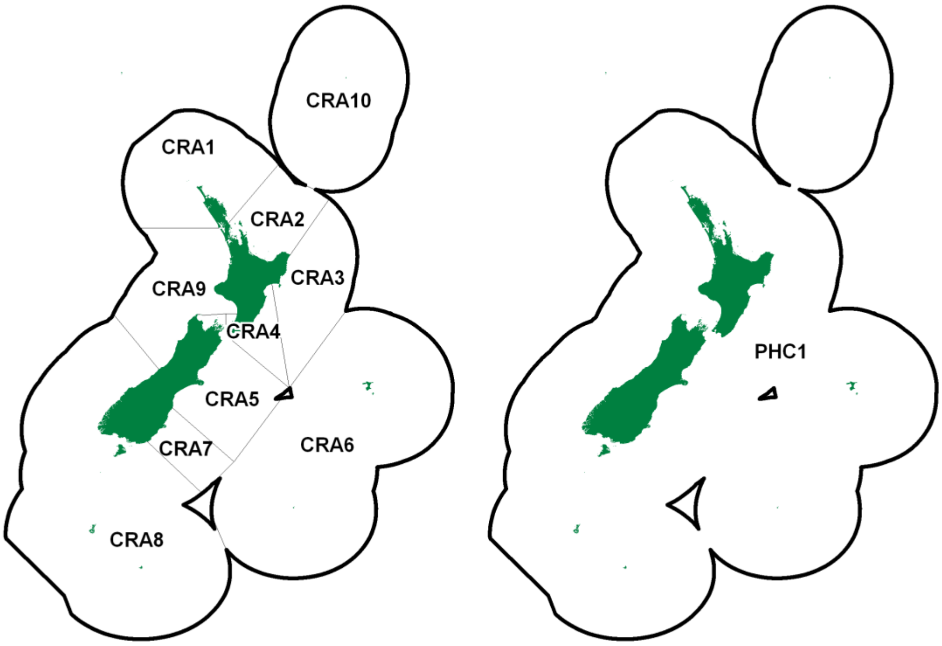
ROCK LOBSTER (CRA and PHC)

(*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.

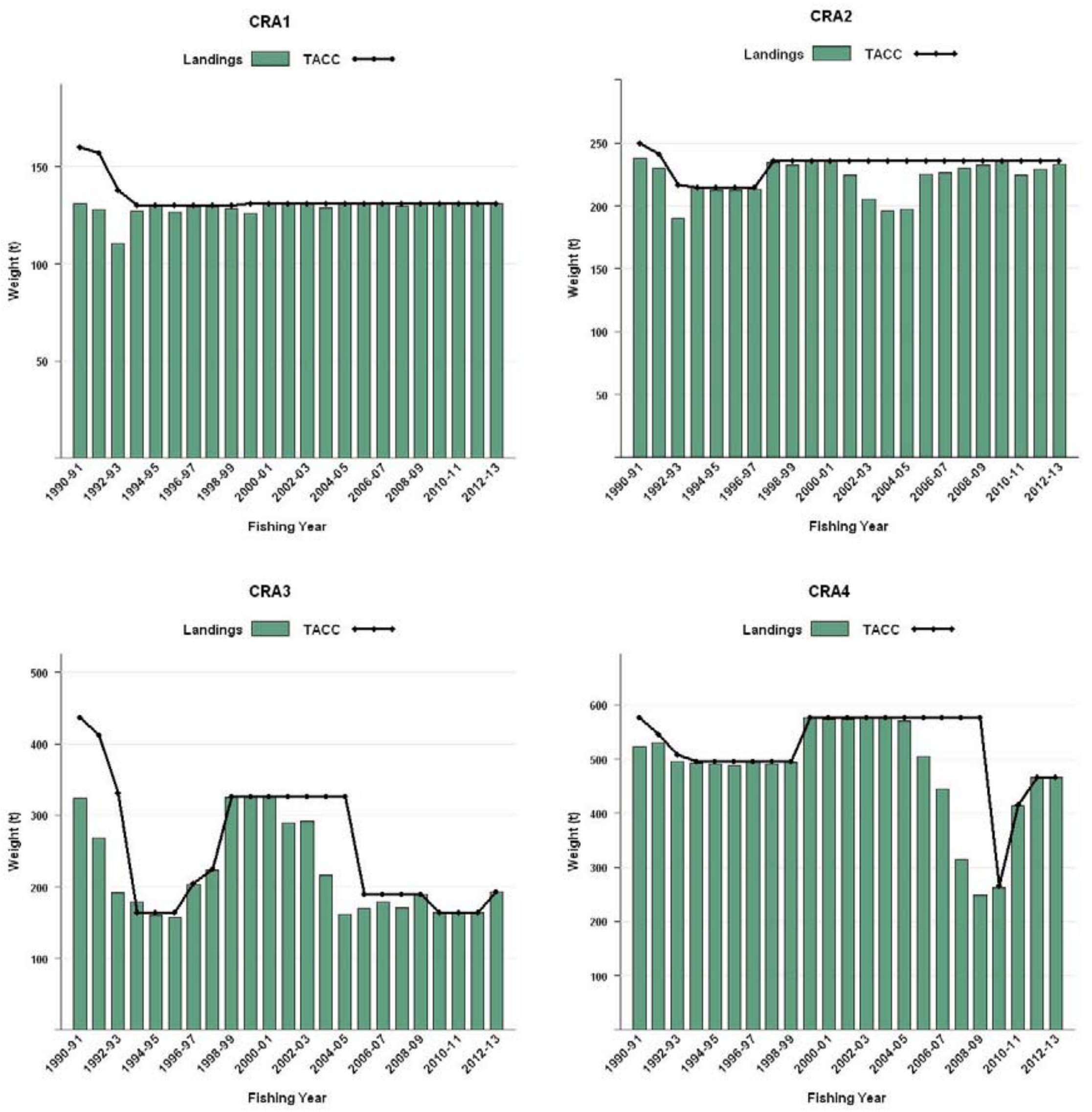


Figure 1: Historical landings and TACC for the 9 main CRA stocks and PHC 1. [Figure continued on next page].

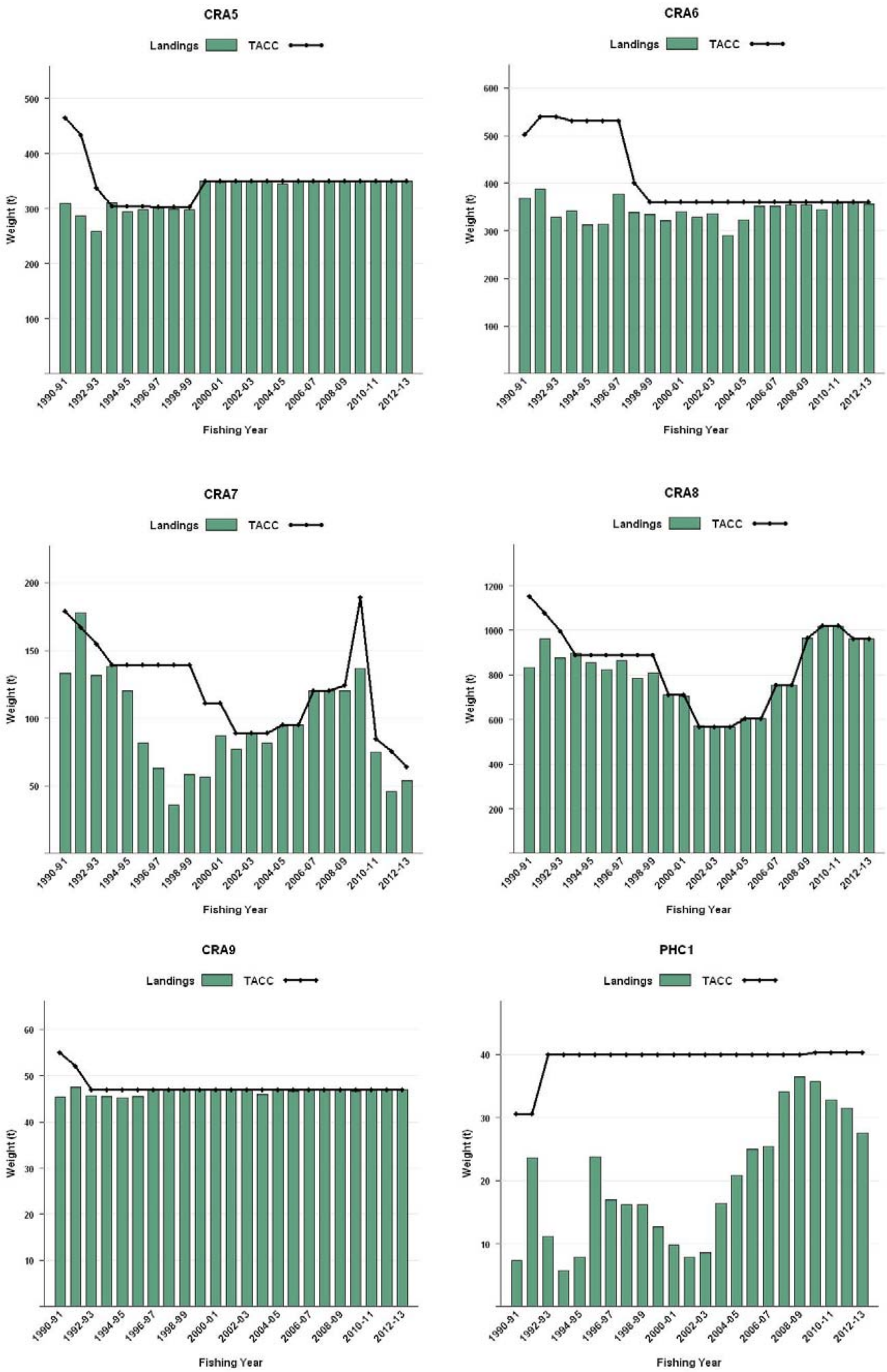


Figure 1 [Continued]: Historical landings and TACC for the 9 main CRA stocks and PHC 1.

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			Total		
	Catch	TACC	TAC	Catch[1]	TACC[1]	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.

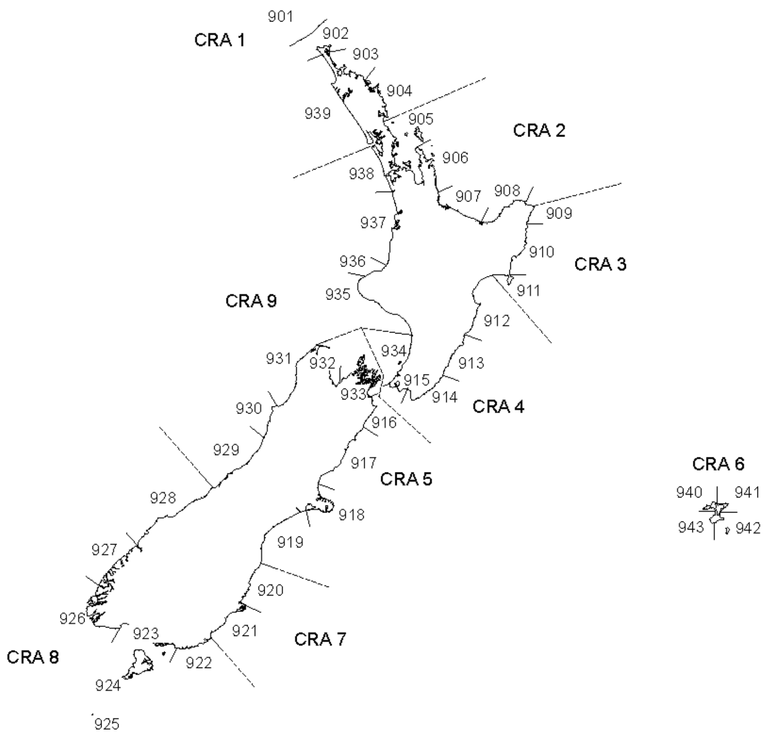


Figure 2: Rock lobster statistical areas as reported on CELR forms.

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.

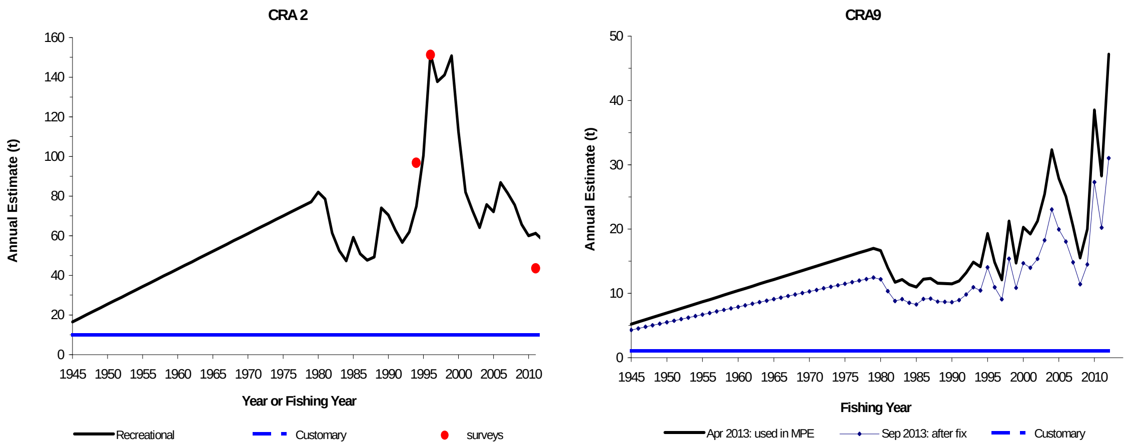


Figure 3. Recreational (grey) and customary (blue) catch trajectories (kg) for the 2013 stock assessment of CRA 2 [left panel] and Management Procedure Evaluation of CRA 9 [right panel]. Section 111 catches have been added to each recreational catch trajectory. Recreational catches were made proportional 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 $\bar{P}_q$ relative to the reported QMA commercial catches is used in each CRA QMA to estimate illegal catches prior to 1990: $I_{q,y} = \bar{P}_q C_{q,y}$ if $y<1974 \| \left(y>1980 \& y<1990\right)$.

Year	Estimates of total export discrepancies (t) I_y	QMA	$\bar{P}_q = \sum_{y=1974}^{1980} I_{q,y} \Big/ \sum_{y=1974}^{1980} C_{q,y}$
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.

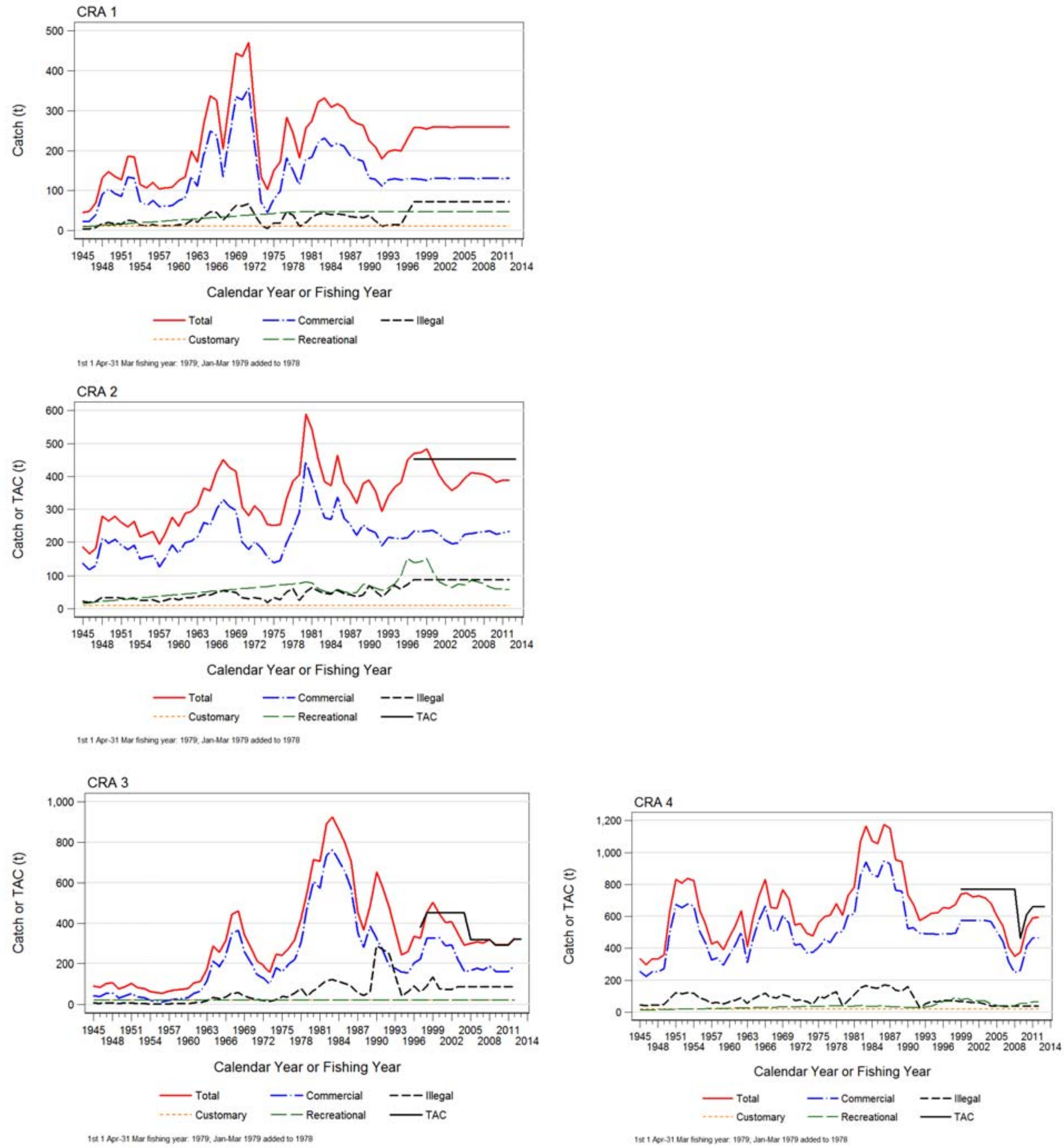
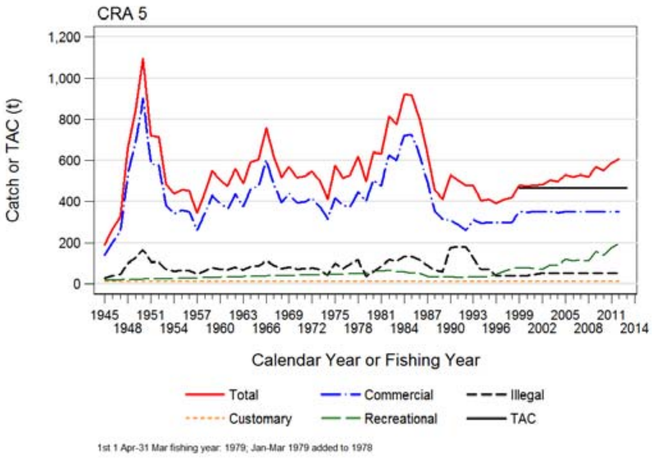
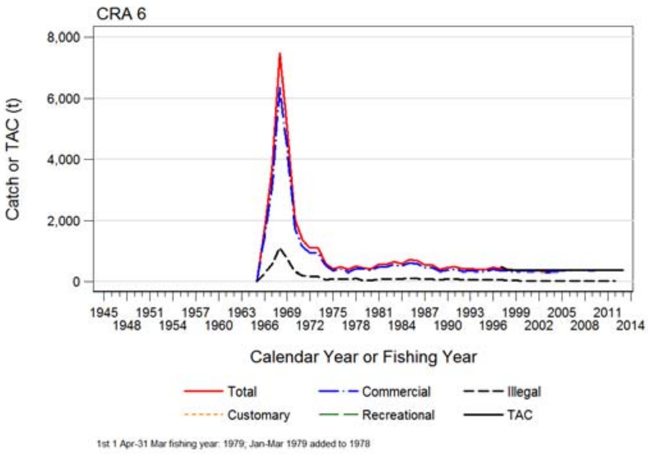
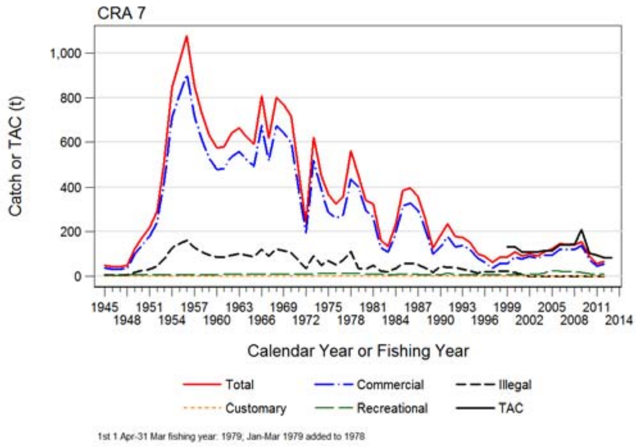
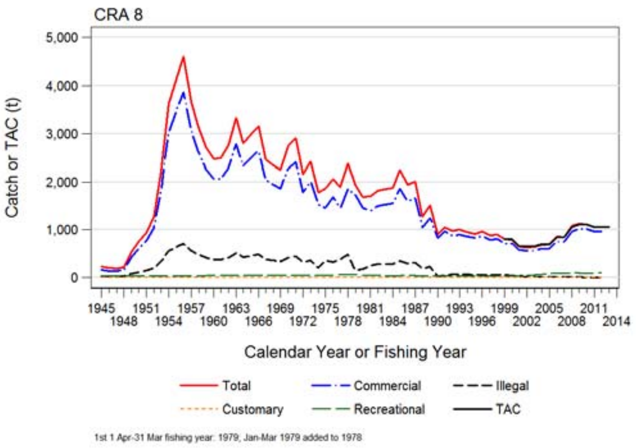


Figure 4: Catch trajectories (t) from 1945 to 2011 and TACs (if in place) from the year of establishment to 2012 for CRA 1 to CRA 9, showing current best estimates for commercial, recreational, customary and illegal categories. Also shown is the sum of these four catch categories. Note that calendar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









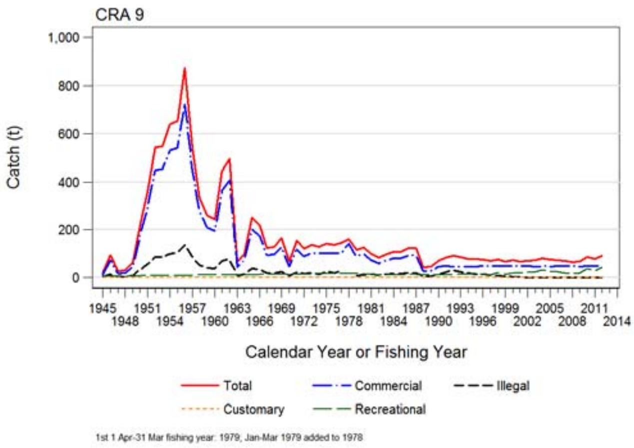


Figure 4 [Continued]: Catch trajectories (t) from 1945 to 2011 and TACs (if in place) from the year of establishment to 2012 for CRA 1 to CRA 9.

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

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

   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.

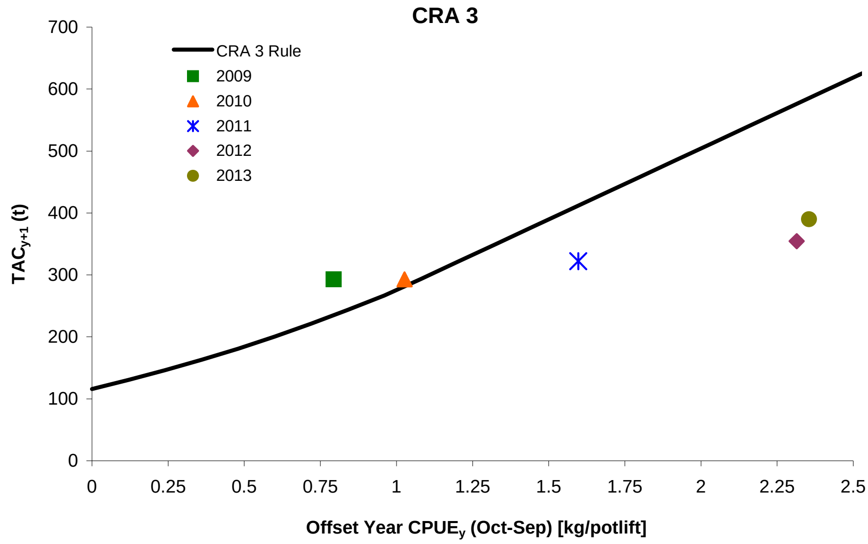


Figure 5: The CRA 3 management procedure, showing the provisional TAC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACs resulting from the rule evaluations performed in 2009 through 2013 for the 2010–11, 2011–12, 2012–13, 2013-14 and 2014–15 fishing years.

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	–	–

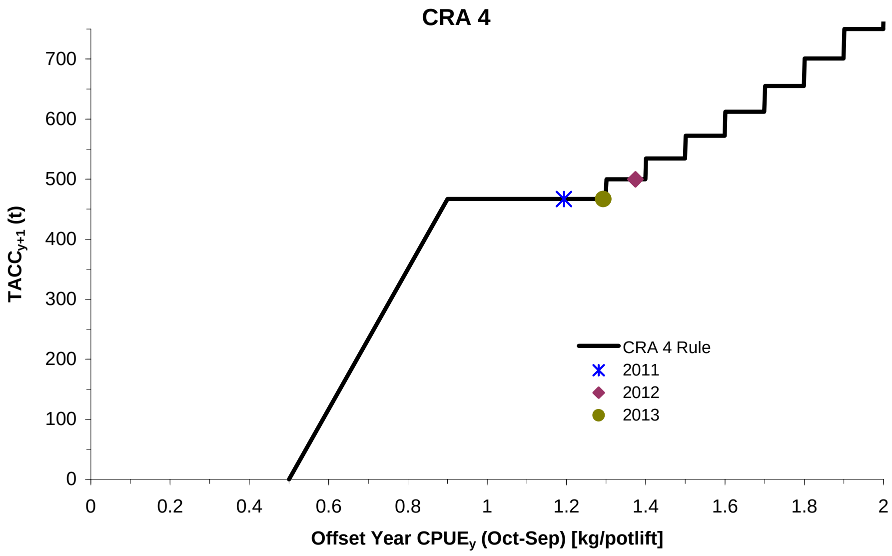


Figure 6: The CRA 4 management procedure, showing the TACC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACCs resulting from the rule evaluations performed in 2011, 2012 and 2013 for the 2012–13, 2013–14 and 2014–15 fishing years.

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

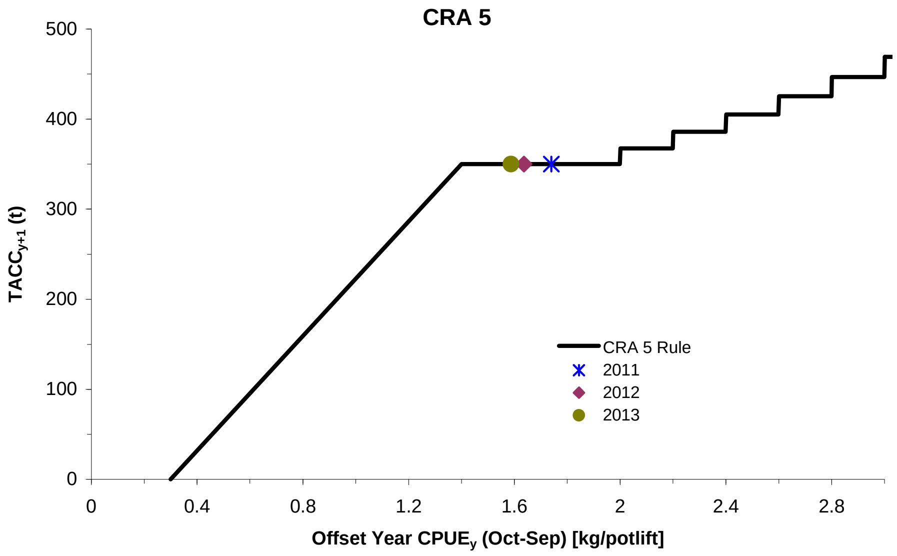


Figure 7: The CRA 5 management procedure, showing the TACC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACCs resulting from the rule evaluations performed in 2011, 2012 and 2013 for the 2012–13, 2013-14 and 2014–15 fishing years.

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 $TACC_{y+1} = par2 \frac{I_y - par5}{par3 - par5}$ **for** $par5 < I_y < par3$

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

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

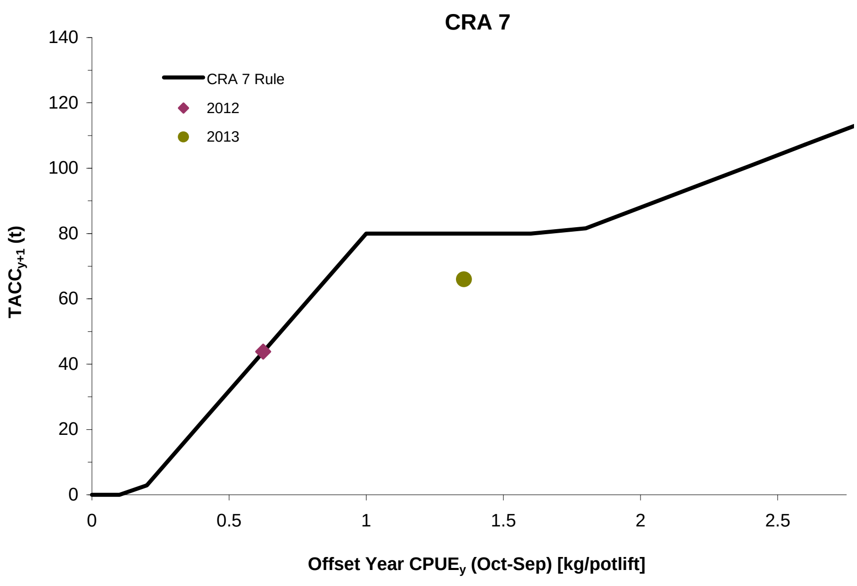


Figure 8: The CRA 7 management procedure, showing the TACC as a function of offset year CPUE, and showing TACCs resulting from the rule evaluations performed in 2012 and 2013 for the 2013-14 and 2014–15 fishing years.

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 $$TACC_{y+1} = 0 \qquad \text{for } I_y < par5$$

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

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

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

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

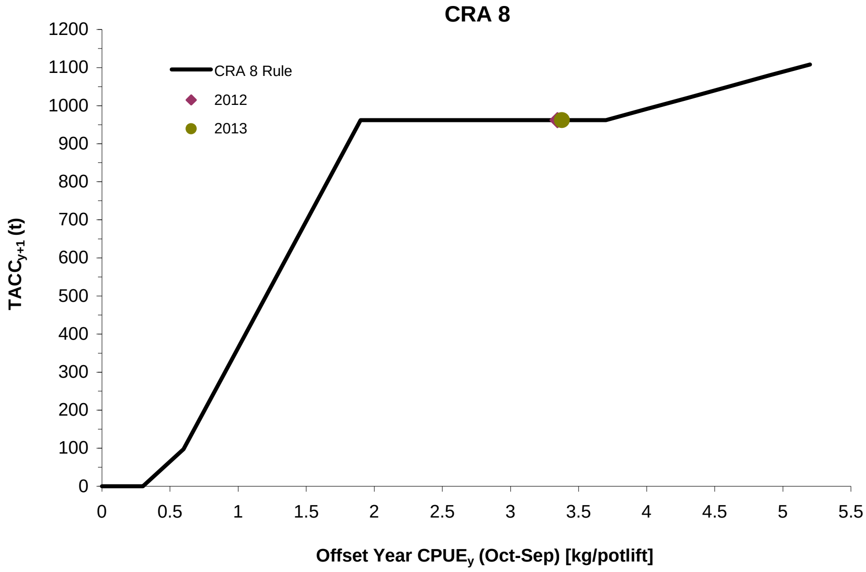


Figure 9: The new Rule 13 CRA 8 management procedure, showing TACCs resulting from the rule evaluations performed in 2012 and 2013 for the 2013-14 and 2014–15 fishing years.

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.

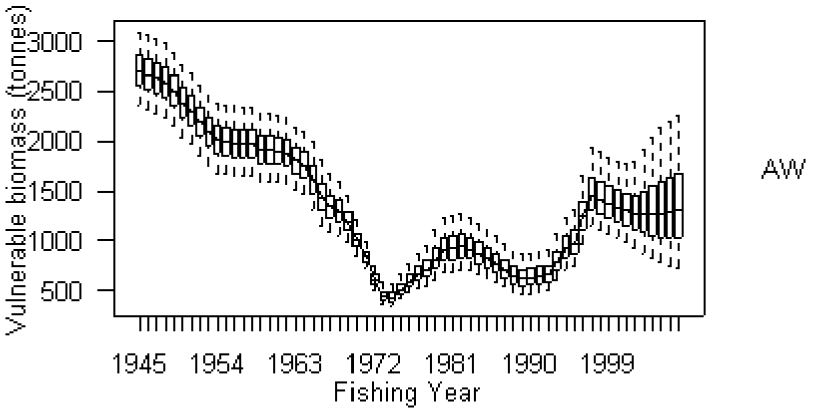
$USL_{02,AW}$ is the exploitation rate for catch taken from the SL vulnerable biomass in the autumn-winter season of 2002–03, and $USL_{06,AW}$ is the exploitation rate for catch taken from the SL vulnerable biomass in the autumn-winter season of 2006–07, the last year of projections. $UNSL_{02,AW}$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



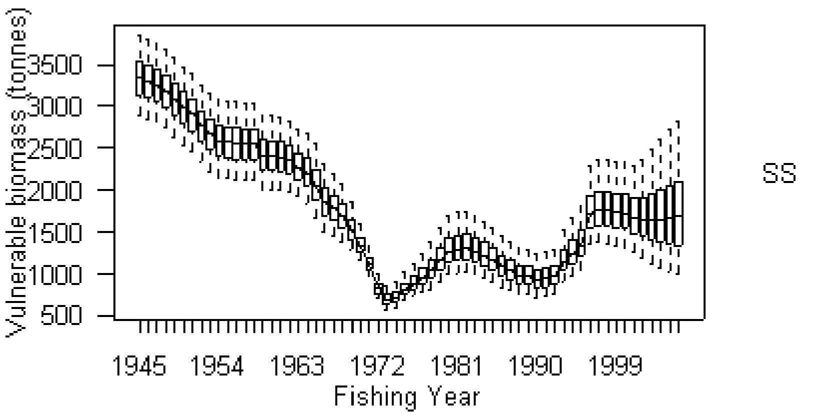


Figure 10: CRA 1: posterior trajectories of vulnerable biomass, for the AW (top) and SS (bottom) seasons, from the CRA 1 base case MCMC simulations. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.

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*.

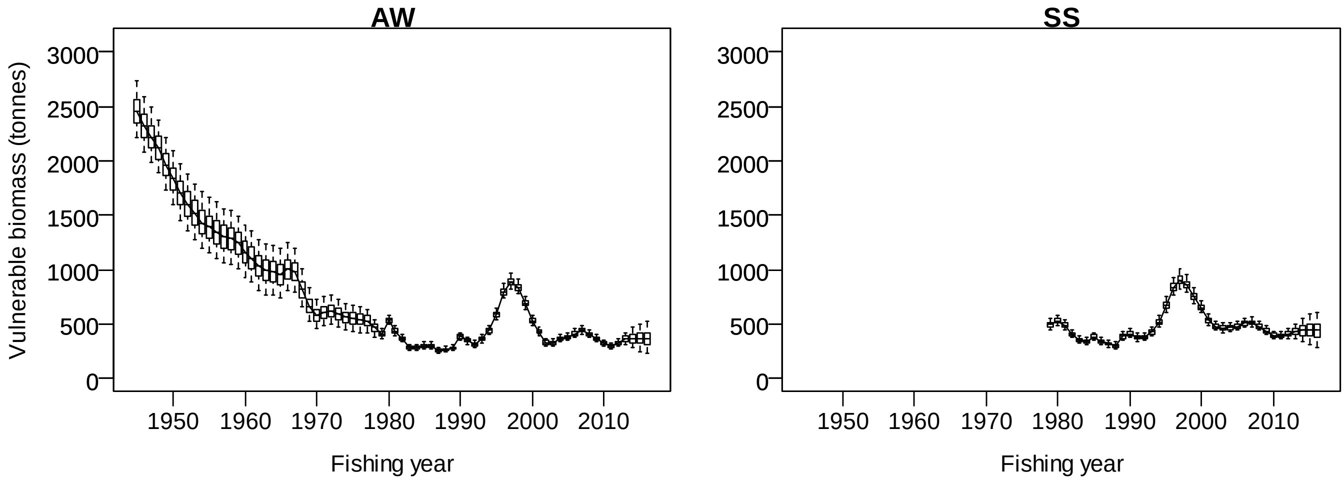


Figure 11: Posterior distributions of the CRA 2 base case McMC vulnerable biomass trajectory by season. Before 1979 there was a single time step, shown in AW. For each year the box spans the 25th and 75th quantiles and the whiskers span the 5th and 95th quantiles.

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.

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

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*.

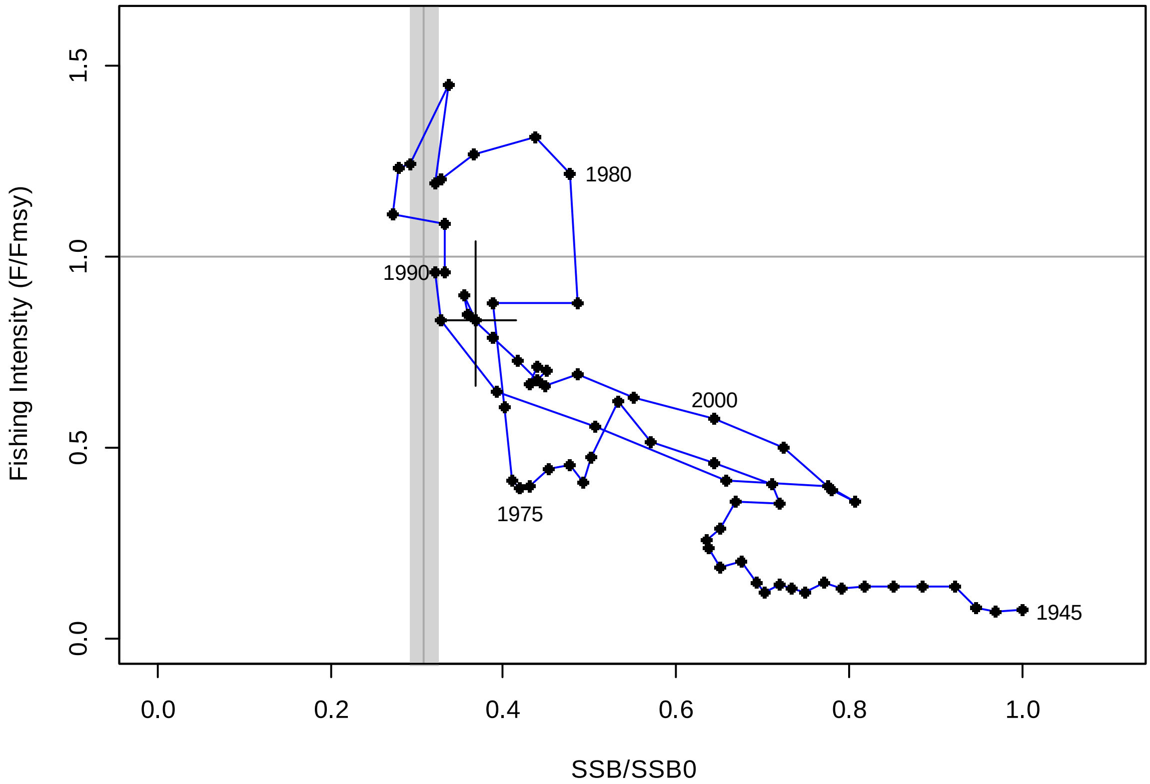


Figure 12: Phase plot that summarises the *SSB* history of the CRA 2 stock. The x-axis is spawning stock biomass *SSB* in each year as a proportion of the unfished spawning stock, *SSB0*. The y-axis is fishing intensity in each year as a proportion of the fishing intensity (*Fmsy*) that would have given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

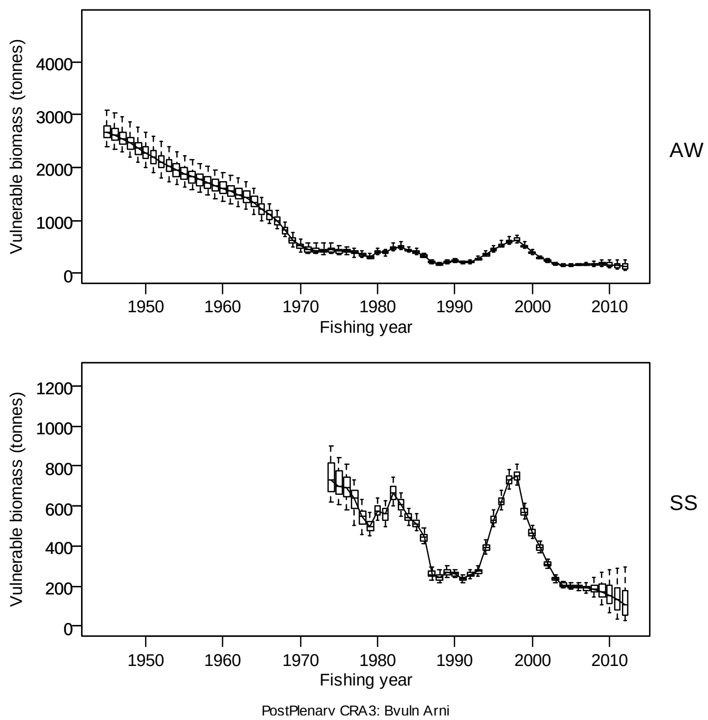


Figure 13: The posterior trajectory of vulnerable biomass, by season, from the CRA 3 base case McMC simulations, including the projections from 2008-12. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.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

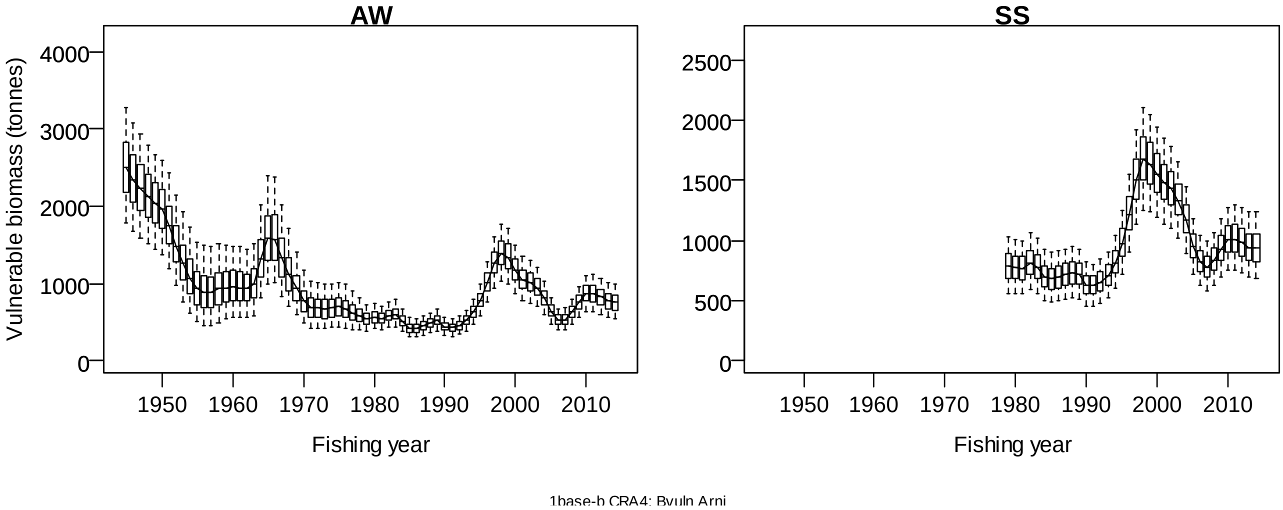


Figure 14: Posterior distributions of the CRA 4 base case McMC biomass vulnerable trajectory. Before 1979 there was a single time step, shown in AW. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th quantiles.

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.

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

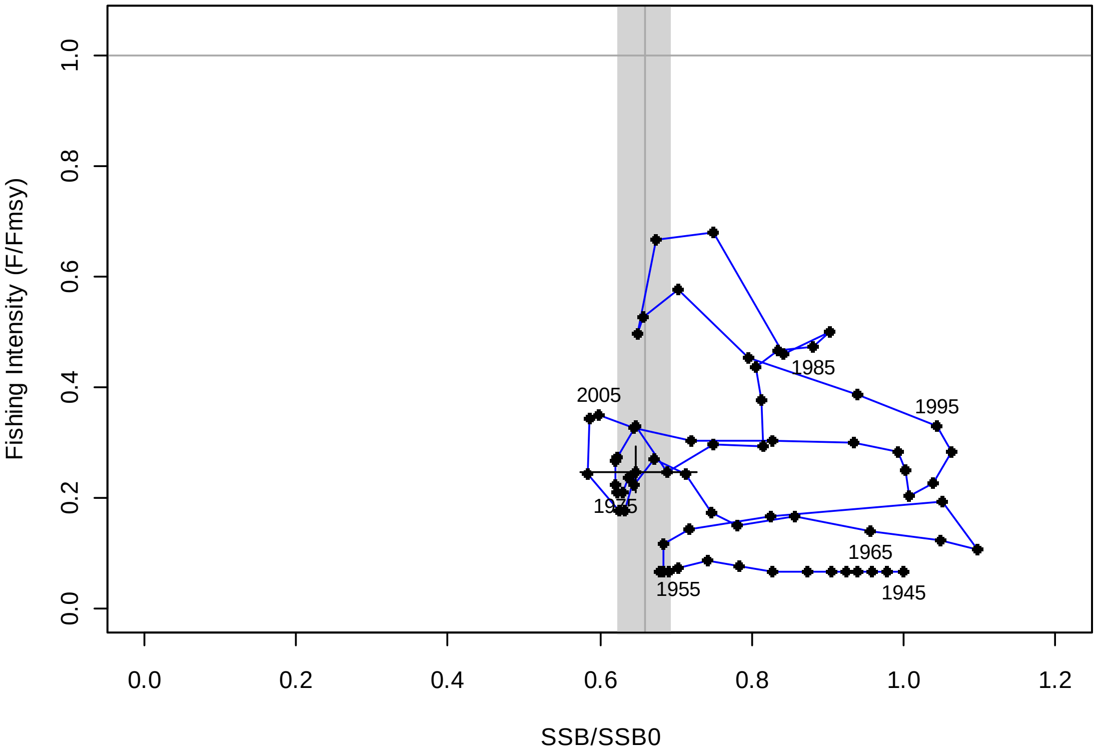


Figure 15: Phase plot that summarises the *SSB* history of the CRA 4 stock. The x-axis is spawning stock biomass *SSB* in year *y* as a proportion of the unfished spawning stock, *SSB0*. *SSB0* is constant for all years of a run, but varies through the 1000 runs. The y-axis is fishing intensity in year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

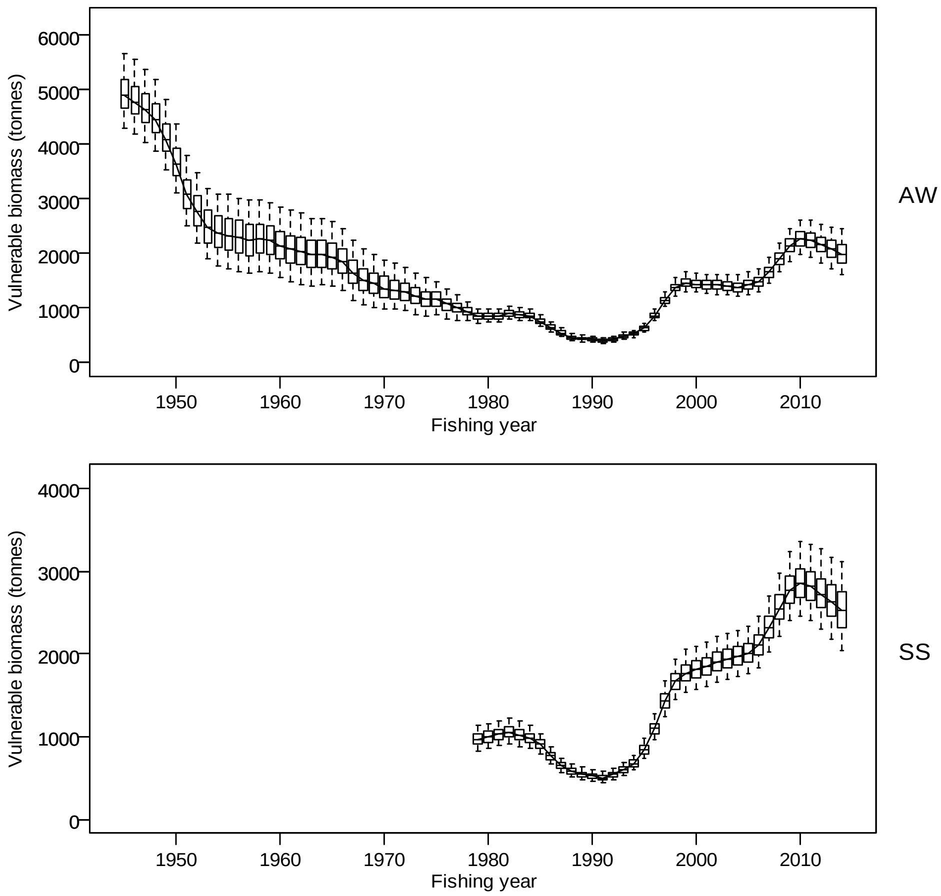


Figure 16: Posterior distributions of the base case McMC biomass vulnerable trajectory. Before 1979 there was a single time step, shown in AW. Projected catches were scenario 1 (Table 43). For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th quantiles.

<u>Indicators based on vulnerable biomass (AW) and *Bmsy*</u>
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.

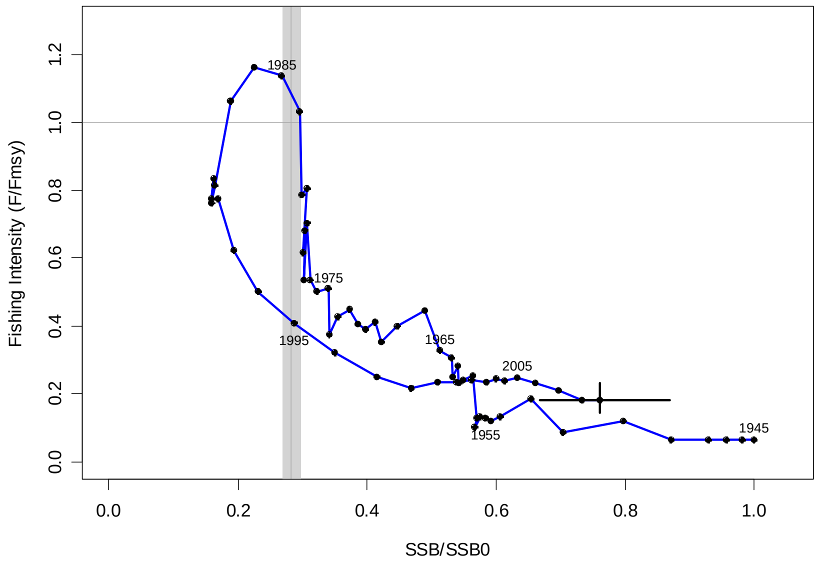


Figure 17: Phase plot that summarises the history of the CRA 5 fishery. The x-axis is the spawning biomass (SSB) as a proportion of B0 (SSB0); the y-axis is the ratio of the fishing intensity (F) relative to Fmsy. Each point is the median of the posterior distributions, and the bars associated with 2009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

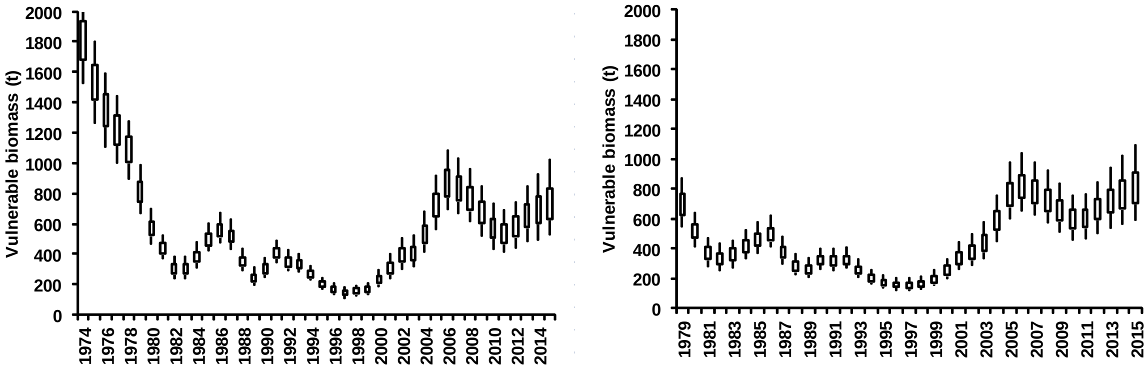


Figure 18: Posterior distributions of the CRA 7 base case McMC vulnerable biomass trajectory. Before 1979 there was a single time step, shown in AW. For each year the box spans the 25th and 75th quantiles and the whiskers span the 5th and 95th quantiles.

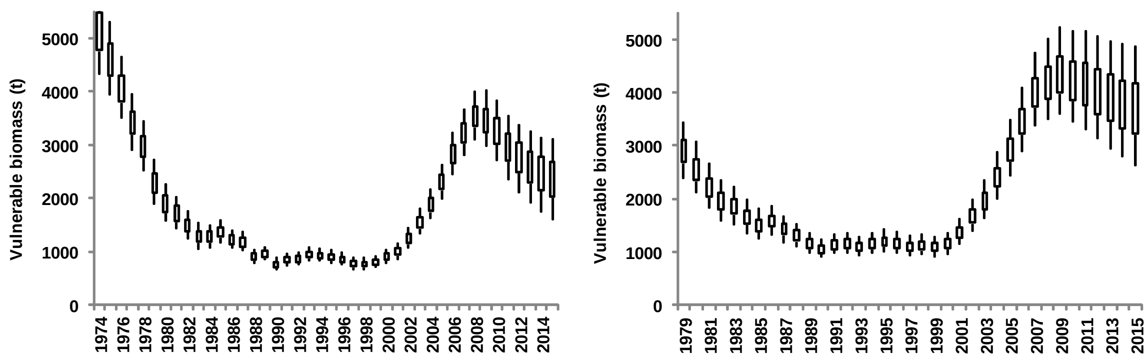


Figure 19: Posterior distributions of the CRA 8 base case McMC vulnerable biomass trajectory. Before 1979 there was a single time step, shown in AW. For each year the box spans the 25th and 75th quantiles and the whiskers span the 5th and 95th quantiles.

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.

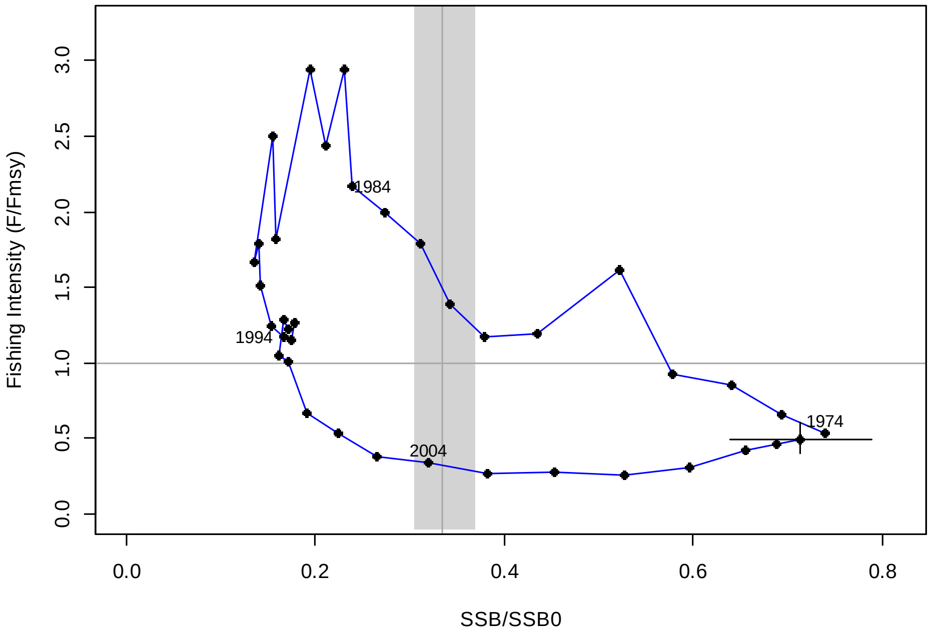


Figure 20: Phase plot that summarises the *SSB* history of the CRA 8 stock. The x-axis is spawning stock biomass *SSB* in each year as a proportion of the unfished spawning stock, *SSB0*. *SSB0* is constant for all years of a run, but varies through the 1000 runs. The y-axis is fishing intensity in each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

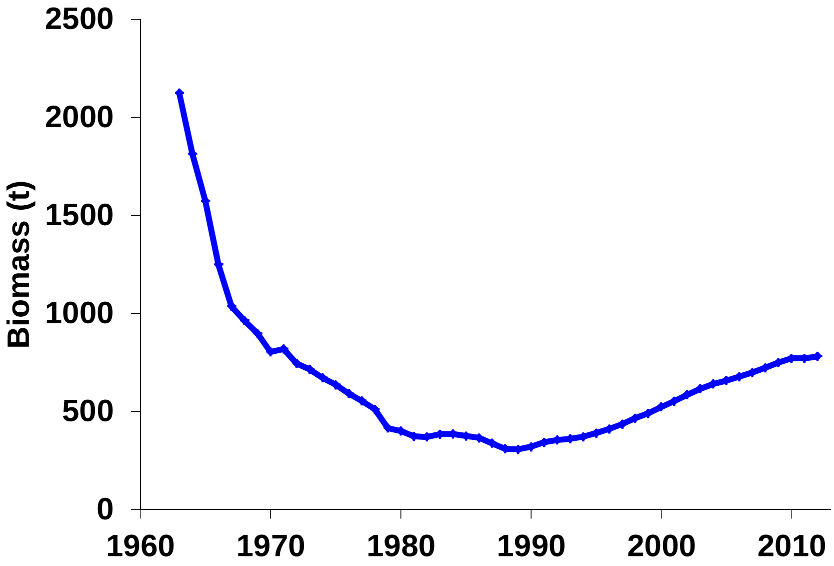


Figure 21: CRA 9 biomass from the base case MPD.

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

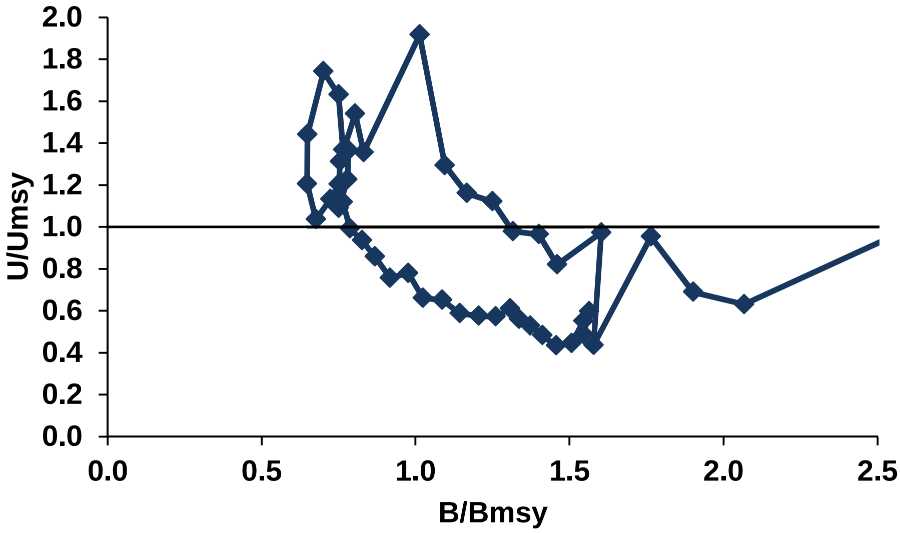


Figure 22: Phase plot of the CRA 9 fishery: the x-axis is the mean of the posterior distribution of biomass as a proportion of *Bmsy*; the y-axis is the mean of the posterior of exploitation rate as a proportion of equilibrium exploitation rate at *Bmsy*; the horizontal line is 1.0 (equilibrium exploitation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

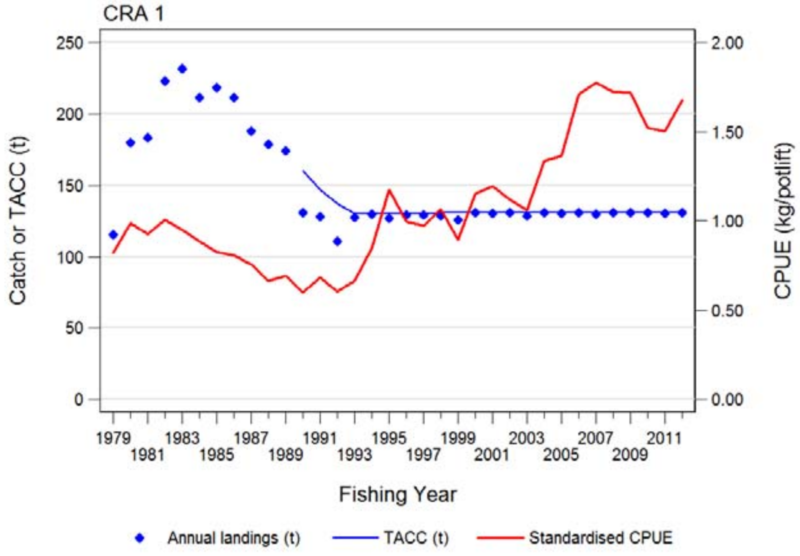
For the purposes of stock assessment and management, rock lobsters are assumed to constitute separate Fishstocks within each CRA quota management area. There is likely to be some degree of relationship and/or exchange between Fishstocks in these CRA areas, either as a result of migration, larval dispersal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

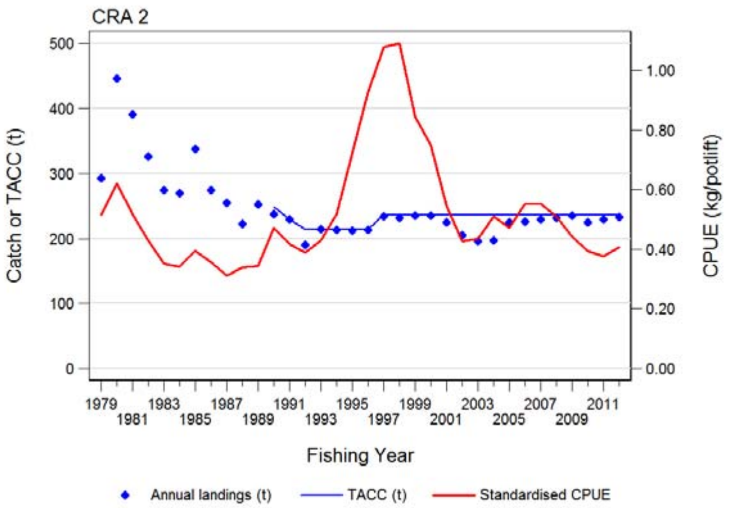
Qualifying Comments
CPUE rose nearly 50% after the 2002 assessment to the highest in the series in 2008, and has remained high since.

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.

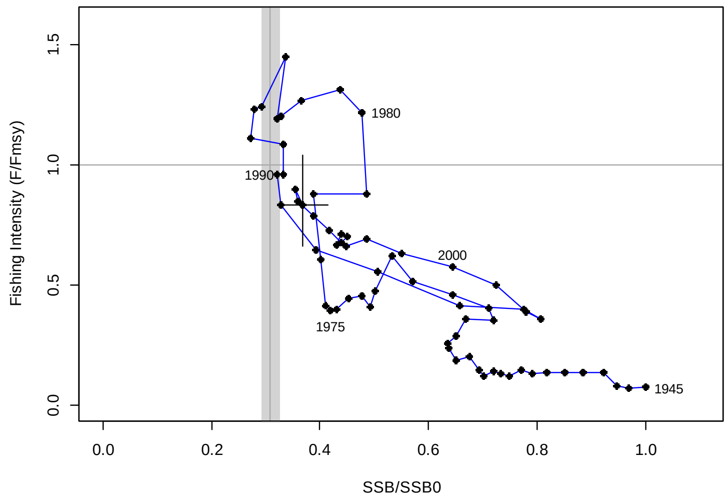
CRA 2 Bay of Plenty

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	-

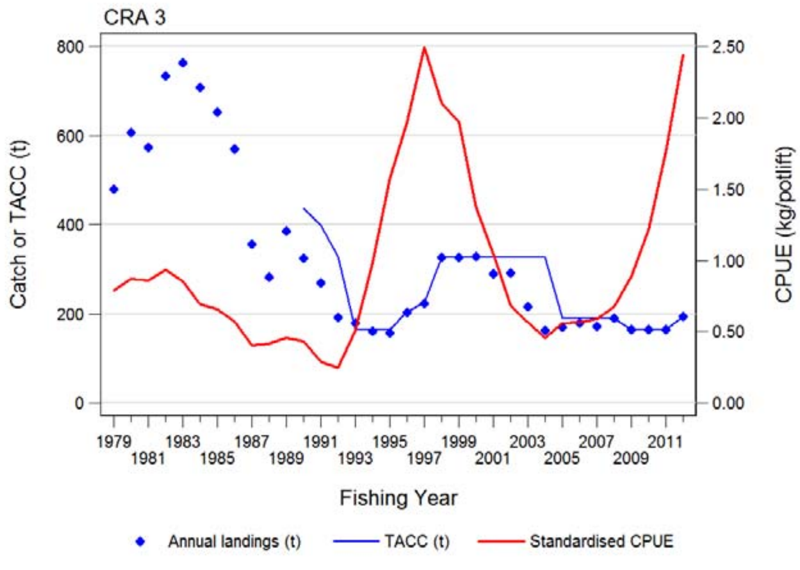
Projections and Prognosis		
Stock Projections or Prognosis	4-year projections conducted in 2013 using 2012 levels of commercial, customary, non-commercial and illegal catches showed that the stock would remain at a similar level.	
Probability of Current Catch or TACC causing Biomass to remain below or 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	

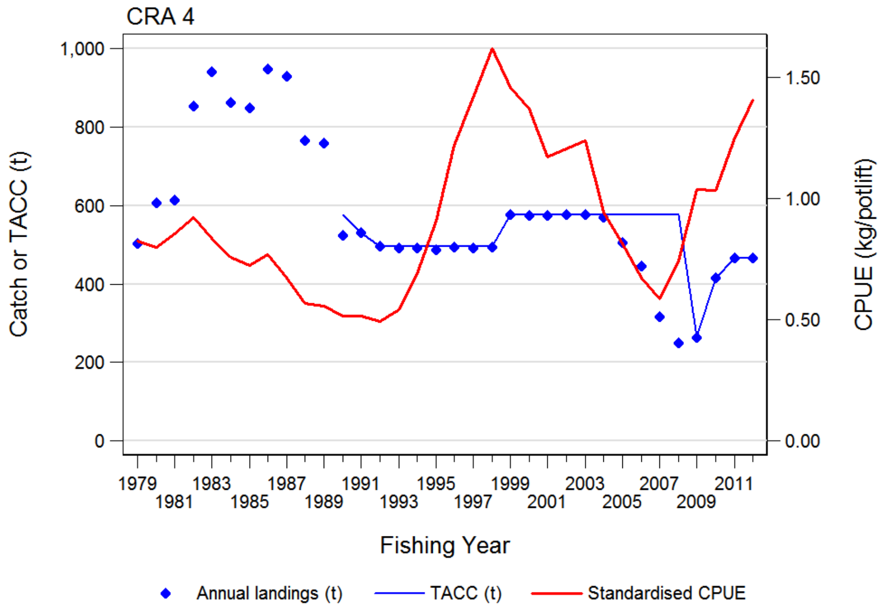
Qualifying Comments
A management procedure has been developed that is used to manage the fishery.

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

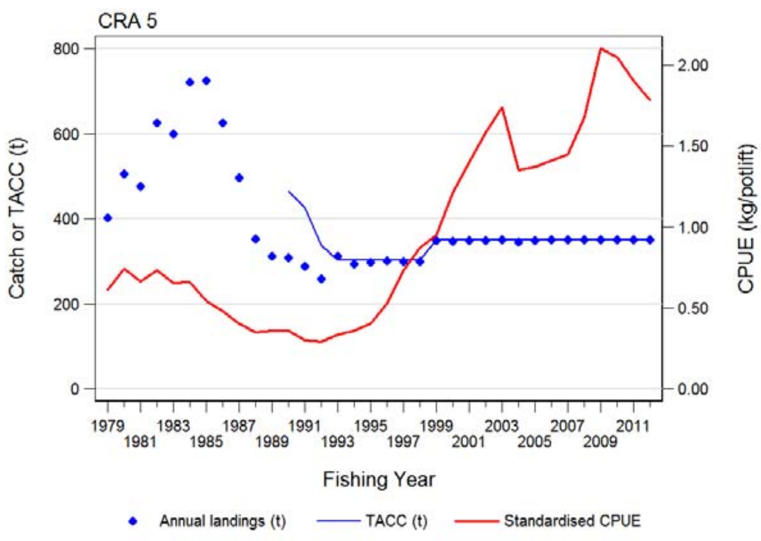
Qualifying Comments
A management procedure has been developed that is used to manage the fishery.

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.

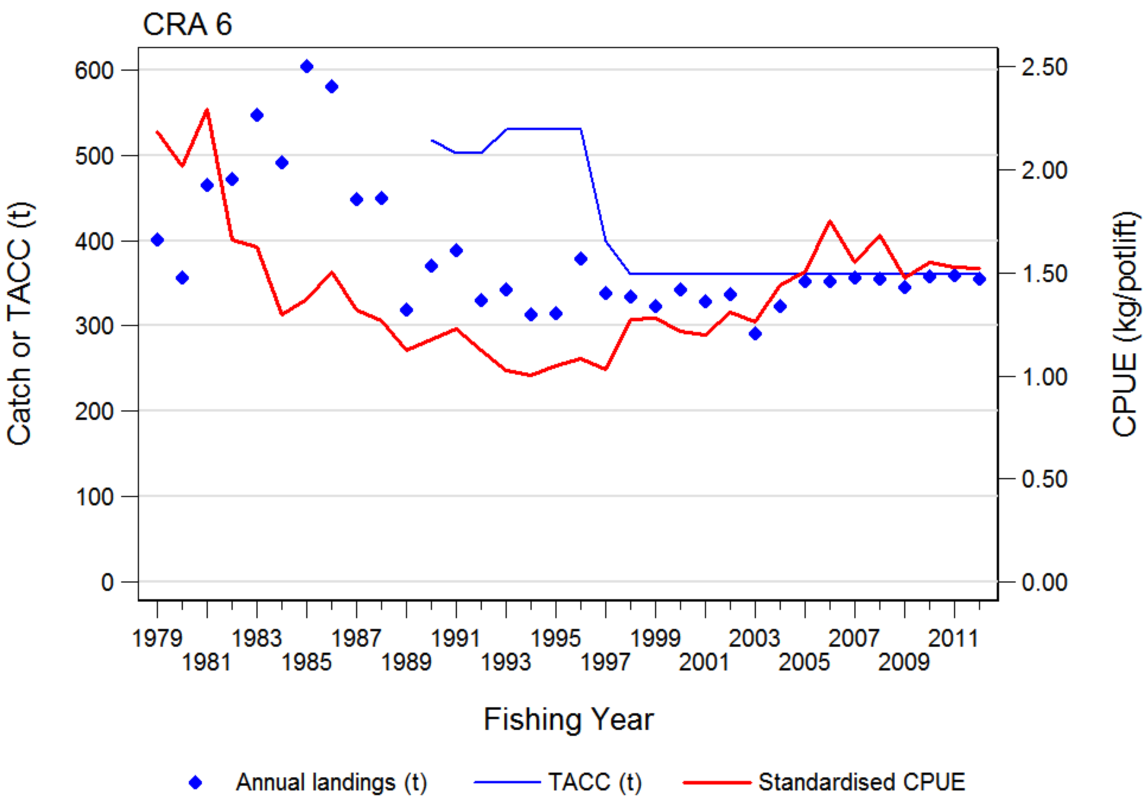
Recent developments in stock status
CPUE dropped in 2010 and 2011 from 2009, the highest point in the series.
Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have very little direct effect on non-target species. For all QMAs, the most frequently reported incidental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

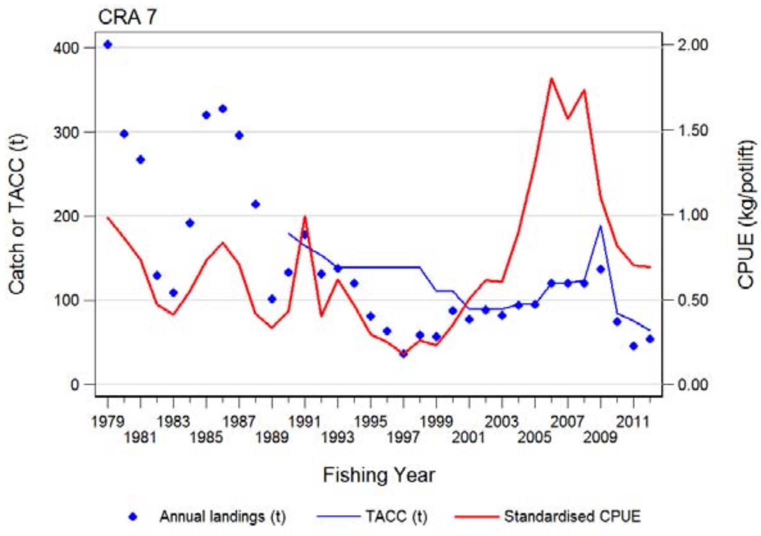
Qualifying Comments
-

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

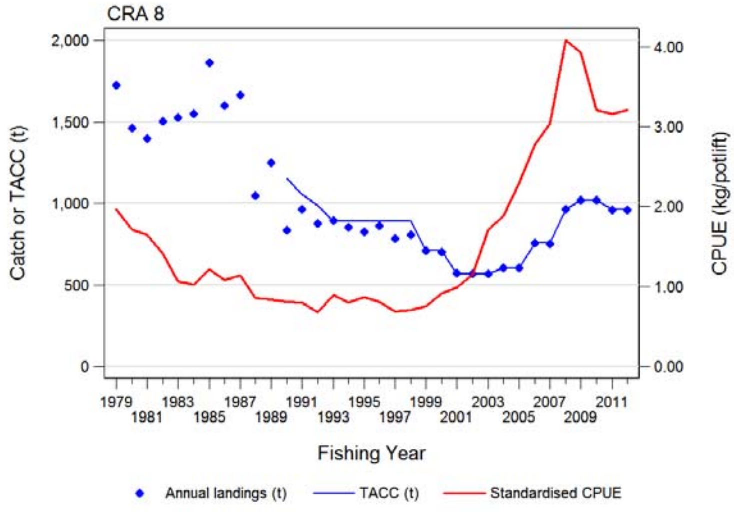
Qualifying Comments
A management procedure has been developed that is used to manage the fishery

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.

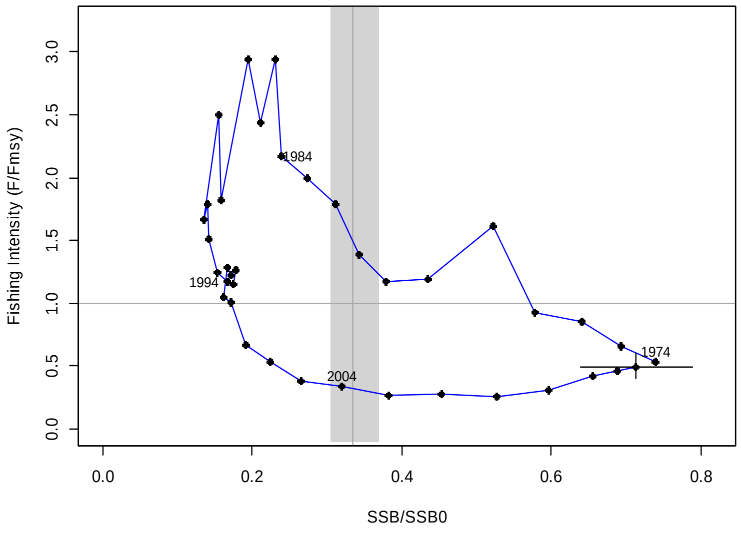
CRA 8 Southern

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

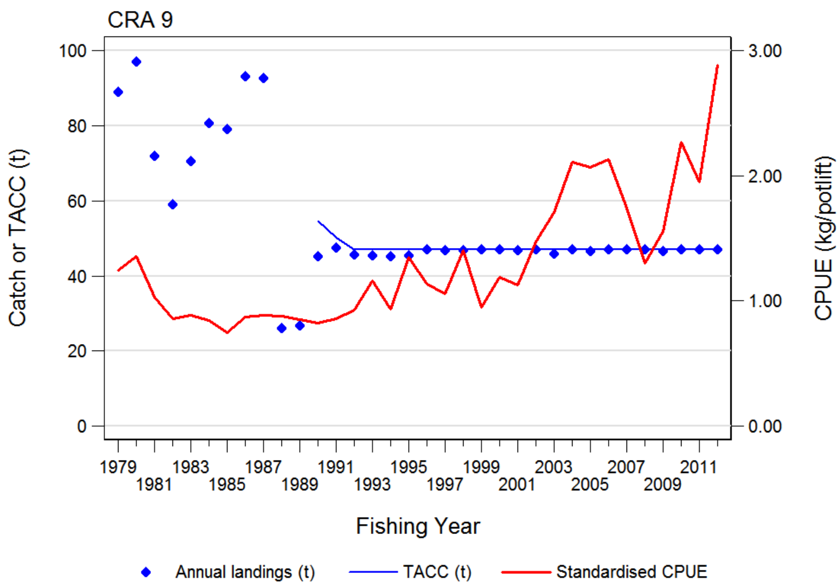
Qualifying Comments
A management procedure has been developed that is used to manage the fishery.

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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