unfished spawning stock, *SSB0*. The y-axis is fishing intensity in each year as a proportion of the fishing intensity (*Fmsy*) that would have given *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 assessment for CRA 3 conducted in 2008.

This assessment used a single-stock version of the multi-stock length-based model (MSLM) (Haist et al 2009). In a simple preliminary trial, the new model was able to reasonably match the MPD results from the 2004 CRA 3 assessment when fitted to the same data.

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 1995–2006,
- standardised CPUE from 1979–2007,
- historical catch rate data from 1963–1973; and
- length frequency data from commercial catches (log book and catch sampling data) from 1989 to 2007.

Because the predicted growth rates were different for the 1975–1981 and 1995–2006 datasets, the RLFAWG agreed that it would inappropriate to fit the model to the combined tag-recapture dataset (as had been done in the 2004 CRA 3 assessment). Two approaches were used instead. First, the model was altered to permit of fitting to the two tag-recapture datasets separately. This alteration was not a formal generalised change to MSLM, but rather was a one-off change to produce a specialised CRA 3 assessment model. In this version, the growth transition matrix for years up to and including 1981 was based on the 1975–1981 tagging dataset (plus whatever contribution was made by other data sets). The growth transition matrix for years from 1995 onwards was based on the 1995–2006 tagging dataset (plus whatever contribution was made by other datasets). The growth transition matrix for the intervening years, 1982–1994, was based on an interpolation of the growth transition matrices estimated for the earlier and later periods. The sensitivity of the model predictions to the specified transition years was also examined.

In this version of the model, the size classes represented by the model were specified differently to deal with a technical problem introduced by the new growth rate handling. The midpoint of the first size bin in the model was increased from 31 mm to 45 mm, and the recruiting cohort mean size was increased to midpoint 47 mm from 33 mm. This was done to avoid growth model misspecification in the small size classes for which there are no observations.

In the second approach, the model was fitted to data from 1983 onwards, using only the 1995–2006 tag-recapture data. This approach was rejected by the RLFAWG, based on the diagnostics of the model and the value of some of the parameters in the results, and will not be described further.

The start date for the accepted model was 1945, with an annual time step through 1973 and then switching to a seasonal time step from 1974 onward: autumn/winter (AW), extending from April to September, and spring/summer (SS), extending from October to March. The last fishing year in the minimisations was 2007, and projections were made through 2012 (five 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 2004. Maximum vulnerability was assumed to be for males in the SS season. A marine reserve was modelled, beginning in 1999 and alienating 10% of the habitat. The model was fit to CPUE, the historical catch rate series, length frequency (LF) data and the two tag-recapture datasets. No pre-recruit index was fit, and the puerulus settlement index was fit 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. Priors for all other parameters were specified as uniform distributions with wide bounds.

Other model options used in the reference case were:

- the dynamics option was set to instantaneous;
- selectivity was set to the double normal form used in previous assessments;
- movements were turned off;
- the relation between CPUE and biomass was fixed to linear;
- maturity parameters were fixed at values estimated outside the model;
- the growth c.v. was fixed to 0.5 to stabilise the analysis;
- the right-hand limb of the selectivity curve was fixed to 200 as in previous assessments;
- 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) results and the results of 13 sets of MPD sensitivity trials:

- altering the specification of the growth transition period,
- varying the transition period between tag data sets,
- using finite dynamics instead of instantaneous,
- varying start year and initial exploitation rate,
- estimating the relation between CPUE and biomass,
- estimating the CV of predicted growth increments,
- estimating maturity parameters,
- fixing the size at maximum selectivity for females to 60,

- fixing M to 0.12 (the mean of the prior),
- removing data sets one at a time
- estimating the right-hand limb of selectivity for both sexes and epochs,
- ignoring the marine reserve,
- fitting to puerulus settlement data and
- adding uncertainty to NSL catches as requested by the WG

Most base case results showed limited sensitivity to these trials, with some notable exceptions being the removal of CPUE data or, to a lesser extent, removal of tag-recapture data. The indicator ratios were reasonably stable, but some sensitivity was observed to model starts after 1945 with different assumed values for initial exploitation rate. Overall, it was not possible to draw strong conclusions from the sensitivity trials, given that the median and mean of the assessment posterior distributions moved a considerable distance from the MPD estimates.

The assessment was based on Markov chain – Monte Carlo (McMC) simulation results. We started the simulation at the base case MPD, and made a chain of three million, with samples saved every 1000 samples, for a sample size of 3000. From the joint posterior distribution of parameter estimates, forward projections were made through 2012. In these projections, catches were assumed to remain constant at their 2007 values, except that the TACC of 190 t was used for commercial catch (which is about 20 t greater than the 2007 commercial catch). The 2007 commercial catch seasonal split was used. Recruitment was re-sampled from 1995-2004, and the estimates for 2005–2007 were overwritten. These projections are sensitive to the period chosen from which to re-sample recruitment, because recruitment trends are different over different periods. The most recent ten years' estimates are considered the best information about likely future recruitments in the short term.

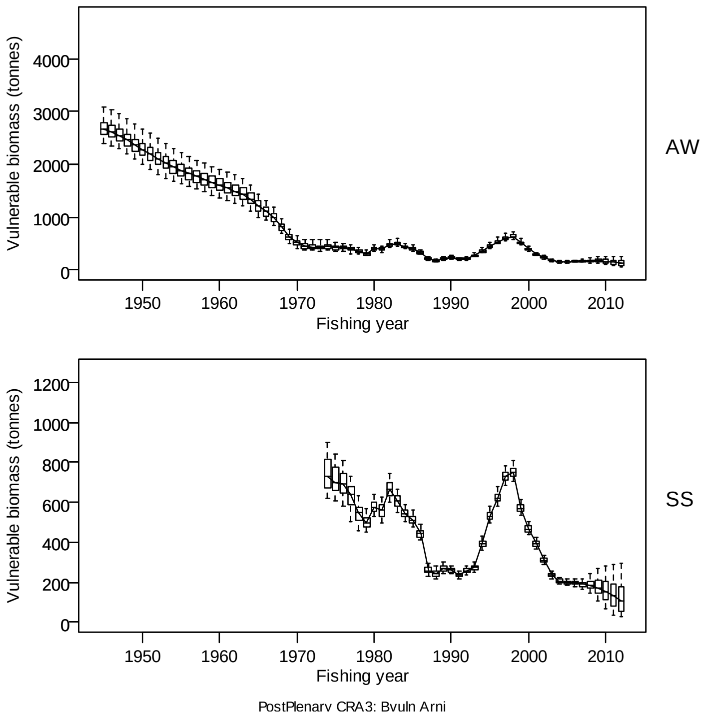


Figure 13: The posterior trajectory of vulnerable biomass, by season, from the CRA 3 base case McMC simulations, including the projections from 2008-12. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles. Values in the AW panel before 1974 reference a complete year rather than the AW season.

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, *B2008*, was taken as vulnerable biomass in AW 2008, and projected biomass, *B2012*, was taken from AW 2012.

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 1979-2004. This period was chosen to represent the recruitments that were estimated from adequate data, and represents the best available information about likely long-term average recruitment. These *MSY* and *Bmsy* calculations are sensitive to the period chosen to represent the mean recruitment, which varies substantially over the range of the period available, causing variation in estimated *Bmsy*. It was agreed to hold the non size-limited (NSL) catches (customary and illegal) constant at their assumed 2007 values, to vary the SL fishery mortality rate *F* to maximise the annual size-limited (SL) catch, and to record the associated AW biomass.

MSY was the maximum yield (the sum of AW and SS "size-limited" [SL] catches) found by searching across a range of multipliers (from 0.1 to 2.5) on the AW and SS *F* values that were estimated for 2007 for the SL catch for each of the 3000 samples from the joint posterior distribution. The model used a Newton-Raphson algorithm to find the NSL fishery mortality rates. The AW vulnerable biomass associated with the *MSY* was taken to be *Bmsy*. 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 (1996–2006) tag dataset.

We also used as indicators the exploitation rate associated with the SL catch from 2007 and 2012: *USL2007* and *USL2012* respectively. At the request of the National Rock Lobster Management Group we also compared projected CPUE with an arbitrary target of 0.75 kg/potlift.

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. The trace for *M* was not as well mixed as one could hope to see and showed some drift throughout the run, with higher values towards the end. The running quantile plots for many estimated parameters also showed a drift through the run, suggesting poor convergence, and a trend to move well away from the MPD estimate. Diagnostic plots of the indicators, however, tended to be more acceptable than those of the parameters.

The posterior trajectory of vulnerable biomass by season from 1976 (Figure 13) shows a nadir near 1989, a strong increase in the 1990s followed by a sharp decrease, and variable projections with an decreasing median. The trajectory of biomass from 1945 to 1960 is difficult to explain as there were only low catches throughout this period; the model output shows low recruitments estimated for these years.

The assessment results are summarised in Table 32. *Bmsy* and *MSY* from the base case were calculated with growth estimates based on the later and slower growth dataset. Current biomass (2008) was above *Bmin* in 83% of runs, and the median result was 11% above *Bmin*. Current biomass was above *Bmsy* in less than 1% of runs, and the median result was half *Bmsy*. Current exploitation rate was about 55%.

Table 32: Quantities of interest to the assessment from the model base case McMCs. USL is the exploitation rate that produces the size-limited catch. All biomass values are in tonnes and represent the beginning of season AW vulnerable biomass.

Type	Indicator	Statistic	Value	5%	95%
biomass	*Bmin*	median	149.1	134.4	172.2
	B2008	median	167.1	135.1	218.7
	B2012	median	123.7	64.9	255.6
	Bmsy	median	330.4	301.2	378.1
CPUE	*CPUEcurr*	median	0.662	0.547	0.835
	CPUE2012	median	0.492	0.260	0.989
	CPUEmsy	median	1.314	1.178	1.476
yield	*MSY*	median	300.4	291.2	310.2
biomass ratios	*B2008/Bmin*	median	1.114	0.936	1.400
	B2008/Bmsy	median	0.505	0.406	0.643
	B2012/B2008	median	0.746	0.424	1.347
	B2012/Bmin	median	0.831	0.445	1.662
	B2012/Bmsy	median	0.372	0.195	0.759
fishing mortality	*USL2007*	median	0.550	0.461	0.621
	USL2012	median	0.811	0.392	1.546
	USL2012/USL2007	median	1.478	0.733	2.761
	Fmult	mean	0.727		
probabilities	P(*2008>Bmin*)	mean	82.5%		
	P(*B2008>Bmsy*)	mean	0.0%		
	P(*B2012>B2008*)	mean	24.5%		
	P(*B2012>Bmin*)	mean	36.5%		
	P(*B2012>Bmsy*)	mean	0.5%		
	P(*CPUE2012>*0.75)	mean	19.0%		
	P(*USL2012>USL2007*)	mean	78.9%		

Biomass increased in only 25% of projections, and the median decrease was 25%. Projected biomass had a median of 124 t, but uncertainty around this was high, with a 5% to 95% range of 65 to 256 t. *B2012* was above *Bmin* in 36% of runs, and the median result was 83% of *Bmin*. *B2012* was greater than *Bmsy* in less than 1% of runs, and the median was 37% of *Bmsy*.

Projected CPUE had a median of 0.5 kg/potlift, and only 20% of runs exceeded 0.75 kg/potlift. The mean *F* multiplier associated with *MSY* was about 75% of current *F*.

These results suggest a stock that is near *Bmin* and well below *Bmsy*. Under current catches and recent recruitments the model predicted a 75% probability of biomass decrease over four years.

Projections were made with alternative levels of SL catch (commercial plus recreational) with the NSL catch (illegal and customary) held constant (Table 33). These were 5-year projections made in the same way as the base case projections described above, and were made at the request of the Plenary for the guidance of the NRLMG, stakeholders and MFish.

Table 33: Results of 5-year projections with alternative SL catch levels.

	SL Projection Catch (t)							
Indicator	206.0	185.4	164.8	144.2	123.6	82.4	41.2	0.01
% of current catch	100%	90%	80%	70%	60%	40%	20%	0%
B2012	123.7	160.9	195.3	229.0	262.0	328.6	396.6	463.6
B2012/Bmin	0.831	1.073	1.307	1.532	1.754	2.199	2.645	3.090
B2012/B2008	0.746	0.948	1.151	1.346	1.548	1.942	2.340	2.740
B2012/Bmsy	0.372	0.481	0.586	0.688	0.788	0.989	1.191	1.394
CPUE2012	0.492	0.639	0.775	0.910	1.041	1.303	1.566	1.832
P(*B2012>Bmin*)	36.5%	57.0%	77.4%	92.4%	98.2%	100.0%	100.0%	100.0%
P(*B2012>B2008*)	24.5%	44.4%	67.6%	88.7%	97.7%	100.0%	100.0%	100.0%
P(*B2012>Bmsy*)	0.5%	1.4%	4.0%	9.0%	18.5%	47.8%	83.6%	98.3%
P(*CPUE2012>0.75*)	19.0%	34.6%	53.7%	73.5%	89.1%	99.1%	100.0%	100.0%

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 34.

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 34: 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 35: Parameters estimated and priors used in basecase assessments for CRA 4. 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	–		–
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	–		–
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 36. CPUE, the historical catch rate, proportions-at-length and tagging data were given relative weights directly by a relative weighting factor.

Table 36: 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 37);

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 37: 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.

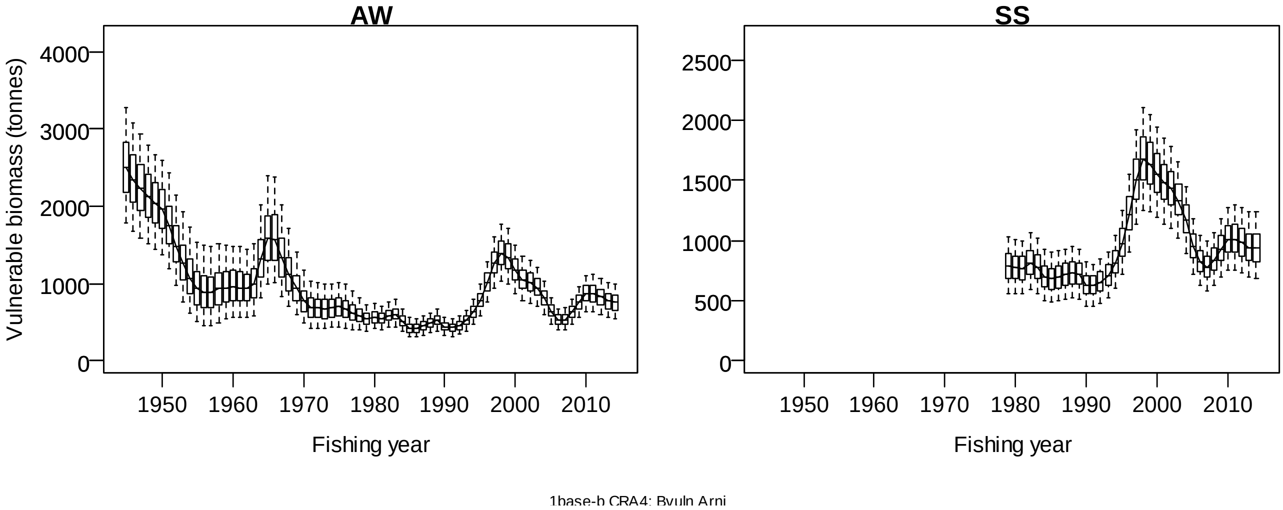


Figure 14: Posterior distributions of the CRA 4 base case McMC biomass vulnerable trajectory. Before 1979 there was a single time step, shown in AW. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th quantiles.

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 14), 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 14).

Table 38: 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*
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*

Reference points	
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 38) are shown in Table 39.

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 39: 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.

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
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

Indicator	basecase	lovuln	nopoo	poolag3	fixed*M*	hiLFwt	hiRecCat
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 15. 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 15 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.

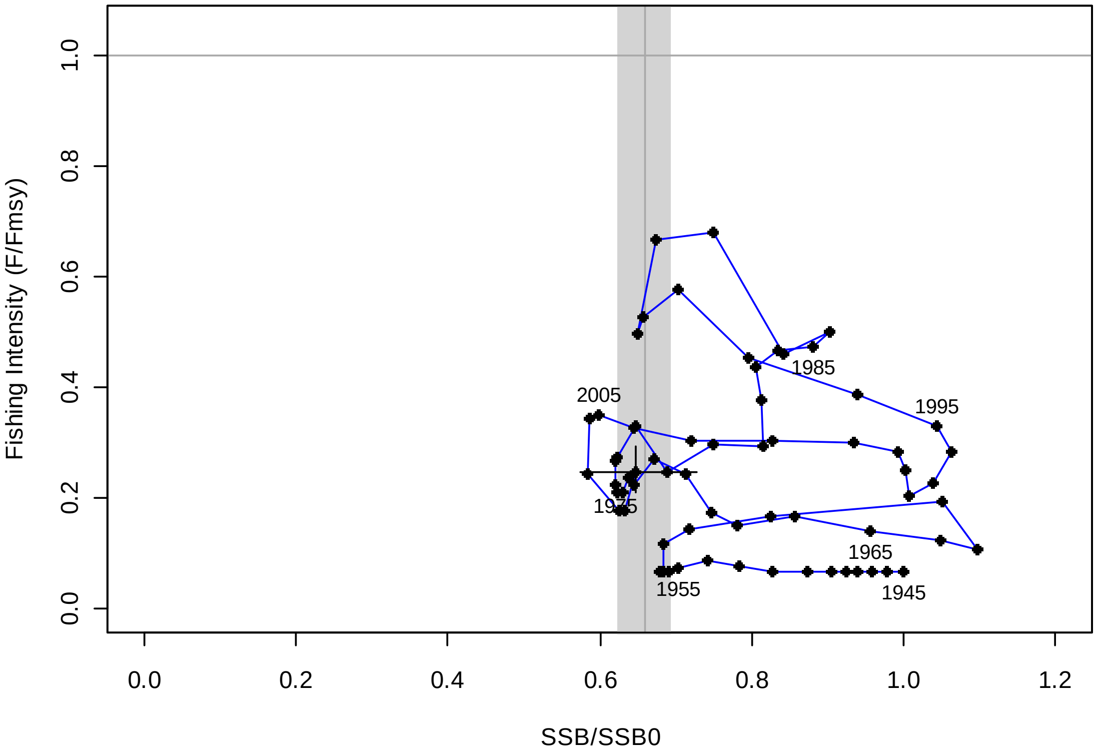


Figure 15: Phase plot that summarises the *SSB* history of the CRA 4 stock. The x-axis is spawning stock biomass *SSB* in year *y* as a proportion of the unfished spawning stock, *SSB0*. *SSB0* is constant for all years of a run, but varies through the 1000 runs. The y-axis is fishing intensity in year *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 40: 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 41. Fixed parameters and their values are given in Table 42.

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 41: 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 42: 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 43);

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 43: 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 16). The current vulnerable stock size (AW) is about 3 times the reference biomass and the spawning stock biomass is well above B_{msy} (Table 45). However, projected biomass would decrease at the level of current catches over the next 4 years (Figure 16).

Table 44: 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 44) are shown in Table 45 for the more aggressive of the two catch scenarios (Scenario 1, Table 43). Indicators from Scenario 2, with lower projected catches, are not reported.

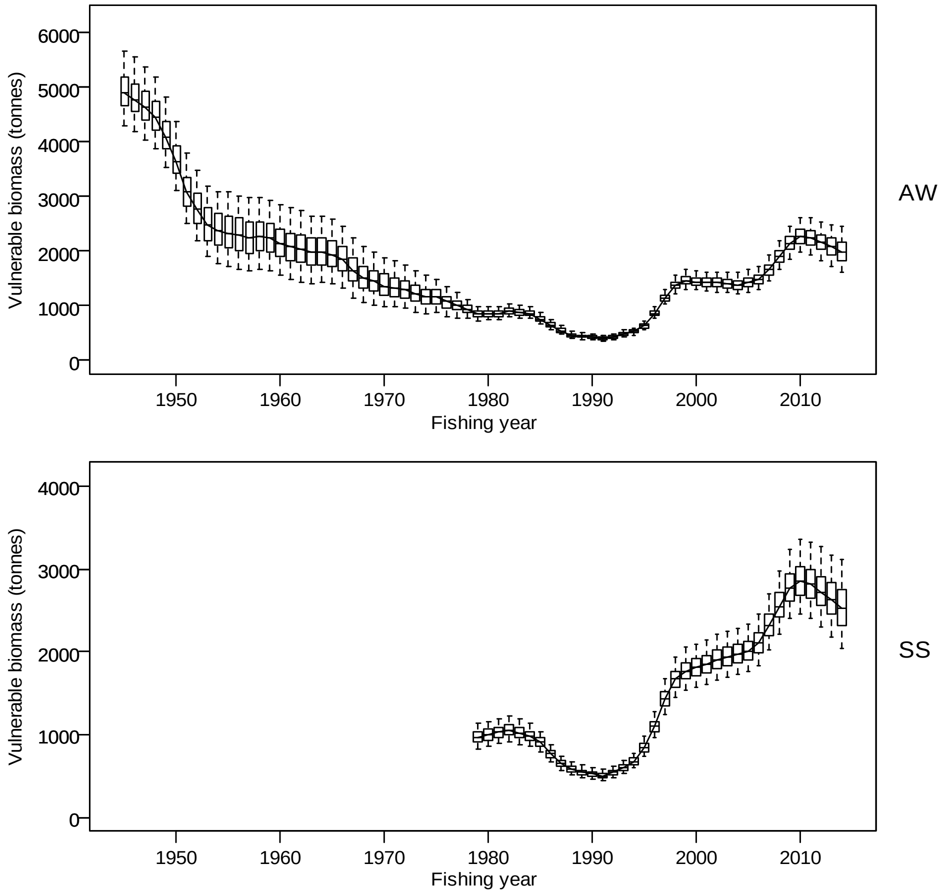


Figure 16: Posterior distributions of the base case McMC biomass vulnerable trajectory. Before 1979 there was a single time step, shown in AW. Projected catches were scenario 1 (Table 43). For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed 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 45: Assessment results – medians of indicators described in Table 44 from the base case and sensitivity trials under Scenario 1 catches (Table 43); 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 17. 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 17 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.

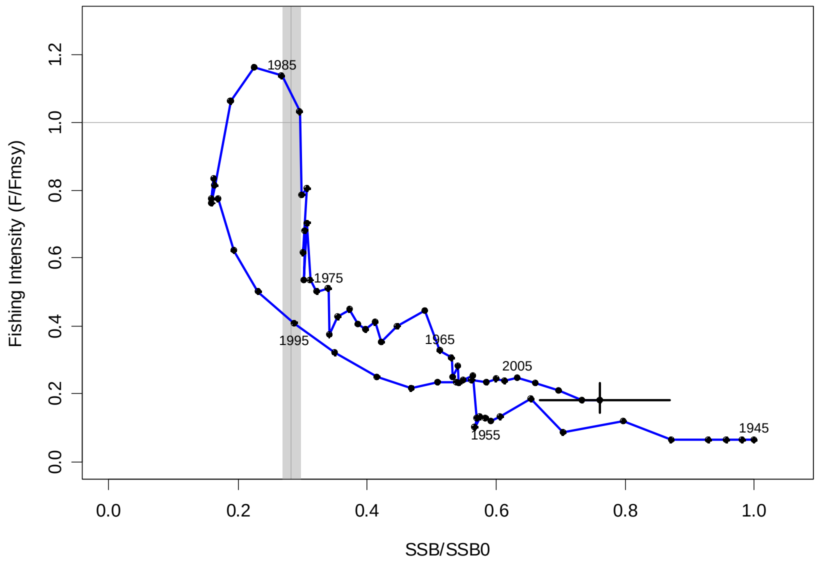


Figure 17: Phase plot that summarises the history of the CRA 5 fishery. The x-axis is the spawning biomass (SSB) as a proportion of B0 (SSB0); the y-axis is the ratio of the fishing intensity (F) relative to Fmsy. Each point is the median of the posterior distributions, and the bars associated with 2009 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.

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 46: 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 47. Fixed parameters and their values are given in Table 48.

Table 47: 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 48: 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 49. 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 18 and Table 50) 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 19 and Table 51) 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.

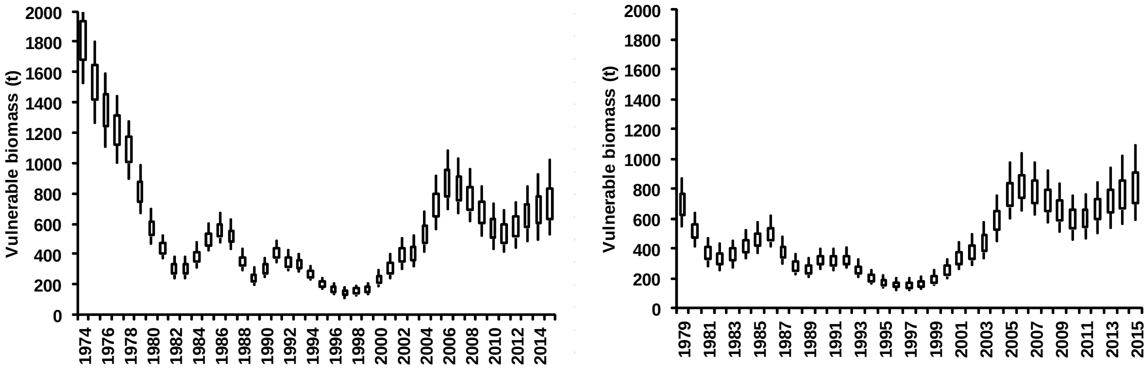


Figure 18: Posterior distributions of the CRA 7 base case McMC vulnerable biomass trajectory. Before 1979 there was a single time step, shown in AW. For each year the box spans the 25th and 75th quantiles and the whiskers span the 5th and 95th quantiles.

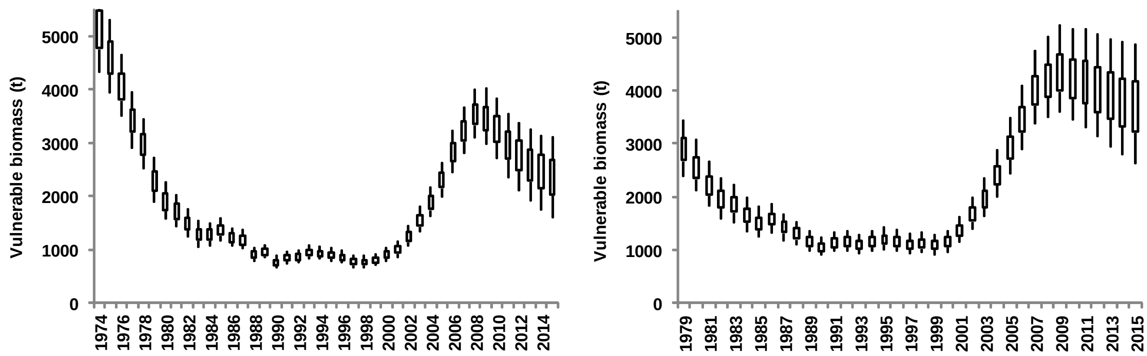


Figure 19: Posterior distributions of the CRA 8 base case McMC vulnerable biomass trajectory. Before 1979 there was a single time step, shown in AW. For each year the box spans the 25th and 75th quantiles and the whiskers span the 5th and 95th quantiles.

Table 49: 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 50 for CRA 7 and Table 51 for CRA 8.

Table 50: 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 51: Assessment results: median and probability indicators for CRA 8 from base case McMC and sensitivity trials; biomass in tonnes and CPUE in kg/pot.

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

indicator	base	TwoMs	Moves5%	Moves25%	FlatRec	FixShape	NoDD
USLproj	0.280	0.274	0.250	0.260	0.276	0.272	0.155
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 20 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 20 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.

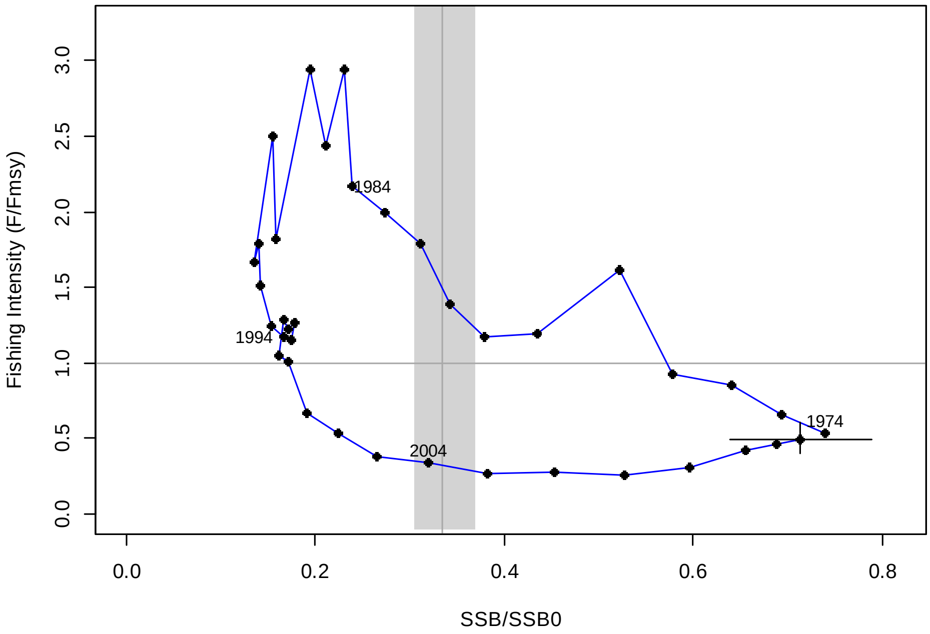


Figure 20: Phase plot that summarises the *SSB* history of the CRA 8 stock. The x-axis is spawning stock biomass *SSB* in each year as a proportion of the unfished spawning stock, *SSB0*. *SSB0* is constant for all years of a run, but varies through the 1000 runs. The y-axis is fishing intensity in each 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 53), but an informed prior on the intrinsic rate of increase was developed.

Table 52: 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 53.

Table 53: 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 21 and Table 54) 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 11) 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.

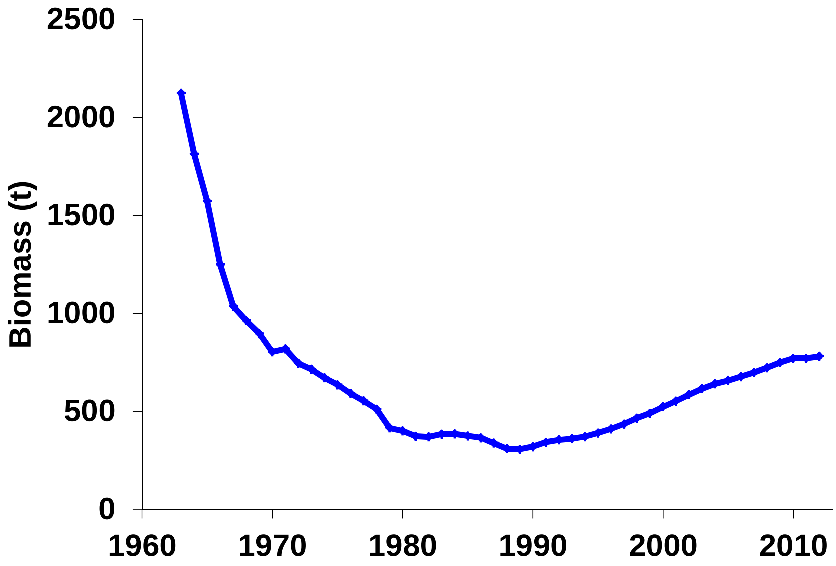


Figure 21: CRA 9 biomass from the base case MPD.

Table 54: 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

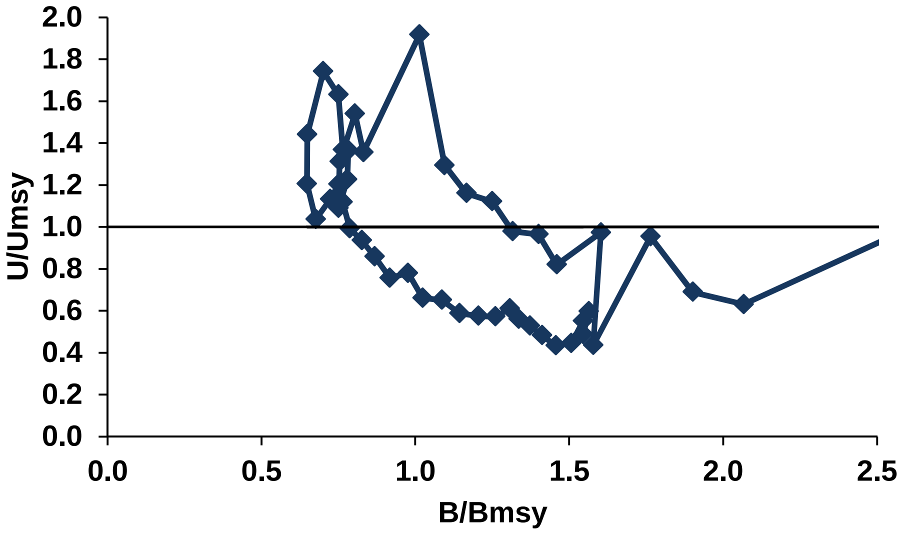


Figure 22: Phase plot of the CRA 9 fishery: the x-axis is the mean of the posterior distribution of biomass as a proportion of *Bmsy*; the y-axis is the mean of the posterior of exploitation rate as a proportion of equilibrium exploitation rate at *Bmsy*; the horizontal line is 1.0 (equilibrium exploitation 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.

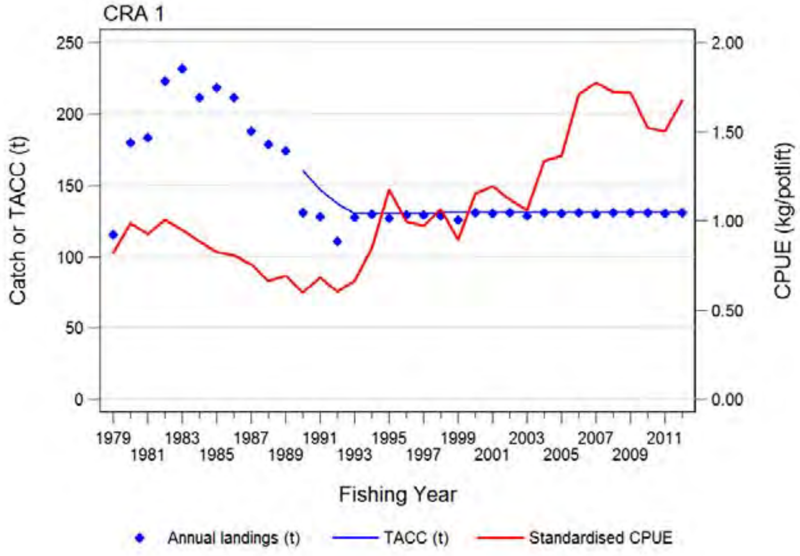
7. STATUS OF THE STOCKS

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	2002
Assessment Runs Presented	Base case and 2 sensitivity runs
Reference Points	Target: Not established (reported against *Bref*) *Bref*: mean of beginning AW vulnerable biomass for the period 1979-88 Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default) Overfishing threshold: F_{MSY}
Status in relation to Target	Biomass in 2002 was 150% of *Bref*
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 CRA1 from 1979 to 2011

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Standardised CPUE increased steadily from 2003 to 2008, and has remained high since.
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	5 year forward projections conducted in 2002 using 2002 levels of commercial, customary, non-commercial and illegal catches showed that the stock would remain at a similar level.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Bayesian length based model	
Assessment Dates	Latest assessment: 2002	Next assessment: 2015?
Overall assessment quality	1- High Quality	
Main data inputs (rank)	CPUE, length frequency data, tagging data	1- High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	Non-commercial catch	

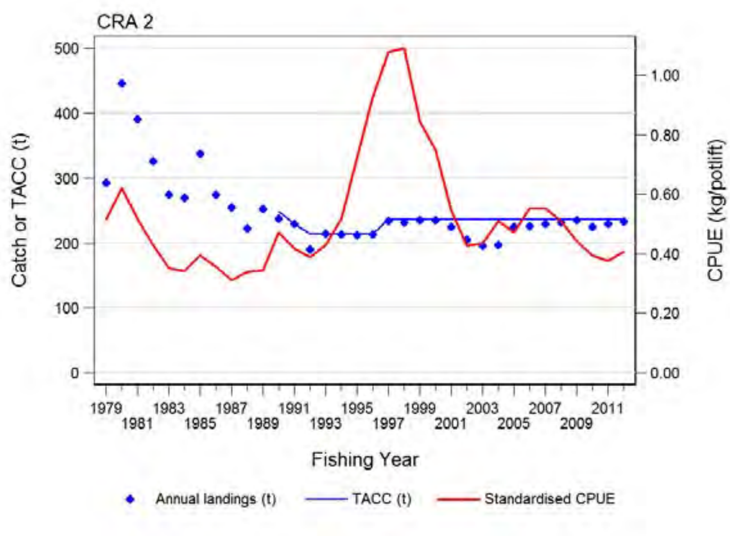
Qualifying Comments
CPUE rose nearly 50% after the 2002 assessment to the highest in the series in 2008, and has remained high since.

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.

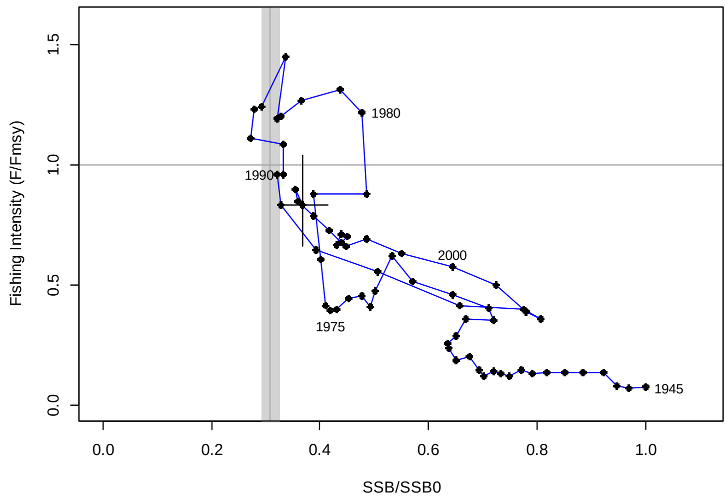
CRA 2 Bay of Plenty

Stock Status	
Year of Most Recent Assessment/Evaluation	2013
Assessment Runs Presented	Base case and 6 sensitivity runs
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	-	

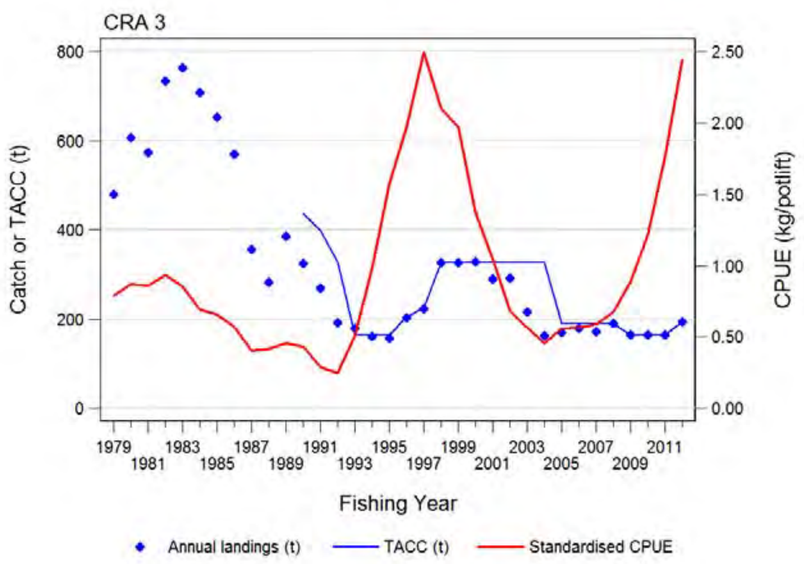
Projections and Prognosis		
Stock Projections or Prognosis	4-year projections conducted in 2013 using 2012 levels of commercial, customary, non-commercial and illegal catches showed that the stock would remain at a similar level.	
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely to go below soft limit Hard Limit: Exceptionally Unlikely to go below hard limit	
Probability of Current Catch or TACC causing Overfishing to continue or commence	Unlikely (< 40%)	
Assessment Methodology and Evaluation		
Assessment Type	Level 1 Quantitative Assessment model	
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/Evaluation	2013
Assessment Runs Presented	MP evaluation updated
Reference Points	Target: reported against B_{MSY} B_{MSY}: AW vulnerable biomass associated with MSY (maximum SL catch summed across AW and SS) Limit: reported against B_{MIN} B_{MIN}: minimum AW vulnerable biomass, 1945–2007 Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default) Overfishing threshold: F_{MSY}
Status in relation to Target	Biomass in 2013 is Very Likely (> 90%) to be above B_{MSY}.
Status in relation to Limits	Biomass in 2013 is Very Unlikely (< 10%) to be below both 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 CRA3 from 1979 to 2012

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass declined steadily from 1997 to 2003 and is increasing after several years of little change; CPUE has increased steadily in the four years since 2008 and is now at about the level of the 1997 peak.
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 2.31 to 2.355 kg/potlift which results in a 10% TAC increase to 390 t 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 Quantitative Assessment model (2008)	
Assessment Method	Multi-stock length based model (Haist et al 2009)	
Assessment Dates	Latest assessment: 2008	Next assessment: 2014?
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)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	Future recruitment and growth rate	

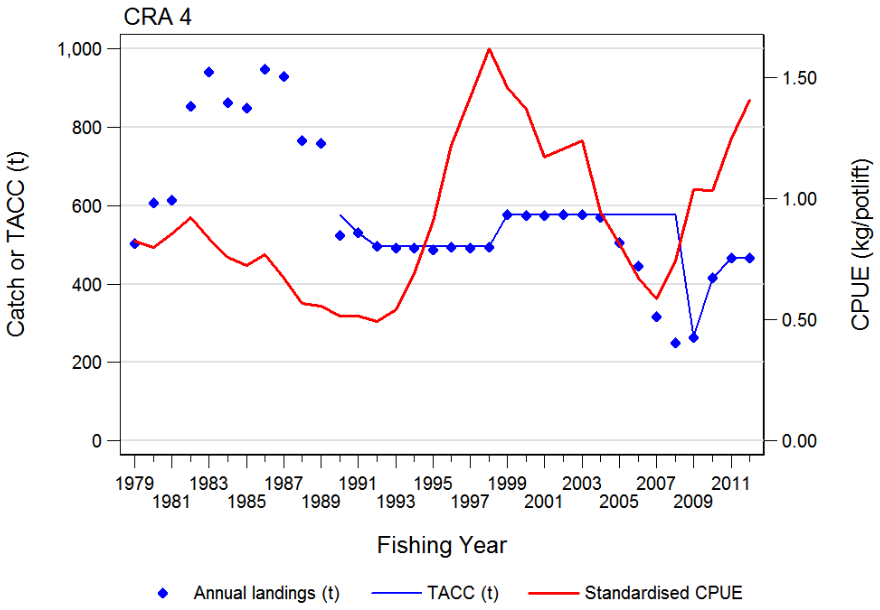
Qualifying Comments
A management procedure has been developed that is used to manage the fishery.

Recent developments in stock status
CPUE has tripled since 2008 to the highest levels seen in the CPUE series.
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 4 Wellington – Hawkes Bay

Stock Status	
Year of Most Recent Assessment	2013
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 2013 decreased from 1.37 to 1.30 kg/potlift which results in a TACC decrease of 33 t to 467 t 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 Quantitative Assessment model (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	Addition of fitting to puerulus settlement indices	

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

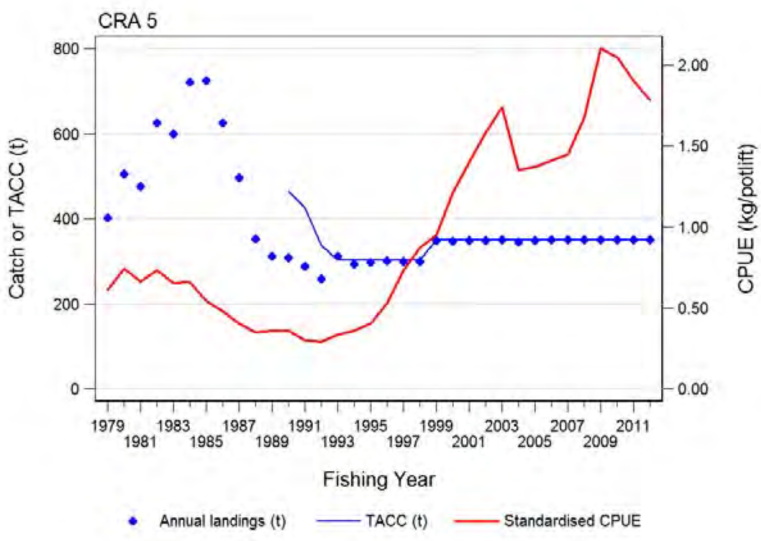
Qualifying Comments
A management procedure has been developed that is used to manage the fishery.

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	2013
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 fall 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 1.64 to 1.590 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 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.

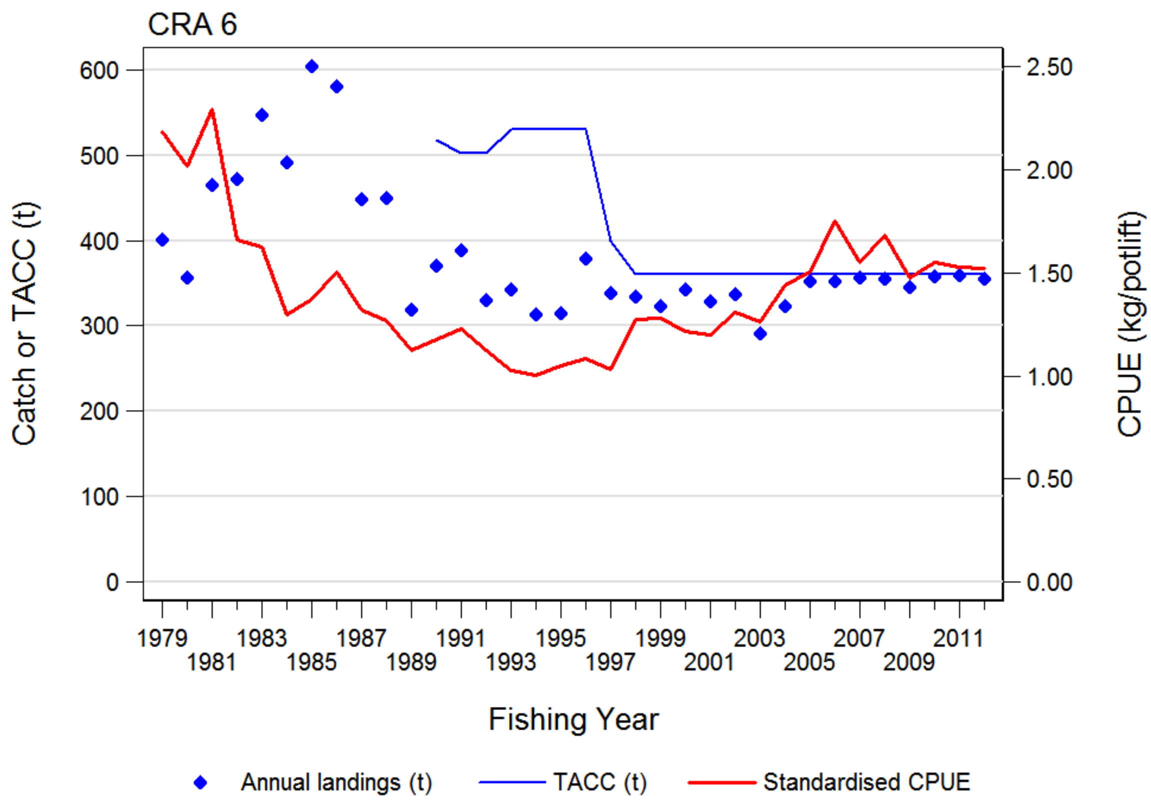
Recent developments in stock status
CPUE dropped in 2010 and 2011 from 2009, the highest point in the series.
Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have very little direct effect on non-target species. For all QMAs, the most frequently reported incidental 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	

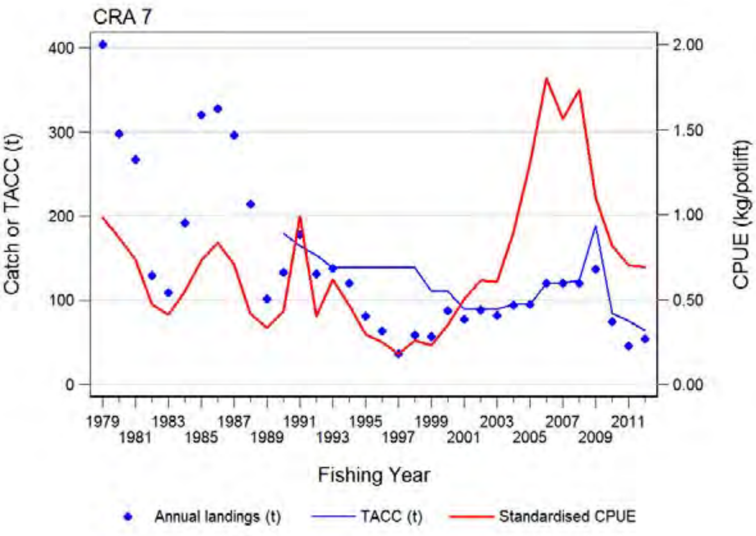
Main data inputs (rank)	CPUE	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	Catch rates are 50% higher than when the production model was fitted in 1996.	

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	2013
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 0.63 to 1.36 kg/potlift which results in a TAC increase from 44 t to 80 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 Quantitative Assessment model (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

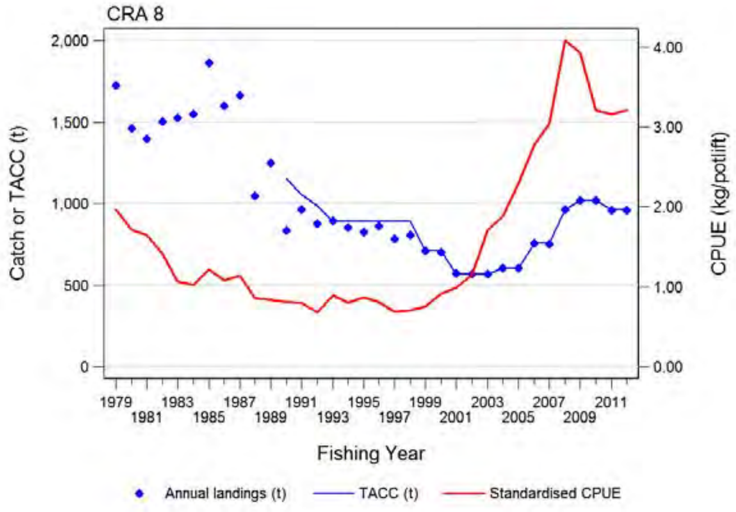
Qualifying Comments
A management procedure has been developed that is used to manage the fishery

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.

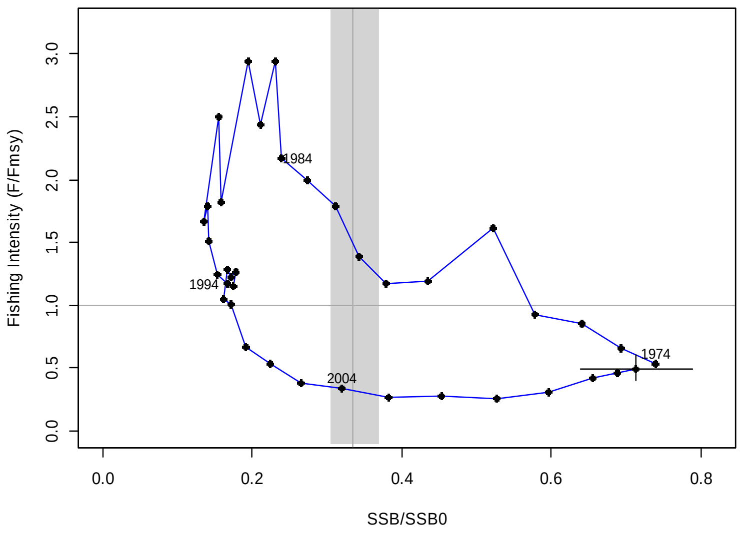
CRA 8 Southern

Stock Status	
Year of Most Recent Assessment	2013
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 2013 increased from 3.35 to 3.38 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 Quantitative Assessment model (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

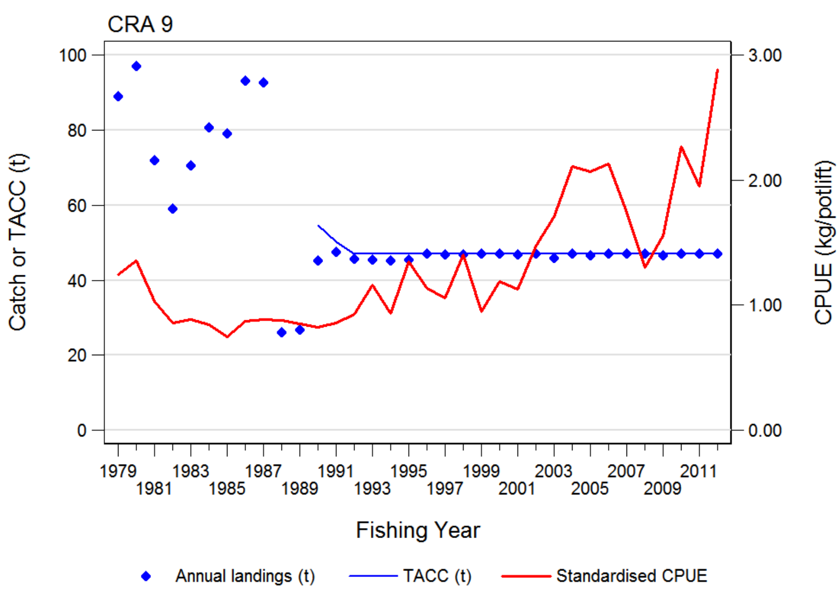
Qualifying Comments
A management procedure has been developed that is used to manage the fishery.

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	2013
Assessment Runs Presented	Base case
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	No short-term projections reported.
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.

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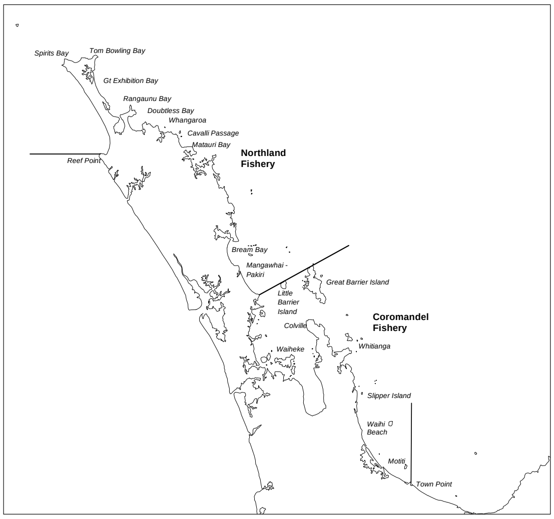
SCALLOPS NORTHLAND (SCA 1)

(*Pecten novaezelandiae*)
Kuakua, Tipa



1. FISHERY SUMMARY

Northland scallops were introduced into the 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

Scallops support regionally important commercial fisheries off the north-east coast of the North Island between Reef Point (Ahipara) and Cape Rodney, the limits of the Northland fishery. 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.

Northern scallop fisheries are 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. Both northern scallop fisheries have been 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

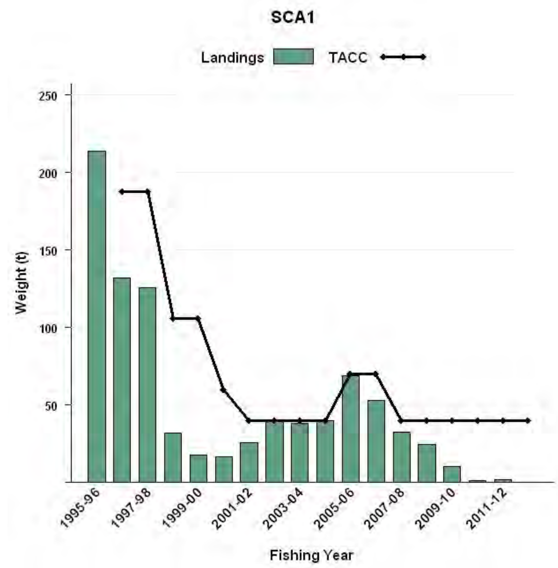


Figure 1: Landings and catch limits for SCA 1 (Northland) from 1997–98 to 2012–13. TACC refers to catch limits and 'Weight' refers to mean weight.

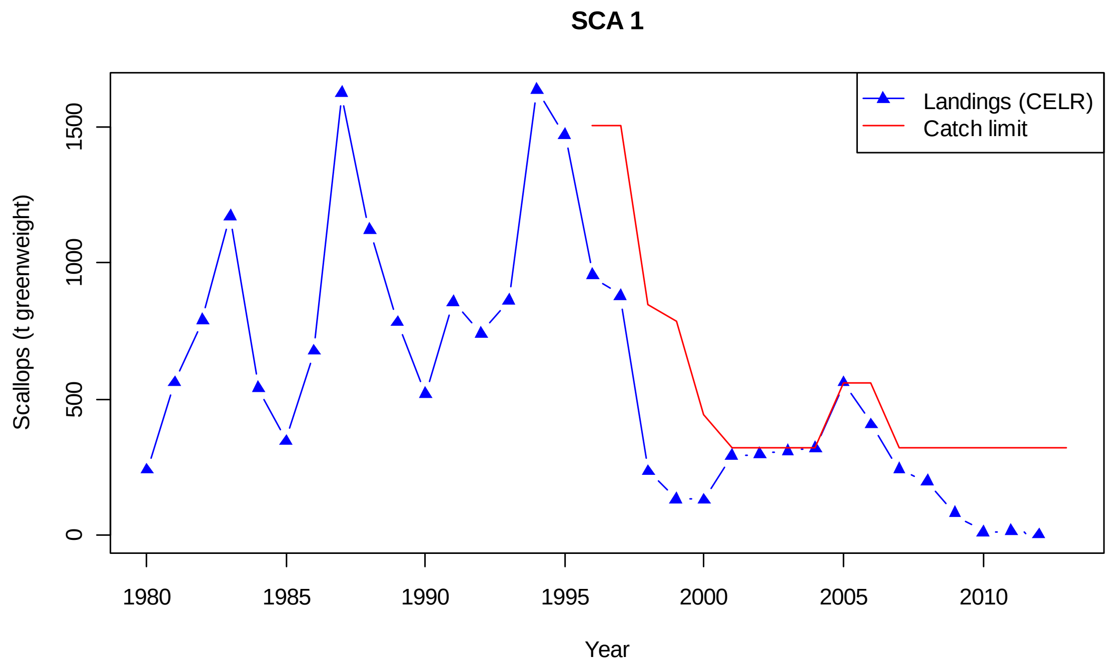


Figure 2: Catch limits and reported landings (from CELRs) in t greenweight for the SCA 1 fishery since 1980.

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 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 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 CS are shown in Table 3; 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). Note the 2011–12 panel survey (Wynne-Jones et al in review) was still under review at the time that this report was written, but appears to provide plausible results. 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). The estimates provided by telephone diary surveys are no longer considered reliable for various reasons. Note the 2011–12 panel survey was still under review at the time that this report was written, but appears to provide plausible results.

Year	Area	Survey method	Number	CV	Green (t)	Meat (t)	Reference
1993–94	SCA 1	Telephone diary	374 000	0.17	40–60	5–8	Bradford (1997)
1996	SCA 1	Telephone diary	272 000	0.18	32	4	Bradford (1998)
1999–00	SCA 1	Telephone diary	634 000	0.34	70	9	Boyd and Reilly (2002)
2000–01	SCA 1	Telephone diary	820 000	0.31	90	11	Boyd et al (2004)
2011–12	SCA 1	Panel survey	148 905	0.36	16	2	Wynne-Jones et al (in review)

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	120	–	300

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, scallops encountered by box dredges in the Coromandel scallop fishery showed 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 very fast 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 and from the various west coast harbours, Golden Bay, Tasman Bay, Marlborough Sounds, Stewart Island and Chatham Island areas.

4. STOCK ASSESSMENT

Northland scallops are managed using a TACC of 40 t meatweight which can be augmented with additional ACE based on a Current Annual Yield (CAY) calculation using $F_{0.1}$ as a reference point. Pre-season research (dredge) surveys are used to estimate recruited biomass. The last biomass survey conducted in SCA 1 was in 2007.

4.1 Estimates of fishery parameters and abundance

At the fishery-wide level, estimated fishing mortality on scallops 100 mm or more in the Northland fishery 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 a reliable index of abundance (Cryer 2001b). However, recent simulation studies in the Coromandel scallop fishery have shown that CPUE could 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 2012). 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.

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.

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

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 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 of scallop dredge efficiency (Bian et al 2012) is now available, but has not yet been used to re-analyse the historical survey time series for SCA 1 (or SCA CS).

Estimates for the Northland fishery calculated using historical average dredge efficiency are shown for scallops 95 mm or more in Table 6. 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 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 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 (www.mpi.govt.nz/Default.aspx?TabId=126&id=1644) (Ministry for Primary Industries 2012).

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

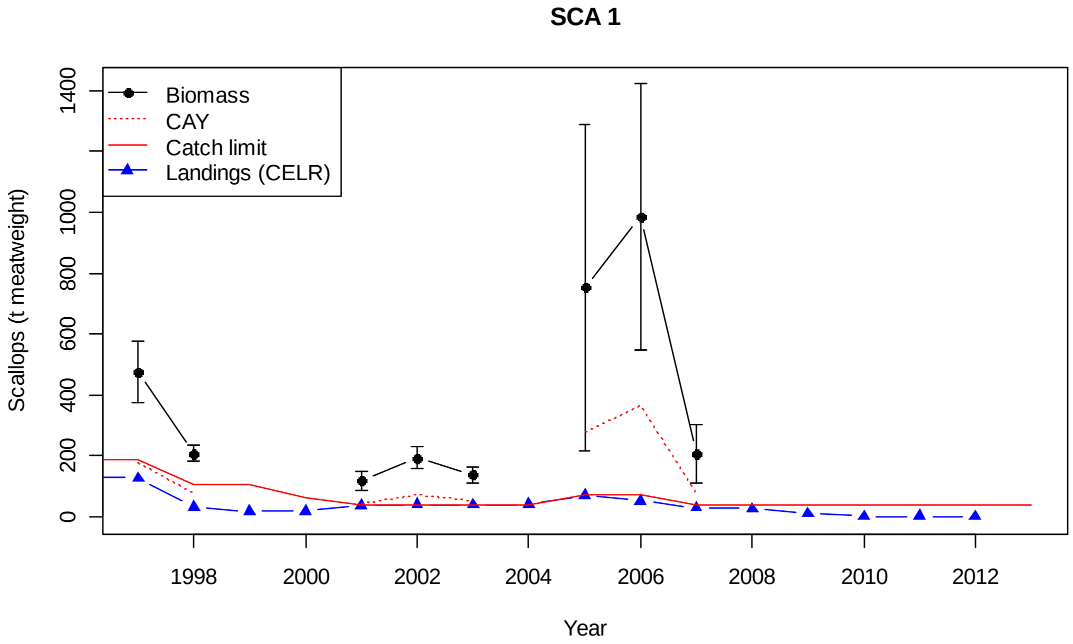
Stock Structure Assumptions
The stock structure of scallops in New Zealand waters is uncertain. For the purposes of this assessment, SCA 1 is assumed to be a single biological stock, although the extent to which the various beds or populations are separate reproductively or functionally is not known.

- **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, and no fishing in 2012–13.

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

Historical Stock Status Trajectory and Current Status



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 2012) trend in biomass is unknown. Industry surveys of core fisheries areas in 2012 and 2013 suggest scallop abundance in those areas was low compared with estimates from the 2005–07 surveys.
Recent Trend in Fishing Intensity or Proxy	F_{est} cannot be estimated for this fishery for recent years. Catches in 2010–11 and 2011–12 were the lowest on record. There was no fishing in 2012–13.
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 (> 60%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2: Partial quantitative stock assessment	
Assessment Method	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 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.

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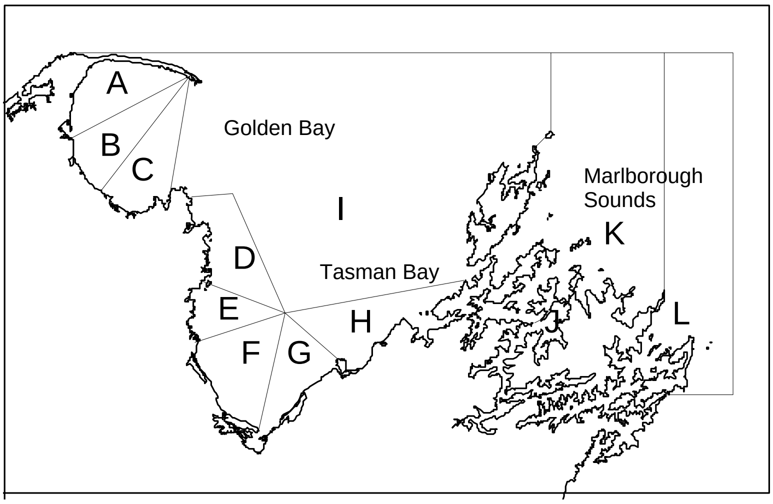
SCALLOPS Nelson/Marlborough (SCA 7)

(*Pecten novaezelandiae*)
Kuakua



1. FISHERY SUMMARY

The SCA 7 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).

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–present	827	40	40	0	747

1.1 Commercial fisheries

The Nelson/Marlborough scallop fishery (SCA 7), often also referred to as the ‘Southern’ or ‘Challenger’ fishery, is comprised of 12 sectors (see A–L in the map above) spread across three regions: Golden Bay, Tasman Bay, and the Marlborough Sounds. Up to 1980, the fishery was managed with a combination of gear restrictions, closed areas and seasons, and a 100 mm size limit, together with limitations on the number of entrants (from 1977). Landings reached an all time peak of 1244 t in 1975, when there were 216 licensed vessels involved in the fishery. The fishery then rapidly declined, and in 1981 and 1982 the fishery was closed. Only 48 licences were issued when it re-opened in 1983, with each vessel being allocated a defined, and equal, catch limit on an annual basis. A scallop enhancement programme was initiated in the same year. By 1989 the success of the enhancement programme enabled rotational fishing in Golden and Tasman Bays (Sectors A–I). Under the rotational fishing strategy, several sectors were opened to fishing each year, and were re-seeded following fishing down. Rotational fishing was accompanied by a reduction in the minimum legal size to 90 mm.

In 1992 when SCA 7 was introduced into the QMS an annual harvest limit of 640 t (12 t to each of the 48 licence holders, plus 64 t to Maori) was initially allocated as Individual Transferrable Quota. 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 10 years, the rotational fishing and stock enhancement management strategy has changed considerably. Reseeding activity has been significantly reduced and closing entire sectors to commercial fishing on an annual rotational basis is no longer practised. Now parts of all sectors are fished wherever scallops are available. Annual dredge surveys, used to estimate biomass levels and population size structures for each sector, are conducted before each season begins. This approach informs the current strategy and enables the fishery to concentrate in areas where scallops are predominantly above the minimum legal size.

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. The actual commercial catch is set by CSEC within the TACC limits 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.

All commercial fishing is by dredge, with fishers using “ring bag” dredges rather than the “box” dredge designs used in the northern (Coromandel and Northland) fisheries. Vessels in the SCA 7 fishery tow one or two ring bag dredges up to 2.4 m in width with heavy tickler chains (there are no teeth or tines on the leading bottom edge of the dredges in the SCA 7 fishery, unlike those of the fixed tooth bars used on dredges in the northern fisheries).

Reported landings (in meatweight; i.e., processed weight, being the adductor muscle plus attached roe) 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 are defined each year, and may differ between years. Historical landings and TACC changes are shown in figure 1.

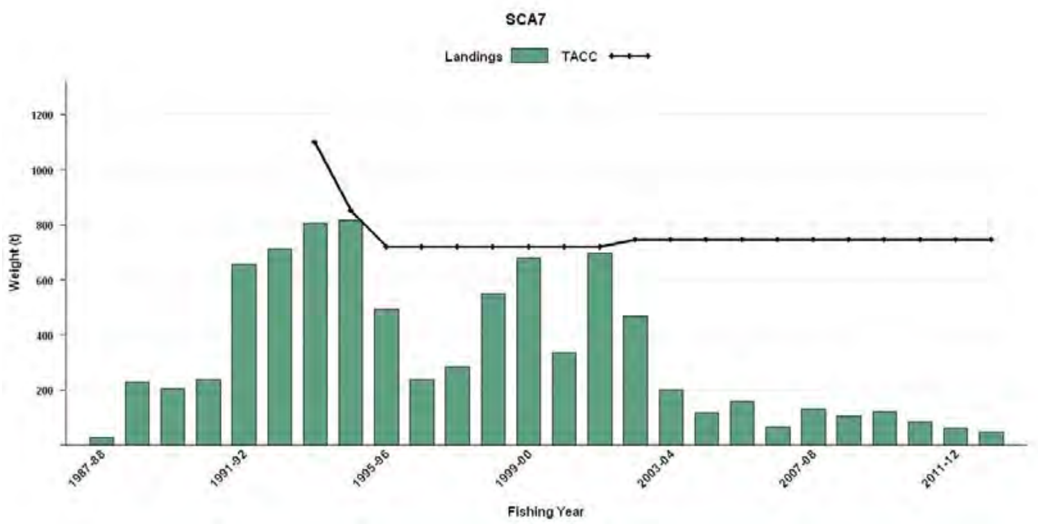


Figure 1: Historical landings and TACC for SCA7 (Nelson Marlborough).

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

*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.

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 review) equate to about 7–18% of the commercial harvest in the areas surveyed in those years; the panel survey (Wynne-Jones et al. in review) was still under review at the time this report was written, but appears to provide plausible results.

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 review)

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 was conducted in the 2009–13 surveys. In 2013, only the Marlborough Sounds substock was surveyed: Golden Bay and Tasman Bay were not surveyed because of the expected low abundance of scallops in those bays. 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 values in Table 6 are absolute estimates, produced by reanalysing the historical survey data using a revised analytical procedure described by Tuck & Brown (2008) to better account for uncertainty in the biomass estimates (Table 6).

Estimates in Table 6 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 this value (although harvesters and processors continued to take only scallops ≥ 90 mm, the minimum legal size). In 2001, 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	–	–

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						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	–	–

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	–	–

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.

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	–	–

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 a revised analytical procedure described by Tuck & Brown (2008) to better account for uncertainty in the start of season biomass estimates (Table 7).

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

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	–	–	184	0.19	–	–

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.

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.

Historically, CAY has not been estimated for Golden and Tasman Bays because those areas operate under a fishing plan that involves enhancement and rotational fishing. Under legislation (section 14 of the Fisheries Act 1996), the catch limit for those parts of the fishery can be set at a level other than at the Maximum Sustainable Yield. However, New Zealand's Harvest Strategy Standard incorporates section 14 stocks, including those that are enhanced or rotationally fished, and it requires that (modified) MSY-related targets should nevertheless be set.

There is no enhancement or rotational fishing plan for the Marlborough Sounds, so harvest levels need to be set there each year. For the Marlborough Sounds, 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 2012 season (nominally 1 September) was an estimated 120 t meatweight with a CV of 22% (Williams & Bian 2012). Using this value and the range in $F_{0.1}$ of 0.553 (assumed M = 0.4) to 0.63 (assumed M = 0.5) gives CAY estimates (in tonnes meatweight) as follows:

		$F_{0.1}$ = 0.55	$F_{0.1}$ = 0.63
B_{beg} =	120 t	51 t	56 t

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.

The actual catch limit (MSCL in Table 3) is usually set at, or close to, the level of recruited relative meatweight biomass as determined in the pre-season abundance survey. This approach usually produces a value in the middle of the CAY range.

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.

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 (www.mpi.govt.nz/Default.aspx?TabId=126&id=1644) (Ministry for Primary Industries 2012).

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).

[1] The F values reported by Breen & Kendrick (1999) are instantaneous Fs.

[2] The F values reported by Cryer (1999) are not instantaneous Fs.

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).

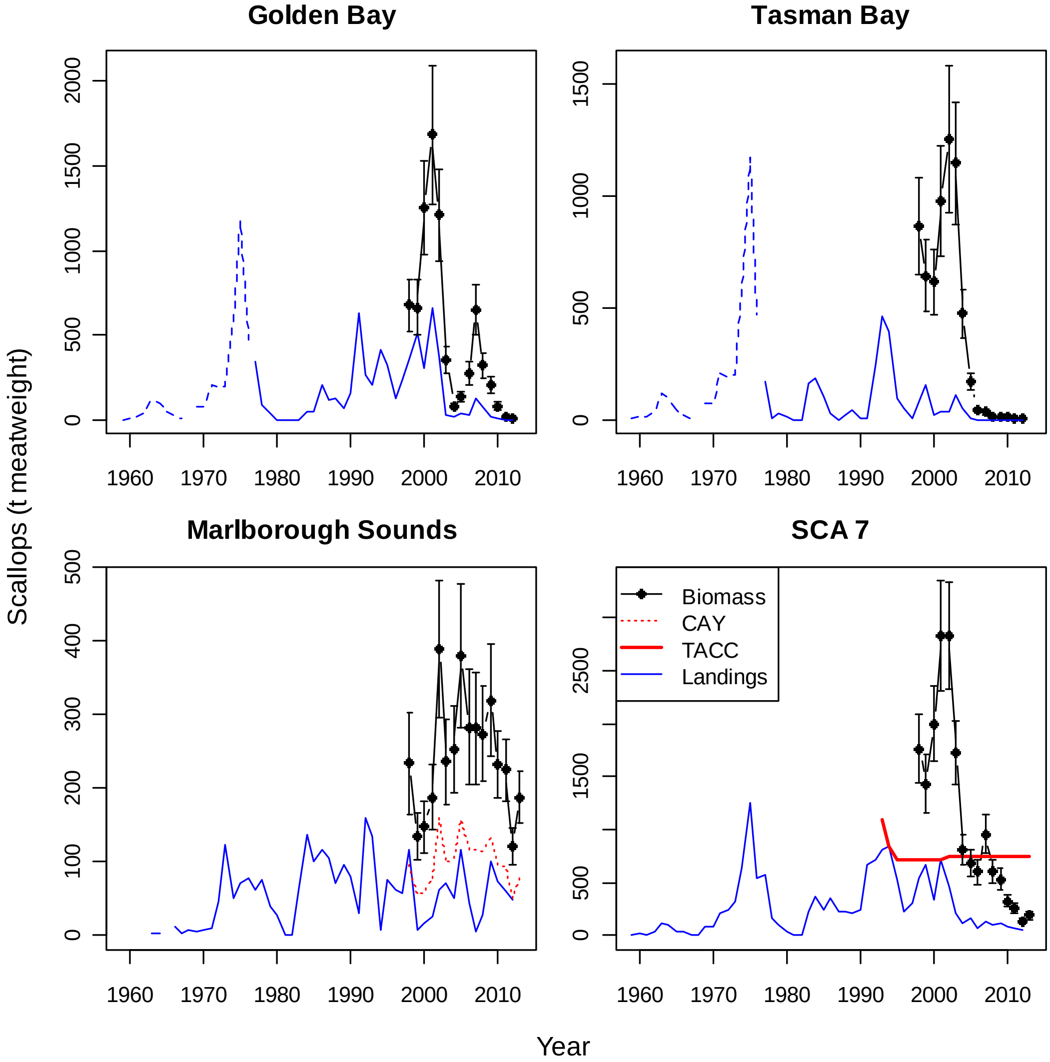
6. STATUS OF THE STOCKS

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.

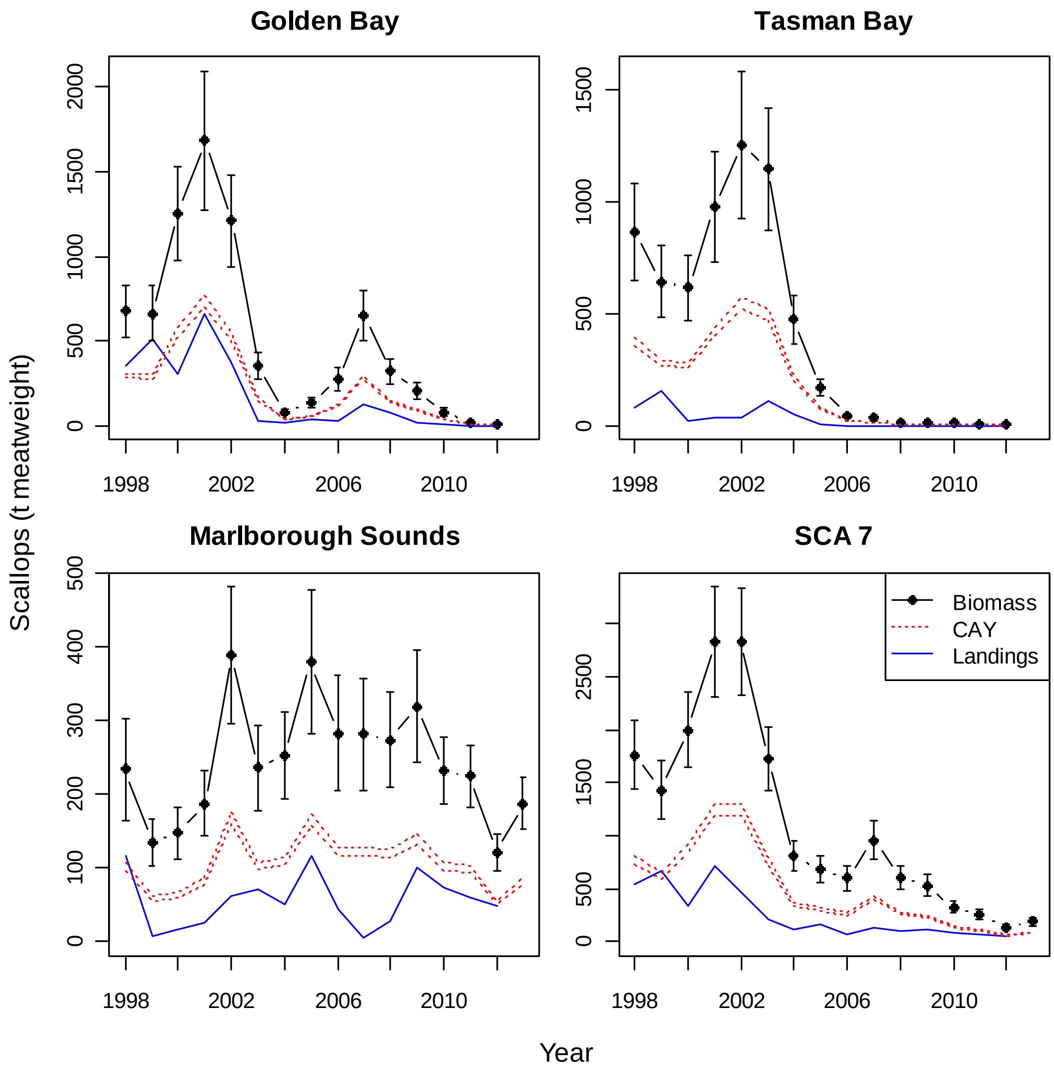
- **Challenger scallops, SCA 7**

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	Two approaches to estimating CAY for Marlborough Sounds in 2013. Estimates of biomass for Golden Bay and Tasman Bay in 2012 (these areas were not surveyed in 2013).
Reference Points	Target: Fishing mortality at or below $F_{0.1}$ for Marlborough Sounds ($F_{0.1}$ = 0.553 y^{-1} or 0.631 y^{-1} if M = 0.4 and 0.5, respectively). No targets have been set for Golden Bay or Tasman Bay; B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	Likely (> 60%) to be below F_{target} for Marlborough Sounds Very Unlikely (< 10%) to be at or above the biomass target for Golden Bay or Tasman Bay
Status in relation to Limits	About as Likely as Not (40-60%) to be below the soft limit and Unlikely (< 40%) to be below the hard limit for Marlborough Sounds Very Likely (> 90%) to be below the soft limit for Golden Bay and Tasman Bay Likely (> 60%) to be below the hard limit for Golden Bay and Tasman Bay
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring for Marlborough Sounds and Unknown for Golden Bay and Tasman Bay

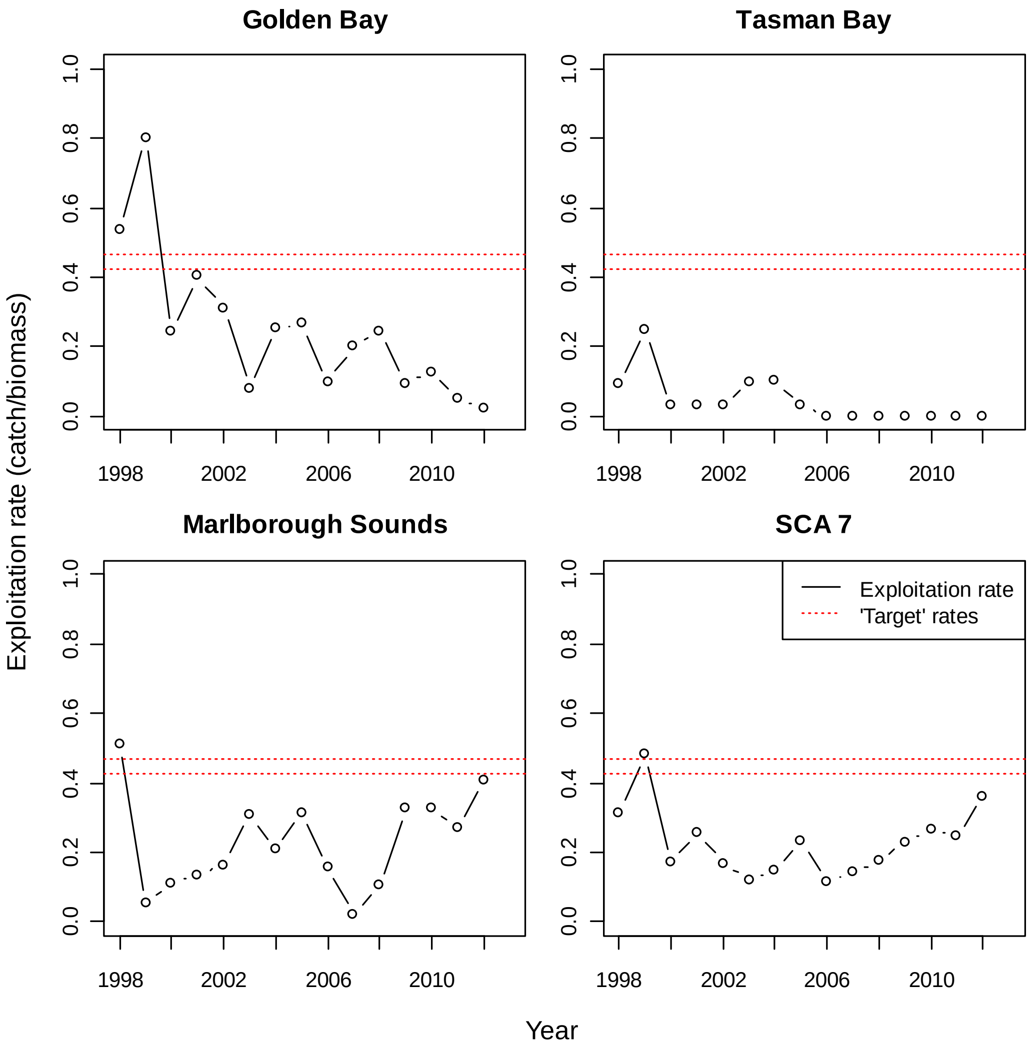
Historical Stock Status Trajectory and Current Status



Recruited (scallops 90 mm or more shell length) mean (and C.V. of) biomass estimates (closed symbols with error bars joined by 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). CAY (using $F_{0.1}$ = 0.553) for the Marlborough Sounds since 1998 is also shown (dotted red 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, and was subsequently managed under a rotationally enhanced regime.



Trends in the SCA 7 stock from 1998–2013. Plots show start of season recruited scallop biomass estimates and CVs (closed symbols with error bars joined by solid black line), CAY estimated retrospectively using $F_{0.1}$ = 0.553 (lower dotted red line) and $F_{0.1}$ = 0.631 (upper dotted red line), and reported landings (solid blue line) by region and for the overall SCA 7 stock. All values in t meatweight. Golden Bay and Tasman Bay were not surveyed in 2013.



Exploitation rate (catch divided by biomass) trends for recruited scallops by region and for the overall SCA 7 stock (solid black lines). Horizontal lines show two 'Target' exploitation rates of 0.42 (lower 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. It has been recognised that these estimates of the target fishing mortality $F_{0.1}$ used in the calculation of CAY may be too high.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass in the Marlborough Sounds region, which was the only region surveyed in 2013, increased slightly over the 2012 level. No surveys were conducted in Golden of Tasman Bays in 2013 because of expected low abundance in these regions. 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 a substantial biomass decline in both Golden Bay and Tasman Bay, and current biomass in both regions is at historically low levels. Biomass in the Marlborough Sounds has exhibited a steady overall decline since 2009.
Recent Trend in Fishing Intensity or Proxy	In Golden Bay, the 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, and was very low (2%) in 2012–13. In Tasman Bay, the peak 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 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, but there has been an increasing trend since then, reaching a high of 40% in 2012–13.
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Stock projections are not available. There is some evidence of a slight increase in the number of juveniles in the Marlborough Sounds from the 2013 survey. The low numbers of pre-recruit scallops (89 mm or smaller) in Golden Bay and Tasman Bay at the time of the 2012 survey suggests recruitment to the fishable biomass in those areas over the next two years is likely to be minimal. High densities of scallop spat were observed in mesh spatbags in Golden Bay in March 2012, suggesting larval abundance was high, but the success of natural settlement and survivorship on the seabed is unknown.
Probability of Current Catch causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown for current catch Hard Limit: Unknown for current catch
Probability of TACC causing Biomass to remain below or to decline below Limits	Very Likely (> 90%) for the current TACC
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial quantitative stock assessment	
Assessment Method	Biomass surveys and CAY management strategy	
Assessment Dates	Latest assessment: 2013	Next assessment: 2014
Overall Assessment Quality Rank	1 – High Quality	
Main data inputs (rank)	Biomass survey: 2013	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.

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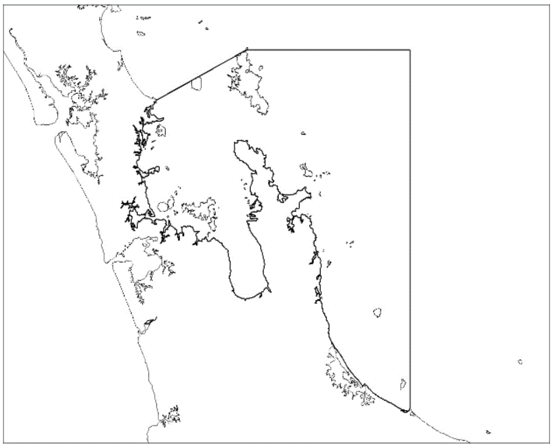
SCALLOPS COROMANDEL (SCA CS)

(*Pecten novaezelandiae*)
Kuakua, Tipa



1. FISHERY SUMMARY

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

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. 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 the 2011 and 2012 seasons. That 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 cannot be 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 50 t to over 1500 t (greenweight). 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 operational decision rules which include an agreed CPUE limit, a minimum meatweight recovery, and an acceptable proportion of legal size scallops in the catch.

Northern scallop fisheries are 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. Both northern scallop fisheries have been 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 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; #2011 and 2012 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.

	Catch limits (t)		Landings (t)			Scaled estimated catch (t green)			
			MHR	CELR					
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
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

	Catch limits (t)		Landings (t)			Scaled estimated catch (t green)			
			MHR	CELR					
Season	Meat	Green[1]	Meat	Meat	Green	Hauraki	Mercury	Barrier	Plenty
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	–	–	–	–	–	–	–

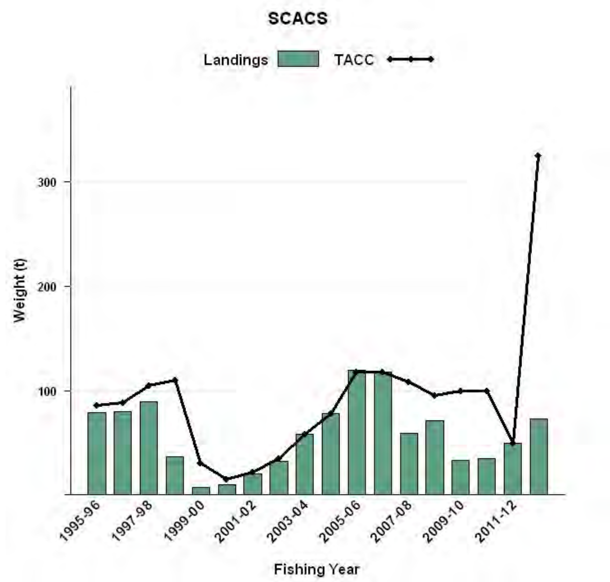


Figure 1: Landings and catch limits for SCACS (Coromandel) from 2002–03 to 2012–13. TACC refers to catch limit, and Weight refers to Meatweight.

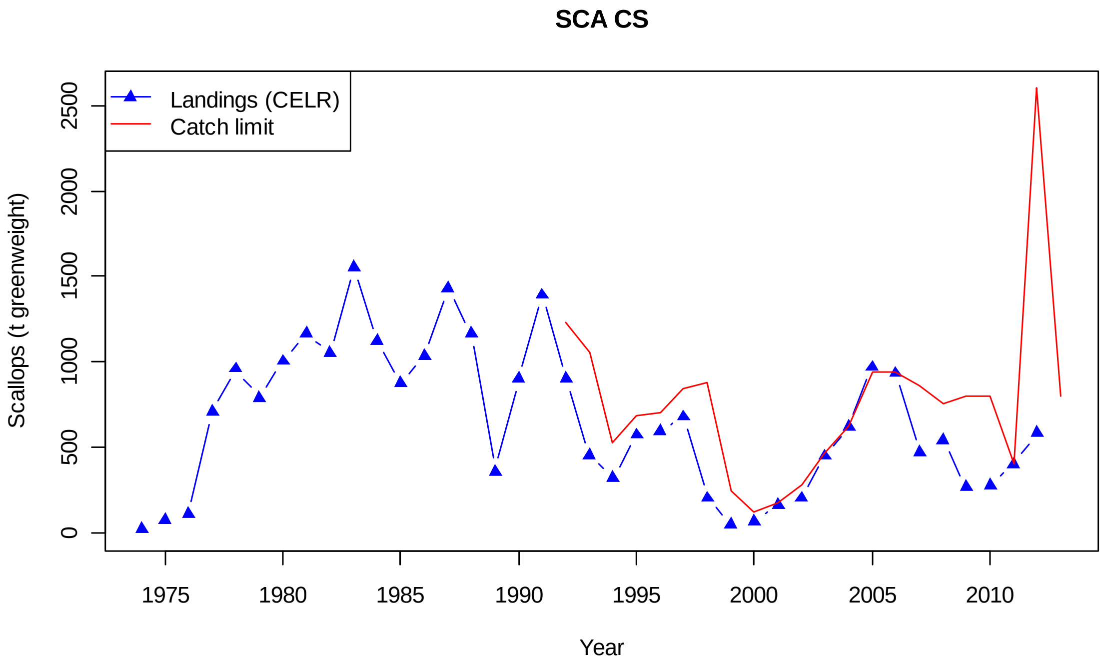


Figure 2: Catch limits and reported landings (from CELRs) in t greenweight for the SCA CS fishery since 1974.

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; note the estimates provided by telephone diary surveys are no longer considered reliable for various reasons (for more information, see Ministry for Primary Industries 2013b: pp 1101-1105 of the snapper section of the Fisheries Assessment Plenary 2013).

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 review) equates to about 16% of the commercial harvest in the area surveyed in that year; that panel survey (Wynne-Jones et al in review) was still under review at the time that this report was written, but appears to provide plausible results. 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 estimates provided by telephone diary surveys are no longer considered reliable for various reasons. The 2007–08 estimates are for a 90 day period of the summer in a defined area (Coromandel peninsular) within SCA CS only. Note the 2011–12 panel survey was still under review at the time that this report was written, but appears to provide plausible results.

Year	Area	Survey method	Number	CV	Green (t)	Meat (t)	Reference
1993–94	SCA CS	Telephone diary	626 000	0.14	60–70	8–9	Bradford (1997)
1996	SCA CS	Telephone diary	614 000	0.12	62	8	Bradford (1998)
1999–00	SCA CS	Telephone diary	257 000	1.01	30	4	Boyd and Reilly (2002)
2000–01	SCA CS	Telephone diary	472 000	0.47	55	7	Boyd et al (2004)
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	Weight (kg)	Number	Unspecified	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	–	440	–	–	440	–

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

Coromandel scallops are managed using a TACC of 100 t meatweight which can be augmented with additional ACE based on a Current Annual Yield (CAY) calculation using $F_{0.1}$ as a reference point. Surveys of selected scallop beds in the fishery have been conducted on an almost annual basis, as a means of estimating stock size, calculating CAY, and informing potential increases in ACE.

In 2011, however, no survey was conducted; instead, CAY for the 2011 season was 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 index 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).

4.1 Estimates of fishery parameters and abundance

Fishing mortality has sometimes been quite high in the Coromandel fishery (Table 6).

CPUE is not presented for this fishery because it is not a reliable index of abundance (Cryer 2001b). However, recent simulation studies have examined the use of CPUE as a basis for some management strategies (Haist & Middleton 2010).

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 have been annual surveys and assessments of Coromandel scallops since 1992 (except for 2000, 2011, and 2013), in support of a CAY management strategy. Assessments are based on pre-season biomass surveys done by diving and/or dredging (Tables 6–8). 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. –, no data. There was no survey in 2000 or 2011. 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.

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

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. However, some changes have been so large as to transcend this combined uncertainty. 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. In future, the data should be re-worked using the new method of Bian et al (2012). 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 and it seems reasonable to conclude 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 remarkable 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 ‘new’ 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 new Hauraki Gulf region of the fishery (2W/2S), 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.

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).

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

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

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.

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). Experiments and modelling showed this method to be sub-optimal however. New estimates of the reference fishing mortality rates $F_{0.1}$, $F_{40\%}$ and F_{max} were therefore 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.

Diver surveys of scallops were conducted annually in June–July from 2006 to 2010 at selected scallop beds in the Coromandel recreational fishing areas (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 and would probably be close to zero.

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.

Management of Coromandel scallops is based on a CAY approach. Since 1998, 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 essentially adult scallops), but also to indirect incidental effects (such as additional juvenile mortality related to reduced habitat heterogeneity in dredged areas).

Consequently, the most recent CAY estimates were derived in 2012 for two scenarios:

1) 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 $F_{0.1} = 1.034\ y^{-1}$ (reported by Cryer et al 2004, as $5/12 * F_{0.1} = 0.431$). Using this value and the 2012 start of season biomass estimate of 1380 t meatweight (median projected value), the CAY for 2012–13 was estimated to be 439 t meatweight (Williams et al 2012).

2) CAY including direct and indirect effects on adults and juveniles

Cryer et al (2004) 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 applied here. Using this value and the 2012 start of season biomass estimate of 1380 t (median projected value), the CAY for 2012–13 was estimated to be 300 t meatweight (Williams et al 2012).

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 (18%), 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.

Regardless of the approach used to estimate CAY, the production of a single 'best estimate' of CAY should be treated with caution; it is better to work with a range of estimates. 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 9).

Table 9: 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}).

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

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.

Stochastic yield-per-recruit (YPR) and spawning-stock-biomass-per-recruit (SSBPR) modelling has been conducted for the Coromandel scallop fishery, including the incidental effects on growth and mortality of the dredge method in use throughout the fishery. Estimates of reference rates of fishing mortality from this study have been used to estimate CAY since 1998. More recent experimental and modelling studies indicate that even these reference rates of fishing mortality may be too high if habitat effects and juvenile scallop mortality are taken into account, causing a positive bias in CAY. CAY may also be over-estimated when either the efficiency of the dredge used during the survey is greater than that assumed in calculations (i.e., the multiplier used to account for dredge efficiency is optimistic), or the density of scallops is low and part of the biomass occurs at a density not viable for commercial fishing.

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 (www.mpi.govt.nz/Default.aspx?TabId=126&id=1644) (Ministry for Primary Industries 2012).

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

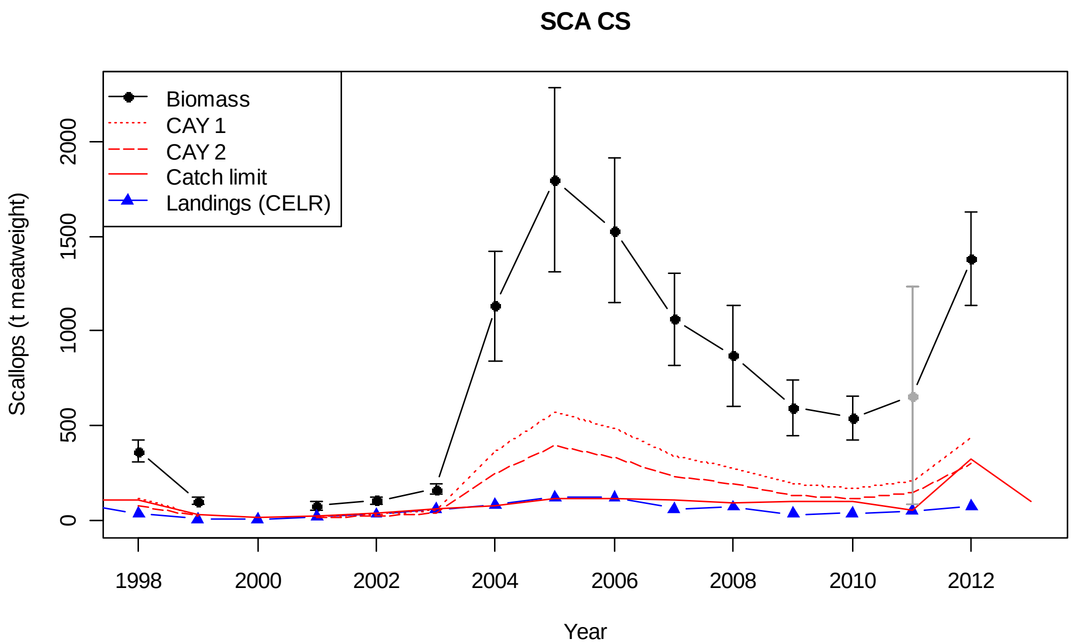
The stock structure of scallops in New Zealand waters is uncertain. For the purposes of this assessment, SCA CS is assumed to be a single biological stock, although the extent to which the various beds or populations are reproductively or functionally separate is not known.

- **Coromandel scallops, SCA CS**

Stock Status	
Year of Most Recent Assessment	2012
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})

	CAY for 2012–13 was estimated at 439 t (using $F_{0.1}$ = 1.034 y^{-1}) or 300 t (using $F_{0.1}$ = 0.658 y^{-1}) meatweight
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), CAY 1 (includes direct effects of fishing on adult scallops), CAY 2 (includes direct and indirect effects of fishing on adults and juveniles), catch limits, and reported landings (from CELRs) 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 (shown in grey).

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 dramatically 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, but this downward trend appeared to have abated in 2010 (540 t). In addition to the core areas, 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}), but much higher between 2001 and 2003 (mean F_{est} = 0.96 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 management strategy	
Assessment Dates	Latest assessment: 2012	Next assessment: 2014
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. Current model has been in use since 1998. In 2011, however, no survey was conducted; instead, CAY was calculated using estimates of projected biomass generated by projecting forward the 2010 survey data to the 2011 season.	

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. At the Shellfish Fishery Assessment Working Group held on 21–22 January 2010, concerns were raised about the large discrepancy that has been observed over recent years between the CAY estimates for the commercial Coromandel scallop fishery and the actual catch taken by the fishers. Fishers that attended the SFWG meeting believe that it is not possible to catch the CAY. MFish project SAP2009-10 (Williams et al 2011) investigated a number of factors which could affect the difference between CAY and the actual commercial catch, and found that the calculated dredge efficiency was the major factor contributing to the difference. Project SAP200913 (Bian et al 2012) modelled the efficiency of box dredges used in northern New Zealand scallop fisheries; results suggest the efficiency of these dredges was underestimated previously (2004 to 2010), resulting in overestimation of biomass and yield. The new model of dredge efficiency (Bian et al 2012) was used in the 2012 assessment.
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.

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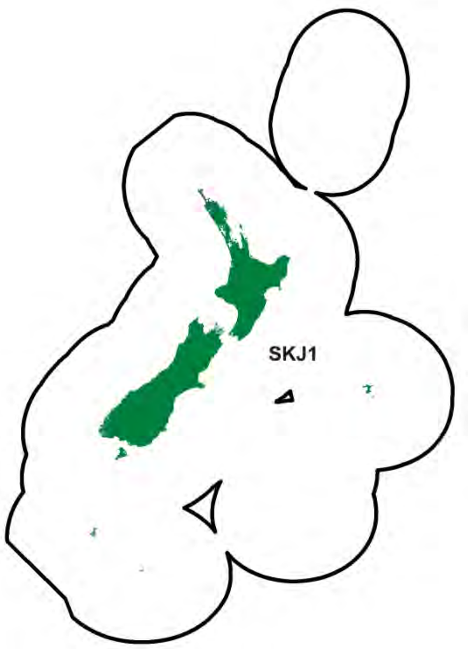
SKIPJACK TUNA (SKJ)

(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 have averaged 11 236 t annually between 2006–07 and 2011–12. Catches in the New Zealand EEZ are variable and can approximate 10 000 t in a good season such as 1999–00, 2003–04, 2004–05, 2006–07, 2007–08 and 2010–11.

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 and longline fishing effort for SKJ fisheries.

Catches from within New Zealand fisheries waters are very small (0.5% average for 2007–2009) compared to those from the greater stock in the WCPO. Catches by New Zealand flagged vessels in the WCPO are larger (1.2% average for 2007–2009).

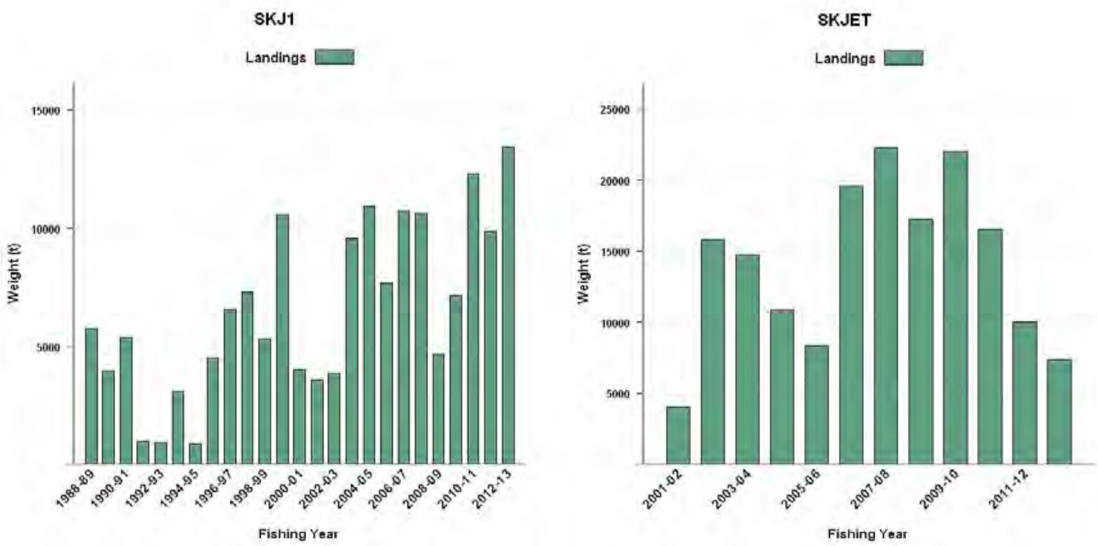


Figure 1: Skipjack purse seine catch from 1988–89 to 2012–13 within New Zealand waters (SKJ 1), and 2001–02 to 2012–13 in the equatorial Pacific by New Zealand vessels.

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 2012.

	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	1 058 042
2002	3 555	15 827	19 382	1 231 133
2003	3 828	14 769	18 597	1 216 468
2004	9 704	10 932	20 636	1 300 463
2005	10 819	8 335	19 154	1 394 691
2006	7 247	19 588	26 835	1 475 849
2007	11 392	22 266	33 659	1 654 389
2008	10 033	17 204	27 237	1 638 943
2009	4 685	21 991	26 676	1 770 574
2010	8 629	16 530	25 153	1 680 631
2011	10 840	9 999	20 839	1 514 817
2012	9 881	7 530	17 411	1 648 810

*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	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			14 896	13 437

Skipjack tuna account for the majority 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).

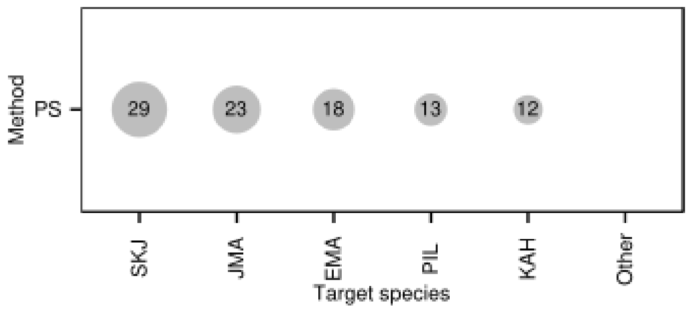


Figure 2: A summary of the proportion of landings target sets in the domestic purse seine fishery. The area of each circle represents the percentage of the vessel days targeting each species PS = purse seine (Bentley et al 2013).

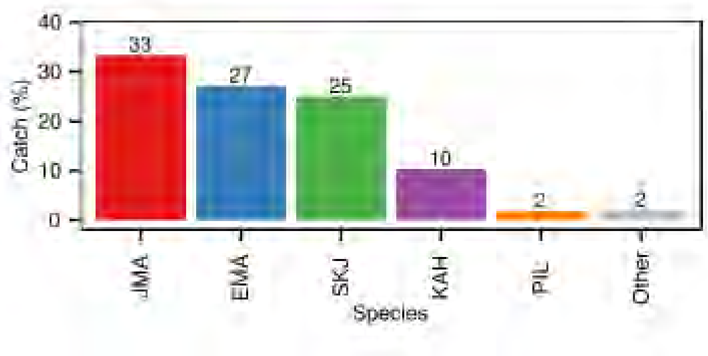


Figure 3: A summary of species composition of the reported purse seine catch. The percentage by weight of each species is calculated for all domestic trips (Bentley et al 2013).

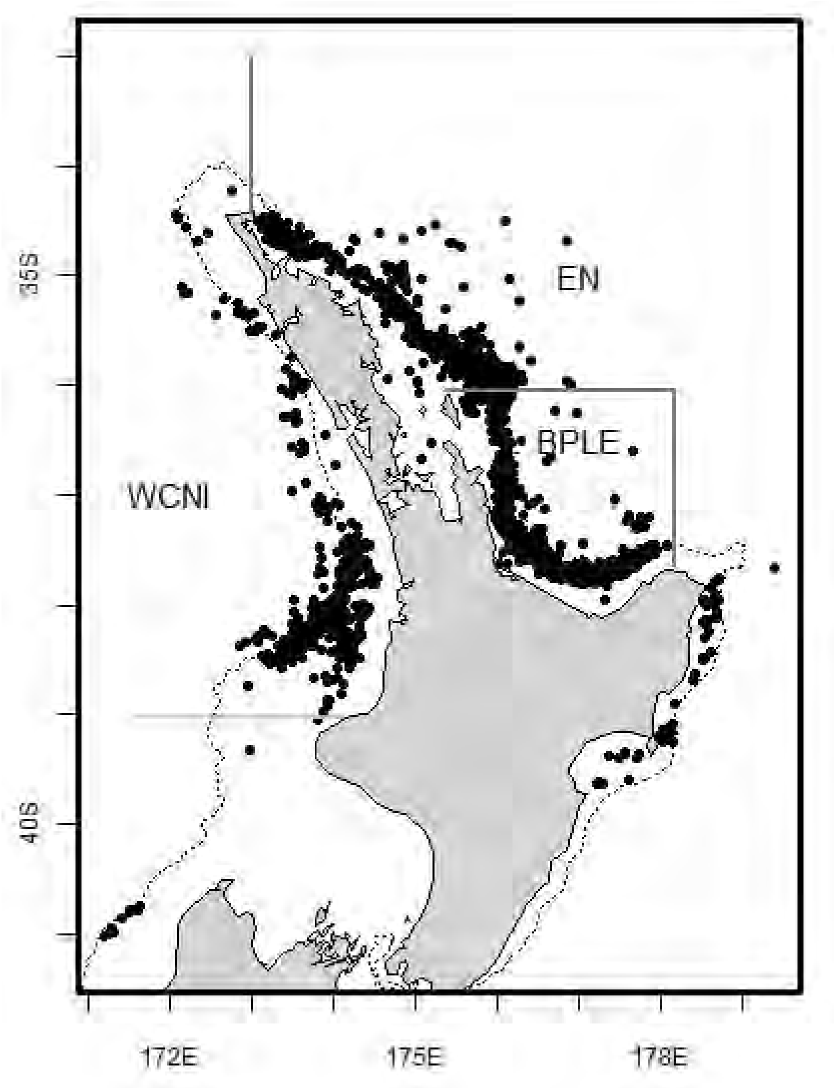


Figure 4: Location of purse-seine sets targeting skipjack tuna from 1999–2000 to 2008–09. The solid grey lines denote the boundaries of the main fishery areas (EN, east Northland, BPLE, Bay of Plenty; WCNI, west coast North Island). The dashed line represents the 200 m depth contour (Langley 2011).

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 1**). 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**). 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 1**). 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**) (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**) (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**) (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

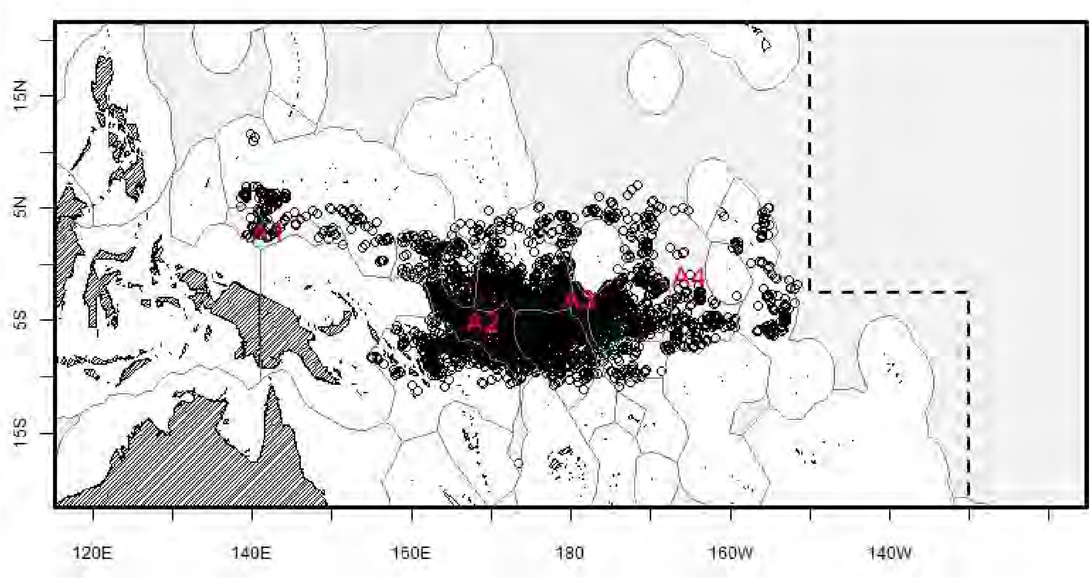


Figure 1: Distribution of purse-seine set locations for New Zealand flagged vessels operating in the equatorial region of the western Pacific Ocean from 2001 to 2009. The red labels (A 1–4) denote the four areas of international waters referred to in the text.

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.

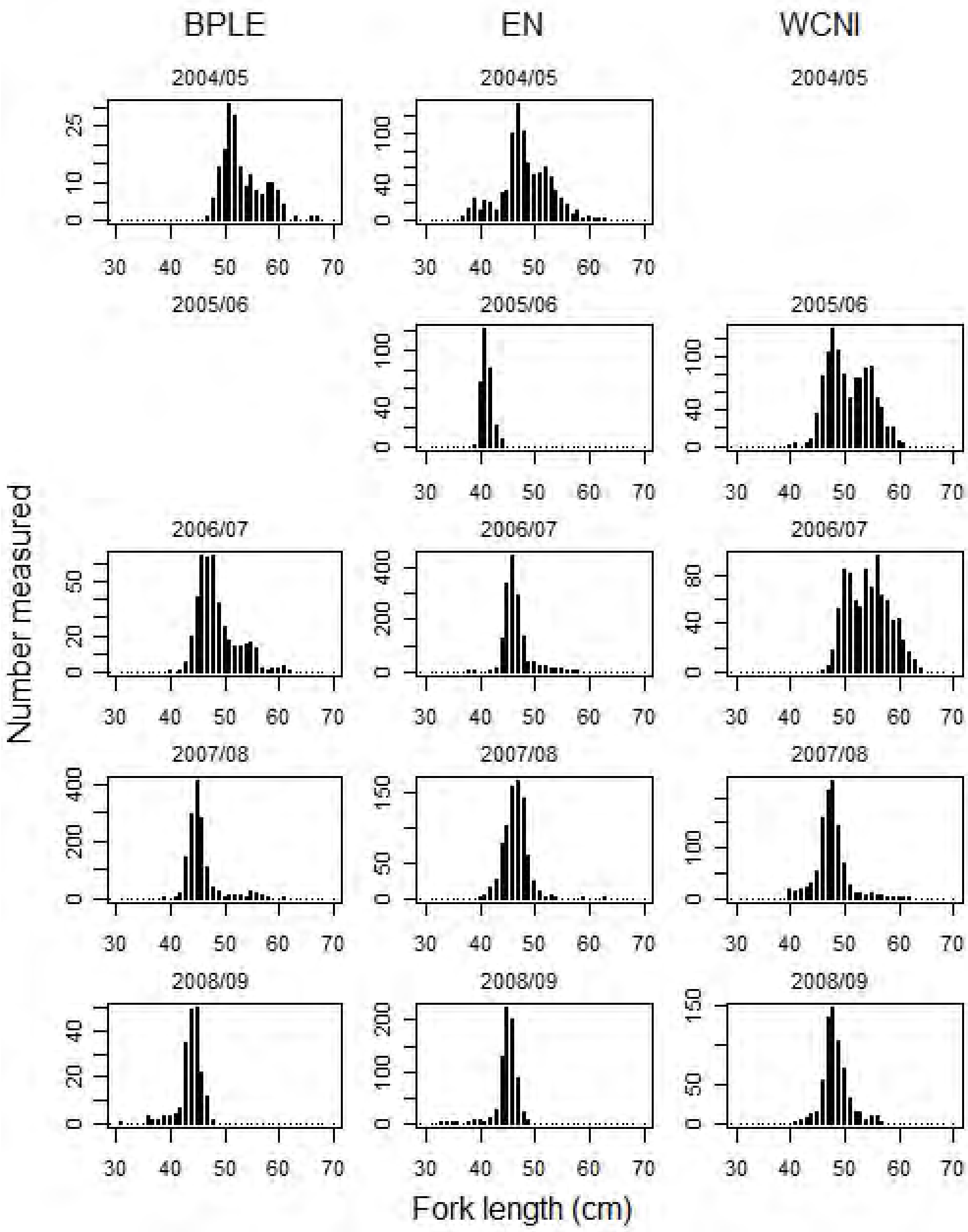


Figure 6: Length (FL) composition of the skipjack tuna catch sampled by MPI observers in the domestic target purse-seine fishery by fishery area (columns) and fishing year (rows) (fishery areas: BPLE, Bay of Plenty; EN, east Northland; WCNI, west coast North Island) (Langley 2011).

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2013 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=1644).

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 manta 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 2005–2012.

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	11.5	19.7

Table 6: Catch composition from six observed purse seine trips targeting skipjack tuna operating within New Zealand fisheries waters in 2011 and 2012.

Common name	**Scientific name**	**Observed catch weight (kg)**	**% Catch**
Skipjack tuna	*Katsuwonus pelamis*	4 360 758	98.50
Jack mackerel	*Trachurus* spp.	37 207	0.84
Blue mackerel	*Scomber australasicus*	17 760	0.40
Sunfish	*Mola mola*	4 516	0.10
Spine-tailed devil ray	*Mobula japanica*	1 990	0.04
Striped marlin	*Tetrapturus audax*	1 320	0.03
Frigate tuna	*Auxis thazard*	1 090	0.02
Albacore tuna	*Thunnus alalunga*	683	0.02
Jellyfish	Scyphozoa	459	0.01
Mako shark	*Isurus oxyrinchus*	418	0.01
Thresher shark	*Alopias vulpinus*	275	0.01
Swordfish	*Xiphias gladius*	150	<0.01
Hammerhead shark	*Sphyrna zygaena*	145	<0.01
Bronze whaler shark	*Carcharhinus brachyurus*	80	<0.01
Ray's bream	*Brama brama*	80	<0.01
Frostfish	*Lepidopus caudatus*	74	<0.01
Flying fish	Exocoetidae	71	<0.01
Slender tuna	*Allothunnus fallai*	50	<0.01
Porcupine fish	*Allomycterus jaculiferus*	47	<0.01
Moonfish	*Lampris guttatus*	40	<0.01
Stingray	Dasyatididae	40	<0.01
Blue shark	*Prionace glauca*	30	<0.01
Discfish	*Diretmus argenteus*	25	<0.01
Snapper	*Pagrus auratus*	15	<0.01
Electric ray	*Torpedo fairchildi*	14	<0.01

Pufferfish	*Sphoeroides pachygaster*	9	<0.01
Octopus	Octopoda	7	<0.01
Squid	Teuthoidea	7	<0.01
Garfish	*Hyporhamphus ihi*	5	<0.01
Starfish	Asteroidea & ophiuroidea	3	<0.01
Salp	*Doliolum* spp.	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
Rudderfish	*Centrolophus niger*	2	<0.01
Smooth skate	*Dipturus innominatus*	2	<0.01
Gurnard	*Chelidonichthys kumu*	1	<0.01
Jack mackerel	*Trachurus murphyi*	1	<0.01
Natant decapod	Decapoda	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 most recent stock assessment of the WCPO stock of skipjack tuna was done in 2011 and reviewed by the WCPFC Scientific Committee in August 2011. The executive summary of the stock assessment report is provided below (from Hoyle et al 2011) and in Figures 7–12 and Tables 7 and 8.

"The assessment uses the stock assessment model and computer software known as MULTIFAN-CL. The skipjack tuna model is age (16 quarterly age-classes) and spatially structured. The catch, effort, size composition, and tagging data used in the model are grouped into 18 fisheries (a change from the 17 fisheries used in the 2010 assessment) and quarterly time periods from 1972 through 2010.

The current assessment incorporates a number of changes from the 2010 assessment, including:

a. Updated catch, effort, and size data;
b. A revised standardised effort series for each region based on a new GLM analysis of catch and effort data from the Japanese distant-water pole-and-line fishery.
c. Adjustment of size frequency data based on observer sampling of skipjack, bigeye, and yellowfin size and species compositions, and adjustment for grab-sampling bias.
d. Changes to the modelling of the Philippines and Indonesia purse seine fisheries. These fisheries are separated into fishing activity in archipelagic waters, and fishing outside archipelagic waters to the east of longitude 125°E. Purse seine effort to the east of 125°E is included in the main associated purse seine fishery, apart from domestically-based vessels which are included in a new PI-ID domestic purse seine fishery.
e. Inclusion of tag releases and recoveries from the recent SPC-PTTP tagging programmes, which increases tagging data in the assessment by 50%.

f. Steepness, a parameter defining the shape of the stock recruitment relationship, was changed from 0.75 to 0.8 in the reference case, with alternative values of 0.65 and 0.95 included in sensitivity analyses.
g. Growth parameters were fixed at their values estimated in 2010.

In addition to these changes, a large suite of additional models were run to aid the development of the final “reference case” model. This reference case model is used as an example for presenting model diagnostics, but the most appropriate model run(s) upon which to base management advice will be determined by the Scientific Committee. The sensitivity of the reference model to key assumptions (i.e., regarding the stock recruitment relationship, the catch per unit effort time series, the purse seine catch and size data, the growth model, and the PTTP tagging data) were explored via sensitivity analyses. The results of these analyses should also be considered when developing management advice.

A number of trends in key data inputs were noted as particularly influential for the assessment results. The large tagging data set, and associated information on tag reporting rates, is relatively informative regarding stock size. The relative sizes of fish caught in different regions are also indicative of trends in total mortality, mediated though growth, catch, and movement rates. The assessment is therefore very dependent on the growth model.

For the northern region, there was little contrast in the Japanese pole and line CPUE time-series. However, both the southern region Japanese pole and line CPUE time series showed increases early in the time series and declines at the end, with greater decline in region 2.

Overall, the main assessment results and conclusions are as follows.

a. Estimates of natural mortality are strongly age-specific, with higher rates estimated for younger skipjack.

b. The model estimates significant seasonal movements between the western and eastern equatorial regions. The performance of the fishery in the eastern region has been shown to be strongly influenced by the prevailing environmental conditions with higher stock abundance and/or availability associated with El Niño conditions. This is likely to be at least partly attributable to an eastward displacement of the skipjack biomass due to the prevailing oceanographic conditions, although this dynamic cannot be captured by the parameterisation of movement in the current model.

c. Recruitment showed an upward shift in the mid-1980s and is estimated to have remained at a higher level since that time. This change in estimated recruitment is driven in the model by the CPUE data, and also by the tagging data, given the relative tag return rates from the SSAP and the RTTP tagging programmes. Recruitment in the eastern equatorial region is more variable with recent peaks in recruitment occurring in 1998 and 2004–2005 following strong El Niño events around those times. Conversely, the lower recruitment in 2001–2003 followed a period of sustained La Nina conditions. Recent recruitment is estimated to be at a high level, but is poorly determined due to limited observations from the fishery.

d. The biomass trends are driven largely by recruitment and fishing mortality. The highest biomass estimates for the model period occurred in 1998–2001 and in 2005–2007, immediately following periods of sustained high recruitment within the eastern equatorial region (region 3).

e. The biomass trajectory is influenced by the underlying assumptions regarding the treatment of the various fishery-specific catch and effort data sets within the model. The Japanese pole-and-line fisheries are all assumed to have constant catchability, with any temporal trend in efficiency assumed to have been accounted for by the standardization of the effort series. The CPUE trends are influential regarding the general trend in both recruitment and total biomass over the model period. In all regions there is a relatively good fit to the observed CPUE data, with some deterioration when PTTP tagging data are introduced.

f. The model also incorporates a considerable amount of tagging data that provides information concerning absolute stock size during the main tag recovery periods. Including the PTTP tagging data in the model resulted in higher estimates of recent biomass and MSY. Initial analyses of the data suggest some conflict with inferences from the CPUE time series about trends in abundance. Further work on both data sources is recommended.

g. Within the equatorial region, fishing mortality increased throughout the model period and is estimated to be highest in the western region in the most recent years. The impact of fishing is predicted to have reduced recent biomass by about 47% in the western equatorial region and 21% in the eastern region. For the entire stock, the depletion is estimated to be approximately 35%.

h. The principal conclusions are that skipjack is currently exploited at a moderate level relative to its biological potential. Furthermore, the estimates of $F_{current} / \tilde{F}_{MSY}$ and $B_{current} / \tilde{B}_{MSY}$ indicate that overfishing of skipjack is not occurring in the WCPO, nor is the stock in an overfished state. These conclusions appear relatively robust, at least within the statistical uncertainty of the current assessment. Fishing pressure and recruitment variability, influenced by environmental conditions, will continue to be the primary influences on stock size and fishery performance.

i. For the model assumptions investigated, there was only moderate variation in the estimates of stock status. The most influential assumptions involved steepness and growth. There are insufficient data to estimate steepness reliably within the assessment model and many of the key management quantities are strongly influenced by the values assumed. Growth and its variation in space, through time, and among individuals is not well understood. However, only a limited range of assumptions was investigated in this assessment, and as a result the true level of uncertainty is likely to be under-estimated. A range of other assumptions in the model should be investigated either internally or through directed research. Further studies are required to refine our estimates of growth and reproductive potential, including spatio-temporal variation; to examine in detail the time-series of size frequency data from the fisheries, which may lead to refinement in the structure of the fisheries included in the model; to consider size-based selectivity processes in the assessment model; to continue to improve the accuracy of the catch estimates from a number of key fisheries; to refine the methods used to adjust catch and size data in the purse seine fisheries; to refine the methodology and data sets used to derive CPUE abundance indices from the pole and line fishery; to refine approaches to integrate the recent tag release/recapture data into the assessment model; and to develop more formal and rigorous methods for prioritizing the many available research options.

j. Based on estimates of $F_{current} / \tilde{F}_{MSY}$ and $B_{current} / \tilde{B}_{MSY}$ from the reference model and associated sensitivity grid, it is concluded that overfishing of skipjack is not occurring in the WCPO, nor is the stock in an overfished state. These conclusions appear relatively robust, at least within the statistical uncertainty of the current assessment. Although the current (2006-2009) level of exploitation is below that which would provide the maximum sustainable yield, recent catches have increased strongly and the mean catch for 2006-2009 of 1.5 million tonnes is equivalent to the estimated MSY at an assumed steepness of 0.8, but below the grid median estimate of 1.9 million tonnes. Maintenance of this level of catch would be expected to decrease the spawning stock size towards MSY levels if recruitment remains near its long-term average level. Fishing mortality and recruitment variability, influenced by environmental conditions, will both continue to affect stock size and fishery performance."

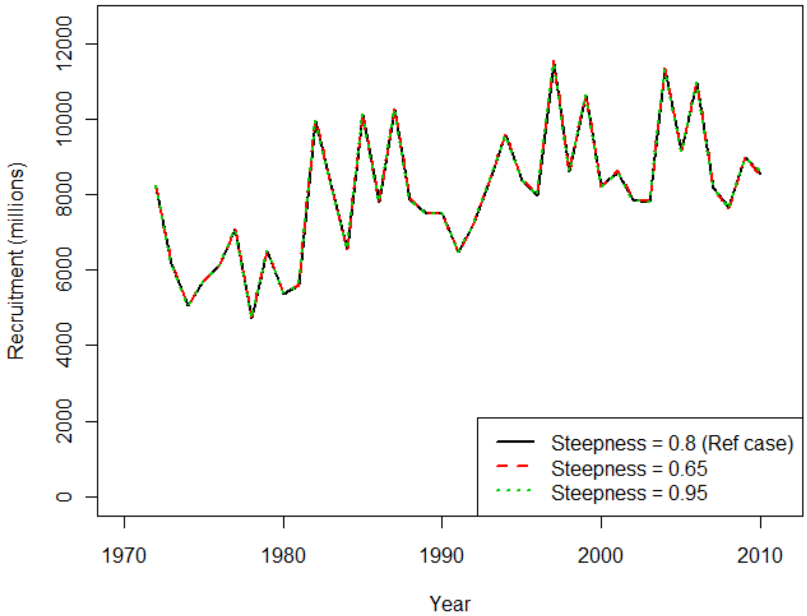


Figure 7: Estimated annual recruitment (millions of fish) for the WCPO obtained from the reference model (steepness = 0.8 - black line) and the two alternative steepness values.

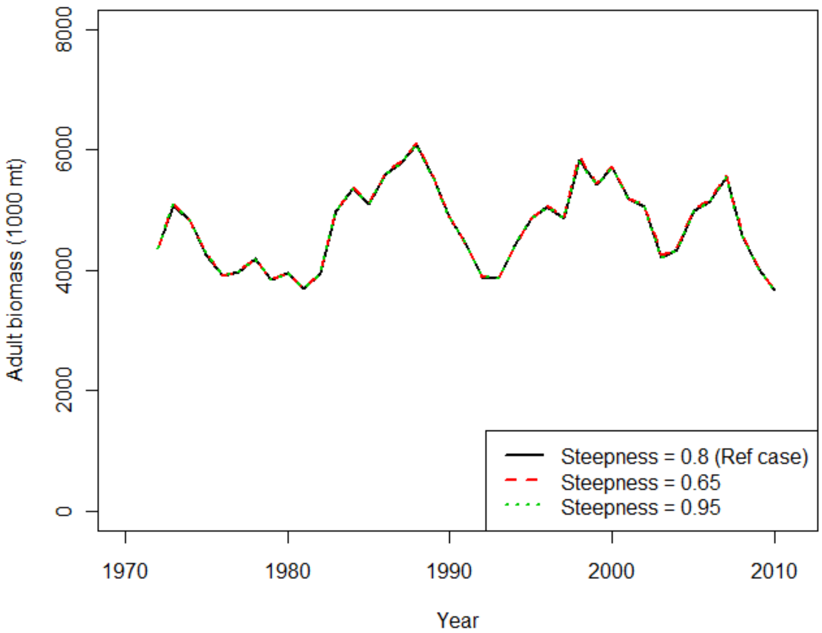


Figure 8: Estimated average annual average spawning biomass for the WCPO obtained from the reference model and the two alternative steepness values.

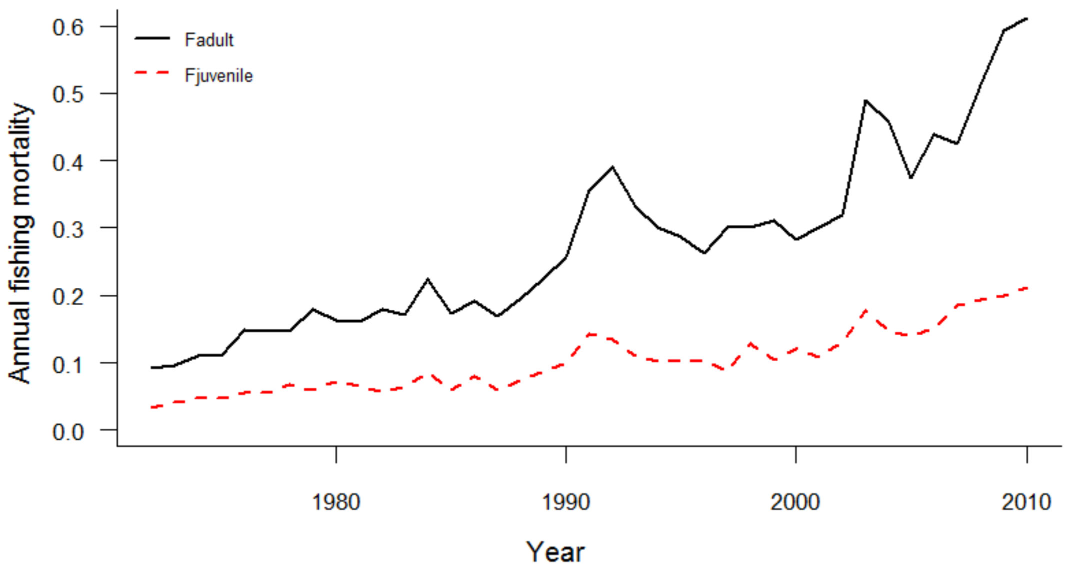


Figure 9: Estimated annual average juvenile and adult fishing mortality for the WCPO obtained from the reference case model.

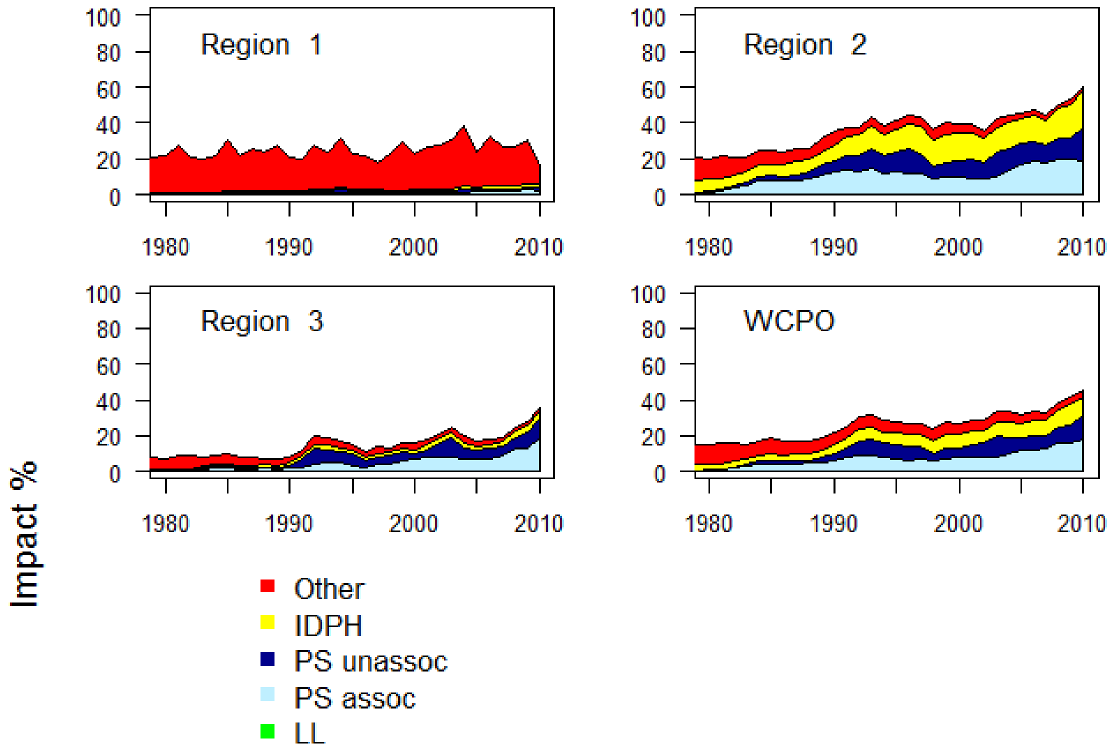


Figure 10: Estimates of reduction in spawning potential due to fishing (fishery impact = 1-$SB_t/SB_{tF=0}$) by region and for the WCPO attributed to various fishery groups (reference case model). L = all longline fisheries; IDPH = Philippines and Indonesian domestic fisheries; PS assoc = purse-seine log and FAD sets; PS unassoc = purse-seine school sets; Other = pole-and-line fisheries and coastal Japan purse-seine.

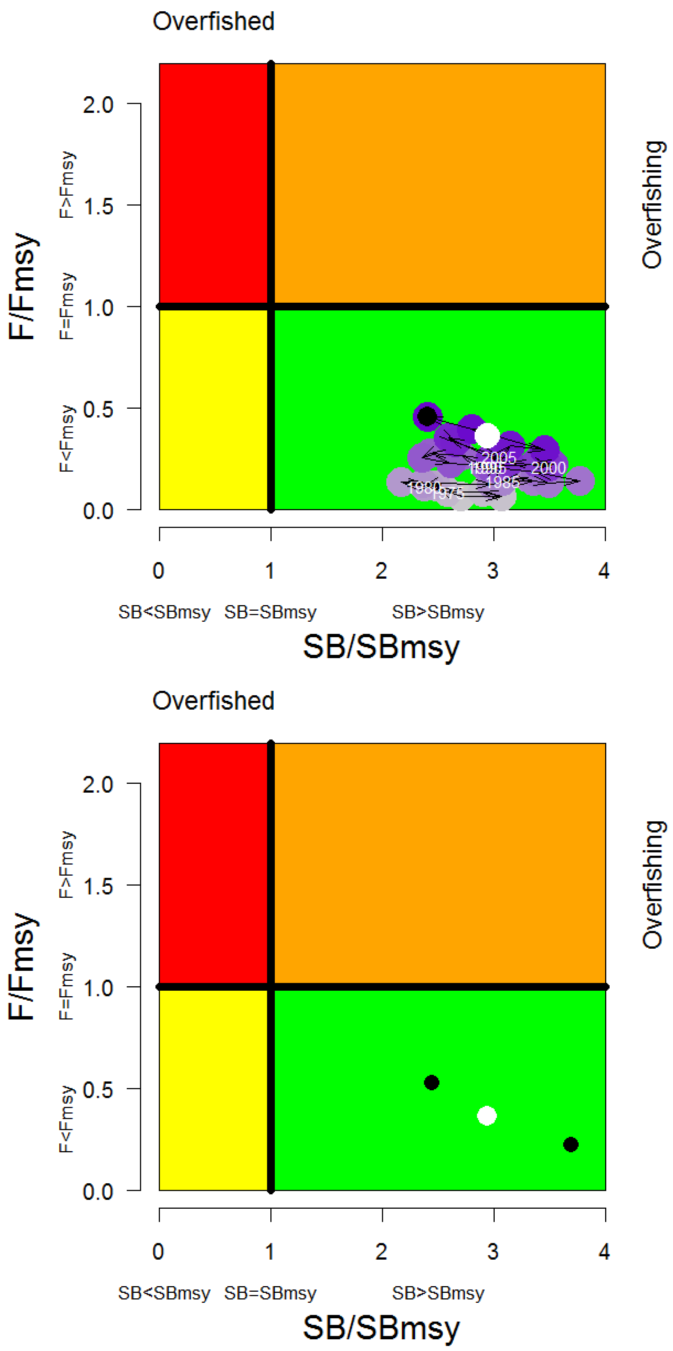


Figure 11: Temporal trend in annual stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the reference case model the colour of the points is graduated from mauve (1972) to dark purple (2010) (top) and $F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for the reference case (white circle) and the two alternative steepness values. See Table 7 to determine the individual model runs.

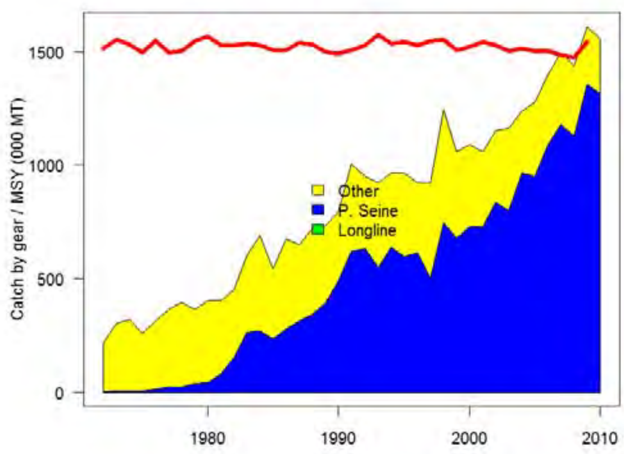


Figure 12: History of annual estimates of MSY [red line] compared with catches of three major fisheries sectors. [other mostly Indonesia and the Philippines catch, longline catch is too low to be shown on the scale].

Table 7. Estimates of management quantities for selected stock assessment models from the 2011 reference case model and the two alternative steepness values. For the purpose of this assessment, "current" is the average over the period 2006–2009 and "latest" is 2010 [*C* = catch].

	H80 (Base case)	H65	H95
1.0 C_{curre}	1 484 702	1 484 729	1 484 894
C_{latest}	1 556 643	1 556 596	1 556 924
MSY	1 503 600	1 274 000	1 818 000
$C_{current}/MSY$	0.99	1.17	0.82
C_{latest}/MSY	1.04	1.22	0.86
1.1 F_{mult}	2.71	1.9	4.46
$F_{current}/F_{MSY}$	0.37	0.53	0.22
SB_0	5 787 000	5 940 000	5 888 000
SB_{MSY}/SB_0	0.27	0.32	0.22
$SB_{current}/SB_0$	0.79	0.77	0.82
SB_{latest}/SB_0	0.60	0.58	0.62
$SB_{current}/SB_{MSY}$	2.94	2.45	3.69
SB_{latest}/SB_{MSY}	2.21	1.84	2.80
$SB_{curr}/SB_{curr_{F=0}}$	0.63	0.63	0.65
$SB_{latest}/SB_{latest_{F=0}}$	0.54	0.54	0.56
Steepness (h)	0.80	0.65	0.95

Table 8. Estimates of reference points from the 2011 (with uncertainty based on the range of models in Table 7), 2010, and 2008 skipjack tuna stock assessments. The spatial domain of the 2008 assessment was limited to the equatorial region of the WCPO.

Management quantity	2011 Assessment (uncertainty)	2010 Assessment	2008 Assessment
Most recent catch	1 556 643	1 575 287 mt (catch based on spill sampling)[a]	1 546 436 mt (2007[b]) 1 726 702 mt (2007[c]) 1 410 389 (WCPO catch based on spill sampling)
MSY	1 503 600 (1 274 000 – 1 818 000)	1 375 600 mt	1 280 000 mt
$Y_{Fcurrent}/MSY$	0.76 (0.65–0.86)	0.80	0.70
$B_{current}/B_{current,\ F=0}$	0.65 (0.65–0.67)	0.63	0.66
$F_{current}/F_{MSY}$	0.37 (0.22–0.53)	0.34	0.26
$B_{current}/B_{MSY}$	2.68 (2.32–3.17)	2.24	2.99
$SB_{current}/SB_{MSY}$	2.94 (2.45–3.69)	2.67	3.82

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 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.

Fishing mortality for juvenile skipjack is very low in all regions, although it has tended to increase slightly over time within the western component of the equatorial WCPO. This is mainly due to the steady increase in catch from the Philippines fishery. For adult skipjack, fishing mortality rates vary considerably between regions. Fishing mortality rates are highest in the western equatorial region and are estimated to have increased considerably over the last five years. For the eastern component of the equatorial WCPO, fishing mortality rates for adult skipjack remained relatively low until recent years. Since 2007, fishing mortality rates in the eastern region are estimated to have increased in line with the higher catches taken from the area.

5.2 Biomass estimates

The biomass trajectories are largely driven by the trends in the pole-and-line CPUE indices. The indices have remained relatively stable and to account for the increasing total catch the stock assessment model estimated an upward shift in recruitment during the mid-1980s. Recruitment is estimated to have remained at a higher level since that time.

5.3 Yield estimates and projections

No estimates of MCY and CAY are available.

5.4 Other yield estimates and stock assessment results

Though no reference points have yet been agreed by the WCPFC, stock status conclusions are generally presented in relation to two criteria. The first relates to “overfished” which compares the current biomass level to that necessary to produce the maximum sustainable yield. The second relates to “over-fishing” which compares the current fishing mortality rate to that which would move the stock towards a biomass level necessary to produce the maximum sustainable yield. The first criteria is similar to that required under our own Fisheries Act while the second has no equivalent in our legislation and relates to how hard a stock can be fished.

Because recent catch data are often unavailable, these measures are calculated based on the average fishing mortality/biomass levels in the ‘recent past’, e.g., 2006–2010 for the 2012 assessment. The assessment included a wide range of sensitivities to key assumptions. Some key reference points for the range of model sensitivities are presented in Table 8.

Recent catches were comparable to the upper limit of the range of estimates of MSY and were considerably higher than the lower range of plausible MSY estimates. The estimates of MSY are sensitive to the assumptions regarding the steepness of the stock-recruitment relationship and current yields are consistent with recent (above average) levels of recruitment. Spawning biomass (SB) was estimated to be about 2–3 times the level necessary to produce MSY and, by definition, well above the overfished threshold. The ratio of $F_{current}$ compared with F_{MSY} (the fishing mortality level that would produce the MSY under equilibrium conditions) is below 1 indicating that recent fishing mortality rates were below F_{MSY}. Fishing mortality rates were estimated to have increased considerably in the last few years but still remain well below the F_{MSY} level.

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 floating objects (FADs) are set on. The fishery in New Zealand fisheries waters is done 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 recent 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

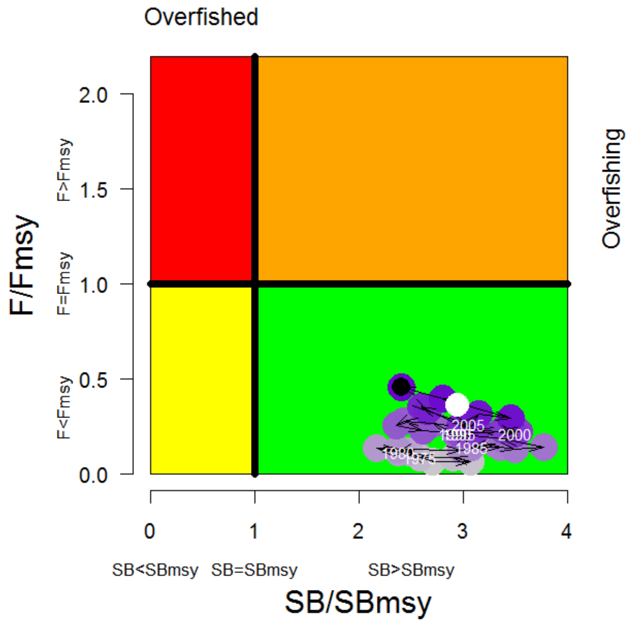
Stock structure assumptions

Skipjack tuna are considered to be a single stock in the WCPO but the assessment presented below is limited to the area north of 20°S and, hence, does not include the component of the fishery within New Zealand waters.

Stock Status	
Year of Most Recent Assessment	A full stock assessment was completed in 2011
Assessment Runs Presented	Base case model only
Reference Points	Target: $B > B_{MSY}$ and $F < F_{MSY}$ Soft Limit: Not established by WCPFC but evaluated using HSS default of 20% B_0 Hard Limit: Not established by WCPFC but evaluated using HSS default of 10% B_0 Overfishing threshold: F_{MSY}

Status in relation to Target	Very Likely (> 60%) to be above B_{MSY} and Very Likely (> 60%) 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 in annual stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the reference case model. The colour of the points is graduated from mauve (1972) to dark purple (2010). The black circle represents the B_{2010}/B_{MSY} and the F_{2010}/F_{MSY} the white circle represents the $B_{2006\text{-}2009}/B_{MSY}$ and $F_{2006\text{-}2009}/F_{MSY}$.

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 in the three most recent years (2008, 2009 and 2010). Recent depletion levels are estimated at 0.35 (i.e., 0.65 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 5 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. Recruitment in the eastern equatorial region is considerably more variable with recent peaks in recruitment occurring in 1998 and 2004–2005 following strong El Niño events around that time. Conversely, the lower recruitment in 2001–2003 followed a period of sustained La Niña conditions.

Projections and Prognosis	
Stock Projections or Prognosis	Recent catches are above the MSY level but have been supported by above average recruitment. If recruitment returned to long-term average levels then the current level of catches would reduce the biomass to below B_{MSY}. Conversely, biomass is likely to remain above B_{MSY} if recruitment remains

	at the recent average level.	
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 1: Quantitative Stock assessment	
Assessment Method	The assessment uses the stock assessment model and computer software known as MULTIFAN-CL.	
Assessment Dates	Latest assessment: 2011	Next assessment: 2014
Overall assessment quality rank	1 - High Quality	
Main data inputs (rank)	The skipjack tuna model is age (16 quarterly age-classes, i.e. 4 years) and spatially structured, and the catch, effort, size composition and tagging data used in the model are classified by 24 fisheries and quarterly time periods from 1972–2009.	1 - High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	a. Updated catch, effort, and size data. b. A revised standardised effort series for each region based on a new GLM analysis of catch and effort data from the Japanese distant-water pole-and-line fishery. c. Adjustment of size frequency data based on observer sampling of skipjack, bigeye, and yellowfin size and species compositions, and adjustment for grab-sampling bias. d. Changes to the modelling of the Philippines and Indonesia purse seine fisheries. These fisheries are separated into fishing activity in archipelagic waters, and fishing outside archipelagic waters to the east of longitude 125°E. Purse seine effort to the east of 125°E is included in the main associated purse seine fishery, apart from domestically-based vessels which are included in a new PI-ID domestic purse seine fishery. e. Inclusion of tag releases and recoveries from the recent SPC-PTTP tagging programmes, which increases tagging data in the assessment by 50%. f. Steepness, a parameter defining the shape of the stock recruitment relationship, was changed from 0.75 to 0.8 in the reference case, with alternative values of 0.65 and 0.95 included in sensitivity analyses. g. Growth parameters were fixed at their values estimated in 2010.	
Major Sources of Uncertainty	A range of sensitivity analyses were undertaken to investigate key sources of uncertainty in the model, including steepness, natural mortality, and catch history. The key conclusions of the stock assessment, in particularly the current stock status, are robust to the range of assumptions	

	investigated. However, there remains considerable uncertainty regarding the utility of the Japanese pole-and-line CPUE indices as an index of stock abundance.

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 substantially 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

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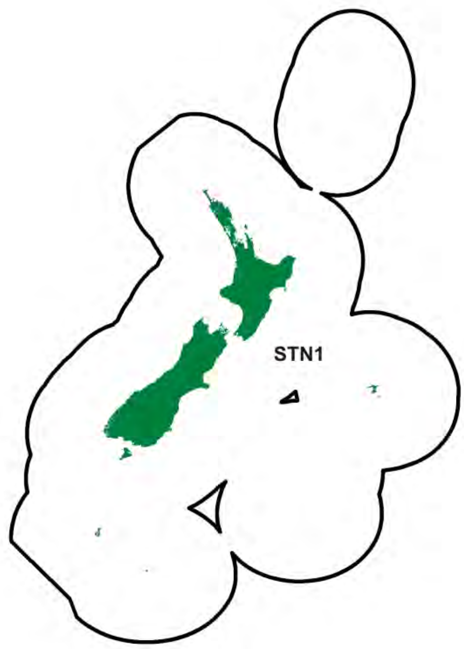
SOUTHERN BLUEFIN TUNA (STN)

(*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 2013.

Member	Effective catch limit (t)
Australia	4698
Fishing Entity of Taiwan	945
Japan	2689
New Zealand	830
Republic of Korea	945
Indonesia	707
Cooperating Non-Member	
European Community	10
Philippines	45
South Africa	80*
TOTAL	10949

* 40 t of this allocation was made to South Africa subject to it acceding to the Convention by a certain time (note, this did not occur in 2013)

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 but for the following 2 years is subject to further review in 2014.

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. Historically New Zealand also supported handline and troll fisheries for STN, although these were small scale and targeted large adults.

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.

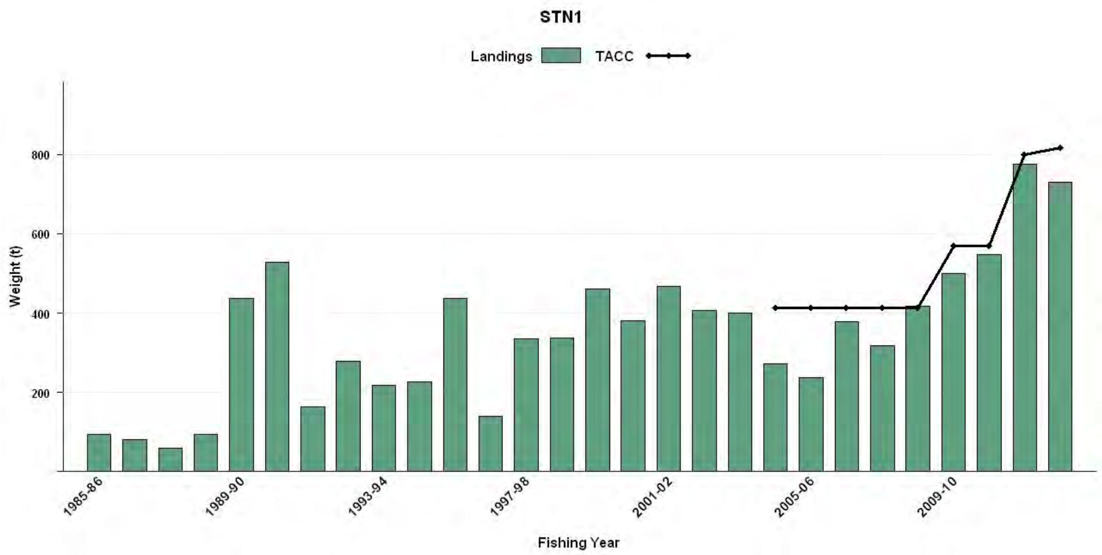


Figure 1: Commercial catch of southern bluefin tuna from 1985-86 to 2012-13 within NZ fishery waters (STN1).

Table 3: Reported domestic[1] and total[2] southern bluefin tuna landings (t) from 1972 to 2011 (calendar year).

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

Year	NZ Landings (t)	Total stock (t)	Year	NZ Landings (t)	Total stock (t)
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
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	775	10 049
1992	279	14 217	2013	759	

[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*		758.9	758.9	758.9	-

* - 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	

* 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).

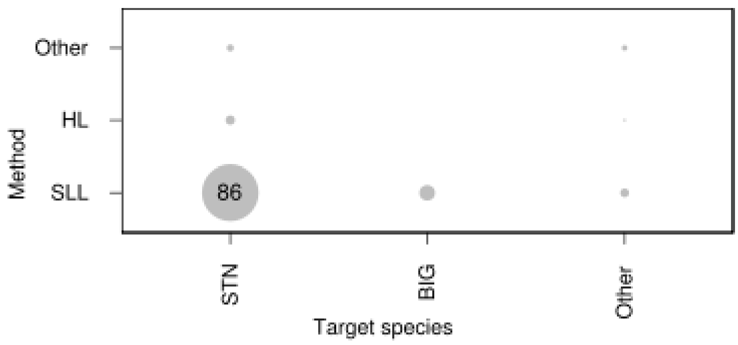


Figure 2: A summary of the proportion of landings of southern bluefin tuna taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bobble is the percentage. SLL = surface longline, HL = hook and line (Bentley et al 2012).

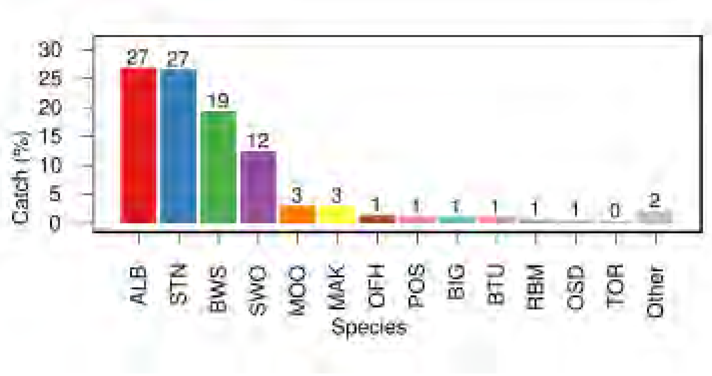


Figure 3: A summary of species composition of the reported southern bluefin tuna target surface longline catch. The percentage by weight of each species is calculated for all surface longline trips targeting southern bluefin tuna (Bentley et al 2012).

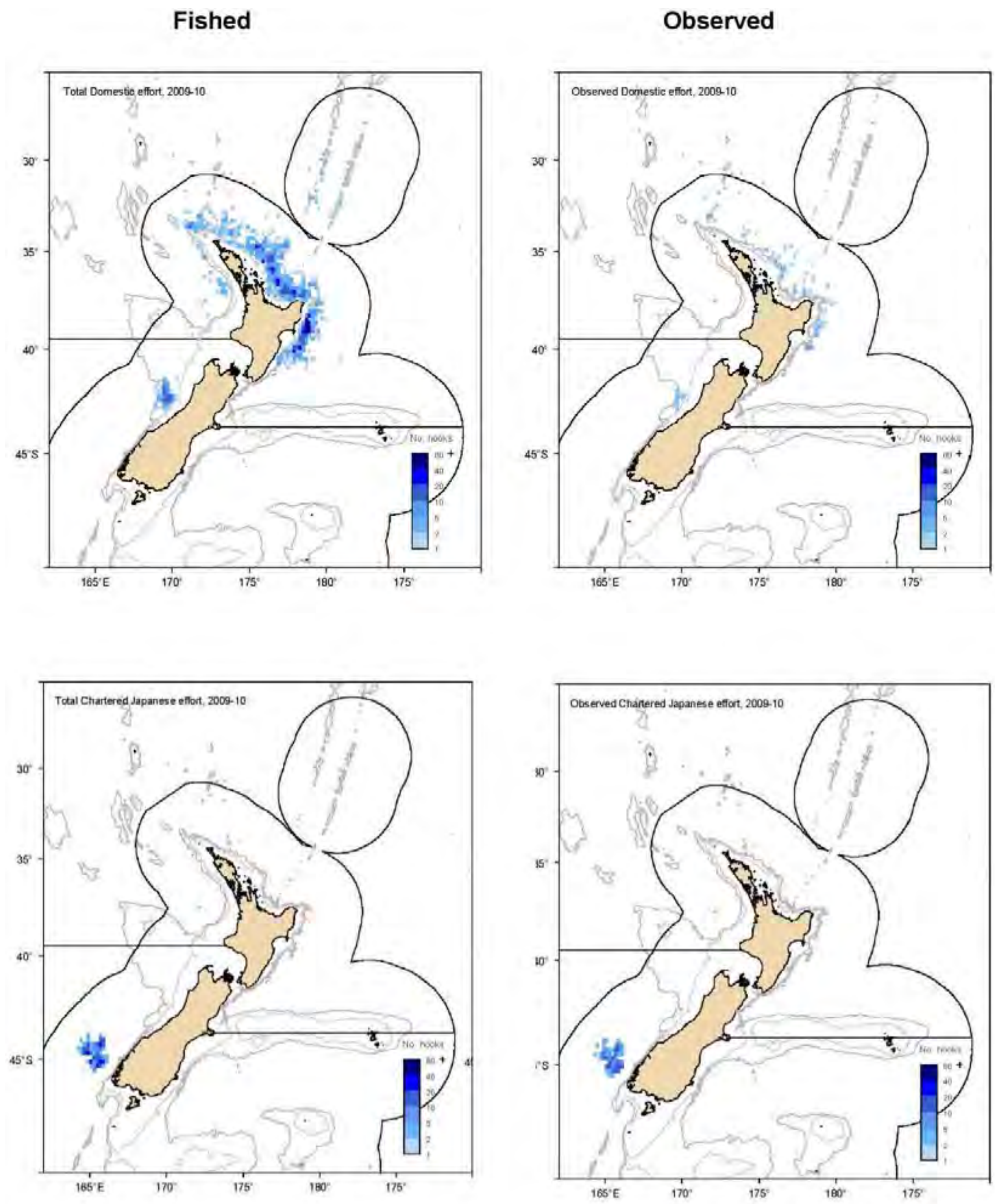


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009-10 fishing year, displaying both fishing effort (left) and observer effort (right).

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:

$$l_t = L_\infty(1 - e^{-k2(t-t0)})(1 + e^{-\beta(t-t0-\alpha)}) / (1 + e^{\beta\alpha})^{-(k2-k1)}, \text{ where t is age in years.}$$

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 2013 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=1644) (Ministry for Primary Industries 2012).

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 2011–12, there were 561 observed captures of birds in southern bluefin longline fisheries. Seabird capture rates since 2003 are presented in Figure 5. The seabird bycatch is most noticeable off Fiordland and around East Cape (see Table 9 and Figure 6). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation was historically used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods but recent estimates are either ratio or model based as specified in the tables below (Abraham et al 2010).

Table 9: Number of observed seabird captures in southern bluefin tuna longline fisheries, 2002–03 to 2011–12, 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 moonfish using longline gear but rather the total risk for each seabird species. Other data, version 20130305.

Albatross species	Risk ratio	Bay of Plenty	East Coast North Island	Fiordland	Northland and Hauraki	Stewart Snares Shelf	West Coast South Island	Total
Salvin's	Very high	1	3	0	0	0	0	4
Southern Buller's	Very high	2	14	278	0	0	33	327
NZ white-capped	Very high	0	3	60	0	10	25	98
Northern Buller's	High	0	1	0	0	0	0	1
Gibson's	High	0	5	3	1	0	1	10
Antipodean	High	0	5	0	1	0	0	6
Southern royal	Medium	0	0	4	0	0	0	4
Campbell black-browed	Medium	2	15	3	2	0	2	24
Light-mantled sooty	Very low	0	0	0	0	0	1	1
Unidentified	N/A	0	6	4	0	0	0	10
Total	**N/A**	**4**	**49**	**352**	**4**	**10**	**62**	**481**
Other seabirds								
Cape petrel	High	0	2	0	0	0	0	2
Westland petrel	Medium	0	0	1	0	0	5	6
White-chinned petrel	Medium	0	1	19	1	1	0	22
Grey petrel	Medium	3	35	0	2	0	0	40
Sooty shearwater	Very low	0	0	1	0	3	0	4
Southern giant petrel		0	2	0	0	0	0	2
Total	**N/A**	**3**	**40**	**21**	**3**	**4**	**5**	**76**

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 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.

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 are based on data version 20121101 and preliminary estimates for 2011–12 are based on data version 20130305.

	Fishing effort			Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	3 510 061	1 133 740	32.3	43	0.038	419	306–579
2003–2004	3 193 871	1 471 964	46.1	70	0.048	427	321–559
2004–2005	1 661 979	734 026	44.2	36	0.049	159	117–217
2005–2006	1 493 418	655 445	43.9	29	0.044	140	102–195
2006–2007	1 938 111	916 660	47.3	111	0.121	212	177–258
2007–2008	1 104 825	376 675	34.1	30	0.08	140	106–185
2008–2009	1 484 438	840 048	56.6	48	0.057	179	139–231
2009–2010	1 559 858	580 395	37.2	112	0.193	309	249–392
2010–2011	1 307 645	567 154	43.4	32	0.056	167	123–228
2011–2012†	1 588 854	645 530	40.6	50	0.077	352	240–586

†Provisional data, model estimates not finalised.

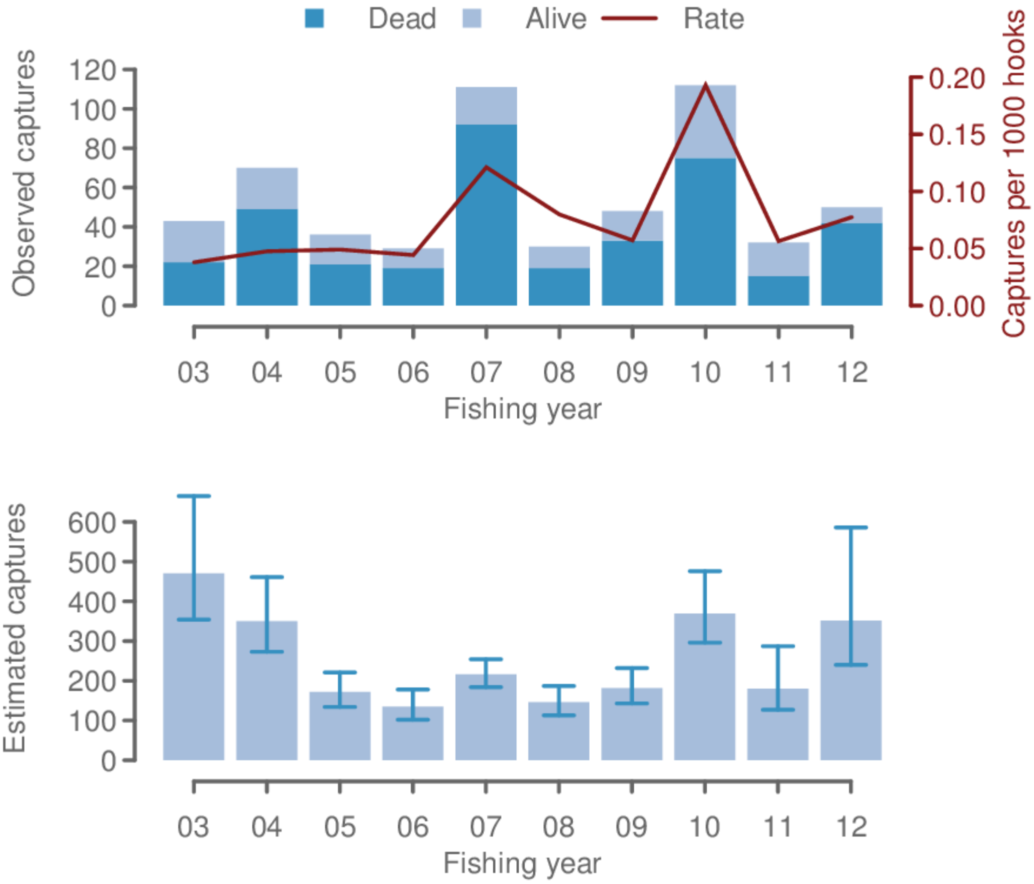


Figure 5: Observed and estimated captures of seabirds in southern bluefin tuna longline fisheries from 2002–03 to 2011–12.

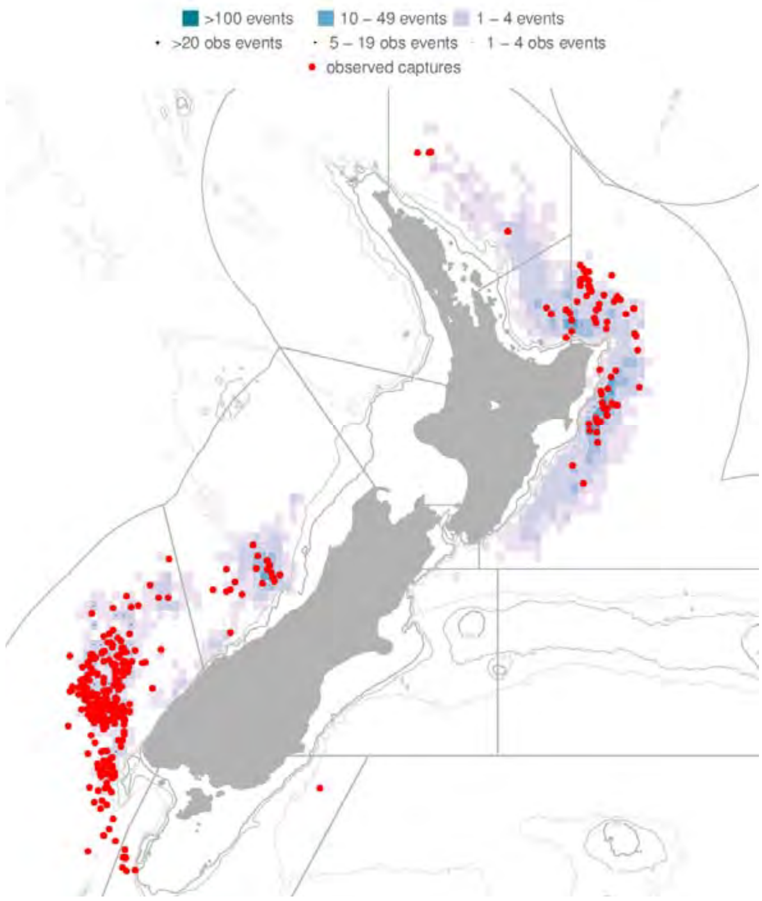


Figure 6: Distribution of fishing effort targeting southern bluefin tuna and observed seabird captures, 2002–03 to 2011–12. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed 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, 77.7% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.2 Sea turtle bycatch

Between 2002–03 and 2011–12, there were three observed captures of sea turtles in southern bluefin longline fisheries (Tables 11 and 12, 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 11: Number of observed sea turtle captures in southern bluefin tuna longline fisheries, 2002–03 to 2011–12, 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 12: 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	3 510 061	1 133 740	32.3	0	0
2003–2004	3 193 871	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	376 675	34.1	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	1 588 854	645 530	40.6	0	0

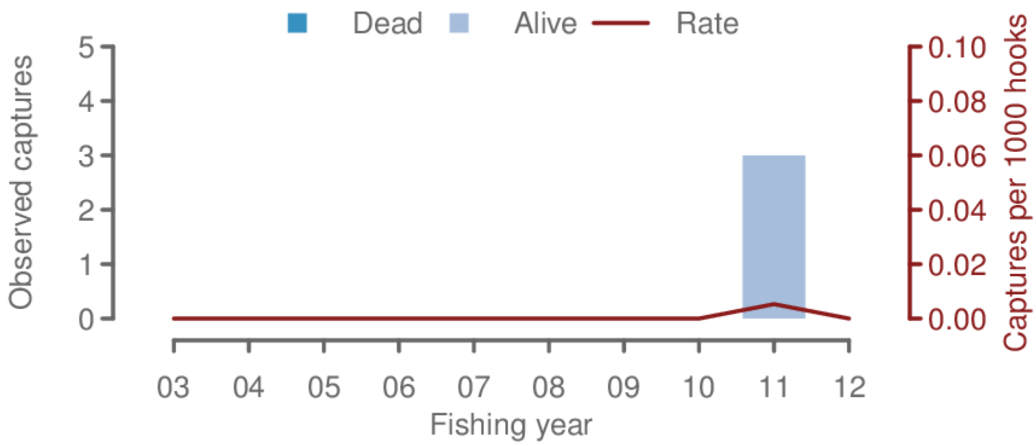


Figure 7: Observed captures of sea turtles in southern bluefin tuna longline fisheries from 2002–03 to 2011–12.

Figure 8: Distribution of fishing effort targeting southern bluefin tuna and observed sea turtle captures, 2002–03 to 2011–12. 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, 77.7% 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 2011–12, there were five observed captures of whales and dolphins in southern bluefin longline fisheries (Tables 13 and 14, 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 13: Number of observed cetacean captures in southern bluefin tuna longline fisheries, 2002–03 to 2011–12, 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 14: 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	3 510 061	1 133 740	32.3	0	0
2003–2004	3 193 871	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	376 675	34.1	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	1 588 854	645 530	40.6	0	0

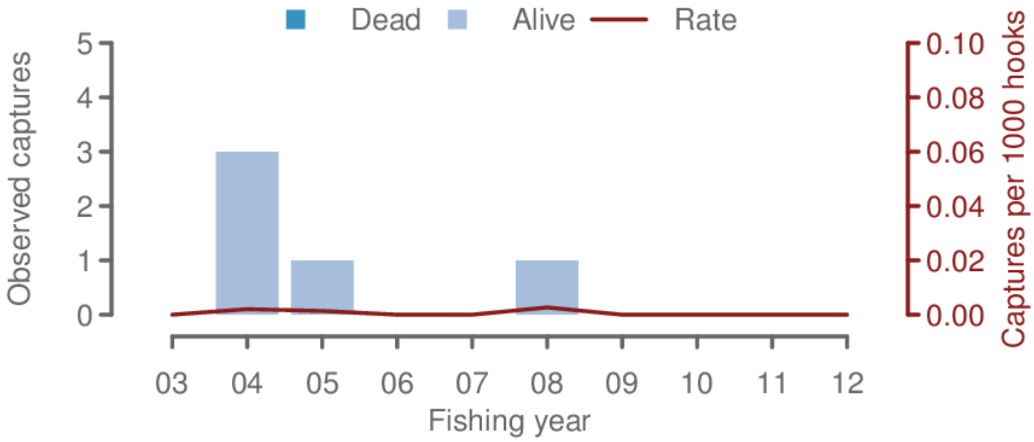


Figure 9: Observed captures of cetaceans in southern bluefin longline fisheries from 2002–03 to 2011–12.

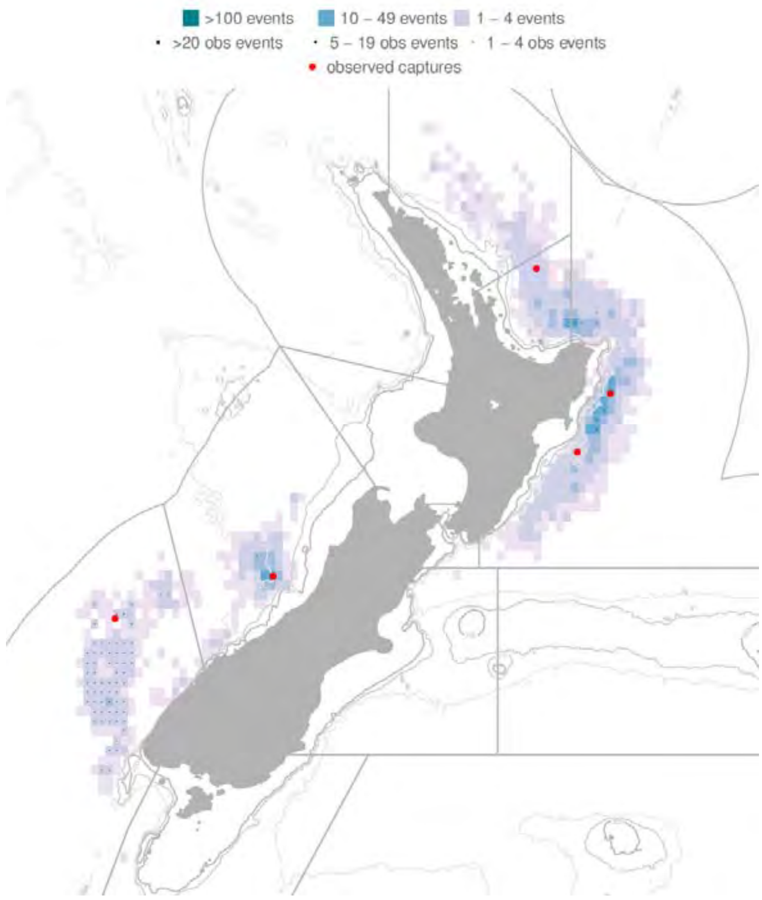


Figure 10: Distribution of fishing effort targeting southern bluefin tuna and observed cetacean captures, 2002–03 to 2011–12. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed 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, 77.7% 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. Captures on longlines occur when the seals attempt to feed on the fish catch and bait during hauling. Most New Zealand fur seals captured in the southern bluefin tuna longline fishery 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) (Table 16). These capture rates include animals that are released alive (100% of observed surface longline capture in 2008–09; Thompson & Abraham 2010). Capture rates in 2010–11 were low, and lower 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 15: Number of observed New Zealand fur seal captures in southern bluefin tuna longline fisheries, 2002–03 to 2011–12, 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	139	3	4	32	202

Table 16: 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). 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 are based on data version 20130305.

			Fishing effort	Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	3 510 061	1 133 740	32.3	56	0.049	154	135
2003–2004	3 193 871	1 471 964	46.1	40	0.027	114	98–131
2004–2005	1 661 979	734 026	44.2	18	0.025	67	53–81
2005–2006	1 493 418	655 445	43.9	12	0.018	57	44–71
2006–2007	1 938 111	916 660	47.3	10	0.011	44	33–56
2007–2008	1 104 825	376 675	34.1	8	0.021	35	25–45
2008–2009	1 484 438	840 048	56.6	22	0.026	55	44–67
2009–2010	1 559 858	580 395	37.2	19	0.033	68	55–82
2010–2011	1 330 265	567 204	42.6	17	0.030	53	42–65
2011–2012†	1 588 854	645 530	40.6	40	0.062	91	77–106

†Provisional data, model estimates not finalised.

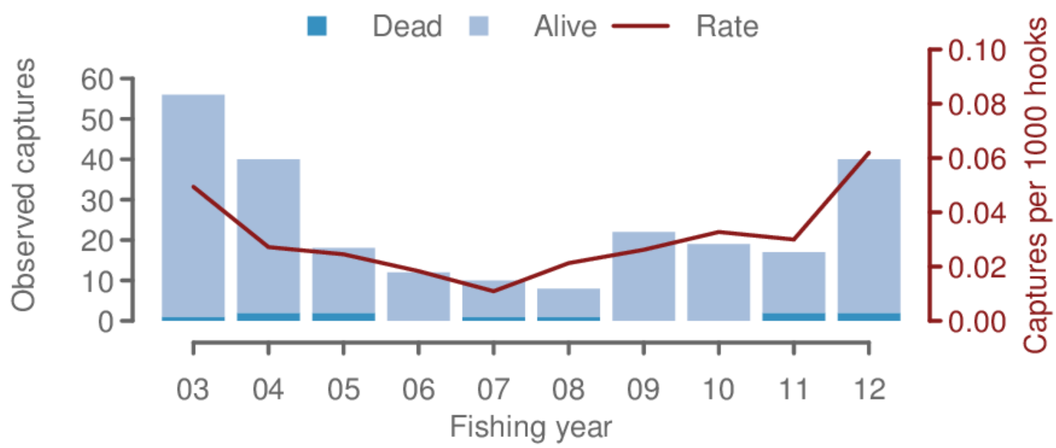


Figure 11: Observed captures of New Zealand fur seal in southern bluefin longline fisheries from 2002–03 to 2011–12.

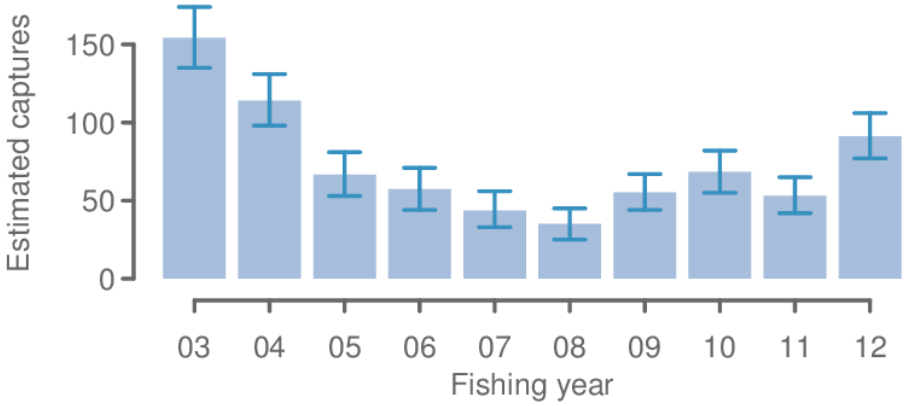


Figure 12: Estimated captures of New Zealand fur seal in southern bluefin longline fisheries from 2002–03 to 2011–12.

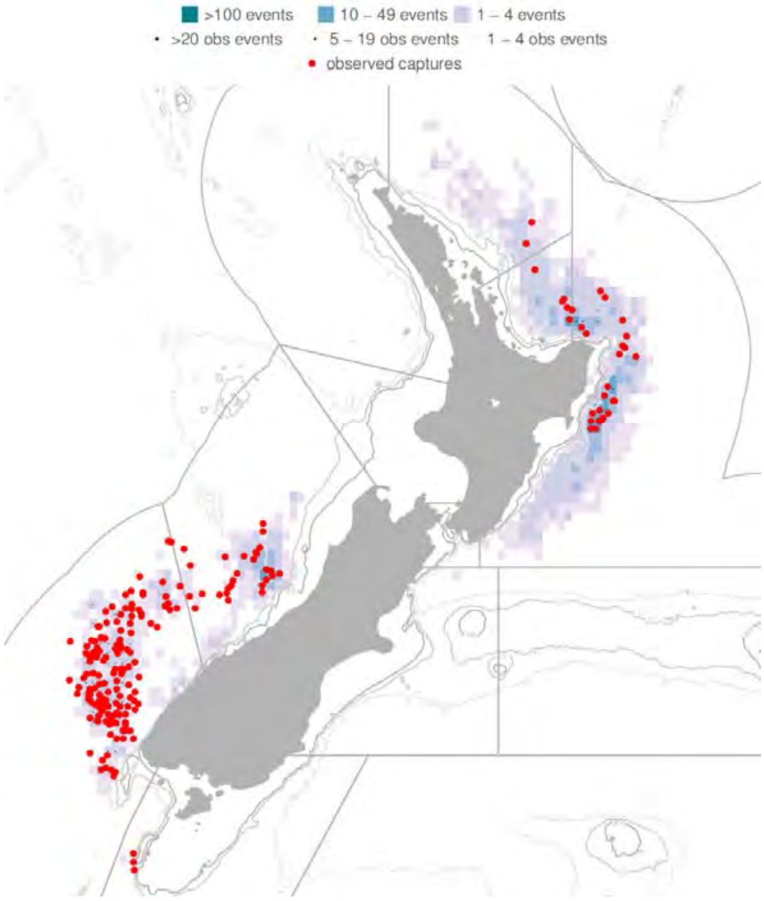


Figure 13: Distribution of fishing effort targeting southern bluefin tuna and observed New Zealand fur seal captures, 2002–03 to 2011–12. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black 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, 77.7% 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 17. 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.

The species most commonly caught were blue shark (*Prionace glauca*), Ray’s bream (*Brama brama*), and albacore (*Thunnus alalunga*). Other non-target fish caught in relatively large numbers were dealfish (*Trachipterus trachypterus*), bigscale pomfret (*Taractichthys longipinnis*), porbeagle shark (*Lamna nasus*), deepwater dogfish (Squaliformes of various species, mostly Owstons dogfish), swordfish (*Xiphias gladius*), lancetfish (*Alepisaurus ferox* & *A. brevirostris*), mako shark (*Isurus oxyrinchus*), moonfish (*Lampris guttatus*), swordfish (*Xiphias gladius*), and butterfly tuna (*Gasterochisma melampus*).

The next most abundant non-target fish species were oilfish (*Ruvettus pretiosus*), school shark (*Galeorhinus galeus*), rudderfish (*Centrolophus niger*), hoki (*Macruronus novaezelandiae*), escolar (*Lepidocybium flavobrunneum*), and thresher shark (*Alopias vulpinus*). In 2009 and 2010, sunfish (*Mola mola*), flathead pomfret (*Taractes asper*), and Pelagic stingray (*Pteroplatytrygon violacea*) were also amongst the 25 most abundant species. Some other non-target tunas and billfish were caught, including Pacific bluefin tuna (*Thunnus orientalis*), skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*) and striped marlin (*Tetrapturus audax*).

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.

Dealfish, bigscale pomfret, and deepwater dogfish were caught in the south by charter vessels, while domestic vessels caught lancetfish, swordfish, and mako sharks in the north. Both caught porbeagle sharks, moonfish and butterfly tuna. Oilfish and escolar were caught in the north, with oilfish recorded by both fleets and escolar by domestic vessels only. Bigscale pomfret and escolar have been more important components of the catch in recent years than in earlier years, possibly because of improved identification.

Observers onboard both the charter and domestic fleets reported on fish that were caught and subsequently discarded, and fish that were lost before they could be brought aboard the vessel. Observers also recorded whether fish were landed alive or dead.

Since their introduction into the QMS, most Ray’s bream and moonfish have been retained. Blue, porbeagle and mako sharks have also been discarded less frequently since their introduction into the QMS. There were some differences between the domestic and charter fleet, with the domestic fleet more likely to discard sharks.

Tunas (other than butterfly tuna) and swordfish were seldom discarded. The charter vessels kept most of the butterfly tuna they caught while domestic vessels discarded more than half of it in 2009 and kept the majority of it in 2010. Almost all of the lancetfish, deepwater dogfish, and dealfish caught were discarded. Charter vessels discarded oilfish and rudderfish while domestic vessels retained the majority of oilfish, rudderfish, and escolar. Charter vessels kept the majority of their bigscale pomfret in 2009 and discarded the majority of it in 2010.

Tunas that were discarded were usually dead (and typically damaged). Most of the sharks that were discarded were alive when they were landed, although some dead sharks were discarded by domestic vessels. Porbeagle sharks did not survive as well on longlines as the other sharks. Most butterfly tuna discarded by the domestic vessels were dead when landed. The majority of the other fish bycatch species that were commonly discarded were landed alive.

Observers record life status on landing but they do not record if live fish are still alive at time of discard. Fish that are landed alive and subsequently discarded are not necessarily returned to the sea alive. Many fishers retrieve their hooks prior to discarding fish and this often damages the fish and reduces its ability to survive. Some species such as dealfish do not survive the dehooking process.

Table 17: 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). In recent years the stock assessment has been based on the results from the reconditioned CCSBT Operating Model. The Scientific Committee made further changes in 2011 to the final grid used for the assessment (Anon. 2011). There is no single agreed stock assessment base case, but an agreed range of values for key input parameters is run and the results averaged over the whole grid. In addition, in 2011 a set of four alternative models considered to be highly plausible were run to test the robustness of the results from the base grid.

5.1 Estimates of fishery parameters and abundance

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).

Trends in juvenile abundance

The latest scientific aerial survey index showed a large increase from the previous year (Figure 15). This was also seen in the surface abundance per unit effort (SAPUE) index for age 2 to 4 in the Great Australian Bight (GAB). Although the highest value in the time series was reported in 2011, the 2012 index was much lower and subsequently was not able to be explained satisfactorily. There is a possibility that the fish were in a different area in 2012 and not measured by the survey. For this reason the Scientific Committee suggested that more detailed analysis of the environmental data was warranted.

CPUE in New Zealand waters

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 the last 4 years for the Charter fleet. 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 13. The domestic fleet mainly operating in area 5 has also experienced increased CPUE since 2008, with a further increase in 2012.

5.2 Biomass estimates

5.2.1 Spawning biomass

The stock assessment was updated by the Scientific Committee in 2011. The results from the reconditioned Operating Model (OM) indicate that the spawning stock biomass is at a very low level. For the base case, the spawning biomass is estimated to be at 5% of the unfished level (SB_0), with a 90% probability interval of 3% to 7%. This very low spawning stock biomass is consistent across all the plausible alternative scenarios (median range: 4 -5%) and is a little more than 15% of the level at which MSY could be obtained.

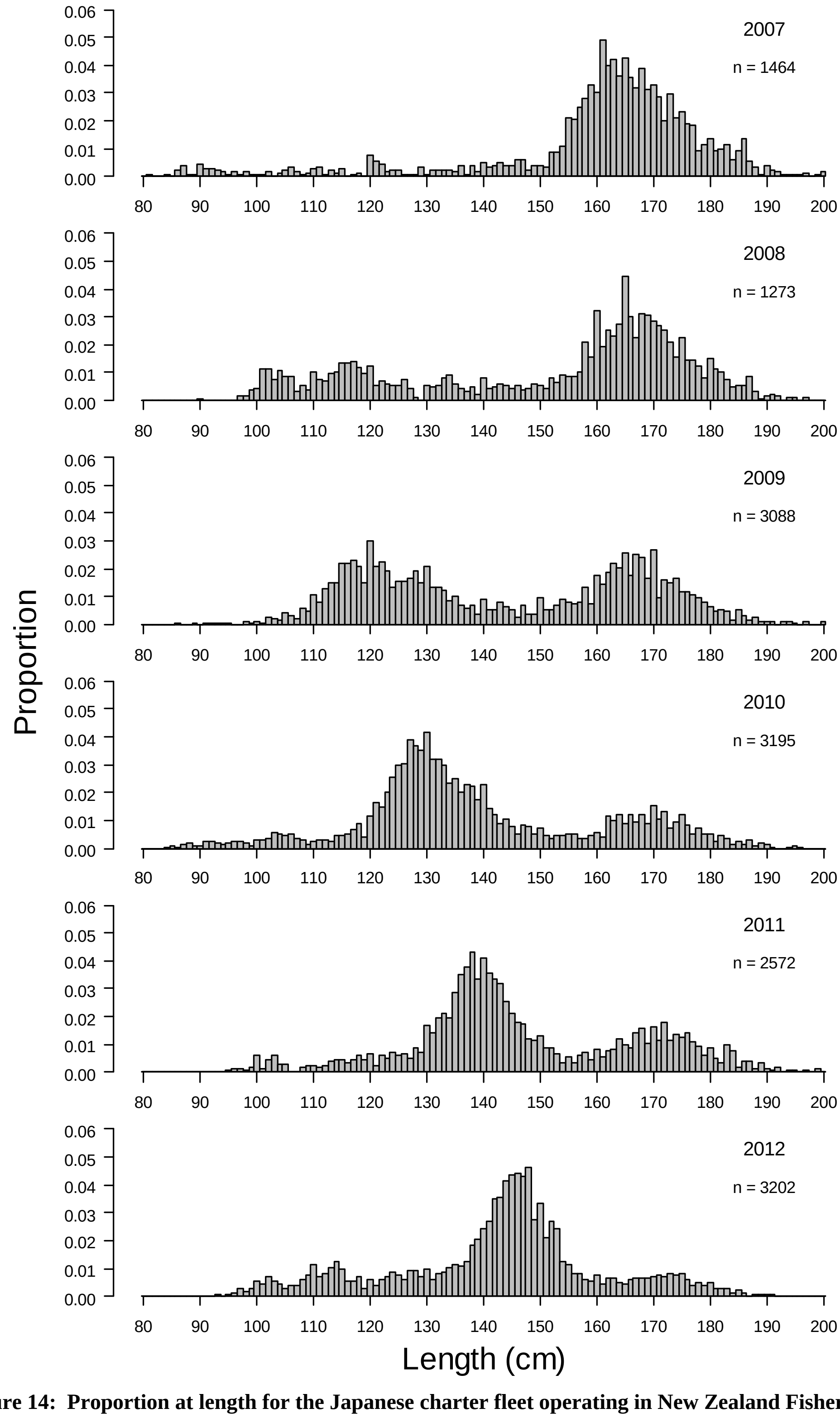


Figure 14: Proportion at length for the Japanese charter fleet operating in New Zealand Fishery waters for 2007 to 2012. Source: CCSBT-ESC/1308/SBT Fisheries New Zealand (2013).

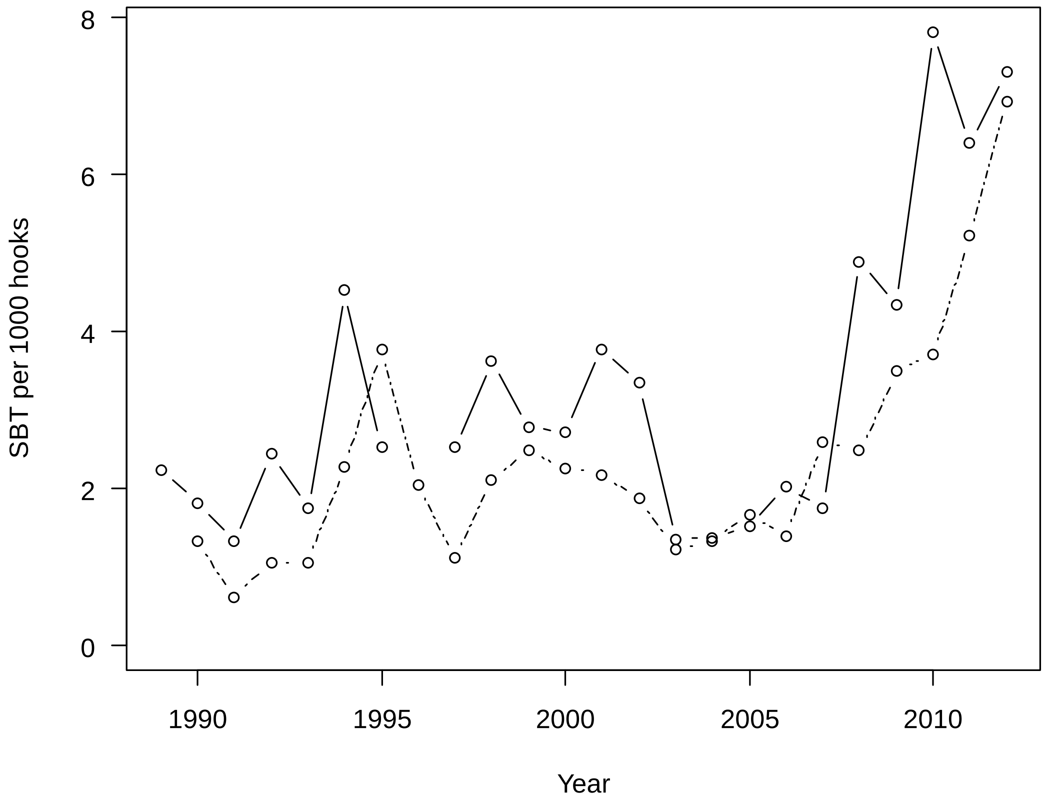


Figure 15: Nominal catch per unit effort (number of STN per thousand hooks) by calendar year for the New Zealand Charter (solid line) and domestic (dashed line) longline fleets operating in New Zealand based only on effort from sets that either targeted or caught southern bluefin tuna. Source: CCSBT-ESC/1308/SBT Fisheries New Zealand (2013).

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. There is no current evidence of the spawning stock rebuilding, but it is projected to start rebuilding after 2012.

There are several positive signs for the spawning stock:

- Total reported catches have dropped as a result of reduced quota limits
- Current fishing mortality is now below F_{MSY}
- The stock is expected to increase under catch levels determined by the Management Procedure

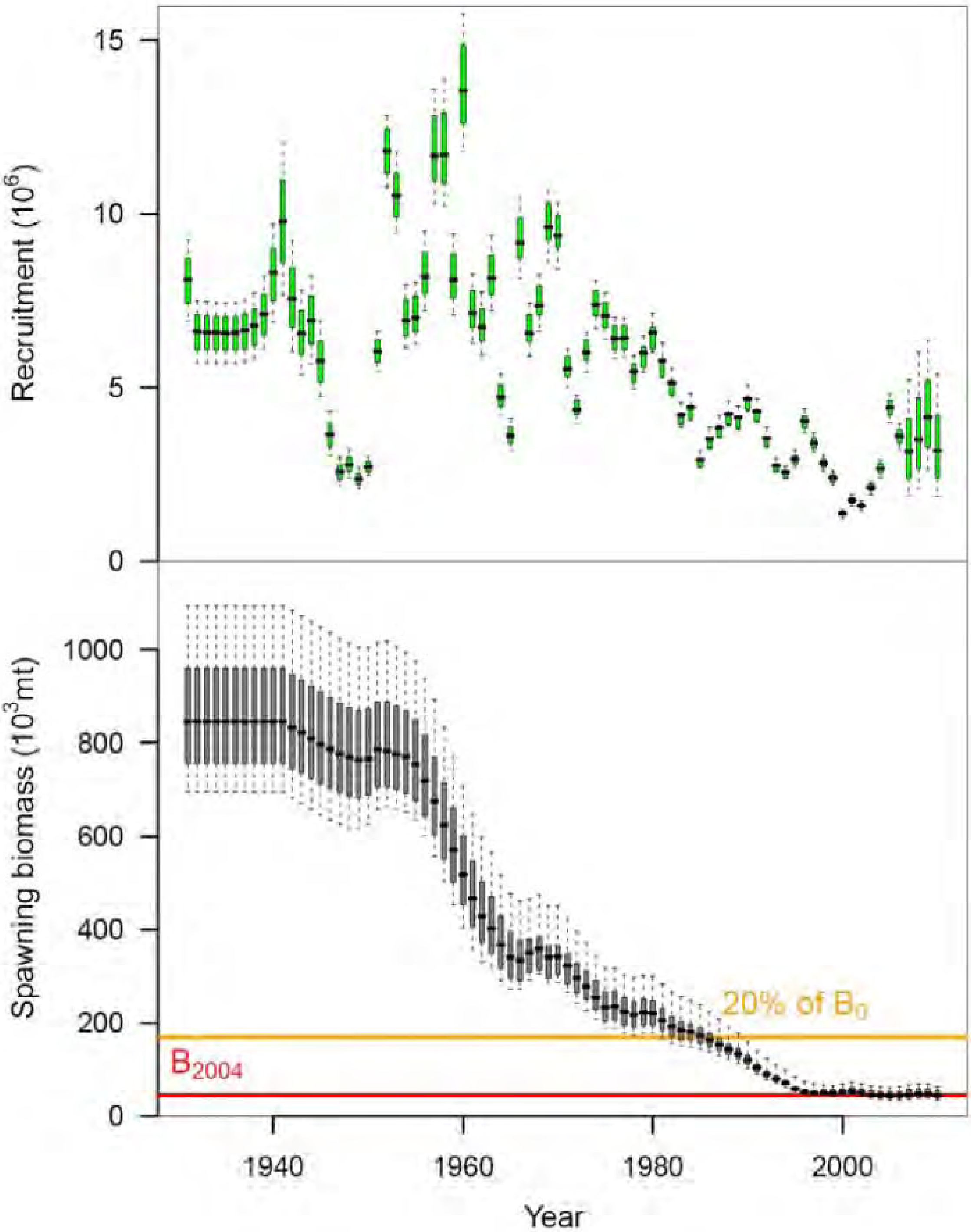


Figure 16: Recruitment and spawning stock biomass for the base case, showing the medians, quartiles and 90th percentiles, together with reference points of 20% of pre-exploitation spawning stock biomass and the spawning stock biomass in 2004 (B_{2004}). Source: Report of the Scientific Committee 2011.

There were both positive and neutral signals from the indicators in 2013:

• Longline CPUE for the Japanese fleet for ages 6 and 7 has continued to increase since 2007. The 12+ year old CPUE shows a slight recent decrease, but this is expected given the weak recruitment from 1999 to 2002. There are no obvious recent trends in the CPUEs for the other age groups.

• Although there was a decline in the scientific aerial survey index in 2012, the index for 2013 has increased and is the second highest over the last nine years. A similar pattern of a decline followed by an increase is evident in the commercial aerial spotting results from 2011 to 2013.
• There has been a decline in the mean length of STN on the spawning ground. There are indications that this may be the result of some Indonesian vessels fishing further south, outside the spawning grounds. This may also reflect the strong 2005 year class arriving on the spawning ground. This is being investigated further and any additional information will be provided to the 2014 meeting.

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).

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 will be incorporated into the Operating Model in 2013.

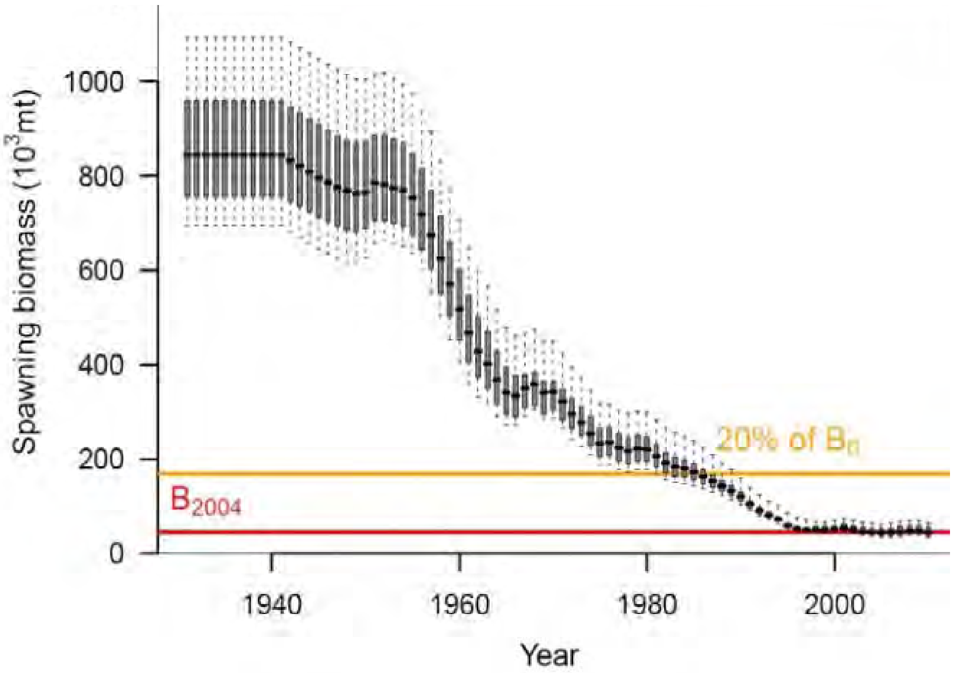
6. STATUS OF THE STOCK

The results from the reconditioned OM indicate that the spawning stock biomass is at a very low level. For the base case, the spawning biomass is estimated to be at 5% of the unfished level (SB0), with a 90% probability interval of 3% to 7%. This very low spawning stock biomass is consistent across all the plausible alternative scenarios (median range: 4-5%) and is a little more than 15% of the level at which MSY could be obtained.

The estimated trajectories of spawning stock biomass integrated over the grid for the base case over the full time series for the fishery are given in Figure 15. 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. There is no current evidence of the spawning stock rebuilding, but it is projected to start rebuilding after 2012.

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	MP evaluation updated
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 5% B_0. Very Unlikely (< 10%) to be at or above B_{MSY}.
Status in relation to Limits	Very Likely (> 90%) to be below the soft limit Likely (> 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 3 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 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 (2011)	
Assessment Method	Basecase grid of reconditioned CCSBT Operating Model	
Assessment Dates	Latest assessment: 2011	Next assessment: 2014
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	CPUE, catch at age and length frequency data, tag recoveries, scientific aerial survey indices, commercial spotting indices, trolling indices	1 – High Quality
Data not use (rank)	N/A	
Changes to Model Structure and Assumptions	Values of steepness and M10 (natural mortality at age 10) were changed in 2011	
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	

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 were not estimated.

7. FOR FURTHER INFORMATION

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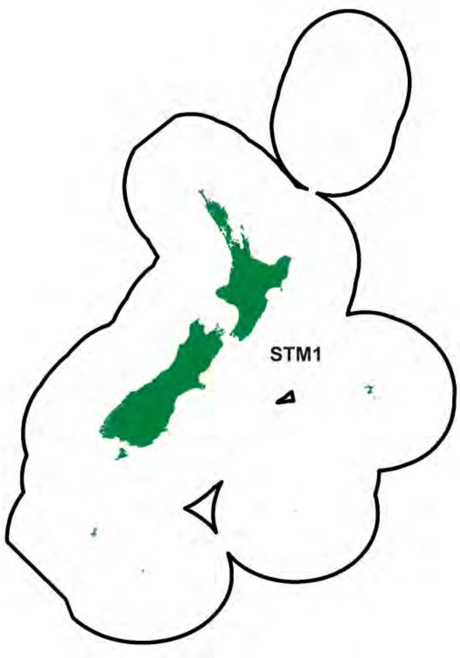
STRIPED MARLIN (STM)

(*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 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; these fish are rarely reported in catch records.

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.

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.

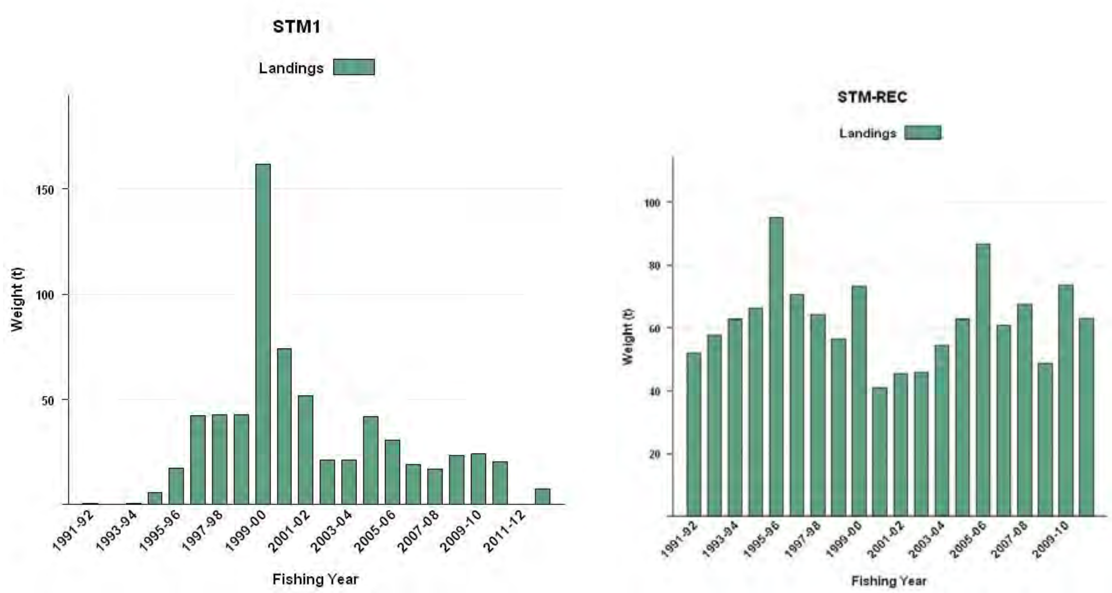


Figure 1: Striped marlin catch between 1991–92 and 2012–13 within New Zealand waters of commercial discards (STM 1) and 1991–92 to 2011–12 for recreational catch (STM-REC). [Figure continued on next page.]

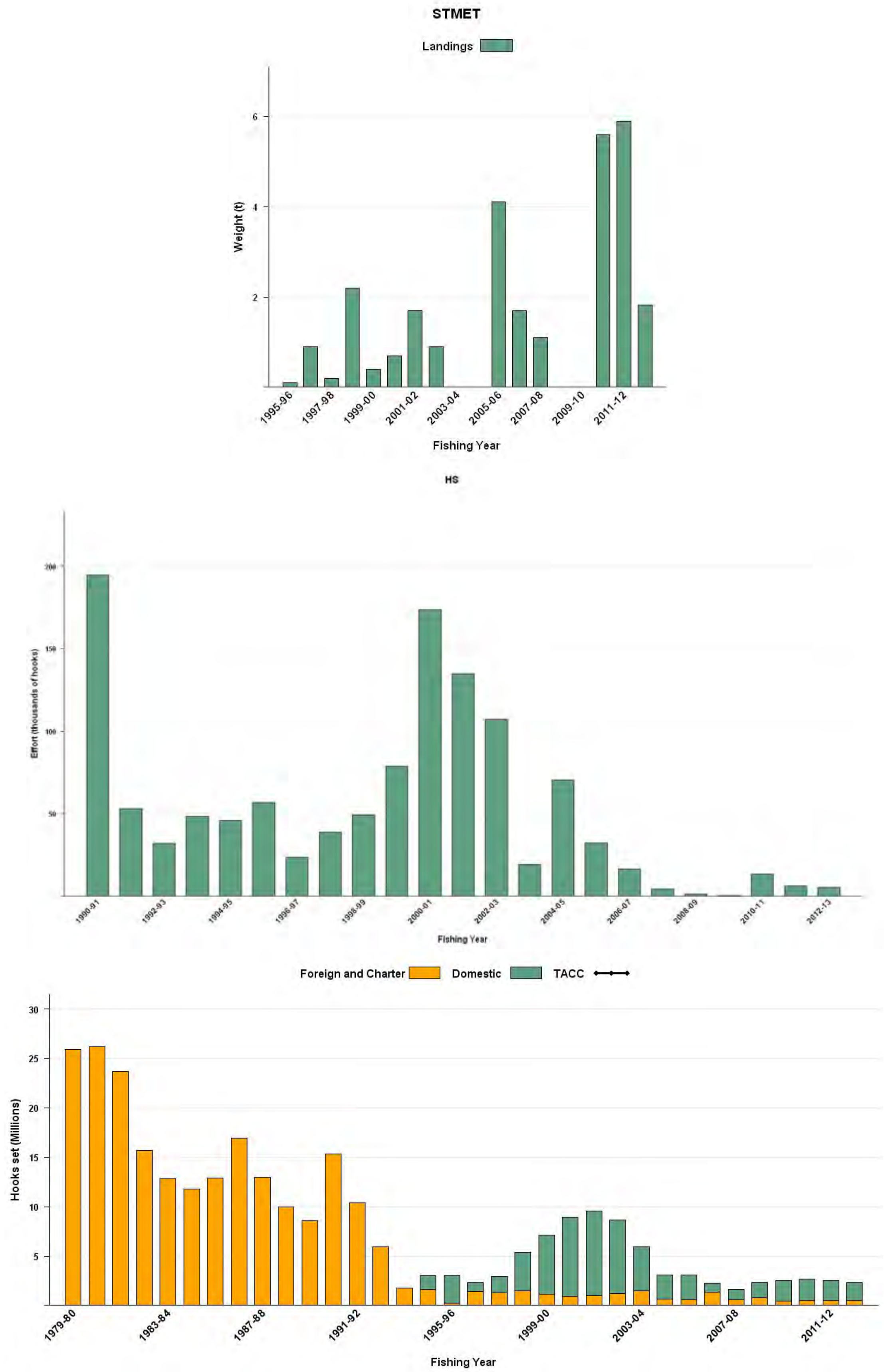


Figure 1 [Continued]: [Top] Striped marlin catch between 1995–96 and 2011–12 on the high seas (STM ET). [Middle] Fishing effort (number of hooks set) for all high seas New Zealand flagged surface longline vessels, and [Bottom] domestic vessels (including effort by foreign vessels chartered by New Zealand 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.

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
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	725	1 601
2011–12						241	635	655	1 531

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 2012.

	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		25.0	48.6	79.7	152	1.1	5 057
2009		18.6	73.7	104.4	202		3 930
2010		27.3	63.1	79.5	163	5.6	3 530
2011		24.3	51.1	66.6	144	5.9	4 174
2012		22.7	75.9	77.6	153	1.8	4 060

Source: TLCER and CELRs; NZSFC; Holdsworth (2008a); Holdsworth and Saul (2013);* 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).

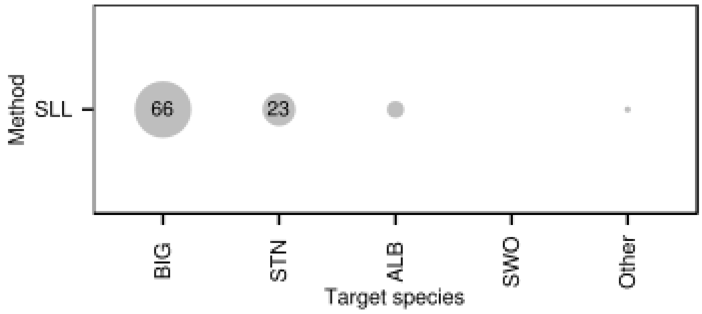


Figure 2: A summary of the proportion of striped marlin taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the circle is the percentage. SLL = surface longline (Bentley et al 2013).

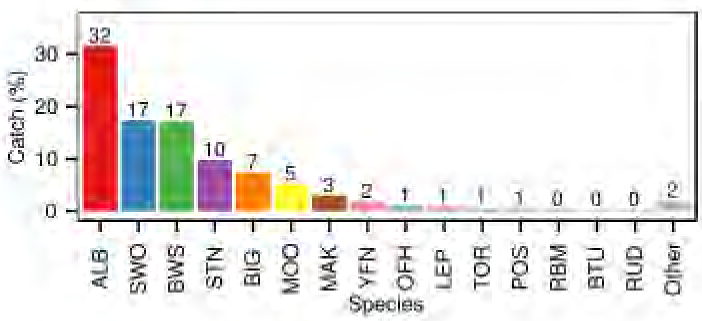


Figure 3: A summary of species composition of the reported surface longline catch. The percentage by weight of each species is calculated for all surface longline trips (Bentley et al 2013).

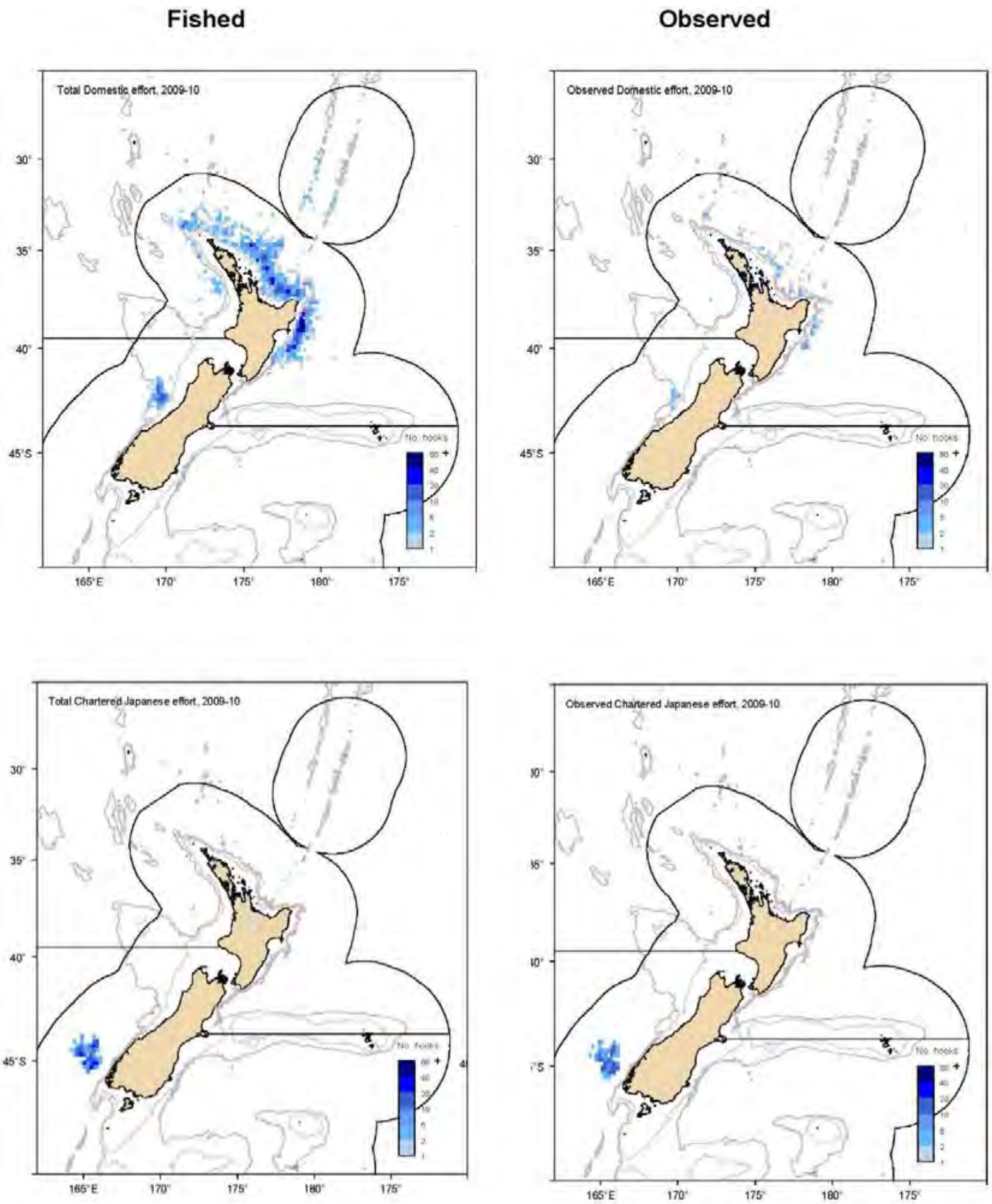


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009–10 fishing year, displaying both fishing effort (left) and observer effort (right).

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 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 2009–10 the 59 recreational fishing clubs affiliated to NZSFC reported landing 2708 billfish, sharks, kingfish, mahimahi, and tuna, and tagged and released a further 1996 gamefish. In 2009–10, 607 striped marlin were landed and weighed at a club (22% of landed fish in NZSFC records) and 764 were tagged and released (38% 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 65% of their striped marlin catch (mean of the last ten years). 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°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 20 627 striped marlin between 1 July 1975 and 30 June 2012. Of the 83 recaptures reported, 31 have been made outside the EEZ spread across the region from French Polynesia (142^{o}W) to eastern Australia (154^{o}E) and from latitude 2^{o}S to 38^{o}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^{o}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 2013 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=1644) (Ministry for Primary Industries 2012)

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 2011–12, there were 791 observed captures of birds across all surface longline fisheries. Seabird capture rates since 2003 are presented in Table 6 and Figure 5. While the seabird capture distributions largely coincide with fishing effort they are more frequent off the south west coast of the South Island (Figure 6). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation was historically used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods but recent estimates are either ratio or model based as specified in the tables below (Abraham et al 2010).

Table 6: Number of observed seabird captures in the New Zealand surface longline fisheries, 2002–03 to 2011–12, 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.

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	3	2	27	0	278	33	0	343
NZ white-capped	Very high	0	2	0	3	10	60	27	0	102
Northern Buller's	High	0	0	0	1	0	0	0	0	1
Gibson's	High	4	16	0	17	0	6	2	1	46
Antipodean	High	12	9	1	8	0	0	0	1	31
Northern royal	Medium	0	0	1	0	0	0	0	0	1
Southern royal	Medium	0	1	0	0	0	4	0	0	5
Campbell black-browed	Medium	2	9	2	29	0	3	3	1	49
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**	**43**	**8**	**93**	**10**	**351**	**66**	**4**	**631**
Other seabirds										
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	19	3	3	37
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**	**22**	**9**	**8**	**158**

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.

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 are based on data version 20120531 and preliminary estimates for 2011–12 are based on data version 20130305.

			Fishing effort	Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	10 764 588	2 195 152	20.4	115	0.052	2 033	1 577–2 737
2003–2004	7 380 779	1 607 304	21.8	71	0.044	1 345	1 044–1 798
2004–2005	3 676 365	783 812	21.3	41	0.052	601	472–780
2005–2006	3 687 339	705 945	19.1	37	0.052	790	585–1 137
2006–2007	3 738 362	1 040 948	27.8	187	0.18	936	720–1 344
2007–2008	2 244 339	426 310	19	41	0.088	513	408–664
2008–2009	3 115 633	937 233	30.1	57	0.061	593	477–746
2009–2010	2 992 285	665 883	22.3	135	0.203	921	732–1 201
2010–2011	3 185 779	674 572	21.2	47	0.07	696	524–948
2011–2012†	3 069 707	728 190	23.7	64	0.088	808	596–1 168

†Provisional data, model estimates not finalised.

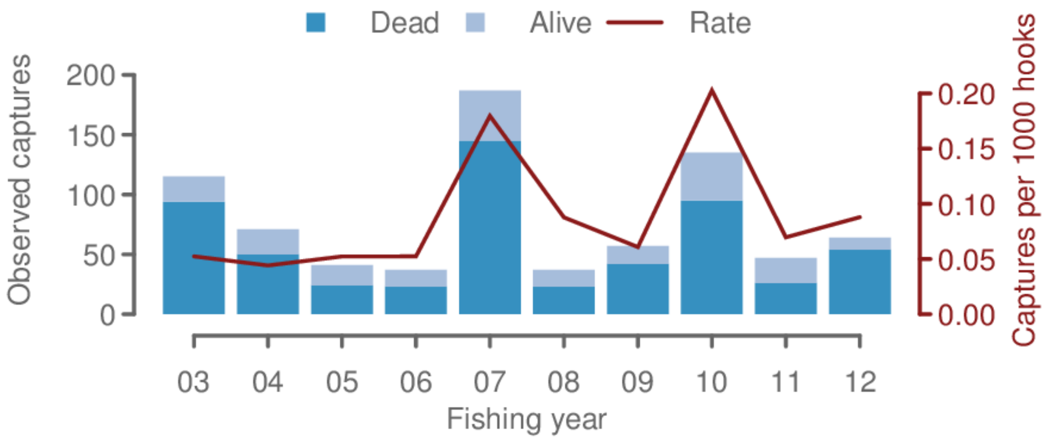


Figure 5: Observed captures of seabirds in the New Zealand surface longline fisheries from 2002–03 to 2011–12.

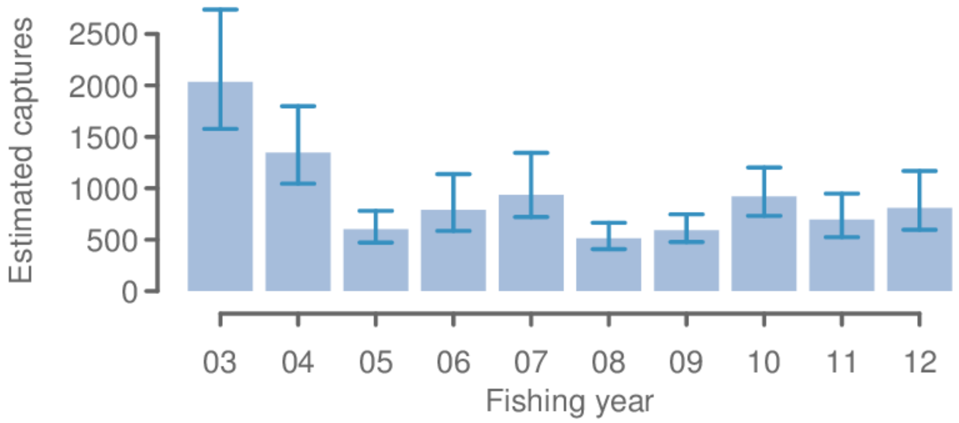


Figure 6: Estimated captures of seabirds in the New Zealand surface longline fisheries from 2002–03 to 2011–12.

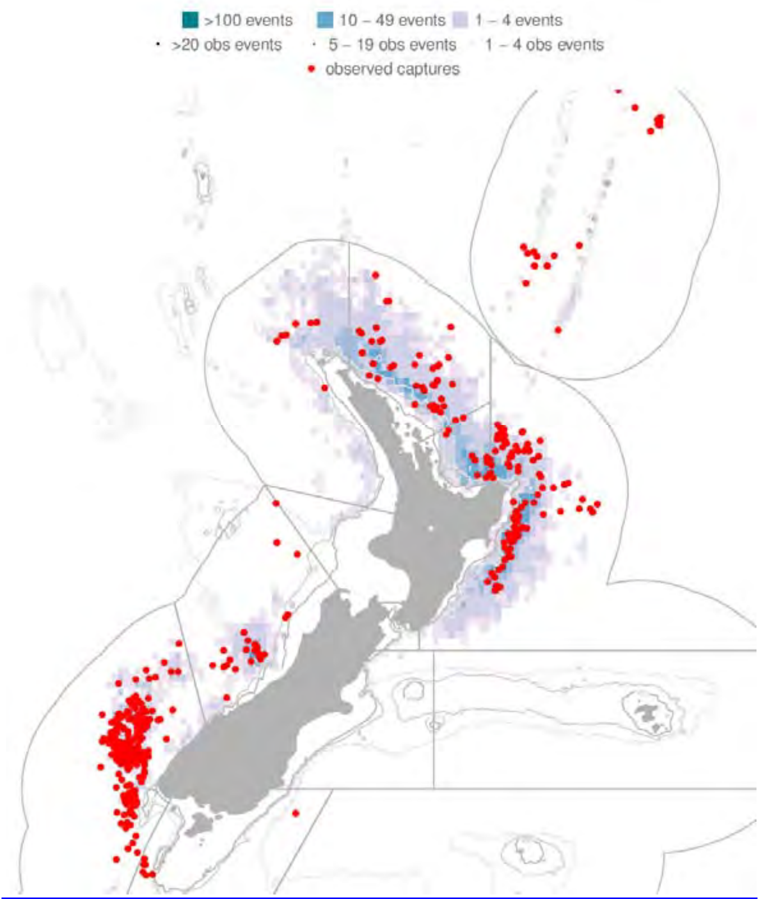


Figure 7: Distribution of fishing effort in the New Zealand surface longline fisheries and observed seabird captures, 2002–03 to 2011–12. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black 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, 94.1% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.2 Sea turtle bycatch

Between 2002–03 and 2011–12, there were 13 observed captures of sea turtles across all surface longline fisheries (Tables 8 and 9, 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 8: Number of observed sea turtle captures in the New Zealand surface longline fisheries, 2002–03 to 2011–12, 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	0	1
Total	1	6	3	3	13

Table 9: 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	10 764 588	2 195 152	20.4	0	0
2003–2004	7 380 779	1 607 304	21.8	1	0.001
2004–2005	3 676 365	783 812	21.3	2	0.003
2005–2006	3 687 362	705 945	19.1	1	0.001
2006–2007	3 738 362	1 040 948	27.8	2	0.002
2007–2008	2 244 339	421 900	18.8	1	0.002
2008–2009	3 115 633	937 496	30.1	2	0.002
2009–2010	2 992 285	665 883	22.3	0	0
2010–2011	3 185 779	674 572	21.3	4	0.006
2011–2012	3 069 707	728 190	23.7	0	0

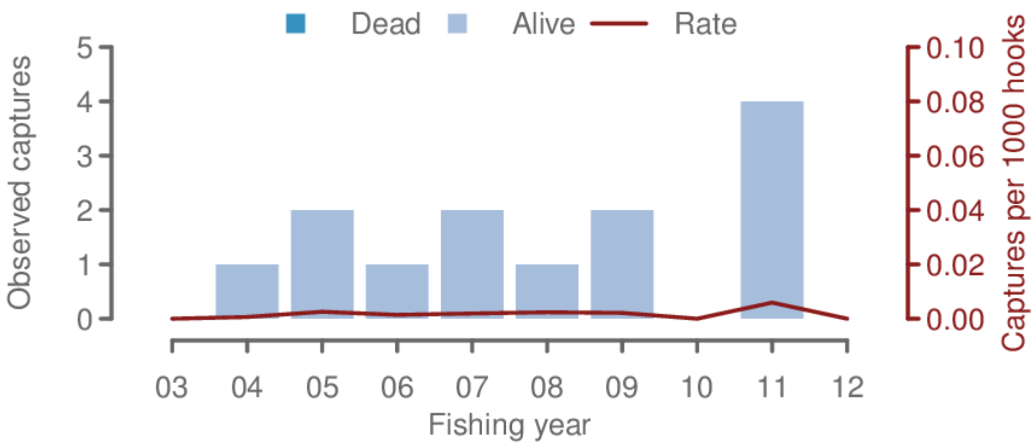


Figure 8: Observed captures of sea turtles in the New Zealand surface longline fisheries from 2002–03 to 2011–12.

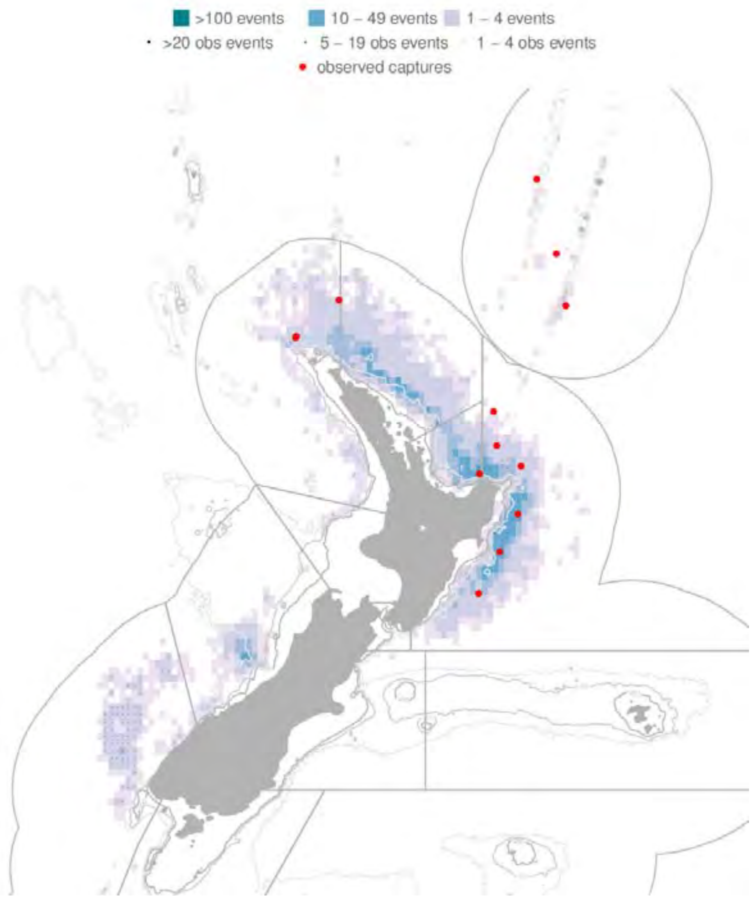


Figure 9: Distribution of fishing effort in the New Zealand surface longline fisheries and observed sea turtle captures, 2002–03 to 2011–12. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black 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, 94.1% 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 2011–12, 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 10 and 11, 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 10: Number of observed cetacean captures in the New Zealand surface longline fisheries, 2002–03 to 2011–12, 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 11: 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	10 764 588	2 195 152	20.4	1	0.0005
2003–2004	7 380 779	1 607 304	21.8	4	0.002
2004–2005	3 676 365	783 812	21.3	1	0.001
2005–2006	3 687 339	705 945	19.1	0	0
2006–2007	3 738 362	1 040 948	27.8	0	0
2007–2008	2 244 339	421 900	18.8	1	0.002
2008–2009	3 115 633	937 496	30.1	0	0
2009–2010	2 992 285	665 883	22.3	0	0
2010–2011	3 185 779	674 572	21.2	0	0
2011–2012	3 069 707	728 190	23.7	0	0

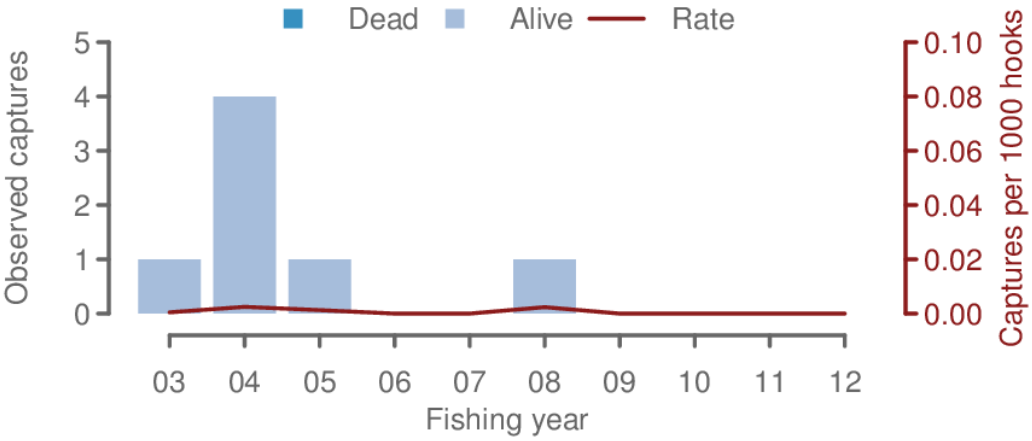


Figure 10: Observed captures of cetaceans in the New Zealand surface longline fisheries from 2002–03 to 2011–12.

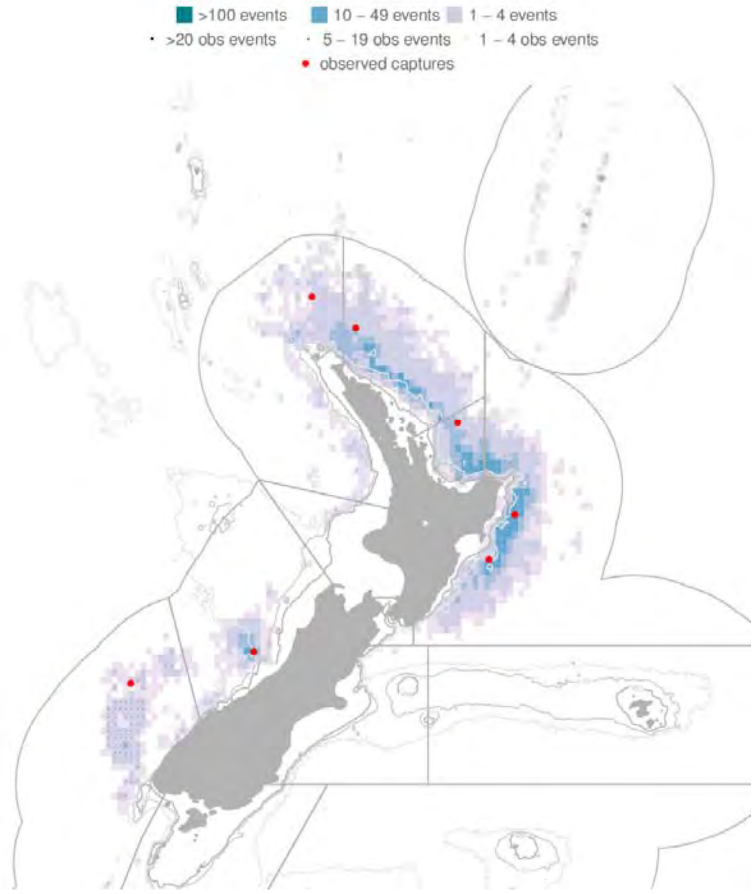


Figure 11: Distribution of fishing effort in the New Zealand surface longline fisheries and observed cetacean captures, 2002–03 to 2011–12. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black 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, 94.1% 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 around much of the South Island and offshore islands slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts. Captures on longlines occur when the seals attempt to feed on bait or fish from the line 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). Bycatch rates in 2011–12 were, low and lower 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 2011–12, there were 246 observed captures of New Zealand fur seal in surface longline fisheries (Tables 12 and 13).

Table 12: Number of observed New Zealand fur seal captures in the New Zealand surface longline fisheries, 2002–03 to 2011–12, 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	10	16	139	3	4	2	32	206

Table 13: 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 2010–11 are based on data version 20120531 and preliminary estimates for 2011–12 are based on data version 20130305.

	Fishing effort			Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	10 764 588	2 195 152	20.4	56	0.026	157	138-178
2003–2004	7 380 779	1 607 304	21.8	40	0.025	116	99-133
2004–2005	3 676 365	783 812	21.3	20	0.026	77	63-93
2005–2006	3 687 339	705 945	19.1	12	0.017	70	55-85
2006–2007	3 738 362	1 040 948	27.8	10	0.010	52	40-66
2007–2008	2 244 339	426 310	19.0	10	0.023	45	34-56
2008–2009	3 115 633	937 233	30.1	22	0.023	57	46-69
2009–2010	2 992 285	665 883	22.3	19	0.029	78	64-94
2010–2011	3 164 159	674 522	21.3	17	0.025	57	45-69
2011–2012†	3 069 707	728 190	23.7	40	0.055	96	81-111

†Provisional data, model estimates not finalised.

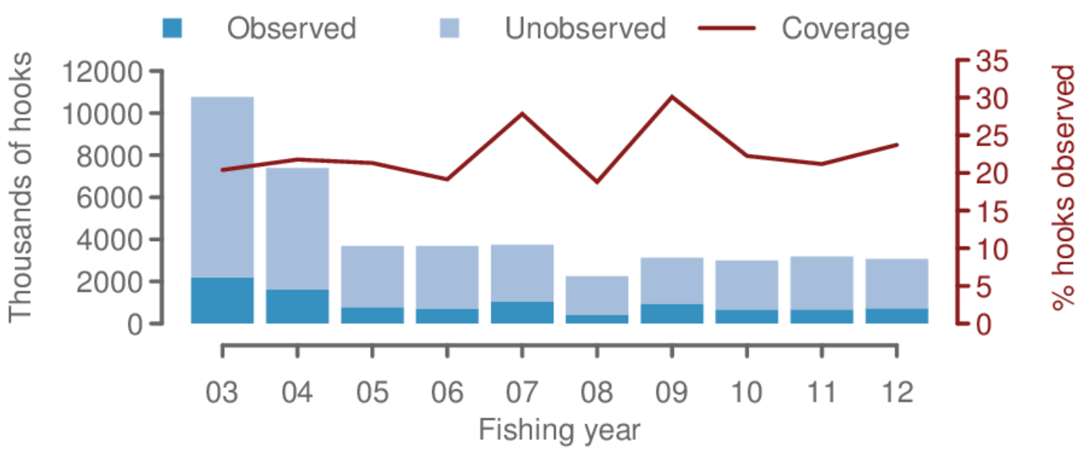


Figure 12: Observed captures of New Zealand fur seal in the New Zealand surface longline fisheries from 2002–03 to 2011–12.

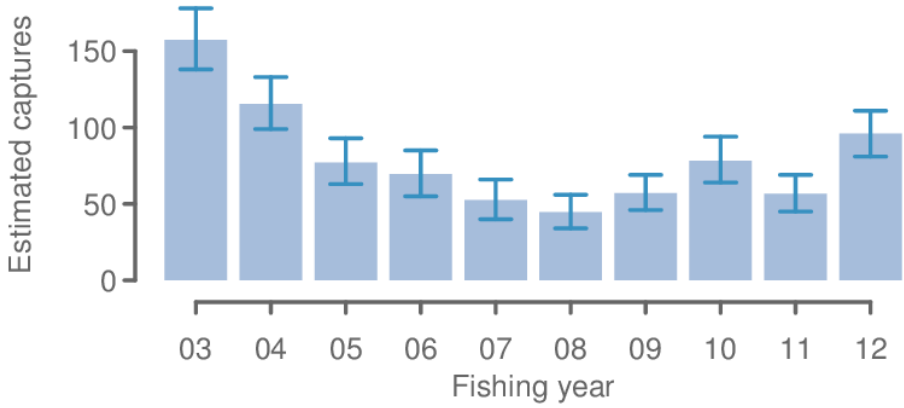


Figure 13: Estimated captures of New Zealand fur seal in the New Zealand surface longline fisheries from 2002–03 to 2011–12.

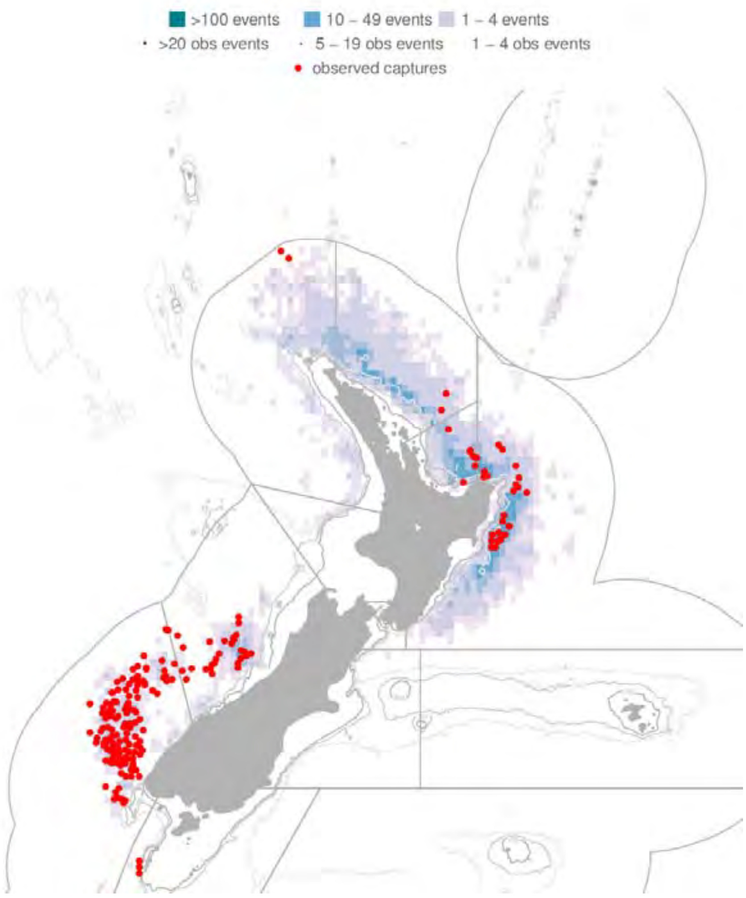


Figure 14: Distribution of fishing effort in the New Zealand surface longline fisheries and observed New Zealand fur seal captures, 2002–03 to 2011–12. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated 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, 94.1% 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 14). Southern bluefin tuna and albacore tuna are the only target species that occur in the top five of the frequency of occurrence.

Table 14: Numbers of the most common fish species observed in the New Zealand longline fisheries during 2009–10 by fleet and area. Species are shown in descending order of total abundance (Griggs & Baird 2013).

	Charter	Domestic		Total
Species	South	North	South	number
Blue shark	2 024	4 650	882	7 556
Ray's bream	3 295	326	88	3 709
Southern bluefin tuna	3 244	211	179	3 634
Lancetfish	3	2 139	1	2 143
Albacore tuna	90	1 772	42	1 904
Dealfish	882	0	7	889
Swordfish	3	452	2	457
Moonfish	76	339	6	421
Porbeagle shark	72	328	20	420
Mako shark	11	343	7	361
Big scale pomfret	349	4	0	353
Deepwater dogfish	305	0	0	305
Sunfish	7	283	5	295
Bigeye tuna	0	191	0	191
Escolar	0	129	0	129
Butterfly tuna	15	100	3	118
Pelagic stingray	0	96	0	96
Oilfish	2	75	0	77
Rudderfish	39	20	2	61
Flathead pomfret	56	0	0	56
Dolphinfish	0	47	0	47
School shark	34	0	2	36
Striped marlin	0	24	0	24
Thresher shark	7	17	0	24
Cubehead	13	0	1	14
Kingfish	0	10	0	10
Yellowfin tuna	0	9	0	9
Hake	8	0	0	8
Hapuku bass	1	6	0	7
Pacific bluefin tuna	0	5	0	5
Black barracouta	0	4	0	4
Skipjack tuna	0	4	0	4
Shortbill spearfish	0	4	0	4
Gemfish	0	3	0	3
Bigeye thresher shark	0	2	0	2
Snipe eel	2	0	0	2
Slender tuna	2	0	0	2
Wingfish	2	0	0	2
Bronze whaler shark	0	1	0	1
Hammerhead shark	0	1	0	1
Hoki	0	0	1	1
Louvar	0	1	0	1
Marlin, unspecified	0	1	0	1
Scissortail	0	1	0	1
Broadnose seven gill shark	1	0	0	1
Shark, unspecified	0	1	0	1
Unidentified fish	2	30	8	40
Total	10 545	11 629	1 256	23 430

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 15 and 16). 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.

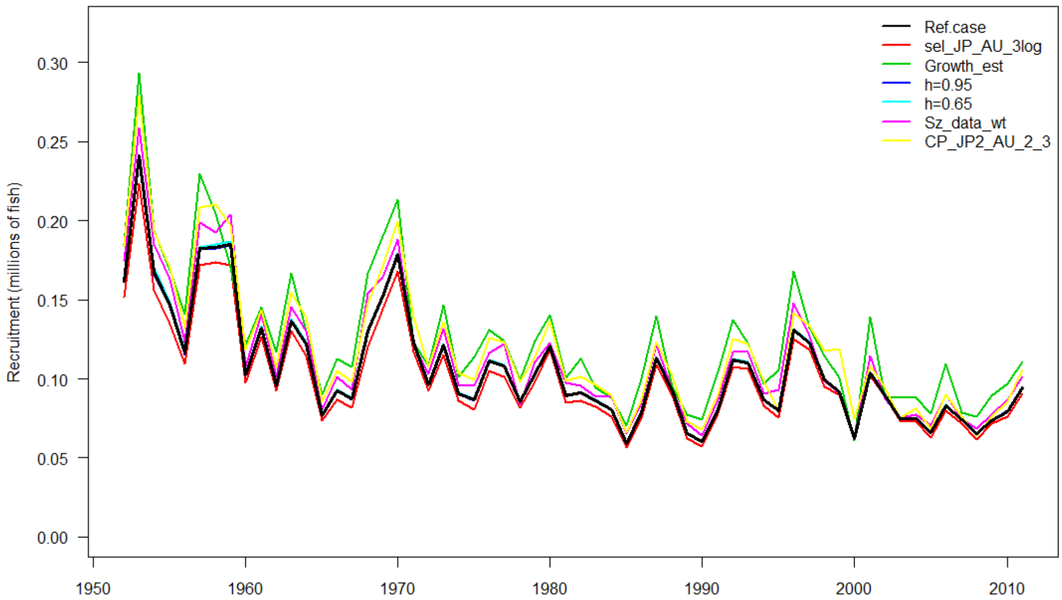


Figure 15: Estimated annual recruitment (millions of fish) for the southwest Pacific Ocean striped marlin obtained from the Ref.case model (black line) and the six plausible key model runs.

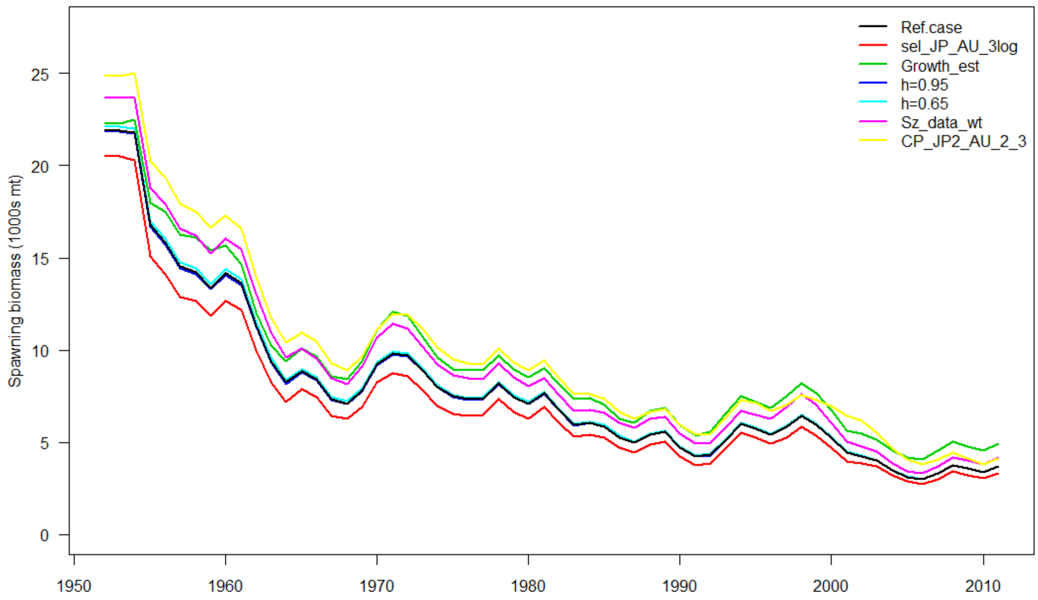


Figure 16: Estimated average annual average spawning potential for the southwest Pacific Ocean striped marlin obtained from the Ref.case model (black line) and the six plausible key model runs.

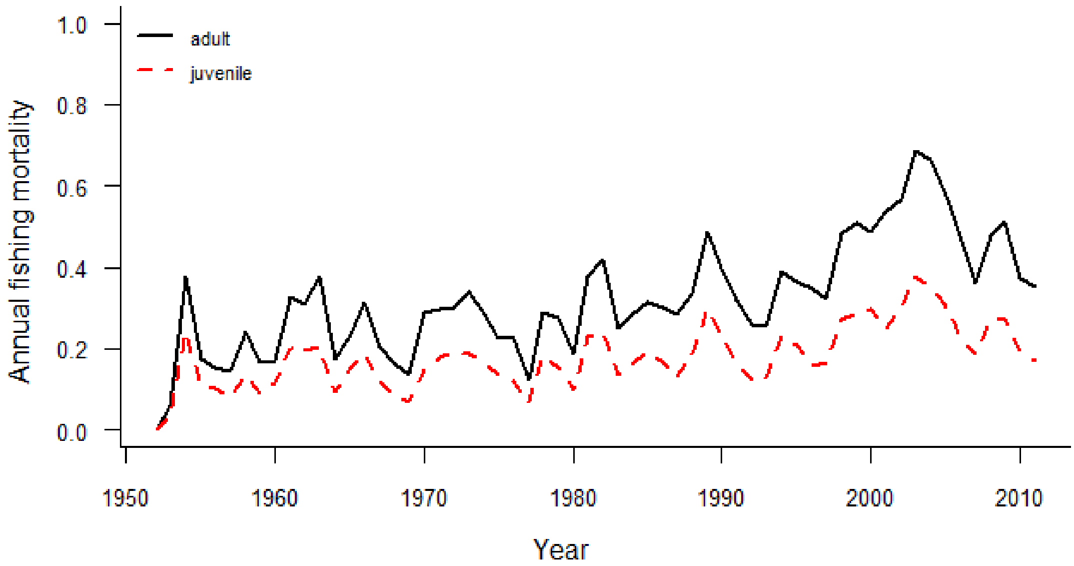


Figure 17: Estimated annual average juvenile and adult fishing mortality for the southwest Pacific Ocean striped marlin obtained from the Ref.case model.

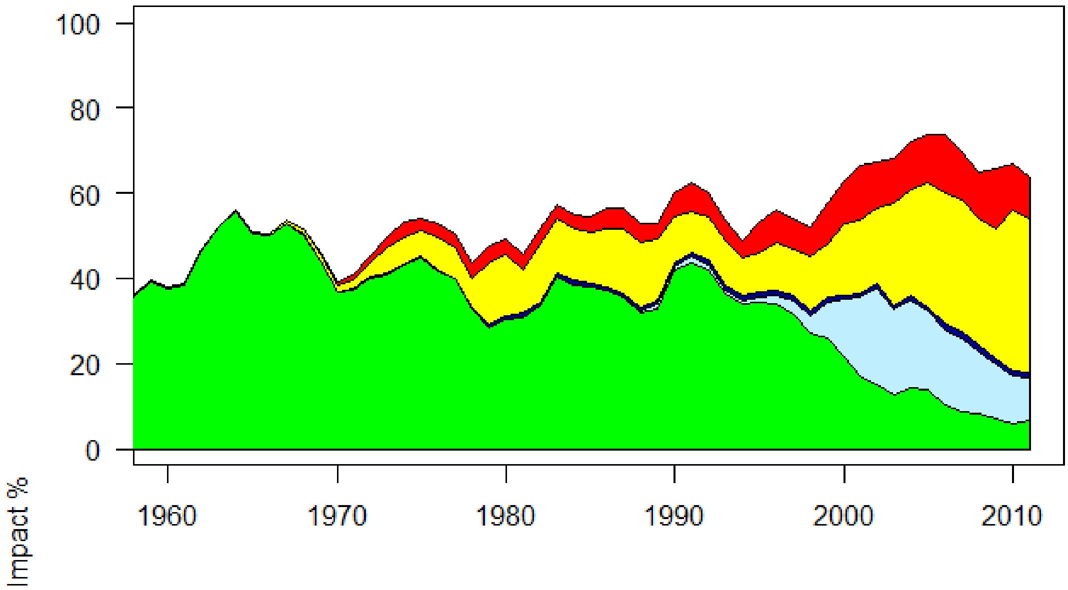


Figure 18: Estimates of reduction in spawning potential due to fishing (fishery impact = 1-SBt/SB$_{tF=0}$) for the southwest Pacific Ocean striped marlin attributed to various fishery groups (Ref.case model). Green = Japanese longline fisheries in sub-areas 1 to 4 and Taiwanese longline fishery in sub-area 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.

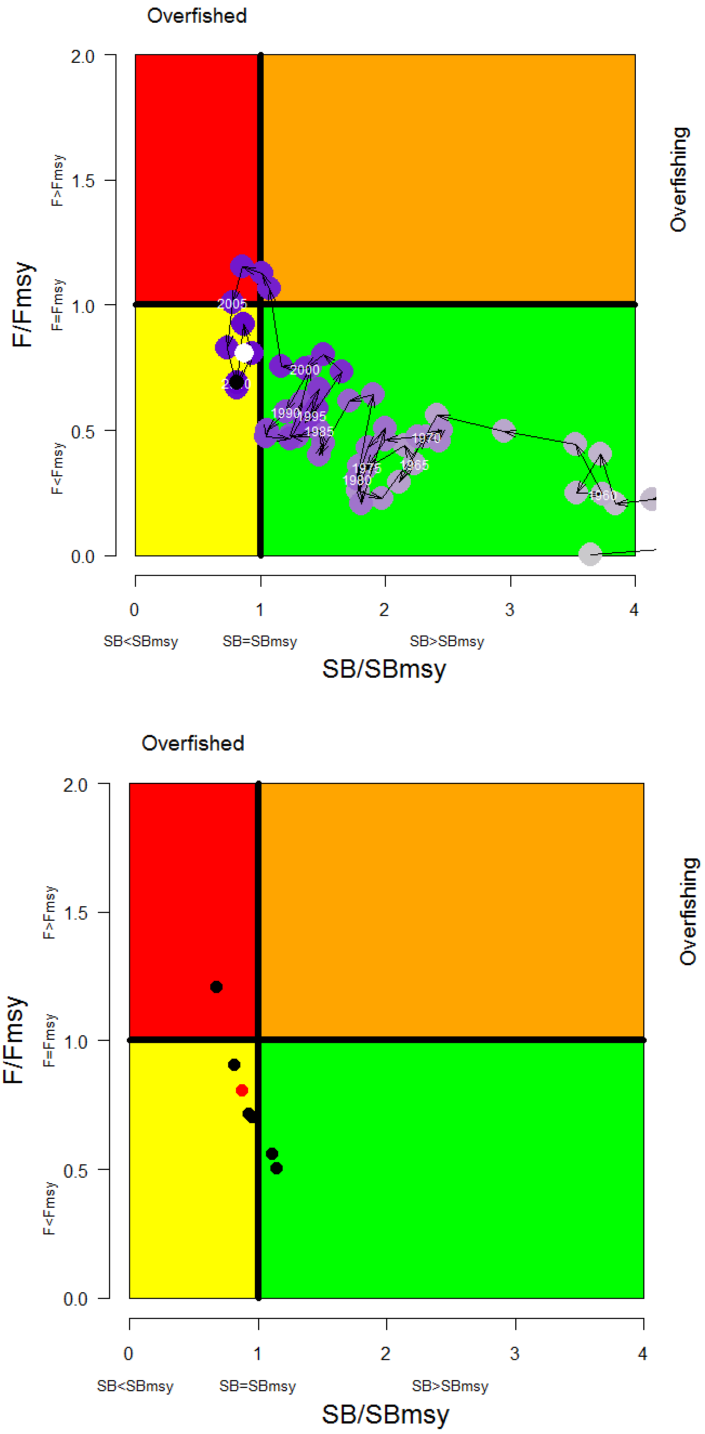


Figure 19: Temporal trend in annual stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the Ref.case (top) and $F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for the Ref.case (red circle) and the six plausible key model runs. See Table 15 to determine the individual model runs.

Table 15. 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 16: 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.

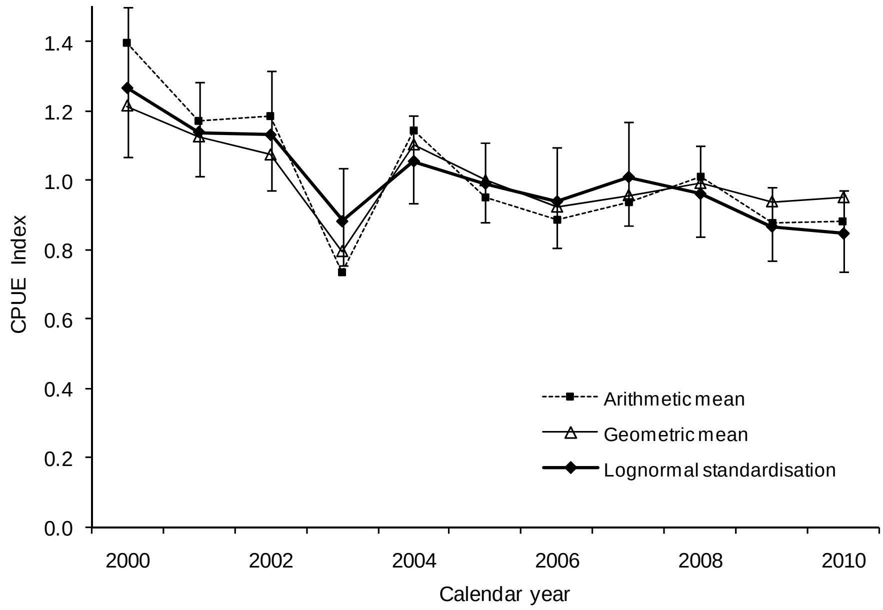


Figure 18: Unstandardised CPUE (annual geometric mean number of STM per set), the year effects from the model of non-zero catches from commercial logbooks (± 2 s.e.).

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).

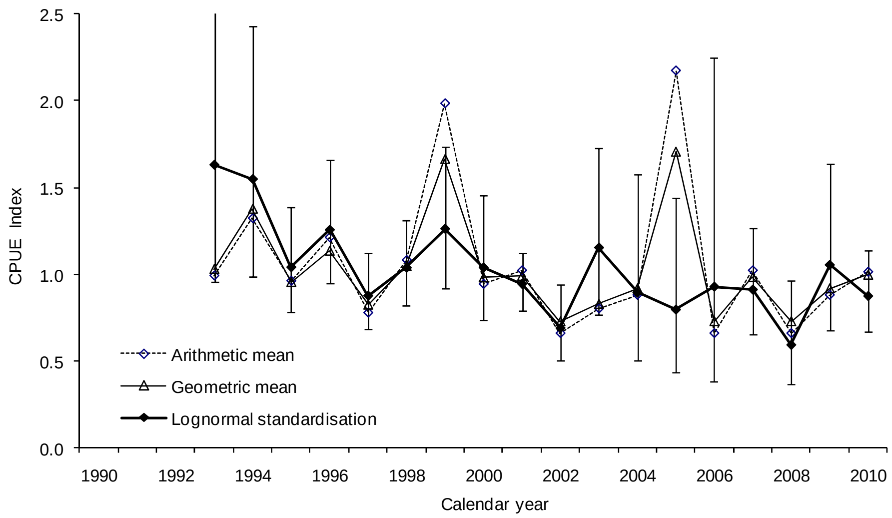


Figure 20: Unstandardised CPUE (arithmetic and geometric mean numbers of STM per set) and the year effects from the lognormal model of catch rates in successful sets (± 2 s.e.).

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.

The final model form was as follows:

Log(number STM per season) = fishing year + log(days fished) + vessel

Club catch tallies and charter catch rates had been low in the 1960s and early 1970s (Holdsworth et al 2003). Higher charter CPUE in the late 1970s and early 1980s were followed by three very poor years (Figure 21). Since then there has been an increasing trend in charter CPUE. 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.

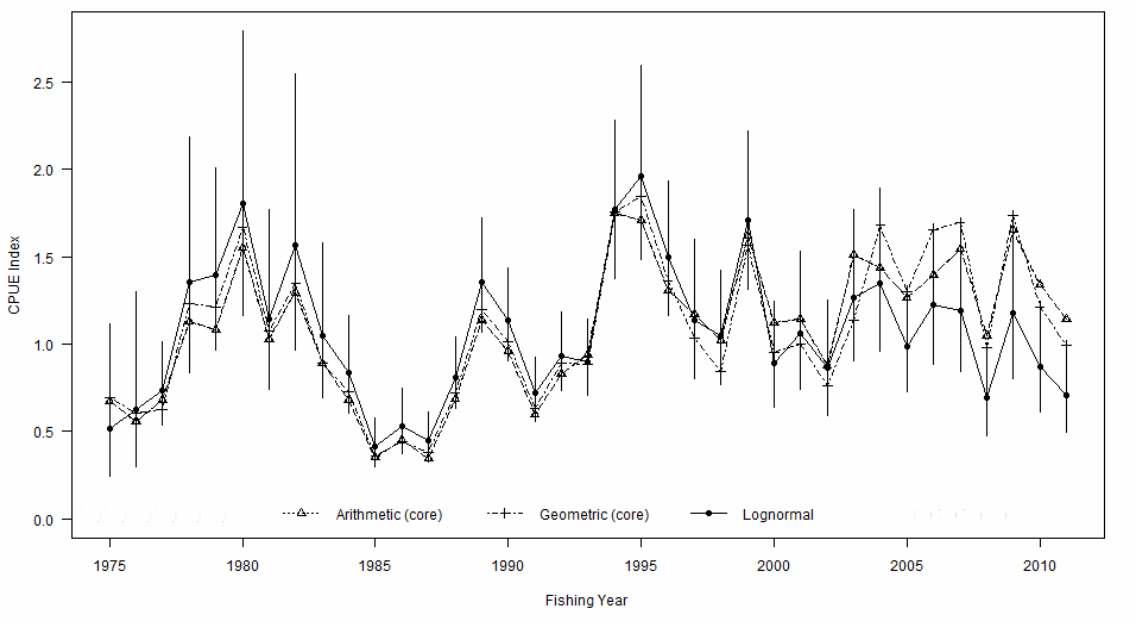


Figure 21: Unstandardised recreational charter boat CPUE (arithmetic and geometric mean number of striped marlin per vessel season) and the year effects from the model of non-zero catches (± 2 s.e.).

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).

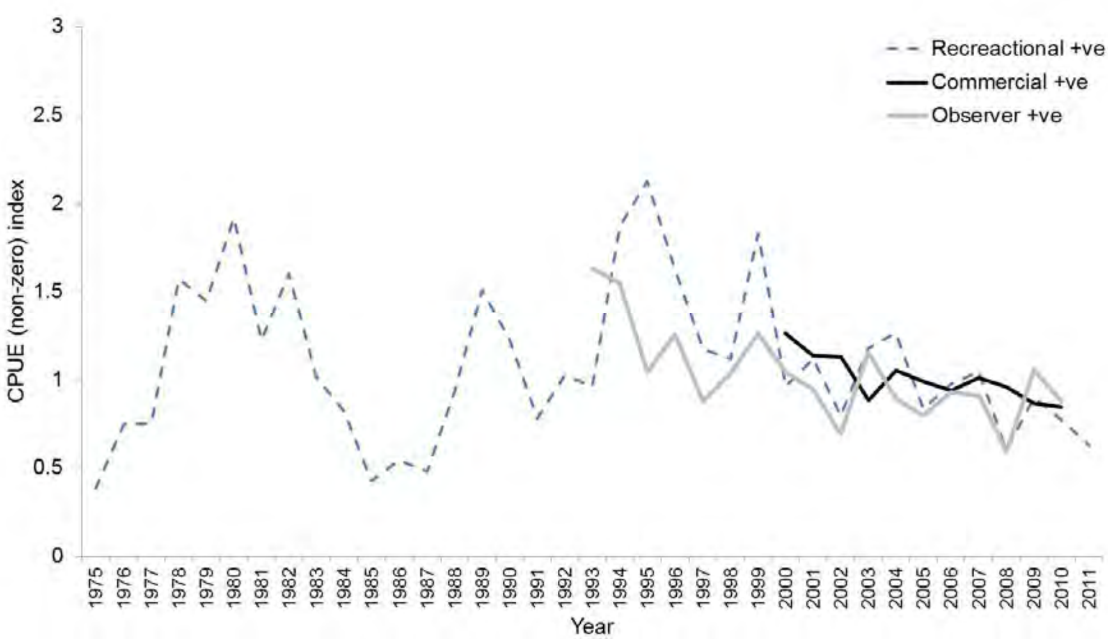


Figure 22: Comparison of standardised CPUE from the non-zero models of recreational charter vessel records with non-zero models of commercial and observer logbook records.

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.

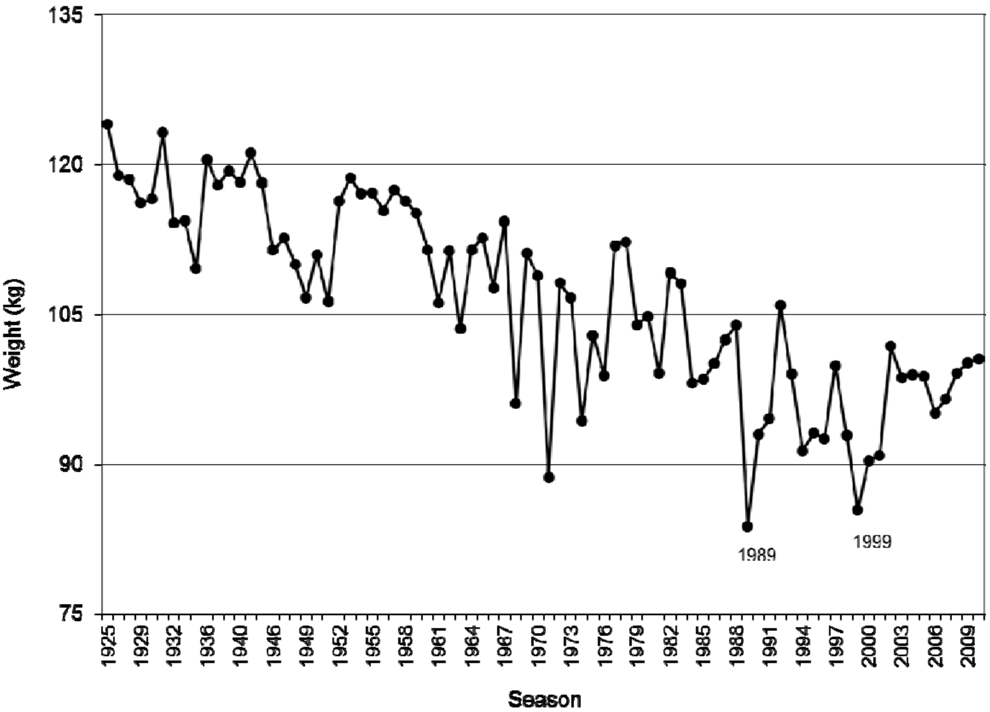


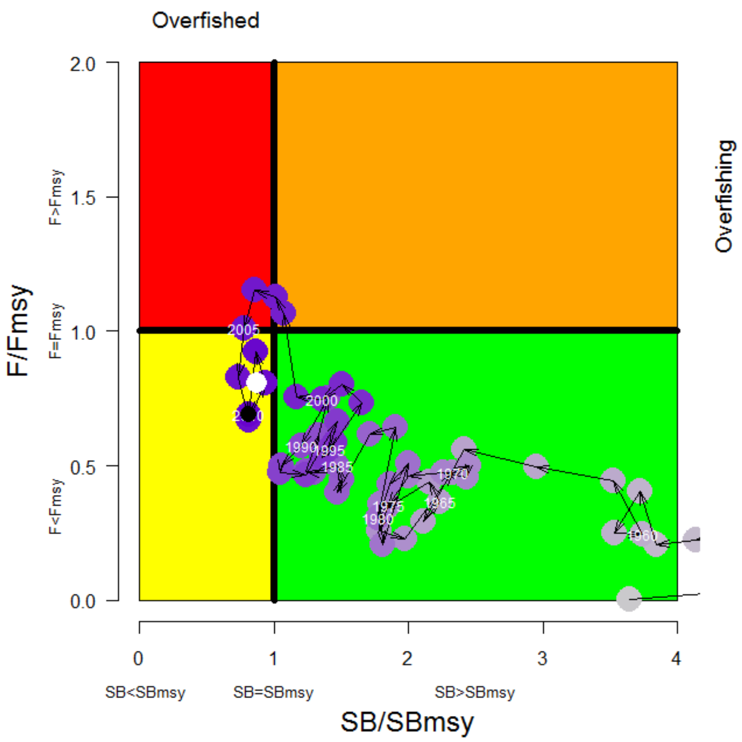
Figure 23: The mean annual weight of striped marlin (landed and tagged) caught in New Zealand fishery waters by recreational fishers by season from club records.

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} and 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 Intensity or Proxy	Overall fishing mortality has shown a slow but continuous increase from the 1950s through to 2011.	
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%; **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.	1 - High Quality 1 - High Quality 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).

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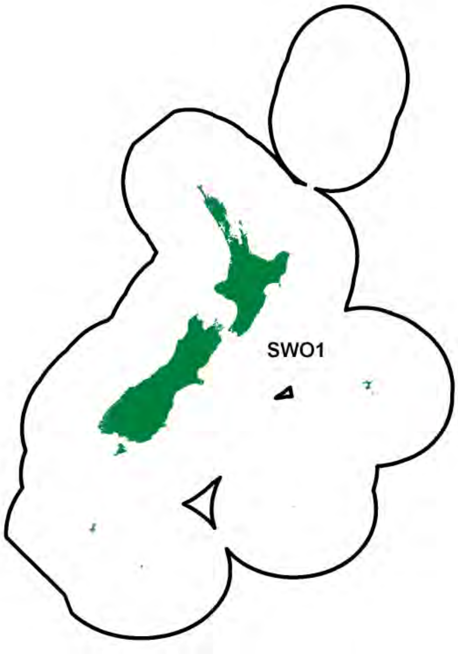
SWORDFISH (SWO)

(*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.

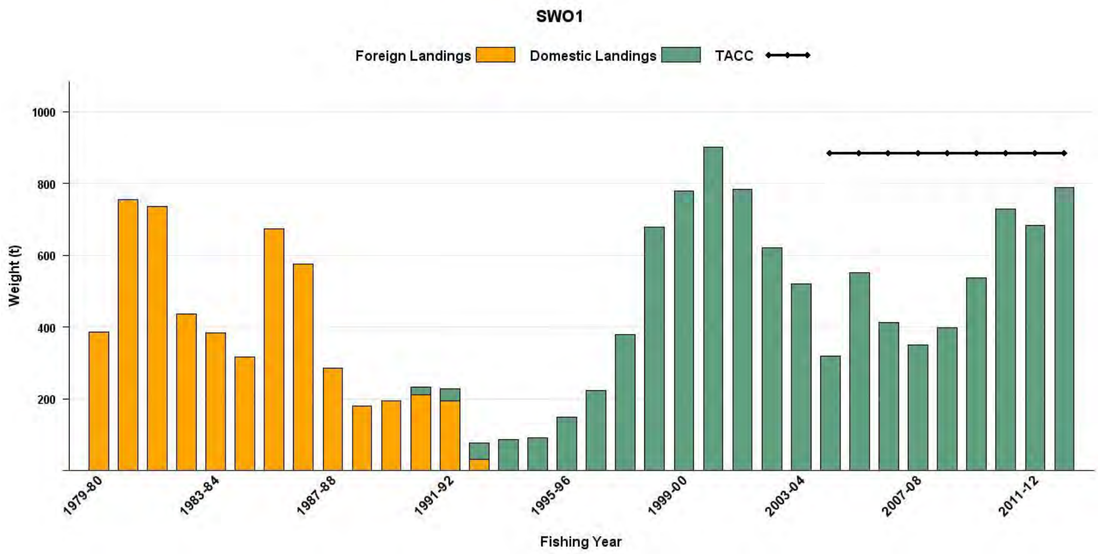


Figure 1: Swordfish catch by foreign licensed and New Zealand vessels from 1979–80 to 2012–13 New Zealand fishery waters (SWO 1). [Figure continued on next page].

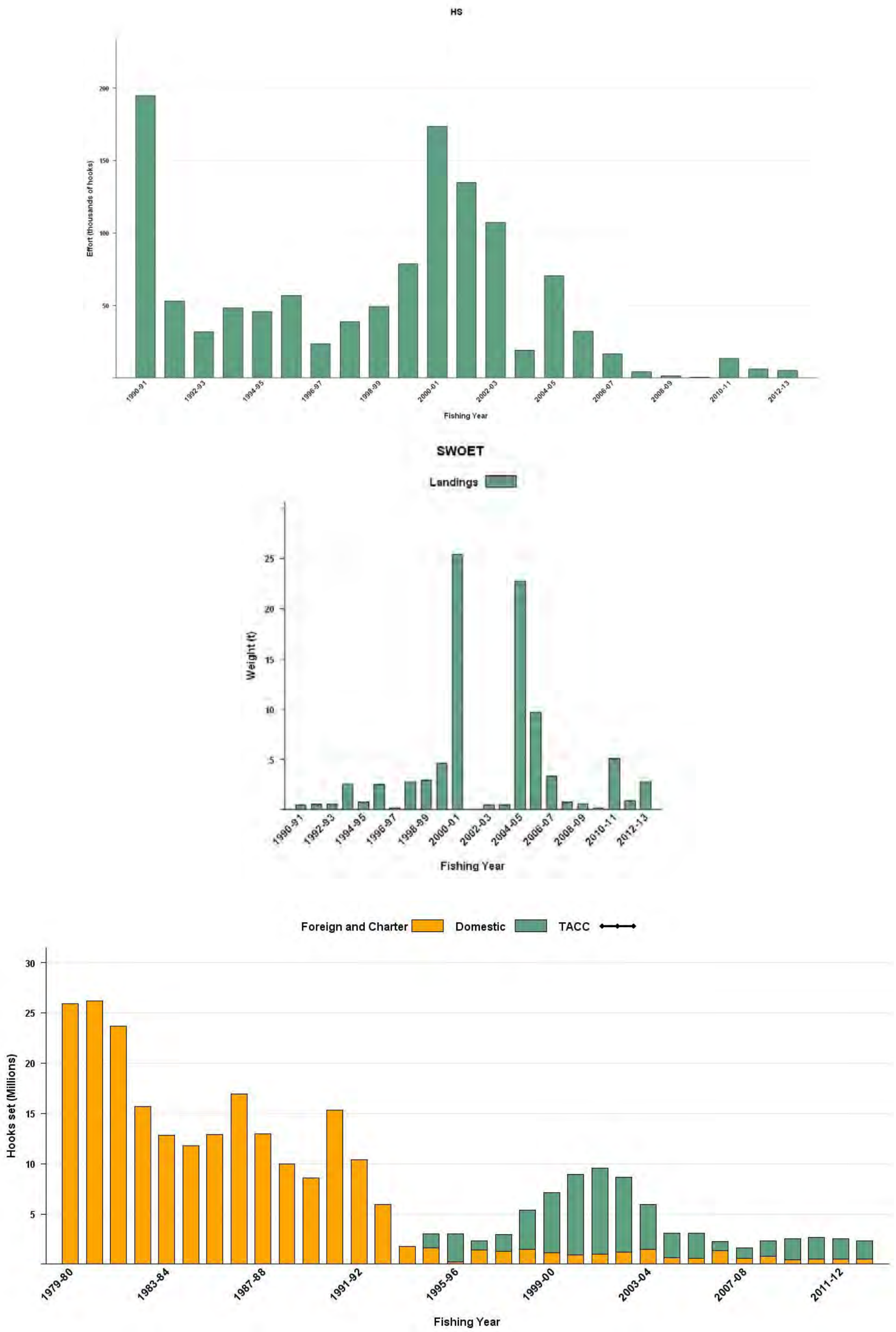


Figure 1 [Continued]: [Top] Swordfish catch by New Zealand vessels fishing on the high seas from 1990–91 to 2012–13. [Middle] Fishing effort (number of hooks set) for all New Zealand vessels fishing on the high seas; and [Bottom] fishing effort (number of hooks set) within New Zealand fishery waters 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 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
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
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		788.3	788.3	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).

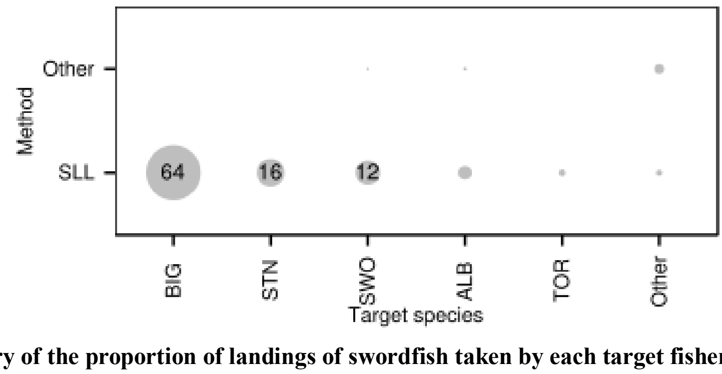


Figure 2: A summary of the proportion of landings of swordfish taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the circle is the percentage. SLL = surface longline (Bentley et al 2013).

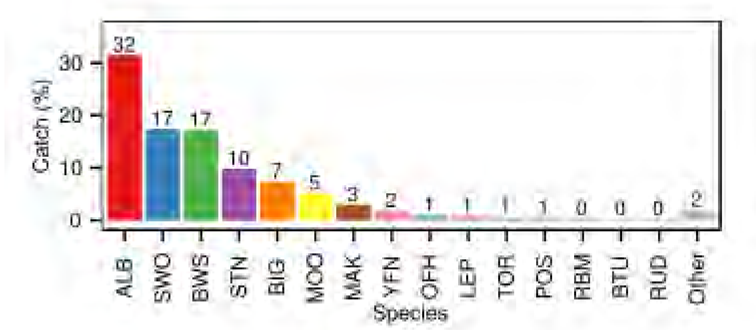


Figure 3: A summary of species composition of the reported surface longline catch. The percentage by weight of each species is calculated for all surface longline trips (Bentley et al 2013).

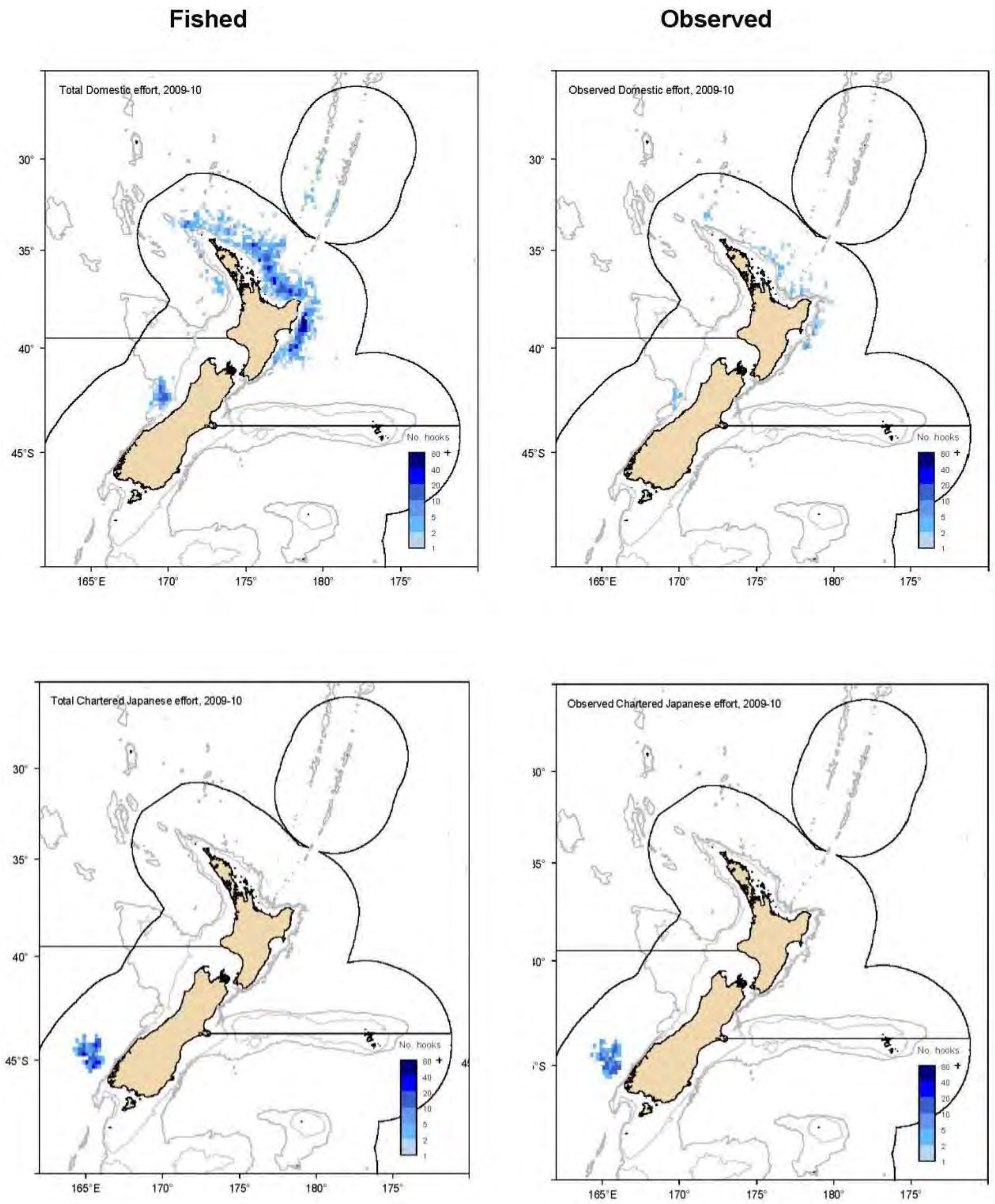


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009–10 fishing year, displaying both fishing effort (left) and observer effort (right).

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 big game fishers with the annual recreational catch averaging 60 swordfish per annum over the last four years. Despite variable and low recreational catch there is considerable recreational interest in swordfish and targeting methods have developed significantly in recent years. Until recently most catch was taken from vessels drifting or slow trolling baits at night. Since 2011 more fishers have been successfully using deep drifted baits during the day. There has also been an increase in the number of swordfish tagged and released with 42 tagged by recreational fishers and 8 by commercial fishers in 2011–12.

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 so far 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 a large distance (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 and Australia was used to describe the stock structure in the south-west Pacific region in a stock assessment model.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the November 2013 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=1644).

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 2011–12, there were 86 observed captures of seabirds in swordfish longline fisheries. Seabird capture rates since 2003 are presented in Figure 5. The seabird bycatch distributions 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. The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation was historically used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods but recent estimates are either ratio or model based as specified in the tables below (Abraham et al 2010).

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.

Table 5: Number of observed seabird captures in swordfish longline fisheries, 2002–03 to 2011–12, 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 moonfish 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	East Coast North Island	West Coast South Island	West Coast North Island	Total
Southern Buller's	Very high	0	0	1	0	0	1
New Zealand white-capped	Very high	0	1	0	2	0	3
Gibson's	High	4	5	0	1	0	10
Antipodean	High	12	3	0	0	0	15
Antipodean and Gibson's	High	5	0	0	0	0	5
Campbell black-browed	Medium	2	1	0	1	0	2
Unidentified	N/A	33	0	0	0	0	33
Total albatrosses	**N/A**	**56**	**10**	**1**	**4**	**0**	**69**
Other seabirds							
Black petrel	Very high	0	1	0	0	1	2
Flesh-footed shearwater	Very high	0	0	1	0	0	1
Westland petrel	Medium	0	0	0	1	0	1
White-chinned petrel	Medium	2	0	0	3	0	5
Grey petrel	Medium	3	0	0	0	0	3
Grey-faced petrel	Very low	1	1	0	0	0	2
Sooty shearwater	Very low	1	0	0	0	0	1
Total other seabirds	**N/A**	**7**	**2**	**1**	**4**	**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 2010–11 are based on data version 20120531 and preliminary estimates for 2011–12 are based on data version 20130305.

Fishing	Fishing effort			Observed captures		Estimated captures	
year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	0	0	N/A	0	N/A	N/A	N/A
2003–2004	0	0	N/A	0	N/A	N/A	N/A
2004–2005	132 503	11 553	8.7	2	0.173	46	24–83
2005–2006	228 305	4 800	2.1	2	0.417	90	46–174
2006–2007	210 175	40 138	19.1	71	1.769	206	128–368
2007–2008	125 330	23 180	18.5	1	0.043	51	26–91
2008–2009	41 700	3 990	9.6	0	0	12	4–25
2009–2010	137 840	500	0.4	3	6	61	34–103
2010–2011	177 248	18 638	10.5	0	0	45	25–76
2011–2012	193 280	43 450	22.5	7	0.161	87	32–244

†Provisional data, model estimates not finalised.

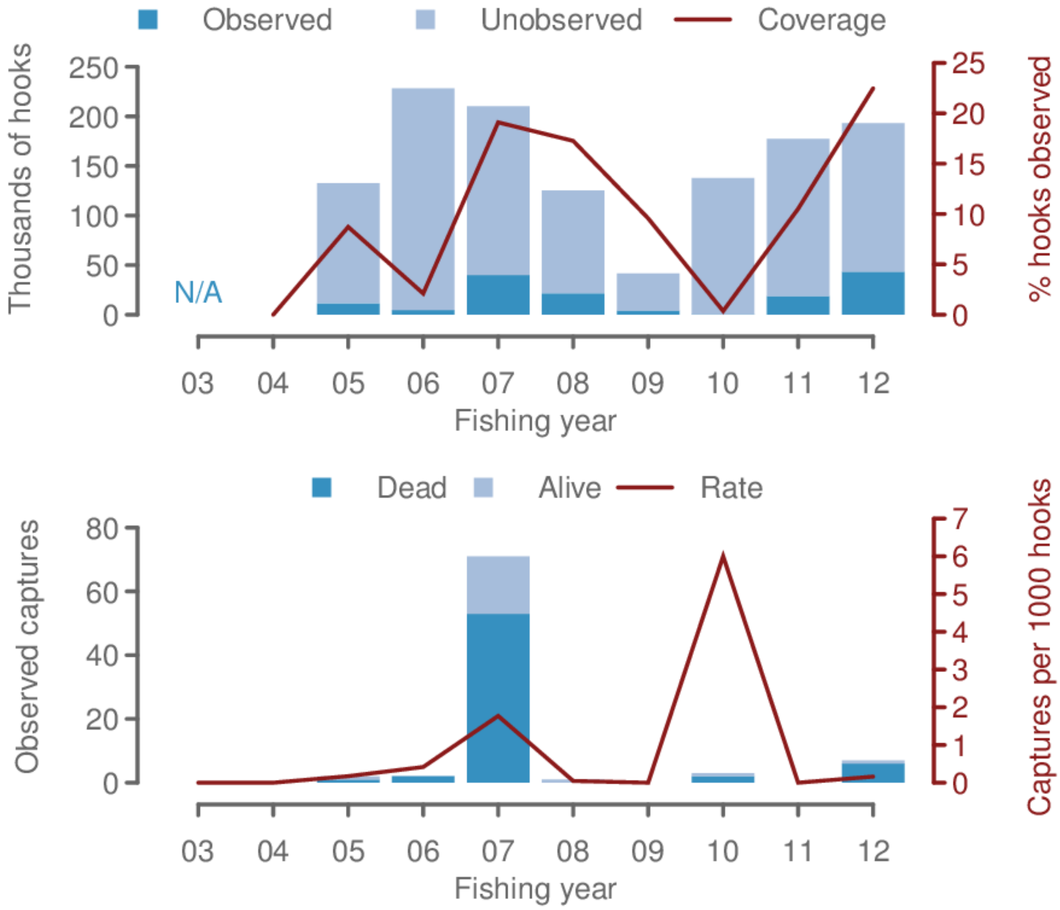


Figure 5: Observed and estimated captures of seabirds in swordfish longline fisheries from 2002–03 to 2011–12.

Figure 6: Distribution of fishing effort targeting swordfish and observed seabird captures, 2002–03 to 2011–12. 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, 33.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.2 Sea turtle bycatch

Between 2002–03 and 2011–12, there were two observed captures of sea turtles in swordfish longline fisheries (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 (Figure 8).

Table 7: Number of observed sea turtle captures in swordfish longline fisheries, 2002–03 to 2011–12, 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	0	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	23 180	18.5	1	0.043
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	193 280	43 450	22.5	0	0

Figure 7: Observed captures of sea turtles in swordfish longline fisheries from 2002–03 to 2011–12.

Figure 8: Distribution of fishing effort targeting swordfish and observed sea turtle captures, 2002–03 to 2011–12. 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, 33.3% 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 2011–12, there were no observed captures of whales or dolphins in swordfish longline fisheries (Table 9 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. Captures on longlines occur when the seals attempt to feed on the fish catch and bait during hauling. Most New Zealand fur seals captured in the SBT lll fishery are released alive, typically with a hook and short snood or trace still attached.

Table 9: 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	0	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	23 180	18.5	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	193 280	43 450	22.5	0	0

Figure 9: Distribution of fishing effort targeting swordfish, 2002–03 to 2011–12. 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, 33.3% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

Between 2002–03 and 2011–12, there were two observed captures of New Zealand fur seals in swordfish longline fisheries (Table 10 and 11, Figures 10 and 11). These captures include animals that are released alive (Thompson et al 2013).

Table 10: Number of observed New Zealand fur seal captures in swordfish longline fisheries, 2002–03 to 2011–12, 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 11: 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 2010–11 are based on data version 20120531 and preliminary estimates for 2011–12 are based on data version 20130305.

	Fishing effort			Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	0	0	N/A	0	N/A	0	0–2
2003–2004	0	0	N/A	0	N/A	0	0–0
2004–2005	132 503	11 553	8.7	2	0.173	9	5–15
2005–2006	228 305	4 800	2.1	0	0	12	6–19
2006–2007	210 175	40 138	19.1	0	0	8	3–15
2007–2008	125 330	23 180	18.5	0	0	7	2–13
2008–2009	41 700	3 990	9.6	0	0	1	0–4
2009–2010	137 840	500	0.4	0	0	9	4–16
2010–2011	177 248	18 638	10.5	0	0	3	0–7
2011–2012	193 280	43 450	22.5	0	0	4	1–9

†Provisional data, model estimates not finalised.

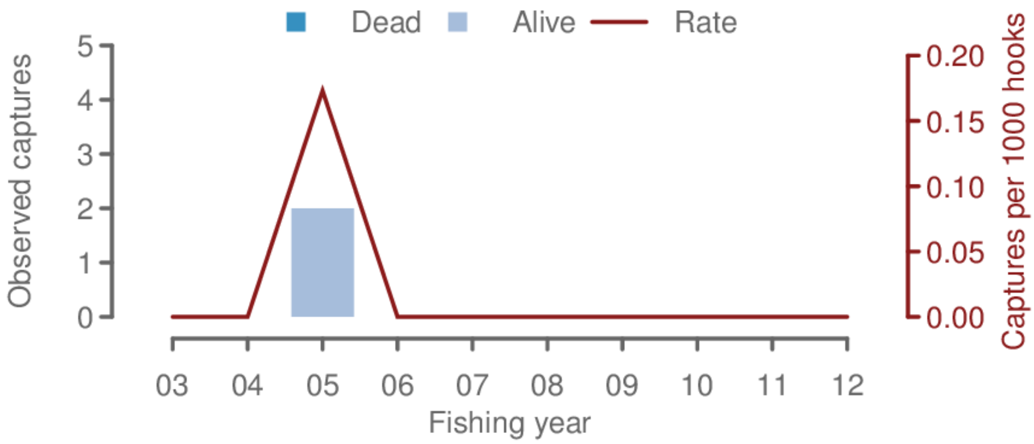


Figure 10: Observed captures of New Zealand fur seal in swordfish longline fisheries from 2002–03 to 2011–12.

Figure 11: Distribution of fishing effort targeting swordfish and observed New Zealand fur seal captures, 2002–03 to 2011–12. 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, 33.3% 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 12). Southern bluefin tuna and albacore tuna are the only target species that occur in the top five of the frequency of occurrence.

Table 12: Numbers of the most common fish species observed in the New Zealand longline fisheries during 2009–10 by fleet and area. Species are shown in descending order of total abundance (Griggs & Baird 2013).

	Charter	Domestic		Total
Species	South	North	South	number
Blue shark	2 024	4 650	882	7 556
Ray's bream	3 295	326	88	3 709
Southern bluefin tuna	3 244	211	179	3 634
Lancetfish	3	2 139	1	2 143
Albacore tuna	90	1 772	42	1 904
Dealfish	882	0	7	889
Swordfish	3	452	2	457
Moonfish	76	339	6	421
Porbeagle shark	72	328	20	420
Mako shark	11	343	7	361
Big scale pomfret	349	4	0	353
Deepwater dogfish	305	0	0	305

Sunfish	7	283	5	295
Bigeye tuna	0	191	0	191
Escolar	0	129	0	129
Butterfly tuna	15	100	3	118
Pelagic stingray	0	96	0	96
Oilfish	2	75	0	77
Rudderfish	39	20	2	61
Flathead pomfret	56	0	0	56
Dolphinfish	0	47	0	47
School shark	34	0	2	36
Striped marlin	0	24	0	24
Thresher shark	7	17	0	24
Cubehead	13	0	1	14
Kingfish	0	10	0	10
Yellowfin tuna	0	9	0	9
Hake	8	0	0	8
Hapuku bass	1	6	0	7
Pacific bluefin tuna	0	5	0	5
Black barracouta	0	4	0	4
Skipjack tuna	0	4	0	4
Shortbill spearfish	0	4	0	4
Gemfish	0	3	0	3
Bigeye thresher shark	0	2	0	2
Snipe eel	2	0	0	2
Slender tuna	2	0	0	2
Wingfish	2	0	0	2
Bronze whaler shark	0	1	0	1
Hammerhead shark	0	1	0	1
Hoki	0	0	1	1
Louvar	0	1	0	1
Marlin, unspecified	0	1	0	1
Scissortail	0	1	0	1
Broadnose seven gill shark	1	0	0	1
Shark, unspecified	0	1	0	1
Unidentified fish	2	30	8	40
Total	10 545	11 629	1 256	23 430

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 where: assume two model regions, that are biologically connected, this was based on the results of recent electronic tagging programmes; and 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 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 were 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 = 44 – 68 % and spawning biomass = 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. 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.*"

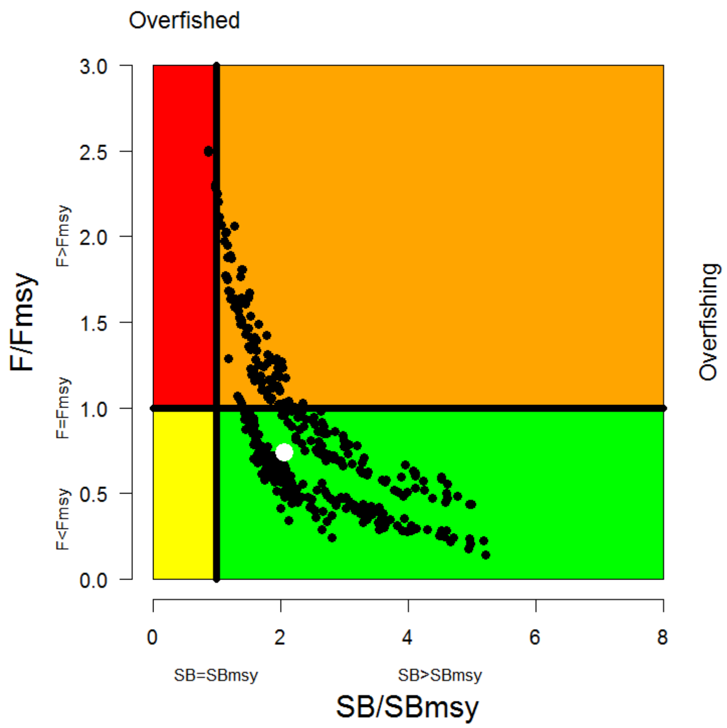


Figure 12: $F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for the median of the selected uncertainty grid (white circle) and the individual uncertainty grid runs.

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.

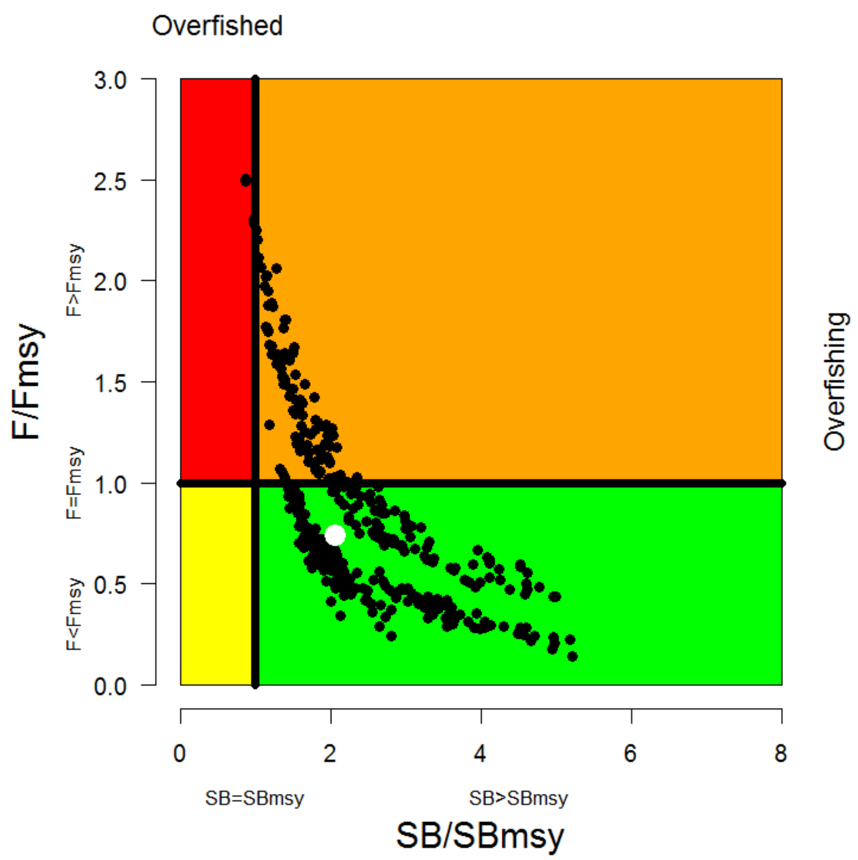
6. STATUS OF THE STOCKS

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	Recruitment trends have fluctuated without trend from 1950

Indicator or Variables	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).

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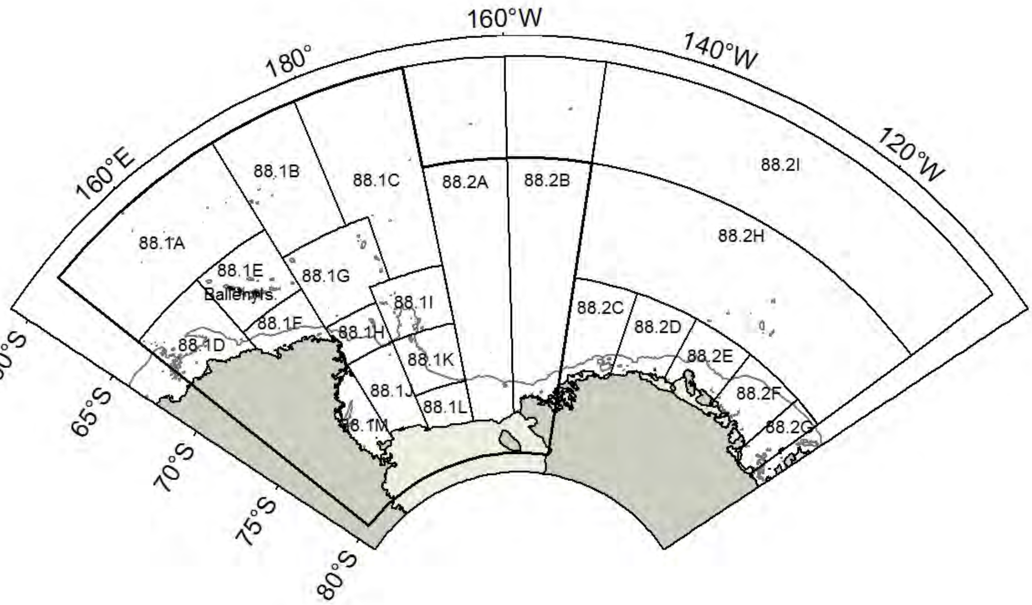
TOOTHFISH (TOT)
(outside EEZ)

(*Dissostichus mawsoni* and *Dissostichus eleginoides*[1])



The wider Ross Sea Region CCAMLR Subareas 88.1 and 88.2 showing the small-scale research units (SSRUs) used for management and the 1000 m depth contour.

1. FISHERY SUMMARY

This working group report is a summary of the toothfish fisheries in CCAMLR Subareas 88.1 and 88.2 and includes the catches of all countries participating in that fishery. These fisheries occur entirely on the high seas within the Convention area of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

Finfish fisheries in Antarctic waters are largely managed under the CAMLR Convention, in particular Article II, paragraph 3. The Convention Area covers the area south of the Antarctic Convergence (varying from 60° S in the Pacific Sector to 45° S in the western Indian Ocean Sector).

1.1 Commercial fisheries

Toothfish are large Nototheniids endemic to Antarctic and Subantarctic waters. There are two main species: Antarctic toothfish (*Dissostichus mawsoni*) and Patagonian toothfish (*Dissostichus eleginoides*). Both have a circumpolar distribution, although *D. mawsoni* has a more southern distribution.

Bottom longline and trawl fisheries for Patagonian toothfish occur around many of the Subantarctic islands and plateaus south of the Subantarctic Front. To date, the main longline fishery for Antarctic

[1] Note that this report does not cover the Patagonian toothfish (*Dissostichus eleginoides*) fishery within the New Zealand Exclusive Economic Zone.

toothfish has taken place in Subarea 88.1, with smaller fisheries in Subarea 88.2, Subarea 48.6 and several CCAMLR divisions in Subarea 58.4. Subarea 88.1 is divided into three broad ecological regions: a region of seamounts, ridges and banks to the north; a region of shallow water (< 800 m) on the Ross Sea shelf in the extreme south; and a region in between covering the continental slope (800–2000 m), where the main longline fishery occurs.

The exploratory longline fishery for *Dissostichus* spp. in Subarea 88.1 was initiated by a single New Zealand longline vessel in 1996–97 (Table 1). Since then, New Zealand vessels, and more recently vessels from other countries, have returned each summer to fish in this area and the adjacent Subarea 88.2. The catch of toothfish in Subarea 88.1 showed a steady increasing trend during the early period of the fishery, reaching the catch limit (TAC) and peaking at about 3000 t between 2004–05 and 2006–07, but being under-caught in Subarea 88.1 in 2007–08, and 2008–09. Failure to reach the catch limit in those two years was due to the severe ice conditions in 2007–08 and early closure of the fishery by the CCAMLR Secretariat in 2008–09 due to overestimation of projected catch rates. The catches have been close to the catch limits since 2009–10, with the closure of the fishery by CCAMLR based on the daily catch reports.

The catch of toothfish in Subarea 88.2 showed a sharp increase in 2003–04, and exceeded catch limits in 2004–05 and 2005–06 but has since declined slightly. Failure to reach the catch limit in the following four years was primarily due to the lower fishing effort in SSRUs CDFG, and difficulty accessing fishable ground to take allocated catch limits in these SSRUs due to ice conditions, but the catch has been close to the catch limit since 2010–11 (Hanchet et al 2013), with the closure of the fishery by CCAMLR based on the daily catch reports. Figure 1 shows historical landings and catch limits (TACs) for Subareas 88.1 and 88.2.

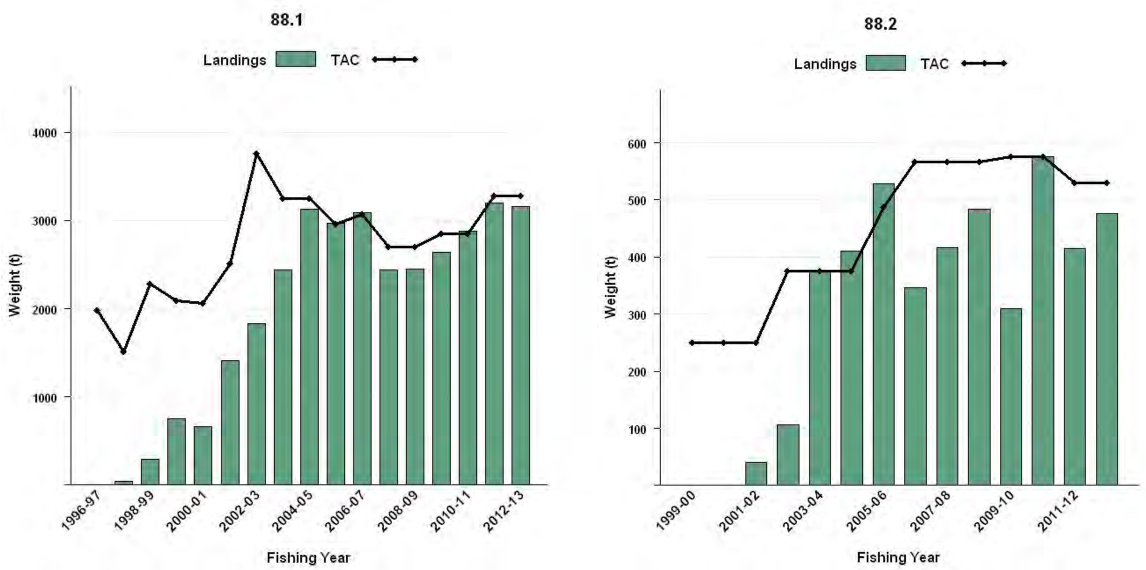


Figure 1: The landings of toothfish and catch limits (TACs) from 1997–98 to 2012–13 in Subarea 88.1, and 1999–00 to 2012–13 in Subarea 88.2.

The toothfish catch from these areas comprises almost entirely Antarctic toothfish. Since the start of the fishery about 136 t of Patagonian toothfish has been caught in Subareas 88.1 and 88.2, almost entirely from the north of Subarea 88.1 (SSRUs 88.1A, 88.1B, and 88.1C) (Hanchet et al 2013). The data in the following tables are collated from weekly reporting forms (vessel to CCAMLR), monthly reporting (vessel to flag state to CCAMLR) and annual reporting (FAO STATLANT reports to CCAMLR from flag state).

The number, size, and catch limits of the SSRUs in Subarea 88.1 have varied over time (see also NZ Delegation 2008). In 1997–98 and 1998–99, Subarea 88.1 was divided into two at 65° S, with separate catch limits in each area. From 1999–2000 to 2002–03, the area south of 65° S was further divided into four SSRUs, with equal catch limits in each SSRU. The number of SSRUs was increased to twelve for the 2003–04 and 2004–05 seasons and the new catch limits were based proportionally on the product of the mean historical CPUE and the fishable seabed area (600–1800 m). The catch limits for the SSRUs were again changed for the 2005–06 and 2006–07 seasons as part of a three-year experiment (NZ Delegation 2008). To assist administration of the SSRUs, the catch limits for SSRUs 88.1B, 88.1C, and 88.1G were amalgamated into a ‘north’ region and those for SSRUs 88.1H, 88.1I, and 88.1K were amalgamated into a ‘slope’ region. A nominal catch of up to 10 t was permissible in each ‘closed’ SSRU under a research fishing exemption. The research provision for closed SSRUs was removed for the 2009 season and the 10 t research catch was absorbed back into the total catch limit. For the 2008–09 season, SSRU 88.1J was split into two at 170º E, creating a new SSRU 88.1M to the west of that line (which is closed to fishing), and reducing the size of 88.1J to the east of that line. The catch limits for SSRUs 88.1J and 88.1L were amalgamated into a ‘shelf’ region. The catch limits for the remaining SSRUs in Subarea 88.1 were adjusted accordingly. These measures have remained in place in the last four years.

Table 1: Estimated catches (t) of *Dissostichus* spp. by area for the period 1996–97 to 2012–13 (Source: FAO STATLANT data to 2011–12, catch and effort reports for 2012–13 – SC-CAMLR-XXX/BG/1). – denotes has not been estimated, but likely to be 0 t.

	Subarea 88.1				Subarea 88.2			
Season	Reported catch	Estimated IUU catch	Total	Catch limit	Reported catch	Estimated IUU catch	Total	Catch limit
1996–97	< 1	0	< 1	1 980*	0	0	0	1 980*
1997–98	42	0	42	1 510	0	0	0	63
1998–99	297	0	297	2 281	0	0	0	0
1999–00	751	0	751	2 090	0	0	0	250
2000–01	660	0	660	2 064	0	0	0	250
2001–02	1 325	92	1 417	2 508	41	0	41	250
2002–03	1 831	0	1 831	3 760	106	0	106	375
2003–04	2 197	240	2 437	3 250	375	0	375	375
2004–05	3 105	23	3 128	3 250	411	0	411	375
2005–06	2 969	0	2 969	2 964	514	15	529	487
2006–07	3 091	0	3 091	3 072	347	0	347	567
2007–08	2 259	186	2 445	2 700	416	0	416	567
2008–09	2 448	0	2 448	2 700	484	0	484	567
2009–10	2 639	0	2 639	2 850	309	0	309	575
2010–11	2 882	0	2 882	2 850	576	0	576	575
2011–12	3 199	–	3 199	3 282	415	–	415	530
2012–13	3 155	–	3 155	3 282	476	–	476	530

* A single catch limit in 1996/97 applied to all of Subareas 88.1 and 88.2.

Although the overall catch limit in Subarea 88.1 has rarely been exceeded, the catch limit for some SSRUs has been exceeded in some seasons. Ice conditions and bycatch limits are an important factor in the fishery. In 2002-03, 2003-04 and 2007-08 heavy ice conditions meant little catch was taken in SSRUs 88.1J–L.

The SSRUs in Subarea 88.2 have also varied over time. In 1997–98 and 1998–99, the Subarea was divided into two at 65° S, with the northern area closed and a catch limit set for the southern area. From 1999–2000 to 2010–11, the area south of 65° S was divided into seven SSRUs, each comprising 20° of longitude. The catch limits for the southern SSRUS in Subarea 88.2 were also changed as part of a three-year experiment. SSRU 88.2E was treated as a separate SSRU with its own catch limit, whilst SSRUs 88.2C, 88.2D, 88.2F, and 88.2G were amalgamated with a single catch limit. Fishing has now been carried out in all SSRUs, however, most of the catch has been taken in SSRU 88.2E. For the 2012 season SSRUs 88.2C–G were further divided and SSRU 88.2H added to separate the north and slope grounds (at 70º 50’ S), with a catch limit for each of these two grounds. The northernmost SSRU, 88.2I, has always been closed to fishing.

In addition to the catch limits on the target species, many other management measures have been in place over the course of the fishery. These include restrictions on bycatch, measures to minimise local depletion of toothfish, and bycatch mitigation measures (CCAMLR Conservation Measures 33-03 (2013), 41-09 (2013) and 41-10 (2013)). In 2005–06, the macrourid bycatch limits were exceeded in SSRUs 88.2CDFG and so Subarea 88.2 was closed before the toothfish catch limit was reached.

1.2 Recreational fisheries
There is no recreational toothfish fishery in Subareas 88.1 and 88.2.

1.3 Customary non-commercial fisheries
There is no customary toothfish fishery in Subareas 88.1 and 88.2.

1.4 Illegal catches
Based on aerial surveillance and other sources of intelligence, the level of illegal and unreported catch is thought to be low (Table 1). CCAMLR stopped estimating the level of IUU catch from 2011, as IUU effort in recent years in the Convention area has typically been comprised of gillnetting vessels and the catch rates for this type of method cannot be reliably estimated. However, CCAMLR estimated that there has been no IUU effort in Subareas 88.1 and 88.2 since 2010–11 (Secretariat 2013).

1.5 Other sources of mortality
Any longline gear that is baited and set, but not successfully retrieved, may result in unaccounted mortality of toothfish or other species. In Subareas 88.1 and 88.2, bottom longline gear is most often lost due to interactions of downlines with moving sea ice, but may also result from tidal currents submerging floats, or gear failure during line retrieval. The fate of fish hooked on lost lines is unknown. Webber & Parker (2011) estimated line loss from 2008 to 2011 to be in the range 3–8% (expressed in terms of percent of all hooks set that are lost attached to sections of lines). Assuming that these hooks caught toothfish at the same rate as those on lines that were retrieved, and that all the toothfish caught on lost lines die as a result of being caught, then an additional 175–244 tonnes of Antarctic toothfish fishing related mortality may be unaccounted for annually.

A small quantity of toothfish is taken by scientific research programmes in most years, typically in the order of 30–40 kg, although in some years it may be considerably more.

Observers monitor discards, with at least 40% of all hooks hauled being directly observed, and no discarding of toothfish has been reported to date. Discarding in the CAMLR Convention area is illegal. However, observers and crew on some New Zealand vessels have reported indirect evidence of discarding by other (unknown) vessels, e.g. the presence of toothfish offal in sampled toothfish stomachs, and in the 2012 and 2013 seasons some vessels acknowledged illegal discard practices after being boarded and inspected by New Zealand fisheries officers from naval patrol vessels. Fish are occasionally lost from the line near the surface – if those fish are dead, fishers can usually recover and land them, if alive they generally swim away and are likely to survive (on the basis of the observed tag-recapture data).

Antarctic toothfish are occasionally caught with evidence of squid depredation (i.e., sucker marks and large flesh wounds), but the amount of depredation due to large squid is insignificant at the scale of the fishery. To date, there have been no reported instances of depredation of toothfish by cetaceans or pinnipeds in the Ross Sea region.

2. BIOLOGY

The Antarctic toothfish has a circumpolar distribution south of the Antarctic convergence (60° S). A summary of the biology of Antarctic toothfish, and related references, are given in detail in a species profile (Hanchet 2010). Although it is primarily a demersal species, adults are believed to be neutrally buoyant and are known to inhabit the pelagic zone at various locations and times during their life cycle (Near et al 2003). Early growth has been well documented (Horn et al 2003) with fish reaching about 60 cm TL after five years and about 100 cm TL after ten years. Growth slows down after 25 years at a length of about 150 cm. The maximum recorded age is 48 years and maximum length recorded is 250 cm. Ages have been validated by following modes in juvenile fish and by tetracycline marking and lead-radium dating in adult fish (Brooks et al 2011, Horn et al 2003). There is a significant difference in growth between sexes with maximum average lengths of 170 cm and 180 cm for males and females respectively (Horn 2002).

The age and length at recruitment to the Ross Sea fishery varies between areas and between years. In the northern SSRUs (88.1A–88.1G), toothfish recruit at a length of about 130 cm to the fishery. In the southern SSRUs (88.1H–88.1M) the length at recruitment depends on the depth of fishing. In some years fish have been fully recruited by about age 7–8, whereas in other years fish have not been fully recruited until at least age 10. In Subarea 88.2, toothfish recruit at a length of about 130 cm in the northern SSRU (88.2H) but at a length of about 60–80 cm (age 5–8) in the southern SSRUs (88.2C–G) (Hanchet et al 2013).

Previous Antarctic toothfish assessments assumed a 50% maturity at 100 cm (with range 85–115 cm) with a logistic relationship by length, and converted the length-based relationship to an age-based relationship via the von Bertalanffy curve for both sexes combined. In 2009, estimates of maturity, based on hindcasting from the presence of post-ovulatory follicles in the ovaries and forecasting from the assessment of oocyte developmental stage, suggested the mean age and length at 50% spawning for females on the Ross Sea slope region were 16.6 y and 133.2 cm and for the mean age and length at 50% maturity for males were 12.8 y and 120.4 cm (Parker & Grimes 2009). These estimates were updated in 2012 to 16.9 years and 135 cm for females and 12.0 years and 109 cm for males (Parker & Marriott, 2012).

The natural mortality rate *M* was estimated by Dunn et al (2006) using the methods of Chapman-Robson (1960), Hoenig (1983), and Punt et al (2005). Estimates of *M* derived from these methods ranged from 0.11 to 0.17 y^{-1}. After a consideration of possible biases, Dunn et al (2006) proposed that a value of 0.13 y^{-1} be used for stock modelling with a range of 0.11–0.15 y^{-1} for sensitivity analyses. They noted that further work is required on values of *M* and in possible changes of *M* with age. Biological parameters relevant to the stock assessment are shown in Table 2.

Table 2: Estimates of biological parameters for Antarctic toothfish.

Biological parameters							Reference
1. Natural mortality (M)							
	Males	Females					
	0.13	0.13					Dunn et al 2006
2. Weight = a(length)^b (Weight in kg, length in cm fork length)							
	Males		Females				
	a	b	a	b			
	0.00001387	2.965	0.000007154	3.108			Dunn et al (2006)
3. von Bertalanffy growth parameters							
	Males			Females			
	K	t_0	L_∞	K	t_0	L_∞	
	0.093	-0.26	169.1	0.090	0.021	180.2	Dunn et al (2006)
4. Maturity							
	Males		Females				
	A_{50}	$\pm A_{to95}$	A_{50}	$\pm A_{to95}$			
	11.99	5.25	16.92	7.68			Parker & Marriott (2012)

Antarctic toothfish feed on a wide range of prey but are primarily piscivorous. The most important prey species of fish caught in the main fishery are grenadiers (*Macrourus* spp.). In continental slope waters, *Macrourus* spp., the icefish *Chionobathyscus dewitti*, eel cods (*Muraenolepis* spp.) and cephalopods predominate in the diet (Stevens et al 2014), while on oceanic seamounts *Macrourus* spp., violet cod (*Antimora rostrata*) and cephalopods are important. In the southern Ross Sea subadult and adult toothfish feed mainly on nototheniids (*Trematomus* spp.) and icefish, whilst in McMurdo Sound, the stomachs of adult toothfish sampled through holes in the ice have been observed to contain mainly Antarctic silverfish (*Pleuragramma antarcticum*) (Eastman, 1985). In the open oceanic waters in the north of the Ross Sea region, Antarctic toothfish feed on small squid. The diet of Antarctic toothfish also varies with fish size. Crustaceans are more common prey items in smaller toothfish, whereas squid are more common in larger toothfish.

The main predators of toothfish are likely to be cetaceans (sperm whales, killer whales), pinnipeds (Weddell seals), and colossal squid (Eisert et al 2013; Pinkerton et al 2010a; Torres et al 2013).

Hanchet et al (2008) developed a hypothesis for the life history of Antarctic toothfish in the Ross Sea. Fish spawn to the north of the Antarctic continental slope, mainly on the ridges and banks of the

Pacific-Antarctic Ridge. The spawning takes place during winter and spring, and may extend over a period of several months. They postulated that depending on the exact location of spawning, eggs and larvae become entrained by the Ross Sea gyres (a small clockwise rotating western gyre located around the Balleny Islands and a larger clockwise rotating eastern gyre covering the rest of 88.1 and 88.2), and move either west settling out around the Balleny Islands and adjacent Antarctic continental shelf, south onto the Ross Sea shelf, or eastwards with the eastern Ross Sea gyre settling out along the continental slope and shelf to the east of the Ross Sea in Subarea 88.2. As the juveniles grow in size it is hypothesized that they move west back towards the Ross Sea shelf and then move out into deeper water (greater than 600 m). The fish gradually move northwards as they mature, feeding in the slope region in depths of 1000–1500 m, where they gain condition before moving north onto the Pacific-Antarctic ridge to start the cycle again. It is not known how long spawning fish remain in the northern area. It is currently thought that toothfish remain in the Pacific-Antarctic ridge region for up to 2–3 years (although this pattern may be different for males versus females) and then theymove southwards back onto the shelf and slope where productivity is higher and food is more plentiful . A multidisciplinary approach incorporating otolith chemistry, age data and Lagrangian particle simulations reached similar conclusions (Ashford et al 2012).

3. STOCKS AND AREAS

The number of stocks or populations of *D. mawsoni* in the Southern Oceans is currently unknown. However, several recent studies looking at genetics, parasites and movements of fish from tag-recapture data have produced information leading to improved knowledge of stock structure.

A genetic analysis was carried out by Parker et al (2002) using random amplified polymorphic DNA (RAPD) markers. They concluded that samples taken from McMurdo Sound (Subarea 88.1) and the Bellingshausen Sea (Subarea 88.3) were from two different genetic groups. Smith & Gaffney (2000) detected little genetic diversity in mitochondrial DNA (mtDNA) samples between the Pacific (Subarea 88.1), Indian Ocean (Division 58.4.2), and Atlantic Ocean (Subarea 48.1) sectors. One mtDNA method showed no genetic variation, whilst two other mtDNA methods showed only weak genetic diversity between regions. Smith & Gaffney (2000) also found only weak genetic variation using nuclear DNA introns. They concluded that despite the weak genetic diversity in Antarctic toothfish there was evidence for differentiation between the ocean sectors. Kuhn & Gaffney (2008) expanded the work of Smith & Gaffney (2000) by examining nuclear and mitochondrial single nucleotide polymorphisms (SNPs) on tissue samples collected from Subareas 48.1, 88.1, and 88.2 and Division 58.4.1. They found broadly similar results to those of the earlier studies, with some evidence for significant genetic differentiation between the three ocean sectors but limited evidence for differentiation within ocean sectors. Suggestions of weak diversity were also reported by Mugue et al (2013).

The occurrence of separate stocks is supported by oceanic gyres, which may act as juvenile retention systems, and by the location of recaptures of adult tagged fish. Most adult tagged fish have been recaptured close to where they were originally tagged, often within 100 km (Parker et al 2013). However, increasing numbers of tagged fish have also been recaptured having moved longer distances within Subarea 88.1; i.e. 44 have been observed to have moved from the Shelf to the Slope, 31 from the Slope to the Shelf, 13 from the Slope to the North, and 5 from the North to the Slope. But despite almost 1500 recaptures, only three adult toothfish have been observed to have moved between Subareas; one fish moved from Subarea 88.1 (Shelf portion of SSRU 88.1K) to Subarea 88.2 (SSRU 88.2H), and two moved from Subarea 88.2 to Subarea 88.1 (one from SSRU 88.2H to 88.1H and one from SSRU 88.2F to 88.1H). Additionally, one fish tagged at McMurdo Sound in SSRU 88.1 M was recaptured after 18 years at liberty almost 2500 km to the northeast, in SSRU 88.2H.

For fisheries management purposes, Subareas 88.1 and 88.2 are split into two broad areas. For stock assessment purposes all of Subarea 88.1 and SSRUs 88.2A and 88.2B are treated as a single ‘Ross Sea’ stock (CCAMLR 2006). For the 2011 and 2013 assessments, the rest of Subarea 88.2 (SSRUs 88.2C–H) has been treated as a second stock. Both subareas include closed SSRUs from which fishing has been excluded for varying numbers of years. The stock affinity of the assessed stocks with toothfish in surrounding areas is not well understood, and assessments in the medium term will consider alternative stock structures including a combined Subarea 88.1 and 88.2 assessment.

4. STOCK ASSESSMENT

Updated estimates of biomass and long term yield (using the CCAMLR Decision Rules) were provided in 2013 for Antarctic toothfish for the Ross Sea and SSRUs 88.2C–H stocks based on analyses using catch-at-age from the commercial fishery, tag-recapture data, and estimates of biological parameters as reported below. This is the sixth stock assessment of the Ross Sea fishery, and the second for the Subarea 88.2 (SSRUs 88.2C–H) fishery.

4.1 Estimates of fishery parameters and abundance indices

CPUE indices

A standardised CPUE analysis of the Antarctic toothfish fishery in the Ross Sea fishery showed a gradually increasing trend over the course of the fishery for the shelf and north fisheries, and an increase followed by a decrease for the slope fishery (Hanchet et al 2013) (Figure 2). The pattern for the Ross Sea fishery overall was similar to the slope fishery.

The patterns of increase and declines in the CPUE indices are thought to reflect a combination of either good or poor ice conditions, vessel interactions, increasing fisher learning and experience, improved knowledge of optimum fishing practice, improvements in gear, and regulation changes (i.e., move-on rules and research set requirements) rather than toothfish abundance, and will also be affected by movement patterns of toothfish (Maunder et al 2006).

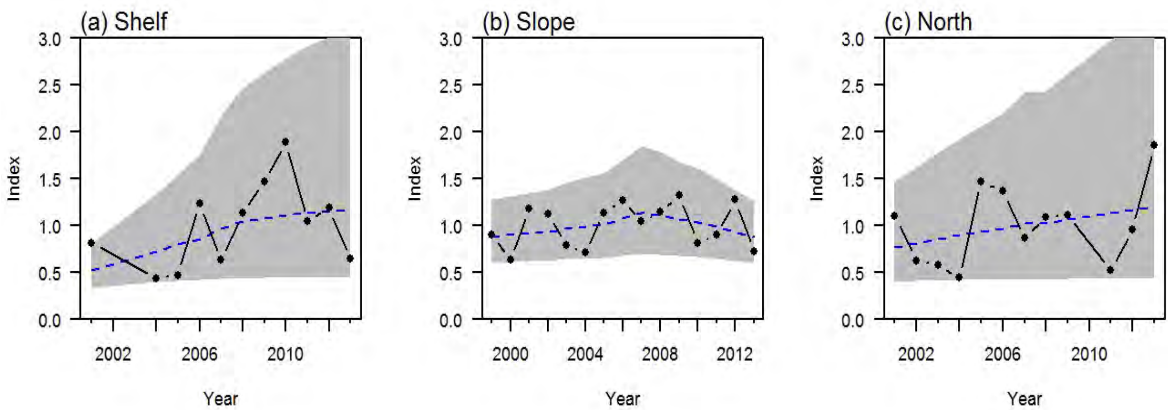


Figure 2: Relative CPUE (scaled to have mean of one) for the Ross Sea fishery showing CPUE indices for the Shelf, Slope, and North, 1999–2013. Blue dashed lines show smoothed fit with 95% confidence intervals (grey area).

A standardised CPUE analysis of the Antarctic toothfish fishery in SSRU 88.2H showed a steep decline at the beginning of the fishery when there had still been little fishing in the area followed by a more recent period of stability. Standardised CPUE in SSRUs 88.2C–G shows an increase over time. In both SSRU 88.2H and SSRUs 88.2C–G the confidence bounds were very wide for the first part and later part of the time series respectively (Hanchet et al 2013) (Figure 3). There has been little consistent fishing effort in Subarea 88.2 and the patterns of increase and declines in the CPUE indices are thought to reflect a combination of either good or poor ice conditions, vessel interactions, increasing fisher learning and experience, improved knowledge of optimum fishing practice, improvements in gear, and regulation changes (i.e., move-on rules and research set requirements) rather than toothfish abundance, and will also be affected by movement patterns of toothfish (Maunder et al 2006).

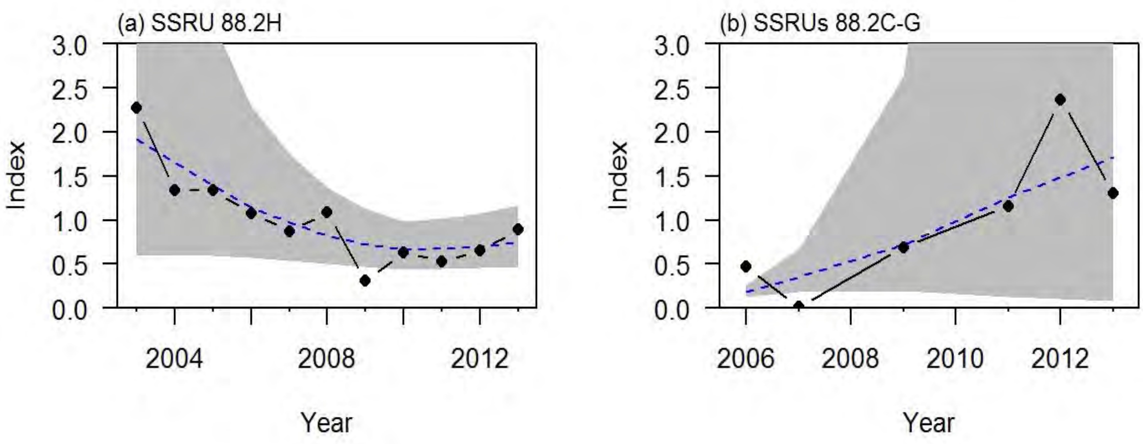


Figure 3: Relative CPUE indices (scaled to have mean of one) for (a) the SSRU 88.2H fishery, and (b) the SSRU 88.2C–G fishery. Blue dashed lines show smoothed fit with 95% confidence intervals (grey area).

Tag-recapture data

The tagging program for *Dissostichus* spp. in the Ross Sea was first initiated in the 2000–01 season in Subarea 88.1 by New Zealand vessels participating in the fishery (Parker al 2013). Since then, the toothfish tagging program has been extended to all vessels participating in the fishery and to Subarea 88.2. An index of vessel-specific tag detection performance for the Ross Sea fishery using a case-control methodology was developed by Mormede & Dunn (2013). The method controls for the inter-annual spatial and temporal variability of commercial fishing operations from which tags are released and recaptured. Selection criteria to determine a subset of vessels for which there was confidence in their tag-recapture data were developed and then applied, resulting in the tagging dataset used for the assessment models (Mormede 2013a).

Since 2001, more than 38 000 *Dissostichus* spp. have been tagged in Subareas 88.1 and 88.2, with almost 34 000 and 4 200 *D. mawsoni* in the Ross Sea and SSRUs 88.2C–H respectively. Table 4 shows the number of releases and recaptured Antarctic toothfish for the Ross Sea fishery from all trips and selected trips — note that recaptured fish at liberty for more than six years, and within-season recaptures, were not used in the assessment.

Although over 700 tags were released on the shelf and slope of Subarea 88.2 (SSRUs 88.2C-G), only two of these fish have been recaptured, likely reflecting the inconsistent pattern of fishing in these areas. The tag data set was therefore restricted to those tags released and recaptured from the seamounts in the north (SSRU 88.2H), hereafter referred to as the ‘north’ fishery (Table 5).

Table 4: Numbers of Ross Sea Antarctic toothfish with tags released for the years 2001–2013 by all and 'selected' trips, and the number recaptured in 2001–2013 by all and 'selected' trips. Note 2001 is the 2000–01 season. Numbers in italics correspond to fish which have been at liberty for over six years.

Data	Released fish														Recaptures
	Year	Number	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
Selected vessels	2001	259	1	1	0	0	0	1	*1*	*1*	*0*	*0*	*0*	*0*	5
	2002	684	2	9	3	9	8	13	6	*5*	*2*	*3*	*0*	*1*	61
	2003	834	–	6	9	9	2	8	2	2	*1*	*2*	*2*	*0*	43
	2004	1 221	–	–	4	19	17	26	22	5	10	*10*	*6*	*12*	131
	2005	2 691	–	–	–	6	21	27	27	7	34	10	*11*	*11*	154
	2006	2 257	–	–	–	–	11	87	67	13	20	13	0	*6*	217
	2007	2 921	–	–	–	–	–	18	58	21	46	20	10	19	192
	2008	2 151	–	–	–	–	–	–	13	16	20	17	5	20	91
	2009	1 825	–	–	–	–	–	–	–	5	27	28	7	14	81
	2010	2 170	–	–	–	–	–	–	–	–	21	49	16	27	113
	2011	2 213	–	–	–	–	–	–	–	–	–	7	25	31	63
	2012	2 115	–	–	–	–	–	–	–	–	–	–	7	8	15
	2013	2 285	–	–	–	–	–	–	–	–	–	–	–	9	9
	Total	23 626	3	16	17	44	60	180	197	75	181	162	91	161	1 187
All vessels	2001	259	1	1	0	0	0	1	*1*	*1*	*0*	*0*	*1*	*0*	6
	2002	684	2	9	4	9	8	13	6	*5*	*2*	*5*	*0*	*2*	65
	2003	862	–	6	13	9	2	9	2	2	*2*	*2*	*2*	*1*	50
	2004	2 031	–	–	9	22	19	32	26	12	13	*11*	*11*	*13*	168
	2005	3 276	–	–	–	8	26	29	30	11	47	15	*13*	*18*	197
	2006	3 035	–	–	–	–	11	89	68	15	28	20	4	*13*	248
	2007	3 545	–	–	–	–	–	18	62	22	50	24	13	21	210
	2008	2 514	–	–	–	–	–	–	14	19	36	18	9	22	118
	2009	2 829	–	–	–	–	–	–	–	9	41	37	10	24	121
	2010	3 064	–	–	–	–	–	–	–	–	27	58	21	32	138
	2011	3 081	–	–	–	–	–	–	–	–	–	12	36	43	91
	2012	3 827	–	–	–	–	–	–	–	–	–	–	9	17	26
	2013	3 748	–	–	–	–	–	–	–	–	–	–	–	12	12
	Total	32 755	3	16	28	53	68	191	210	96	247	206	131	222	1 471

Table 5: Numbers of SSRU 88.2H Antarctic toothfish with tags released in 2003–2013 and recaptured in 2003–2013 for selected vessels and all vessels. Numbers in italics correspond to fish which have been at liberty for over six years.

Area	Released fish													Recaptures
	Year	Number	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
Selected	2003	0	0	0	0	0	0	0	0	*0*	*0*	*0*	*0*	0
vessels	2004	159	–	7	4	3	2	1	0	0	*0*	*0*	*0*	17
	2005	269	–	–	5	3	1	1	1	1	0	*1*	*0*	13
	2006	260	–	–	–	12	20	3	2	0	1	1	*0*	39
	2007	210	–	–	–	–	4	6	4	3	0	0	0	17
	2008	387	–	–	–	–	–	22	15	5	0	0	1	43
	2009	303	–	–	–	–	–	–	28	15	9	5	0	57
	2010	259	–	–	–	–	–	–	–	15	30	14	3	62
	2011	360	–	–	–	–	–	–	–	–	14	33	2	49
	2012	384	–	–	–	–	–	–	–	–	–	27	34	61
	2013	294	–	–	–	–	–	–	–	–	–	–	8	8
	Total	2 885	0	7	9	18	27	33	50	39	54	82	49	368
All														
vessels	2003	94	0	1	1	2	0	0	0	*0*	*0*	*0*	*0*	4
	2004	397	–	15	10	9	5	1	0	0	*0*	*0*	*0*	40
	2005	269	–	–	5	4	1	1	1	1	0	*1*	*0*	14
	2006	271	–	–	–	12	21	3	2	0	2	1	*0*	41
	2007	277	–	–	–	–	6	6	4	3	0	0	1	20
	2008	389	–	–	–	–	–	25	16	6	0	0	1	48
	2009	340	–	–	–	–	–	–	32	16	10	5	1	64
	2010	315	–	–	–	–	–	–	–	17	32	15	3	67
	2011	427	–	–	–	–	–	–	–	–	14	36	4	54
	2012	422	–	–	–	–	–	–	–	–	–	27	35	62
	2013	381	–	–	–	–	–	–	–	–	–	–	8	8
	Total	3 582	0	16	16	27	33	36	55	43	58	86	54	424

Catch-at-age data

Strata for the Antarctic toothfish length and age frequency data were determined using tree-based regression (a post-stratification method) (Hanchet et al 2013). The analysis used the median length of fish in each longline set, and the explanatory variables SSRU and depth. On average, about 800 Antarctic toothfish otoliths collected by observers were selected for ageing each year, and used to construct annual area-specific age-length keys for the Ross Sea region (ALKs). Age data were available for the 1998–99 to 2011–12 seasons, but were not available for the 2012–13 season. In the Ross Sea, ALKs for each sex were applied to the shelf/slope fisheries and the north fishery separately. The ALKs were applied to the scaled length-frequency distributions for each year to produce annual catch-at-age distributions (Hanchet et al 2013).

In the Subarea 88.2 (SSRU 88.2C–H) fishery, otoliths were only available from the New Zealand fleet, which did not fish there every year. Therefore, for this fishery a single ALK for each sex using otolith ages from all available years was used to construct annual age frequencies for the ‘north’, SSRU 88.2G, and ‘south’ fisheries separately. As a sensitivity, annual age-length keys for the ‘north’ fishery were calculated in the years when sufficient information was available, and applied to the length frequencies in these years.

Recruitment surveys

Two years of an intended annual research longline survey of sub-adult (70–110 cm long) toothfish have now been carried out in the southern Ross Sea (Hanchet et al 2012, Parker et al 2013). Catches and size structure were very similar between the two surveys and some indication of year class progression was apparent in the age distributions. Incorporating the survey age structure into the assessment as a sensitivity analysis had the effect of stabilizing the index of year class strength; on this basis continuation of the survey has been recommended.

Parameter estimates
A list of parameter values used for the assessments is given in Table 6.

4.2 Biomass estimates

(i) The Ross Sea fishery (Subarea 88.1 and SSRUs 88.2A and 88.2B)

The stock assessment model
The model was sex- and age-structured, with ages from 1–50, where the last age group was a plus group (Mormede et al 2013a). The annual cycle was broken into three discrete time steps, nominally summer (November–April), winter (May–October), and end-winter (age-incrementation) (Table 7).

Table 6: Parameter values for *D. mawsoni* in Subarea 88.1 and 88.2.

Component	Parameter	Value			Units
		Male	Female	All	
Natural mortality	M	0.13	0.13		y^{-1}
VBGF	K	0.093	0.090		y^{-1}
VBGF	t_0	-0.256	0.021		y
VBGF	L_∞	169.07	180.20		cm
Length to mass	'*a*'	0.00001387	0.00000715		cm, kg
Length to mass	'*b*'	2.965	3.108		
Length to mass variability (CV)				0.1	
Maturity	A_{m50}	12.8	16.6		y
Range: 5% to 95% maturity		9.3–16.3	9.3–23.9		y
Recruitment variability	σ_R			0.6	
Stock recruit steepness (Beverton-Holt)	h			0.75	
Ageing error (CV)				0.1	
Initial tagging mortality				10%	
Instantaneous tag loss rate (single tagged)				0.062	y^{-1}
Instantaneous tag loss rate (double tagged)				0.0084	y^{-1}
Tag detection rate				98.7%	
Tagging related growth retardation (TRGR)				0.5	y

Table 7: Annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

Step	Period	Processes	M^1	Age[2]	Observations	
					Description	M^3
1	Nov–April	Recruitment and fishing mortality	0.5	0.0	Tag-recapture	0.5
					Catch-at-age proportions	0.5
2	May–November	Spawning	0.5	0.0		
3	-	Increment age	0.0	1.0		

1. M is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length at age, which was assumed to occur in that time step.
3. M is the proportion of the natural mortality in each time step that was assumed to have taken place at the time each observation was made.

The model was run from 1995 to 2013, and was initialised assuming an equilibrium age structure at an unfished equilibrium biomass, i.e., a constant recruitment assumption. Recruitment was assumed to occur at the beginning of the first (summer) time step. Recruitment was assumed to be 50:50 male to female, and was parameterised as a year class strength multiplier (assumed to have mean equal to one over a defined range of years), multiplied by an average (unfished) recruitment (R_0) and a spawning stock-recruitment relationship. In this model, the year class strength multipliers were assumed fixed, and set equal to 1.

The base-case model was implemented as a single-area, three-fishery model. A single area was defined with the catch removed using three concurrent fisheries (slope, shelf and north). Each fishery was parameterised by a sex-based double-normal selectivity ogive (i.e. domed selectivity) and allowed for annual selectivity shifts that shifted left or right (shelf fishery) with changes in the mean depth of the fishery (slope and north fisheries in the Ross Sea). The double-normal selectivity was parameterised using four estimable parameters and allowed for differences in maximum selectivity by sex – the maximum selectivity was fixed at one for males, but estimated for females. The double-normal selectivity ogive was employed as it allowed the estimation of a declining right-hand limb in the selectivity curve.

Fishing mortality was applied only in the first (summer) time step. The process was to remove half of the natural mortality occurring in that time step, then apply the mortality from the fisheries instantaneously, then to remove the remaining half of the natural mortality.

The population model structure includes tag–release and tag–recapture events. Each tagged fish was assigned an age-sex based on its length and the modelled population structure of fish at that age and sex. Tagging from each year was applied as a single tagging event. The usual population processes (natural mortality, fishing mortality etc.) were then applied over the tagged and untagged components of the model simultaneously. Tagged fish were assumed to suffer a retardation of growth from the effect of tagging (TRGR), equal to 0.5 of a year for the year immediately following release.

Model estimation

The model parameters were estimated using Bayesian analysis, first by maximising an objective function (MPD), which is the combination of the likelihoods from the data, prior expectations of the values of the those parameters, and penalties that constrain the parameterisations; and second, by estimating the Bayesian posterior distributions using Monte Carlo Markov Chains (MCMCs). Initial model fits were evaluated at the MPD, by investigating model fits and residuals. Parameter uncertainty was estimated using MCMCs. These were estimated using a burn-in length of 5×10^5 iterations; with every 1000^{th} sample taken from the next 1×10^6 iterations (i.e. a final sample of length 1000 was taken).

Observation assumptions

The catch proportions-at-age data for 1998–2012 were fitted to the modelled proportions-at-age composition using a multinomial likelihood. Following previous recommendations of WG-SAM that CPUE indices were not indexing changes in abundance, the CPUE indices were not used. Tag–release events were defined for the 2001–2012 years. Within-season recaptures were ignored. Tag–release events were assumed to have occurred at the end of the first (summer) time step, following all (summer) natural and fishing mortality.

The estimated number of scanned fish (i.e. those fish that were caught and inspected for a possible tag) was derived from the sum of the scaled length frequencies from the vessel observer records, plus the numbers of fish tagged and released. Tag recapture events were assumed to occur at the end of the first (summer) time step, and were assumed to have a detection probability of 98.7% to account for unlinked tags.

For each year, the recovered tags at length for each release event were fitted, in 10 cm length classes (range 40–230 cm), using a binomial likelihood.

Process error and data weighting

Additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance for all observations, following the methods of Francis (2011). Adding such additional errors to each observation type has two main effects, (i) it alters the relative weighting of each of the data sets (observations) used in the model, and (ii) it typically increases the overall uncertainty of the model, leading to wider credible bounds on the estimated and derived parameters. The additional variance, termed process error, was estimated for each MPD run, and the total error assumed for each observation was calculated by adding process error and observation error. A single process error was estimated for each of the observation types (i.e. one for the catch-at-age data and one for the tag-recapture data).

Penalties

Two types of penalties were included within the model. First, the penalty on the catch constrained the model from returning parameter estimates where the population biomass was such that the catch from an individual year would exceed the maximum exploitation rate (see earlier). Second, a tagging penalty discouraged population estimates that were too low to allow the correct number of fish to be tagged.

Priors

The parameters estimated by the models, their priors, the starting values for the minimisation, and their bounds are given in Table 8. In models presented here, priors were chosen that were relatively non-informative and that also encouraged conservative estimates of B_0.

Table 8: Number (N), start values, priors, and bounds for the free parameters (when estimated) for the Ross Sea base case.

Parameter		*N*	Start value	Prior	Bounds	
					Lower	Upper
B_0		1	80 000	Uniform-log	$1x10^4$	$1x10^6$
Male fishing selectivities	a_1		8.0	Uniform	1.0	50.0
	s_L		4.0	Uniform	1.0	50.0
	s_R	9	10.0	Uniform	1.0	500.0
Female fishing selectivities	a_{max}		1.0	Uniform	0.01	10.0
	a_1		8.0	Uniform	1.0	50.0
	s_L		4.0	Uniform	1.0	50.0
	s_R	12	10.0	Uniform	1.0	500.0
Selectivity shift (ykm^{-1})	E	2	1.0	Uniform	0.0	20.0
Annual selectivity shift[1]	E_f	14	Mean depth	Uniform	-10.0	10.0

Base case and sensitivity models

The model runs conducted for the base case (R2) and sensitivity tests (R1 and R3) are described in Table 9. The base-case model included tag–release and tag–recapture data from only the 'selected' trips. Sensitivity models were determined as modifications to the base-case, and were chosen to investigate the effect of alternative data and selectivity assumptions in the assessment.

Model estimates

MCMC samples from the posterior were estimated. MCMC diagnostics suggested no evidence of poor convergence in the key biomass parameters and between-sample autocorrelations were low.

Table 9: Labels and description of the Ross Sea base case and sensitivity models.

Model	Description
R1	2013 implementation of the 2011 base case
R2	Base case: Model R1, with updated data selection method, maturity curve, and data weighting
R3	Model R2, with logistic selectivity in the north

Key output parameters for the base case (R2) are summarised in Table 10 and the posterior distributions are shown in Figure 4. MCMC estimates of initial (equilibrium) spawning stock biomass (B_0) were 68 790 tonnes (95% credible intervals 59 540 – 78 470 tonnes), and current (B_{2013}) biomass was estimated as 75% B_0 (95% CIs 71–78%). Results of sensitivity models are shown in Table 10. The increase in uncertainty in the parameter estimates (wider CIs) in models R2 and R3 compared to model R1 can be attributed to the use of the Francis (2011) data weighting method in those two models.

Diagnostic plots of the observed proportions-at-age of the catch versus expected values show little evidence of inadequate model fit. Estimated selectivity curves appeared reasonable, with strong evidence of domed shaped selectivity, although the sensitivity run with logistic selectivity (R3) showed little difference with the base-case model (R2). The tag-recapture data are reasonably well fitted, and provide most of the information on abundance in the model.

Table 10: Median MCMC estimates (and 95% credible intervals) of B_0, B_{2013}, and B_{2013} as $\%B_0$ for the Ross Sea base case (R2) and sensitivity models. The 2011 base case model is also reported (model 2011).

Model	B_0	B_{2013}	B_{2013} ($\%B_0$)
2011	73 870 (69 070 – 78 880)	–	–
R1	83 880 (78 650 – 90 270)	66 400 (61 170 – 72 670)	79.1 (78 – 81)
R2	68 790 (59 540 – 78 470)	51 530 (42 330 – 61 120)	74.8 (71 – 78)
R3	69 410 (60 650 – 79 920)	52 150 (43 420 – 62 670)	75.2 (72 – 78)

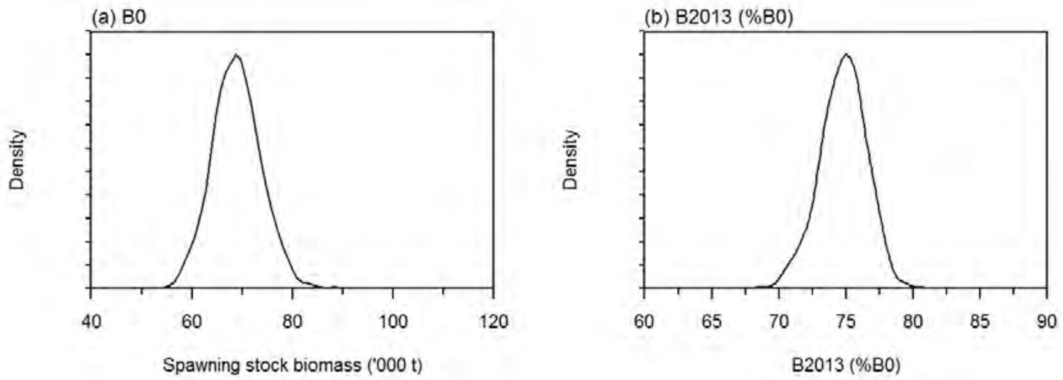


Figure 4: MCMC posterior distributions of (a) B_0 and (b) current biomass ($\%B_{2013}/B_0$) for the Ross Sea base case model.

(ii) Subarea 88.2 (SSRUs 88.2C–H)

The stock assessment model

The stock assessment model for the Subarea 88.2 (SSRUs 88.2C–H) fishery had a similar structure to that used for the Ross Sea fishery and is described in detail by Mormede et al (2013b). The models were run from 2002–2013, using a single-area, three-fishery model with selectivity assumed to be double-normal. The base case model used tag data from the 'selected' trip data set for the north fishery only together with catch and age frequency data from both fisheries. Sensitivity models were determined as modifications to the base-case, and were chosen to investigate the effect of alternative catch-at-age data and selectivity assumptions in the assessment (Table 11).

Table 11: Labels and description of the Subarea 88.2 base case and sensitivity models.

Model	Description
R1	The 2013 implementation of the 2011 base case: using selected vessel tag data in the north only, and age data from all fisheries
R2	Updated selection method, maturity curve, and data weighting
R3	Model R2, with logistic selectivity in the north
R4	Base case: model R2 with age frequencies down-weighted
R5	Model R2 with annual north age length keys

Model estimates

Key output parameters for the base case (R4) are summarised in Table 12 and the posterior distributions are shown in Figure 5. Estimated initial (equilibrium) spawning stock biomass (B_0) was estimated to be 6 590 t (95% credible intervals 4 800 – 9 190 t), and current (B_{2013}) biomass was estimated as 65% B_0 (95% CIs 52–75%).

In all models, the age frequency data indicated higher biomass, the tag data from releases between 2010 and 2012 indicated lower biomass, and the other tag data release years indicated an intermediate biomass. Models R3, R4, and R5 all indicated a lower biomass than the other two models because the influence of the catch-at-age data, particularly in the north fishery, was reduced so that the tag data had more weight.

In all models, there was some evidence of non-convergence in the right-hand declining limb of the slope selectivity curves. This is unsurprising as the age frequency on the slope is double-moded and is variable between years. Analysis of the age data showed there was no satisfactory spatial separation for those two modes, which were both present on most individual sets, therefore it would be difficult to improve the fit to those data.

Model R4 showed poor fitting to all the age frequencies, because those data were strongly down-weighted. As a result, the selectivity parameters were poorly estimated, and the estimates of biomass presented higher uncertainty. Model R5 showed initial poor fitting to the north age frequencies, with an improvement through the time series. This model was not able to completely fit the change in age frequencies through the series, as shown in the data. As a consequence all parameters were also estimated with high uncertainty.

Table 12: Median MCMC estimates (and 95% credible intervals) of B_0, B_{2013}, and B_{2013} as %B_0 for the Subarea 88.2 (SSRUs 88.2C-H) fishery base case (R4) and sensitivity models.

Model		B_0	B_{2013}	B_{2013} (%B_0)
R1	The 2013 implementation of the 2011 base case	10 620 (9 510 – 12 000)	8 080 (6 970 – 9470)	76.1 (73 – 79)
R2	Updated maturity, tag data selection, and weighting	13 190 (10 390 – 18 680)	10 660 (7 870 – 16 140)	80.8 (76 – 86)
R3	Logistic selectivity in the north	7 840 (6 510 – 9 850)	5 340 (4 020 – 7 340)	68.1 (62 – 75)
R4	Base case: down-weighted age frequencies	6 590 (4 800 – 9 190)	4 280 (2 510 – 6 900)	65.1 (52 – 75)
R5	Annual north ALK	7 330 (5 250 – 10 770)	4 840 (2 830 – 8 280)	66.0 (53 – 77)

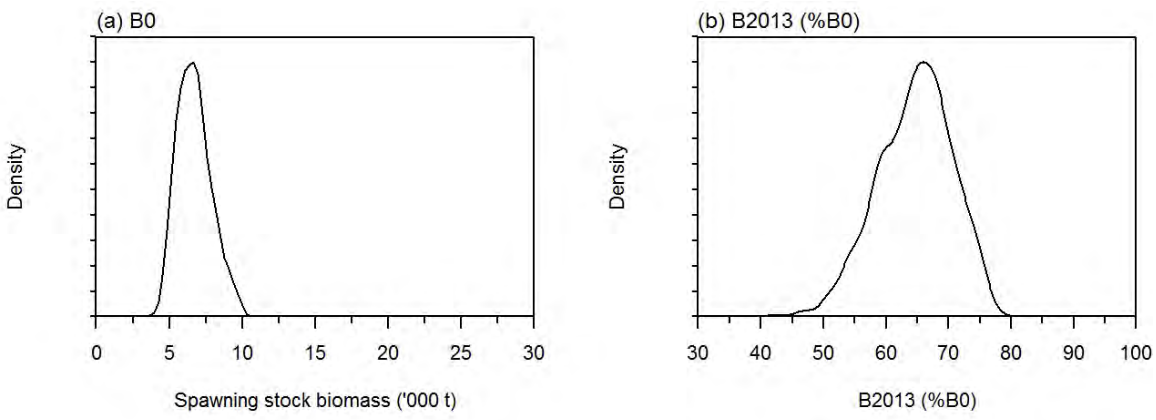


Figure 5: MCMC posterior distributions for (a) B_0 and (b) B_{2013} for the Subarea 88.2 (SSRUs 88.2C-H) fishery base case model.

4.3 Yield estimates and projections

Yields were estimated for the Ross Sea fishery using the methods described in Mormede et al (2013a). For each sample from the posterior distribution estimated for each model, the stock status was projected forward 35 years under a scenario of a constant annual catch (i.e., for the period 2014–2049). Recruitment from 2005–2048 was assumed to be lognormally distributed with a standard deviation of 0.6 with a Beverton-Holt stock-recruitment steepness $h = 0.75$. Future catch was assumed to follow the same split between fisheries as that in the years 2011–2013 (i.e. 11%, 75% and 14% of the total future catch was allocated to the shelf, slope and north fisheries respectively). The selectivity shift was assumed to be the average of shifts estimated for previous years. The same method was used for Subarea 88.2 (SSRUs 88.2C-H) with a catch split assumption of 12.4%, 8.1 and 79.5% allocated to the shelf, 88.2G and north fisheries respectively.

The decision rules are $rule_1 = \max(Pr[\mathrm{SSB}_i < 0.2 \times B_0]) \leq 0.10$, where i is any year in the projection period, and $rule_2 = Pr[SSB_{+35} < 0.5 \times B_0] \leq 0.50$. They were evaluated by calculating the maximum future catch that meets both decision rule criteria.

(i) Ross Sea (Subareas 88.1 and SSRUs 88.2A and 88.2B)
The constant catch for which there was median escapement of 50% of the median pre-exploitation spawning biomass level at the end of the 35-year projection period was 3044 tonnes. At this yield there is a less than 10% chance of spawning biomass dropping to less than 20% of the initial biomass. The allocation method used to set the 2009–10 catch limits for SSRUs in Subarea 88.1 was continued for 2013–14 and 2014–15 resulting in 397 tonnes in the north (SSRUs 88.1B, C, G), 2 247 tonnes on the slope (SSRUs 88.1H, I, K) and 357 tonnes on the shelf (SSRUs 88.1J, L). A total of 43 t was set aside from the shelf catch limit for a directed research survey for sub-adult toothfish on the shelf in 2013–14.

(ii) Subarea 88.2 (SSRUs 88.2C-H)
The constant catch for which there was median escapement of 50% of the median pre-exploitation spawning biomass level at the end of the 35-year projection period was 266 tonnes. At this yield there is a less than 10% chance of spawning biomass dropping to less than 20% of the initial biomass. However, all of the tag-recapture data, and most of the catch-at-age data, used in the assessment has come from SSRU 88.2H, and therefore the estimate of biomass and yield from the assessment apply mainly to this SSRU rather than to the Subarea as a whole. As a consequence, CCAMLR agreed to apply the catch limit of 266 tonnes to SSRU 88.2H and to retain the previous catch limit of 124 tonnes for SSRUs 88.2C–G for the 2013–14 season only.

5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

5.1 Incidental catch (fish and invertebrates)
The bycatch of fish species in the Subarea 88.1 and 88.2 fisheries was last characterised by Stevenson et al (2012). The main bycatch species in this fishery are grenadiers, which contributed about 4–16% of the total annual toothfish catch by weight from 1997–98 to 2012–13 (Hanchet et al 2013). Recent taxonomic studies have shown that specimens originally identified in the Ross Sea region as *Macrourus whitsoni* do in fact comprise two sympatric species: *Macrourus whitsoni* and *Macrourus caml* (McMillan et al 2011) with different biology and ecology (Pinkerton et al 2013). Work is underway to determine the degree of overlap of these two species both within the Ross Sea region and circum-Antarctic. The other major bycatch group is skates (mainly *Amblyraja georgiana* and *Bathyraja* cf. *eatonii*). Skates (rajids) made up 9–10% of the total toothfish landings in 1997–98 and 1998–99, but the reported landings of skates has decreased in more recent years due to a tag release programme and the live release of untagged skates. In both programmes, all live skates are returned to the water and as a result are not included in landing data. Other fish bycatch species, including moray cods (*Muraenolepis* spp.), morid cods (mainly *Antimora rostrata*), icefish (mainly *Chionobathyscus dewitti*), and rock cods (*Trematomus* spp.) each contributed 1% or less of the overall catch (Stevenson et al 2012).

Table 13: Landings of managed by-catch species (macrourids, rajids and other species) in Subarea 88.1. Rajids cut from the longlines and released are not included in these estimates. Source: fine-scale data.

Season	Macrourids		Rajids			Other species	
	Catch limit (t)	Reported landings (t)	Catch limit (t)	Reported landings (t)	Number released	Catch limit (t)	Reported landings (t)
1996–97	-	0	-	0	-	-	0
1997–98	-	9	-	5	-	50	1
1998–99	-	22	-	39	-	50	5
1999–00	-	74	-	41	-	50	7
2000–01	-	61	-	9	-	50	14
2001–02	100	154	-	25	-	50	10
2002–03	610	66	250	11	966	100	12
2003–04	520	319	163	23	1 745	180	23
2004–05	520	462	163	69	5 057	180	24
2005–06	474	258	148	5	14 640	160	18
2006–07	485	153	152	38	7 336	160	43
2007–08	426	112	133	4	7 190	160	20
2008–09	430	183	135	7	7 088	160	16
2009–10	430	119	142	8	6 796	160	15
2010–11	430	118	142	4	5 409	160	8
2011–12	430	143	164	1	2238	160	4
2012–13	430	127	164	4	5675	160	10

Current catch limits for macrourids were derived from biomass estimates of the IPY-2008 trawl survey for the slope of the Ross Sea (see below). In each of the 2003–04, 2004–05, and 2005–06 seasons, the bycatch limit for *Macrourus* spp. was exceeded in at least one of the SSRUs leading to the closure of the fishery in those areas. No bycatch limit has been exceeded since then.

Current catch limits for Rajids and other species in Subarea 88.1 and Subarea 88.2 are proportional to the catch limit of *Dissostichus* species in each small-scale research unit (SSRU) based on the following rules:

- Rajids: 5% of the catch limit of *Dissostichus* spp. or 50 tonnes per SSRU whichever is greater;
- Other species combined: 20 tonnes per SSRU.

Catch limits for Rajids or for other species have never been exceeded.

Table 14: Landings of managed by-catch species (macrourids, rajids and other species) in Subarea 88.2. Rajids cut from the longlines and released are not included in these estimates. Source: fine-scale data.

Season	Macrourids		Rajids			Other species	
	Catch limit (t)	Reported landings (t)	Catch limit (t)	Reported landings (t)	Number released	Catch limit (t)	Reported landings (t)
1996–97	-	0	-	0	-	-	0
1997–98	-	0	-	0	-	-	0
1998–99	-	0	-	0	-	-	0
1999–00	-	0	-	0	-	-	0
2000–01	-	0	-	0	-	-	0
2001–02	40	4	-	0	-	20	0
2002–03	60	18	-	0	-	140	8
2003–04	60	37	50	0	107	140	8
2004–05	60	21	50	0	-	140	3
2005–06	78	92	50	0	923	100	12
2006–07	88	54	50	0	-	100	13
2007–08	88	17	50	0	–	100	4
2008–09	90	58	50	0	265	100	14
2009–10	92	49	50	0	-	100	15
2010–11	92	52	50	0	171	100	13
2011–12	84	29	50	0	-	120	11
2012–13	84	25	50	0	-	120	8

5.2 Population assessments for rajids and macrourids

O'Driscoll et al (2005) considered approaches to monitoring and assessing macrourids and rajids in Subarea 88.1 and recommended that a random bottom trawl survey would be the best approach to obtaining estimates of standing stock. Tag-recapture experiments for rajids, catch-curve analysis for macrourids and experimental manipulation of fishing effort are alternative methods that could be used to monitor abundance. An experimental skate tagging programme in the Ross Sea fishery was started in 2000, and a preliminary assessment of skates completed by Dunn et al (2007). The IPY trawl survey of the Ross Sea slope was carried out in 2008 leading to an assessment of macrourids for the first time.

Rajids

Preliminary estimates of the age and growth of *Amblyraja georgiana* in the Ross Sea suggested that these skates initially grow very rapidly for about five years, after which growth almost ceases (Francis & Ó Maolagáin, 2005). However, Francis & Gallagher (2008) presented an alternative interpretation of age and growth in *A. georgiana* that is radically different from the published interpretation. By counting fine growth bands in the caudal thorns instead of broad diffuse bands, they generated growth curves that suggest much slower growth, greater ages at maturity (about 20 years compared with 6–11 years) and greater maximum ages (28–37 years compared with 14 years). Several pieces of circumstantial evidence support the new interpretation, but a validation study is required to determine which growth scenario is correct. Updated length-weight relationships for skates were provided by Francis (2010).

A fishery-wide tagging programme and sampling programme for skates was instituted by CCAMLR in 2008–09. It was anticipated that this initiative would lead to more Antarctic skates being tagged in Subareas 88.1 and 88.2. However, only 1907 and 99 skates were tagged in Subareas 88.1 and 88.2 respectively in 2008–09. This programme was extended for the 2009–10 season but discontinued in 2010–11.

Mormede & Dunn (2010) provided a characterisation of skate catches in the Ross Sea region. The paper concluded that aspects of the catch history were very uncertain, including the species composition, the weight and number of skates caught, the proportion discarded, and the survival of those fish that were tagged. While the size composition of the commercial catch was uncertain before 2009 because of the low numbers sampled each year, data collected in the Year-of-the-Skate resulted in improved estimates of the length frequency of the catch. Tag data from the Year-of-the-Skate were also improved, with a total of about 3 300 *Amblyraja georgiana* and 700 *Bathyraja* cf. *eatoni* tagged and a total of 179 skates recaptured.

Macrourids

In 2011, it was recognised that specimens originally identified in the Ross Sea region as *M. whitsoni* did in fact comprise two sympatric species: *M. whitsoni* and *M. caml* (McMillan et al 2012). *M. caml* grows larger than *M. whitsoni* and is about 20% heavier for a given length (Pinkerton et al 2013). The two species can be distinguished morphologically through two main characters (number of rays in the left pelvic fin; number of rows of teeth in the lower jaw). The distribution of *M. whitsoni* and *M. caml* seems to almost completely overlap by depth and area, with both appearing to be abundant between depths of 900 and 1900 m. Catches of females of both species exceed that of males (especially for *M. caml*) and this sex-selectivity cannot be explained by size or age of fish (Pinkerton et al 2013). It is almost certain that previous work which was presumed to have been carried out on *M. whitsoni* would actually have been carried out on a mix of the two species.

Otolith aging data show that the two species have very different growth rates (Pinkerton et al 2013). *M. whitsoni* approaches full size at about 10–15 years of age and can live to at least 27 years, whereas *M. caml* reaches full size at about 15–20 years and can live in excess of 60 years. However, sexual maturity in female *M. whitsoni* is reached at 52 cm and 16 years, but in female *M. caml* at 46 cm and 13 years. Gonad staging data imply that the spawning period of both species is protracted extending from before December to after February. Work describing the distribution and ecology of each species is ongoing.

Biomass and yield estimates of *Macrourus* spp. for the Ross Sea fishery (Subareas 88.1 and SSRUs 88.2A and 88.2B) based on extrapolations under three different density assumptions from a trawl survey were given by Hanchet et al (2008) (Table 15). The resulting biomass estimates had a CV of about 0.3.

Yield estimates were calculated using the constant density assumption when extrapolating the biomass estimate across the slope region, noting that this would provide a more precautionary estimate of yield than one based on extrapolations using longline CPUE data. The resulting biomass estimate for SSRUs 88.1HIK was 21 410 t which gave a yield estimate of 388 t. This yield estimate was then apportioned across the 5 SSRUs taking into account maximum historical catches (Table 16). The catch limits per SSRU detailed in Table 16 have been used by CCAMLR since the 2009–10 season.

Table 15: Biomass estimates of *Macrourus* spp. from the trawl surveys for the BioRoss 400–600 and 600–800 m and IPY-CAML 600–1200 and 1200–2000 m strata and extrapolated biomass estimates (with CVs) for the remaining strata based on three methods of extrapolation.

Survey	Depth range (m)	Biomass (t)	Extrapolated biomass (t) constant density	CPUE (all vessels)	CPUE (NZ vessels)
BioRoss – 88.1H	400–600	230	230 (49)	230 (49)	230 (49)
BioRoss – 88.1H	600–800	3 531	3 531 (38)	3 531 (38)	3 531 (49)
SSRU 88.1H west	800–1200		92 (50)	83 (54)	103 (55)
SSRU 88.1H west	1200–2000		713 (40)	1 114 (49)	1 038 (47)
IPY - 88.1H	600–1200	975	975 (50)	975 (50)	975 (50)
IPY - 88.1H	1200–2000	3 356	3 356 (40)	3 356 (40)	3 356 (40)
SSRU 88.1 I	600–1200		3 297 (50)	7 883 (51)	5 992 (50)
SSRU 88.1 I	1200–2000		4 670 (40)	11 168 (42)	8 576 (41)
SSRU 88.1 K	600–1200		1 539 (50)	5 027 (51)	2 774 (51)
SSRU 88.1 K	1200–2000		2 998 (40)	5 995 (45)	9 111 (43)
HIK Sub-total			21 410		
SSRU 88.2 A+B	600–1200		1 404 (50)	1 396 (58)	857 (60)
SSRU 88.2 A+B	1200–2000		4 087 (40)	525 (70)	—
88.2 A, B Sub-total			5 491		
Total			26 892 (29)	41 823(28)	36 542(30)

Table 16: Estimate yield, maximum historic catch, and revised catch limit of *Macrourus* spp. for the Ross Sea fishery.

Region	Estimated yield	Maximum historic catch	Revised catch limit
88.1BCG	-	34	40
88.1HIK	}388	390	320
88.1JL		52	70
88.1M	0	0	0
88.2AB	100	8	0
Total	488		430

Identification of levels of risk

Risk categorisation tables were prepared for rajids and macrourids by O'Driscoll (2005). *Amblyraja georgiana* were categorised as risk category 3. The risk to *A. georgiana* is potentially mitigated due to the requirement to cut rajids from longlines whilst still in the water and release them. *Macrourus whitsoni* were categorised as between risk category 2 and 3 but this analysis predates the realisation of two species of *Macrourus* in the Ross Sea.

Mitigation measures

Since the start of the 2000–01 season, rajids likely to survive have been cut free and released at the surface as a measure to reduce rajid mortality. The survival of at least some of these skates has been demonstrated by the recapture of over 130 tagged skates (Mormede & Dunn 2010), and by the results of survivorship experiment in tanks carried out by the UK.

There is a 'move-on' rule in place to help prevent excessive fishing in localised areas of high abundance of bycatch species. This rule requires a vessel to move to another location at least 5 n. miles distant if the bycatch of any one species is equal to or greater than 1 tonne in any one set. The vessel is not allowed to return to within 5 n. miles of the location where the bycatch exceeded 1 tonne for a period of at least five days (Conservation Measure 33-03 (2010)).

5.3 Incidental catch (seabirds and marine mammals)

Only one seabird has ever been caught in this toothfish fishery: a Southern giant petrel (*Macronectes* *giganteus*) caught in 2003–04 (Table 17). Considerable effort has been put into mitigation of seabird captures in the fishery, through implementation of CCAMLR Conservation Measures regarding line sink rate, use of streamer lines, seasonal restrictions on fishing, prohibition of offal dumping, line weighting and only allowing daytime setting under strict conditions.

Table 17: Seabird incidental mortality limit, reported seabird incidental mortality, incidental mortality rate, and estimated incidental mortality in Subareas 88.1 and 88.2.

Season	Incidental mortality limit	Incidental mortality rate (seabirds/thousand hooks)	Estimated incidental mortality
1997–98		0	0
1998–99		0	0
1999–00		0	0
2000–01		0	0
2001–02	3*	0	0
2002–03	3*	0	0
2003–04	3*	0.0001	1
2004–05	3*	0	0
2005–06	3*	0	0
2006–07	3*	0	0
2007–08	3*	0	0
2008–09	3*	0	0
2009–10	3*	0	0
2010–11	3*	0	0
2011–12	3*	0	0
2012–13	3*	0	0

* Per vessel during daytime setting.

Assessment of risk

The risk levels of seabirds in the fishery in Subarea 88.1 is category 1 (low) south of 65°S, category 3 (average) north of 65°S and overall is category 3 (SC-CAMLR-XXX, Annex 8, paragraph 8.1).

Mitigation measures

Mitigation measures have been implemented in line with recommendations from the CCAMLR *ad hoc* Working Group on Incidental Mortality Associated with Fishing (WG-IMAF). This group again in 2011 assessed the risk level of seabirds in the fishery in Subarea 88.1 as low (category 1, lowest risk, with highest risk being category 5) south of 65°S, medium (category 3) north of 65°S and overall as medium (category 3) and CCAMLR applied:

- Conservation Measure 25-02 (2011). This Conservation Measure concerns line-weighting, night setting, use of streamer lines and prohibition of offal dumping. Under the risk category for these Subareas, there is an exemption to paragraph 4 to allow for daytime setting subject to line sink rate requirements and seabird incidental mortality limits.

- No restriction to the longline fishing season south of 65°S, but longline fishing north of 65°S is restricted to the period outside the breeding season of at risk species (where known or relevant).

WG-IMAF assessed the risk level of seabirds in the longline toothfish fishery in Subarea 88.2 as low (category 1) and CCAMLR applied:

- Conservation Measure 25-02 (2011) (with exemption to paragraph 4 to allow for daytime setting) and no need to restrict the longline fishing season.

Conservation Measure 25-02 applies and in recent years has been linked to an exemption for night setting in Conservation Measure 24-02 subject to a seabird incidental mortality limit. Vessels catching three birds are required to stop fishing in the sub-area concerned. Offal and other discharges are regulated under annual CCAMLR conservation measures (Conservation Measures 41-09 and 41-10).

Near full implementation of the required CCAMLR Conservation Measures has meant that seabird captures have been successfully avoided during this toothfish longline fishery. There is a high degree of certainty in the estimates provided of seabird captures, given the high level of observer coverage (100% of vessels covered by two observers, greater than 40% of all hooks hauled directly observed).

5.4 Maintenance of ecological relationships

Developments in evaluating ecosystem effects of the Antarctic toothfish fishery were discussed at the FEMA and FEMA II workshops (SC-CAMLR-XXVI/BG/6, paragraphs 45 to 48 and SC-CAMLR-XXVIII/3). The FEMA and FEMA II workshops noted that the fishery for Antarctic toothfish may affect ecological relationships in the Ross Sea region by interaction between toothfish and its predators and interactions between toothfish and its prey. Effects of fishing may also "cascade" through marine food-webs.

The predators of toothfish include Type C killer whales, sperm whales and Weddell seals (Eisert et al 2013; Torres et al 2013; Pinkerton et al 2010a). A mass-balance food-web model suggested that toothfish formed about 6–7% of the diet of its predators at the scale of the Ross Sea averaged over a year (Pinkerton et al 2010a), but provided no support for the hypothesis that depletion of toothfish stocks would greatly change the diet of toothfish predators at the population scale (Pinkerton et al 2010a). However, the consumption of toothfish in particular locations at particular times of the year, or by particular parts of predator populations may be important to some predators, even though the total consumption of toothfish by all individuals of a predator species is relatively low. With respect to Weddell seals, Pinkerton et al (2008) and Eisert et al (2013) reviewed information on interactions with toothfish from habitat overlap, diver observations, animal-mounted cameras, observations from field scientists in McMurdo Sound, stomach contents, vomit and scats analysis, stable isotopes of carbon and nitrogen, and also compared natural mortality rates of Antarctic toothfish in McMurdo Sound with potential consumption by Weddell seals. Pinkerton et al (2008) concluded that while toothfish are a prey item for Weddell seals in McMurdo Sound between October and January, the extent of the relationship was not known. Energetic analyses of other potential Wedell seal prey in McMurdo Sound compared to Weddell seal seasonal dietary requirements suggest that toothfish are likely to be valued prey during particular times of year and in particular locations but are unlikely to be a major dietary component throughout the year (Eisert et al 2013). Research in the 2013-14 field season funded by the New Zealand Antarctic Research Institute (NZARI) aims to provide new data to help resolve this issue.

Torres et al (2013) considered to what extent toothfish are an important prey item for killer whales in the Ross Sea. There are direct observations of killer whales with toothfish in their mouths near McMurdo Sound, but the proportion of toothfish consumed by killer whales in the Ross Sea in general is not known. Habitat overlap information, stable isotope data and a comparison between natural mortality rates of Antarctic toothfish in McMurdo Sound and potential consumption by killer whales were inconclusive. At present, the balance of evidence suggests that toothfish are likely to be significant in the diet of type C killer whales in McMurdo Sound in summer, but it is not possible to say whether toothfish are an important prey item to type C killer whales in other locations on the Ross Sea shelf or at the scale of the whole Ross Sea shelf and slope (Torres et al 2013). NZARI-funded research in the 2013-14 field season aims to provide new data on this issue.

The mass-balance food-web model suggested that toothfish consumed 64% of the annual production of demersal species as prey items (Pinkerton et al 2010a), and so a reduction of the toothfish population might have a large impact on the mortality of these species through a "predation release" effect. The FEMA workshop noted that demersal fish are taken as by-catch so that a reduction in natural mortality may be partially offset by an increase in fishing mortality, but this offsetting effect is likely to be minor. As toothfish are large and mobile, their prey species are long-lived, functional predator diversity is low, and predator intra-guild predation is weak or absent, then the potential predation release effect is likely to be high in the Ross Sea region (Pinkerton & Bradford-Grieve, 2012).. Preliminary work towards developing a Minimum Realistic Model of toothfish and the main demersal fish prey species was discussed by Pinkerton et al (2010b).

Changes to the abundance of toothfish prey species may have effects on other species in the food-web through second-order effects (e.g. a "keystone" effect[2] or trophic cascades[3]), however, these are likely

[2] Keystone predators maintain biodiversity by preferentially consuming competitively dominant prey species. If keystone predators are removed or their biomass reduced, abundance of some prey species can increase to levels where they start to exclude subordinate competitors.

to be dependent on the particular ecosystem and are difficult to predict. The potential ecosystem effects of fishing in the Ross Sea region were investigated using mixed trophic impact (MTI) analysis (Pinkerton & Bradford-Grieve, 2012). Overall, Antarctic toothfish had moderate trophic importance in the Ross Sea food-web as a whole and the MTI analysis did not support the hypothesis that changes to toothfish will cascade through the ecosystem by simple trophic effects. Because of limitations to MTI analysis, cascading effects on the Ross Sea ecosystem due to changes in the abundance of toothfish cannot be ruled out, but, for such changes to occur, a mechanism other than simple trophic interactions is likely to be involved.

The FEMA II workshop also noted that the escapement level of 50% is the proportion of spawning biomass permitted to escape the fishery over the long term, and that as a consequence, the sub-mature fish would have a much higher escapement (e.g., > 90% for fish < 100 cm) (SC-CAMLR-XXVIII, Annex 3, Figure 1). However, the FEMA II workshop noted that the escapement level in the decision rule for the spawning biomass may need to be modified upwards if the size/age classes of *Dissostichus* spp. that are important prey for predators are reduced below the level needed to safeguard predators.

5.5 Effects of fishing on biogenic habitats

In 2006, the United Nations General Assembly (UNGA) agreed the Sustainable Fisheries Resolution (61/105), which calls on States and RFMOs or other arrangements to ensure fish stocks are managed sustainably and to prevent significant adverse impacts on vulnerable marine ecosystems (VMEs, UNGA Resolution 61/105, OP80–OP91). The 23 taxa included as VME indicator taxa (Parker & Bowden 2010) are defined in the CCAMLR VME taxa classification guide, which is available on the CCAMLR website (http://www.ccamlr.org/pu/e/sc/obs/vme-guide.pdf).

CCAMLR has implemented several Conservation Measures pertaining to VMEs (CM 22-05 (2008), CM 22-06 (2009), CM 22-07 (2009), and CM 22-08 (2009). In addition, specific measures are present in the general new and exploratory fisheries notification requirements to evaluate impacts of bottom fishing gear on VMEs (CM 21-01, CM 21-02). Combined, these measures form an approach to constrain gear types used, constrain areas fished, monitor fishing effort for evidence of VMEs, and to evaluate the potential effects of fishing on VMEs.

Sharp et al (2009) developed a bottom fishing impact assessment method, which was revised by Sharp (2010), and subsequently adopted by the Commission and used to summarize the current spatially-resolved fishing footprint and potential impact (% mortality) within the fishing footprint. This assessment method has demonstrated that regardless of the distribution of VMEs within the fishing footprint, the level of impact is exceptionally low.

Parker et al (2010) analysed spatial patterns of VME taxa from fishery bycatch in the Ross Sea region. Some taxa are relatively common as bycatch (e.g. Porifera, anemones, stylasterid hydrocorals) and the detectability of habitats containing these taxa with autoline longline gear is moderate to high (e.g., 70+%), enabling the use of fishery longline bycatch as a monitoring tool. This study also showed that VME taxa distributions vary spatially within the Ross Sea, and that some areas have shown no evidence of VME taxa despite consistent fishing effort.

Following fishery impacts, the potential recovery times for the VME taxa in the Ross Sea with the lowest productivities were evaluated with a spatially explicit production model (Dunn et al 2010). This model also showed that with current understandings of fishing gear performance, fishing effort distribution, and VME taxon life history, fishery impacts are low and recovery is likely to take place under the current management response to high bycatch levels. However, methods to determine the presence of high densities of rare taxonomic groups or unique community assemblages specific to the Ross Sea Region may need to be developed.

CCAMLR maintains a register of designated VMEs, currently including 36 VMEs, with two designated on the Admiralty seamount in the Ross Sea in 2011 in CM 22-09 (2011). These were

[3] Trophic cascade: reorganisation of the lower trophic levels of an ecosystem due to the change in abundance of a predator.

closed to fishing in 2011–12. Risk Areas have also been designated based on an observed fishery bycatch of > 10 kg or litres of VME taxa in a 1200-m longline segment. A total of 42 VME Risk Areas have been designated in Subareas 88.1 and 4 in Subarea 88.2, each closing a 1 nautical mile radius area surrounding the location of the bycatch observation to bottom fishing until reviewed by the Commission.

5.6 Ecosystem indicators

At present our ability to predict the effects of the toothfish fishery on ecosystem relationships in the Ross Sea region is limited. There is a need to establish appropriate monitoring in the Ross Sea to ascertain how species and ecological relationships are affected by the fishery. Monitoring should focus on species most likely to be affected by the toothfish fishery in the first instance. Baseline data on toothfish diet has been developed. Periodic analysis of the stomach-contents of toothfish can be used to look for changes in toothfish diet that may be indicative of changes to the demersal fish community. Better direct information is required on the abundance of *Macrourus* spp. and icefish on the Ross Sea slope. Research continues to test to what extent acoustic methods could be used to detect changes in *Macrourus* spp. abundance at the fishery scale (O'Driscoll et al 2012).

NZARI-funded research in the 2013-14 field season aims to provide new data on the importance of toothfish as prey for Weddell seals and type C killer whales in the southwest Ross Sea in summer. A survey of sub–adult toothfish abundance in the southwest Ross Sea was started in the 2011–12 season and the intention is for this to continue annually. This sub–adult toothfish survey will provide information on changes to the availability of toothfish to predators in this region.

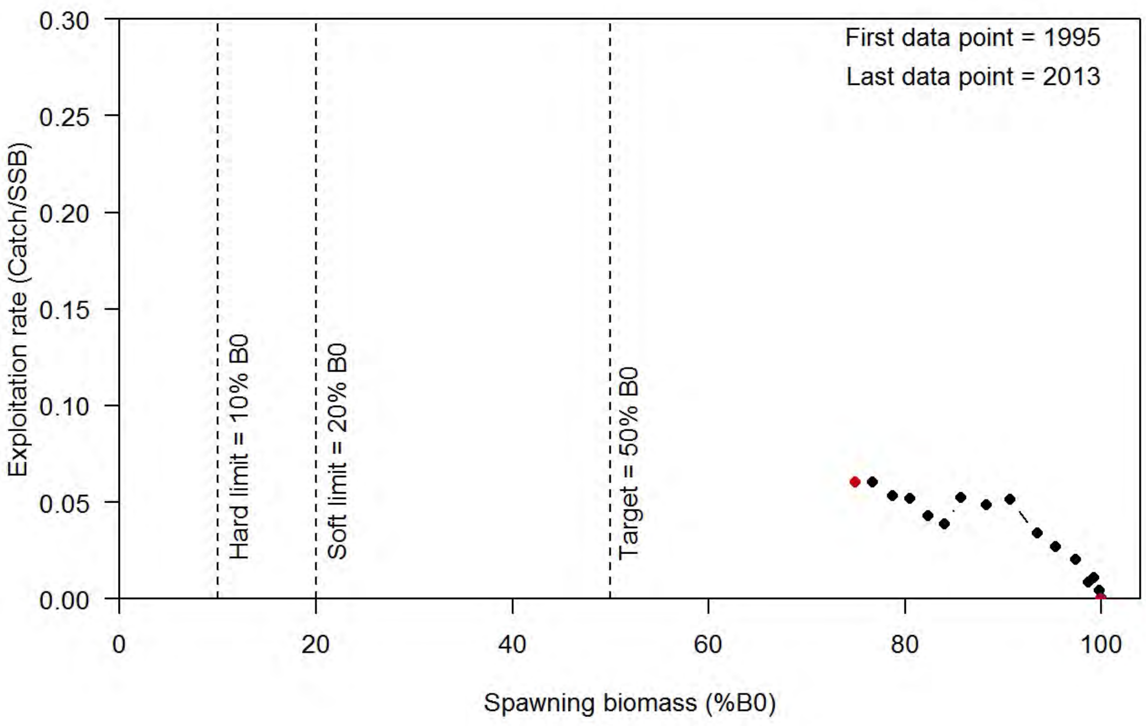
6. STATUS OF THE STOCKS

Stock structure assumptions

Uncertainty remains with respect to spawning dynamics and early life history of Antarctic toothfish. The present hypothesis is that Antarctic toothfish in Subareas 88.1 and 88.2 spawn to the north of the Antarctic continental slope, mainly on the ridges and banks of the Pacific-Antarctic Ridge. It has been recommended that for stock assessment purposes Subarea 88.1 and SSRUs 88.2A and 88.2B be treated as a 'Ross Sea' stock, whilst Subarea 88.2 SSRU 88.2C–H be treated as a separate 'Subarea 88.2' stock (CCAMLR 2011). In 2013, the Commission of CAMLR recognised that the stock assessment for 88.2C-H was probably only indexing the stock in the northern hills (SSRU88.2H), and that further work on assessing SSRUs88.2C-G is required. It is also noted that the stock affinity of the assessed stocks with toothfish in surrounding areas is not well understood.

Ross Sea stock

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	A single base case model (R2) was accepted by CCAMLR.
Reference Points	CCAMLR decision rule[4]: Target = 50% B_0 after 35 years with Pr(SSB > 20% B_0) ≥ 0.9 for a constant catch harvest strategy Soft Limit: 20% B_0 with Pr(SSB > 20% B_0) ≥ 0.9 Hard Limit: HSS default 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to CCAMLR Target	B_{2013} was estimated to be 74.8% B_0. Virtually Certain (> 99%) to be above the long term target (50% B_0).
Status in relation to Limits	B_{2013} is 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


Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Estimates of biomass have never been below 50% B_0, and the fishery is still in a fish-down phase.
Recent Trend in Fishing Intensity or Proxy	Fishing pressure increased early in the fishery and has stabilised at about target levels.
Other Abundance Indices	–
Trends in Other Relevant Indicators or Variables	The CPUE indices are not deemed to be an index of abundance. The catch-at-age data, although a relatively short time series, is showing indication of truncation of the right-hand limb, which is captured in the stock assessment. A change in the sex ratio in the north is becoming apparent, also captured in the stock assessment. For assessments, the tag-recapture data provide the best information on stock size, but the total number of fish recaptured is small and may introduce bias into the model. Spatial population operating models have indicated that the stock assessment is likely to be negatively biased (precautionary). Although the absolute stock size is uncertain, the available evidence (tag recapture data, catch rates, age frequency data) suggests that the stock has been lightly exploited to date.
Projections and Prognosis	
Stock Projections or Prognosis	The biomass of the stock is expected to decline slowly over the 35 year projection period
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Decision rule: About as Likely as Not (40-60%) at the end of a 35 year projection period Soft Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to	Very Unlikely (< 10%)

continue or commence	

Assessment Methodology		
Assessment Type	Level 1 – Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2013	Next assessment: 2015
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Multi-year tag-recapture data - Commercial catch-at-age proportions - Sub-adult survey series (2012 onwards) to estimate annual year class strength	1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	CPUE	
Changes to Model Structure and Assumptions	-	

Major Sources of Uncertainty	The model assumes homogenous mixing of tags within the population, which is unlikely to be true in the short term. Other major sources of uncertainty include estimates of initial mortality of tagged fish, detection rates of tagged fish, natural mortality rate, stock structure and migration patterns, stock-recruit steepness and natal fidelity assumptions with respect to other areas.

Qualifying Comments
For the base case and sensitivity models, current biomass is estimated to be between 71% and 82% B_0. The estimate of long term yield based on the CCAMLR decision rules[4] was 3044 t. At its 2013 meeting CCAMLR agreed to set the catch limit in 2013–14 and 2014–15 to 3044 t for the Ross Sea (CCAMLR 2013).

Fishery Interactions
Main bycatch species are macrourids for which there is an estimate of biomass and yield and rajids which are released alive.

Subarea 88.2 SSRUs 88.2C-H

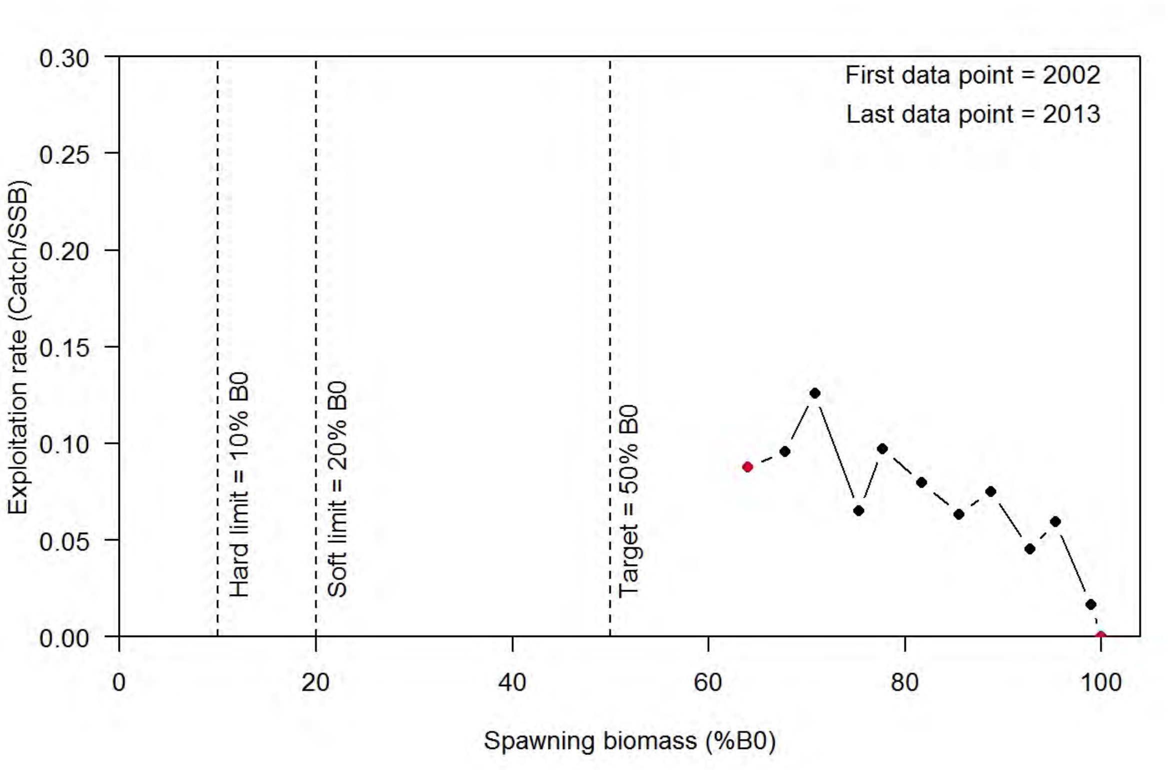
Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	A single base case model (R4) was accepted by CCAMLR but deemed to be representative of only the north area (SSRU 88.2H). No assessment or estimates of abundance are available for the southern area (SSRUs 88.2C–G).
Reference Points	CCAMLR decision rule[4]: Target = 50% B_0 after 35 years with Pr(SSB > 20% B_0) ≥ 0.9 for a constant catch harvest strategy Soft Limit: 20% B_0 with Pr(SSB > 20% B_0) ≥ 0.9 Hard Limit: HSS default 10% B_0

[4] Yield estimates are calculated by projecting the estimated current status under a constant catch assumption, using the decision rules:
1. Choose a yield, γ_1, so that the probability of the spawning biomass dropping below 20% of its median pre-exploitation level over a 35-year harvesting period is 10% (the depletion probability);
2. Choose a yield, γ_2, so that the median escapement in the SSB at the end of a 35 year period is 50% of the median pre-exploitation level (the level of escapement); and
3. Select the lower of γ_1 and γ_2 as the yield.

In the models, the depletion probability was calculated as the proportion of samples from the Bayesian posterior where the predicted future spawning stock biomass (SSB) was below 20% of B_0 in that respective sample in any one year, for each year over a 35-year projected period. The level of escapement was calculated as the proportion of samples from the Bayesian posterior where the predicted future status of the SSB was below 50% of B_0 in that respective sample at the end of a 35-year projected period.

	Overfishing threshold: F_{MSY}
Status in relation to CCAMLR Target	B_{2013} was estimated to be 65.1% B_0. Virtually certain (> 99%) to be above the long term target (50% B_0).
Status in relation to Limits	B_{2013} is 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



Fishery and Stock Trends	
Recent Trend in Biomass or Proxy[7]	Estimates of biomass have never been below 50% B_0, and the fishery is still in a fish-down phase.
Recent Trend in Fishing Intensity or Proxy	Fishing pressure has increased early in the fishery and has stabilised at about target levels. Fishing pressure on the northern hills has increased significantly, particularly in 2010 and 2012 as seen by an increased number of tags recovered and a reduction in the expected biomass from the stock assessment.
Other Abundance Indices	–
Trends in Other Relevant Indicators or Variables	The CPUE indices are not deemed to be an index of abundance. The catch-at-age data, when age length keys are applied annually, is showing an indication of truncation of the right-hand limb, which is not adequately captured in the stock assessment. The paucity of otoliths each year makes annual age length keys uncertain, and is seen as a priority work to improve upon. There has been no change in the sex ratio in this fishery. For assessments purposes, the tag-recapture data provide the best information on stock size, but the concentrated nature of some of the fishing on the hills is likely introduce bias into the model.

Projections and Prognosis	
Stock Projections or Prognosis	The biomass of the stock is expected to decline slowly over the 35 year projection period.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Decision rule: About as likely as Not (40-60%) at the end of a 35 year projection period Soft Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or commence	Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Level 1 – Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2013	Next assessment: 2014
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Multi-year tag-recapture data - Commercial catch-at-age proportions - Catch at age from annual age length keys where possible	1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	CPUE	3 – Low Quality
Changes to Model Structure and Assumptions	-	

Major Sources of Uncertainty	The model assumes homogenous mixing of tags within the population, yet is likely to be a measure of the local abundance of toothfish on the northern hills. No separate assessment or estimate of abundance is currently available for the southern area (SSRUs 88.2C–G). Other major sources of uncertainty include estimates of initial mortality of tagged fish, detection rates of tagged fish, natural mortality rate, stock structure and migration patterns, stock-recruit steepness and natal fidelity assumptions with respect to other areas.

Qualifying Comments
For the base case model and for sensitivity runs, current biomass is estimated to be between 52% and 86% B_0. The estimate of long term yield based on the CCAMLR decision rules[4] was 266 tonnes. At its 2013 meeting CCAMLR agreed to set the catch limit in 2013–14 to 266 t in the north (SSRU 88.2H) and 124 t in the south (SSRUs 88.2C-G) (CCAMLR 2013). But note that no separate assessment or estimate of abundance is currently available for the southern area (SSRUs 88.2C–G).

Fishery Interactions
Main bycatch species are macrourids and rajids.

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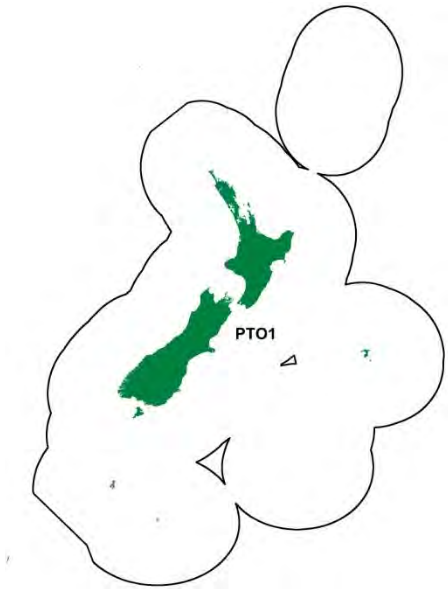
PATAGONIAN TOOTHFISH (PTO)
(within EEZ)

(*Dissostichus eleginoides*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

Patagonian toothfish, *Dissostichus eleginoides*, was introduced into the QMS on 1 October 2010. The Total Allowable Catch (TAC), Total Allowable Commercial Catch (TACC), recreational, customary and other mortality allowances issued for Patagonian toothfish (PTO) on entering the QMS are given in Table 1.

Table 1: Total Allowable Catch (TAC, t), Total Allowable Commercial Catches (TACC, t), customary non-commercial (t), recreational, and other mortality allowances for PTO on entering the QMS on 1 October 2010.

Fishstock	TAC	TACC	Customary Non-commercial	Recreational	Other Mortality
PTO 1	50	49.5	0	0	0.5

Internationally, fishing for Patagonian toothfish started in the 1950s in the Pacific Ocean off the coast of Chilé. Catch was initially comprised of juveniles that were seen as a bycatch in the shallow trawl fishery. The development of long-line gear capable of fishing deepwater led to the development of the fishery off Chilé in the mid 1980s, and the rapid spread to the Patagonian shelf and South Georgia in the Atlantic, and Kerguelen in the Indian Ocean. Technological advancements along with a high price per kg for toothfish lead to a rapid expansion of the fishery within territorial seas and the CCAMLR region, with catches increasing from 5 000 t in 1984 to 40 000 t in 1992 (Collins *et al.* 2006).

Within the NZ EEZ, prior to 1 October 2004, PTO were subject to a management regime where a special permit was needed to undertake exploratory fishing. Four exploratory fishing trips were undertaken between 1996 and 2003, catching less than 30 t (Table 2). After 2004 access to PTO was managed as part of a non-QMS regime. During 2009 toothfish were targeted on two fishing trips, resulting in just over 20 t of catch. Within the EEZ most fishing to date has taken place along the northern end of the Macquarie Ridge, around the southern periphery of the Campbell Plateau and on the Bounty Plateau. In total about 100 t have been taken since 1994/95. Reported landings of PTO caught within the EEZ age given in Table 2.

PTO is also caught in the Ross Sea fisheries managed by CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) from Antarctica to the south of the New Zealand EEZ. The Ross Sea region fisheries have been developing since the late 1990s with the majority of the catch comprising the sympatric Antarctic toothfish, *Dissostichus mawsoni* (Horn 2002).

Table 2: Reported PTO landings (t) reported from 1994-95 to 2012-13 within the EEZ. - indicates nil catches recorded.

Fishing Year	PTO 1
1994-95	0.1
1995-96	18.6
1996-97	4.1
1997-98	< 0.1
1999-00	1.0
2000-01	< 0.1
2001-02	0.2
2002-03	0.1
2003-04	3.3
2004-05	< 0.1
2005-06	< 0.1
2006-07	0.1
2007-08	-
2008-09	20.5
2009-10	-
2010-11	22.7
2011-12	34.5
2012-13	26.9

1.2 Recreational fisheries
There is no known recreational fishery for PTO.

1.3 Customary non-commercial fisheries
There is no information on customary non-commercial catch for PTO.

1.4 Illegal catch
No quantitative information is available on the level of illegal catch for PTO within the New Zealand EEZ.

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

2. BIOLOGY
Toothfish are large Notothenids and are endemic to Antarctic and Sub-Antarctic waters. There are two species of toothfish, the Antarctic toothfish, *Dissostichus mawsoni*, which is generally confined to the waters around the Antarctic continent, and the Patagonia toothfish, *Dissostichus eleginoides*, which are found further north around the sub-Antarctic islands and widely distributed around the 40-60° Southern latitudes (Collins *et al*. 2010, Horn 2002). There is limited overlap between distributions of the two species. In the Ross Sea the main area of overlap is thought to occur between latitudes 62.5°S and 65°S.

D. eleginoides can grow to over 2 m long and weigh over 150 kg. Large individuals are thought to be 40-50 years old. PTO grow relatively quickly until around 10 years of age, at which point females continue to grow more than males. Females reach maturity around 110-130 cm in comparison to males (thought to mature at 90-100 cm). Although growth rates differ between genders, there seem to be comparable maximum age for males and females (Horn 2002). Von Bertalanffy growth parameters are given in Table 2.

Toothfish feed on a variety of other fish, octopods, squid and crustaceans and change their feeding pattern with age. Juveniles, which live in relatively shallow water (< 200 m), are pelagic predators and feed primarily on small fish and amphipods. As adults, PTO move deeper (> 500m) and feed on deep dwelling species such as hoki (*Macruronus magellanicus*) and southern blue whiting (*Micromesistius australis*), and have also exhibited scavenging behaviour (Garcia de la Rosa *et al.* 1997).

Spawning is believed to occur between June and September (Kock & Kellerman 1991), with a peak in July/August, but has been found to vary with stock location. Spawning is believed to occur in deep water, around 1000 m, producing pelagic eggs and pelagic larval stages. Embryogenesis is quite rapid (~ 3.5 months) and larvae switch to a demersal habitat around 100 mm in size or 1 year of age (North 2002, Collins *et al*. 2010)

Juvenile toothfish have been located around Macquarie Island. As they grow individuals are assumed to move both north-east, into the New Zealand EEZ, and south-east down the Macquarie Ridge into northern CCAMLR waters.

Table 3: Estimates of biological parameters of Patagonian toothfish (PTO)

Fishstock						**Estimate**	**Source**
1. von Bertalanffy growth parameters							
			Females			Males	
Macquarie Ridge	*K*	t_0	$L\infty$	*K*	t_0	$L\infty$	
PTO 1	0.0850	-0.3500	158.7	0.1180	0.0800	134.3	Horn (2002)

3. STOCKS AND AREAS

Patagonian toothfish occur around sub Antarctic islands and seamounts between the 40 and 60°S including the southern region of New Zealand's EEZ (Horn 2002). There is evidence indicating that the New Zealand PTO resource is part of a straddling stock also found in Australia's abutting EEZ around Macquarie Island.

A tagging study on Patagonian tooth fish found that one fish, released in early 2009 on the northern extension of the Macquarie Ridge inside the NZ EEZ, was recaptured in the Macquarie Island fishing zone in mid 2009. Another fish tagged within the Macquarie Island fishing zone was recaptured from northern CCAMLR waters in the Ross Sea.

There is still uncertainty regarding the distribution of PTO within the EEZ and the potential size of the resource. Although recent fishing activity has achieved catch rates considered commercially viable, more information is needed on stock structure, biology and abundance.

4. STOCK ASSESSMENT

There are no abundance or biomass indices available for Patagonian toothfish within the New Zealand EEZ at this time.

5. STATUS OF THE STOCKS

The status of the PTO stock within the New Zealand EEZ is unknown.

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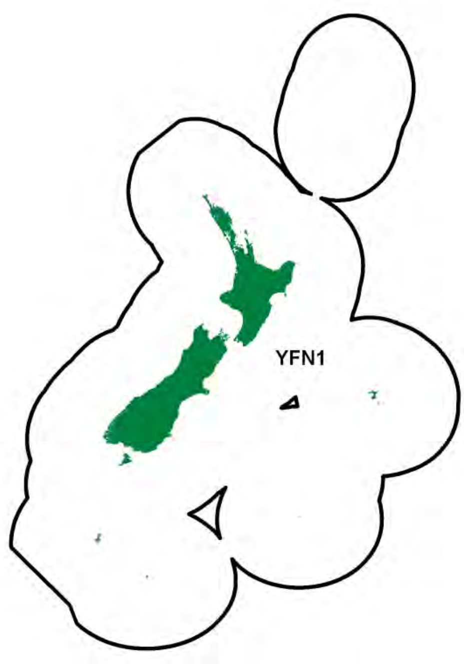
YELLOWFIN TUNA (YFN)

(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.

	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
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	1 006

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 2012.

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	1 006	639 912

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.

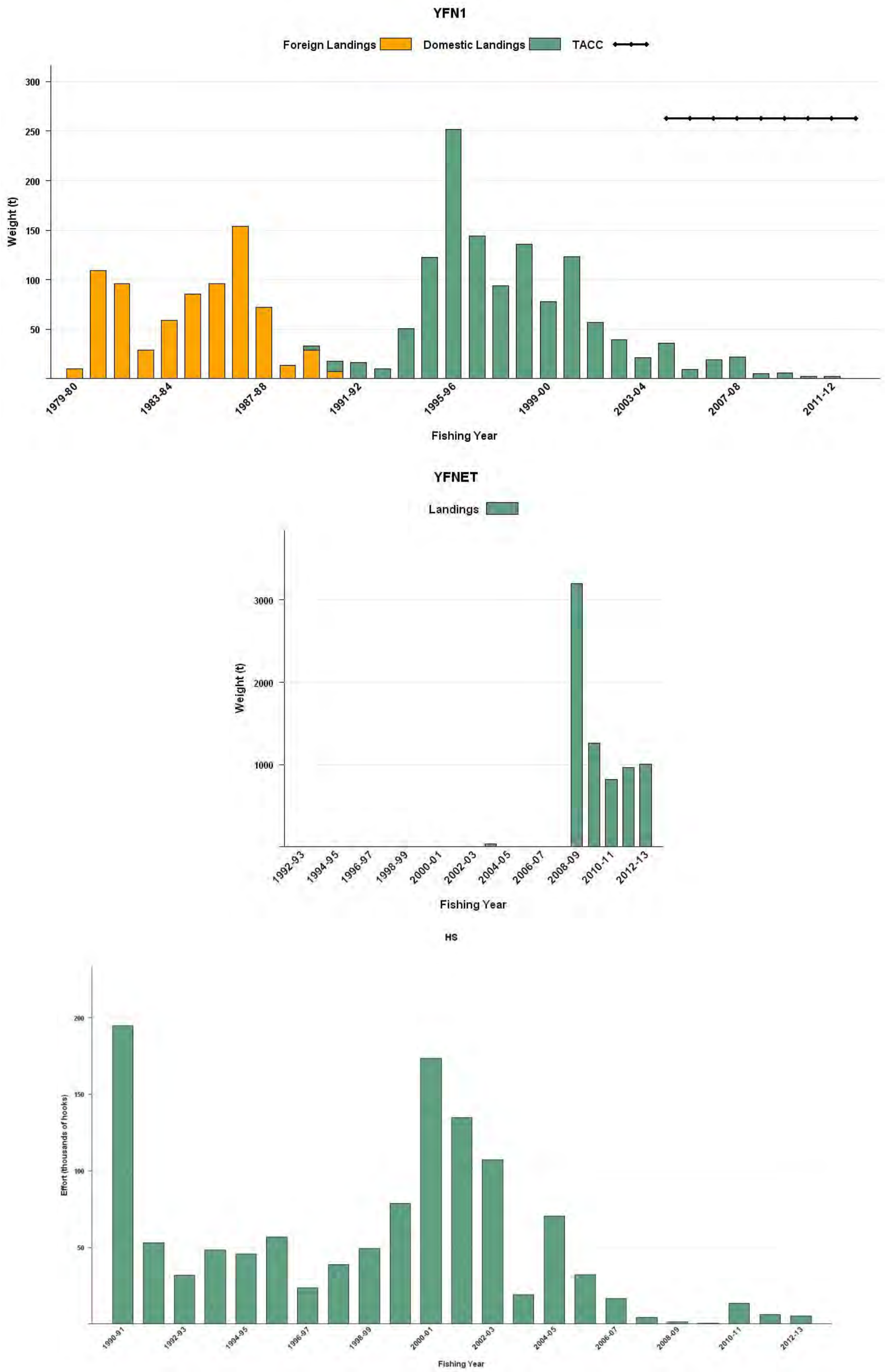


Figure 1: [Top] Yellowfin catch by foreign licensed and New Zealand vessels from 1979–80 to 2012–13 within New Zealand waters (YFN 1), and [middle] 1992–93 to 2012–13 on the high seas (YFN ET). [Bottom] Fishing effort (number of hooks set) for all high seas New Zealand flagged surface longline vessels from 1990–91 to 2012–13. [Figure continued on next page].

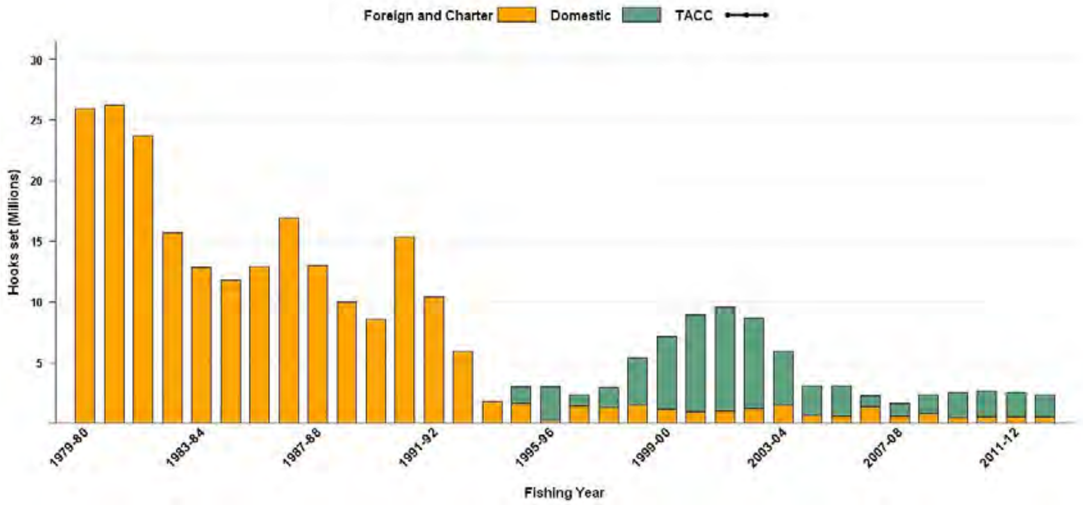


Figure 1 [Continued]: Yellowfin effort by domestic vessels (including effort by foreign vessels chartered by New Zealand fishing companies) from 1979–80 to 2011–12.

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).

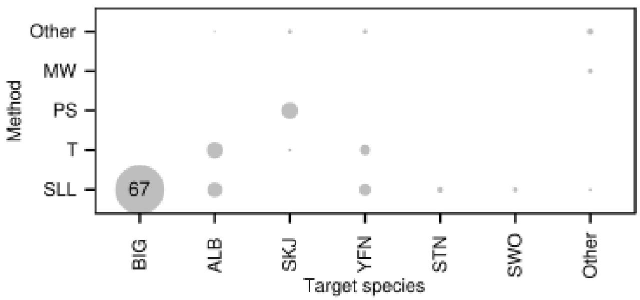


Figure 2: A summary of the proportion of landings of yellowfin tuna taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the circle is the percentage. SLL = surface longline, T = trawl, PS = purse seine, MW = mid-water trawl (Bentley et al 2013).

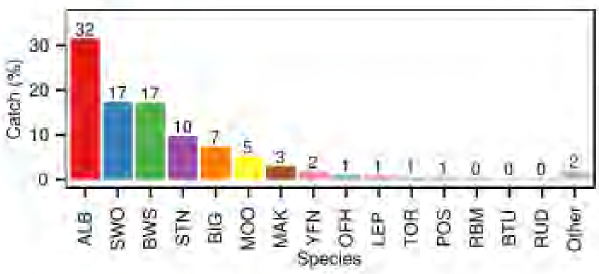


Figure 3: A summary of species composition of the reported surface longline catch. The percentage by weight of each species is calculated for all surface longline trips (Bentley et al. 2013).

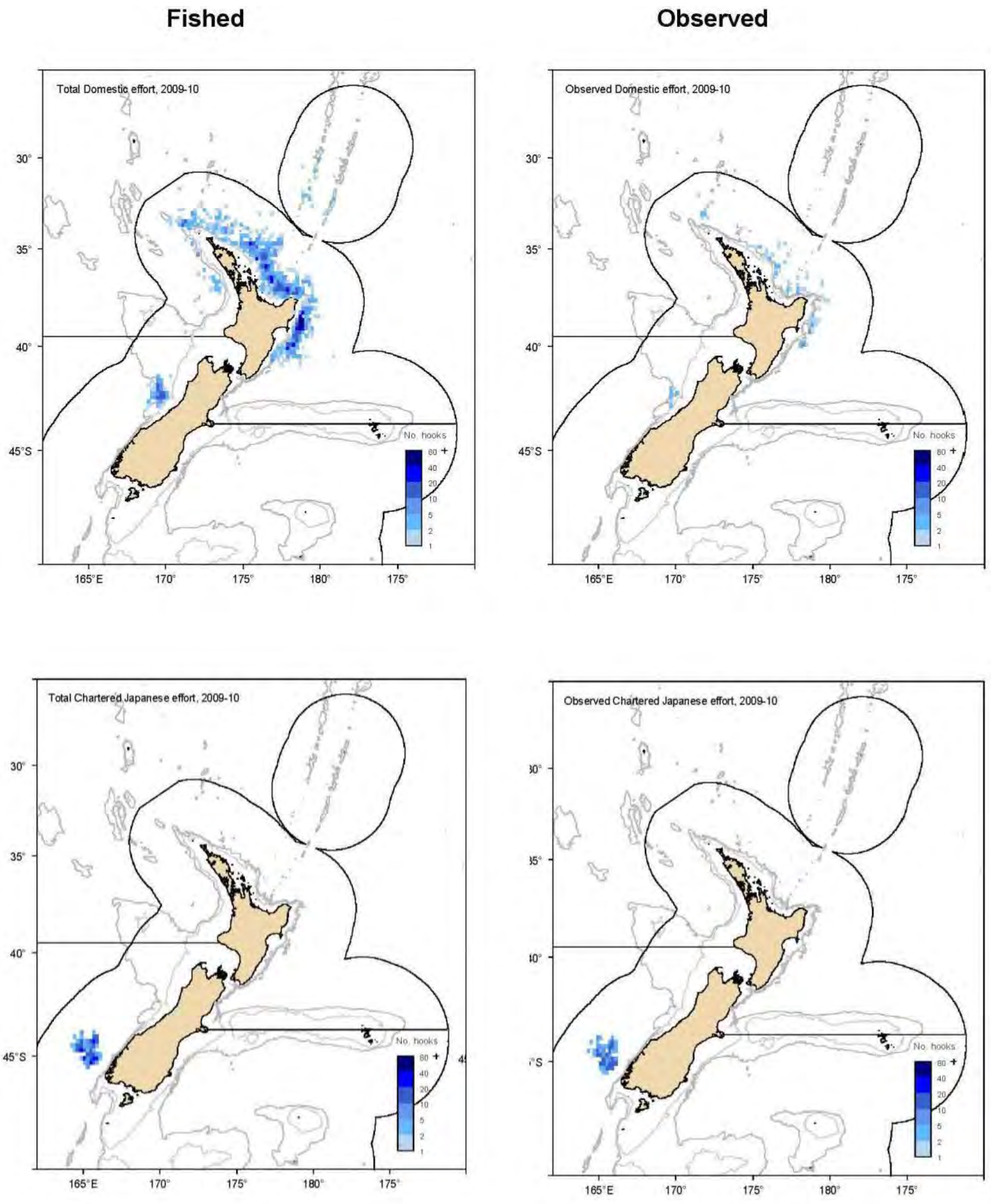


Figure 4: Distribution of fishing positions for domestic (top two panels) and charter (bottom two panels) vessels, for the 2009–10 fishing year, displaying both fishing effort (left) and observer effort (right).

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 2013 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=1644) (Ministry for Primary Industries 2012).

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 2011–12, there were 731 observed captures of birds across all surface longline fisheries. Seabird capture rates since 2003 are presented in Table 7 and Figure 5. While the seabird capture distributions largely coincide with fishing effort they are more frequent off the south west coast of the South Island (Figure 6). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Ratio estimation was historically used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods but recent estimates are either ratio or model based as specified in the tables below (Abraham et al 2010).

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.

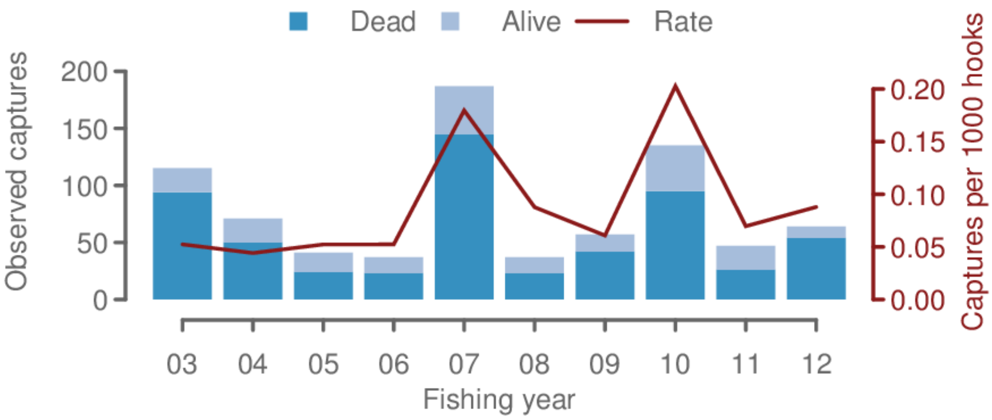
Table 7: Number of observed seabird captures in the New Zealand surface longline fisheries, 2002–03 to 2011–12, by species and area. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures. The risk ratio is an estimate of aggregate potential 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	3	2	27	0	278	33	0	343
NZ white-capped	Very high	0	2	0	3	10	60	27	0	102
Northern Buller's	High	0	0	0	1	0	0	0	0	1
Gibson's	High	4	16	0	17	0	6	2	1	46
Antipodean	High	12	9	1	8	0	0	0	1	31
Northern royal	Medium	0	0	1	0	0	0	0	0	1
Southern royal	Medium	0	1	0	0	0	4	0	0	5
Campbell black-browed	Medium	2	9	2	29	0	3	3	1	49
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**	**43**	**8**	**93**	**10**	**351**	**66**	**4**	**631**
Other seabirds										
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	19	3	3	37
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**	**22**	**9**	**8**	**158**

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 2010–11 are based on data version 20120531 and preliminary estimates for 2011–12 are based on data version 20130305.

	Fishing effort			Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	10 764 588	2 195 152	20.4	115	0.052	2 033	1 577–2 737
2003–2004	7 380 779	1 607 304	21.8	71	0.044	1 345	1 044–1 798
2004–2005	3 676 365	783 812	21.3	41	0.052	601	472–780
2005–2006	3 687 339	705 945	19.1	37	0.052	790	585–1 137
2006–2007	3 738 362	1 040 948	27.8	187	0.18	936	720–1 344
2007–2008	2 244 339	426 310	19	41	0.088	513	408–664
2008–2009	3 115 633	937 233	30.1	57	0.061	593	477–746
2009–2010	2 992 285	665 883	22.3	135	0.203	921	732–1 201
2010–2011	3 185 779	674 572	21.2	47	0.07	696	524–948
2011–2012†	3 069 707	728 190	23.7	64	0.088	808	596–1 168

†Provisional data, model estimates not finalised.



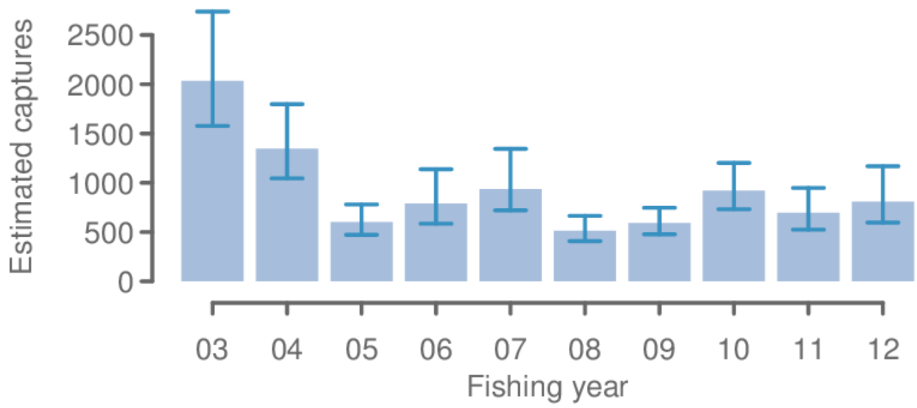


Figure 5: Observed and estimated captures of seabirds in the New Zealand surface longline fisheries from 2002–03 to 2011–12.

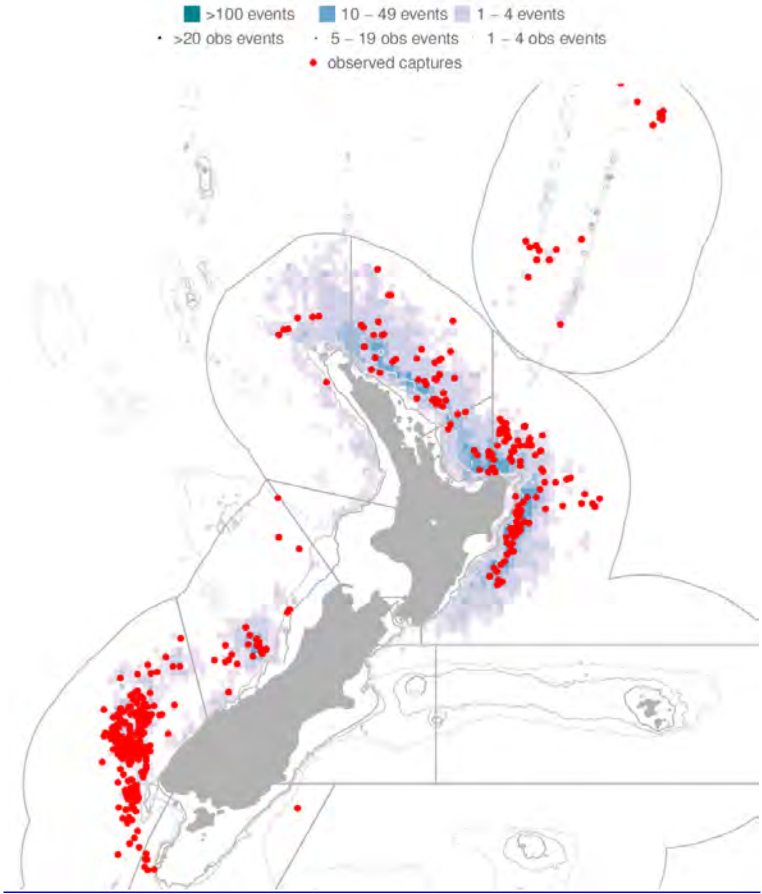


Figure 6: Distribution of fishing effort in the New Zealand surface longline fisheries and observed seabird captures, 2002–03 to 2011–12. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black 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, 94.1% of the effort is shown. See glossary for areas used for summarising the fishing effort and protected species captures.

4.2.2 Sea turtle bycatch

Between 2002–03 and 2011–12, there were 13 observed captures of sea turtles across all surface longline fisheries (Tables 9 and 10, 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 9: Number of observed sea turtle captures in the New Zealand surface longline fisheries, 2002–03 to 2011–12, 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	0	1
Total	1	6	3	3	13

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	10 764 588	2 195 152	20.4	0	0
2003–2004	7 380 779	1 607 304	21.8	1	0.001
2004–2005	3 676 365	783 812	21.3	2	0.003
2005–2006	3 687 362	705 945	19.1	1	0.001
2006–2007	3 738 362	1 040 948	27.8	2	0.002
2007–2008	2 244 339	421 900	18.8	1	0.002
2008–2009	3 115 633	937 496	30.1	2	0.002
2009–2010	2 992 285	665 883	22.3	0	0
2010–2011	3 185 779	674 572	21.3	4	0.006
2011–2012	3 069 707	728 190	23.7	0	0

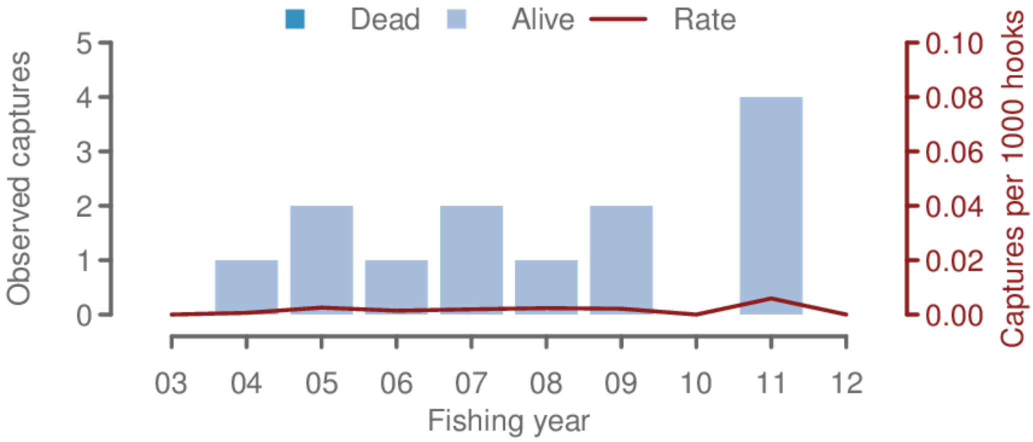


Figure 7: Observed captures of sea turtles in the New Zealand surface longline fisheries from 2002–03 to 2011–12.

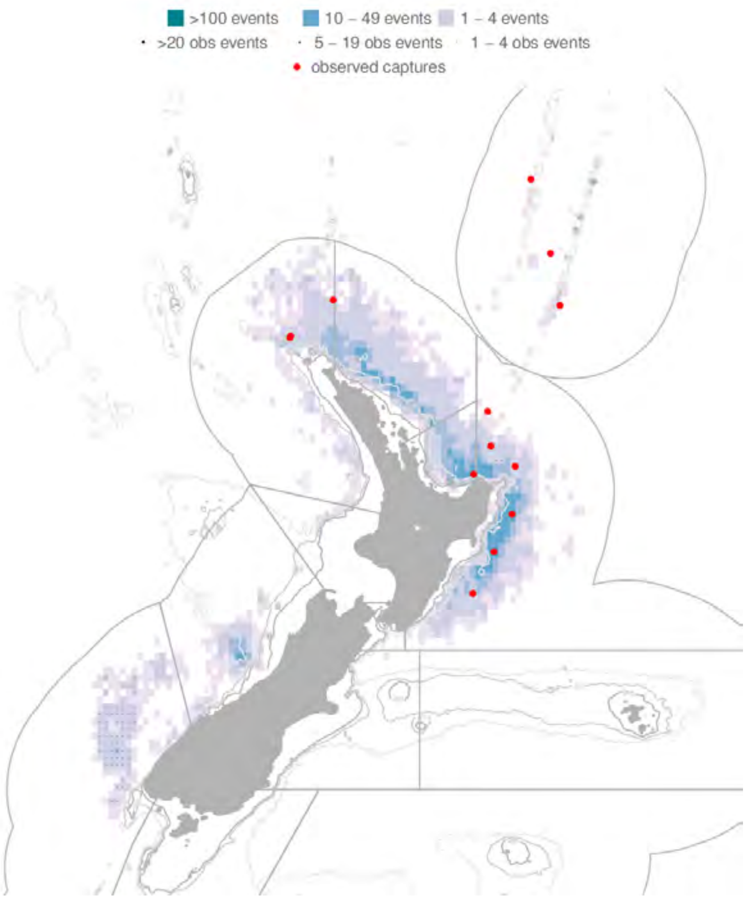


Figure 8: Distribution of fishing effort in the New Zealand surface longline fisheries and observed sea turtle captures, 2002–03 to 2011–12. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black 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, 94.1% 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 2011–12, 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 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 11: Number of observed cetacean captures in the New Zealand surface longline fisheries, 2002–03 to 2011–12, 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	10 764 588	2 195 152	20.4	1	0.0005
2003–2004	7 380 779	1 607 304	21.8	4	0.002
2004–2005	3 676 365	783 812	21.3	1	0.001
2005–2006	3 687 339	705 945	19.1	0	0
2006–2007	3 738 362	1 040 948	27.8	0	0
2007–2008	2 244 339	421 900	18.8	1	0.002
2008–2009	3 115 633	937 496	30.1	0	0
2009–2010	2 992 285	665 883	22.3	0	0
2010–2011	3 185 779	674 572	21.2	0	0
2011–2012	3 069 707	728 190	23.7	0	0

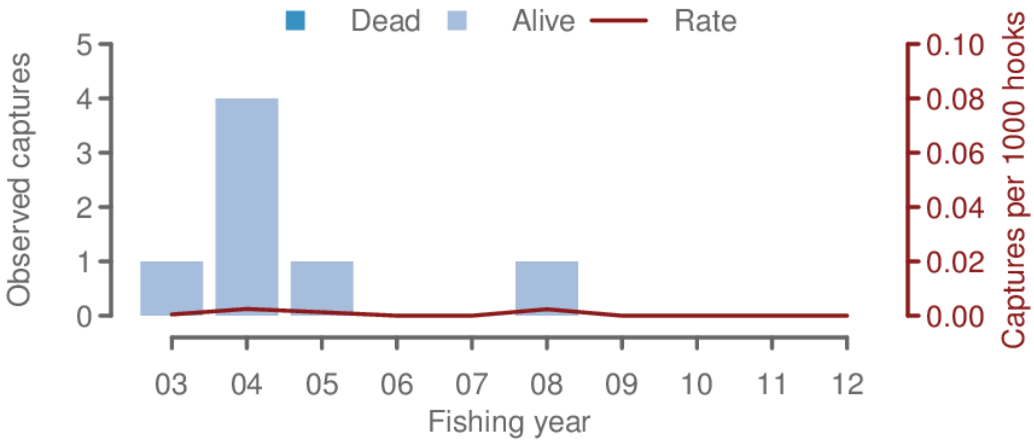


Figure 9: Observed captures of cetaceans in the New Zealand surface longline fisheries from 2002–03 to 2011–12.

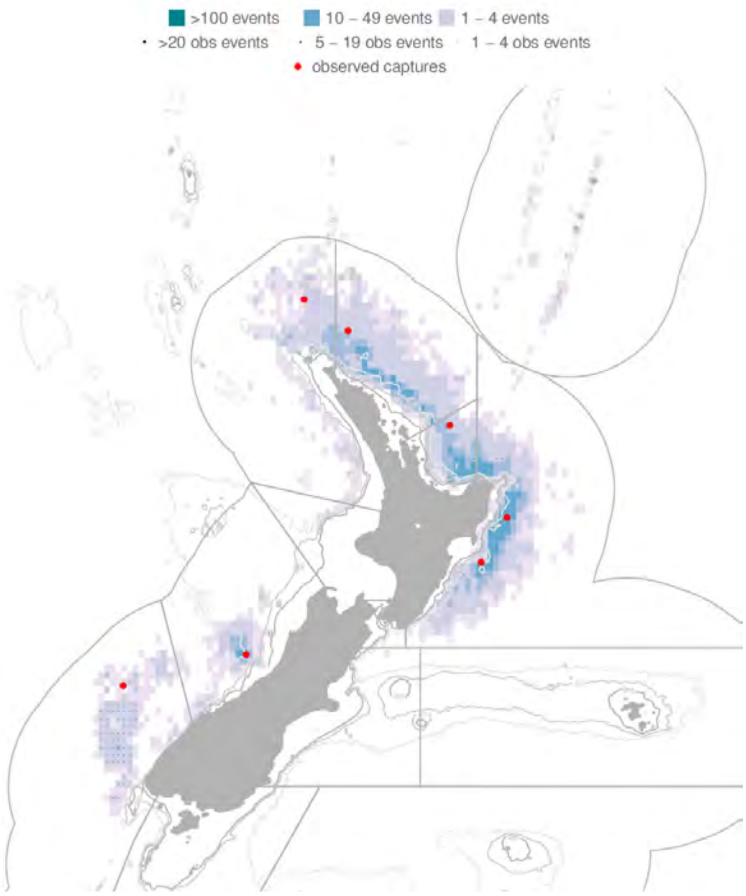


Figure 10: Distribution of fishing effort in the New Zealand surface longline fisheries and observed cetacean captures, 2002–03 to 2011–12. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black 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, 94.1% 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 around much of the South Island and offshore islands slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts. Captures on longlines occur when the seals attempt to feed on bait or fish from the line 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). Bycatch rates in 2011–12 were, low and lower 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 2011–12, there were 246 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 2011–12, 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	10	16	139	3	4	2	32	206

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). 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 are based on data version 20120531 and preliminary estimates for 2011–12 are based on data version 20130305.

	Fishing effort			Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	10 764 588	2 195 152	20.4	56	0.026	157	138-178
2003–2004	7 380 779	1 607 304	21.8	40	0.025	116	99-133
2004–2005	3 676 365	783 812	21.3	20	0.026	77	63-93
2005–2006	3 687 339	705 945	19.1	12	0.017	70	55-85
2006–2007	3 738 362	1 040 948	27.8	10	0.010	52	40-66
2007–2008	2 244 339	426 310	19.0	10	0.023	45	34-56
2008–2009	3 115 633	937 233	30.1	22	0.023	57	46-69
2009–2010	2 992 285	665 883	22.3	19	0.029	78	64-94
2010–2011	3 164 159	674 522	21.3	17	0.025	57	45-69
2011–2012†	3 069 707	728 190	23.7	40	0.055	96	81-111

†Provisional data, model estimates not finalised.

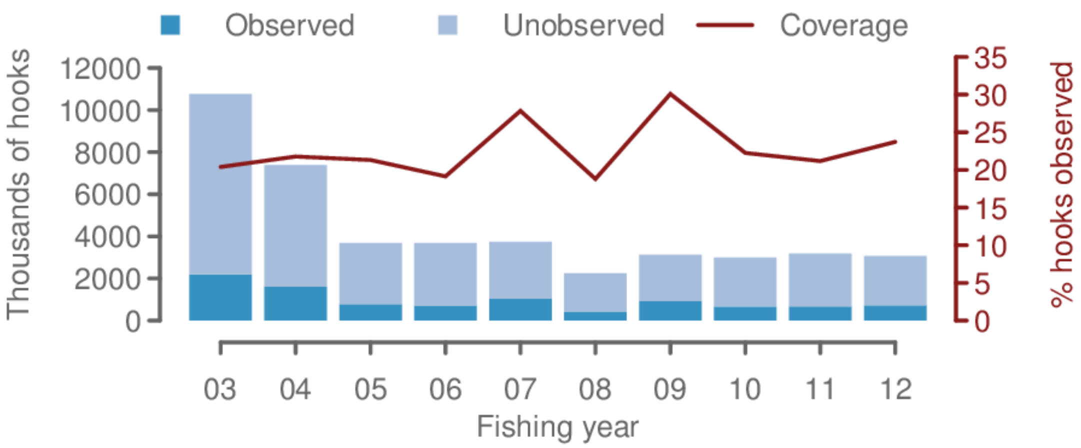


Figure 11: Observed captures of New Zealand fur seal in the New Zealand surface longline fisheries from 2002–03 to 2011–12.

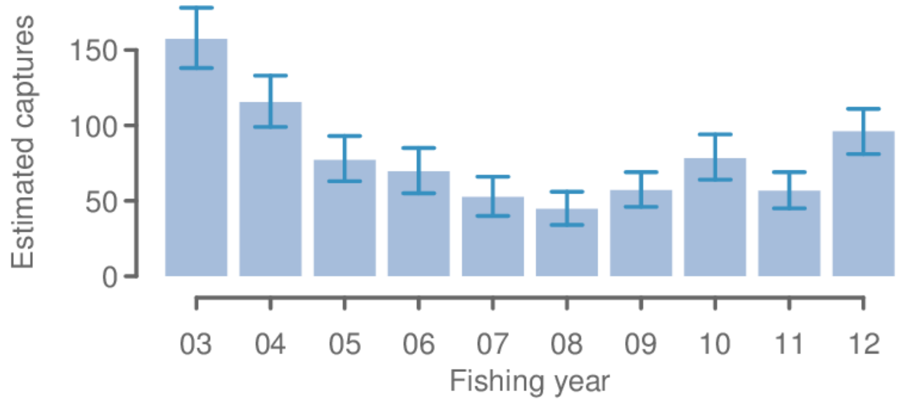


Figure 12: Estimated captures of New Zealand fur seal in the New Zealand surface longline fisheries from 2002–03 to 2011–12.

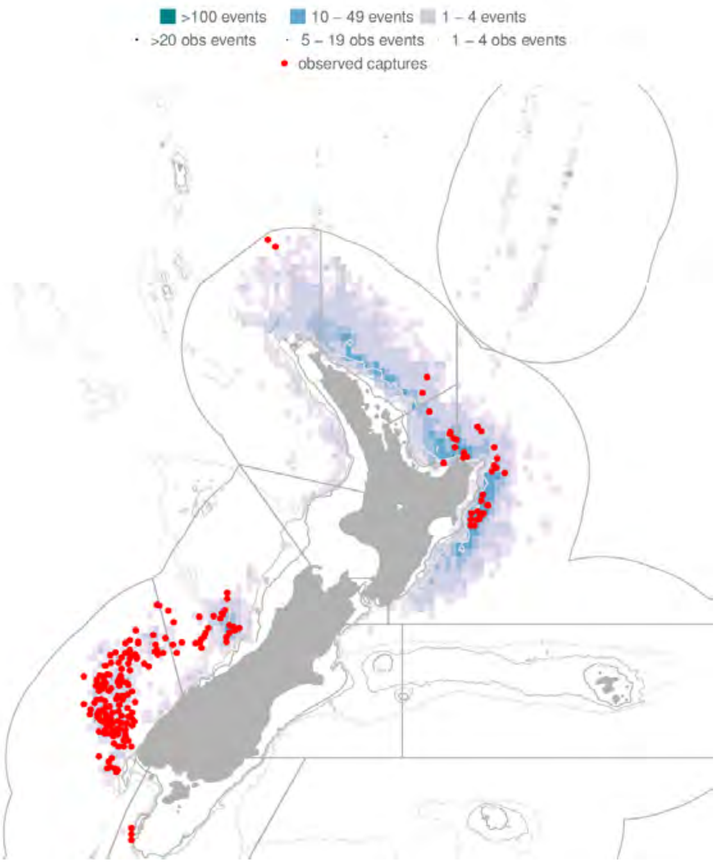


Figure 13: Distribution of fishing effort in the New Zealand surface longline fisheries and observed New Zealand fur seal captures, 2002–03 to 2011–12. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated 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, 94.1% 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: Numbers of the most common fish species observed in the New Zealand longline fisheries during 2009–10 by fleet and area. Species are shown in descending order of total abundance (Griggs & Baird 2013).

	Charter	Domestic		Total
Species	South	North	South	number
Blue shark	2 024	4 650	882	7 556
Ray's bream	3 295	326	88	3 709
Southern bluefin tuna	3 244	211	179	3 634
Lancetfish	3	2 139	1	2 143
Albacore tuna	90	1 772	42	1 904
Dealfish	882	0	7	889
Swordfish	3	452	2	457
Moonfish	76	339	6	421
Porbeagle shark	72	328	20	420
Mako shark	11	343	7	361
Big scale pomfret	349	4	0	353
Deepwater dogfish	305	0	0	305
Sunfish	7	283	5	295
Bigeye tuna	0	191	0	191
Escolar	0	129	0	129
Butterfly tuna	15	100	3	118
Pelagic stingray	0	96	0	96
Oilfish	2	75	0	77
Rudderfish	39	20	2	61
Flathead pomfret	56	0	0	56
Dolphinfish	0	47	0	47
School shark	34	0	2	36
Striped marlin	0	24	0	24
Thresher shark	7	17	0	24
Cubehead	13	0	1	14
Kingfish	0	10	0	10
Yellowfin tuna	0	9	0	9
Hake	8	0	0	8
Hapuku bass	1	6	0	7
Pacific bluefin tuna	0	5	0	5
Black barracouta	0	4	0	4
Skipjack tuna	0	4	0	4
Shortbill spearfish	0	4	0	4
Gemfish	0	3	0	3
Bigeye thresher shark	0	2	0	2
Snipe eel	2	0	0	2
Slender tuna	2	0	0	2
Wingfish	2	0	0	2
Bronze whaler shark	0	1	0	1
Hammerhead shark	0	1	0	1
Hoki	0	0	1	1
Louvar	0	1	0	1
Marlin, unspecified	0	1	0	1
Scissortail	0	1	0	1
Broadnose seven gill shark	1	0	0	1
Shark, unspecified	0	1	0	1
Unidentified fish	2	30	8	40
Total	10 545	11 629	1 256	23 430

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.

A summary of the 2011 assessment undertaken by OFP (Langley et al 2011) and reviewed by the WCPFC Scientific Committee in August 2011 is provided below.

~~-~~The assessment uses the stock assessment model and computer software known as MULTIFAN-CL. The yellowfin tuna model is age (28 age-classes) and spatially structured (6 regions) and the catch, effort, size composition and tagging data used in the model are classified by 24 fisheries and quarterly time periods from 1952 through 2010. The assessment included a range of model options and sensitivities that were applied to investigate key structural assumptions and sources of uncertainty in the assessment.

While the structure of the assessment model(s) was similar to the previous (2009) assessment, there were some substantial revisions to a number of key data sets, specifically the longline CPUE indices, catch and size data, purse-seine catch and size data, and the configuration of the Indonesian and Philippines domestic fisheries. Cumulatively, these changes resulted in a substantial change in the key results from the 2009 assessment, reducing the overall level of biomass and the estimates of MSY, $B_{current}/\widetilde{B}_{MSY}$ and $SB_{current}/\widetilde{SB}_{MSY}$, while increasing the estimate of $F_{current}/\widetilde{F}_{MSY}$ Overall, the current models represent a considerable improvement to the fit to the key data sets compared to 2009 indicating an improvement in the consistency among the main data sources, principally the longline CPUE indices and the associated length and weight frequency data.

The current assessment represents the first attempt to integrate the tagging data from the recent PTTP. The model diagnostics indicate a relatively poor fit to these data compared to the data from earlier tagging programmes, particularly for fish of the older age classes and/or longer periods at liberty. For all model options, there was a positive bias in the model‘s prediction of the number of tags recovered from older fish, indicating that estimated exploitation rates for recent years were higher than observed directly from the tag recoveries. This indicates a degree of conflict between the tagging data and the other key data sources, specifically the longline CPUE indices and, to a lesser extent, the longline size data. Consequently, the inclusion of PTTP data set in the model yields a rather more optimistic assessment (when contrasted with models that exclude these data).

The main conclusions of the current assessment are as follows.

For all analyses, there are strong temporal trends in the estimated recruitment series. Initial recruitment was relatively high but declined during the 1950s and 1960s. Recruitment remained relatively constant during the 1970s and 1980s, declined steadily from the early 1990s and then recovered somewhat over the last decade. Recent recruitment is estimated to be lower than the long-term average (approximately 85%).

Trends in biomass are generally consistent with the underlying trends in recruitment. Biomass is estimated to have declined throughout the model period. The biomass trends in the model are principally driven by the time-series of catch and GLM standardised effort from the principal longline fisheries. Over recent years, there has been considerable refinement of the longline CPUE indices, largely as a result of the utilisation of the operational level data from the longline fishery, principally from the Japanese fleet. This data enables a number of factors to be incorporated within the analysis to account for temporal trends in the catchability of the fleet.

Refinement in the approach applied to process the longline size frequency data (length and weight data) has resulted in a more coherent trend in these data over the model period. As a result, there has been a substantial improvement in the fit to both the size frequency data and the CPUE indices compared to recent assessments.

There is considerable conflict between the tagging data (principally from the PTTP) and the other key sources of data included in the model, primarily the CPUE indices. The inclusion of the PTTP tagging data results in a the estimation of a substantially lower level of fishing mortality, particularly for the both the younger age classes vulnerable to the purse-seine associated fishery (age classes 3–4) and the older age classes (age classes > 9) vulnerable to the unassociated purse-seine fishery. The resulting assessment is more optimistic when the PTTP tags are incorporated in the model. Further auxiliary analysis of the PTTP tagging data are required to resolve the conflict between these key sources of data.

Fishing mortality for adult and juvenile yellowfin tuna is estimated to have increased continuously since the beginning of industrial tuna fishing. A significant component of the increase in juvenile fishing mortality is attributable to the Philippines and Indonesian surface fisheries, which have the weakest catch, effort and size data. There has been recent progress made in the acquisition of a large amount of historical length frequency data from the Philippines and these data were incorporated in the assessment. However, there is an ongoing need to improve estimates of recent and historical catch from these fisheries and maintain the current fishery monitoring programme within the Philippines. Previous analyses have shown that the current stock status is relatively insensitive to the assumed level of catch from these fisheries, although yield estimates from the fishery vary in accordance to the assumed levels of historical catch. Therefore, improved estimates of historical and current catch from these fisheries are important in the determination of the underlying productivity of the stock.

The ratios $B_t / B_{t,F=0}$ provide a time-series index of population depletion by the fisheries. Depletion has increased steadily over time, reaching a level of about 50–55% of unexploited biomass (a fishery impact of 45–50%) in 2006–2009. This represents a moderate level of stock-wide depletion although the stock remains considerably higher than the equivalent equilibrium-based reference point ($\widetilde{B}_{MSY} / \widetilde{B}_0$ of approximately 0.35–0.40). However, depletion is considerably higher in the equatorial region 3 where recent depletion levels are approximately 0.30 for total biomass (a 70% reduction from the unexploited level). Impacts are moderate in region 4 (37%), lower (about 15–25%) in regions 1, 5, and 6 and minimal (9%) in region 2. If stock-wide over-fishing criteria were applied at the level of our model regions, we would conclude that region 3 is fully exploited and the remaining regions are under-exploited.

The attribution of depletion to various fisheries or groups of fisheries indicates that the associated purse-seine fishery and Philippines/Indonesian domestic fisheries have the highest impact, particularly in region 3, while the unassociated purse seine fishery has a moderate impact. These fisheries are also contributing to the fishery impacts in all other regions. Historically, the coastal Japanese pole-and-line and purse-seine fisheries have had a significant impact on biomass levels in their home region (1). In all regions, the longline fishery has a relatively small impact, less than 5%.

For the most plausible range of models, the fishing mortality based reference point $F_{current}/\widetilde{F}_{MSY}$ is estimated to be 0.56–0.90 and on that basis conclude that **overfishing is not occurring**. The corresponding biomass based reference points $B_{current}/\widetilde{B}_{MSY}$ and $SB_{current}/\widetilde{SB}_{MSY}$ are estimated to be above 1.0 (1.25–1.60 and 1.34–1.83, respectively) and, therefore, the stock is **not in an overfished state**. The stock status indicators are sensitive to the assumed value of steepness for the stock-recruitment relationship. A value of steepness greater than the default value (0.95) yields a more optimistic stock status and estimates considerably higher potential yields from the stock. Conversely, for a lower (0.65) value of steepness, the stock is estimated to be approaching the *MSY* based fishing mortality and biomass thresholds.

The western equatorial region accounts for the most of the WCPO yellowfin catch. In previous assessments, there have been concerns that the stock status in this region (region 3) might differ from the stock status estimated for the entire WCPO. A comparison between the results from the WCPO models and a model encompassing only region 3 yielded very similar results, particularly with respect to stock status. Nonetheless, there appear to be differences in the biological characteristics of yellowfin tuna in this region that warrant further investigation.

The estimates of *MSY* for the principal model options (480 000–580 000 mt) are comparable to the recent level of (estimated) catch from the fishery (550 000 mt). Further, under equilibrium conditions, the predicted yield estimates ($Y_{Fcurrent}$) are very close to the estimates of *MSY* indicating that current yields are at or above the long-term yields available from the stock. Further, while estimates of current fishing mortality are generally below F_{MSY}, any increase in fishing mortality would most likely occur within region 3 — the region that accounts for most of the catch. This would further increase the levels of depletion that is occurring within that region.

The current assessment investigated the impact of a range of sources of uncertainty in the current model and the interaction between these assumptions. Nonetheless, there remains a range of other assumptions in the model that should be investigated either internally or through directed research. Further studies are required to refine our estimates of growth, natural mortality and reproductive potential, incorporating consideration of spatio-temporal variation and sexual dimorphism; to examine in detail the time-series of size frequency data from the fisheries, which may lead to refinement in the structure of the fisheries included in the model; to consider size-based selectivity processes in the assessment model; to collect age frequency data from the commercial catch in order to improve current estimates of the population age structure; to continue to improve the accuracy of the catch estimates from a number of key fisheries, particularly those catching large quantities of small yellowfin; to refine the methodology and data sets used to derive CPUE abundance indices from the longline fishery; and to refine approaches to integrate the recent tag release/recapture data into the assessment model."

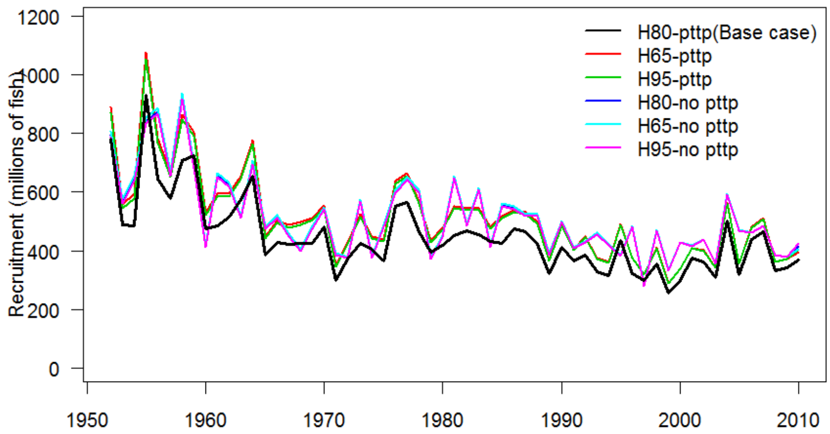


Figure 14: Estimated annual recruitment (millions of fish) for the WCPO obtained for the base case (LLcpueOP_TWcpueR6_PTTP – H80pttp) and the five combinations of steepness and tagging data sets included.

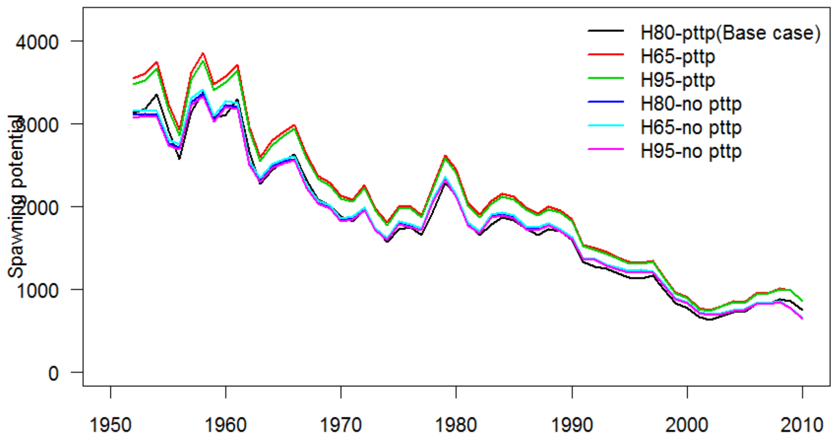


Figure 15: Estimated average annual spawning potential for the WCPO obtained from for the base case (LLcpueOP_TWcpueR6_PTTP – H80pttp) and the five combinations of steepness and tagging data sets included.

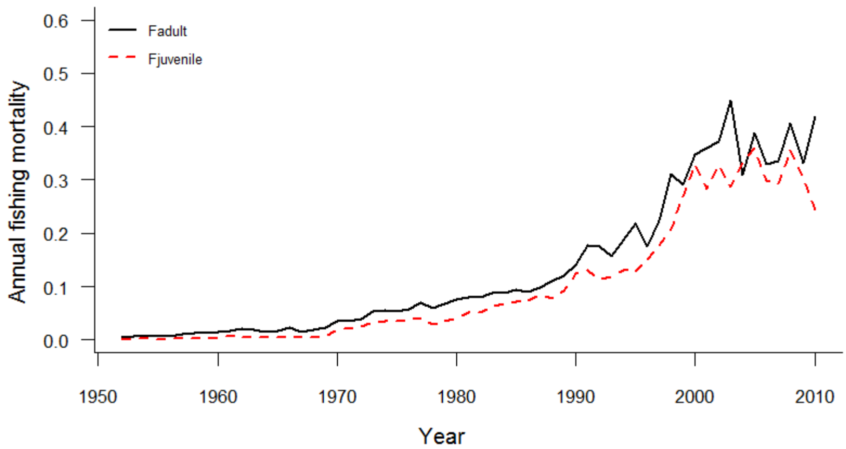


Figure 16: Estimated annual average juvenile and adult fishing mortality for the WCPO obtained from the base case model (LLcpueOP_TWcpueR6_PTTP – H80pttp).

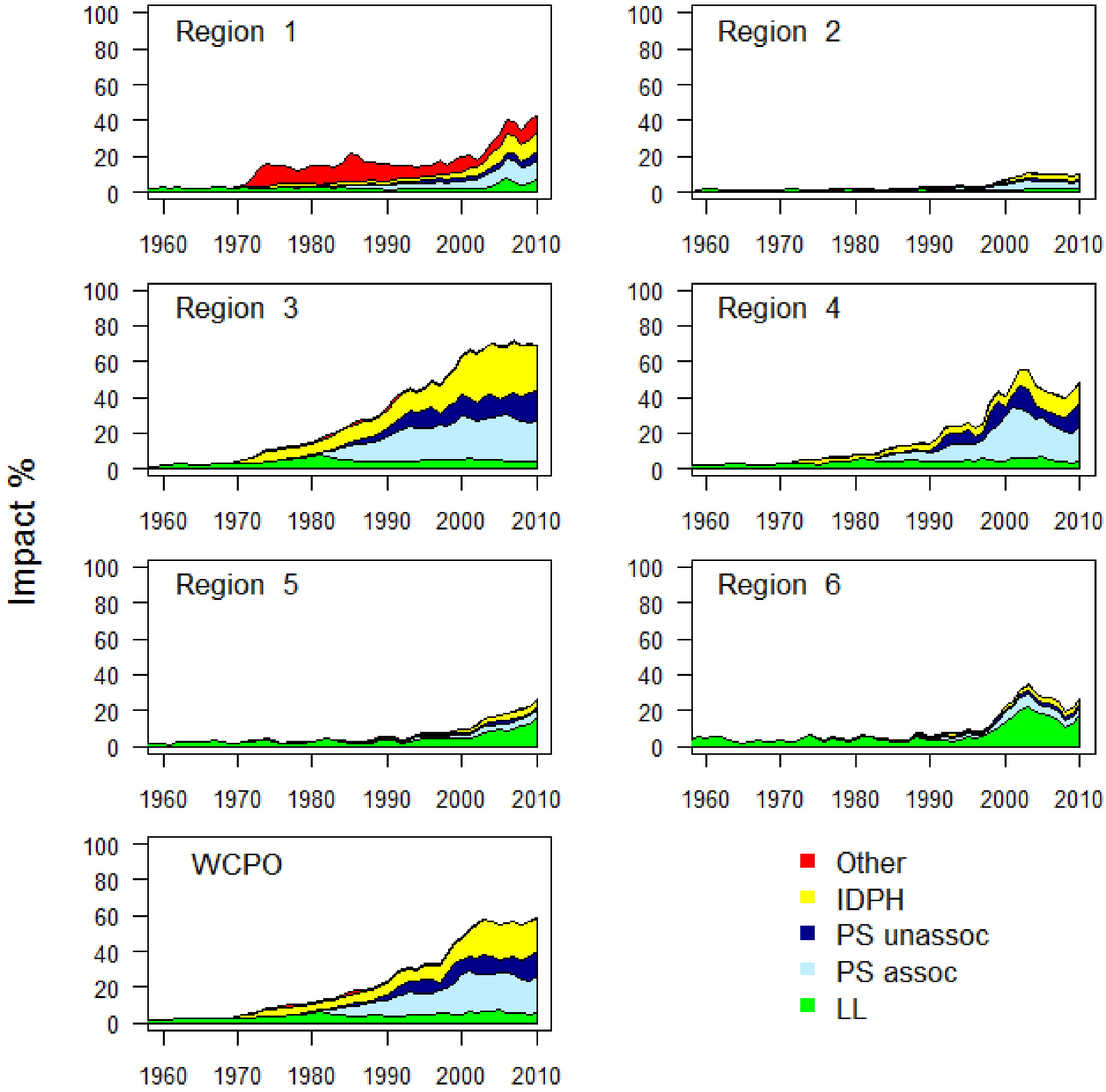


Figure 17: Estimates of reduction in spawning potential due to fishing (fishery impact = 1- $SB_t/SBt_{F=0}$) by region and for the WCPO attributed to various fishery groups (base case model (LLcpueOP_TWcpueR6_PTTP – H80pttp)). L = all longline fisheries; IDPHIDPH = Philippines and Indonesian domestic fisheries; PS assoc = purse-seine log and FAD sets; PS unassoc = purse-seine school sets; Other = pole-and-line fisheries and coastal Japan purse-seine.

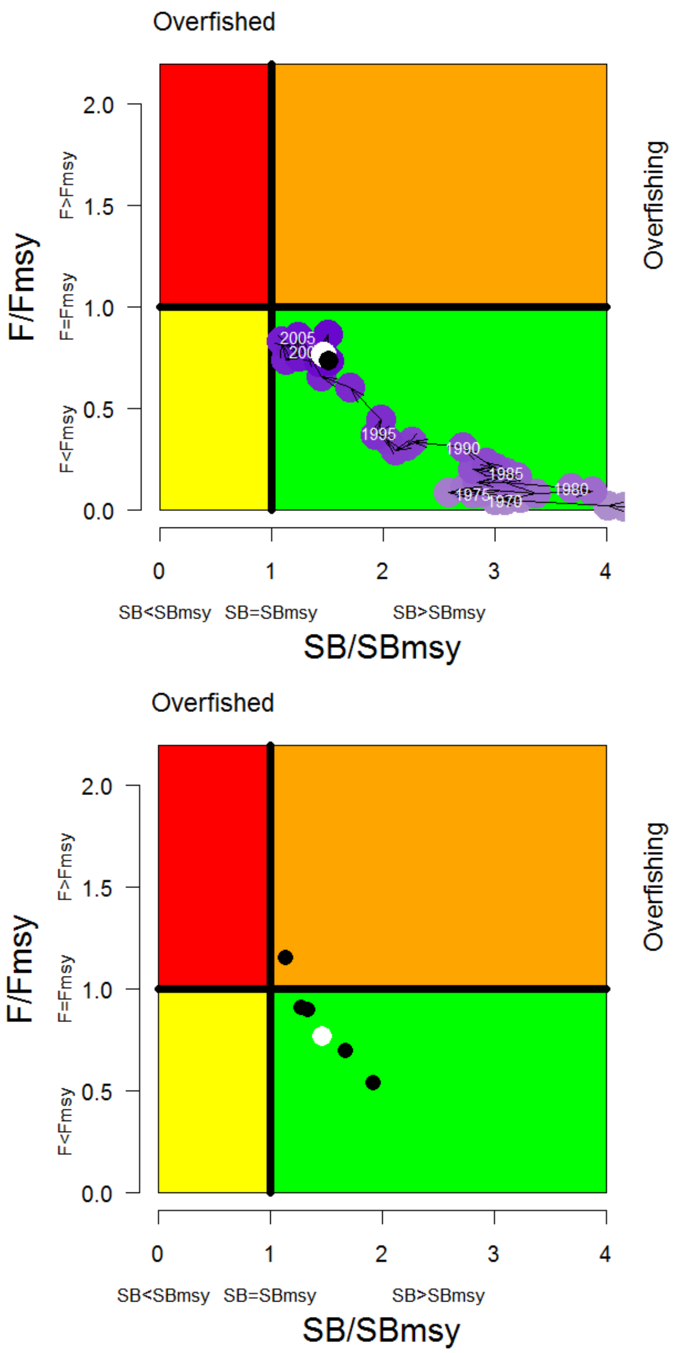


Figure 18: Temporal trend in annual stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the base case model (LLcpueOP_TWcpueR6_PTTP – H80pttp, the colour of the points is graduated from mauve (1972) to dark purple (2010) top) and $F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for the base case (white circle) and the five combinations of steepness and tagging data sets included. See Table 16 to determine the individual model runs.

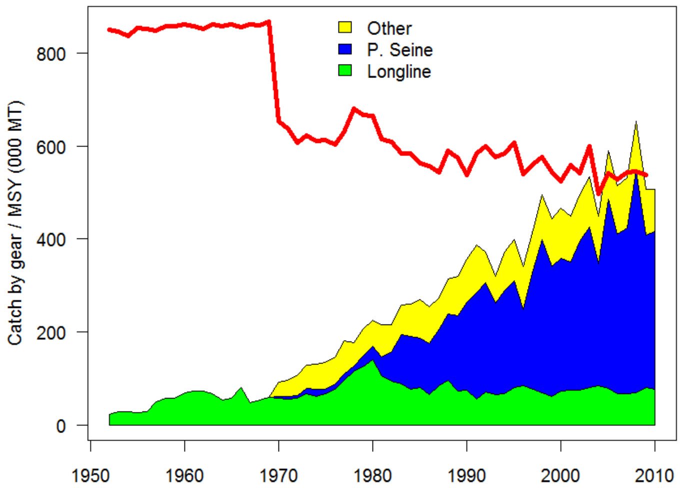


Figure 19: History of annual estimates of MSY compared with catches of three major fisheries sectors. Declining MSY results from the change in selectivity of fishing gear and increases in catches of small yellowfin.

Table 16. Estimates of management quantities for selected stock assessment models from the 2011 base case model LLcpueOP_TWcpueR6_PTTP (H80-pttp) and the five combinations of steepness and tagging data sets included. For the purpose of this assessment, "current" is the average over the period 2006–2009 and "latest" is 2010.

	H80-pttp (Base case)	H65-pttp	H95-pttp	H80-no pttp	H65- no pttp	H95- no pttp
	551 120	551 300	551 283	551 488	551 508	551 480
	507 100	507 443	507 358	508 329	508 398	508 286
	538 800	498 000	644 800	493 600	432 000	551 200
	1.02	1.11	0.85	1.12	1.28	1.00
	0.94	1.02	0.79	1.03	1.18	0.92
	1.30	1.10	1.84	1.11	0.87	1.44
	0.77	0.91	0.54	0.90	1.15	0.70
	2 001 000	2 272 000	2 145 000	2 035 000	2 108 000	1 984 000
	0.29	0.34	0.24	0.30	0.34	0.25
	0.42	0.43	0.45	0.40	0.39	0.41
	0.37	0.38	0.40	0.32	0.31	0.32
	1.47	1.28	1.92	1.34	1.14	1.67
	1.30	1.12	1.69	1.06	0.90	1.32
	0.44	0.47	0.47	0.40	0.40	0.40
	0.41	0.44	0.44	0.35	0.35	0.35
Steepness (*h*)	0.80	0.65	0.95	0.80	0.65	0.95

Table 17. Comparison of WCPO yellowfin tuna reference points from the 2011 reference case model (with uncertainty based on the six models in Table 16); the 2009 and 2007 assessments (across a range of models).

Management quantity	2011 assessment	2009 Assessment	2007 Assessment
Most recent catch	507 100	539 481 mt (2008)	426 726 mt (2006)
MSY	538 800 (432 000–644 800)	Range: 493 600 ~ 767 200 mt	Base case: 400 000 mt Range: 344 520 ~ 549 200 mt
$F_{current}/F_{MSY}$	0.77 (0.54–1.15)	Range: 0.41 ~ 0.85	Base case: 0.95 Range: 0.56 ~ 1.0
$B_{current}/B_{MSY}$	1.33 (1.12–1.54)	Range: 1.38 ~ 1.88	Base case: 1.17 Range: 1.13 ~ 1.42
$SB_{current}/SB_{MSY}$	1.47 (1.14–1.92)	Range: 1.44 ~ 2.43	Base case: 1.25 Range: 1.12 ~ 1.74
$Y_{Fcurrent}/MSY$	0.97 (0.88–0.99)	Range: 0.76 ~ 0.98	Base case: 1.0 Range: 0.88 ~ 1.0
$B_{current}/B_{current,\ F=0}$	0.53 (0.48–0.55)	Range: 0.53 ~ 0.63	Base case: 0.51 Range: 0.51 ~ 0.58
$SB_{current}/SB_{current,\ F=0}$	0.44 (0.40–0.47)		

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 longline catch per unit effort data, though there is no agreement on the best method to standardise these. Returns from a 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 trend in biomass for the WCPO is largely driven by the biomass trend from the tropics i.e. region 3 (Langley et al 2011) (http://www.wcpfc.int/). The ratios $B_{current}/B_{current\ F=0}$ provide a time-series index of population depletion by the fisheries. Depletion has increased steadily over time, reaching a level of about 53% of unexploited biomass (a fishery impact of 47%) in 2010. This represents a moderate level of stock-wide depletion. Overall, the impact of fishing has reduced the current total biomass in region 3 to about 42% of the unexploited level, while the current total WCPO biomass is sustained by the lower impacts outside of the equatorial regions. If stock-wide over-fishing criteria were applied at the level of the model regions, we would conclude that region 3 is fully exploited and the remaining regions are under-exploited.

The attribution of depletion to various fisheries or groups of fisheries indicates that the Philippines/Indonesian domestic fisheries and associated purse-seine fishery have the highest impact, particularly in region 3, while the unassociated purse seine fishery has a moderate impact. These fisheries are also contributing significantly to the fishery impact in all other regions. Historically, the coastal Japanese pole-and-line and purse-seine fisheries have had a significant impact on biomass levels in their home region (1). Overall, the longline fishery has a relatively small impact, less than 5%.

5.3 Yield estimates and projections

No estimates of MCY and CAY are available.

5.4 Other yield estimates and stock assessment results

Although no reference points have yet been agreed by the WCPFC, stock status conclusions are generally presented in relation to two criteria. The first reference point relates to ―overfished" which compares the current biomass level to that necessary to produce the maximum sustainable yield (MSY). The second relates to ―over-fishing" which compares the current fishing mortality rate to that which would move the stock towards a biomass level necessary to produce the MSY. The first criteria is similar to that required under the New Zealand Fisheries Act while the second has no equivalent in our legislation and relates to how hard a stock can be fished.

Because recent catch data are often unavailable, these measures are calculated based on the average fishing mortality/biomass levels in the ‗recent past', e.g., 2006–2009 for the 2011 assessment.

The estimate of MSY is lower than recent catches in some model runs. This is due to high fishing mortality and fishing down the stock towards B_{MSY}-levels. The SB ratio larger than 1.0 indicates that the stock is not in an overfished state. The ratio of $F_{current}$ compared with F_{MSY} (the fishing mortality level that would keep the stock at MSY) is less than 1.0 indicating that overfishing is not occurring.

5.5 Other factors

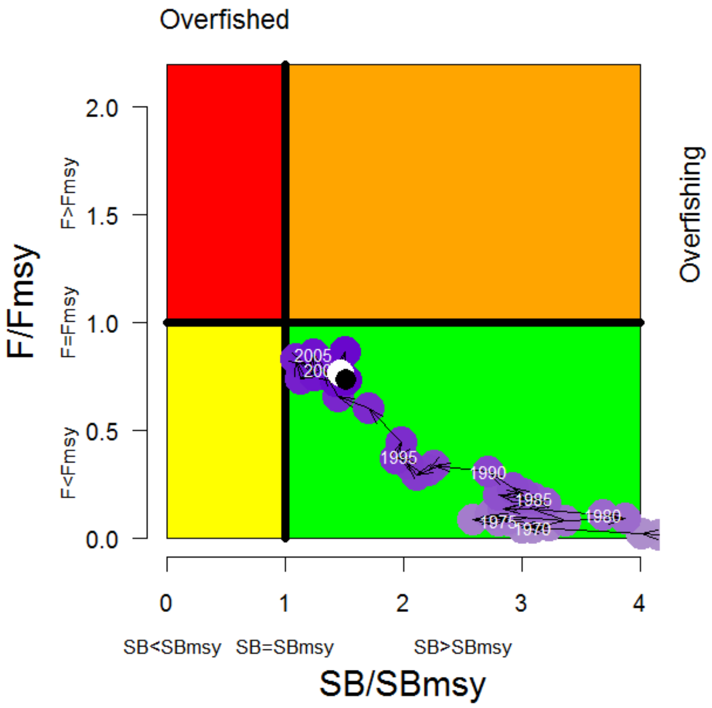
It is thought that large numbers of small yellowfin tuna are taken in surface fisheries in Indonesia and the Philippines. There are considerable uncertainties in the exact catches and these lead to uncertainties in the assessment. Programmes are in place to improve the collection of catch statistics in these fisheries.

6. STATUS OF THE STOCKS

Stock structure assumptions
Western and Central Pacific Ocean
All biomass in this Table refer to spawning biomass (SB)

Stock Status	
Year of Most Recent Assessment	2011
Assessment Runs Presented	Base case model only
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	Likely (> 60%) that SB is at or above SB_{MSY} and Likely (> 60%) that $F < F_{MSY}$
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. The colour of the points is graduated from mauve (1972) to dark purple (2010). The black circle represents the B_{2010}/B_{MSY} and the F_{2010}/F_{MSY} the white circle represents the $B_{2006\text{-}2009}/B_{MSY}$ and $F_{2006\text{-}2009}/F_{MSY}$ (Langley et al 2011).

Fishery and Stock Trends	
Recent trend in Biomass or Proxy	Biomass has been reduced steadily over time reaching a level of about 53% of unexploited biomass in 2005–2009. However, depletion is considerably higher in the equatorial regions 3 and 4 where biomass is estimated to have declined to about 17% of the level that is estimated to occur in the absence of fishing.
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 but for lower values of steepness is approaching F_{MSY}.
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	Recent (1998–2009) levels of estimated recruitment are considerably lower (80%) than the long-term average level of recruitment used to calculate the estimates of MSY. If recruitment remains at recent levels, then the overall yield from the fishery will be lower than the current MSY estimates.

Projections and Prognosis	
Stock Projections or Prognosis	Region 3 (the tropical WPO) is fully exploited and the remaining regions are under-exploited. Future stock trends are uncertain due to exploitation patterns and recruitment autocorrelation.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)

Probability of Current Catch or TACC causing Overfishing to continue or commence	Unlikely (< 40%)	
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: 2011	Next assessment: 2014
Overall assessment quality rank	1 - High Quality	
Main data inputs (rank)	The yellowfin tuna model is age (28 age-classes) and spatially structured (6 regions) and the catch, effort, size composition and tagging data used in the model are classified by 24 fisheries and quarterly time periods from 1952 through 2009.	1 - High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	While the structure of the assessment model was similar to the previous (2009) assessment, there were some substantial revisions to a number of key data sets, specifically the longline CPUE indices, catch and size data, purse-seine catch and size data, and the configuration of the Indonesian and Philippines domestic fisheries.	
Major Sources of Uncertainty	-	

Qualifying Comments
The biomass trends in the model are principally driven by the time-series of catch and GLM standardised effort from the principal longline fisheries. The current assessment incorporated a revised set of longline CPUE indices and, for some model options, the indices were modified to account for an estimate increase in longline catchability. Further research is required to explore the relationship between longline CPUE and yellowfin abundance and the methodology applied to standardise the longline CPUE data. The spawning biomass in region 3 is estimated to have been reduced to approximately 30% of the unexploited level; however, due to the lower overall depletion of the entire WCPO stock, the model assumes that there has been no significant reduction in the spawning capacity of the stock.

Fishery Interactions
Interactions with protected species are known to occur in the longline fisheries of the South Pacific, particularly south of 25^{o}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).

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ISBN: 978-0-478-42310-5 (print)
ISBN: 978-0-478-42309-9 (online)

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