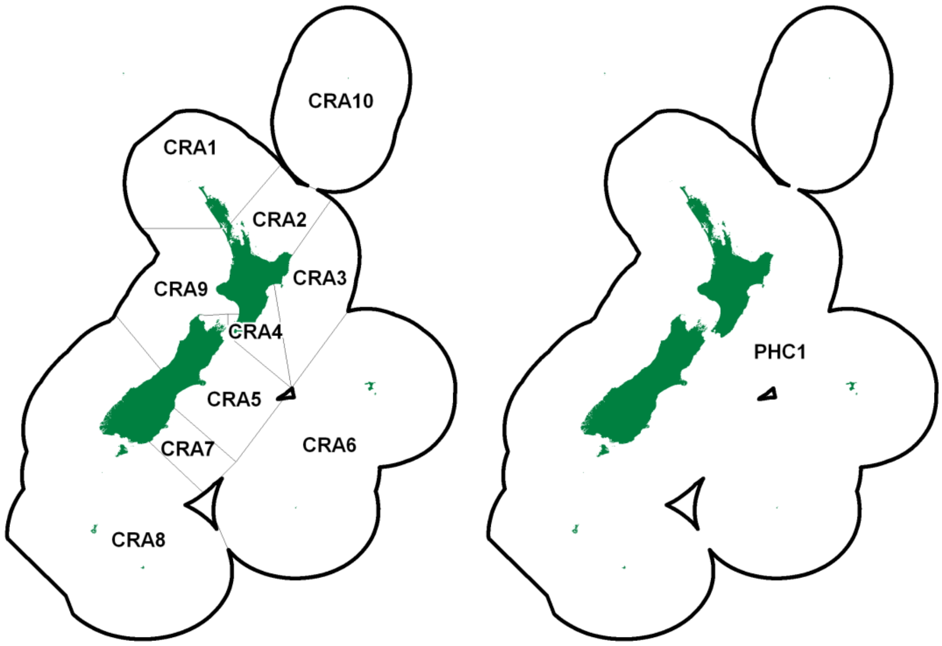
ROCK LOBSTER (CRA and PHC)

(*Jasus edwardsii*, *Sagmariasus verreauxi*)
Crayfish, 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 limited entry, 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, assessments have been carried out at the QMA level. The fishing year runs from 1 April to 31 March.

For eight of the nine rock lobster QMAs, management involves the operation of management procedures (MPs), which include a "harvest control rule" to convert observed abundance (standardised CPUE) into a TACC for the following year. These rules have been evaluated through extensive computer simulation and found to meet the requirements of the Fisheries Act. All QMAs use MPs except CRA 6 (see Section 4 for a detailed discussion of each rule). CRA 6 has never had a formal stock assessment. The TACC for CRA 10 is nominal because it is not fished commercially. The TACC for PHC 1 increased from 30 t in 1990 to its current value of 40.3 t at the beginning of the 1992–93 fishing year following quota appeals.

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

QMA	Type of management	Frequency of review	Year first MP implemented	Year of TACC|TAC changes since 1990
CRA 1 (Northland)	MP	5 years	2015	1991, 1992, 1993, 1996, 1999, 2015
CRA 2 (Bay of Plenty)	MP	5 years	2014	1991, 1992, 1993, 1997, 2014
CRA 3 (Gisborne)	MP	5 years	2005	1991, 1992, 1993, 1996, 1997, 1998, 2005, 2009, 2012, 2013, 2014
CRA 4 (Wairarapa)	MP	5 years	2007 [3]	1991, 1992, 1993, 1999, 2009, 2010, 2011 , 2013, 2014
CRA 5 (Marlborough/Kaikoura)	MP	5 years	2009[1,2]	1991, 1992, 1993, 1996, 1999
CRA 6 (Chatham Islands	Not assessed	Unspecified	Not applicable	1991, 1993, 1997, 1998
CRA 7 (Otago)	MP	5 years	1996[2]	1991, 1992, 1993, 1996, 1999, 2001, 2004, 2006, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015
CRA 8 (Stewart Island/Fiordland)	MP	5 years	1996[2]	1991, 1992, 1993, 1999, 2001, 2004, 2006, 2008, 2009, 2011
CRA 9 (Westland, Taranaki)	MP	5 years	2014	1991, 1992, 1993, 2014
CRA 10 (Kermadec Island)	Not assessed	Unspecified	Not applicable	–
PHC 1 (all NZ)	Not assessed	Unspecified	Not applicable	1991, 1992

[1] the CRA 5 MP was implemented by MPI in 2012 but industry had operated a voluntary rule since 2009
[2] CRA 5, CRA 7 and CRA 8 are being assessed in 2015 and MPs have been developed for possible implementation in April 2016
[3] 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

TACs (Total Allowable Catch: includes TACC plus all non-commercial allowances) 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 TACs have been set since 1997–98 whenever adjustments have been made to the TACCs. Figure 1 shows historical commercial landings and TACC values for all CRA stocks.

The MLS in the commercial fishery for red rock lobster is based on tail width (TW), except in the Otago (CRA 7) fishery, where the MLS for commercial fishing is a tail length (TL) of 127 mm for both sexes. The female MLS in all other rock lobster QMAs except Southern (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 for all QMAs since 1988, except in Otago (see above) and Gisborne (CRA 3), where since 1993 it has been 52 mm TW for the June-August period, a measure that changed the commercial CRA 3 fishery to a mainly winter fishery for males from 1993– 2002.

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

In 1992–93 the CRA 3 fishery was closed to all users from September to the end of November. In 2000–01 the closure was changed to 1 October through 30 November. Since 2008–09 commercial fishers have voluntarily closed Statistical Areas 909 and 910 from 1 September to mid-January and Statistical Area

911 from mid-December to mid-January. Fishers in Statistical Area 911 have voluntarily landed only males above 54 mm TW in June to August since 2009.

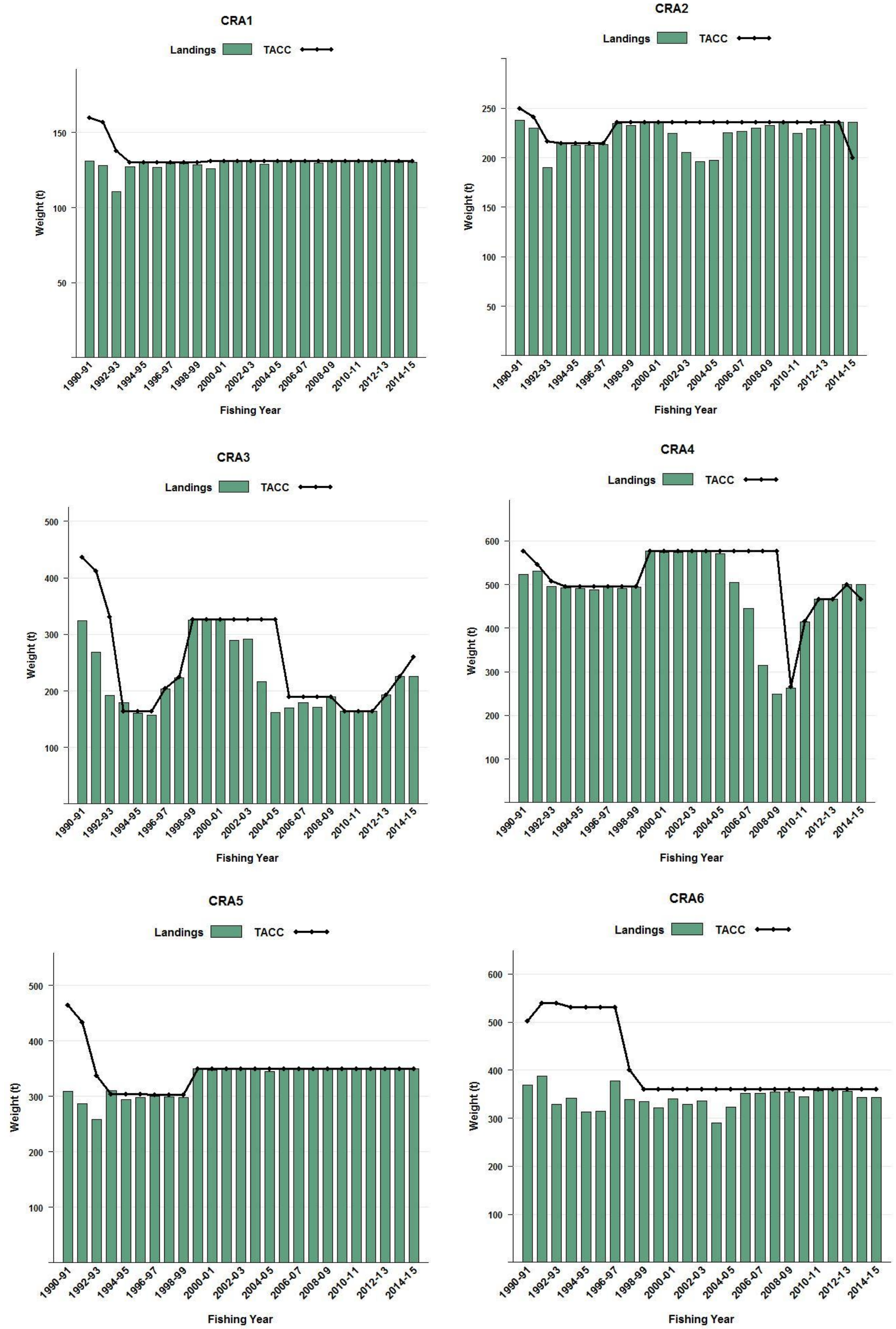


Figure 1: Historical commercial landings and TACC for the 9 main CRA stocks and PHC 1. [Continued on next page]

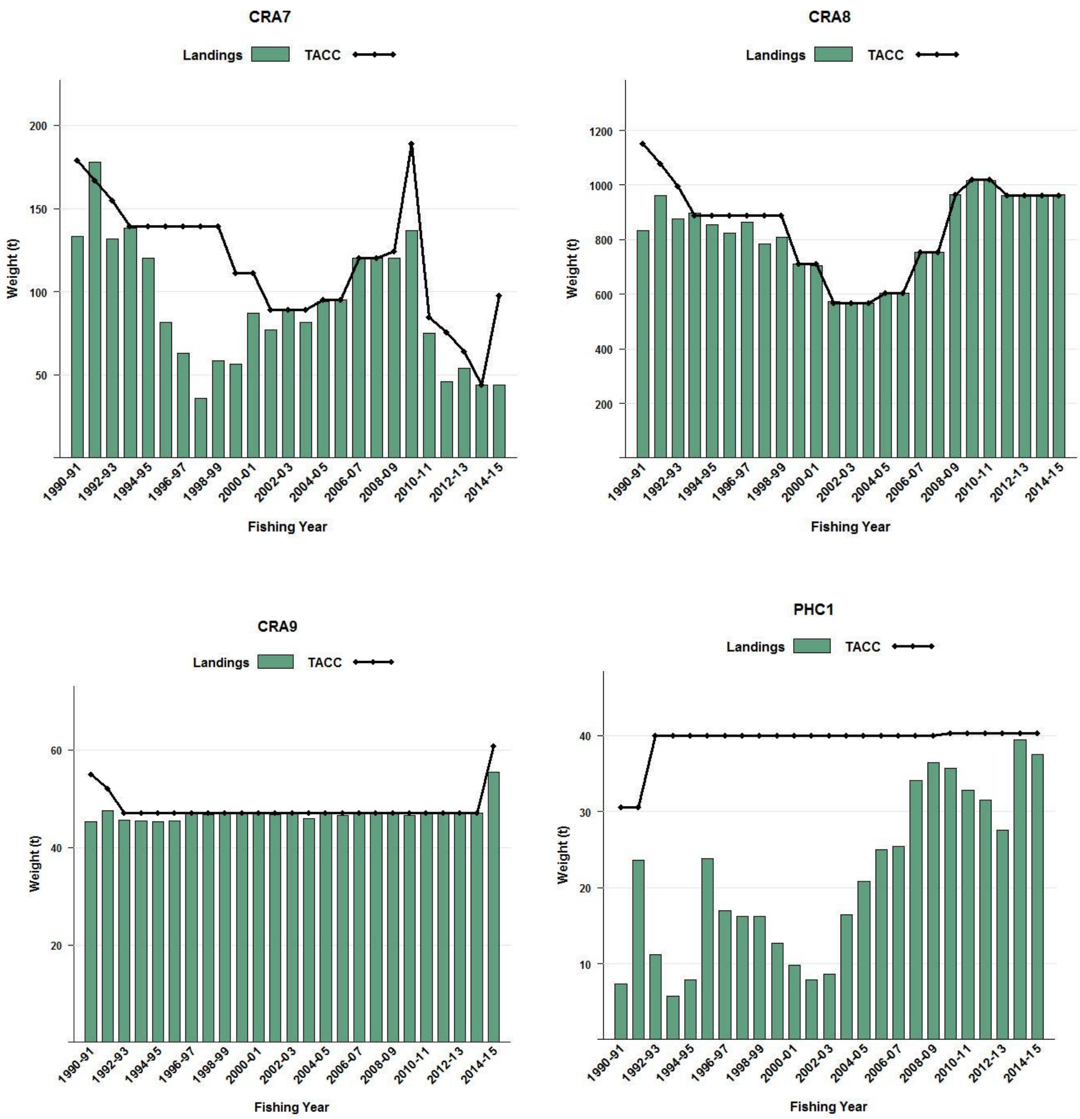


Figure 1 [Continued]: Historical landings and TACC for the 9 main CRA stocks and PHC 1.

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. The commercial and recreational MLS for packhorse rock lobster is 216 mm TL for both sexes.

1.1 Commercial fisheries

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

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

			CRA 1			CRA 2			CRA 3			CRA 4
Fishing Year	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC
1990–91	131.1	160.1	–	237.6	249.5	–	324.1	437.1	–	523.2	576.3	–
1991–92	128.3	157.0	–	229.7	241.3	–	268.8	411.9	–	530.5	545.7	–
1992–93	110.5	138.0	–	190.3	216.6	–	191.5	330.9	–	495.7	506.7	–
1993–94	127.4	130.5	–	214.9	214.6	–	179.5	163.9	–	492.0	495.7	–
1994–95	130.0	130.5	–	212.8	214.6	–	160.7	163.9	–	490.4	495.7	–
1995–96	126.7	130.5	–	212.5	214.6	–	156.9	163.9	–	487.2	495.7	–
1996–97	129.4	130.5	–	213.2	214.6	–	203.5	204.9	–	493.6	495.7	–
1997–98	129.3	130.5	–	234.4	236.1	452.6	223.4	224.9	379.4	490.4	495.7	–
1998–99	128.7	130.5	–	232.3	236.1	452.6	325.7	327.0	453.0	493.3	495.7	–
1999–00	125.7	131.1	–	235.1	236.1	452.6	326.1	327.0	453.0	576.5	577.0	771.0
2000–01	130.9	131.1	–	235.4	236.1	452.6	328.1	327.0	453.0	573.8	577.0	771.0
2001–02	130.6	131.1	–	225.0	236.1	452.6	289.9	327.0	453.0	574.1	577.0	771.0
2002–03	130.8	131.1	–	205.7	236.1	452.6	291.3	327.0	453.0	575.7	577.0	771.0
2003–04	128.7	131.1	–	196.0	236.1	452.6	215.9	327.0	453.0	575.7	577.0	771.0
2004–05	130.8	131.1	–	197.3	236.1	452.6	162.0	327.0	453.0	569.9	577.0	771.0
2005–06	130.5	131.1	–	225.2	236.1	452.6	170.1	190.0	319.0	504.1	577.0	771.0
2006–07	130.8	131.1	–	226.5	236.1	452.6	178.7	190.0	319.0	444.6	577.0	771.0
2007–08	129.8	131.1	–	229.7	236.1	452.6	172.4	190.0	319.0	315.2	577.0	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	–	234.3	236.1	452.6	193.3	193.3	322.3	466.3	466.9	661.9
2013–14	130.3	131.1	–	235.7	236.1	452.6	225.5	225.5	354.5	499.4	499.7	694.7
2014–15	130.4	131.1	–	198.6	200.0	416.5	260.1	261.0	390.0	465.5	467.0	662.0
2015–16	–	131.1	273.1	–	200.0	416.5	–	261.0	390.0	–	467.0	662.0

			CRA 5			CRA 6			CRA 7			CRA 8
Fishing Year	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC
1990–91	308.6	465.2	–	369.7	503.0	–	133.4	179.4	–	834.5	1152.4	–
1991–92	287.4	433.7	–	388.3	539.6	–	177.7	166.8	–	962.7	1077.0	–
1992–93	258.8	337.7	–	329.4	539.6	–	131.6	154.5	–	876.5	993.7	–
1993–94	311.0	303.7	–	341.8	530.6	–	138.1	138.9	–	896.1	888.1	–
1994–95	293.9	303.7	–	312.5	530.6	–	120.3	138.9	–	855.6	888.1	–
1995–96	297.6	303.7	–	315.3	530.6	–	81.3	138.9	–	825.6	888.1	–
1996–97	300.3	303.2	–	378.3	530.6	–	62.9	138.7	–	862.4	888.1	–
1997–98	299.6	303.2	–	338.7	400.0	480.0	36.0	138.7	–	785.6	888.1	–
1998–99	298.2	303.2	–	334.2	360.0	370.0	58.6	138.7	–	808.1	888.1	–
1999–00	349.5	350.0	467.0	322.4	360.0	370.0	56.5	111.0	131.0	709.8	711.0	798.0
2000–01	347.4	350.0	467.0	342.7	360.0	370.0	87.2	111.0	131.0	703.4	711.0	798.0
2001–02	349.1	350.0	467.0	328.7	360.0	370.0	76.9	89.0	109.0	572.1	568.0	655.0
2002–03	348.7	350.0	467.0	336.3	360.0	370.0	88.6	89.0	109.0	567.1	568.0	655.0
2003–04	349.9	350.0	467.0	290.4	360.0	370.0	81.4	89.0	109.0	567.6	568.0	655.0
2004–05	345.1	350.0	467.0	323.0	360.0	370.0	94.2	94.9	114.9	603.0	603.4	690.4
2005–06	349.5	350.0	467.0	351.7	360.0	370.0	95.0	94.9	114.9	603.2	603.4	690.4
2006–07	349.8	350.0	467.0	352.1	360.0	370.0	120.2	120.2	140.2	754.9	755.2	842.2
2007–08	349.8	350.0	467.0	356.0	360.0	370.0	120.1	120.2	140.2	752.4	755.2	842.2
2008–09	349.7	350.0	467.0	355.3	360.0	370.0	120.3	123.9	143.9	966.0	966.0	1053.0
2009–10	349.9	350.0	467.0	345.2	360.0	370.0	136.5	189.0	209.0	1018.3	1019.0	1110.0
2010–11	350.0	350.0	467.0	357.4	360.0	370.0	74.8	84.5	104.5	1018.3	1019.0	1110.0
2011–12	350.0	350.0	467.0	359.7	360.0	370.0	45.7	75.7	95.7	961.2	962.0	1053.0
2012–13	350.0	350.0	467.0	355.9	360.0	370.0	53.8	63.9	83.9	960.8	962.0	1053.0
2013–14	350.0	350.0	467.0	343.6	360.0	370.0	44.0	44.0	64.0	964.5	962.0	1053.0
2014–15	349.4	350.0	467.0	333.9	360.0	370.0	66.0	66.0	86.0	960.2	962.0	1053.0
2015–16	–	350.0	467.0	–	360.0	370.0	–	97.7	117.7	–	962.0	1053.0

			CRA 9			Total
Fishing Year	Catch	TACC	TAC	Catch[1]	TACC[1]	TAC[1]
1990–91	45.3	54.7	–	2907.4	3777.8	–
1991–92	47.5	51.5	–	3020.9	3624.5	–
1992–93	45.7	47.1	–	2629.9	3264.9	–
1993–94	45.5	47.0	–	2746.2	2913.0	–
1994–95	45.2	47.0	–	2621.5	2913.0	–
1995–96	45.4	47.0	–	2548.6	2913.0	–
1996–97	46.9	47.0	–	2690.5	2953.3	–
1997–98	46.7	47.0	–	2584.2	2864.1	1312.0
1998–99	46.9	47.0	–	2726.0	2926.2	1275.6
1999–00	47.0	47.0	–	2748.5	2850.2	3442.6
2000–01	47.0	47.0	–	2795.9	2850.2	3442.6

Table 1 [Continued]

	CRA 9			Total		
Fishing Year	Catch	TACC	TAC	Catch[1]	TACC[1]	TAC[1]
2001-02	46.8	47.0	-	2593.0	2685.2	3277.6
2002–03	47.0	47.0	–	2591.1	2685.2	3277.6
2003–04	45.9	47.0	–	2451.5	2685.2	3277.6
2004–05	47.0	47.0	–	2472.3	2726.4	3318.8
2005–06	46.6	47.0	–	2475.8	2589.4	3184.8
2006–07	47.0	47.0	–	2604.6	2766.6	3362.0
2007–08	47.0	47.0	–	2472.5	2766.6	3362.0
2008–09	47.0	47.0	–	2640.7	2981.0	3576.5
2009–10	46.6	47.0	–	2688.8	2762.2	3362.6
2010–11	47.0	47.0	–	2781.7	2807.3	3407.7
2011–12	47.0	47.0	–	2753.0	2792.8	3393.2
2012–13	47.0	47.0	–	2792.2	2810.3	3410.7
2013–14	47.1	47.0	–	2839.9	2855.4	3455.8
2014–15	60.8	60.8	115.8	2824.8	2857.8	3560.3
2015–16	–	60.8	115.8	–	2889.5	3865.0

[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 2014–15. Sources of data: from 1979–80 to 1988–89 from the QMS-held FSU data; from 1989–90 to 2014–15 from the CELR data held by MPI, using the "F2" algorithm corrected for "LFX" destination code landings (see text for definition. See Booth et al. (1994) for a discussion of problems with the QMS-held FSU data; see Starr (2015) 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	0.819	0.518	0.780	0.828	0.604	2.190	0.965	1.967	1.266
1980–81	0.984	0.622	0.865	0.803	0.735	2.020	0.849	1.710	1.375
1981–82	0.924	0.518	0.854	0.860	0.656	2.300	0.722	1.645	1.043
1982–83	0.999	0.431	0.923	0.926	0.722	1.663	0.466	1.408	0.872
1983–84	0.949	0.354	0.844	0.840	0.647	1.632	0.403	1.061	0.899
1984–85	0.881	0.342	0.683	0.762	0.654	1.302	0.540	1.027	0.857
1985–86	0.823	0.396	0.652	0.728	0.537	1.373	0.720	1.215	0.760
1986–87	0.804	0.358	0.566	0.773	0.473	1.506	0.823	1.080	0.881
1987–88	0.751	0.313	0.402	0.675	0.396	1.324	0.695	1.135	0.896
1988–89	0.660	0.340	0.414	0.569	0.345	1.271	0.407	0.851	0.891
1989–90	0.689	0.347	0.450	0.560	0.354	1.128	0.329	0.835	–
1990–91	0.599	0.474	0.428	0.516	0.355	1.179	0.424	0.811	0.834
1991–92	0.681	0.418	0.287	0.518	0.296	1.230	0.980	0.796	0.871
1992–93	0.600	0.390	0.243	0.498	0.288	1.126	0.394	0.675	0.944
1993–94	0.664	0.431	0.500	0.544	0.330	1.032	0.609	0.898	1.181
1994–95	0.849	0.518	0.976	0.693	0.357	1.007	0.458	0.800	0.948
1995–96	1.171	0.727	1.554	0.912	0.400	1.049	0.290	0.862	1.367
1996–97	0.998	0.932	1.946	1.226	0.522	1.084	0.246	0.807	1.155
1997–98	0.971	1.083	2.465	1.425	0.727	1.038	0.178	0.689	1.074
1998–99	1.062	1.095	2.079	1.625	0.862	1.277	0.257	0.704	1.424
1999–00	0.894	0.848	1.948	1.467	0.941	1.282	0.225	0.754	0.964
2000–01	1.152	0.753	1.354	1.375	1.201	1.219	0.345	0.916	1.204
2001–02	1.191	0.546	1.031	1.177	1.392	1.201	0.498	0.990	1.144
2002–03	1.120	0.428	0.682	1.210	1.573	1.309	0.603	1.154	1.494
2003–04	1.055	0.435	0.561	1.246	1.740	1.262	0.593	1.720	1.739
2004–05	1.334	0.511	0.450	0.949	1.347	1.444	0.884	1.888	2.149
2005–06	1.361	0.474	0.556	0.816	1.361	1.505	1.284	2.304	2.098
2006–07	1.706	0.554	0.562	0.675	1.400	1.756	1.777	2.793	2.173
2007–08	1.772	0.555	0.583	0.590	1.441	1.550	1.542	3.057	1.770
2008–09	1.719	0.512	0.668	0.745	1.663	1.688	1.709	4.102	1.322
2009–10	1.719	0.443	0.880	1.040	2.092	1.478	1.083	3.941	1.584
2010–11	1.518	0.396	1.202	1.036	2.039	1.553	0.803	3.227	2.311
2011–12	1.501	0.377	1.741	1.255	1.897	1.532	0.691	3.179	1.984
2012–13	1.694	0.408	2.419	1.410	1.764	1.537	0.682	3.314	2.949
2013–14	1.479	0.363	2.260	1.195	1.636	1.495	2.194	3.417	2.208
2014–15	1.335	0.332	2.049	1.044	1.790	1.409	2.219	3.245	2.323

Problems with rock lobster commercial catch and effort data

There are two types of data on the Catch Effort Landing Return (CELR) form: the top part of each form contains the fishing effort and an estimated catch associated with that effort. The bottom part of the form contains the landed catch and other destination codes, which may span several records of effort. Estimated catches from the top part of the CELR form often show large differences from the catch totals on the bottom part of the form, particularly in 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 estimated catch record in a QMA for the vessel. Vessels are removed entirely from the analysis when the ratio is less than 0.8 (overestimates of landed catch) or greater than 1.2 (underestimates of landed catch). Testing of the "F2" method was undertaken to establish that CPUE series based on the new procedure did not differ substantially from previous series. In general, the differences tended to be minor for most QMAs, with the exception of CRA 1 and particularly CRA 9, where there were greater differences (Starr 2014). Additional work completed in June 2013 determined that the problems with the CRA 9 standardised CPUE analysis could be resolved if vessels that had landed less than 1 t in a year were excluded from the analysis (Breen 2014). Consequently, the standardised CPUE analyses reported in Table 2 use the F2 algorithm, scaled to the combined "L", "F" and "X" landings (see following paragraph). This now includes CRA 5, which previously used the "B4" algorithm because of the poor reporting practices used in the 1990s (Vignaux & Kendrick 1998). CRA 5 was switched to the "F2 "algorithm as part of a 2015 stock assessment to align it with the other QMAs and because the two algorithms estimate nearly identical CPUE indices before 2005.

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 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 discarding legal lobsters with the overall increase in abundance. 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 (2015).

Description of Fisheries

Jasus edwardsii, CRA 1 and CRA 2

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

A TAC was set for CRA 1 for the first time in 2015 even though the CRA 1 stakeholders elected to maintain the TACC at its original level (Table 1). Commercial landings have remained at or near the 131 t TACC since the early 1990s (Table 1). In the 2013–14 fishing year, there were 14 vessels operating in CRA 1, a total that has remained nearly unchanged since the mid-2000s (Starr 2015).

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 2006–07, compared to 0.6 kg/potlift or less in CRA 2 from 2001–02 (Table 2). CRA 2 currently has the lowest CPUE of all nine CRA QMAs, and has been below 0.5 kg/potlift for 9 of the most recent 14 fishing years.

Jasus edwardsii, CRA 3, CRA 4 and CRA 5

CRA 3 extends from East Cape to below the Mahia peninsula (Figure 2). Commercial fishing occurs throughout this QMA. TACs and TACCs have been set for this QMA six times since the mid-2000s. Twenty-six vessels caught at least one tonne of rock lobster in 2013–14 and the number of commercial vessels operating in CRA 3 has been below 30 since 2005–06 (Starr 2015)

CPUE trends have differed among these three QMAs, with CRA 3 CPUE peaking in 1997–98, CRA 4 in 1998–99, and CRA 5 in 2008–09 (Table 2). However, these QMAs all show approximately the same pattern: low CPUEs in the 1980s (below 1 kg/potlift) followed by a strong rise in CPUE beginning in the early 1990s (first in CRA 3, followed closely by CRA 4 and finally by CRA 5 in the late 1990s). CRA 3 and CRA 4 dropped from their respective peaks in the late 1990s to lows in the mid-2000s followed by a rising trend to 2012–13 in both QMAs. CPUE in both QMAs dropped in 2013–14 and 2014–15 relative to their 2012–13 highs, but still remain at relatively high levels. CRA 5, unlike CRA 3 and CRA 4, rose in 2014–15 but remains below its most recent peak in 2009–10.

When at their recent 2012–13 peaks, both CRA 3 and CRA 4 were near the high CPUE levels observed in the late 1990. CRA 3 has since dropped 15% relative to 2012–13, to near 2 kg/potlift in 2014–15 while CRA 4 has dropped 26% relative to 2012–13 to just above 1 kg/potlift. CRA 5 has remained high throughout the 2000s, although the 2014–15 CPUE index is 14% below the recent 2009–10 peak (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 1.76 kg/potlift in 2006–07, the highest value since the mid-1990s.

Jasus edwardsii, CRA 7 and CRA 8

Catch rates are generally lower in CRA 7 compared with those in CRA 8, with CPUE in CRA 7 being 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 1.7 kg/potlift in CRA 7 and rising to more than 4 kg/potlift in CRA 8. The CRA 8 annual CPUE of greater than 4.0 kg/potlift observed in 2008–09 is the highest of any of the rock lobster QMAs over the 35 years of record (Table 2). CPUE declined by 60% in CRA 7 from 2008–09 to 2012–13 while the decline in CRA 8 was 23% between 2008–09 and 2011–12. CPUE in both these QMAs rose between 2012–13 and 2013–14, although the rise in CRA 8 was small (3%) compared to the 220% increase seen in CRA 7. The 2014–15 CPUE index for CRA 7 is the highest in the series, maintaining the high level seen in 2012–13 index (Table 2). The CRA 8 2014–15 CPUE index, at 3.2 kg/potlift, remains at a level similar to those observed in the most recent five years.

Jasus edwardsii, CRA 9

Mean annual CPUE had been near to or less than 1.0 kg per potlift from 1981–82 to 1994–95, followed by a strong increase that peaked in 2006–07, with CPUE exceeding 2 kg/potlift between 2004–05 and 2006–07. CPUE dropped to a low of 1.3 kg/potlift in 2008–09 but rose to 2.9 kg/potlift in 2012–13 and then declined to 2.2 and 2.3 kg/potlift in 2013–14 and 2014–15 respectively (Table 2).

Sagmariasus verreauxi, PHC stock

QMS reported landings of the PHC stock more than halved between 1998–99 and 2001–02 and were below 30 t/year up to 2007–08 (Table 3). Landings have since exceeded 30 t/year, except for 2012–13, when 27.5 t were reported. The 2013–14 annual landing total of nearly 39 t is the largest annual total since entering the QMS in 1990–91 and approaches the annual TACC. The 2014–15 landings of 37.5 t are the second highest total in the series and also approach the annual TACC.

Jasus edwardsii CPUE by statistical area

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

Table 3: Reported landings and TACC for *Sagmariasus verreauxi* (PHC) from 1990–91 to 2014–15. 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]	2003–04	16.4	40.3
1991–92	23.6	30.5	2004–05	20.8	40.3
1992–93	11.1	40.3	2005–06	25.0	40.3
1993–94	5.7	40.3	2006–07	25.4	40.3
1994–95	7.9	40.3	2007–08	34.0	40.3
1995–96	23.8	40.3	2008–09	36.4	40.3
1996–97	16.9	40.3	2009–10	35.7	40.3
1997–98	16.2	40.3	2010–11	32.8	40.3
1998–99	16.2	40.3	2011–12	31.6	40.3
1999–00	12.6	40.3	2012–13	27.5	40.3
2000–01	9.8	40.3	2013–14	39.4	40.3
2001–02	3.4	40.3	2014–15	37.5	40.3
2002–03	8.6	40.3			

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

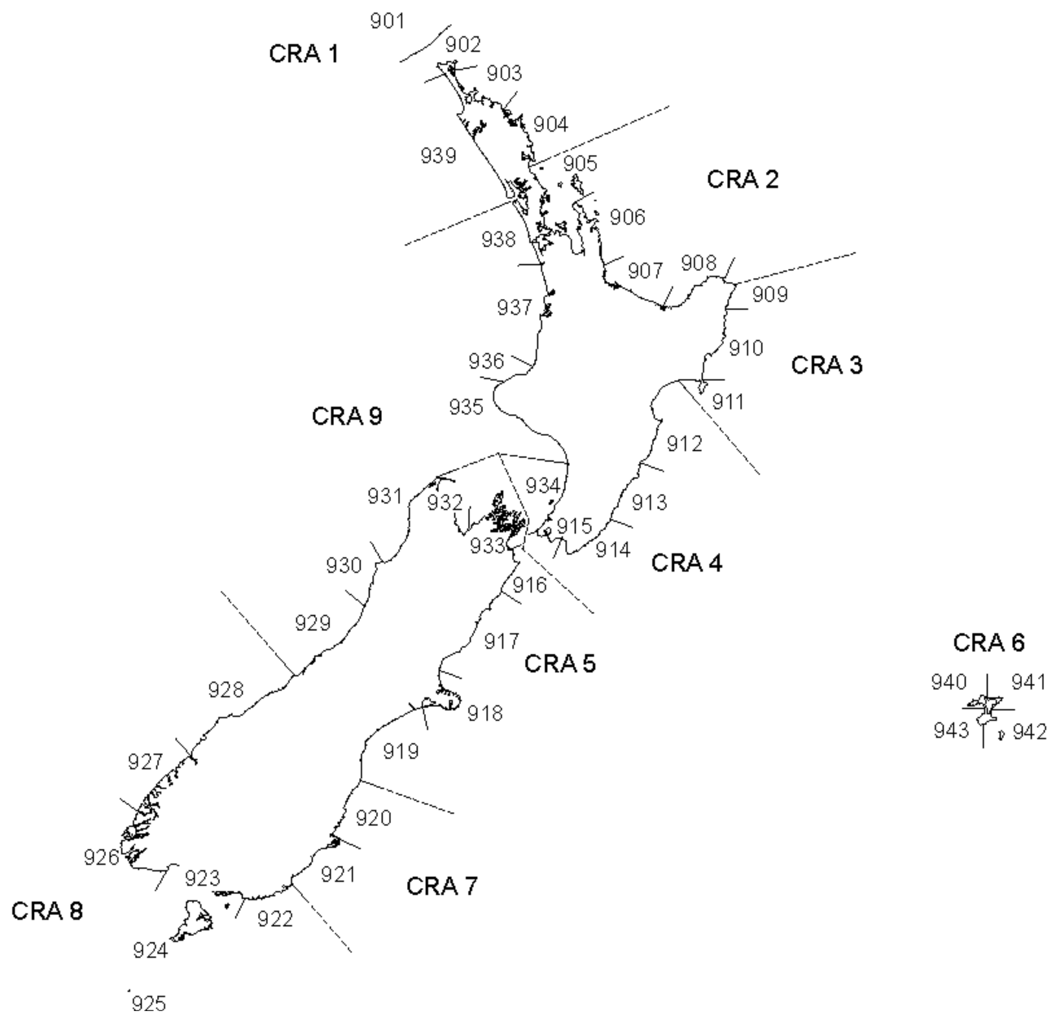


Figure 2: Rock lobster statistical areas as reported on CELR forms.

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

CRA	Stat Area	09/10	10/11	11/12	12/13	13/14	14/15	CRA	Stat Area	09/10	10/11	11/12	12/13	13/14	14/15
1	901	3.64	2.95	2.77	2.58	2.06	2.19	6	940	1.13	1.37	1.32	1.69	1.53	1.55
1	902	2.36	1.84	1.39	1.45	1.85	–	6	941	1.18	1.33	1.32	1.56	1.53	1.39
1	903	1.07	0.86	0.76	1.38	1.17	2.48	6	942	1.67	1.37	1.61	1.49	1.42	1.32
1	904	–	–	0.46	0.54	0.49	0.39	6	943	1.25	1.49	1.49	1.81	1.75	1.43
1	939	2.15	1.43	1.89	2.98	2.62	2.14	7	920	0.98	0.67	0.69	0.64	1.85	1.65
2	905	0.51	0.40	0.37	0.43	0.39	0.40	7	921	1.84	1.11	0.62	0.65	1.51	2.17
2	906	0.39	0.38	0.35	0.37	0.31	0.29	8	922	–	–	–	–	–	–
2	907	0.70	0.61	0.57	0.51	0.51	0.44	8	923	–	–	–	–	2.39	4.29
2	908	0.45	0.42	0.47	0.44	0.40	0.36	8	924	4.26	3.61	4.05	3.90	3.36	3.83
3	909	1.13	1.29	1.52	–	2.43	1.74	8	925	–	–	–	2.69	–	–
3	910	0.94	1.18	1.43	1.82	1.66	1.44	8	926	2.77	2.77	3.33	3.20	3.93	3.50
3	911	0.73	1.02	1.69	2.34	2.14	2.20	8	927	3.95	2.33	2.47	3.68	3.58	3.49
4	912	0.73	0.76	0.87	0.88	0.66	0.59	8	928	5.45	4.40	4.57	5.01	4.61	4.47
4	913	1.10	1.23	1.58	1.93	1.48	0.94	9	929	–	–	–	–	–	–
4	914	1.08	1.08	1.32	1.59	1.53	1.09	9	930	–	–	–	–	–	–
4	915	1.30	0.94	1.31	1.37	1.54	1.78	9	931	–	2.86	–	–	–	–
4	934	–	–	2.04	–	–	–	9	935	–	2.52	–	–	–	–
5	916	2.23	2.32	2.15	1.37	1.50	1.71	9	936	–	–	–	–	–	–
5	917	2.25	2.38	2.75	2.64	2.11	2.37	9	937	–	–	–	–	–	–
5	918	–	–	–	–	–	–	9	938	–	–	–	–	–	–
5	919	–	–	–	–	–	–								
5	932	–	–	–	–	–	–								
5	933	0.74	0.76	0.72	0.73	0.62	0.60								

1.2 Recreational fisheries

There are two approaches to estimating recreational fisheries harvest: A) the use of “onsite” or access point methods where participants are surveyed on the water or at boat ramps; B) “offsite” methods where post-event interviews and/or diaries are used to collect data.

Table 5: 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..), Kaikoura/Motunau 2012–13: Kendrick & Handley (2014); ‘–’ : not available.

QMA/FMA	Number	CV (%)	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
Kaikoura & Motunau 2012–13:			
CRA 5	96 800	10	54.56
Northland : 1 Apr 2013–31 Mar 2014			
CRA1	50 400	17	37.3

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

The harvest estimates provided by these historical telephone diary surveys are not considered reliable by the Marine Amateur Fishing Working Group (MAFWG). Participants in the early surveys were recruited to fill in diaries by way of a telephone survey that also estimated the proportion of the population that was likely to fish recreationally. Subsequently, it was realised that a "soft refusal" bias would occur in the eligibility proportion if interviewees who do not wish to co-operate falsely stated that they did not fish. This bias resulted in an underestimate of the population of recreational fishers and consequently an underestimate of the harvest. Pilot studies for the 2000 telephone/diary survey suggested that this effect could occur when recreational fishing was established as the subject of the interview at the outset. Another source of bias in these telephone/diary surveys was that diarists tended to overstate their catch, the number of trips made, and did not report non-productive trips.

Table 6: Historical recreational and customary catch estimates used in recent CRA assessments. All ramped catches started from 20% of the 1979 estimate of recreational catch.

QMA	First year	Last year	"Base" Recreational catch (t)	Notes: Recreational Catch	Customary catch (t)	Notes: Customary catch
CRA 1 [1]	1945	2013	1994=40.152 1996=53.058 2011=24.089 2013=40.747	Ramped from 1945; after 1979, the mean unstandardised Area 903/904 SS CPUE in each year was scaled by the mean of the ratios of the "base recreational catches" relative to the unstandardised SS CPUE	10	Constant from 1945
CRA 2 [2]	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 [3]	1945	2013	1992=4.272 1996=14.418 2011=8.069	Ramped from 1945; after 1979, the CRA 3 SS CPUE in each year was scaled by the mean of the ratios of the "base recreational catches" relative to the standardised SS CPUE	20	Constant from 1945
CRA 4 [4]	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 [5]	1945	2014	1994=37.72 1996=23.08 2011=80	Fitted exponential function (Eq. 1) to the 1994, 1996 and assumed (80 t) 2011 recreational survey estimates. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table 9) was added to the calculated time series.	10	Constant from 1945
CRA 6	–	–	–	Not used	–	–
CRA 7 [6]	1963	2014	5 t/year	Constant values were used from 1979 to 2014 and ramped values beginning at 1 t (=20% of constant value) in 1945 and ending at 5 t in 1979 were used from 1945 to 1979. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table 7) was then added.	1	Constant from 1963
CRA 8 [6]	1963	2014	20 t/year	Constant values were used from 1979 to 2014 and ramped values beginning at 1 t (=20% of constant value) in 1945 and ending at 5 t in 1979 were used from 1945 to 1979. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table 7) was then added.	6 (15)	Constant at 6 t from 1963–2012 and then increased proportionately to 15 t in 2014
CRA 9 [7]	1945	2012	2011=17.96	Ramped from 1945; after 1979, the CRA 9 SS CPUE in each year was scaled by the ratio of the "base recreational catch" relative to the 2011 standardised SS CPUE	1	Constant from 1963

[1] Starr et al. (2015a);[2] Starr et al. (2014a); [3] Starr et al. (2015b); [4] Starr et al. (2012); [5] see Section 1.3; [6] see Section 1.4; [7] Breen (2014)

The recreational harvest estimates provided by the 2000 and 2001 telephone diary surveys were thought by the MAFWG to be implausibly high, which led to the development of alternative "onsite" methods for estimating recreational harvest. These methods provided direct estimates of recreational harvest in fisheries that were suitable for this form of survey. However, "onsite" methods tend to be costly and difficult to mount, leading to a reconsideration of the "offsite" approach. This process led to the implementation of a national panel survey during the 2011–12 finfish fishing year (October through September) which used face-to-face interviews of a random sample of New Zealand households to recruit a panel of participants and non-participants for the full year (Table 5). The panel members were contacted regularly about their fishing activities and catch information was collected using standardised phone interviews. "Onsite" surveys targeted towards rock lobster were completed for CRA 5 (Kaikoura–Motunau only) from January–April 2013 (2012–13, Kendrick & Handley 2014) and for CRA 1 in 2013–14, extending from Rangiputa to Mangawhai Heads and covering most of Areas 903 and 904 (Table 5: Holdsworth, pers. comm.). This latter area is estimated to represent 70% of the total CRA 1 recreational catch.

Table 6 presents the recreational catch estimates used in all recent rock lobster stock assessments, including CRA 5, CRA 7 and CRA 8 in 2015. The RLFAWG has little confidence in the early estimates of recreational catch, but is hopeful that the national panel survey and recent onsite surveys have provided more reliable estimates of recreational catch in those QMAs with a relatively large number of participants.

1.3 CRA 5 recreational catch

MPI, in its response to the request from the Rock Lobster Stock Assessment team for guidance on setting recreational catches for CRA 5, CRA 7 and CRA 8, recommended the following for the CRA 5 recreational fishery:

> "*MPI recommends that the rock lobster stock assessment team model an 80 tonne recreational harvest (which includes amateur charter take) for the 2011–12 fishing year in the base case of this year's CRA 5 assessment and scaling this harvest relative to the CRA 5 spring-summer commercial CPUE in 2011–12. It is also suggested that a sensitivity trial of 140 tonnes is carried out.*
>
> *These recommendations are based on recent MAFWG discussions noting that the 80 tonne harvest estimate for modelling purposes takes into account:*
>
> - *The 43.47 tonne 2011–12 NPS recreational harvest estimate, while acknowledging it, is assumed to be an underestimate (the degree to which it is an underestimate is unknown).*
> - *The latest Kaikoura and Motunau boat ramp survey in 2012–13 that estimated 54.56 tonnes of rock lobster were harvested by recreational fishers and charter operators in these areas.*
> - *Anecdotal reports from recreational fishers and MPI compliance that rock lobster harvest is perceived to be high at times (particularly in Kaikoura).*
>
> *The MAFWG did consider combining the NPS and Kaikoura/Motunau survey results; however, due to interannual variability in potential harvest and the unknown proportion of resident vs. non-resident anglers between and within the two survey years, it is not practical or plausible to combine harvest estimates from different years.*"

Recreational catches of rock lobster are poorly known throughout New Zealand, but reports of increased recreational activity in CRA 5 coupled with an increasing trend in abundance makes it unlikely that recreational catches have remained constant in CRA 5. The RLFAWG agreed for the 2003 (Kim et al. 2004) and 2010 CRA 5 stock assessments (Haist et al. 2011) to use a catch trajectory that reflected the increasing abundance of lobster in this QMA, based on SS CPUE. These stock assessments calculated the ratios of the CPUE relative to the recreational survey catch weight, took the mean of these ratios and applied it to the observed SS CPUE (in 2003 using CRA 5 standardised SS CPUE and in 2010 using unstandardised CPUE for Area 917 [Kaikoura]). When this method was repeated for the 2015 CRA 5 stock assessment (using the survey estimates in Table 6), the estimated recreational catches were much higher than were considered credible. Consequently, the stock assessment team recommended a revised model based on a power function (Eq. 1), with the parameters estimated by fitting to the 1994 and 1996 recreational survey estimates (Table 6) and to the 80 t estimate for 2011–12 specified by MPI.

$$W_i = \alpha CPUE_i^{\beta} \quad \text{if } i >= 1979$$
$$W_{1945} = 0.2 * W_{1979}$$
$$W_i = W_{i-1} + \frac{(W_{1979} - W_{1945})}{(1979 - 1945)} \quad \text{if } i > 1945 \;\&\; i < 1979$$

Eq. 1

where

$CPUE_i =$ Area 917 SS CPUE from 1979 to 2014

$W_i =$ recreational survey catch by weight for year i

$\alpha, \beta =$ parameters of a power function estimated through least squares

$\beta = 0.55$ when Eq.1 was fitted to the survey estimates in Table 6 and the estimated recreational catch trajectory is plotted in Figure 3. Recreational catch is split between seasons, with 90% assumed taken in the SS and the remainder in AW.

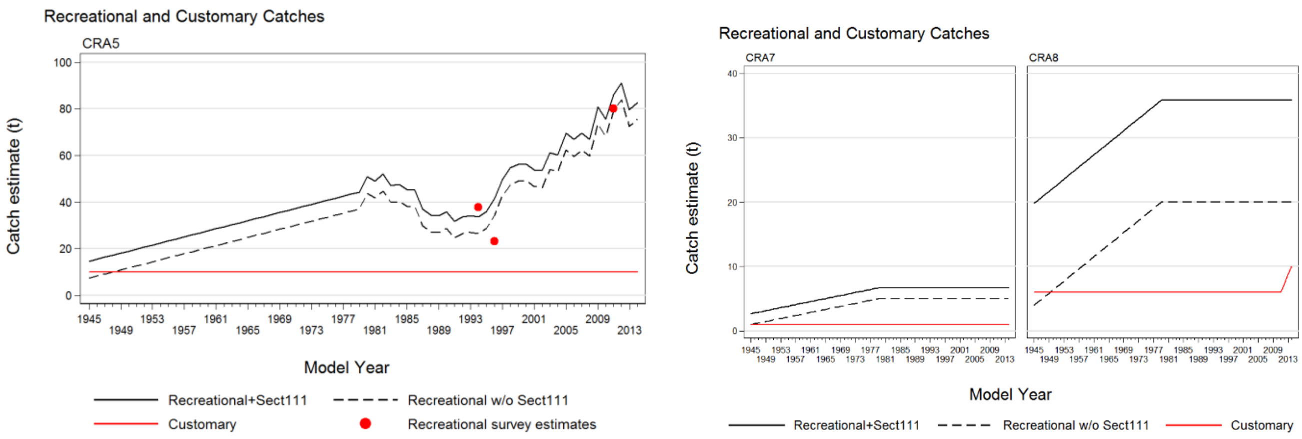


Figure 3. Recreational catch trajectories (t) for the 2015 stock assessment of CRA 5 [left panel] and CRA 7/8 [right panel]. Trajectories with and without the additional Section 111 catches are shown. CRA 5 recreational catches ([left panel] black dashed line) were estimated using an exponential function based on the mean unstandardised Area 917 CPUE from 1979, scaled to the mean catch weight estimated from three recreational diary surveys. Customary catches used in the QMA stock assessments are also shown for the three QMAs.

1.4 CRA 7 and CRA 8 recreational catch

MPI, in its response to the request from the Rock Lobster Stock Assessment team for guidance on recreational catches for CRA 5, CRA 7 and CRA 8, recommended the following for the CRA 7 and CRA 8 recreational fisheries:

> *"CRA 7: MPI recommends that a 5 tonne recreational harvest for the 2014/15 year is used in the CRA 7 stock assessment and scaling this harvest to CRA 7 spring-summer commercial CPUE. It is also suggested that a sensitivity trial of 15 tonnes is carried out.*

> <u>CRA 8:</u> *MPI recommends that a 20 recreational harvest estimate for the 2014/15 year is used in the CRA 8 stock assessment and scaling this estimate to CRA 8 spring-summer commercial CPUE. It is also suggested that a sensitivity trial of 50 tonnes is carried out."*

These recommendations were implemented as described in Table 6 and the estimated recreational catch trajectories are plotted in Figure 3. Recreational catch is split in the model between seasons, with 90% assumed taken in the SS and the remainder in AW.

1.5 Section 111 commercial landings

Commercial fishermen are allowed to take home lobsters for personal use under Section 111 of the Fisheries Act. These lobsters must be declared on landing forms using the destination code "F". The maximum in any fishing year for these landings by QMA has ranged from about 1 t (CRA 6) to nearly 16 t (CRA 8) (Table 7).

Table 7: Section 111 commercial landings (in tonnes, summed from landing destination code "F") by fishing year and QMA.

Fishing Year	CRA1	CRA2	CRA3	CRA4	CRA5	CRA6	CRA7	CRA8	CRA9
1992–93	0.005	–	–	–	–	–	–	–	–
1999–00	–	–	–	–	0.008	–	–	–	–
2000–01	0.003	–	–	–	0.030	–	–	–	–
2001–02	0.111	0.227	0.136	0.648	0.465	–	0.077	0.253	0.005
2002–03	0.489	0.609	0.495	2.660	1.960	–	0.152	1.954	0.907
2003–04	2.221	1.025	0.372	3.399	2.907	0.060	0.093	1.679	0.973
2004–05	3.554	0.733	0.311	3.706	3.191	0.087	0.095	3.505	1.636
2005–06	3.083	0.775	0.993	3.680	4.388	0.002	0.153	4.572	2.133
2006–07	5.016	1.284	0.981	3.110	5.102	0.019	0.289	5.813	1.219
2007–08	3.831	1.032	1.167	2.706	5.412	0.411	0.929	7.786	1.461
2008–09	3.628	1.185	1.374	2.188	6.110	0.538	1.498	9.571	1.597
2009–10	4.010	1.370	2.253	3.222	6.244	0.299	1.688	10.721	2.264
2010–11	3.669	1.186	2.182	4.699	6.584	0.284	0.429	13.538	1.851
2011–12	4.159	1.169	2.214	4.730	4.828	0.473	0.080	14.913	1.899
2012–13	4.212	1.189	2.576	5.835	7.215	1.027	0.098	15.824	1.847
2013–14	3.943	1.658	2.941	4.803	6.629	1.005	0.141	13.232	1.700
2014–15	3.678	2.030	3.003	5.179	6.117	0.612	0.134	13.847	3.752
Maximum	5.016	2.030	3.003	5.835	7.215	1.027	1.688	15.824	3.752

1.6 Customary non-commercial fisheries

MPI, in its response to the request from the Rock Lobster Stock Assessment team for guidance on customary catches for CRA 5, CRA 7 and CRA 8, recommended the following for the CRA 5, CRA 7 and CRA 8 customary fisheries:

> "*Based on the* [customary] *information available on CRA 5, CRA 7 and CRA 8 customary harvest, noting its incompleteness and uncertainty, MPI considers it appropriate to continue to use a 10 tonne constant customary catch estimate for CRA 5, a 1 tonne constant estimate for CRA 7 and to consider increasing the CRA 8 customary estimate from 6 to 15 tonnes. MPI also suggests that the RLFAWG considers carrying out sensitivity analyses for higher levels of customary catch for CRA 5 and CRA 8 (i.e. double the estimate).*"

Further enquiry determined that MPI meant for CRA 8 to increase the customary harvest estimate from 6 t in 2011 (the final year of the previous assessment) to 15 t in 2014 (the final year of the current assessment) (see Figure 3). Customary catch is split in the model between seasons using the same proportions as for the recreational catch, with 90% assumed taken in the spring/summer season and the balance in the autumn/winter.

1.7 Illegal catch

MPI were asked, before undertaking the 2015 CRA 5, CRA 7 and CRA 8 stock assessments, to provide estimates of current and historical illegal catches, along with an appreciation of their uncertainty. MPI were also asked to provide an estimate of the proportion of illegal catch that was eventually reported as legal catch. MPI pointed to estimates given in the past (Table 8) and suggested the following:

> "*Taking into account the uncertainty in the available information on illegal take, MPI suggests that a 30 tonne illegal catch estimate is used in the upcoming CRA 5 stock assessment, 1 tonne continues to be used for CRA 7 and 3 tonnes continues to be used for CRA 8. It is also suggested that the RLFAWG considers carrying out sensitivity analyses with higher levels of illegal take for CRA 5 and CRA 8 (i.e. double the estimate).*"

Given this advice from MPI, 30 t was used as the illegal estimate for CRA 5 in 2014 and the missing years from 2004 to 2013 were filled in by scaling the illegal catch down proportionately from the 52 t estimated for 2003 to 30 t in 2014. For CRA 7, a constant illegal catch of 1 t/year was used to fill in all years from 2003 (Table 8). For CRA 8, an estimate of 3 t was used as the estimate for 2011 (the final year of the previous CRA 8 stock assessment) and the missing years from 2003 to 2010 were filled in by scaling the illegal catch down proportionately from the 18 t estimated for 2002. The series was continued with 3 t to 2014.

In the past, MPI Compliance estimates for illegal catch have frequently been provided in two categories ("reported" or "R" and "not reported" or "NR"). The category of "commercial illegal reported" or "reported" (="R" in Table 8) is assumed to represent illegal commercial catch that is eventually reported to the QMS as legitimate catch. Therefore this catch is subtracted from the reported commercial catch to avoid double-counting. Missing categories are treated as zeroes and the available values are used to estimate the overall proportion of R/NR for each QMA, which is then applied to all years (including interpolated years). MPI Compliance has stated that it no longer includes the "R" category in its estimates, so the step of moving the estimated "R" catches from "commercial" to "illegal" has now been discontinued for all CRA QMAs, beginning in 2012.

Table 8: 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. Years without any MPI estimates in any QMA have been suppressed in this table.

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	–	288.3	–	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	–	40	–	–	–	–	–	–	–	–
2001	–	72	–	88	0	75	–	–	–	–	–	10	–	–	–	–	–	1
2002	–	–	–	–	0	75	9	51	5	47	–	–	–	1	–	18	–	–
2003	–	–	–	–	0	89.5	–	–	–	–	–	–	–	–	–	–	–	–
2004	–	–	–	–	–	–	10	30	–	–	–	–	–	–	–	–	–	–
2011	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	3	–	–
2014	–	–	–	–	–	–	–	–	–	30	–	–	–	–	–	–	–	–

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

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

Illegal catch estimates before 1990 have been derived from unpublished estimates of discrepancies between reported catch totals and total exported weight that were developed for the period 1974 to 1980 (Table 9; McKoy pers. comm.). For years before 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 9). 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.

1.8 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, rock lobster assessments assume that handling mortality is 10% of returned lobsters.

1.9 Time series of mortalities

Plots of all rock lobster catches by QMA from 1945 are presented in

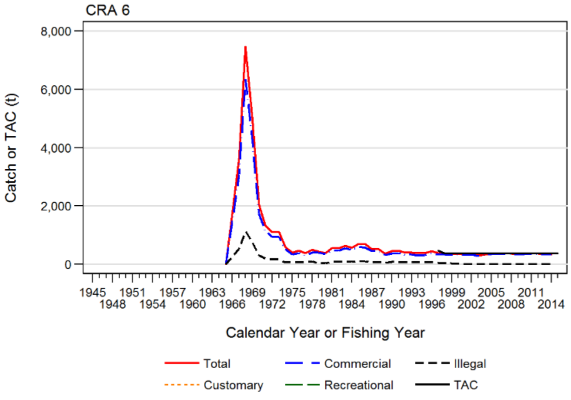


Figure 4. Commercial catches before 1979 have been obtained from unpublished reports (Annala, pers. comm.). Historical estimates of recreational, customary and illegal catches have been generated for each stock assessment and these have been extended using the same rules for those assessments that are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

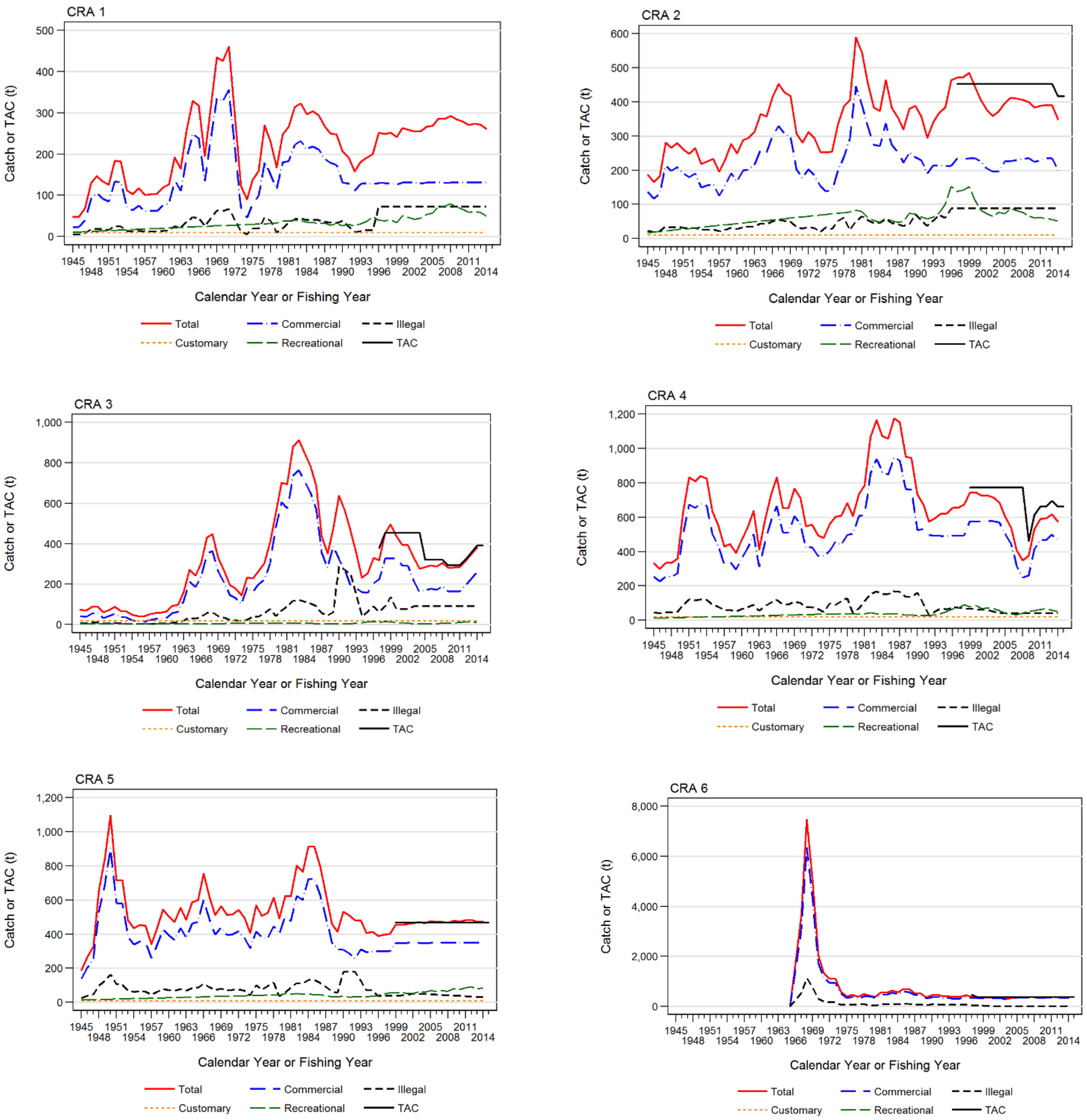


Figure 4: Catch trajectories (t) from 1945 to 2014 and TACs (if in place) from the year of establishment to 2015 for CRA 1 to CRA 3, showing current best estimates for commercial, recreational, customary and illegal categories. Also shown is the sum of these four catch categories. Note that calendar year catches are plotted from 1945 to 1977. Statutory fishing years (1 April to 31 March) catches are plotted from 1979 on. Catches for 1978 are for 15 months, including January to March 1979. [Continued on next page]

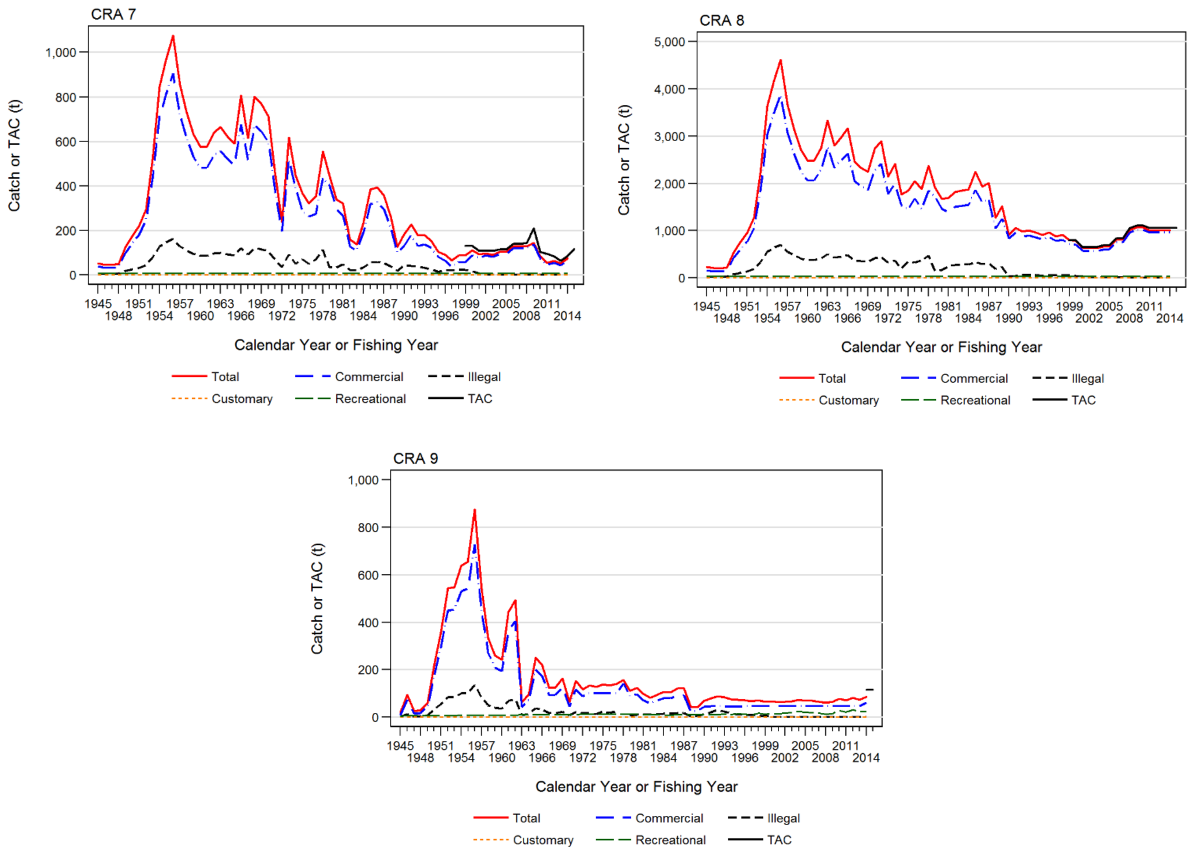


Figure 4 [cont]: Catch trajectories (t) from 1945 to 2014 and TACs (if in place) from the year of establishment to 2015 for CRA 7 to CRA 9.

2. BIOLOGY

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

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

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

Values used for some biological parameters in stock assessments are shown in Table 10.

Table 10: Values used for some biological parameters.

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

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

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

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

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

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

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

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

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

Growth modelling

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

The growth model contains parameters for expected increment at 50 mm and 80 mm TW, a shape parameter (1 = linear), the CV 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 – whereas the older versions assumed specific moulting periods between which growth did not occur. For assessment models used from 2006 to 2014, records from lobsters at liberty for fewer than 30 days were excluded. In that period, the robust likelihood fitting procedure precluded the need for extensive grooming of outliers. In 2015 the stock assessment switched to normal likelihood, and the records with extreme 0.2 quantile residuals in a tag-only fit were excluded. Growth parameters are estimated simultaneously with other parameters of the assessment model in an integrated way, so that growth estimates might be affected by the size frequency and CPUE data as well as the tag-recapture data.

Settlement indices

Annual levels of puerulus settlement have been collected from 1979 at sites in Gisborne, Napier, Castlepoint, Kaikoura, Moeraki, Chalky Inlet, Halfmoon Bay, and Jackson Bay (Table 11). Each site has at least one group of three collectors that are checked monthly when possible, and the monthly catches of the puerulus from each collector are used as the basis for producing a standardised index of settlement (Forman et al. 2015). Standardised settlement indices are available for each key site (Table 12).

Table 11: Location of collector groups used for the standardisation of puerulus settlement indices, the years of operation, and the number of collectors monitored within each group at the last sampling.

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

Table 12: Standardised puerulus settlement indices by fishing year 1 April–31 March (source: A. McKenzie, NIWA). '–': no usable sampling was done; 0.00: no observed settlement.

	Gisborne CRA 3	Napier CRA 4	Castlepoint CRA 4	Kaikoura CRA 5	Moeraki CRA 7	Halfmoon Bay CRA 8	Chalky Inlet CRA 8	Jackson Bay CRA 8
1979	–	0.76	–	–	–	–	–	–
1980	–	1.22	–	–	–	–	–	–
1981	–	1.99	–	0.55	–	8.15	–	–
1982	–	1.10	2.56	0.76	–	0.38	–	–
1983	–	1.30	1.23	0.16	–	3.93	–	–
1984	–	0.40	0.75	0.37	–	0.30	–	–
1985	–	0.21	0.59	0.24	–	0.00	0.36	–
1986	–	–	0.86	0.09	–	0.12	0.21	–
1987	3.28	–	1.70	1.05	–	1.58	1.42	–
1988	2.82	1.33	0.96	0.40	–	0.22	1.31	–
1989	0.99	1.15	1.17	0.79	–	0.60	1.64	–
1990	0.44	1.02	1.13	1.58	–	0.43	1.84	–
1991	1.07	2.40	2.19	6.69	0.00	0.93	1.03	–
1992	2.83	2.06	2.17	5.18	0.14	0.54	0.52	–
1993	1.77	2.17	1.08	2.04	0.00	0.00	0.14	–
1994	3.05	1.52	0.90	1.09	0.00	1.19	1.64	–
1995	1.09	1.05	0.94	0.60	0.11	0.40	0.40	–
1996	1.67	1.53	1.31	0.64	0.98	0.33	1.76	–
1997	1.00	1.07	1.74	1.91	0.42	0.56	1.41	–
1998	1.80	0.96	1.09	1.87	0.57	0.30	0.50	–
1999	0.28	0.43	0.36	1.28	0.11	0.23	1.70	0.30
2000	0.91	0.73	0.54	1.30	3.88	1.22	1.26	0.63
2001	1.14	1.23	0.73	0.54	1.85	1.75	0.60	0.26
2002	0.95	1.46	0.79	3.36	0.92	1.48	1.42	1.65
2003	2.77	1.31	0.96	3.38	7.68	3.89	1.56	0.64
2004	0.73	1.06	0.50	1.02	0.37	0.16	0.30	0.47
2005	2.51	1.26	1.31	2.25	0.08	0.00	–	1.56
2006	0.28	0.64	0.49	1.09	0.05	0.13	–	0.33
2007	0.36	0.92	1.06	1.86	0.05	0.49	–	0.27
2008	0.64	0.65	1.08	1.77	0.11	0.09	–	0.10
2009	1.75	0.89	1.10	0.61	0.64	1.02	–	0.18
2010	0.62	0.94	1.19	1.39	1.49	1.65	7.03	2.16
2011	0.19	0.49	0.92	0.64	1.11	0.14	1.44	2.50
2012	0.67	0.70	0.60	1.18	0.76	0.18	4.37	8.65
2013	0.94	0.96	1.74	0.72	2.13	0.75	–	15.20
2014	0.39	1.04	0.72	0.87	0.55	0.87	–	23.23

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 1, CRA 2, CRA 3, CRA 4, CRA 5, CRA 7, CRA 8 and CRA 9 management procedures (MPs) for the 2015–16 fishing year, based on CPUE data extracted in early November 2014 and standardised as described below. All rules have been evaluated through simulation from operating models based on the stock assessment results (MP evaluations or MPEs). A new management procedure for CRA 1 was implemented in 2015. The CRA 3 MP was revised for the 2015–16 fishing year. New MPs were developed in 2015 for CRA 5 and CRA 8 and may be used to set catch limits for the 2016–17 fishing year; the outcome will be reported in the 2016 Report.

The rule descriptions provided below are simplified using the specific parameters for each QMA. For the generalised rules and their parameters, see Breen (2015).

4.1 Data preparation

Data were obtained from the Ministry for Primary Industries mandatory catch and effort reporting system and groomed (Bentley et al 2005) and the estimated catches were scaled either to the LFR (“L”) landings using the “B4” procedure (CRA 4 and CRA 5) or to the combined LFR, Destination “X” and Section 111 (Destination “F”) landings (designated “LFX” below; all other stocks). These methodologies are described in Section 1.3, in Bentley et al (2005) and in Starr (2015). All data were aggregated by fishing year, month, rock lobster statistical area and vessel before being processed by the standardisation procedure (Maunder & Starr 1995; Bentley et al 2005, Starr 2015), 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” (October through September) 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. The most recent rule evaluations below were based on the offset year from 1 October 2014 to 30 September 2015, giving a proposed TACC for the fishing year starting 1 April 2016.

CPUE standardisation follows the suggestion of Francis (1999) and calculates “canonical” coefficients and standard errors for each year. 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. This procedure scales the standardised indices to CPUE levels consistent with those observed by fishermen.

Management Procedure for CRA 1

The CRA 1 MP is based on the 2014 stock assessment and MPEs (Webber & Starr 2015). The output is TACC (t) and the input variable is offset year standardised CPUE (kg/potlift), calculated in November and scaled to the "LFX" destination code using the "F2" data preparation procedure. There is no latent year, no maximum change threshold and a 5% minimum change threshold.

Figure 5 shows the relationship between CPUE and the TACC for the CRA 1 MP and Eq. 1 describes the MP: TACC is zero when CPUE is below 0.1 kg/potlift; between a CPUE of 0.1 and 1.1 kg/potlift, the TACC increases linearly with CPUE to a plateau of 131 t. The plateau extends to a CPUE of 1.7 kg/potlift. As CPUE increases above 1.7 kg/potlift, TACC increases in steps with a width of 0.25 kg/potlift and a height of 5% of the preceding TACC.

The rule is specified as follows: TACC is given by:

Eq. 2

$$TACC_{y+1} = 0 \qquad \text{for } I_y \le 0.1$$

$$TACC_{y+1} = 131.062\left(I_y - 0.1\right) \qquad \text{for } 0.1 < I_y \le 1.1$$

$$TACC_{y+1} = 131.062 \qquad \text{for } 1.1 < I_y \le 1.7$$

$$TACC_{y+1} = 131.062\left(1.05^{\mathrm{floor}\left(\left(I_y - 1.7\right)/0.25\right)+1}\right) \qquad \text{for } I_y > 1.7$$

where $TACC_{y+1}$ is the provisional TACC (before thresholds operate) and I_y is the standardised offset-year CPUE in the preceding year. There was no change to the TACC in 2016–17 in accordance with the rule evaluation (Table 13).

Table 13: History of the CRA 1 management procedure. "Rule result" is the result of the management procedure after operation of all its components including thresholds.

Year	Applied to fishing year	Offset CPUE (kg/potlift)	Rule result: TACC (t)	Applied TACC (t)	Applied TAC (t)
2014	2015–16	1.5803	131.062	131.062	273.062
2015	2016–17	1.3154	131.062		

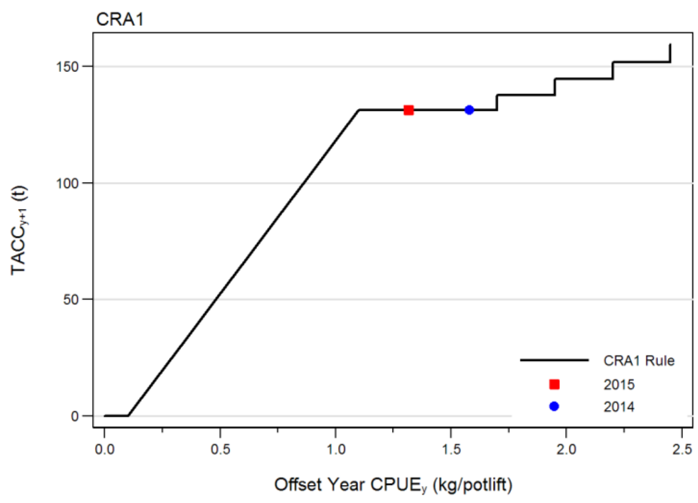


Figure 5: The CRA 1 harvest control rule. The red square shows the 2015 offset-year CPUE and TACC.

4.2 Management Procedure for CRA 2

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

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

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

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

Figure 6 shows the relationship between CPUE and the TACC for the CRA 2 MP and Eq. 3 describes the MP: between a CPUE of 0 and 0.5 kg/potlift, the TACC increases linearly with CPUE to a plateau of 200 t, which extends to a CPUE of 0.5 kg/potlift. As CPUE increases above 0.5 kg/potlift, TACC increases in steps with a width of 0.1 kg/potlift and a height of 10% of the preceding TACC

Eq. 3

$$TACC'_{y+1} = 200\left(\frac{I_y}{0.3}\right) \quad \text{for } 0.0 < I_y \le 0.3$$

$$TACC'_{y+1} = 200 \quad \text{for } 0.3 < I_y \le 0.5$$

$$TACC'_{y+1} = 200\left(1.10^{\text{floor}\left((I_y - 0.5)/0.1\right)+1}\right) \quad \text{for } I_y > 0.5$$

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

The Minister accepted and implemented this management procedure for the 2013–14 fishing year. The TACC decreased in 2013-14 in accordance with the rule evaluation (Table 14). In November 2015, the standardised offset-year CPUE was 0.2991 kg/potlift. The rule generated a proposed TACC of 199.4 t for 2015–16, however, as this would be a change of only 0.3% (below the minimum change threshold of 5%) the result of the MP is no change to the current TACC.

Table 14: History of the CRA 2 management procedure and proposed limit to the commercial fishery in the 2016–17 fishing year. "Rule result" is the result of the management procedure after operation of all its components including thresholds.

Year of analysis	Applied to fishing year	Offset-year CPUE at time of analysis (kg/potlift)	Rule result: TACC (t)	TACC (t)	TAC (t)
2013	2014–15	0.3668	200.0	200.0	416.5
2014	2015–16	0.3661	200.0	200.0	416.5
2015	2016–17	0.2991	200.0		

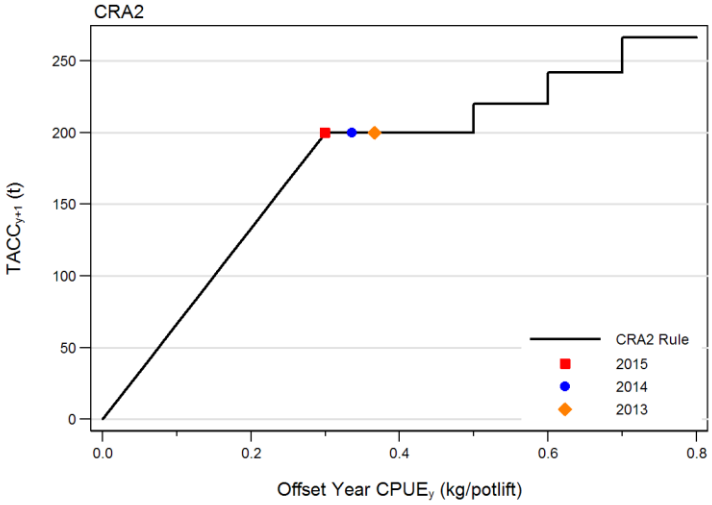


Figure 6: The CRA 2 management procedure, showing the provisional TACC in year y+1 as a function of offset year CPUE in year y, and showing the 2013 to 2015 results.

4.3 Management Procedure for CRA 3

The CRA 3 MP was revised for the 2015–16 fishing year based on the 2014 stock assessment and MPEs (Haist et al. 2015). The output variable is TACC (t) and the input variable is offset year standardised CPUE (kg/potlift), calculated in November and scaled to the "LFX" destination code using the "F2" data preparation procedure. The rule has no latent year, a maximum change threshold of 10% and a minimum change of 5%.

The new harvest control rule is a modified plateau slope rule (Eq. 4). The modification involves a) fixing the intercept to zero, b) having two straight-line segments between zero and the left of the plateau (Figure 7) and c) having a different slope equation from the generalised plateau slope rule. When CPUE is between 0 and 1.0 kg/potlift, the TACC rises linearly to 180 t; when CPUE is between 1 and 2 kg/potlift, CPUE rises linearly from 180 to 260 t. A plateau of 260 extends from 2 to 3 kg/potlift, then TACC increases with a slope of 100 t per 1 kg/potlift.

This management procedure is specified as follows:

Eq. 4

$$TACC'_{y+1} = 180 I_y \qquad \text{for } I_y \le 1.0$$

$$TACC'_{y+1} = 180 + 80\left(I_y - 1.0\right) \qquad \text{for } 1.0 < I_y \le 2.0$$

$$TACC'_{y+1} = 260 \qquad \text{for } 2.0 < I_y \le 3.0$$

$$TACC'_{y+1} = 260 + 50\left(\frac{\left(I_y - 3.0\right)}{0.5}\right) \qquad \text{for } I_y > 3.0$$

where $TACC'_{y+1}$ is the provisional TAC (before thresholds operate) and I_y is the CPUE (kg/potlift) in the preceding year.

In November 2015, standardised offset-year CPUE was 1.8842 kg/potlift, and was no longer on the plateau. The preliminary rule result was a TACC of 250.74 t, but as this would have been a TACC change of 3.9% (below the minimum change threshold of 5%), the result of the MP is no change to the current TACC (Table 15).

Table 15: History of the current CRA 3 management procedure. "Rule result" is the result of the management procedure after operation of all its components including thresholds.

Year	Applied to fishing year	Offset CPUE (kg/potlift)	Rule result: TACC (t)	Applied TACC (t)	Applied TAC (t)
2014	2015–16	2.214	260.95	260.95	389.95
2015	2016–17	1.8842	260.95		

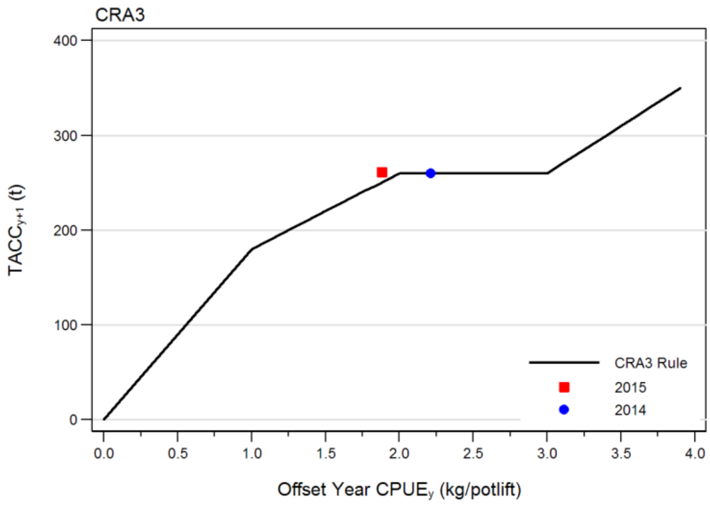


Figure 7: The CRA 3 harvest control rule; the red square shows the 2015 CPUE and TACC.

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 (t) and the input variable is offset year 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 is no minimum change threshold but a maximum change threshold of 25% applies to increases below the plateau.

Figure 8 shows the relationship between CPUE and the TACC for the CRA 4 MP and Eq. 5 describes the MP: below a CPUE of 0.5 kg/potlift, the TACC is zero; between a CPUE of 0.5 and 0.9 kg/potlift, the TACC increases linearly with CPUE to a plateau of 467 twhich extends to a CPUE of 1.3 kg/potlift. 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.

Eq. 5 $TACC'_{y+1} = 0$ **for** $I_y \le 0.5$

$$TACC'_{y+1} = 467\left(\frac{I_y - 0.5}{0.4}\right) \quad \text{for } 0.5 < I_y \le 0.9$$

$$TACC'_{y+1} = 467 \quad \text{for } 0.9 < I_y \le 1.3$$

$$TACC'_{y+1} = 467\left(1.07^{\operatorname{floor}\left((I_y - 1.3)/0.1\right)+1}\right) \quad \text{for } I_y > 1.3$$

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

The Minister accepted and implemented this management procedure for the 2012–13 fishing year. The TACC increased in 2013–14 but was reduced in 2014–15 in accordance with the rule evaluation (Table 16). In November 2015, the standardised offset-year CPUE was 0.8822 kg/potlift. The rule generated a proposed TACC of 446.219 t for 2016–17. (Note: there is no minimum change threshold for the CRA 4 MP).

Table 16: History of the CRA 4 management procedure and proposed limit to the commercial fishery in the 2016–17 fishing year. "Rule result" is the result of the management procedure after operation of all its components including thresholds.

Year of analysis	Applied to fishing year	Offset-year CPUE at time of analysis (kg/potlift)	Rule result: TACC (t)	TACC (t)	TAC (t)
2011	2012–13	1.194	466.9	466.9	661.9
2012	2013–14	1.374	499.69	499.7	694.7
2013	2014–15	1.293	467.0	467.0	662.0
2014	2015–16	1.168	467.0	467.0	662.0
2015	2016-17	0.882	446.22		

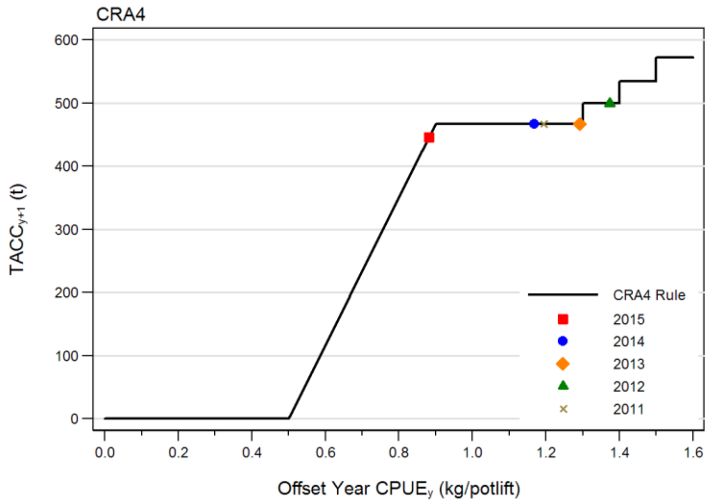


Figure 8: The CRA 4 management procedure, showing the TACC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACCs resulting from the rule evaluations performed in 2011 through to 2015.

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 (t) and the input variable is offset year 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.

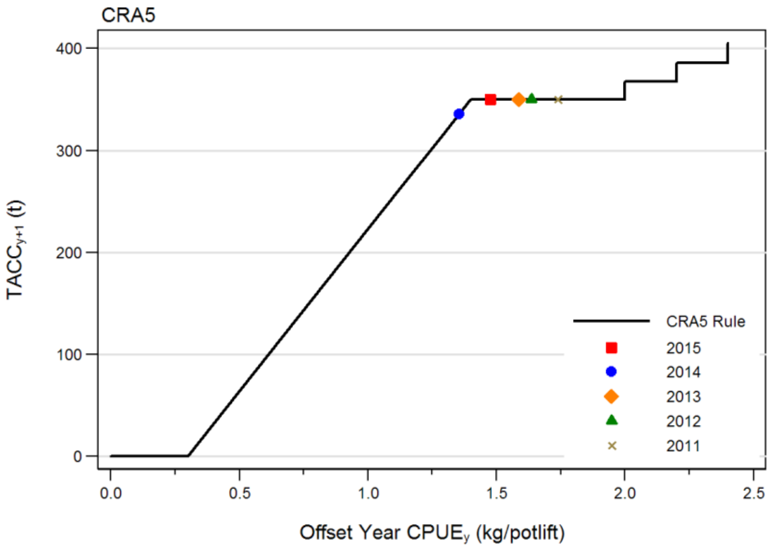


Figure 9 shows the relationship between CPUE and the TACC for the CRA 5 MP and Eq. 6 describes the MP: below a CPUE of 0.3 kg/potlift, the TACC is zero; between a CPUE of 0.3 and 1.4 kg/potlift, the TACC increases linearly with CPUE to a plateau of 350 t which extends to a CPUE of 2.0 kg/potlift. As 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.

Eq. 6

$$TACC'_{y+1} = 0 \qquad \textbf{for } I_y \le 0.3$$

$$TACC'_{y+1} = 350\left(\frac{I_y - 0.3}{1.1}\right) \qquad \textbf{for } 0.3 < I_y \le 1.4$$

$$TACC'_{y+1} = 350 \qquad \textbf{for } 1.4 < I_y \le 2.0$$

$$TACC'_{y+1} = 350\left(1.05^{\mathrm{floor}\left((I_y - 2.0)/0.2\right)+1}\right) \qquad \textbf{for } I_y > 2.0$$

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

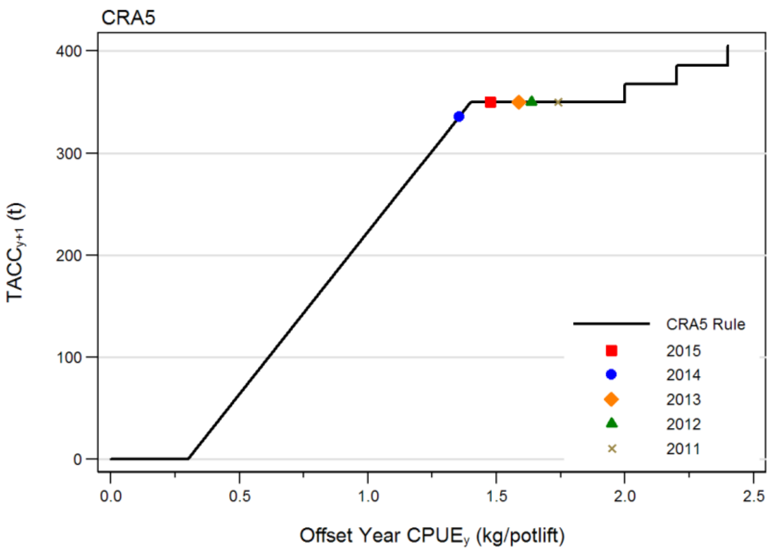
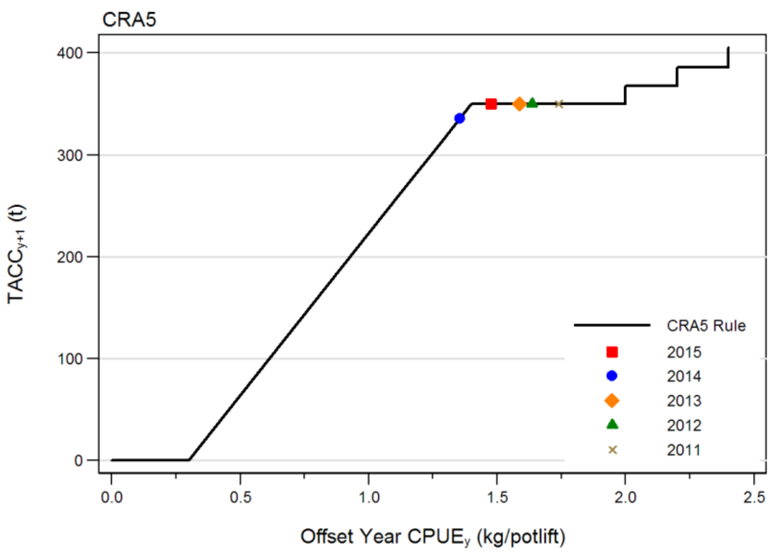


Figure 9: The CRA 5 management procedure, showing the TACC in year *y+1* as a function of offset year CPUE in year *y*, and showing the TACCs resulting from the rule evaluations performed in 2011 through to 2015.

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 2014, the standardised offset-year CPUE was 1.3554 kg/potlift. The rule generated a proposed TACC of 335.81 t for 2015–16, a reduction of 4.05% as the CPUE lies to the left of the plateau



(

Figure 9). After much discussion, the NRLMG recommended that no change be made, because the change was less than 5% and most other QMAs have at least a minimum 5% change threshold, and because there would be a re-evaluation of this rule in 2015. The Minister accepted this recommendation and the TACC remained at 350 t. This is the first instance in the history of NZ rock lobster MPs of a rule result not being implemented.

In November 2015, the standardised offset-year CPUE was 1.478 kg/potlift, which is on the plateau. The rule generated a proposed TACC of 350 t for 2016–17.

Table 17: History of the CRA 5 management procedure and proposed limit to the commercial fishery in the 2016–17 fishing year. "Rule result" is the result of the management procedure after operation of all its components including thresholds.

Year of analysis	Applied to fishing year	Offset-year CPUE in year of analysis (kg/potlift)	Rule result: TACC (t)	TACC (t)	TAC (t)
2011	2012–13	1.740	350	350	467
2012	2013–14	1.636	350	350	467
2013	2014–15	1.587	350	350	467
2014	2015–16	1.355	335.81	350	467
2015	2016-17	1.478	350		

A revised management procedure for CRA 5 is currently under development.

4.6 Management Procedure for CRA 7

CRA 7 has been managed since 1996 using management procedures, although the original MP was based on 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 (t) and the input variable is offset year standardised CPUE (kg/potlift), calculated in November and scaled to the "LFX" destination codes using the "F2" data preparation procedure. The minimum change is 10% and the maximum change is 50%. There is no latent year. The CRA 7 rule (Figure 10) is described by Eq. 7:

Eq. 7

$$TACC_{y+1} = 0 \quad \textbf{for } I_y < 0.17$$

$$TACC_{y+1} = 80\left(\frac{I_y - 0.17}{0.83}\right) \quad \textbf{for } 0.17 < I_y < 1.0$$

$$TACC_{y+1} = 80 \quad \textbf{for } 1.0 \le I_y \le 1.75$$

$$TACC_{y+1} = 80\left(1 + \frac{0.5\left(I_y - 1.75\right)}{1.25}\right) \quad \textbf{for } I_y > 1.75$$

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*.

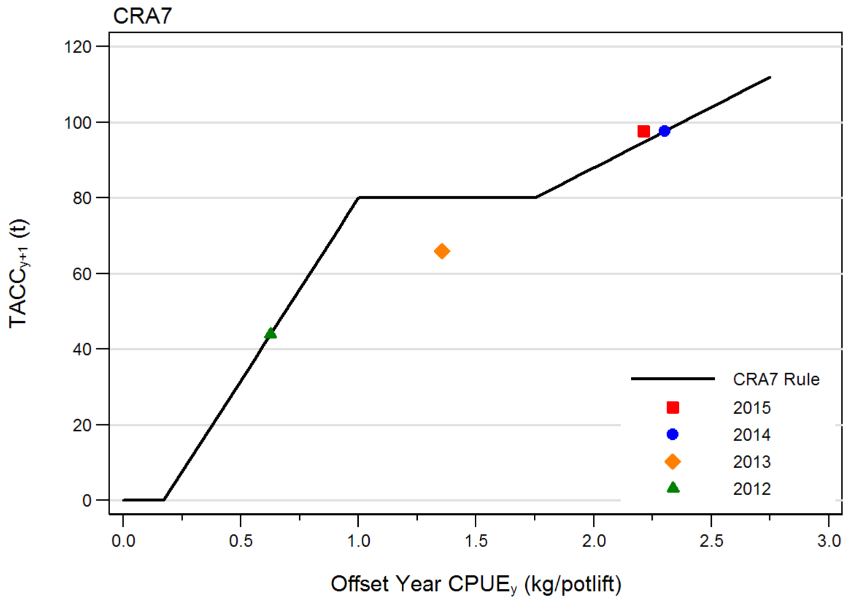


Figure 10: The CRA 7 management procedure, showing the TACC as a function of offset year CPUE, and showing TACCs resulting from the rule evaluations performed in 2012 through to 2015.

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 18). CPUE doubled in 2012–13 to 1.356 kg/potlift, resulting in a provisional TACC of 80 t. But this would have been a larger increase than the 50% maximum allowed by the rule. The TACC was set at 66.0 t and the TAC was set at 86.0 t. In November 2014, CPUE had increased further to 2.3036 kg/potlift, a 48% increase, which gave a proposed TACC of 97.72 t (Figure 10).

In November 2015, CPUE had decreased to 2.2124 kg/potlift, giving a TACC of 94.797 t, however, as this would be a change of only 2.9% (below the minimum threshold of 10%), the MP results in no change to the TACC.

Table 18: History of the CRA 7 management procedure and proposed limit to the commercial fishery in the 2016–17 fishing year. "Rule result" is the result of the management procedure after operation of all its components including thresholds.

Year	Applied to fishing year	Offset-year CPUE (kg/potlift)	Rule result: TACC (t)	TACC (t)	TAC (t)
2012	2013–14	0.625	43.96	44.0	64.0
2013	2014–15	1.356	66	66.0	86.0
2014	2015–16	2.3036	97.72	97.72	117.72
2015	2016-17	2.2124	97.72		

4.7 Management Procedure for CRA 8

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

The current management procedure uses the most recent offset-year standardised CPUE, scaled to the "LFX" destination code using the "F2" data preparation procedure, as input. 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 11 and the MP is described in Eq. 8. 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.

Eq. 8

$$TACC_{y+1} = 0 \qquad \textbf{for } I_y < 0.4535$$

$$TACC_{y+1} = 962\left(\frac{I_y - 0.4535}{1.4465}\right) \qquad \textbf{for } 0.4535 < I_y < 1.9$$

$$TACC_{y+1} = 962 \qquad \textbf{for } 1.9 \le I_y \le 3.7$$

$$TACC_{y+1} = 962\left(1 + \frac{0.5\left(I_y - 3.7\right)}{4.9244}\right) \qquad \textbf{for } I_y > 3.7$$

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 19). The offset-year CPUE for 2012–13 was 3.377, slightly increased from 2011–12, which resulted in a TACC that was 1.6% greater than the existing TACC of 962 t. This increase was below the minimum change threshold of 5% and consequently there was no increase for 2014–15. In November 2014, CPUE was 3.5615, again giving a TACC on the plateau. In November 2015, CPUE decreased to 3,297 but was still on the plateau (Figure 11).

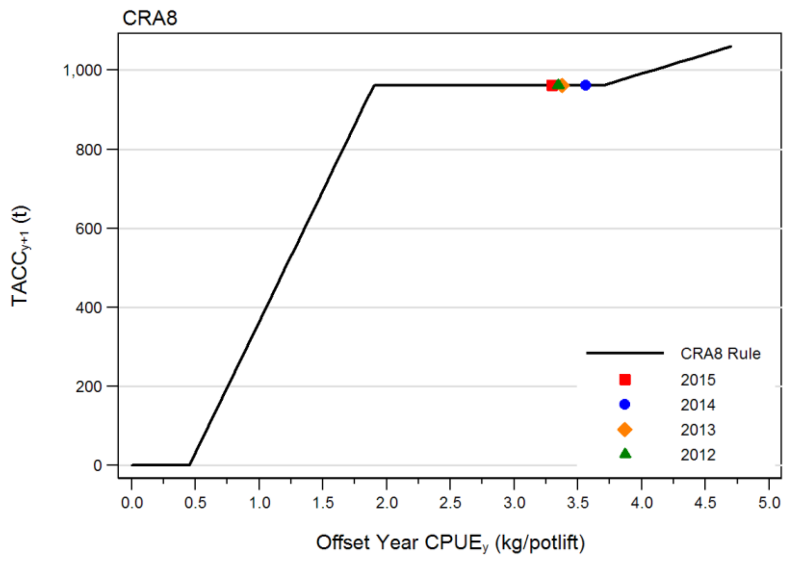


Figure 11: The CRA 8 management procedure, showing TACCs resulting from the rule evaluations performed in 2012 through to 2015.

Table 19: History of the CRA 8 management procedure and proposed limit to the commercial fishery in the 2016–17 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	3.346	962	962	1053
2013	2014–15	3.377	962	962	1053
2014	2015–16	3.5615	962	962	1053
2015	2016-17	3.297	962		

A revised management procedure for CRA 8, based on retained rock lobsters, is currently under development.

4.8 Management Procedure for CRA 9

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

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

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

c) a maximum change threshold of 15% applies only to increases; the minimum change is 5%.

Figure 12 shows the relationship between CPUE and the TACC for the CRA 9 MP and Eq. 9 describes the MP: below a CPUE of 0.5 kg/potlift, the TACC is zero; between a CPUE of 0.5 and 1.0 kg/potlift, the TACC increases linearly with CPUE to a plateau of 40 t, which extends to a CPUE of 1.4 kg/potlift. As CPUE increases above 1.4 kg/potlift, TACC increases in steps with a width of 0.75 kg/potlift and a height of 15% of the preceding TACC.

Eq. 9

$$TACC'_{y+1} = 0.0 \qquad \text{for } I_y < 0.5$$

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

$$TACC'_{y+1} = 40.0 \qquad \text{for } 1.0 < I_y \le 1.4$$

$$TACC'_{y+1} = 40\left(1.15^{\text{floor}\left((I_y - 1.4)/0.75\right)+1}\right) \qquad \text{for } I_y > 1.4$$

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

The Minister accepted and implemented this management procedure for the 2013–14 fishing year. The TACC increased in 2013-14 in accordance with the rule evaluation (Table 20). In November 2014, the standardised offset-year CPUE was 2.095 kg/potlift. The rule generated a proposed TACC of 46 t for 2015–16, a decrease of 24.3% to the current TACC. CRA 9 opposed this decrease on the basis that there were problems with CPUE, and the NRLMG recommended no change to the TACC pending an audit of CPUE data; the Minister accepted this recommendation. This was only the second instance of an MP not being followed in the short history of NZ rock lobster MPs.

In November 2015, CPUE has further decreased to 1.8853 kg/potlift, and the MP results is a TACC of 46 t.

Table 20: History of the CRA 9 management procedure and proposed limit to the commercial fishery in the 2016–17 fishing year. "Rule result" is the result of the management procedure after operation of all its components including thresholds.

Year of analysis	Applied to fishing year	Offset-year CPUE at time of analysis (kg/potlift)	Rule result: TACC (t)	TACC (t)	TAC (t)
2013	2014–15	3.141	60.8	60.8	115.8
2014	2015–16	2.095	46.0	60.8	115.8
2015	2016-17	1.8853	46.0		

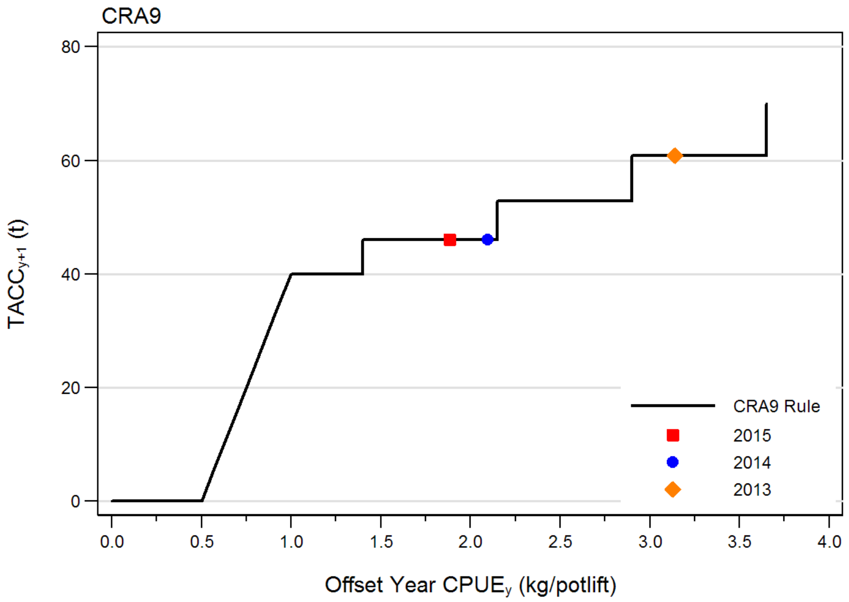


Figure 12: The CRA 9 management procedure, showing the provisional TACC in year y+1 as a function of offset year CPUE in year y, and showing the TACCs resulting from the rule evaluations performed from 2013 to 2015.

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

New stock assessments conducted in 2015 included CRA 5, CRA 7 and CRA 8. Summaries of the results for these analyses are presented below. This section also repeats stock assessment results for other stocks from previous Mid-Year Plenary documents. The text relating to these other stocks has not been updated from the originals and reflects the TAC, TACC and allowances that were current at the time each assessment was completed.

6.1 CRA 1

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

Model structure

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

The reconstruction assumed that the stock was unexploited before 1945. MLS and escape gap regulations in 1945 differed from those in 2013. To accommodate these differences, the model incorporated a time series of MLS regulations by sex and modelled escape gap regulation changes by estimating separate selectivity functions before and after 1993. A comparison of landed commercial grade weights with observer length frequency data converted to an equivalent weight distribution indicated that it was not necessary to adjust for the discarding of legal lobsters in CRA 1. Data used in the assessment and their sources are listed in Table 22.

Table 22: Data types and sources available for the 2014 stock assessment of CRA 1. Fishing years are named from the first 9 months, *viz.* 1998–99 is called 1998. NA – not applicable or not used; MPI – NZ Ministry for Primary Industries; NZ RLIC – NZ Rock Lobster Industry Council Ltd.; FSU – Fisheries Statistics Unit; CELR – catch and effort landing returns; NIWA – National Institute of Water and Atmosphere.; NA: not used.

Data type	Data source	CRA 1 Begin year	CRA 1 End year
CPUE	FSU & CELR	1979	2013
Observer proportions-at-size	MPI and NZ RLIC	1997	2013
Logbook proportions-at-size	NZ RLIC	1993	2013
Tag recovery data	NZ RLIC & MFish	1975	2013

Table 22 [Continued]

Data type	Data source	CRA 1 Begin year	CRA 1 End year
Historical MLS regulations	Annala (1983), MPI	1950	2013
Escape gap regulation changes	Annala (1983), MPI	1945	2013
Puerulus settlement	NIWA	NA	NA
Retention	NZ RLIC	NA	NA

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

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

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

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

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

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

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

Proportions-at-length, assumed to be representative of the commercial catch, were available (see Table 22) from observer catch sampling and voluntary logbooks. These data were summarised by area/month strata and weighted by the commercial catch taken in each stratum, the number of lobsters measured and the number of days sampled. Data from observers and logbooks were fitted separately. Fitting the length data followed the procedure used in 2013 for CRA 2, which differed from previous assessments which normalised across males, immature and mature females before fitting, thus fixing the sex ratios to those observed in the data. For this assessment, proportions were normalised and fitted within each sex category, with the model also estimating proportions-at-sex using a multinomial likelihood. These data were weighted within the model using the method of Francis (2011). One length frequency sample was removed from the data set because of the enormous residuals (greater than 800) generated when fitting to these data.

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

Parameters estimated in the base case and their priors are provided in Table 23. Informed normal priors were used to constrain the selectivity parameters for both sexes. This step was necessary because there were no length frequency data available to inform the first epoch (which ended in 1992 and the LF data started in 1993). The mean of the prior for each selectivity parameter was taken from the median of the posterior for the same parameter from the 2013 CRA 2 stock assessment and a CV of 20% was assumed. Fixed parameters and their values are given in Table 24.

Model projections

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

1. Model parameters were estimated by AD Model Builder™ using maximum likelihood and the prior probability distributions. These estimates are called the MPD (mode of the joint posterior distribution) estimates;
2. Samples from the joint posterior distribution of parameters were generated with Markov chain Monte Carlo (MCMC) simulations using the Metropolis-Hastings algorithm. Twenty-two million simulations were done, starting from the base case MPD, and 1000 samples were saved;
3. From each sample of the posterior, 4-year projections (2014–2017) were generated using the 2013 catches, with annual recruitment randomly sampled from a distribution based on the model's estimated recruitments from 2002–11.

Table 23: Parameters estimated and priors used in the base case assessment for CRA 1. Prior type abbreviations: U – uniform, N – normal, L – lognormal.

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

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

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

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

Performance Indicators and Results

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

Agreed indicators are summarised in Table 25. After inspection of the vulnerable biomass trajectory, the RLFAWG agreed to keep *Bref* as defined in the previous (2002) stock assessment (mean 1979–1988 biomass), using the current MLS and selectivity.

Base case results (Figure 12 and Table 26) suggest that AW biomass decreased to a low point in the early-1970s, remained low until the mid-1990s and has increased since. Median projected biomass, with current catches over four years, was slightly higher than the current biomass. Estimated current biomass is well above *Bref* and neither current nor projected biomass was near the soft limit of 20% *SSB0*.

MCMC sensitivity trials were also made:

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

Results from the base case and sensitivity trials are compared in Table 26.

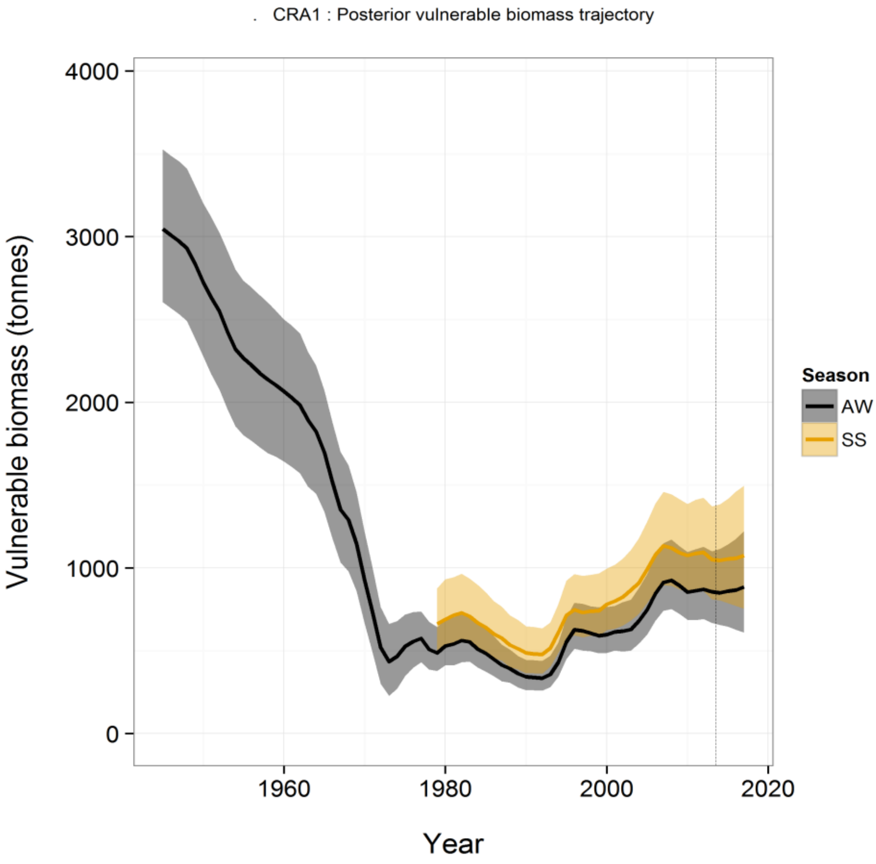


Figure 12: Posterior distributions of the CRA 1 base case vulnerable biomass and projected vulnerable biomass by season from 1945 to 2013. Shaded areas show the 90% credibility intervals and the solid line is the median of the posterior distributions. The vertical line shows 2013, the final fishing year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

Table 25: Performance indicators used in the CRA 1 stock assessment.

Reference points	**Description**
Bmin	The lowest beginning AW vulnerable biomass in the series
Bcurrent	Beginning of season AW vulnerable biomass for 2014
Bref	Beginning of AW season mean vulnerable biomass for 1979–88
Bproj	Projected beginning of season AW vulnerable biomass (ie, 2017)
Bmsy	Beginning of season AW vulnerable biomass associated with MSY, calculated by doing deterministic forward projections with recruitment *R0* and current fishing patterns
MSY	Maximum sustainable yield (sum of AW and SS SL catches) found by searching across a range of multipliers on *F*.
Fmult	The multiplier that produced *MSY*
SSBcurr	Current spawning stock biomass at start of AW season
SSBproj	Projected spawning stock biomass at start of AW season (2017)
SSBmsy	Spawning stock biomass at start of AW season associated with *MSY*
CPUE indicators	**Description**
CPUEcurrent	CPUE at *Bcurrent*
CPUEproj	CPUE at *Bproj*
CPUEmsy	CPUE at *Bmsy*
Performance indicators	**Description**
Bcurrent / Bmin	ratio of *Bcurrent* to *Bmin*
Bcurrent / Bref	ratio of *Bcurrent* to *Bref*
Bcurrent / Bmsy	ratio of *Bcurrent* to *Bmsy*
Bproj / Bcurrent	ratio of *Bproj* to *Bcurrent*
Bproj / Bref	ratio of *Bproj* to *Bref*
Bproj / Bmsy	ratio of *Bproj* to *Bmsy*
SSBcurr/SSB0	ratio of *SSBcurrent* to *SSB0*
SSBproj/SSB0	ratio of *SSBproj* to *SSB0*
SSBcurr/SSBmsy	ratio of *SSBcurrent* to *SSBmsy*
SSBproj/SSBmsy	ratio of *SSBproj* to *SSBmsy*
SSBproj/SSBcurr	ratio of *SSBproj* to *SSBcurrent*
USLcurrent	The current exploitation rate for SL catch in AW
USLproj	Projected exploitation rate for SL catch in AW (2017)

Table 25 [Continued]

Reference points	**Description**
USLproj/USLcurrent	ratio of SL projected exploitation rate to current SL exploitation rate
Btotcurrent	Total biomass (all sizes and sex, regardless of maturity) at beginning of AW 2014
Btotcurrent/Btot0	Total biomass[2014]/[equilibrium unfished total biomass]
Ntotcurrent	Total numbers (all sizes and sex, regardless of maturity) at beginning of AW 2014
Ntotcurrent/Ntot0	Total numbers[2014]/[equilibrium unfished total numbers]
Probabilities	**Description**
P*(Bcurrent > Bmin)*	probability *Bcurrent* > *Bmin*
P*(Bcurrent > Bref)*	probability *Bcurrent* > *Bref*
P*(Bcurrent > Bmsy)*	probability *Bcurrent* > *Bmsy*
P*(Bproj > Bmin)*	probability *Bproj* > *Bmin*
P*(Bproj > Bref)*	probability *Bproj* > *Bref*
P*(Bproj > Bmsy)*	probability *Bproj* > *Bmsy*
P*(Bproj > Bcurrent)*	probability *Bproj* > *Bcurrent*
P*(SSBcurr>SSBmsy)*	probability *SSBcurr>SSBmsy*
P*(SSBproj>SSBmsy)*	probability *SSBproj>SSBmsy*
P*(USLproj>USLcurr)*	probability SL exploitation rate *proj* > SL exploitation rate *current*
P*(SSBcurr<0.2SSB0)*	soft limit: probability *SSBcurrent* < 20% *SSB0*
P*(SSBproj<0.2SSB0*	soft limit: probability *SSBproj* < 20% *SSB0*
P*(SSBcurr<0.1SSB0)*	hard limit: probability *SSBcurrent* < 10% *SSB0*
P*(SSBproj<0.1SSB0)*	hard limit: probability *SSBproj* < 10% *SSB0*
P(*Bcurr*<50%*Bref*)	soft limit: probability *Bcurr* < 50% *Bref*
P(*Bcurr*<25%*Bref*)	hard limit: probability *Bcurr* < 25% *Bref*
P(*Bproj*<50%*Bref*)	soft limit: probability *Bproj* < 50% *Bref*
P(*Bproj*<25%*Bref*)	hard limit:probability *Bproj*< 25% *Bref*

Table 26: Assessment results: median and probability indicators for CRA 1 from the base case MCMC and sensitivity trials. Biomass in tonnes and CPUE in kg/pot.

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

Table 26 [Continued]

Indicator	basecase	uniform *M*	Alt recreational catch	Half illegal catch	Double illegal catch	Fixed *M*=0.2
P(USLproj>USLcurr)	0.507	0.478	0.443	0.486	0.533	0.577
P(SSBcurr<0.2SSB0)	0	0	0	0	0	0
P(SSBproj<0.2SSB0	0	0	0	0	0	0
P(SSBcurr<0.1SSB0)	0	0	0	0	0	0
P(SSBproj<0.1SSB0)	0	0	0	0	0	0

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

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

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

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

Each point on Figure 13 shows the median of the posterior distributions of biomass ratio and fishing intensity ratio. The vertical line in the Figure 13 is the median (line) and 90% interval (shading) of the posterior distribution of *SSBmsy* as a proportion of *SSB0*. This ratio was calculated using the fishing pattern in 2013. The horizontal line in Figure 13 is drawn at 1, the fishing intensity associated with *Fmsy*. The bars at the final year of the plot show the 90% intervals of the posterior distributions of biomass ratio and fishing intensity ratio.

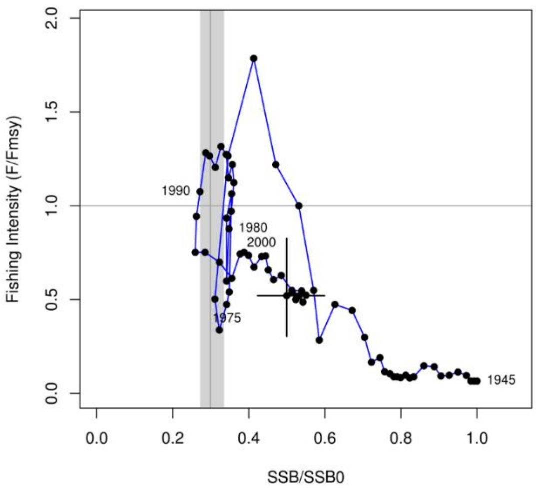


Figure 13: Snail trail summary of the CRA 1 base case model. The line tracks the median values for each axis from the MCMC posteriors and the cross marks the 90% credibility interval on both axes for the final model year (2013). The vertical line in the figure is the median (line) and 90% interval (shading)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

6.2 CRA 2

This section describes a 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 14 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*.

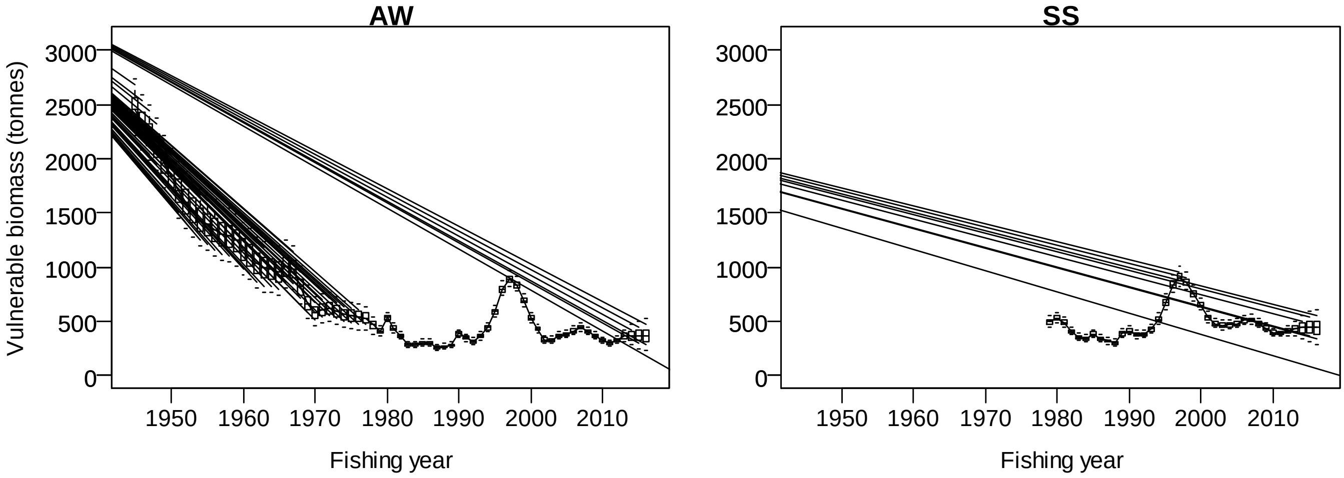


Figure 14: Posterior distributions of the CRA 2 base case MCMC vulnerable biomass trajectory by season. Before 1979 there was a single time step, shown in AW. For each year the box spans the 25th and 75th quantiles and the whiskers span the 5th and 95th quantiles.

Table 30: Performance indicators used in the CRA 2 stock assessment.

Reference points	**Description**
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*.
Reference points	**Description**
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	**Description**
CPUEcurrent	CPUE at *Bcurrent*
CPUEproj	CPUE at *Bproj*
CPUEmsy	CPUE at *Bmsy*
Performance indicators	**Description**
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	**Description**
P*(Bcurrent > Bmin)*	probability *Bcurrent > Bmin*
P*(Bcurrent > Bref)*	probability *Bcurrent > Bref*

Table 30 [Continued].

Reference points	Description
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:

- *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
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

Table 31 Continued]

Indicator	basecase	CPUE pow3	CPUE pow5	Old LFs	Untrunc LFs	noDD	HiRec
P(USLproj>USLcurr)	0.323	0.284	0.274	0.268	0.313	0.358	0.019
P(SSBcurr<0.2SSB0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
P(SSBproj<0.2SSB0	0.001	0.000	0.000	0.001	0.000	0.004	0.000

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

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

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

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

Each point in Figure 15 shows the median of the posterior distributions of biomass ratio and fishing intensity ratio. The vertical line in Figure 15 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 track suggests 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*.

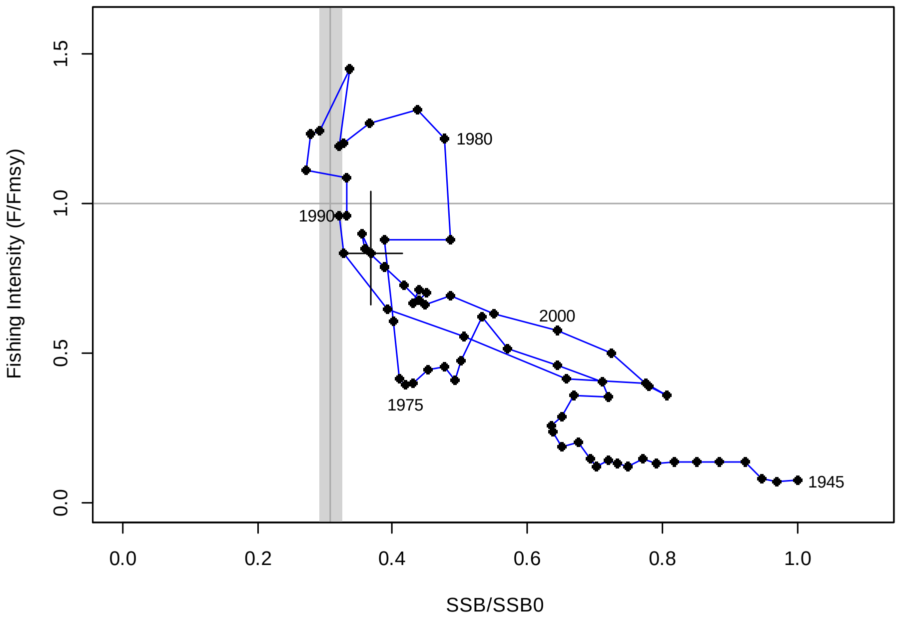


Figure 15: Phase plot that summarises the *SSB* history of the CRA 2 stock. The x-axis is spawning stock biomass *SSB* in each year as a proportion of the unfished spawning stock, *SSB0*. The y-axis is fishing intensity in each year as a proportion of the fishing intensity (*Fmsy*) that would have given *MSY* under the fishing patterns in that year. Each point on the figure shows the median of the posterior distributions of biomass ratio and fishing intensity ratio for one year. The vertical line in the figure is the median (line) and 90% interval (shading) of the posterior distribution of *SSBmsy*; this ratio was calculated using the fishing pattern in 2012. The horizontal line in the figure is drawn at 1, the fishing intensity associated with *Fmsy*. The bars at the final year of the plot (2012) show the 90% intervals of the posterior distributions of biomass ratio and fishing intensity ratio.

6.3 CRA 3

This section reports the 2014 stock assessment for *J. edwardsii* for CRA 3 (Haist et al. 2015).

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

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

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

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

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

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

Other model options used in the reference base cases were:

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

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

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

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

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

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

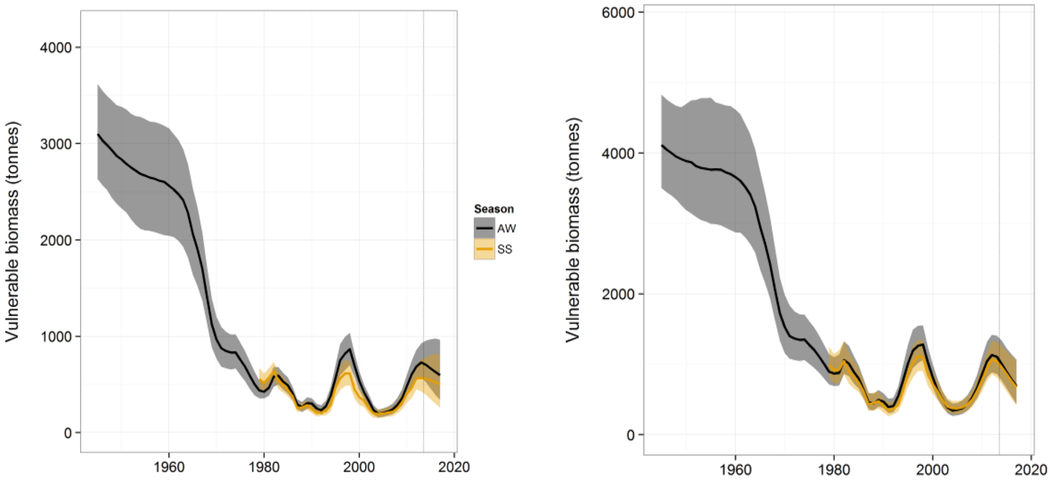


Figure 16: CRA 3: posterior of the trajectory of vulnerable biomass by season, for the fixed growth CV base (left) and the fixed growth shape base case. Shaded areas show the 50% and 90% credibility intervals and the heavy solid line is the median of the posterior distribution. The vertical line shows 2013, the final fishing year of the model reconstruction.

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

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

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

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

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

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

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

The assessment results are summarised in Table 32. Current biomass (*B2014*) was above *Bmin* in all runs, and the median result was 3.0 to 3.5 times *Bmin*. Current biomass was also above *Bmsy* in all of runs, and the median result was between 3 and 5 times *Bmsy*. Current SL exploitation rate was 16% to 24%. Current and projected spawning stock biomass were estimated at about 1.5 times *SSBmsy*. Total biomass was estimated at more than half *B0*, and total numbers at 76% to 90% of *N0*.

Table 32: Quantities of interest to the assessment from the two base case MCMCs; see text for explanation; all biomass values are in tonnes.

			fixed *GCV*			fixed *Gshape*
Indicator	**5%**	**median**	**95%**	**5%**	**median**	**95%**
Bmin	156.3	194.3	235.7	265.6	334.3	412.9
B2014	524.7	704.1	956.1	765.8	1001.2	1335.0
Bref	508.1	633.8	777.3	915.0	1134.7	1418.8
B2017	338.2	596.3	964.8	435.7	690.1	1065.9
Bmsy	173.8	212.8	252.4	173.0	211.7	261.6
MSY	210.2	242.6	282.0	177.1	212.4	253.0
Fmult	4.80	6.02	7.79	5.57	7.34	9.37
SSB2013	1104.9	1243.7	1405.3	2061.3	2389.7	2842.6
SSB2017	1035.2	1273.0	1576.9	1785.2	2241.2	2896.9
SSBmsy	771.5	880.8	1008.2	1351.9	1544.9	1786.7
CPUE2013	1.782	2.094	2.477	1.467	1.714	2.005
CPUE2017	0.774	1.662	2.799	0.609	1.003	1.517
CPUEmsy	0.233	0.288	0.351	0.156	0.196	0.241
B2014/Bmin	2.89	3.64	4.61	2.45	3.01	3.73
B2014/Bref	0.846	1.119	1.497	0.679	0.886	1.121
B2014/Bmsy	2.609	3.333	4.405	3.820	4.725	5.827
B2017/B2014	0.566	0.846	1.157	0.510	0.686	0.903
B2017/Bref	0.526	0.943	1.500	0.399	0.608	0.898
B2017/Bmsy	1.639	2.797	4.554	2.239	3.234	4.640
SSB2013/SSB0	0.619	0.697	0.804	0.930	1.068	1.254
SSB2017/SSB0	0.582	0.713	0.892	0.803	0.995	1.273
SSB2013/SSBmsy	1.247	1.410	1.610	1.357	1.549	1.800
SSB2017/SSBmsy	1.174	1.433	1.792	1.172	1.449	1.831
SSB2017/SSB2013	0.861	1.019	1.196	0.787	0.930	1.123
USL2013	0.188	0.238	0.305	0.123	0.157	0.202
USL2017	0.180	0.292	0.514	0.163	0.252	0.399
USL2017/USL2013	0.830	1.210	1.965	1.164	1.599	2.244
Btot2013	2485.0	2898.7	3438.1	4814.6	5821.1	7170.6
Btot2013/Btot0	0.417	0.495	0.593	0.560	0.672	0.809
Ntot2013	7400000	8950000	11200000	15200000	19200000	25000000
Ntot2013/Ntot0	0.627	0.756	0.948	0.744	0.909	1.137
P(B2014>Bmin)	1.00			1.00		
P(B2014>Bref)	0.75			0.19		
P(B2014>Bmsy)	1.00			1.00		
P(B2017>Bmin)	1.00			0.99		
P(B2017>Bref)	0.44			0.02		
P(B2017>Bmsy)	1.00			1.00		
P(B2017>B2014	0.21			0.02		
P(SSB2013>SSBmsy)	1.00			1.00		
P(SSB2017>SSBmsy)	1.00			1.00		
P(USL2017>USL2013	0.77			1.00		
P(SSB2013<0.2SSB0)	0.00			0.00		
P(SSB2017<0.2SSB0	0.00			0.00		
P(SSB2013<0.1SSB0)	0.00			0.00		
P(SSB2017<0.1SSB0)	0.00			0.00		

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

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

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

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

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

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

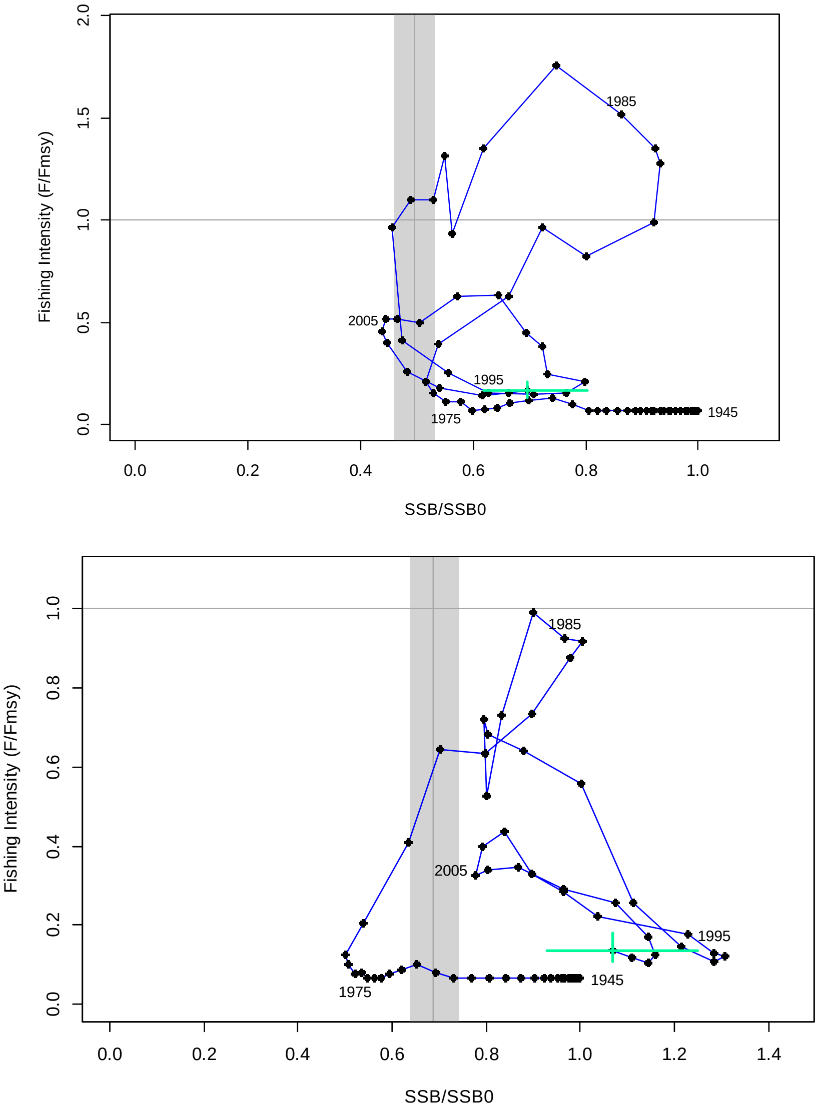


Figure 17: Snail trails from the two CRA 3 base case MCMCs: fixed growth CV on the left. The phase space in the plot is relative spawning biomass on the abscissa and relative fishing intensity on the ordinate; thus high biomass/low fishing intensity is in the lower right-hand corner, where a stock would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

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

- with *M* fixed to 0.12, using the covariance matrix was from a run with *M* fixed to 0.20
- with a uniform prior on *M*; for the fixed growth shape base the covariance matrix was from the base case
- fitted to the puerulus index with lag of 2 years between settlement and recruitment to the model

- fitted to a single combined tag data file
    - this was based on examination of the tag residuals, showing positive for the most recent years

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

6.4 CRA 4

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

Model structure

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

Significant catches occurred in the historical series for CRA 4. Different MLS regulations existed in the past and pots were not required to have escape gaps. The model incorporated a time series of sex-specific MLS regulations. Data and their sources are listed in Table 33.

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 33: 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 34: Parameters estimated and priors used in basecase assessments for CRA 4. Prior type abbreviations: U – uniform; N – normal; L – lognormal. [Continued on next page]

Parameter	Prior Type	No. of parameters	Bounds	Mean	SD	CV
ln(*R0*) (mean recruitment)	U	1	1–25	–		–
M (natural mortality)	L	1	0.01–0.35	0.12		0.4
Recruitment deviations	N [1]	67	-2.3–2.3	0	0.4	
ln(*qCPUE*)	U	1	-25-0	–		–
ln(*qCR*)	U	1	-25-2	–		–
ln(*qpuerulus*)	U	1	-25-0	–		–
Increment at TW=50 (male & female)	U	2	0.1-20.0	–		–
difference between increment at TW=50 and increment at TW=80 (male & female)	U	2	0.001-1.000	–		–
shape of growth curve (male & female)	N	2	0.1-15.0	5.0	0.5	
TW at 50% probability female maturation	U	1	30–80	–		–
TW at 95% probability female maturation minus TW at 50% probability female maturation	N	1	5-80	14	2.8	–
Relative vulnerability (all sexes and seasons) [2]	U	3	0.01-1.0	–		–
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 CV 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 34; fixed values used in the assessment are provided in Table 35. CPUE, the historical catch rate, proportions-at-length and tagging data were given relative weights directly by a relative weighting factor.

Table 35: 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:

1. 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;
2. 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 36);
3. 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 36: Catches (t) used in the four-year projections. Projected catches are based on the current TACC for CRA 4, and the current estimates of recreational, customary and illegal catches. SL= commercial+recreational-reported illegal; NSL=reported illegal+unreported illegal+customary

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

Performance Indicators and Results

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

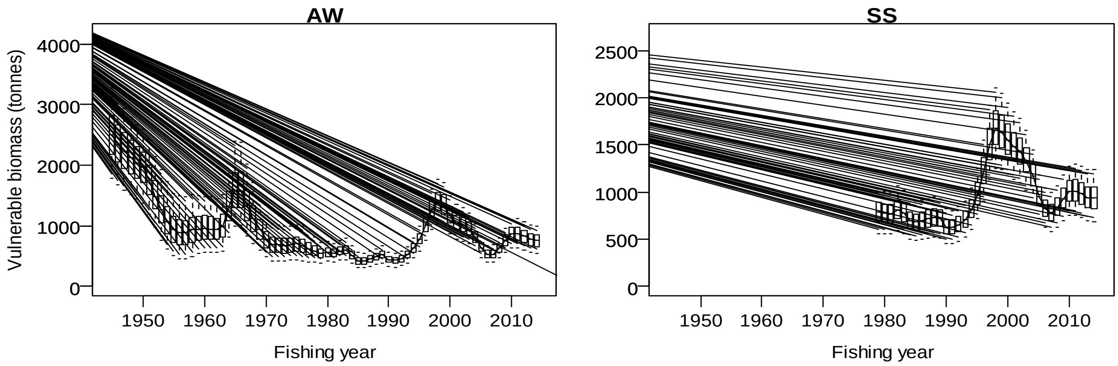


Figure 18: Posterior distributions of the CRA 4 base case MCMC biomass vulnerable trajectory. Before 1979 there was a single time step, shown in AW. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th quantiles.

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

Table 37: Performance indicators used in the CRA 4 stock assessment.

Reference points	**Description**
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	**Description**
CPUEcurrent	CPUE at *Bcurrent*
CPUEproj	CPUE at *Bproj*
CPUEmsy	CPUE at *Bmsy*
Performance indicators	**Description**
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	**Description**
P(Bcurrent > Bmin)	probability *Bcurrent > Bmin*
P(Bcurrent > Bref)	probability *Bcurrent > Bref*
P(Bcurrent > Bmsy)	probability *Bcurrent > Bmsy*
P(Bproj > Bmin)	probability *Bproj > Bmin*
P(Bproj > Bref)	probability *Bproj > Bref*
P(Bproj > Bmsy)	probability *Bproj > Bmsy*
P(Bproj > Bcurrent)	probability *Bproj > Bcurrent*
P(SSBcurr>SSBmsy)	probability *SSBcurr>SSBmsy*
P(SSBproj>SSBmsy)	probability *SSBproj>SSBmsy*
P(USLproj>USLcurr)	probability SL exploitation rate *proj* > SL exploitation rate *current*
P(SSBcurr<0.2SSB0)	soft limit: probability *SSBcurrent* < 20% *SSB0*

Table 37 [Continued]

Probabilities	**Description**
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 37) are shown in Table 38.

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 38: Assessment results – medians of indicators described in Table 37 from the base case and sensitivity trials; the lower part of the table shows the probabilities that events are true; biomass in t and CPUE in kg/potlift. [Continued on next page]

Indicator	basecase	lovuln	nopoo	poolag3	fixed*M*	hiLFwt	hiRecCat
Bmin	407	398	416	355	365	321	423
Bcurr	862	844	941	742	674	805	898
Bref	514	495	521	438	477	411	536
Bproj	751	727	770	607	571	663	831
Bmsy	377	385	374	343	547	416	408
MSY	680	655	676	662	532	610	715
Fmult	4.05	3.76	4.44	3.81	1.50	2.96	3.57
SSBcurr	2 615	809	2 496	1 826	1 513	1 999	2 654
SSBproj	2 796	829	2 457	1 690	1 576	2 147	2 864
SSBmsy	2 646	652	2 387	1 757	1 739	2 143	2 675
CPUEcurrent	0.91	0.91	1.01	0.91	0.91	0.95	0.91
CPUEproj	0.77	0.75	0.78	0.69	0.74	0.73	0.83
CPUEmsy	0.29	0.31	0.29	0.30	0.68	0.38	0.31
Bcurr/Bmin	2.12	2.11	2.27	2.08	1.87	2.52	2.11
Bcurr/Bref	1.68	1.70	1.82	1.69	1.42	1.96	1.68
Bcurr/Bmsy	2.30	2.20	2.56	2.15	1.26	1.94	2.21
Bproj/Bcurr	0.87	0.86	0.82	0.82	0.85	0.83	0.93
Bproj/Bref	1.46	1.47	1.49	1.38	1.22	1.61	1.56
Bproj/Bmsy	2.01	1.90	2.08	1.78	1.08	1.60	2.04
SSBcurr/SSB0	0.65	0.43	0.67	0.62	0.46	0.58	0.63
SSBproj/SSB0	0.69	0.44	0.65	0.57	0.48	0.62	0.68
SSBcurr/SSBmsy	0.98	1.24	1.04	1.04	0.87	0.93	0.99
SSBproj/SSBmsy	1.05	1.27	1.01	0.96	0.91	1.01	1.07
SSBproj/SSBcurr	1.07	1.03	0.96	0.92	1.04	1.08	1.08
USLcurrent	0.24	0.24	0.21	0.27	0.31	0.25	0.23
USLproj	0.30	0.31	0.30	0.38	0.40	0.34	0.25
USLproj/USLcurrent	1.28	1.29	1.38	1.39	1.29	1.36	1.07
P(*Bcurr*>*Bmin*)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P(*Bcurr*>*Bref*)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P(*Bcurr*>*Bmsy*)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P(*Bproj*>*Bmin*)	1.00	1.00	0.99	1.00	1.00	1.00	1.00
P(*Bproj*>*Bref*)	1.00	1.00	0.91	1.00	0.94	1.00	1.00
P(*Bproj*>*Bmsy*)	1.00	1.00	0.99	1.00	0.69	1.00	1.00
P(*Bproj*>*Bcurr*)	0.01	0.02	0.18	0.01	0.02	0.01	0.12

Table 38 [Continued]

Indicator	basecase	lovuln	nopoo	poolag3	fixed*M*	hiLFwt	hiRecCat
P(*SSBcurr*>*SSBmsy*)	0.39	1.00	0.64	0.71	0.01	0.13	0.45
P(*SSBproj*>*SSBmsy*)	0.73	1.00	0.52	0.35	0.10	0.53	0.79
P(*USLproj*>*USLcurr*)	1.00	1.00	0.91	1.00	1.00	1.00	0.83
P(*SSBcurr*<*0.2SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P(*SSBproj*<*0.2SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P(*SSBcurr*<*0.1SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P(*SSBproj*<*0.1SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Indicators based on SSBmsy

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

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

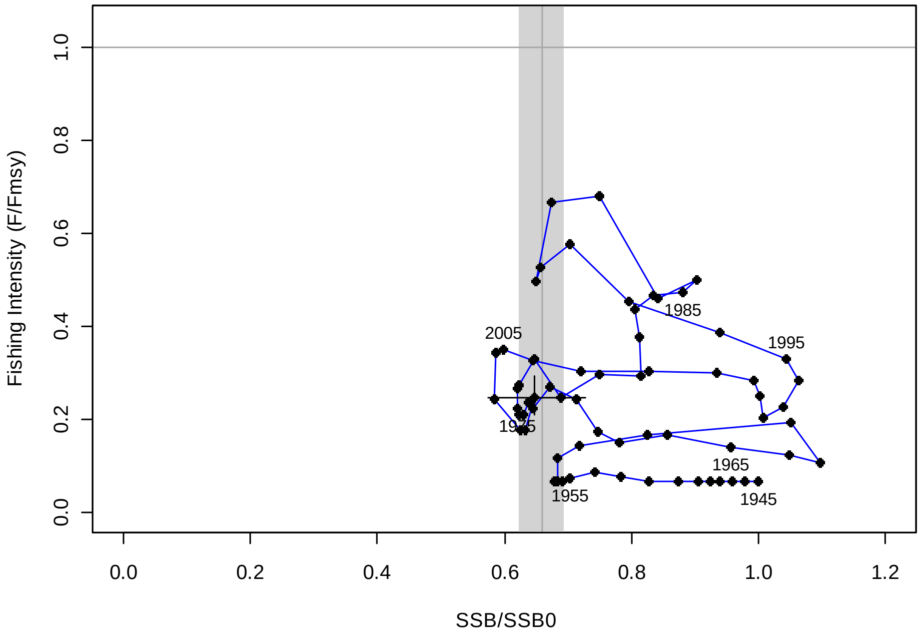


Figure 19: Phase plot that summarises the *SSB* history of the CRA 4 stock. The x-axis is spawning stock biomass *SSB* in year *y* as a proportion of the unfished spawning stock, *SSB0*. *SSB0* is constant for all years of a run, but varies through the 1000 runs. The y-axis is fishing intensity in year *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.

6.5 CRA 5

This section reports the assessment for CRA 5 conducted in 2015.

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 sources available to the model are listed in Table 39.

The assessment assumed that recreational catch was equal to survey estimates in 1994, 1996 and an assumed value of 80 t in 2011, fitted to an exponential model driven by the Area 917 AW CPUE from 1979-2009, and increased linearly from 20% of the 1979 value in 1945 up to the 1979 value (see Section 1.4 for a description of the procedure followed).

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 with standard deviation of 0.4. It was assumed that stock size has no influence on recruitment because of the long duration of the pelagic larval phase coupled with long-distance movements during this phase.

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. A constant handling mortality of 10% was applied to all discarded lobsters, independent of size. Two fisheries were modelled: one fishery that operated only on fish above the size limit (SL fishery – consisting of 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 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.

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 (the right-hand limb was fixed at a high value for the base case and most sensitivity runs to avoid the creation of cryptic biomass). Changes in regulations over time (for instance, changes in escape gap regulations) were modelled by estimating two separate selectivity epoch, pre-1993 and 1993-2014.

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 a 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. Outliers (defined as lying in the ±0.2% quantiles of the standardised residuals when fitting to the tag data without other model data) were dropped. 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 with the size data from each source (research sampling or voluntary logbooks) fitted independently. Seasonal proportions-at-length summed to one for each sex category (males, immature and mature females) and the sex ratios by season were fitted using a multinomial likelihood. Randomisation trials were conducted to establish that puerulus settlement data contained a recruitment signal; these established that the puerulus data contributed recruitment information to the model with a lag of a single year.

Two base case models were accepted by the RLFAWG: both included the puerulus settlement indices but differed by the inclusion/exclusion of density-dependent growth. The RLFAWG was not able to choose between these two models because it was felt that each was equally plausible. The remaining aspects of the base case were the same, with the same weighting assumptions made for each model. Recruitment deviations were estimated for the entire period: 1945–2015, given that the final 2014 puerulus index applies to 2015 with a one-year lag.

Table 39: Data types and sources for the 2015 assessment for CRA 5. Year codes apply to the first 9 months of each fishing year (i.e., 1998-99 is called 1998). MPI – NZ Ministry for Primary Industries; 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	2014
Observer proportions-at-size	MPI	1989	2010
Logbook proportions-at-size	NZRLIC	1994	2014
Tag recovery data	NZRLIC & MPI	1974	2014
MLS regulations	Annala (1983), MPI	1945	2014
Escape gap regulation changes	Annala (1983), MPI	1945	2014
Puerulus settlement	MPI	1980	2014

Parameters estimated in each model and their priors are provided in Table 40. Fixed parameters and their values are given in Table 41.

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 40: 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	–		–
shape of growth curve (male)	N	0.1-15.0	4.81	0.38	
shape of growth curve (female)	N	0.1-15.0	4.51	0.24	
CV of growth increment (male)	N	0.01-2.0	0.59	.0076	
CV of growth increment (female)	N	0.01-2.0	0.82	.013	

Table 40 [Continued]

	Prior Type	Bounds	Mean	SD	CV
growth observation std.dev. (male & female)	N	0.00001-10.0	1.48	.0015	
TW at 50% probability female maturation	U	30–80	–		–
(TW at 95% probability female maturity) – (TW at 50% probability female maturity)	U	1-60	–		–
density dependence parameter	U	0-1	–	–	
Relative vulnerability (all sexes and seasons)[2]	U	0-1	–		–
Shape of selectivity left limb (males & females)	U	1–50	–		–
Size at maximum 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 41: Fixed values used in base case assessment for CRA 5.

Parameter/description	CRA 5
shape parameter for CPUE vs biomass	1
minimum std. dev. of growth increment	0.0001
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	2015
Relative weight for length frequencies	4
Relative weight for CPUE	2.6
Relative weight for CR	4
Relative weight for puerulus	0.3
Relative weight for tag-recapture data	1.0

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. These 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; five million simulations were made, starting from the base case MPD, and 1000 samples were saved. From each sample of the posterior, 4-year projections (2015–2018) were generated with an agreed catch scenario (Table 42);

c) Future annual recruitment was randomly sampled with replacement from the model's estimated recruitments from 2006–15 (except for the no puerulus sensitivity trial which resampled from 2003–12).

Table 42: 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
350	82.8	0	30	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.

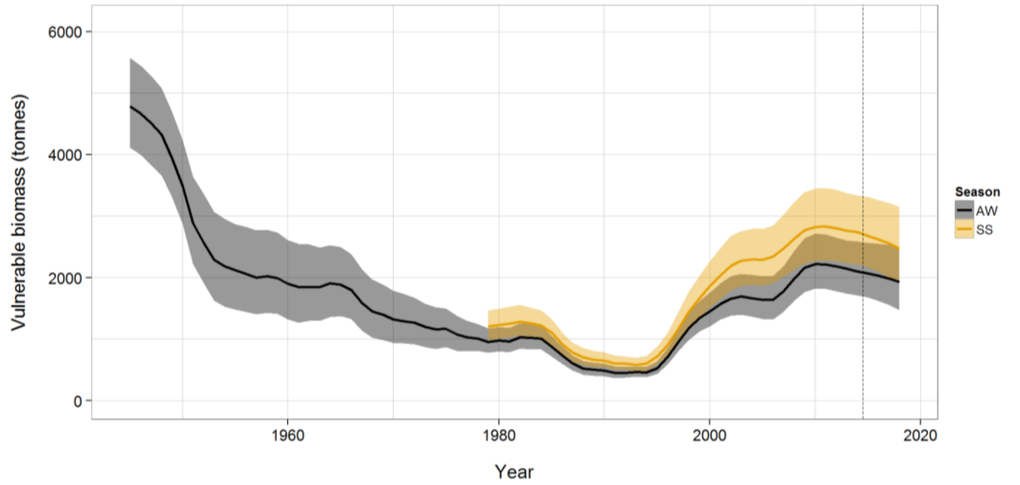
Base case results suggested that biomass decreased to a low level in the late 1980s, remained low through to about 1995, and then increased (Figure 20) to a peak around 2010. The current vulnerable stock size (AW) is about twice the reference biomass and the spawning stock biomass is well above *Bmsy* (Table 44). However, projected biomass would decrease at the level of current catches over the next 4 years (Figure 20).

Table 43: Performance indicators used in the CRA 5 stock assessment (SL=size limited fishery; AW=autumn/winter season; SS=spring/summer season).

Reference points	**Description**
Bmin	The lowest beginning AW vulnerable biomass in the series
B2015	Beginning of season AW vulnerable biomass for 2015
Bref	Beginning of AW season mean vulnerable biomass for 1979–81
B2018	Projected beginning of season AW vulnerable biomass in 2018
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*
SSB2015	Current spawning stock biomass at start of AW season
SSB2018	Projected spawning stock biomass at start of AW season
SSBmsy	Spawning stock biomass at start of AW season associated with *MSY*
CPUE indicators	**Description**
CPUE2014	CPUE predicted for AW 2014
CPUE2018proj	CPUE predicted for AW 2018
CPUEmsy	CPUE at *Bmsy*
Performance indicators	**Description**
B2015 / Bmin	ratio of *B2015* to *Bmin*
B2015/ Bref	ratio of *B2015* to *Bref*
B2015 / Bmsy	ratio of *B2015* to *Bmsy*
B2018 / B2015	ratio of *B2018* to *B2015*
B2018/ Bref	ratio of *B2018* to *Bref*
B2018/ Bmsy	ratio of *B2018* to *Bmsy*
SSB2015/SSB0	ratio of *SSB2015* to *SSB0*
SSB2018/SSB0	ratio of *SSB2018* to *SSB0*
SSB2015/SSBmsy	ratio of *SSB2015* to *SSBmsy*
SSB2018/SSBmsy	ratio of *SSB2018* to *SSBmsy*
SSB2015/SSB2015	ratio of *SSB2018* to *SSB2015ent*
USL2015	The 2015 exploitation rate for SL catch in AW
USL2018	2018 exploitation rate for SL catch in AW
USL2018/USL2015	ratio of SL 2018 exploitation rate to 2015 SL exploitation rate
Btot2014	total biomass in 2014
Ntot2014	total numbers in 2014
Btot0	total biomass without fishing
Ntot0	total numbers without fishing
Probabilities	**Description**
P*(B2015 > Bmin)*	probability *B2015 > Bmin*
P*(B2015 > Bref)*	probability *B2015 > Bref*
P*(B2015 > Bmsy)*	probability *B2015 > Bmsy*
P*(B2018 > Bmin)*	probability *B2018 > Bmin*
P*(B2018 > Bref)*	probability *B2018 > Bref*
P*(B2018 > Bmsy)*	probability *B2018 > Bmsy*
P*(B2018 > B2015)*	probability *B2018 > B2015*
P*(SSB2015>SSBmsy)*	probability *SSB2015>SSBmsy*
P*(SSB2018>SSBmsy)*	probability *SSB2015>SSBmsy*
P*(USL2018>USL2015)*	probability SL exploitation rate *2018* > SL exploitation rate *2015*
P*(SSB2015<0.2SSB0)*	soft limit CRA 8: probability *SSB2015*< 20% *SSB0*
P*(SSB2018<0.2SSB0*	soft limit CRA 8: probability *SSB2018* < 20% *SSB0*
P*(SSB2015 <0.1SSB0)*	hard limit CRA 8: probability *SSB2015*< 10% *SSB0*
P*(SSB2018<0.1SSB0)*	hard limit CRA 8: probability *SSB2018*< 10% *SSB0*

A series of MCMC sensitivity trials was also made, including exclusion of puerulus data, using an alternative (higher) recreational catch vector, wider CVs on the growth priors, stronger CVs on the CPUE indices (to obtain a better fit), and a descending right-hand limb to the selectivity functions. The assessment results from the base case and sensitivity trials calculated as a series of agreed indicators (Table 43) are shown in Table 44.

(a) base case without DD



(b) base case with DD

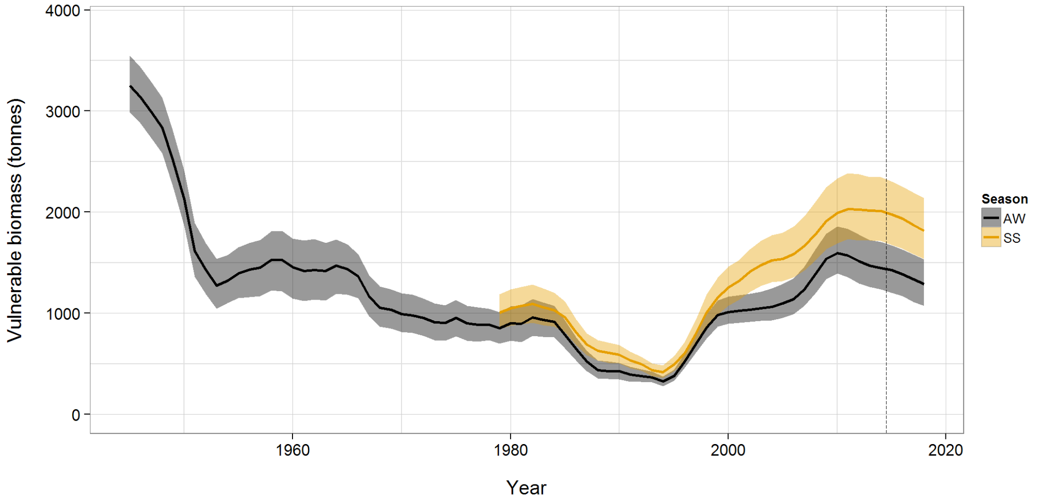


Figure 20: Posterior distributions of the two base case MCMCs biomass vulnerable trajectory (with and without density dependence [DD]). Before 1979 there was a single time step, shown in AW. The trajectory to the right of the vertical dotted catches are projections based on the catches in Table 42. For each year the horizontal line represents the median and the coloured envelope represent the 5 and 95% quantiles.

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

In the base case and for all trials, current and projected biomass levels were larger than *Bref* and *Bmsy* reference levels by substantial amounts for both catch projection scenarios (Table 44). Projected biomass decreased in most runs but remained well above the reference levels in the base case and for all trials.

Table 44: Assessment results – medians of indicators described in Table 43 from the base case and sensitivity trials under catches given in Table 42; the lower part of the table shows the probabilities that events are true (DD=density dependence). The last four models were all run without density-dependence.

Indicator	Basecase: no DD	Basecase: with DD	Basecase: no DD and no puerulus	Basecase: with DD and no puerulus	Alternative recrea-tional catch	estimate R-H selectivity	growth prior CV=30%	double weight to CPUE series
Bmin	438.8	323.9	425.9	319.1	431.6	450.3	370.3	378.0
B2015	2070.0	1428.8	2086.2	1373.1	2019.0	2020.2	1650.7	1686.0
Bref	871.0	788.6	841.2	744.7	857.5	903.6	760.2	755.2
B2018	1935.6	1290.3	2250.7	1257.9	1844.6	1869.0	1548.4	1594.4
Bmsy	505.2	483.6	503.8	481.9	517.1	568.3	474.6	498.1
MSY	536.6	560.1	545.3	564.5	540.2	591.6	504.2	494.5
Fmult	6.18	4.78	6.30	4.72	5.17	6.01	4.93	4.66
SSB2015	2926.2	2250.3	3022.4	2195.8	2867.6	3556.2	2406.1	2541.6
SSB2018	2669.6	2018.0	3139.5	2016.8	2574.5	3313.0	2218.0	2335.5
SSBmsy	1500.4	1094.2	1511.8	1086.8	1456.2	1736.2	1267.6	1411.4

Table 44 [Continued]

Indicator	Basecase: no DD	Basecase: with DD	Basecase: no DD and no puerulus	Basecase: with DD and no puerulus	Alternative recrea-tional catch	estimate R-H selectivity	growth prior CV=30%	double weight to CPUE series
CPUEcurrent	1.54	1.54	1.54	1.52	1.53	1.49	1.50	1.46
CPUEproj	1.40	1.36	1.68	1.35	1.34	1.33	1.36	1.36
CPUEmsy	0.267	0.362	0.266	0.364	0.291	0.296	0.311	0.318
B2015/Bmin	4.74	4.40	4.90	4.27	4.65	4.47	4.43	4.42
B2015/Bref	2.40	1.82	2.51	1.84	2.36	2.25	2.16	2.22
B2015/Bmsy	4.11	2.94	4.14	2.85	3.89	3.57	3.46	3.41
B2018/B2015	0.92	0.90	1.07	0.92	0.91	0.92	0.93	0.94
B2018/Bref	2.22	1.65	2.69	1.68	2.12	2.05	2.02	2.11
B2018/Bmsy	3.84	2.67	4.46	2.62	3.53	3.27	3.25	3.20
SSB2015/SSB0	0.781	0.970	0.805	0.965	0.751	0.779	0.701	0.702
SSB2018/SSB0	0.707	0.871	0.837	0.888	0.668	0.720	0.649	0.642
SSB2015/SSBmsy	1.96	2.05	2.00	2.02	1.97	2.05	1.89	1.81
SSB2018/SSBmsy	1.78	1.84	2.08	1.86	1.75	1.90	1.74	1.66
SSB2018/SSB2015	0.905	0.897	1.032	0.918	0.889	0.928	0.921	0.916
USL2014	0.113	0.164	0.115	0.170	0.118	0.115	0.142	0.140
USL2018	0.123	0.184	0.106	0.189	0.132	0.127	0.154	0.149
USL2018/USL2014	1.10	1.12	0.93	1.11	1.12	1.11	1.10	1.07
Btot2015	6986.9	5193.8	7448.8	5109.5	6835.4	8463.3	5558.3	5952.1
Btot2015/Btot0	0.673	0.668	0.720	0.667	0.645	0.668	0.577	0.588
Ntot2015	16,854,400	12,830,400	19,078,650	12,767,250	16,562,000	18,648,300	13,185,100	14,581,600
Ntot2015/Ntot0	0.832	0.698	0.927	0.699	0.823	0.829	0.771	0.781
P(*B2015>Bmin*)	1	1	1	1	1	1	1	1
P(*B2015>Bref*)	1	1	1	1	1	1	1	1
P(*B2015>Bmsy*)	1	1	1	1	1	1	1	1
P(*B2018>Bmin*)	1	1	1	1	1	1	1	1
P(*B2018>Bref*)	1	0.999	1	1	1	1	1	1
P(*B2018>Bmsy*)	1	1	1	1	1	1	1	1
P(*B2018>B2015*)	0.188	0.026	0.726	0.081	0.133	0.189	0.24	0.281
P(*SSB2015>SSBmsy*)	1	1	1	1	1	1	1	1
P(*SSB2018>SSBmsy*)	1	1	1	1	1	1	1	1
P(*USL2018>USL2014*)	0.822	0.985	0.281	0.956	0.871	0.833	0.788	0.705
P(*SSB2015<0.2SSB0*)	0	0	0	0	0	0	0	0
P(*SSB2018<0.2SSB0*)	0	0	0	0	0	0	0	0
P(*SSB2015<0.1SSB0*)	0	0	0	0	0	0	0	0
P(*SSB2018<0.1SSB0*)	0	0	0	0	0	0	0	0

Indicators based on *SSBmsy*

SSBmsy is biomass of mature females associated with B_{MSY}. The historical track of biomass versus fishing intensity is shown in Figure 21. The phase space in the plot shows biomass on the x-axis and fishing intensity on the y-axis. High biomass/low intensity is in the lower right-hand corner, the location of the stock when fishing first began, and low biomass/high intensity is in the upper left-hand corner, in a period when the fishery was largely uncontrolled. Note that fishing patterns include MLS, selectivity and the seasonal catch split and that *Fmsy* varies in each year because fishing patterns change. The reference *SSBmsy* in Figure 21 has been calculated using the 2014 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. It climbed towards the low biomass/high intensity region, reaching highest fishing intensity in 1985 and lowest biomass in 1989 to 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.

Two alternative base case models were investigated for CRA 5: one which assumed that growth was faster at low abundance (density-dependent growth) and another which assumed a constant average growth rate regardless of abundance. The model which assumed density-dependent growth had lower productivity and smaller average biomass than the model without density dependence. However, biomass at the end of 2015/16 was estimated by both models to be well above all reference points (*Bmin*, *Bmsy* and *Bref*), with a nearly certain expectation that biomass would remain above these reference points at the end of the next four years. However, both models predict with a high probability (about 90%) that biomass will have declined by the end of the four year projection period.

Future research needs

- For the new growth analysis:
    - Investigate potential seasonal effects such as seasonal patterns in growth and the probability of recapture
    - Modify the “Q” matrix (matrix of similarities between areas) to determine how much assumptions about similarities matter
    - Further work with alternative error distributions would be useful
    - Explore the utility of contamination models
- Recreational catch estimates are highly uncertain and improving them should be a high priority for the future. Estimates of illegal catch are also large and uncertain.
- CPUE is used as a continuous series from 1979 to 2014, yet there have been substantial technological changes over that time; the potential effects of changes in CPUE should be investigated by breaking the series in one or two places – e.g. around 1992 or 1993, when the species was introduced into the quota management system and when GPS began to be widely used.
- Plot the expected growth increment as a function of %*SSB0*, in order to determine the effect of density-dependence.
- There are few data available to estimate *a50* for females in the first epoch; therefore, examine alternative approaches other than estimating it – e.g. setting the value to the same as that estimated for the second epoch.
- Estimates of the size at maturity are uncertain; consider conducting a maturity ogive meta-analysis using all rock lobster data.
- Examine the effect of returning large females in influencing sex ratios.
- Examine the sensitivity of the model to the assumption of 10% mortality for rock lobsters returned to the sea.

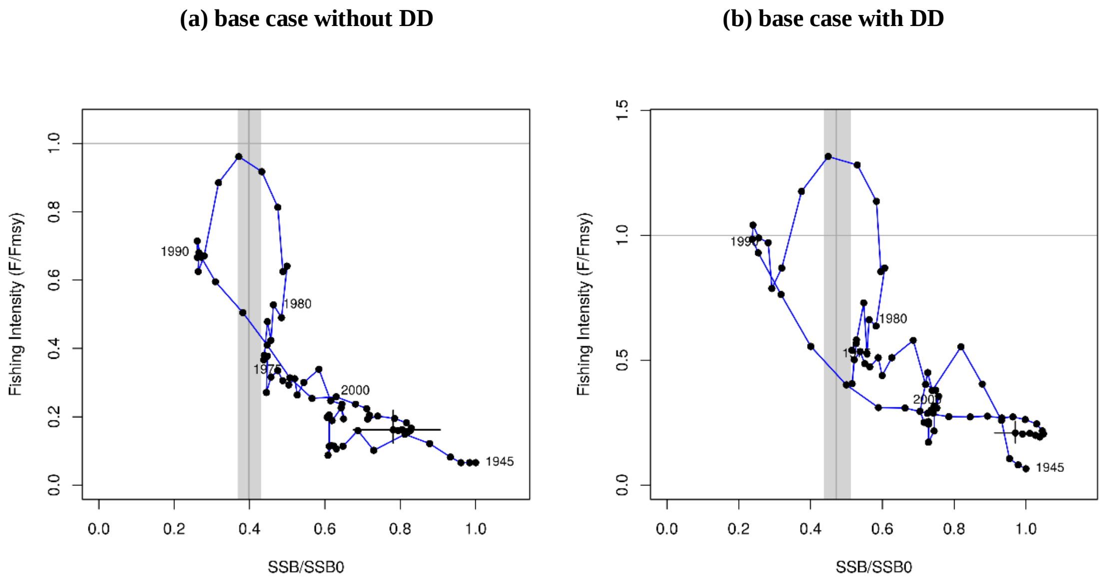


Figure 21: Phase plots that summarise the history of the CRA 5 fishery for the two base cases. The x-axis is the spawning biomass (*SSB*) as a proportion of B0 (*SSB0*); the y-axis is the ratio of the fishing intensity (F) relative to *Fmsy*. Each point is the median of the posterior distributions, and 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. B0 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 2015.

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 1979-2014, older catch rate data (CR), length frequencies from observer and voluntary (logbook) catch sampling, and tag-recapture data . Puerulus settlement data are available from Halfmoon Bay, Chalky Inlet and Jackson bay for different periods, but they showed differing trends. Because the puerulus indices appeared to have limited predictive power in the 2012 assessment, they were not used. The model used an annual time step from 1963 through 1978 and then switched to a seasonal time step with autumn-winter (AW, April through September) and spring-summer (SS, Octorber through March) from 1979 through 2014. 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 before 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 the current ones. 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 before 1993. The model simulated the return of large legal lobsters to the sea in CRA 8, where this practice is 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 45.

Historic and recent recreational catch surveys were examined and the stock assessment assumed that recreational catch was constant from 1979 (see Section 1.2) and that it increased linearly from 20% of the 1979 value in 1945 up to the 1979 value.

Table 45: Data types and sources for the 2015 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	2014	1979	2014
Older catch rate (CR)	Annala & King (1983)	1963	1973	1963	1973
Observer proportions-at-size	MPI and NZ RLIC	1988	2014	1987	2010
Logbook proportions-at-size	NZ RLIC	not used	not used	1993	2014
Tag recovery data	NZ RLIC & MFish	1965	2013	1966	2011
Historical MLS regulations	Annala (1983), MPI	1974	2014	1974	2014
Escape gap regulation changes	Annala (1983), MPI	1974	2014	1974	2014
Puerulus settlement (not used)	NIWA	1990	2014	1980	2014
Retention	NZ RLIC	NA	NA	2000	2014

The initial populations in 1963 were assumed to be in equilibrium with estimated exploitation rates for each stock. Each season, numbers of male, immature female and mature female lobsters in each size class were updated as a result of:

a) **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 1963 through 2012. It was assumed that stock size has no influence on recruitment because of the long duration of the pelagic larval phase coupled with long-distance movements during this phase.

b) **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 value was estimated for each stock. 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) based on catch and model biomass.

c) **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 maximum selectivity. Changes in MLS and escape gap regulations were accommodated for CRA 8 only (in CRA 7 there have been no MLS changes) by estimating selectivity in two separate epochs, pre–1993 and 1993–2014. As in all recent stock assessments the descending limb of the selectivity curve was fixed to prevent under-estimation of selectivity of large lobsters.

d) **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. The growth parameters for shape, CV and observation error were estimated with priors based on exploratory fits using only the growth model (Webber, unpublished data); these stabilised the estimation considerably. Maturation of females was estimated as a two-parameter logistic curve from the maturity-at-size information in the size frequency data. Maturation parameters were estimated as common parameters for both stocks (all other estimated parameters were stock-specific).

e) **Movements between stocks:** For each year from 1985-2014, 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.

Model fitting:

A total negative log likelihood function was minimised using AD Model Builder™. The model was fitted to standardised CPUE and CR using lognormal likelihood, to proportions-at-length with multinomial likelihood and to tag-recapture data with normal likelihood after removal of outliers based on tag-only fits. For the CPUE 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 45) 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 each sex category. These data were weighted within the model using the method of Francis (2011).

In the base case, it was assumed that biomass was proportional to CPUE, that growth was not density-dependent but for CRA 8 had changed between the pre-1993 and 1993 onwards periods, there was no stock-recruit relationship and 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 (1963 was chosen), exploring the effect of excluding SS LF data from CRA 7 (it was not excluded), and changing the prior on *M* (a prior with a smaller CV was chosen).

Parameters estimated in the base case and their priors are provided in Table 46. Fixed parameters and their values are given in Table 47.

Table 46: 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	Number of parameters	Bounds	Mean	SD	CV
ln(*R0*) (mean recruitment)	U	2	1–25	–	–	–
M (natural mortality)	L	2	0.01–0.35	0.12	–	0.10
Initial exploitation rate	U	2	0.00–0.99	–	–	–
Recruitment deviations	N [1]	100	-2.3–2.3	0	0.4	
ln(*qCPUE*)	U	2	-25–0	–	–	–
ln(*qCR*)	U	2	-25-2.0	–	–	–
Increment at TW=50 (male & female)	U	6	1–20	–	–	–
ratio of TW=80 increment at TW=50 (male & female)	U	6	0.001–1.000	–	–	–
shape of growth curve (male)	N	2	0.1–15.0	4.812	0.384	–
shape of growth curve (female)	N	2	0.1–15.0	4.508	0.236	
growth CV (male)	N	2	0.01-5.0	0.587	0.0076	
growth CV (female)	N	2	0.01-5.0	0.820	0.0131	
growth observation error (male and female)	N	1	1E-5-10.0	1.482	0.0152	
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	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	–	–	–
Movement parameters	U	30	0.00–0.50	–	–	–

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

Table 47: 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	0.001	0.001
Handling mortality	10%	10%
Process error for CPUE	0.25	0.25
process error for CR	0.3	0.3
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	1963	1963
Last year for recruitment deviations	2012	2012
Relative weight for male length frequencies	0.227	1.849
Relative weight for immature female LFs	0.239	5.145
Relative weight for mature female LFs	0.422	1.272
relative weight for proportion-at-sex	3.645	3.645
Relative weight for CPUE	1.251	1.251
relative weight for CR	1.062	1.062
Relative weight for tag-recapture data*	1	1
length-weight intercept (male)	3.39E-6	3.39E-6
length-weight intercept (female)	1.04E-5	1.04E-5
length-weight slope (male)	2.9665	2.9665
length-weight slope (female)	2.6323	2.6323

*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; 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 (2015–2018) were generated using the 2014 catches, with annual recruitment randomly sampled from the model's estimated recruitments from 2003–12, and with annual movement resampled from the estimated values.

Performance Indicators and Results

The definition of the "current fishing pattern", used to calculate MSY statistics, was modified to include the retention pattern. That is, for CRA 8 the estimated 2015 retention pattern was included in the definition of *Fmsy* (for other CRA QMAs retention is assumed to be 1, so does not influence *Fmsy*). This is somewhat anomalous because fishing at *Fmsy* would result in lower biomass and it would be expected that there would be full retention of all legal rocklobster. The alternative, to ignore retention in the definition of *Fmsy*, is also problematic because it results in the conclusion that the current fishing intensity exceeds *Fmsy* (which is not the case because greater than 40% of the biomass of legal rocklobster is returned to the sea). The retention pattern was not included in the definitions of "vulnerable biomass", used to calculate *Bmsy* and *Bref*, because that would also lead to inconsistency between the retention pattern used to define those reference levels and the retention pattern expected at the biomass levels.

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 (ovigerous) and not legally available to the fishery in AW and not berried, thus vulnerable, in SS.

Agreed indicators are summarised in Table 48.

For CRA 7, base case results (Figure 22 and Table 49) suggested that AW biomass decreased to a low point in 1997, increased to a high in the late 2000s, decreased and then increased again. *B2015* was about twice *Bref*. Median projected biomass was 8% less than current biomass at the level of current catches over the next four years, but indicators remained above reference levels. Neither current nor projected biomass was anywhere near the soft limit. Note that *MSY* from CRA 7 was estimated as a high proportion of *Bmsy*, thus that fishing intensity *Fmsy* is very high.

For CRA 8, base case results (Figure 23 and Table 50) suggested that AW biomass decreased to a low point in 1990, remained relatively low until 2000, then increased strongly and has remained relatively high. *B2015* was well above *Bmsy* and 35% above *Bref* (mean biomass for 1979-81). Biomass was projected to remain about the same in four years at the current level of catches and was projected to remain well above both *Bref* and *Bmsy*. Spawning biomass was a high proportion – 43% – of the unfished level. Neither current nor projected biomass was anywhere near the soft limit.

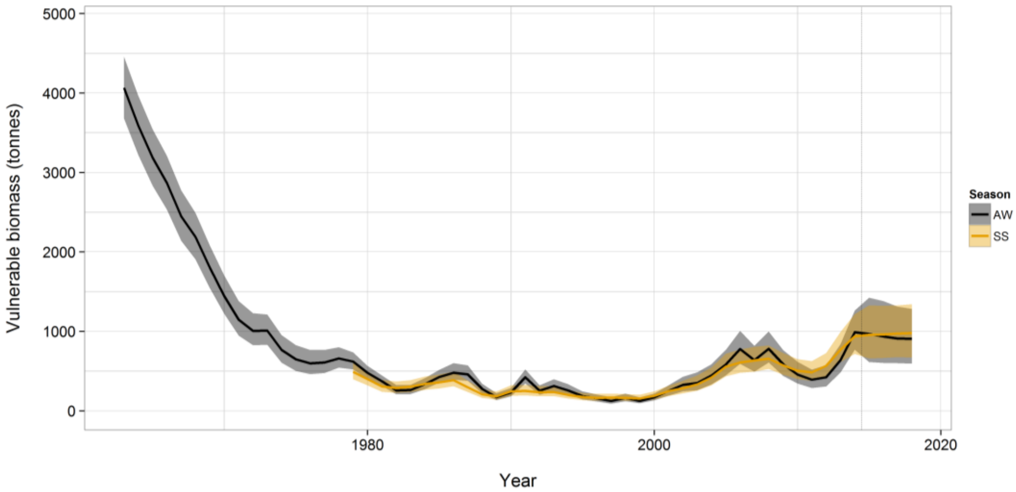


Figure 22: Posterior distribution of the CRA 7 base case MCMC vulnerable biomass trajectory. Before 1979 there was a single time step, shown in AW. The shaded areas span the 5th and 95th quantiles.

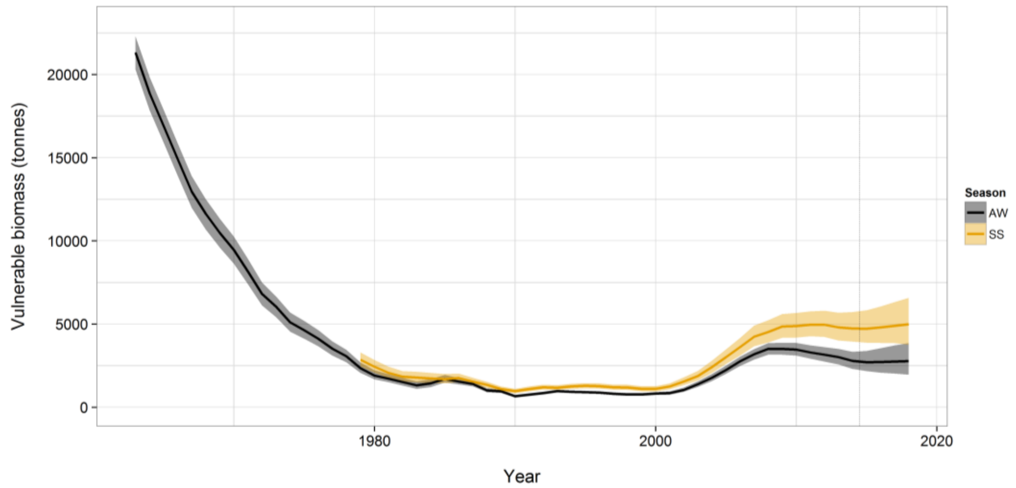


Figure 23: Posterior distribution of the CRA 8 base case MCMC vulnerable biomass trajectory. Before 1979 there was a single time step, shown in AW. The shaded areas span the 5th and 95th quantiles.

Table 48: Performance indicators used in the CRA 7 and CRA 8 stock assessments.

Reference points	Description
Bmin	The lowest beginning AW vulnerable biomass in the series
B2015	Beginning of season AW vulnerable biomass for 2015
Bref	Beginning of AW season mean vulnerable biomass for 1979–81
B2018	Projected beginning of season AW vulnerable biomass in 2018
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*

Table 48 [Continued]

Reference points	**Description**
SSB2015	Current spawning stock biomass at start of AW season
SSB2018	Projected spawning stock biomass at start of AW season
SSBmsy	Spawning stock biomass at start of AW season associated with *MSY*
CPUE indicators	**Description**
CPUE2014	CPUE predicted for AW 2014
CPUE2018proj	CPUE predicted for AW 2018
CPUEmsy	CPUE at *Bmsy*
Performance indicators	**Description**
B2015 / Bmin	ratio of *B2015* to *Bmin*
B2015/ Bref	ratio of *B2015* to *Bref*
B2015 / Bmsy	ratio of *B2015* to *Bmsy*
B2018 / B2015	ratio of *B2018* to *B2015*
B2018/ Bref	ratio of *B2018* to *Bref*
B2018/ Bmsy	ratio of *B2018* to *Bmsy*
SSB2015/SSB0	ratio of *SSB2015* to *SSB0*
SSB2018/SSB0	ratio of *SSB2018* to *SSB0*
SSB2015/SSBmsy	ratio of *SSB2015* to *SSBmsy*
SSB2018/SSBmsy	ratio of *SSB2018* to *SSBmsy*
SSB2015/SSB2015	ratio of *SSB2018* to *SSBcurrent*
USL2015	The 2015 exploitation rate for SL catch in AW
USL2018	2018 exploitation rate for SL catch in AW
USL2018/USL2015	ratio of SL 2018 exploitation rate to 2015 SL exploitation rate
Btot2014	total biomass in 2014
Ntot2014	total numbers in 2014
Btot0	total biomass without fishing
Ntot0	total numbers without fishing
Probabilities	**Description**
P*(B2015 > Bmin)*	probability *B2015 > Bmin*
P*(B2015 > Bref)*	probability *B2015 > Bref*
P*(B2015 > Bmsy)*	probability *B2015 > Bmsy*
P*(B2018 > Bmin)*	probability *B2018 > Bmin*
P*(B2018 > Bref)*	probability *B2018 > Bref*
P*(B2018 > Bmsy)*	probability *B2018 > Bmsy*
P*(B2018 > B2015)*	probability *B2018 > B2015*
P*(SSB2015>SSBmsy)*	probability *SSB2015>SSBmsy*
P*(SSB2018>SSBmsy)*	probability *SSB2015>SSBmsy*
P*(USL2018>USL2015)*	probability SL exploitation rate *2018* > SL exploitation rate *2015*
P*(SSB2015<0.2SSB0)*	soft limit CRA 8: probability *SSB2015*< 20% *SSB0*
P*(SSB2018<0.2SSB0*	soft limit CRA 8: probability *SSB2018* < 20% *SSB0*
P*(SSB2015 <0.1SSB0)*	hard limit CRA 8: probability *SSB2015*< 10% *SSB0*
P*(SSB2018<0.1SSB0)*	hard limit CRA 8: probability *SSB2018*< 10% *SSB0*
P(*B2015* <50%*Bref*)	soft limit CRA 7: probability *B2015* < 50% *Bref*
P(*B2015* <25%*Bref*)	hard limit CRA 7: probability *B2015* < 25% *Bref*
P(*B2018*<50%*Bref*)	soft limit (CRA 7): probability *B2015* < 50% *Bref*
P(*B2018*<25%*Bref*)	hard limit (CRA 7):probability *B2015* < 25% *Bref*

MCMC sensitivity trials were also made:

- *d-d*:estimating growth density-dependence, and using a single tag data file for CRA 8 instead of two (as in the base case);
- *wideG*: using priors on the growth parameters for shape, CV and observation error with CVs that were 30% of the mean;
- *noMoves*: with no estimated movements from CRA 7 to CRA 8;
- *rawLFs*: using the calculated weights on LF records, instead of truncating them between 1 and 10*wideM*: with the CV of the prior on *M* 0.40 instead of 0.10;

Results from the base case and sensitivity trials are compared in Table 49 for CRA 7 and Table 50 for CRA 8.

Table 49: 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.

	base median	d-d median	wide G prior median	no moves median	raw LFs median	wide M prior median
Bmin	114.7	118.3	102.8	125.9	113.2	104.1
B2015	965.7	994.4	755.1	931.2	940.3	962.3
Bref	489.2	510.3	443.3	455.7	477.6	453.1
B2018	905.3	858.7	604.3	1118.5	891.1	916.8
Bmsy	241.1	268.0	265.5	770.9	232.0	223.4
MSY	192.1	208.6	248.7	219.5	187.9	183.6
Fmult	15.2	15.2	15.2	3.25	15.2	15.2
SSB2014	413.5	419.6	464.1	505.7	400.1	427.3
SSB2018	575.1	567.0	541.1	723.0	568.2	636.2
SSBmsy	43.1	50.2	74.9	660.8	39.4	43.3
CPUE2014	2.121	2.172	2.088	1.911	2.112	2.254
CPUE2018	1.900	1.724	1.360	2.658	1.966	2.206
CPUEmsy	0.375	0.412	0.463	1.700	0.367	0.387
B2015/Bmin	8.440	8.251	7.282	7.386	8.374	9.263
B2015/Bref	1.974	1.940	1.712	2.050	1.956	2.130
B2015/Bmsy	4.002	3.719	2.873	1.220	4.042	4.345
B2018/B2015	0.925	0.851	0.789	1.202	0.946	0.948
B2018/Bref	1.833	1.677	1.384	2.463	1.861	2.021
B2018/Bmsy	3.697	3.180	2.300	1.465	3.831	4.126
SSB2014/SSB0	0.167	0.178	0.222	0.191	0.161	0.134
SSB2018/SSB0	0.234	0.244	0.257	0.273	0.229	0.195
SSB2014/SSBmsy	9.577	8.266	6.209	0.760	10.149	10.084
SSB2018/SSBmsy	13.307	10.982	7.276	1.087	14.416	14.905
SSB2018/SSB2014	1.384	1.346	1.153	1.423	1.411	1.513
USL2014	0.048	0.046	0.053	0.060	0.050	0.052
USL2018	0.076	0.080	0.113	0.061	0.077	0.075
USL2018/USL2014	1.575	1.758	2.129	1.030	1.500	1.424
Btot2014	2445.7	2723.1	3561.0	1777.7	2315.2	2343.9
Btot2014/Btot0	0.320	0.369	0.540	0.232	0.304	0.254
Ntot2014	7.7E+06	9.0E+06	1.4E+07	4.4E+06	7.3E+06	7.3E+06
Ntot2014/Ntot0	0.661	0.681	0.815	0.468	0.648	0.581
P(B2015>Bmin)	1.000	1.000	1.000	1.000	1.000	1.000
P(B2015>Bref)	0.998	0.999	0.994	1.000	0.998	1.000
P(B2015>Bmsy)	1.000	1.000	1.000	0.934	1.000	0.997
P(B2018>Bmin)	1.000	1.000	1.000	1.000	1.000	1.000
P(B2018>Bref)	0.991	0.981	0.911	1.000	0.996	0.998
P(B2018>Bmsy)	1.000	1.000	1.000	0.993	1.000	0.997
P(B2018>B2015	0.236	0.101	0.104	0.999	0.327	0.300
P(SSB2014>SSBmsy)	1.000	1.000	1.000	0.007	1.000	0.968
P(SSB2018>SSBmsy)	1.000	1.000	1.000	0.747	1.000	0.982
P(USL2018>USL2014	0.993	0.999	1.000	0.615	0.994	0.987
P(SSB2014<0.2SSB0)	0.919	0.716	0.233	0.674	0.948	0.992
P(SSB2018<0.2SSB0	0.213	0.182	0.069	0.002	0.240	0.536
P(SSB2014<0.1SSB0)	0.000	0.000	0.000	0.000	0.000	0.274
P(SSB2018<0.1SSB0)	0.000	0.000	0.000	0.000	0.000	0.120

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

	base median	d-d median	wide G prior median	no moves median	raw LFs median	wide M prior median
Bmin	658.2	674.2	550.9	651.5	635.9	601.8
B2015	2698.1	2529.9	2362.5	2624.9	2175.2	2506.1
Bref	1983.4	1873.9	1687.1	2024.7	1902.7	1781.7
B2018	2770.6	2383.3	2971.5	2334.1	2004.4	2674.3
Bmsy	1464.9	1170.9	1393.0	1494.3	1410.9	1949.5
MSY	1091.3	1072.6	1104.79	1117.5	1015.5	1047.2
Fmult	1.59	2	1.6	1.57	1.23	1.17
SSB2014	5043.3	4815.6	4631.9	4974.7	4974.5	5525.7
SSB2018	5321.6	4868.4	5345.3	5003.0	4950.2	6176.7
SSBmsy	3103.6	2364.0	2937.370	3093.9	3399.4	4878.0
CPUE2014	2.504	2.468	2.524	2.441	2.173	2.494
CPUE2018	2.539	2.181	3.391	2.075	1.879	2.654
CPUEmsy	1.147	0.867	1.325	1.159	1.185	1.774
B2015/Bmin	4.104	3.772	4.289	3.990	3.399	4.148
B2015/Bref	1.352	1.358	1.389	1.288	1.140	1.404
B2015/Bmsy	1.834	2.161	1.701	1.746	1.536	1.317
B2018/B2015	1.024	0.935	1.257	0.895	0.926	1.071
B2018/Bref	1.399	1.269	1.747	1.159	1.055	1.505

Table 50 [Continued]

	base median	d-d median	wide G prior median	no moves median	raw LFs median	wide M prior median
B2018/Bmsy	1.889	2.043	2.140	1.571	1.425	1.421
SSB2014/SSB0	0.438	0.774	0.391	0.432	0.393	0.253
SSB2018/SSB0	0.462	0.789	0.450	0.436	0.391	0.285
SSB2014/SSBmsy	1.620	2.028	1.572	1.611	1.462	1.132
SSB2018/SSBmsy	1.711	2.060	1.812	1.622	1.453	1.270
SSB2018/SSB2014	1.055	1.019	1.152	1.003	0.994	1.115
USL2014	0.181	0.187	0.218	0.183	0.217	0.196
USL2018	0.182	0.211	0.169	0.216	0.251	0.188
USL2018/USL2014	1.002	1.137	0.8	1.184	1.168	0.962
Btot2014	9749.9	9689.3	8030.890	10038.7	9020.7	9729.8
Btot2014/Btot0	0.269	0.403	2.3E-01	0.273	0.235	0.157
Ntot2014	1.6E+07	1.7E+07	1.2E+07	1.8E+07	1.5E+07	1.5E+07
Ntot2014/Ntot0	0.415	0.405	0.352	0.423	0.372	0.294
P(B2015>Bmin)	1.000	1.000	1.000	1.000	1.000	1.000
P(B2015>Bref)	0.995	0.999	0.997	0.975	0.862	0.990
P(B2015>Bmsy)	1.000	1.000	1.000	1.000	1.000	0.954
P(B2018>Bmin)	1.000	1.000	1.000	1.000	1.000	1.000
P(B2018>Bref)	0.942	0.916	0.999	0.724	0.602	0.961
P(B2018>Bmsy)	0.998	1.000	1.000	0.961	0.944	0.932
P(B2018>B2015	0.575	0.203	0.974	0.241	0.275	0.711
P(SSB2014>SSBmsy)	1.000	1.000	1.000	1.000	1.000	0.855
P(SSB2018>SSBmsy)	1.000	1.000	1.000	1.000	1.000	0.970
P(USL2018>USL2014	0.510	0.893	0.045	0.804	0.824	0.395
P(SSB2014<0.2SSB0)	0.000	0.000	0.000	0.000	0.000	0.056
P(SSB2018<0.2SSB0	0.000	0.000	0.000	0.000	0.000	0.017
P(SSB2014<0.1SSB0)	0.000	0.000	0.000	0.000	0.000	0.000
P(SSB2018<0.1SSB0)	0.000	0.000	0.000	0.000	0.000	0.000

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

For both stocks, median current and projected biomass were above medians of *Bref* and *Bmsy*. Projected biomass decreased in 76% of runs for CRA 7 and decreased in 42% of runs for CRA 8 but remained well above the reference levels in both stocks.

Indicators based on *SSBmsy*

The historical track of biomass versus fishing intensity is shown in Figure 24 for the CRA 7 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. Figure 24 was calculated using the 2014 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.

Figure 24 suggests that for CRA 7, *SSBmsy* was estimated as a very small fraction of *SSB0*, and that, while the fishery has driven the stock to low levels of *SSB0* in the past, the stock has never gone below *SSBmsy* and has recovered to 20% of *SSB0* over the past decade. As noted above, the fishing intensity associated with *MSY* was very high, and similarly the fishery has never exceeded *Fmsy*. The figure suggests that fishing intensity is now lower than in 1963 and far below its peak in 1979.

For CRA 8, Figure 25 shows declining biomass after 1963 and increasing fishing intensity after 1975. After 1970, until 2005, fishing intensity exceeded *Fmsy*. *SSB* was below *SSBmsy* from 1979 until 2009. The current position of the stock is relatively good, well above *SSBmsy* and with fishing intensity well below *Fmsy*.

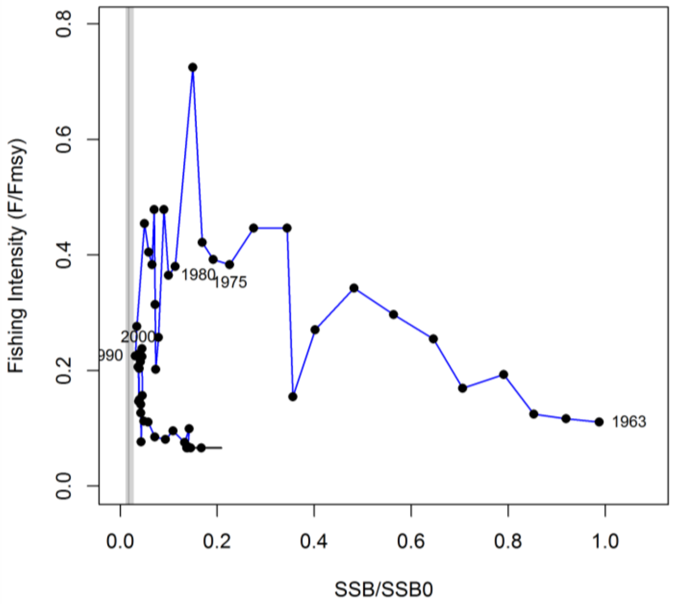


Figure 24: Phase plot (base case MCMC) for CRA 7, showing median spawning stock biomass for each year on the x-axis and median fishing intensity for each year on the y-axis; thus high biomass/low fishing intensity is in the lower right-hand corner, where a stock would be when fishing first began, and low biomass/high intensity is in the upper left-hand corner, where an uncontrolled fishery would be likely to go. Specifically, the x-axis is spawning stock biomass *SSB* as a proportion of the unfished spawning stock *SSB0*. *SSB0* is constant for all years of a simulation, but varies among the 1000 samples from the posterior distribution. The y-axis is fishing intensity as a proportion of the fishing intensity that would have given *MSY* (*Fmsy*) under the fishing patterns in year y; fishing patterns include MLS, selectivity, the seasonal catch split, retention curves and the balance between SL and NSL catches. *Fmsy* varies among years because the fishing patterns change. It was calculated with a 50-year projection for each year in each simulation, 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* was *Fmsy*, and the multiplier was *Fmult*. Each point on the figure was plotted as the median of the posterior distributions of biomass ratio and fishing intensity ratio. The vertical line in the figure is the median (line) and 90% interval (shading) of the posterior distribution of *SSBmsy* as a proportion of *SSB0*; this ratio was calculated using the fishing pattern in 2013. The horizontal line in the figure is drawn at 1, the fishing intensity associated with *Fmsy*. The bars at the final year of the plot show the 90% intervals of the posterior distributions of biomass ratio and fishing intensity ratio.

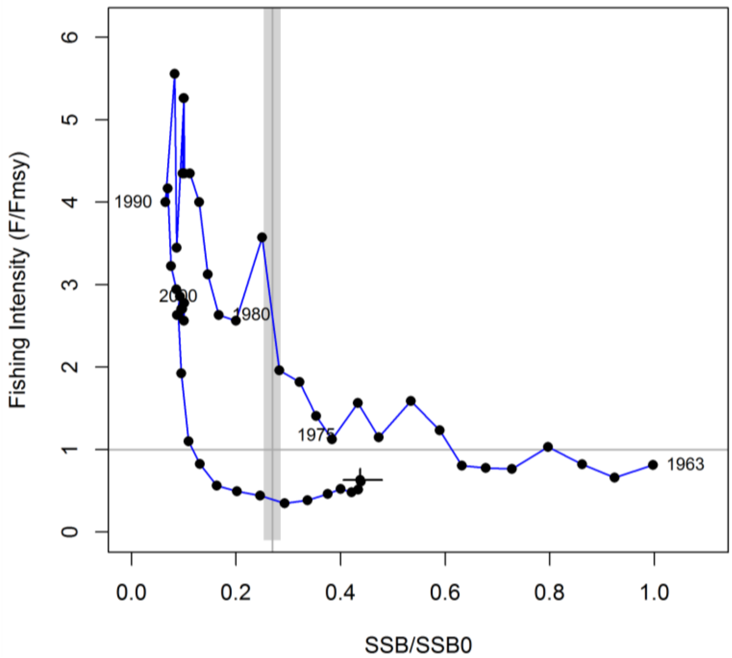


Figure 25: Phase plot for CRA 8; see the caption for Figure 24.

Future research needs

- For the new growth analysis:
  - o Investigate potential seasonal effects such as seasonal patterns in growth and the probability of recapture
  - o Modify the “Q” matrix (matrix of similarities between areas) to determine how much assumptions about similarities matter
  - o Further work with alternative error distributions would be useful
  - o Explore the utility of contamination models
- The uncertainty of the length-frequency datasets needs further investigation (by, for example, bootstrapping to obtain appropriate estimates of uncertainty).
- Further work is needed on the influence of returning a high proportion of large lobsters to the sea on the calculation and interpretation of reference points.
- Examine the sensitivity of the model to the assumption of 10% mortality for lobsters returned to the sea.

6.8 CRA 9

This section describes work conducted for CRA 9 in 2013 (Breen 2014).

Model structure

A Fox surplus-production model was fitted to catch and effort data from CRA 9. Data sources are listed in Table 51. 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 2014).

The model was fitted using uniform priors on most parameters (Table 52), but an informed prior on the intrinsic rate of increase was developed.

Table 51: 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 52.

Table 52: Parameters estimated and priors used in the base case assessment for CRA 9. 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 26 and Table 53) 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 27) 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.

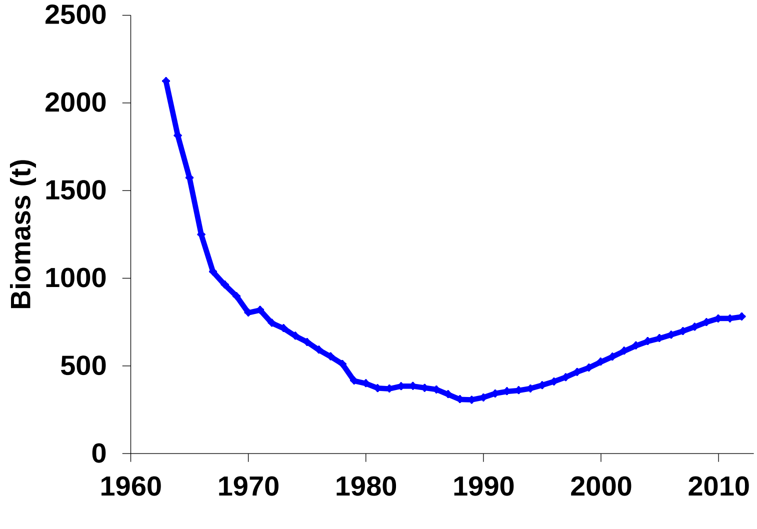


Figure 26: CRA 9 biomass from the base case MPD.

Table 53: 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

Table 53 [Continued]

	5%	mean	median	95%	MPD
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

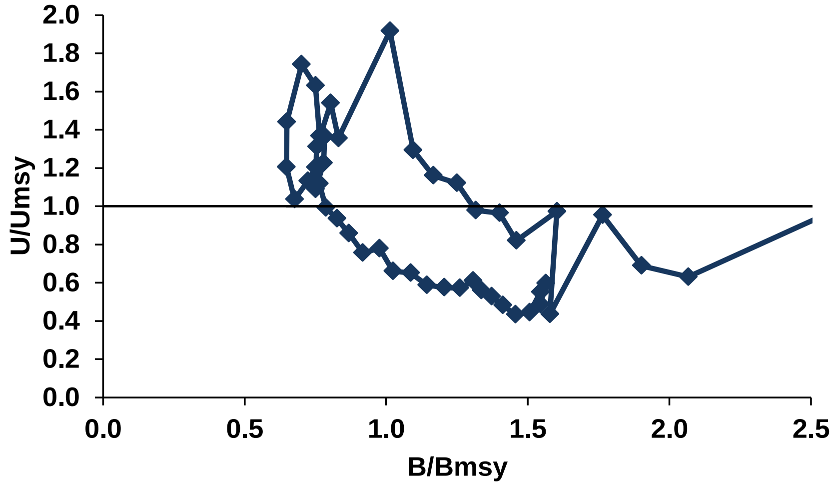


Figure 27: Phase plot of the CRA 9 fishery: the x-axis is the mean of the posterior distribution of biomass as a proportion of *Bmsy*; the y-axis is the mean of the posterior of exploitation rate as a proportion of equilibrium exploitation rate at *Bmsy*; the horizontal line is 1.0 (equilibrium exploitation 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.

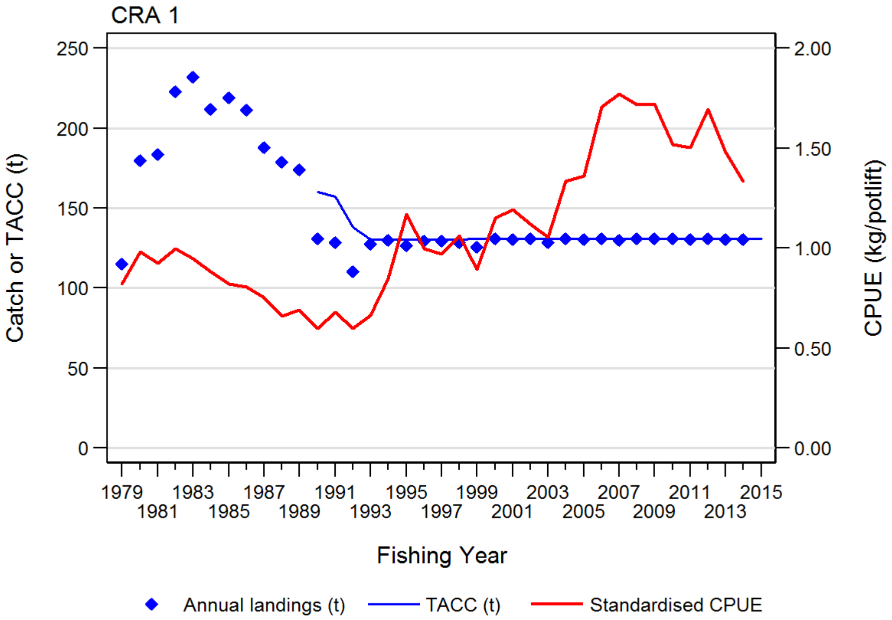
7.1 *Jasus edwardsii*

CRA 1 Northland

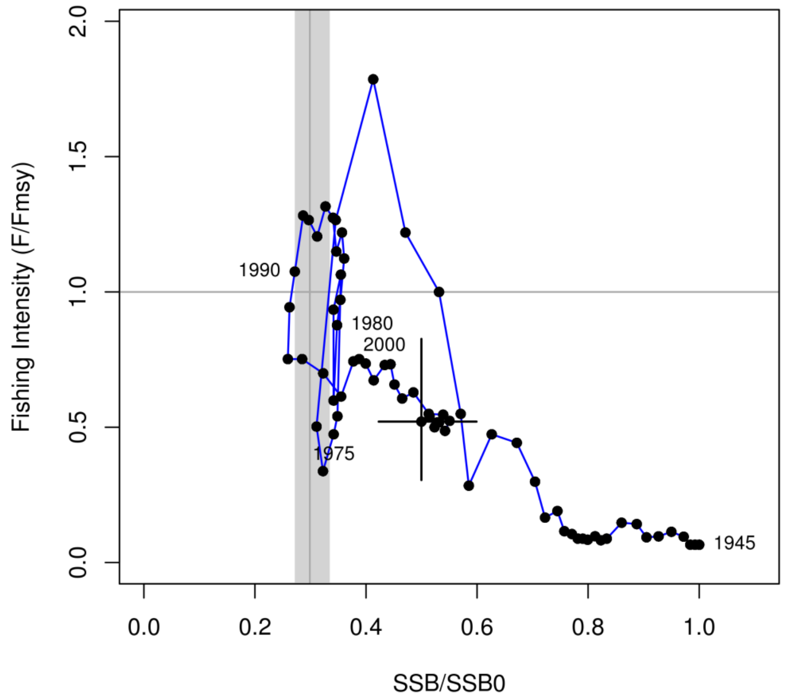
Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	MP evaluated
Reference Points	Target: *Bref*: mean of beginning AW vulnerable biomass for the period 1979–88 Limit: reported against B_{MIN}: minimum AW vulnerable biomass, 1945–2013 Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default)
Status in relation to Target	Virtually Certain (> 99%) that $B_{2014} > B_{ref}$
Status in relation to Limits	Biomass in 2014 was 200% of B_{MSY} and 173% of B_{REF} Exceptionally Unlikely (< 1%) that $B_{2014} < B_{min}$ Exceptionally Unlikely (< 1%) that B_{2014} < soft and hard limits

Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA1 from 1979 to 2015.



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

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	AW biomass decreased to a low point in the early-1970s, remained low until the mid-1990s and has increased since then.
Recent Trend in Fishing Intensity or Proxy	Size-limited and non-size-limited exploitation have declined since the early 1990s.

Other Abundance Indices	Catch rates (CR) not fitted (1963-73)
Trends in Other Relevant Indicators or Variables	-
Projections and Prognosis	
Stock Projections or Prognosis	Offset CPUE to Sept 2015 decreased from 1.58 to 1.315 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	Exceptionally Unlikely (< 1%) that $B_{2017} < B_{min}$ Soft Limit: Exceptionally Unlikely that (< 1%) $B_{2017} < 0.2SSB0$ Hard Limit: Exceptionally Unlikely that (< 1%) $B_{2017} < 0.1SSB0$
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Exceptionally Unlikely (< 1%)

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

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

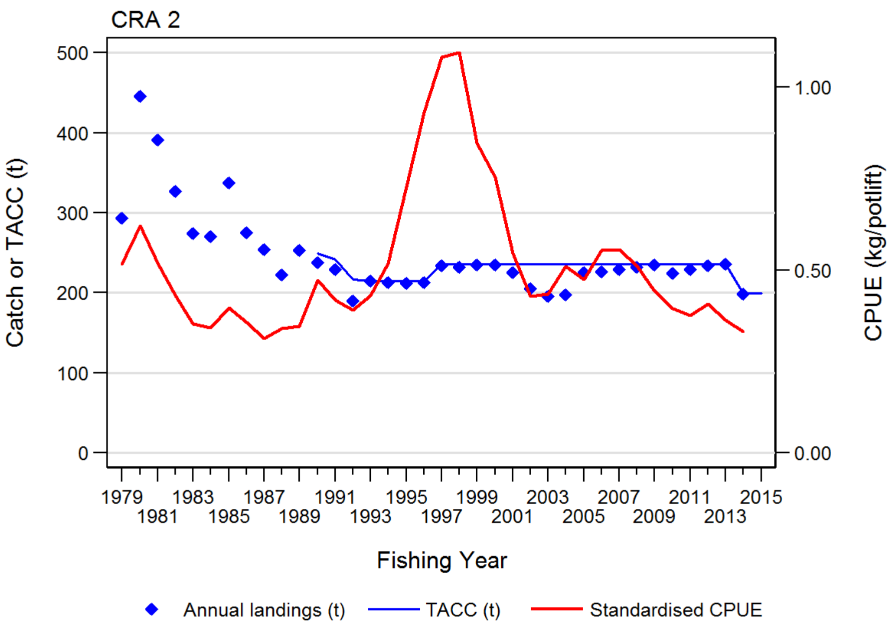
Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have little direct effect on non-target species.

CRA 2 Bay of Plenty

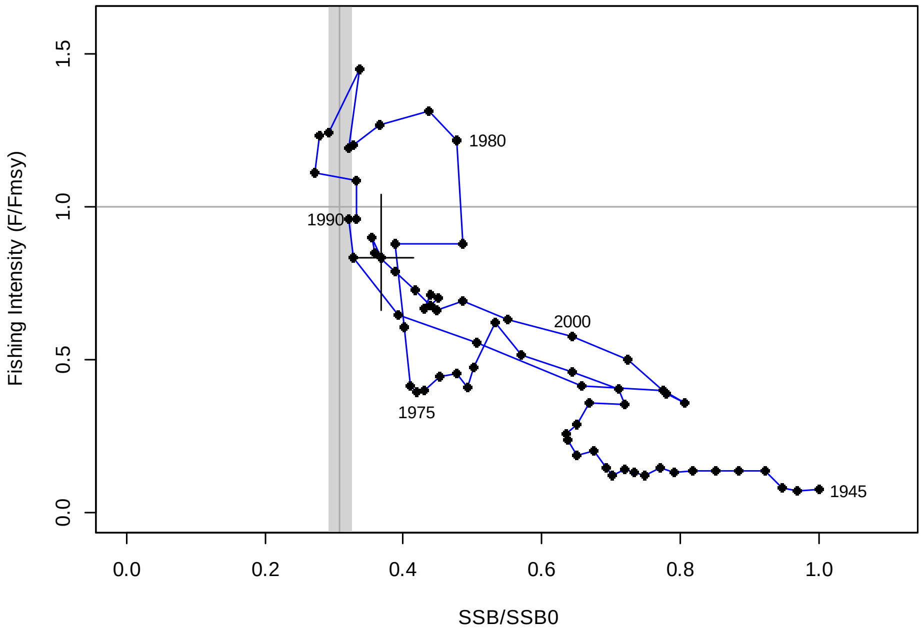
Stock Status	
Year of Most Recent Assessment/Evaluation	2015
Assessment Runs Presented	MP evaluation updated
Reference Points	Target: Not established (reported against B_{MSY} and B_{REF}) B_{REF} : mean of beginning AW vulnerable biomass for the period 1979-81 Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default) Overfishing threshold: F_{MSY}
Status in relation to Target	Biomass in 2013 was 136% of B_{MSY} and 80% of B_{REF} Very Likely (> 90%) to be above B_{MSY} Unlikely (< 40%) to be above B_{REF}
Status in relation to Limits	Exceptionally Unlikely (< 1%) to be below soft and hard limits

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

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA2 from 1979 to 2015.



Phase plot for CRA 2.

Fishery and Stock Trends

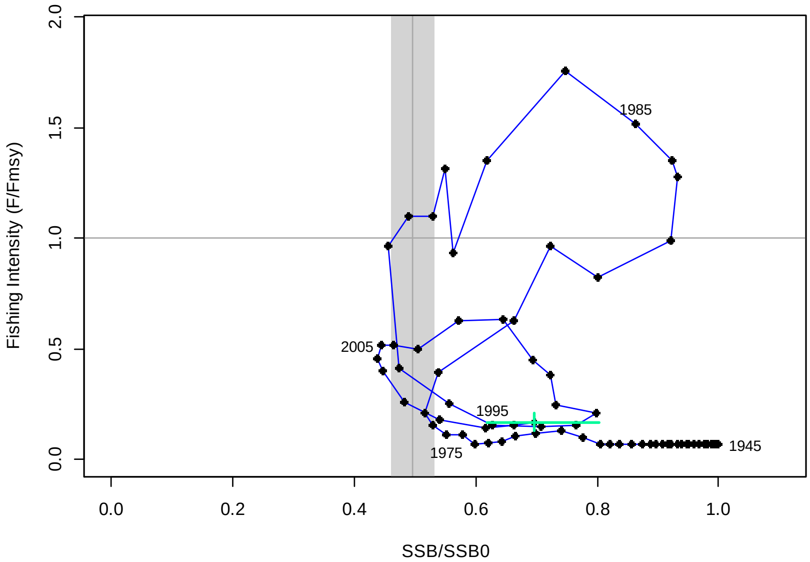
Recent Trend in Biomass or Proxy	Biomass has remained at relatively consistent levels after coming down from high levels in the late 1990s; there was a drop in abundance from the mid-2000s to 2011.
Recent Trend in Fishing Intensity or Proxy	Has been less than F_{MSY} since 1989 (see phase plot).
Other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

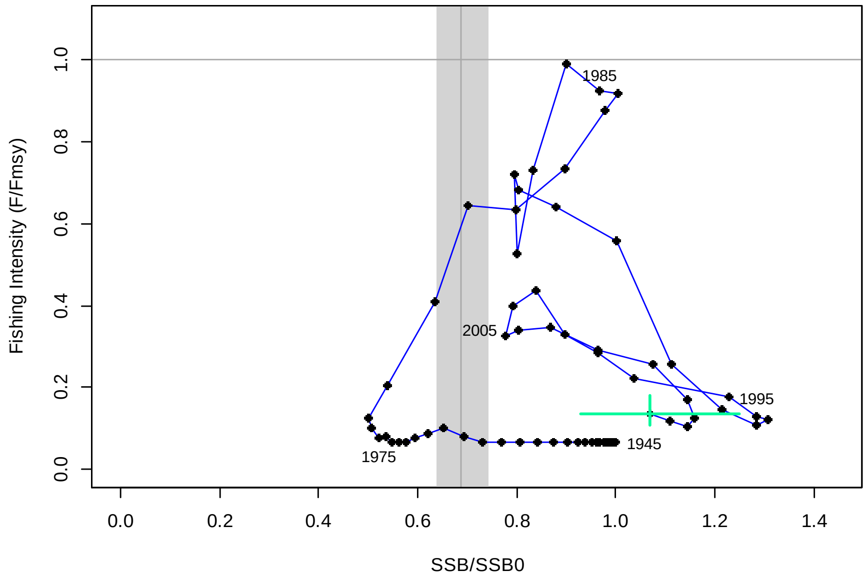
Projections and Prognosis		
Stock Projections or Prognosis	Offset CPUE to Sept 2015 decreased from 0.366 to 0.299 kg/potlift which results in no change to the TACC based on the MP rule evaluation.	
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)	
Probability of Current Catch or TACC causing Overfishing to continue or commence	Unlikely (< 40%)	
Assessment Methodology and Evaluation		
Assessment Type	Level 1 Full Quantitative Stock Assessment (2013)	
Assessment Method	Bayesian length-based model	
Assessment dates	Latest assessment: 2013	Next assessment: 2018?
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- CPUE data 1979-2012 - Length frequency data - Tag-recapture data - Catch rate (CR) data 1963-73	1 – High quality 1 – High quality 1 – High quality 1 – High quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Changes to length frequency weighting regime	
Major Sources of Uncertainty	- Non-commercial catch	
Qualifying Comments		
A management procedure has been developed that may be used to manage the fishery in the future.		
Fishery Interactions		
Potting is the main method of targeting rock lobster and is thought to have little direct effect on non-target species. For all QMAs, the most frequently reported incidental species caught are, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets. However, these comprise less than 10% of the rock lobster catch.		

CRA 3 Gisborne

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	MP evaluated
Reference Points	Target: no target agreed Reported against B_{MSY}: autumn winter (AW) vulnerable biomass associated with *MSY* (maximum size-limited catch summed across AW and SS) Limit: reported against B_{MIN}: minimum AW vulnerable biomass, 1945–2013 Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default)
Status in relation to Target	Virtually Certain (> 99%) to be above B_{MSY}
Status in relation to Limits	Biomass in 2014 was 261% of B_{MSY} and 85% of B_{REF} Exceptionally Unlikely (< 1%) to be below B_{MIN} Exceptionally Unlikely (< 1%) to be below soft and hard limits
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

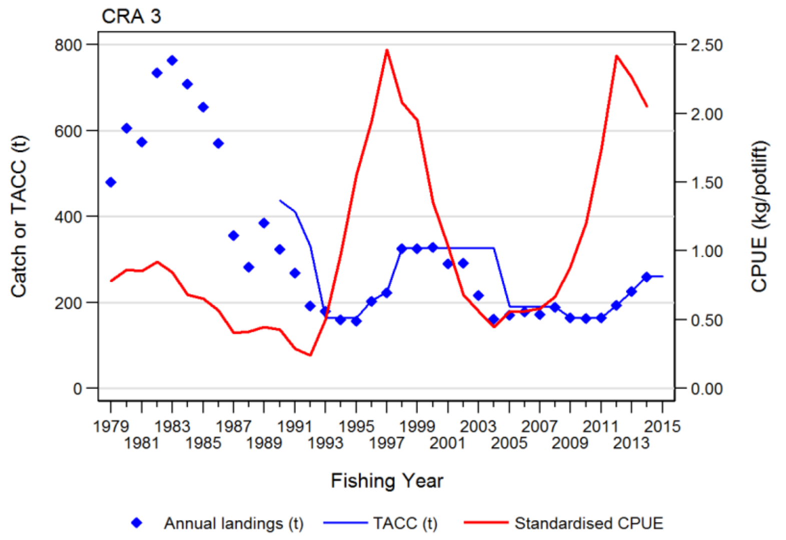
Historical Stock Status Trajectory and Current Status





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

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

Trends in Other Relevant Indicators or Variables	 **Annual landings, TACC and standardised CPUE for CRA3 from 1979 to 2015**

Projections and Prognosis	
Stock Projections or Prognosis	Offset CPUE to Sept 2015 decreased from 2.2139 to 1.8842 kg/potlift which results in no change to the TACC based on the MP rule evaluation.
Probability of Current Catch or TACC causing decline below Limits	Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or commence	Unlikely (< 40%)

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

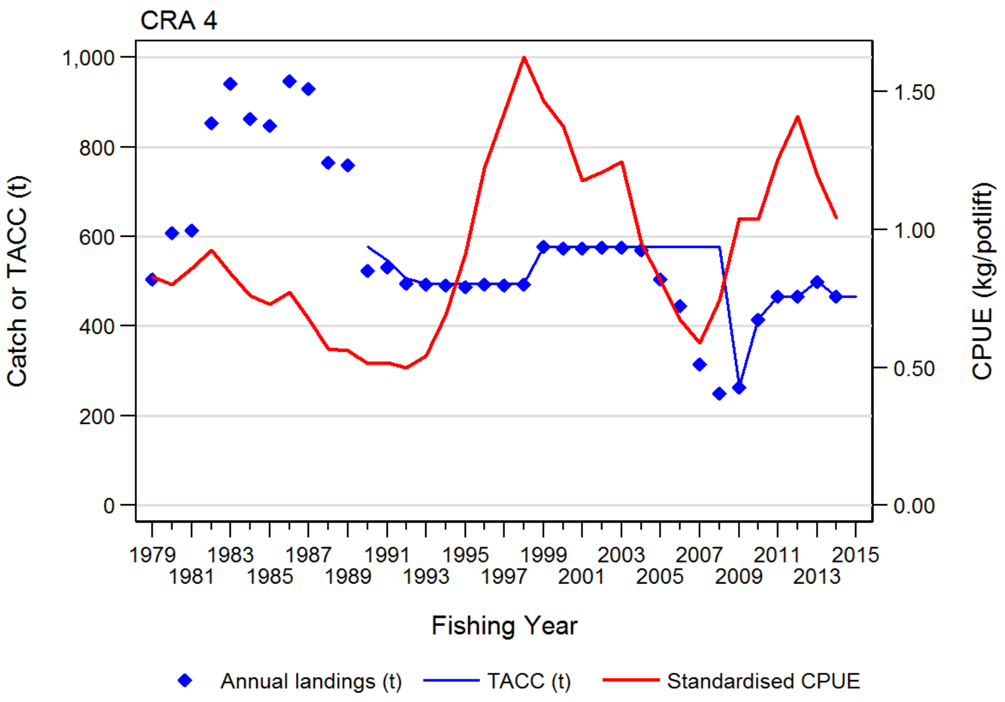
Qualifying Comments
Two base cases presented with different growth model fitting assumptions are presented.

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

CRA 4 Wellington – Hawkes Bay

Stock Status	
Year of Most Recent Assessment	2015
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	Biomass in 2011 was 230% of B_{MSY} and 168% of B_{REF} 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 2015

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 2015 decreased from 1.168 to 0.8822 kg/potlift which results in a reduction of 4.5% in the TACC based on the MP rule evaluation.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or commence	Very Unlikely (< 10%)

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

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

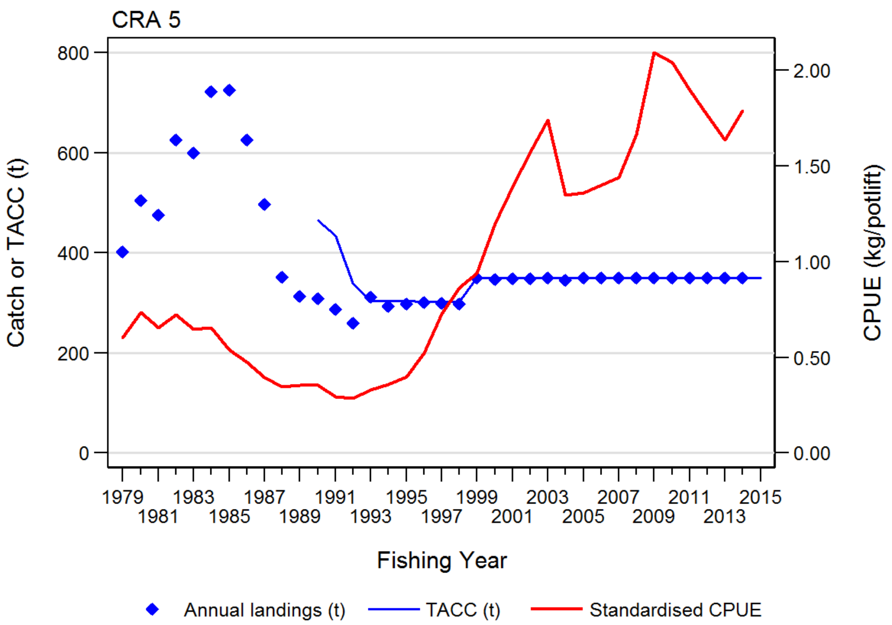
Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have little direct effect on non-target species. For all QMAs, the most frequently reported incidental species caught are, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter,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

CRA 5 Canterbury - Marlborough

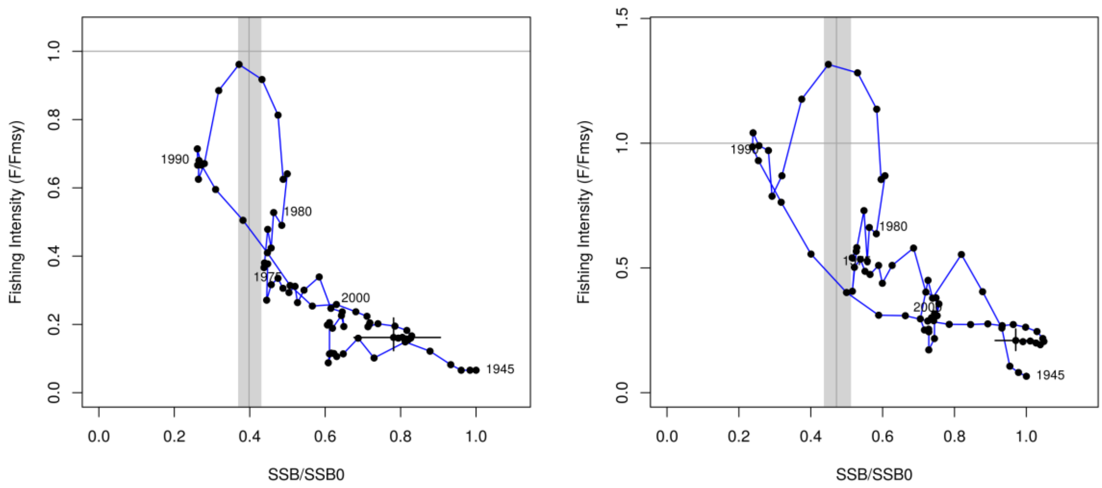
Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Two base cases
Reference Points	Target: Not established (reported against *Bref* and SSB_{MSY}) *Bref*: mean of beginning AW vulnerable biomass for the period 1979-88 SSB_{MSY}: mature female biomass associated with B_{MSY} Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default) Overfishing threshold: F_{MSY}
Status in relation to Target	CPUE is at a level well above the levels during the reference period. Virtually Certain (> 99%) to be above *Bref* Virtually Certain (> 99%) to be above SSB_{MSY}
Status in relation to Limits	Exceptionally Unlikely (< 1%) to be below the soft and hard limits

Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA5 from 1979 to 2014.



Phase plots for the two base case runs (without and with density dependence).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has decreased since 2009, the highest level observed in the 36 year series, but remains at high levels.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality has remained well below the overfishing threshold in recent years.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

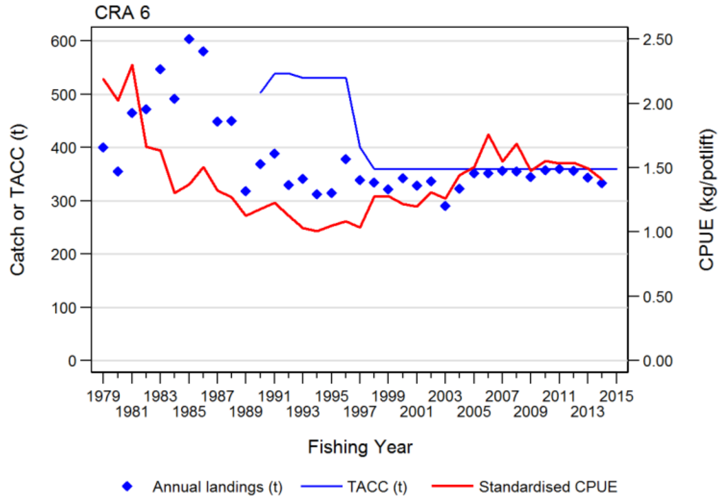
Projections and Prognosis		
Stock Projections or Prognosis	Biomass is expected to decrease over the next four years but will remain above all reference levels for either of the two base case results.	
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Very 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	
Assessment Method	Bayesian length based model	
Assessment Dates	Latest assessment: 2015	Next assessment: 2020
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	- new growth priors - addition of a density-dependence parameter	
Major Sources of Uncertainty	- Level of non-commercial catches, illegal catches, validity of the assumption of constant catchability since 1979 in the CPUE series	
Qualifying Comments		
A management procedure has been developed that is used to set the TAC.		

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: CPUE updated to 2015
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 2015.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has declined slightly over the last 3 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	
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
-

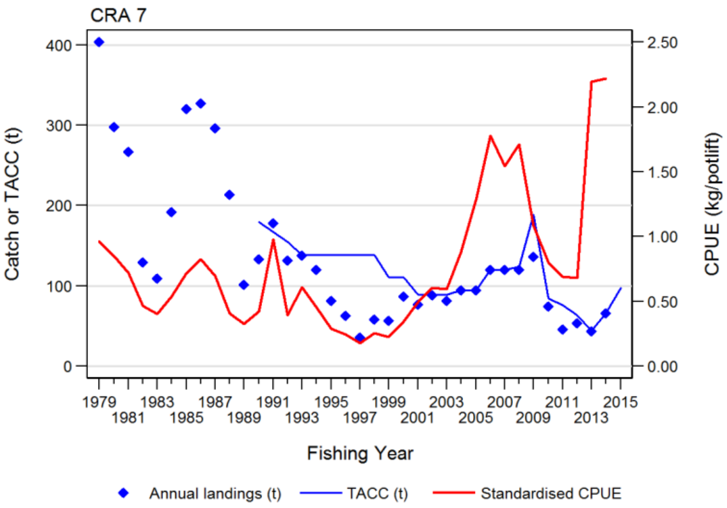
Fishery Interactions
Potting is the main method of targeting rock lobster and is thought to have little direct effect on non-target species. For all QMAs, the most frequently reported incidental species caught are, in decreasing order of catch across all stocks: octopus, conger eel, blue cod, trumpeter,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

7.1 *Jasus edwardsii*

CRA 7 Otago

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	MCMC base case
Reference Point	Target: Not established (reported against B_{REF}) B_{REF}: mean of beginning AW vulnerable biomass for the period 1979-81 *Bmsy*: biomass at fishing intensity high enough to maximise the catch SSB_{MSY}: spawning stock biomass associated with *Bmsy* 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 relatively high level. Very Likely (> 90%) 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 Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA 7 from 1979 to 2014.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass levels have increased since the mid-2000s to a level well above the reference period
Recent Trend in Fishing Intensity or Proxy	Stable over the past decade
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	4-year projections suggest median biomass will decline by 8% but will remain well above reference levels.
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	Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Level 1 Full Quantitative Stock Assessment	
Assessment Method	Bayesian length based model	
Assessment Dates	Latest assessment: 2015	Next assessment: 2020
Overall assessment quality rank	1– High Quality	
Main data inputs (rank)	CPUE, historic catch rate, length frequency, tagging data	1– High Quality
Data not used (rank)	Puerulus indices	3 – Low quality: three indices in CRA 7 and CRA 8, with conflicting trends
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; no density-dependent growth	
Major Sources of Uncertainty	Variation in LF data, uncertain movement patterns out of CRA 7 (with potential change over time), lack of mature females	

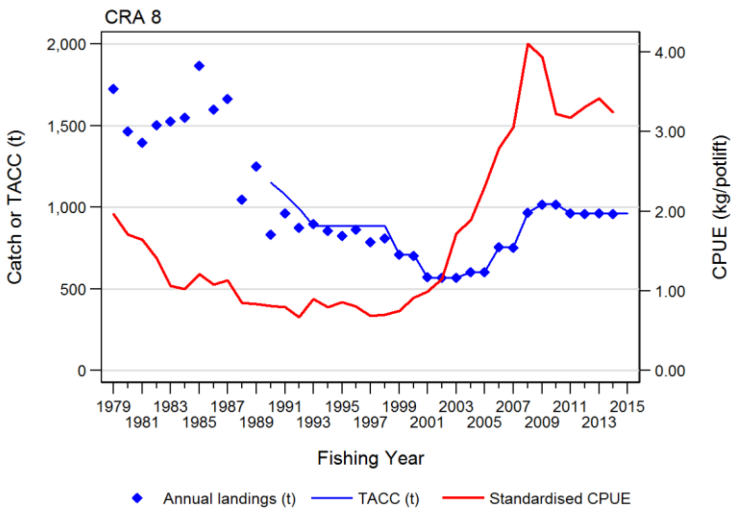
Qualifying Comments
A management procedure has been developed that is used to set the TAC.

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

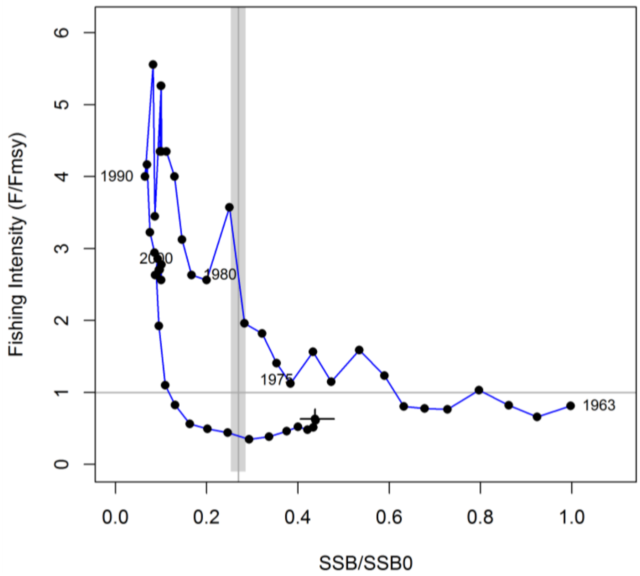
CRA 8 Southern

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	2015 MCMC base case
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 Virtually Certain (> 99%) 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.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has been increasing steadily in recent years.
Recent Trend in Fishing Intensity or Proxy	Relatively stable and well below *Fmsy*
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Projections suggest the stock will remain near its current level.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Exceptionally Unlikely (< 1%)

Probability of Current Catch or TACC causing Overfishing to continue or commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 Full Quantitative Stock Assessment	
Assessment Method	Bayesian length based model	
Assessment Dates	Latest assessment: 2015	Next assessment: 2020
Overall assessment quality rank	1– High Quality	
Main data inputs (rank)	CPUE, historic catch rate, length frequency, tagging data	1– High Quality
Data not used (rank)	Puerulus indices	3 – Low quality: three indices in CRA 7 and CRA 8, with conflicting trends
Changes to Model Structure and Assumptions	- Francis (2011) weights for composition data; change in tag recapture likelihood	
Major Sources of Uncertainty	Effect of returning a high proportion of large lobsters to the sea (including for the calculation of reference points); assumption of constant catchability over the entire CPUE time series	

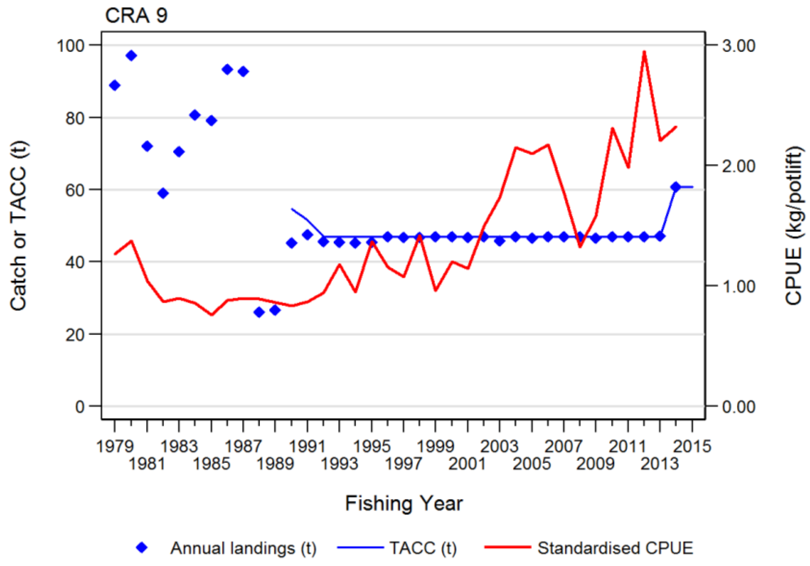
Qualifying Comments
A management procedure has been developed that is used to manage the fishery.

Fishery Interactions
Potting is the main method of targetting rock lobster and is thought to have little direct effect on non-target species. Across all QMAs, the most frequently reported incidental species caught are, in decreasing order of catch: 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	2015
Assessment Runs Presented	MP evaluation updated
Reference Points	Target: Not established (reported against B_{MSY}) Soft limit: 20% *K* (default) Hard limit: 10% *K* (default) Overfishing threshold: F_{MSY}
Status in relation to Target	Biomass in 2012 was 150% of B_{MSY}; Very Likely (> 90%) to be above B_{MSY}
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA9 from 1979 to 2015

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

Projections and Prognosis	
Stock Projections or Prognosis	The offset CPUE to Sept 2015 decreased from 2.095 to 1.8853 kg/potlift which results in a decrease to the TACC to 46 t based on the MP rule evaluation.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) to drop below either the soft or hard limits at current catch levels
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

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

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

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

7.2 *Sagmariasus verreauxi*, PHC stock

The status of this stock is unknown.

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