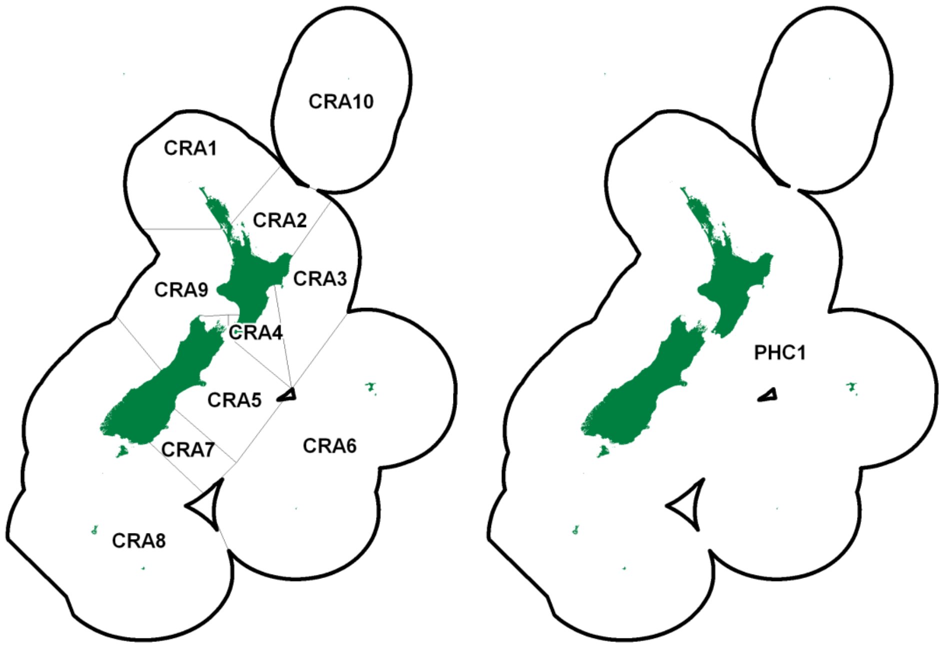
ROCK LOBSTER (CRA and PHC)

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



1. FISHERY SUMMARY

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

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

Historically, three rock lobster stocks were recognised for stock assessment purposes:

- NSI – the North and South Island (including Stewart Island) red rock lobster stock
- CHI – the Chatham Islands red rock lobster stock
- PHC – the New Zealand packhorse rock lobster stock

In 1994, the Rock Lobster Fishery Assessment Working Group (RLFAWG) agreed to divide the historical NSI stock into three substocks based on groupings of the existing QMAs (without assigning CRA 9):

- NSN – the northern stocks CRA 1 and 2
- NSC – the central stocks CRA 3, 4 and 5
- NSS – the southern stocks CRA 7 and 8

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

The management of four of the nine rock lobster QMAs involves the operation of "management procedures" (MPs), also known as "decision rules". These are rules that use data observations to specify catch limits, and which have been evaluated to meet the requirements of the Fisheries Act. The four QMAs which use this methodology are CRA 3, CRA 4, CRA 7 and CRA 8, all of which use standardised CPUE to specify a commercial fishery catch limit (see Section 4 for a detailed discussion of each rule). A management procedure was evaluated for CRA 5 in 2010, but was not accepted by stakeholders. An earlier management procedure has been voluntarily accepted by CRA 5 industry to shelve catch below a CPUE threshold. CRA 1 and CRA 2 currently rely on formal stock assessments to make changes in catch limits, as does CRA 5 for increases. Neither CRA 6 nor CRA 9 have used formal stock assessments to set catch limits. The TACC for CRA 10 is nominal because it is not fished commercially. The TACC for PHC 1 increased from 30 t in 1990 to its current value of 40.3 t at the beginning of the 1992–93 fishing year following appeals.

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

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

[1] voluntary TACC reductions based on an MP were made by the CRA 4 Industry in 2007 and 2008. The MP was implemented by MFish in 2009

[2] the CRA 5 MP applies to decreases in catch limit only; a formal stock assessment would be required for an increase

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

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

A closed season applies in CRA 6 from 01 March to 30 April in each year. The commercial fishing season in CRA 7 currently runs from 1 June to 19 November.

Special conditions have applied to the Gisborne (CRA 3) fishery from April 1993. During June, July and August, commercial fishers are permitted to retain males at least 52 mm TW but females cannot be landed. These measures changed the commercial CRA 3 fishery to a mainly winter fishery for male lobsters from 1993 to 2002. The fishery was closed to all users from September to the end of November from 1993. This changed in 2000, when the beginning date for the closure was changed to 1 October. In 2002, the closed season was shortened further and CRA 3 now remains officially closed to commercial fishers only in May (May has been closed to commercial operators in CRA 3 since 1993). Commercial fishers in 2008–09, 2009–10 and 2010–11 have closed, by voluntary agreement, Statistical Areas 909 and 910 from the beginning of September to mid-January and Statistical Area

911 from mid-December to mid-January. Fishers in Statistical Area 911 have voluntarily landed only males above 54 mm TW in June to August for each of 2009, 2010 and 2011.

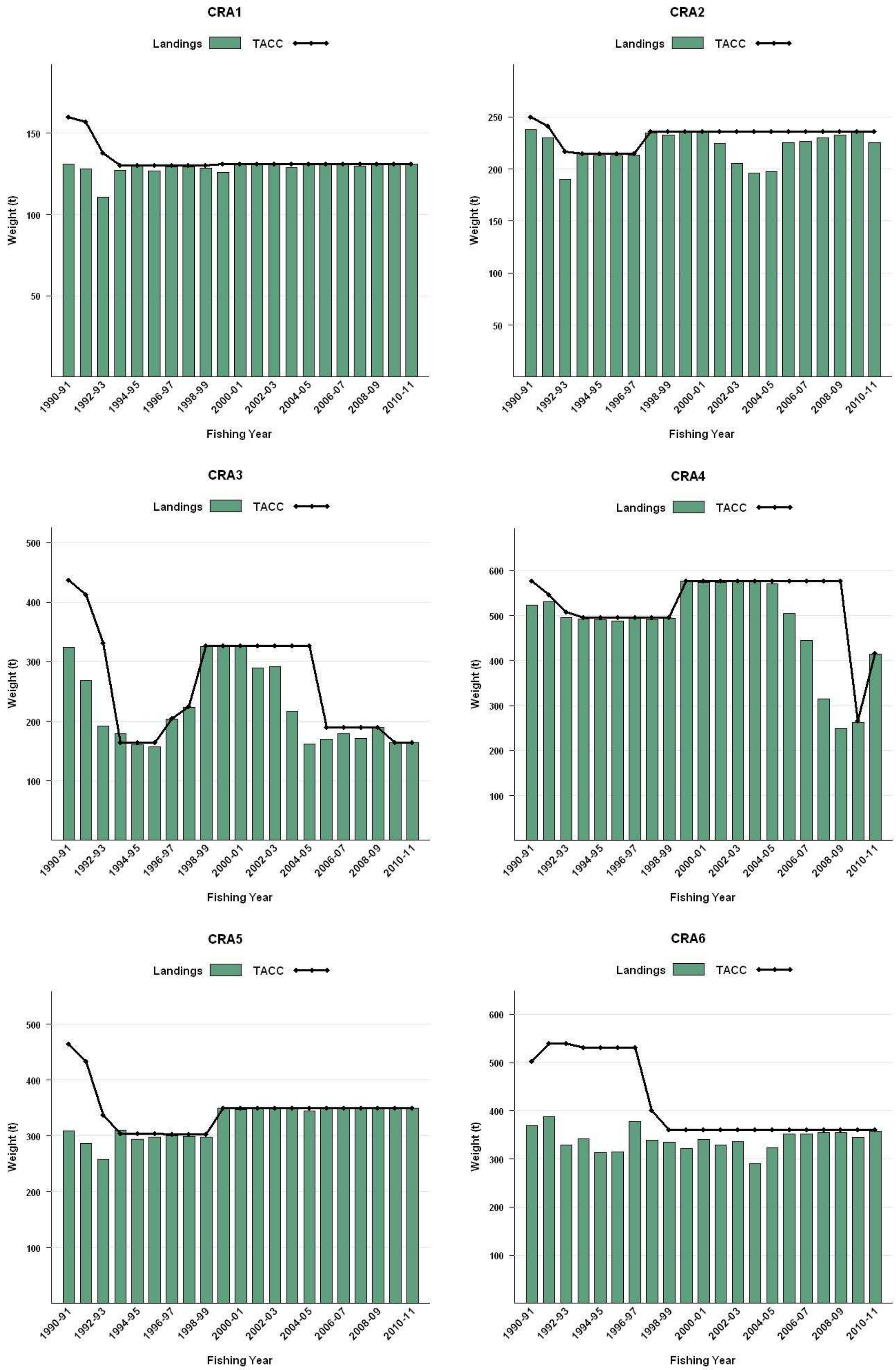


Figure 1: Historical landings and TACC for the 9 main CRA stocks and PHC 1. **[Continued on next page]**

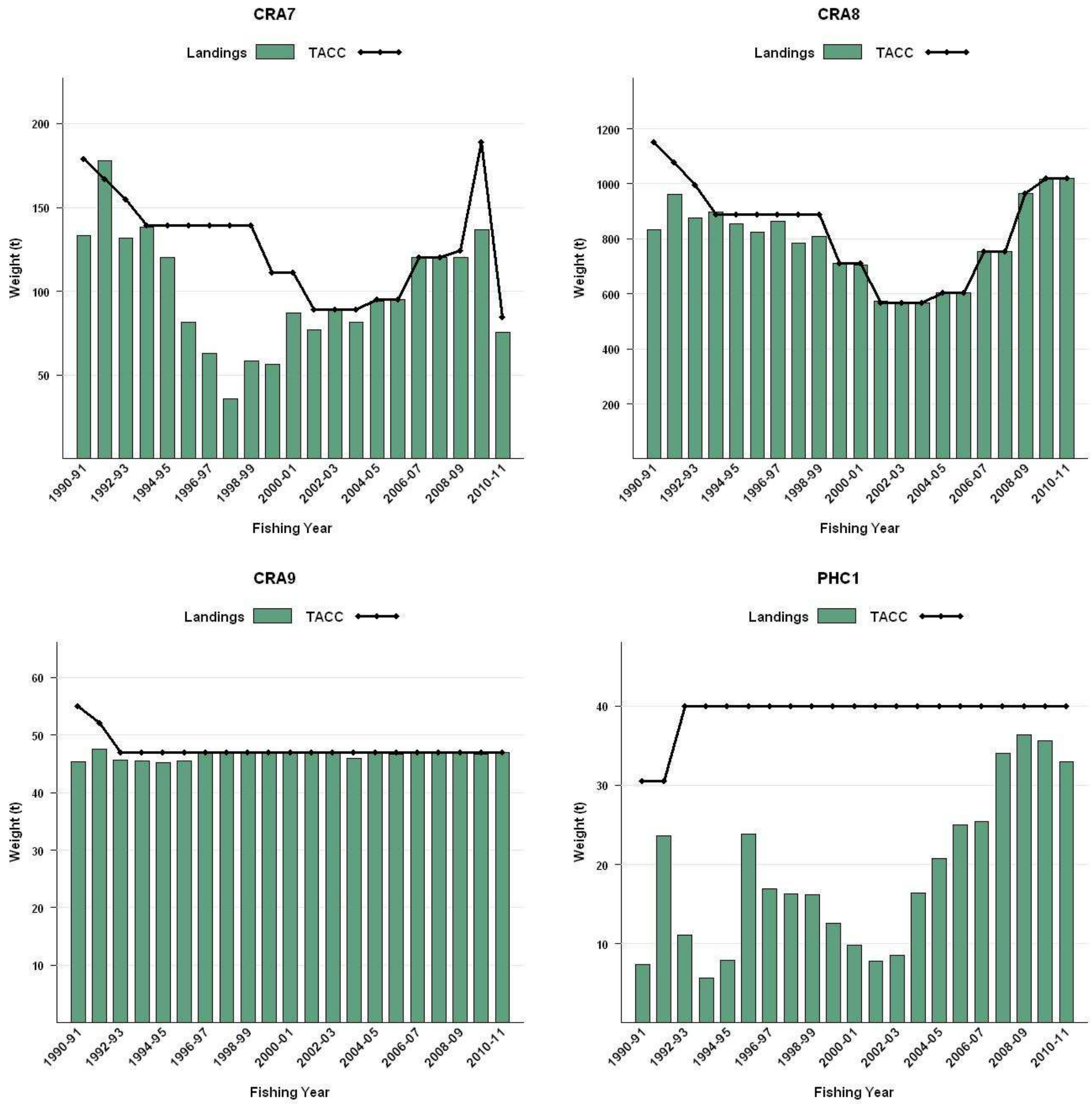


Figure 1 [cont]: Historical landings and TACC for the 9 main CRA stocks and PHC 1.

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

1.1 Commercial fisheries

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

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

	CRA 1			CRA 2			CRA 3			CRA 4		
Fishing Year	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC
1990–91	131.1	160.1	–	237.6	249.5	–	324.1	437.1	–	523.2	576.3	–
1991–92	128.3	146.8	–	229.7	229.4	–	268.8	397.7	–	530.5	529.8	–
1992–93	110.5	137.4	–	190.3	214.6	–	191.5	327.5	–	495.7	495.7	–
1993–94	127.4	130.5	–	214.9	214.6	–	179.5	163.7	–	492.0	495.7	–
1994–95	130.0	130.5	–	212.8	214.6	–	160.7	163.7	–	490.4	495.7	–
1995–96	126.7	130.5	–	212.5	214.6	–	156.9	163.7	–	487.2	495.7	–
1996–97	129.4	130.5	–	213.2	214.6	–	203.5	204.7	–	493.6	495.7	–
1997–98	129.3	130.5	–	234.4	236.1	452.6	223.4	224.9	379.4	490.4	495.7	–
1998–99	128.7	131.1	–	232.3	236.1	452.6	325.7	327.0	453.0	493.3	495.7	–
1999–00	125.7	131.1	–	235.1	236.1	452.6	326.1	327.0	453.0	576.5	577.0	771.0
2000–01	130.9	131.1	–	235.4	236.1	452.6	328.1	327.0	453.0	573.8	577.0	771.0
2001–02	130.6	131.1	–	225.0	236.1	452.6	289.9	327.0	453.0	574.1	577.0	771.0
2002–03	130.8	131.1	–	205.7	236.1	452.6	291.3	327.0	453.0	575.7	577.0	771.0
2003–04	128.7	131.1	–	196.0	236.1	452.6	215.9	327.0	453.0	575.7	577.0	771.0
2004–05	130.8	131.1	–	197.3	236.1	452.6	162.0	327.0	453.0	569.9	577.0	771.0
2005–06	130.5	131.1	–	225.2	236.1	452.6	170.1	190.0	319.0	504.1	577.0	771.0
2006–07	130.8	131.1	–	226.7	236.1	452.6	178.7	190.0	319.0	444.6	577.0	771.0
2007–08	129.8	131.1	–	229.7	236.1	452.6	172.4	190.0	319.0	315.2[1]	577.0	771.0
2008–09	131.0	131.1	–	232.3	236.1	452.6	189.8	190.0	319.0	249.4[1]	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	N/A	131.1	–	N/A	236.1	452.6	N/A	164.0	293.0	N/A	466.9	661.9

	CRA 5			CRA 6			CRA 7			CRA 8		
Fishing Year	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC
1990–91	308.6	465.2	–	369.7	518.2	–	133.4	179.4	–	834.5	1152.4	–
1991–92	287.4	426.8	–	388.3	503.0	–	177.7	164.7	–	962.7	1054.6	–
1992–93	258.8	336.9	–	329.4	503.0	–	131.6	153.1	–	876.5	986.8	–
1993–94	311.0	303.2	–	341.8	530.6	–	138.1	138.7	–	896.1	888.1	–
1994–95	293.9	303.2	–	312.5	530.6	–	120.3	138.7	–	855.6	888.1	–
1995–96	297.6	303.2	–	315.3	530.6	–	81.3	138.7	–	825.6	888.1	–
1996–97	300.3	303.2	–	378.3	530.6	–	62.9	138.7	–	862.4	888.1	–
1997–98	299.6	303.2	–	338.7	400.0	480.0	36.0	138.7	–	785.6	888.1	–
1998–99	298.2	303.2	–	334.2	360.0	370.0	58.6	138.7	–	808.1	888.1	–
1999–00	349.5	350.0	467.0	322.4	360.0	370.0	56.5	111.0	131.0	709.8	711.0	798.0
2000–01	347.4	350.0	467.0	342.7	360.0	370.0	87.2	111.0	131.0	703.4	711.0	798.0
2001–02	349.1	350.0	467.0	328.7	360.0	370.0	76.9	89.0	109.0	572.1	568.0	655.0
2002–03	348.7	350.0	467.0	336.3	360.0	370.0	88.6	89.0	109.0	567.1	568.0	655.0
2003–04	349.9	350.0	467.0	290.4	360.0	370.0	81.4	89.0	109.0	567.6	568.0	655.0
2004–05	345.1	350.0	467.0	323.0	360.0	370.0	94.2	94.9	114.9	603.0	603.4	690.4
2005–06	349.5	350.0	467.0	351.7	360.0	370.0	95.0	94.9	114.9	603.2	603.4	690.4
2006–07	349.8	350.0	467.0	352.1	360.0	370.0	120.2	120.2	140.2	754.9	755.2	842.2
2007–08	349.8	350.0	467.0	356.0	360.0	370.0	120.1	120.2	140.2	752.4	755.2	842.2
2008–09	349.7	350.0	467.0	355.3	360.0	370.0	120.3	123.9	143.9	966.0	966.0	1053.0
2009–10	349.9	350.0	467.0	345.2	360.0	370.0	136.5	189.0	209.0	1018.3	1019.0	1110.0
2010–11	350.0	350.0	467.0	357.4	360.0	370.0	74.8	84.5	104.5	1018.2	1019.0	1110.0
2011–12	N/A	350.0	467.0	N/A	360.0	370.0	N/A	75.7	95.7	N/A	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	3793.0	–
1991–92	47.5	50.2	–	3020.9	3502.9	–
1992–93	45.7	47.0	–	2629.9	3201.9	–
1993–94	45.5	47.0	–	2746.2	2912.1	–
1994–95	45.2	47.0	–	2621.5	2912.1	–
1995–96	45.4	47.0	–	2548.6	2912.1	–
1996–97	46.9	47.0	–	2690.5	2953.1	–
1997–98	46.7	47.0	–	2584.2	2864.1	1312.0
1998–99	46.9	47.0	–	2726.0	2926.8	1275.6
1999–00	47.0	47.0	–	2748.5	2850.2	3442.6
2000–01	47.0	47.0	–	2795.9	2850.2	3442.6
2001–02	46.8	47.0	–	2593.0	2685.2	3277.6
2002–03	47.0	47.0	–	2591.1	2685.2	3277.6
2003–04	45.9	47.0	–	2451.5	2685.2	3277.6
2004–05	47.0	47.0	–	2472.3	2726.4	3318.8
2005–06	46.6	47.0	–	2475.8	2589.4	3184.8
2006–07	47.0	47.0	–	2604.8	2766.6	3362.0
2007–08	47.0	47.0	–	2472.5	2766.6	3362.0
2008–09	47.0	47.0	–	2640.7	2981.0	3576.5
2009–10	46.6	47.0	–	2688.8	2762.2	3362.6
2010–11	47.0	47.0	–	2781.6	2807.3	3407.7
2011–12	N/A	47.0	–	N/A	2792.8	3393.2

[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 2010–11. Sources of data: from 1979–80 to 1988–89 from the QMS-held FSU data; from 1989–90 to 2010–11 from the CELR data held by the Ministry of Fisheries, corrected for "L" destination code landings (set text for definition). See Booth *et al.* (1994) for a discussion of problems with the QMS-held FSU data; see Starr (2011) for a discussion of the standardisation methodology, including the procedure for preparing the data for analysis.

Fishing year	CRA 1	CRA 2	CRA 3	CRA 4	CRA 5	CRA 6	CRA 7	CRA 8	CRA 9
1979–80	0.80	0.52	0.80	0.82	0.63	2.16	0.98	2.01	1.18
1980–81	0.96	0.62	0.89	0.79	0.77	2.00	0.86	1.75	1.27
1981–82	0.91	0.52	0.87	0.85	0.68	2.27	0.73	1.69	0.98
1982–83	0.98	0.43	0.95	0.91	0.75	1.64	0.47	1.44	0.82
1983–84	0.93	0.35	0.86	0.83	0.67	1.61	0.41	1.08	0.86
1984–85	0.87	0.34	0.70	0.76	0.68	1.28	0.55	1.05	0.81
1985–86	0.81	0.40	0.67	0.72	0.56	1.36	0.73	1.24	0.72
1986–87	0.79	0.36	0.58	0.77	0.49	1.49	0.83	1.10	0.83
1987–88	0.74	0.31	0.41	0.67	0.41	1.30	0.70	1.15	0.85
1988–89	0.65	0.34	0.42	0.56	0.36	1.25	0.41	0.86	0.83
1989–90	0.64	0.35	0.46	0.54	0.38	1.13	0.34	0.79	0.74
1990–91	0.54	0.47	0.43	0.50	0.37	1.16	0.43	0.80	0.83
1991–92	0.64	0.43	0.30	0.50	0.31	1.20	0.95	0.77	0.86
1992–93	0.54	0.42	0.25	0.48	0.30	1.17	0.41	0.69	0.96
1993–94	0.62	0.44	0.49	0.54	0.37	1.04	0.61	0.93	1.12
1994–95	0.79	0.53	0.92	0.67	0.38	1.03	0.46	0.84	0.89
1995–96	1.21	0.76	1.41	0.86	0.45	1.05	0.27	0.86	1.08
1996–97	1.17	0.90	1.89	1.18	0.61	1.11	0.23	0.81	0.97
1997–98	1.17	1.02	2.66	1.40	0.87	1.05	0.17	0.69	0.83
1998–99	1.35	1.11	2.02	1.56	1.11	1.29	0.26	0.71	1.10
1999–00	1.11	0.83	1.89	1.47	1.13	1.32	0.27	0.73	0.91
2000–01	1.12	0.74	1.40	1.26	1.33	1.18	0.35	0.88	1.08
2001–02	1.28	0.53	1.07	1.10	1.48	1.18	0.45	0.94	1.05
2002–03	1.12	0.42	0.73	1.19	1.56	1.28	0.62	1.17	1.24
2003–04	1.12	0.42	0.57	1.22	1.70	1.21	0.61	1.78	1.77
2004–05	1.27	0.48	0.49	0.95	1.52	1.33	0.84	1.74	2.31
2005–06	1.31	0.48	0.59	0.82	1.39	1.44	1.24	2.10	2.12
2006–07	1.41	0.56	0.57	0.68	1.34	1.64	1.76	2.70	2.19
2007–08	1.72	0.55	0.60	0.59	1.34	1.61	1.60	2.92	1.83
2008–09	1.78	0.51	0.69	0.71	1.46	1.59	2.01	3.87	1.25
2009–10	1.64	0.46	0.89	1.03	1.83	1.40	0.98	3.87	1.49
2010–11	1.25	0.41	1.18	1.03	1.64	1.53	0.71	2.76	1.46

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 actual landed catch, which may span several records of effort. Estimated catches from the top part of the CELR form may show differences from the catch totals on the bottom part of the form, particularly in some QMAs such as CRA 5 and CRA 8 (Vignaux & Kendrick 1998; Bentley *et al.* 2005). Substantial discrepancies were identified in 1997 between the estimated and weighed catches in CRA 5 (Vignaux & Kendrick 1998) and were attributed to fishers including all rock lobster catch in the estimated total, including those returned to the sea. This led to an overestimate of CPUE, but this problem appeared to be confined to CRA 5, which was remedied by providing additional instruction to fishers on how to properly complete the forms.

After 1998, all CELR catch data have been modified to reflect the actual 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 which 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 MFish 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, which in turn means that tracing capture from the fishing event to the landing event for the same lobster is not possible under the current system.

The catch and effort data used in these analyses have been calculated using a revised procedure since 2003. 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 even out at the month level. However, in some areas there are vessel/month combinations with no landings. In these instances, the method drops all data for the vessel in the month with zero landings and in the following month; it is thought that a method that excludes uncertain data is preferable to one that might incorrectly reallocate landings. This method is described as "Method B4" in Bentley *et al.* (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 to landings made to Licensed Fish Receivers ("L" destination code) using the "Method B4" correction procedure. All other destination codes have been dropped. Methods for calculating the standardised and arithmetic CPUE estimates are documented in Starr (2011).

Another potential problem with assuming CPUE indices are proportional to abundance has been identified by the RLFAWG. Fishers may sort their catch, discarding parts not expected to provide a reasonable economic return. This "high-grading" (permitted by legislation) could lead to biases in the estimated CPUE relative to previous years when sorting did not occur, if fishermen do not report the catch they could legally have retained. This practice has become more prevalent in recent years, especially in QMAs where rock lobster abundance has increased. The RLFAWG agreed to identify this issue for further investigation.

Descriptions of Fisheries

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

CPUE levels in CRA 1 and CRA 2 differ: CRA 1 has always had higher catch rates than CRA 2, even in the 1980s when catch rates were lower. CPUE in CRA 1 has been above 1.3 kg/potlift since 2004–05, compared to 0.5 kg/potlift or less in CRA 2 since 2001–02 (Table 2). CRA 2 presently has the lowest CPUE of all nine CRA QMAs, and has been below 0.5 kg/potlift for six of the most recent nine fishing years.

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

Trends in CPUE have differed between these three QMAs, with CRA 3 CPUE peaking in 1997–98, CRA 4 in 1998–99, and CRA 5 in 2009–10 (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 2010–11. CRA 5 remained high throughout the 2000s (Table 2).

The CRA 4 fishery extends from the Wairoa River on the east coast, southwards along the Hawkes Bay, Wairarapa and Wellington coasts, through Cook Strait and north to the Manawatu River.

A CRA 4 TAC was first set in April 1999 at 771 t, with a TACC of 577 t, which was increased from the 495.7 t TACC set in 1992, based on a stock assessment done in 1998. In 2009, the TAC was reduced to 461 t and the TACC was reduced to 266 t, guided by a management procedure. For two years before this, the CRA 4 quota holders had voluntarily shelved ACE using the same management procedure. Increases to the TACC using this management procedure were made in 2010 and 2011: the 2011 TAC was 661.9 t and the TACC was 466.9 t. Within the TAC, allowances were made of 85 t for recreational, 35 t for customary catches and 75 t for illegal catch.

There were 85 CRA 4 quota share owners in the 2009–10 fishing year with a fleet comprising an 43 vessels (Starr 2011), mostly operating from coastal bases in isolated rural areas. The CRA 4 commercial catch had a landed value of about $23 million in 2009–10, based on the average landed value, and supported processing and export operations in Napier, Wellington and Auckland.

The recreational catch history is unknown but was assumed as described in Section 1.3 (above), based on the 1994 and 1996 recreational surveys. Most recreational catch is taken in summer by potting and diving.

Stock monitoring for the CRA 4 fishery has been done mostly by observer catch sampling. Each year the stock assessment team assigns samples to statistical area x quarterly blocks based on the previous year's fishing pattern. In recent years, the annual sampling intensity has been 40 sampling days. A small voluntary logbook program with a few participants has been active in this fishery until the most recent year, and the CRA 4 industry has been making a concerted effort to expand the coverage from the voluntary logbook programme. Tag recapture data are routinely reported by commercial fishermen, and the stock assessment in 2011 had just over 1750 useable records.

Jasus edwardsii, CRA 7 and CRA 8

Catch rates are relatively low in CRA 7 compared with those in CRA 8, but both QMAs show similar patterns in CPUE. CPUE in CRA 7 was stable but low (often below 0.5 kg/potlift) until the early 2000s, while CRA 8 showed a similar pattern but at a higher level (Table 2). Both QMAs then showed spectacular increases in CPUE, peaking in the late 2000s at over 2.0 kg/potlift in CRA 7 and rising to nearly 4 kg/potlift in CRA 8. The CRA 8 annual CPUEs of 3.9 kg/potlift observed in 2008–09 and 2009–10 are the highest of any of the rock lobster QMAs over the 32 years of record (Table 2). CPUE declined by 65% in CRA 7 from 2008–09 to 2010–11 while the decline in CRA 8 was 29% between 2009–10 and 2010–11.

Jasus edwardsii, CRA 9

Mean annual CPUE has been near to or greater than 0.9 kg per potlift since 1979–80, followed by a strong increase beginning in 2003–04, with CPUE approaching or exceeding 2 kg/potlift in most years (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 since the mid-1980s to levels similar to those observed in other QMAs (Table 2). CPUE has fluctuated around 1.5 kg/potlift since 2001–02, peaking at 1.8 kg/potlift in 2009–10, the highest value in the series.

Sagmariasus verreauxi, PHC stock

QMS reported landings of the PHC stock halved between 1998–99 and 2001-02 and were below 30 t/year up to 2007–08 (Table 3). Landings have exceeded 30 t/year since 2007–08.

Jasus edwardsii CPUE by statistical area

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

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

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

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

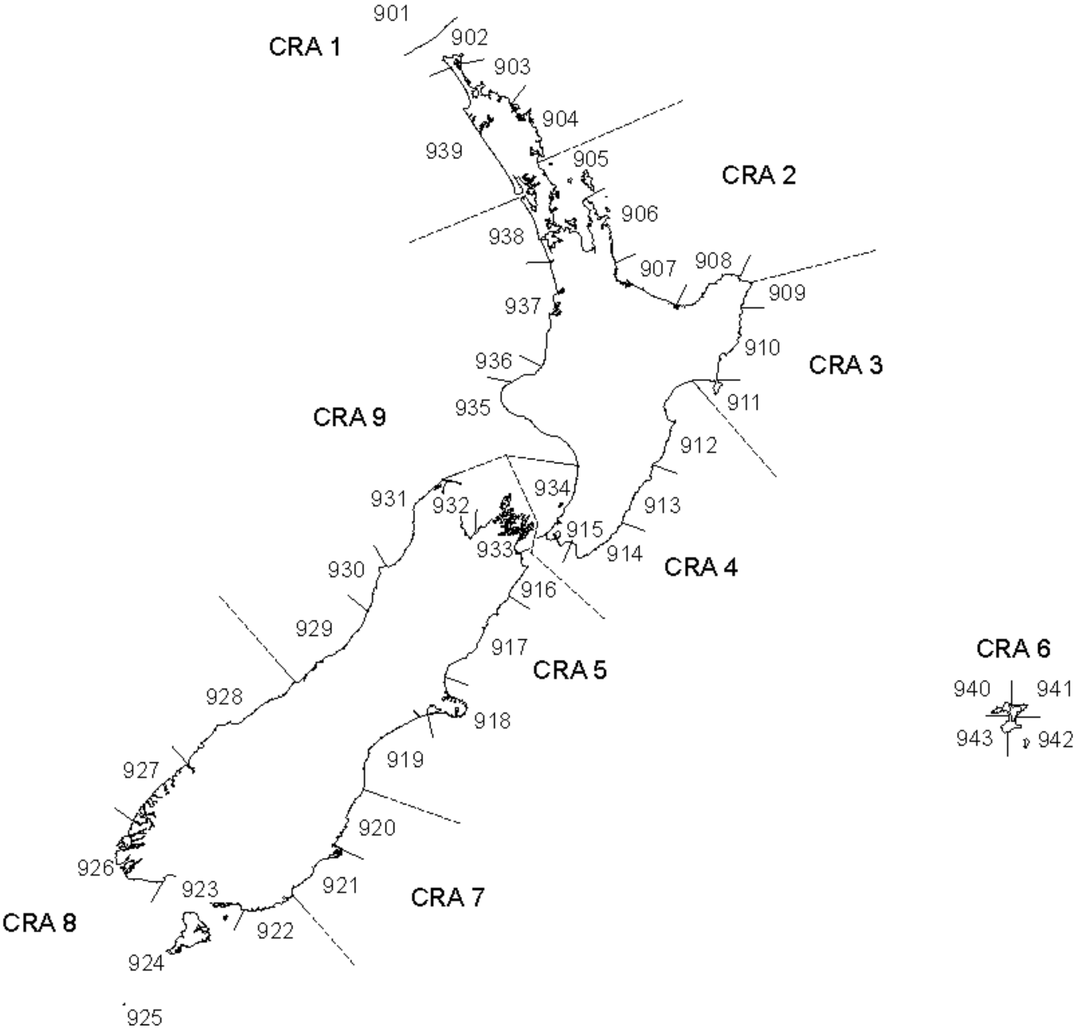


Figure 2: Rock lobster statistical areas as reported on CELR forms.

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

CRA	Stat Area	05/06	06/07	07/08	08/09	09/10	10/11	CRA	Stat Area	05/06	06/07	07/08	08/09	09/10	10/11
1	901	3.20	2.96	3.48	3.99	3.50	2.88	6	940	1.21	1.23	1.37	1.35	1.08	1.30
1	902	2.37	–	2.46	1.69	2.35	1.83	6	941	0.90	1.00	1.13	1.31	1.16	1.36
1	903	0.86	1.33	1.47	1.19	0.90	0.81	6	942	1.65	1.89	1.96	1.63	1.61	1.40
1	904	–	–	0.62	–	–	0.47	6	943	1.49	1.91	1.39	1.44	1.23	1.50
1	939	0.57	0.86	1.08	1.28	2.05	1.51	7	920	0.94	1.34	1.13	1.66	0.80	0.57
2	905	0.51	0.60	0.57	0.60	0.53	0.40	7	921	1.81	2.02	1.99	2.02	1.73	0.99
2	906	0.46	0.51	0.54	0.44	0.40	0.38	8	922	–	–	–	–	1.12	–
2	907	0.46	0.56	0.61	0.82	0.69	0.60	8	923	4.25	2.07	4.16	3.32	–	0.62
2	908	0.42	0.55	0.43	0.48	0.45	0.42	8	924	3.00	4.04	3.18	3.17	4.13	2.96
3	909	0.79	0.97	1.00	1.04	1.19	1.06	8	925	–	–	2.87	–	–	–
3	910	0.58	0.47	0.60	0.71	0.88	1.12	8	926	2.21	2.63	2.28	2.92	2.60	2.53
3	911	0.59	0.60	0.50	0.57	0.70	1.00	8	927	1.17	1.72	2.89	3.65	4.09	2.61
4	912	0.59	0.55	0.62	0.68	0.75	0.79	8	928	1.68	2.13	5.33	6.25	4.22	3.73
4	913	0.94	0.74	0.69	0.80	1.05	1.14	9	929	–	–	–	–	–	–
4	914	0.93	0.55	0.44	0.56	1.11	1.06	9	930	–	–	–	–	–	–
4	915	0.81	0.67	0.78	0.83	1.25	0.93	9	931	–	2.94	–	–	–	1.97
4	934	–	1.50	0.86	–	–	–	9	935	1.98	1.69	1.77	2.39	–	1.31
5	916	2.19	2.09	2.09	2.41	2.20	2.22	9	936	–	–	–	–	–	–
5	917	1.18	1.22	1.34	1.44	2.02	1.94	9	937	1.58	–	–	–	–	–
5	918	1.85	–	–	1.68	–	–	9	938	–	–	–	–	–	–
5	919	–	–	–	–	–	–								
5	932	–	–	–	–	–	–								
5	933	0.72	0.72	0.72	0.74	0.76	0.71								

Table 5: All available estimates of recreational rock lobster harvest (in numbers and in tonnes by QMA, where available) from regional telephone and diary surveys in 1992, 1993, 1994, 1996, 2000 and 2001 (Bradford 1997, 1998; Teirney *et al.* 1997). Data were provided by the chairman of the Recreational Fisheries Fishery Assessment Working Group (Peter Todd, MFish; pers. comm.).

QMA/FMA	Number	c.v. (%)	Nominal point estimate (t)
Recreational Harvest South Region 1 Sept 1991 to 30 Nov 1992			
CRA5	65 000	31	40
CRA7	8 000	29	7
CRA8	29 000	28	21
Recreational Harvest Central Region 1992–93			
CRA1	1 000		
CRA2	4 000		
CRA3	8 000		
CRA4	65 000	21	40
CRA5	11 000	32	10
CRA8	1 000		
Northern Region Survey 1993–94			
CRA1	56 000	29	38
CRA2	133 000	29	82
CRA9	6 000		
1996 Survey			
CRA1	74 000	18	51
CRA2	223 000	10	138
CRA3	27 000		
CRA4	118 000	14	73
CRA5	41 000	16	35
CRA7	3 000		
CRA8	22 000	20	16
CRA9	26 000		
2000 Survey			
CRA1	107 000	59	102.3
CRA2	324 000	26	235.9
CRA3	270 000	40	212.4
CRA4	371 000	24	310.9
CRA5	151 000	34	122.3
CRA7	1 000	63	1.3
CRA8	13 000	33	23.3
CRA9	65 000	64	52.8
2001 Roll Over Survey			
CRA1	161 000	68	153.5
CRA2	331 000	27	241.4
CRA3	215 000	48	168.7
CRA4	419 000	22	350.5
CRA5	226 000	22	182.4
CRA7	10 000	67	9.4
CRA8	29 000	43	50.9
CRA9	34 000	68	27.7

1.2 Recreational fisheries

Recreational catches have been estimated from a series of regional and national surveys based on telephone interviews and a sub-sample of diarists. Each survey estimated the New Zealand recreational catch by scaling up the reported catch in numbers by diarists with the ratio of diarists to the total estimated New Zealand population. The catch in numbers was converted to catch in weight using mean weights of recruited lobsters observed in the appropriate catch sampling or voluntary logbook programs during the survey years. Results for rock lobster from each of these recreational surveys – South region (1991–92), Central region (1992–93), North region (1993–94), the 1996 National Diary Survey, and the 1999–2000 National survey – are presented in Table 5.

In previous assessments, the RLFAWG has not accepted the results from the 1999–2000 national survey and the subsequent “roll-over” survey (Table 5), both of which tended to have much higher catch estimates in most of the QMAs when compared to the earlier surveys (with the exception of CRA 7 and CRA 8). Table 6 presents the recreational catch estimates used in all recent rock lobster stock assessments and Table 7 presents the rationale used when setting the levels presented in Table 6. The RLFAWG has little confidence in these estimates of recreational catch.

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

QMA	First year	Last year	"Best" Recreational catch (t)	Notes: Recreational Catch	Customary catch (t)	Notes: Customary catch
CRA 1 [1]	1945	2001	47.19	Ramped from 1945; constant from 1979	10	Constant from 1945
CRA 2 [1]	1945	2001	122.64	Ramped from 1945; constant from 1979	10	Constant from 1945
CRA 3 [2]	1945	2007	20.0	Constant from 1945	20	Constant from 1945
CRA 4 [3]	1945	2010	46.709	Ramped from 1945; after 1979, the "best recreational catch" was scaled by the ratio of the CRA 4 standardised SS CPUE relative to the mean 1994/1996 SS CPUE	20	Constant from 1945
CRA 5 [4]	1945	2009	30.424	Ramped from 1945; after 1979, the "best recreational catch" was scaled by the ratio of the arithmetic SS CPUE for Area 917 relative to the mean 1994/1996 SS CPUE for Area 917	10	Constant from 1945
CRA 6	–	–	–	Not used	–	–
CRA 7 [5]	1976	2006	4.514	Constant from 1976	1	Constant from 1976
CRA 8 [5]	1976	2006	20.101	Constant from 1976	2	Constant from 1976
CRA 9	–	–	–	Not used	–	–

[1] Starr *et al.* (2003);[2] Breen *et al.* (2009); [3] see Section 5; [4] Starr *et al.* (2011); [5] Breen *et al.* (2007)

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

QMA	Notes: Recreational Catch	Notes: Customary Catch
CRA 1 and CRA 2 [1]	Mean of 1994 and 1996 recreational survey estimates in numbers X 1994/96 SS mean weight from catch sampling	MFish Compliance estimate
CRA 3 [2]	By WG agreement	MFish Compliance estimate
CRA 4 [3]	Mean of 1994 and 1996 recreational survey estimates in numbers X 1994/96 SS mean weight from catch sampling. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table) was added to the calculated time series.	MFish Compliance estimate, supported by returns of numbers of lobster harvested under Kaimoana regulations
CRA 5 [4]	Mean of 1994 and 1996 recreational survey estimates in numbers X 1994/96 SS mean weight from catch sampling. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table) was added to the calculated time series.	By WG agreement
CRA 6	Not used	Not used
CRA 7 [5] CRA 8 [5]	Mean of recreational survey estimates (mean in numbers: 1992/1996 and 2000/2001) X mean SS weight from catch sampling in same years. The maximum of catches declared under the 1996 Fisheries Act Section 111 (Table) was then added to the survey estimates	Expanded from estimates provided by MFish Compliance which were thought to be too low by the WG
CRA 9	No assessment	No assessment

[1] Starr *et al.* (2003);[2] Breen *et al.* (2009); [3] see Section 5; [4] Starr *et al.* (2011); [5] Breen *et al.* (2007)

1.3 CRA 4 recreational catch

Recreational catch estimates were required for the 2011 CRA 4 assessment. The RLFAWG agreed to apply the same approach as used in 2010 for CRA 5, allowing recreational catch to vary with abundance, as reflected by the spring-summer standardised CPUE index series. Recreational catch was calculated by scaling the mean SS CPUE for 1994/1996 to the SS CPUE in each year multiplied by the mean CRA 4 catch in Table 6 (Figure 3).

Table

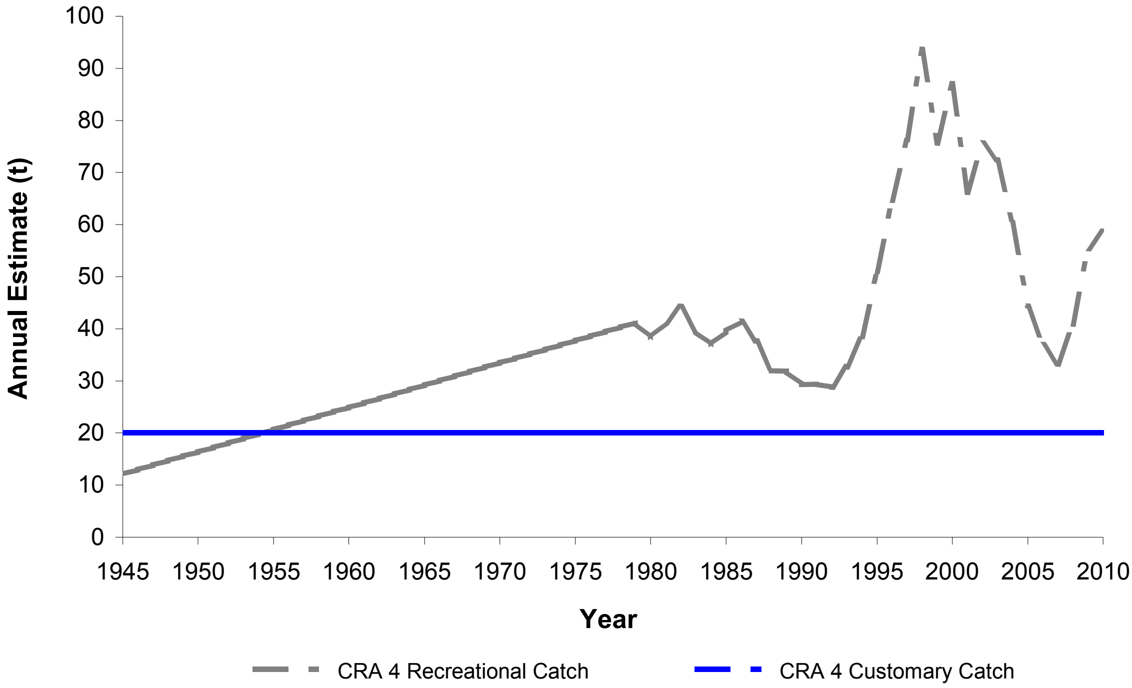


Figure 3. Recreational (grey) and customary (blue) catch trajectories (kg) for the 2011 stock assessment of CRA 4. Section 111 catches have been added to the 2011 recreational catch trajectory. Recreational catches were made proportional to the standardised SS CPUE after 1979, scaled to the mean catch weight estimated from the 1994 and 1996 recreational diary surveys.

The RLFAWG agreed to use the following algorithm to represent the CRA 4 recreational catches:

$$\bar{W}_{94,96} = \bar{w}_{94,95,96} * \bar{N}_{94,96}$$

$$\hat{W}_i = \frac{CPUE_i * \bar{W}_{94,96}}{0.5\left(CPUE_{94} + CPUE_{96}\right)} \quad \text{if } i >= 1979$$

$$\hat{W}_{1945} = 0.2 * \hat{W}_{1979}$$

$$\hat{W}_i = \hat{W}_{i-1} + \frac{(\hat{W}_{1979} - \hat{W}_{1945})}{(1979-1945)} \quad \text{if } i > 1945 \,\&\, i < 1979$$

where

$\bar{W}_{94,96} =$ mean recreational catch weight for 1994 & 1996

$\bar{w}_{94,95,96} =$ mean spring/summer weight >= MLS for sampled lobster

$\bar{N}_{94,96} =$ mean numbers lobster from 1994 & 1996 diary surveys

$CPUE_i =$ spring/summer standardised CPUE from 1979 to 2010

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

This algorithm is similar to that adopted by the RLFAWG for the 2010 CRA 5 stock assessment, except that the spring/summer (SS) standardised CPUE indices for all of CRA 4 has been used instead of the unstandardised CPUE from Area 917. This was done in acknowledgement that the recreational fishery is spread over a wide area of CRA 4 rather than concentrated in one statistical area. The mean number of lobsters from the 1994 and 1996 surveys was 91,500 and the SS mean weight of legal lobsters, estimated from the commercial sampling data, was 0.510 kg. The resulting recreational catch trajectory (Figure 3) showed a strong increasing trend up to the end of the 1990s, following by a steep drop to 2007–08, which has since recovered by 2010–11. The largest annual catch since 1979–80 was estimated at 89 t in 1998–99 and has averaged 44 t/year since 1979–80, before adding on the Section 111 landings (see following Section).

1.4 Section 111 commercial landings

Commercial fishermen are allowed to take home lobsters for personal use under the provisions of Section 111 of the Fisheries Act. These lobsters are required to be declared on landing forms using the destination code "F". The maximum total in any fishing year for these landings by QMA has ranged from less than 1 t (CRA 6) to greater than 13 t (CRA 8) (Table 8).

Table 8: Section 111 commercial landings (in kg, summed from landing destination code "F") by fishing year and QMA.

Fishing Year	CRA1	CRA2	CRA3	CRA4	CRA5	CRA6	CRA7	CRA8	CRA9
1992–93	5								
1999–00					8				
2000–01	3				30				
2001–02	111	227	136	648	465		77	253	5
2002–03	489	609	495	2 660	1 960		152	1 954	907
2003–04	2 221	1 025	372	3 399	2 907	60	93	1 679	973
2004–05	3 554	733	311	3 706	3 191	87	95	3 505	1 636
2005–06	3 083	775	993	3 680	4 388	2	153	4 572	2 133
2006–07	5 016	1 284	981	3 110	5 102	19	289	5 813	1 219
2007–08	3 831	1 032	1 167	2 706	5 412	411	929	7 786	1 461
2008–09	3 628	1 185	1 374	2 188	6 110	538	1 498	9 571	1 597
2009–10	4 010	1 370	2 253	3 222	6 244	299	1 688	10 721	2 264
2010–11	3 669	1 186	2 182	4 836	6 578	284	429	13 508	1 851
Maximum	5 016	1 370	2 253	4 836	6 578	538	1 688	13 508	2 264

1.5 Customary non-commercial fisheries

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

In 2011, MFish provided summaries for CRA 4 of the "quantity of lobsters harvested under Kaimoana regulations", as reported to the regulators. The maximum number of lobster in a year reported in this way was 12 000, which equates to about 6 t using the mean weight per lobster (0.510 kg; Table 6). The RLFAWG considered that this total may be incomplete and decided to continue to use a constant estimate of 20 t/year as was done for the 2005 assessment.

Table 6 presents the customary catch estimates used in all recent rock lobster stock assessments and Table 7 presents the rationale used when setting the levels presented in Table 6 The RLFAWG has little confidence in these estimates.

1.6 Illegal catch

MFish Compliance has provided estimates of illegal catch in two categories: catch that subsequently was reported against quota (columns labelled 'R' in Table 9) and catch which is outside of the MFish catch reporting system (columns labelled 'NR' in Table 9). Table 9 shows all the available illegal catch estimates by CRA QMA. When these data are used in stock assessments, missing cells are filled in by interpolation (for missing years) or by extrapolation (to extend the series after 2004–05). The illegal catches for these filled-in years are apportioned between the 'R' and 'NR' categories within each QMA (q) using the mean proportion $r_q = \sum R_{q,y} \Big/ \sum I_{q,y}$, where $R_{q,y}$ is the "reported" ('R') catch for those years with MFish Compliance estimates in the QMA and $I_{q,y}$ is the total illegal catch in the same years. This quantity is then subtracted from the total reported QMR/MHR catch to avoid counting the same catch twice when using these catches in stock assessments and the total illegal catch is summed.

Table 9: Available estimates of illegal catches (t) by CRA QMA from 1990, as provided by MFish Compliance over a number of years. R (reported): illegal catch that will eventually be processed though the legal catch/effort system; NR (not reported): illegal catch outside of the catch/effort system. Cells without data or missing rows have been deliberately left blank.

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

Table 10: Expot discrepancy estimates by year for all of New Zealand (McKoy, pers. comm.). The QMA export discrepancy catch is calculated using the fraction for the reported QMA commercial catch $C_{q,y}$ relative to the total NZ commercial catch C_y, starting with the total NZ export discrepancy for that year I_y: $I_{q,y} = I_y \left(C_{q,y} / C_y \right)$. This calculation is not performed for CRA 9 as there were no estimates of commercial catch available from 1974 to 1978. The average ratio of the export discrepancy catch for each QMA $\overline{P}_q$ relative to the reported QMA commercial catches is used in each CRA QMA to estimate illegal catches prior to 1990: $I_{q,y} = \overline{P}_q C_{q,y} \text{ if } y<1974 \| \left(y>1980 \& y<1990 \right)$.

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

Illegal catch estimates prior to 1990 have been derived from unpublished estimates of discrepancies between reported catch totals and total exported weight (Table 10; McKoy pers. comm.) that were developed for the period 1974 to 1980. For years prior to 1973 and from 1981–82 to 1989–90, illegal catch is estimated using the average ratio of annual exports of rock lobster relative to the reported catch in each year from 1974 to 1980 (Table 10). This ratio is calculated for each QMA by assuming that the exports are distributed by QMA in the same proportion as the reported catches. This procedure does not work for CRA 9 because there are no commercial catch estimates available for this QMA from 1974 to 1978.

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

1.7 Other sources of mortality

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

1.8 Time series of mortalities

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

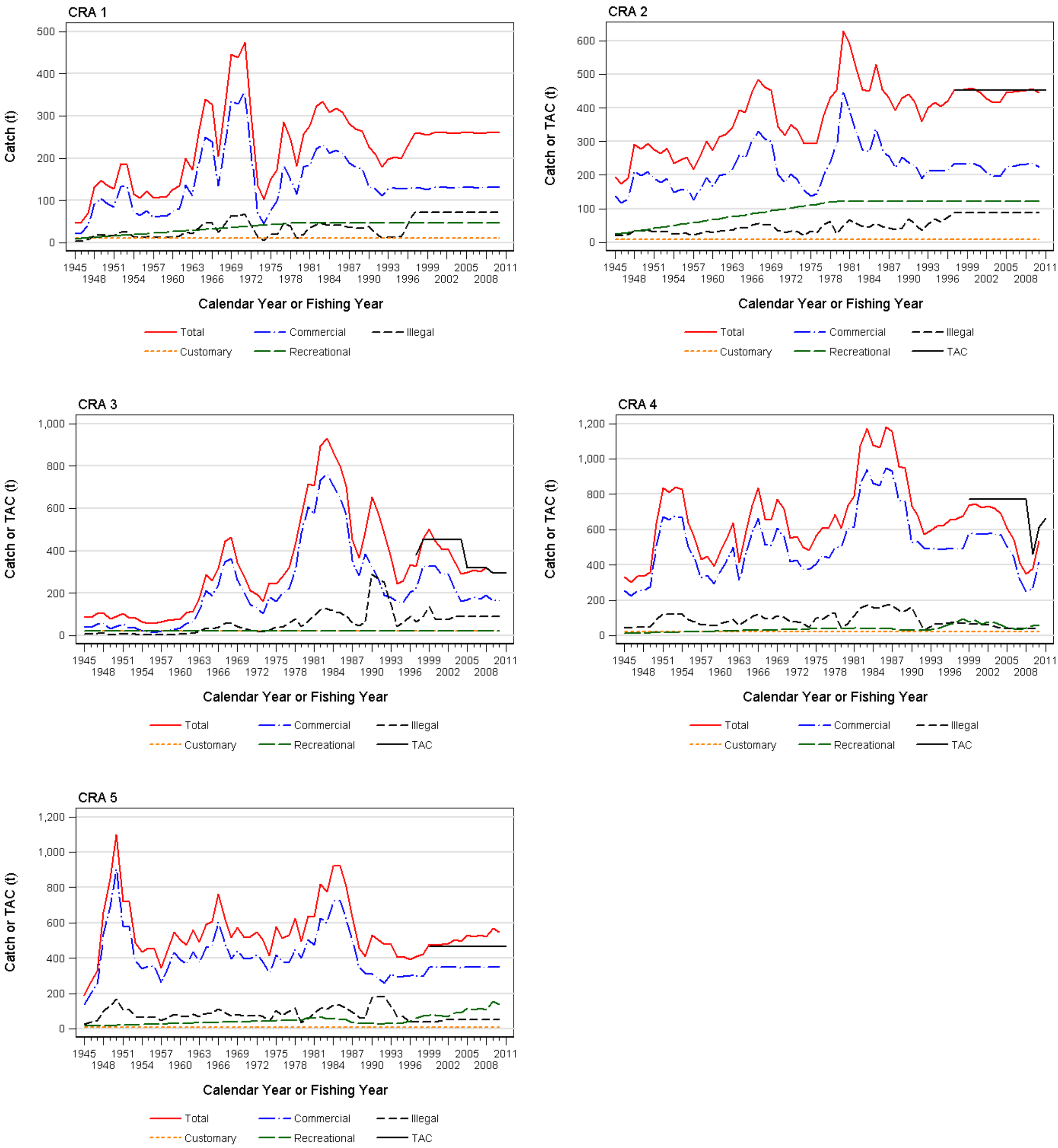


Figure 4A: **Catch trajectories (t) from 1945 to 2011 for CRA 1 to CRA 5, showing current best estimates for commercial, recreational, customary and illegal categories. Also shown is the sum of these four catch categories and the TAC (t) if it exists. Note that calendar year catches are plotted from 1945 to 1977. Statutory fishing years (1 April to 31 March) catches are plotted from 1979 on. Catches for 1978 are for 15 months, including January to March 1979.**

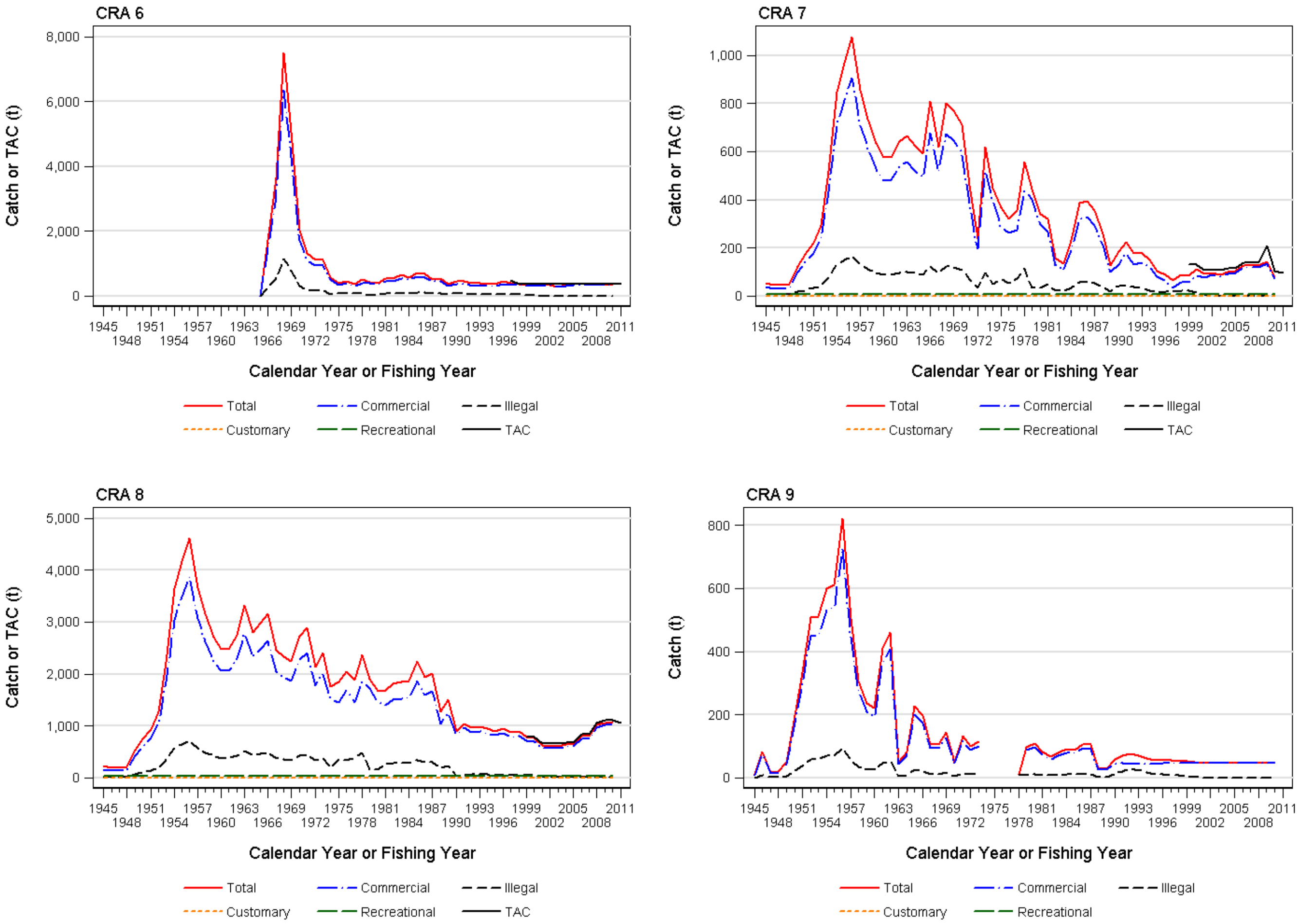


Figure 4B: Catch trajectories (t) from 1945 to 2011 for CRA 6 to CRA 9 (see Figure 4A for caption)

2. BIOLOGY

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

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

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

Values used for some biological parameters in stock assessments are shown in Table 11.

Table 11: Values used for some biological parameters.

1. Natural mortality (M)[1]

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

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

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

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

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

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

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

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

Growth modelling

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

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

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

Settlement indices

Annual levels of puerulus settlement have been collected from 1979 at sites in Gisborne, Castlepoint, Napier, Kaikoura, Moeraki, Halfmoon Bay, and Jackson Bay (Table 12). Each site has at least one group of five collectors that are checked monthly when possible, resulting in a monthly mean catch per group of collectors, which in turn is used as the basis for producing a standardised index of settlement (Forman *et al.* 2011). Standardised settlement indices are available for each major site, as well as for combined CRA 4 (Napier and Castlepoint) (Figure 5, Table 13). The combined CRA 4 index series has been based on the fishing year so that it is consistent with the CRA 4 stock assessment; all other index series are based on the calendar year.

Table 12: 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.

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
CRA 7	Moeraki	Wharf (MOE002)	1990–2006	3
		Pier (MOE007)	1998–Present	15
CRA 8	Halfmoon Bay	Wharf (HMB001)	1980–Present	8
		Thompsons (HMB002)	1988–2002	3
		Old Mill (HMB003)	1990–2002	3
		The Neck (HMB004)	1992–2002	3
		Mamaku Point (HMB005)	1992–2002	3
CRA 8	Jackson Bay	Wharf (JAC001)	1999–Present	5
		Jackson Head (JAC002)	1999–2006	3

Table 13: Standardised puerulus settlement indices (source: J. Forman & A. McKenzie, NIWA). '–': no sampling was done; 0: no observed settlement. All indices represent a calendar year, except for "Combined CRA 4", which represents a 1 April–31 March fishing year, with the year index coded to the final fractional fishing year.

	Gisborne CRA 3	Napier CRA 4	Castlepoint CRA 4	Combined CRA 4	Kaikoura CRA 5	Moeraki CRA 7	Halfmoon Bay CRA 8	Jackson Bay CRA8
1979	–	0.81	–	0.69	–	–	–	–
1980	–	1.46	–	1.34	0.00	–	1.71	–
1981	–	1.97	–	1.92	1.46	–	7.47	–
1982	–	0.96	–	1.73	0.04	–	0.35	–
1983	–	1.19	1.42	1.31	1.18	–	4.16	–
1984	–	0.39	1.35	0.66	0.34	–	0.35	–
1985	–	0.18	0.87	0.51	0.48	–	0.00	–
1986	–	–	0.50	0.84	0.15	–	0.10	–
1987	–	–	1.70	1.58	1.68	–	1.49	–
1988	–	1.45	0.98	1.02	0.74	–	0.19	–
1989	–	1.04	1.53	1.20	1.23	–	0.51	–
1990	–	1.09	0.94	1.13	0.41	0.79	0.41	–
1991	1.51	2.18	1.95	2.24	8.11	0.00	0.78	–
1992	2.19	2.31	2.41	2.00	9.41	0.15	0.57	–
1993	1.87	1.83	1.45	1.21	4.76	0.00	0.00	–
1994	2.86	1.37	0.92	1.02	1.27	0.00	1.03	–
1995	1.11	1.02	0.88	0.98	1.50	0.12	0.30	–
1996	1.03	1.62	1.29	1.36	1.12	1.13	0.29	–
1997	1.08	1.23	1.13	1.26	2.36	0.69	0.49	–
1998	1.49	1.05	1.66	0.98	3.13	0.66	0.24	–
1999	0.10	0.28	0.34	0.35	2.10	0.14	0.22	0.86
2000	0.97	0.63	0.55	0.57	1.83	3.93	1.11	0.81
2001	1.17	1.33	0.76	0.93	0.68	2.43	1.59	0.96
2002	1.14	1.07	0.67	0.91	1.79	0.95	1.22	3.50
2003	2.29	1.24	0.75	0.84	7.64	7.42	3.24	1.81
2004	0.79	1.04	0.64	0.57	2.64	0.42	0.12	0.34
2005	2.53	1.21	1.15	1.18	3.43	0.11	0.00	4.39
2006	0.38	0.57	0.63	0.50	2.86	0.06	0.12	0.45
2007	0.31	1.00	0.87	1.00	1.92	0.04	0.42	0.52
2008	0.71	0.57	0.88	0.81	3.62	0.10	0.08	0.33
2009	1.06	0.73	0.91	1.03	0.77	0.46	0.88	0.29
2010	0.58	1.25	1.59	1.13	2.85	1.40	1.56	7.08

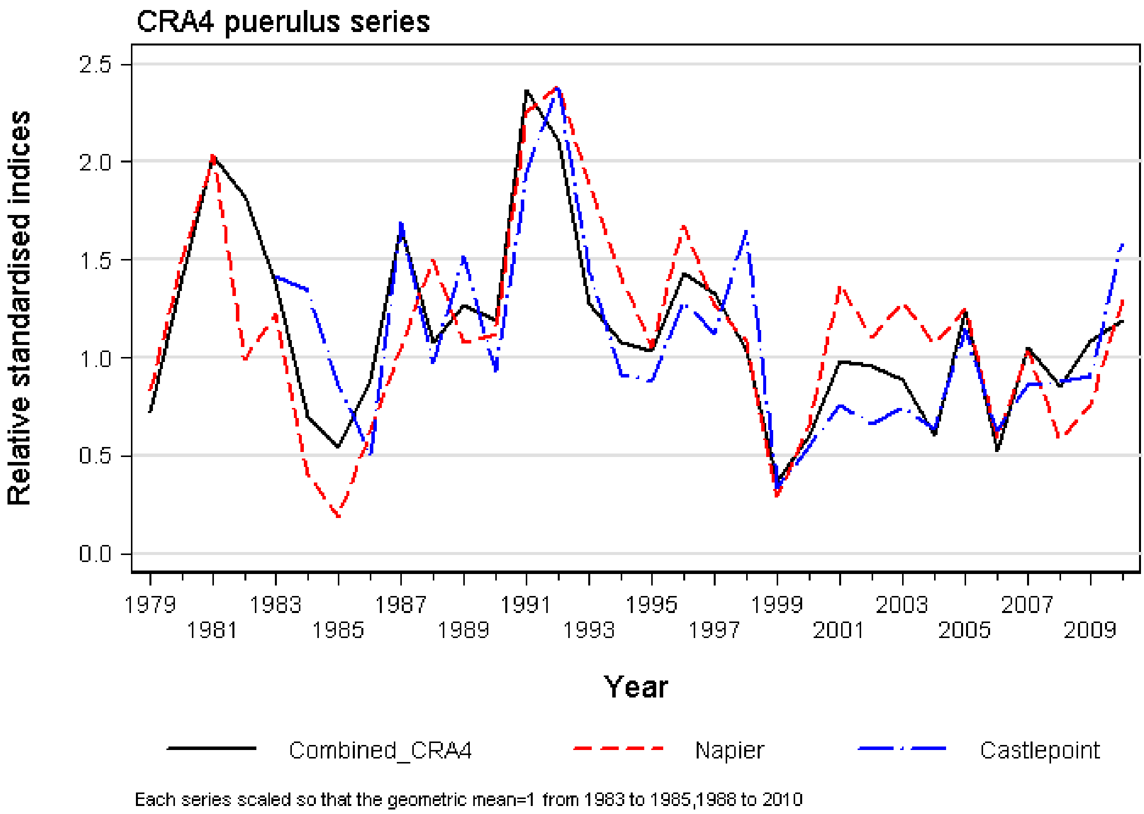


Figure 5. Comparative plot of the standardised puerulus series for CRA 4, using the series presented in Table 13, normalised relative to each other as indicated in the note printed at the bottom of the figure. "Year" for the Napier and Castlepoint series is a calendar year but denotes the first part of the fishing year for the "combined CRA 4" series

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 even occurs to New Zealand from populations in Australia (Chiswell *et al.* 2003).

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

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

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

4. DECISION RULES AND MANAGEMENT PROCEDURES

This section presents evaluations of the existing CRA 3, CRA 4, CRA 7 and CRA 8 management procedures (MP) for the 2012-13 fishing year, based on CPUE data extracted in early November 2011 and standardised as described below. The CRA 4 MP described in this document is scheduled to be replaced for the 2012–13 fishing year. These discussions are ongoing and the outcome will be reported in next year's Report. For CRA 5, a voluntary ACE-shelving rule was adopted by the CRA 5 industry. A new management procedure for CRA 5 was proposed by the NRLMG in 2010 but was not accepted by the Minister.

4.1 Data preparation

Data were obtained from the Ministry of Fisheries catch/effort mandatory reporting system, groomed Bentley *et al.* (2005) and the estimated catches scaled to the LFR ("L") landings using the "B4" procedure described in Section 1.3 and in Bentley *et al.* (2005). These data are then aggregated by fishing year, month, rock lobster statistical area and vessel prior to being processed by the.standardisation procedure (Maunder & Starr 1995; Bentley *et al.* 2005), which uses month, statistical area and year (or period for CRA 4) as explanatory variables. Each QMA analysis was done separately.

Management procedures for CRA 3, CRA 7 and CRA 8 use the annual standardised CPUE estimates, based on an "offset year" which is the AW season and the preceding SS season, whereas the statutory rock lobster fishing year comprises the SS season and the preceding AW season. The expired CRA 4 management procedure is based on the most recent AW season from an analysis where each AW or SS season is evaluated as an independent time step (Bentley *et al.* 2005).

Standardisation for the offset year management procedure analyses (CRA 3, CRA 7 and CRA 8) follows the suggestion of Francis (1999) and calculates "canonical" coefficients and standard errors for each year, which allows calculation of standard errors for every coefficient including the base year coefficient. Each standardised index is then scaled by the geometric mean of the simple arithmetic CPUE indices (using the summed annual catch divided by summed annual effort for each offset year). The geometric mean CPUE is preferred to the arithmetic mean because it is less affected by outliers than the arithmetic mean. This procedure scales the standardised indices to CPUE levels consistent with those observed by fishermen.

4.3 Management Procedure for CRA 3

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

1. A conditional initial fixed TAC applies for 3 years (2010–11, 2011–12 and 2012–13) and is set at 293 tonnes, unless offset-year CPUE falls below 0.75 kg/potlift or increases above 1.08 kg/potlift. If the CPUE falls outside these limits, the initial TAC expires and the harvest control rule equations determine the TAC;

2. The conditional initial fixed TAC will expire after the 2012–13 fishing year and the harvest control rule equations will determine the TAC;

3. Offset-year standardised CPUE, calculated in November, will be used as input to the rule to determine the TAC for the statutory fishing year that begins in the following April;

4. The management procedure is to be evaluated every year (no "latent year"), based on offset-year CPUE;

5. The provisional TAC (before minimum and maximum change rules operate, and exclusive of considering the initial fixed TAC determined by the rule), is given by:

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

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

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

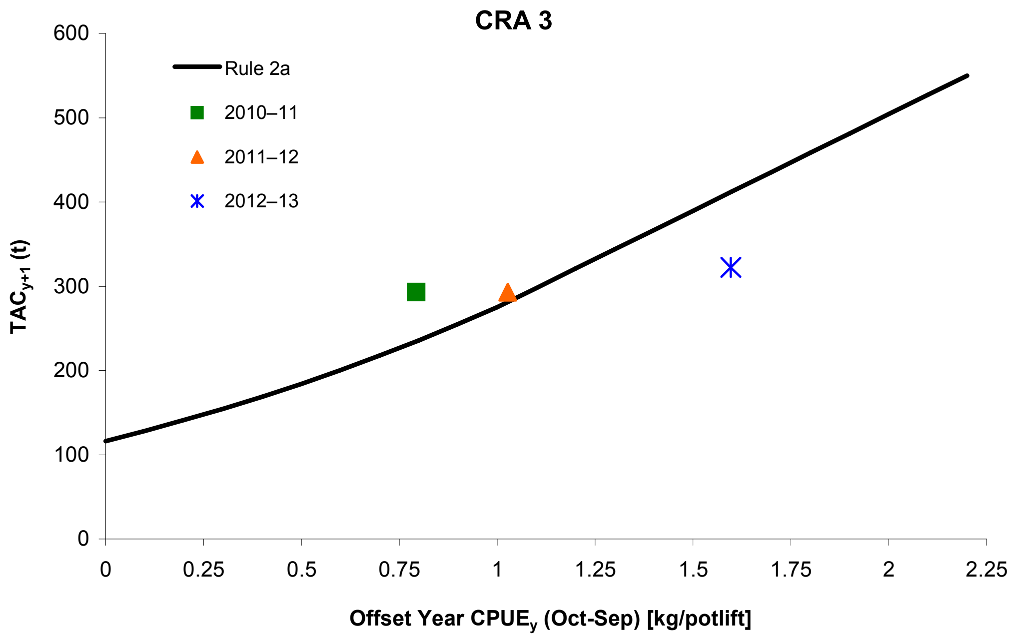


Figure 6: The CRA 3 management procedure, showing the provisional TAC as a function of offset year CPUE, and showing the TAC outcomes resulting from the rule evaluations performed for the 2010–11, 2011–12 and 2012–13 fishing years.

6. After the initial fixed TAC expires, if the procedure results in a TAC that does not change by more than 5%, no change will be made; and if the procedure results in a TAC that changes by more than 10%, the TAC will be changed by 10% only.

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

The Minister of Fisheries accepted this rule in March 2010. The standardised offset-year CPUE for 2008–09 was 0.794 kg/pot. Because this was greater than the 0.75 kg/potlift threshold and less than the 1.08 kg/potlift threshold, the 2010–11 TAC remained at the conditional initial fixed TAC of 293 t. The TACC was determined by subtracting non-commercial allowances of 129 t, to obtain 164 t (Table 14).

In November 2011, the standardised offset-year CPUE was 1.597 kg/potlift. Because this is above the upper threshold of 1.08 kg/potlift, the TAC is determined by the harvest control rule equation Eq. 1B, which evaluates to a TAC of 411.744 t. This is a greater increase than the maximum increase of 10%, so the TAC would increase by 10% to 322.3 t.

Table 14: History of the CRA 3 management procedure. "Rule result" is the result of the management procedure after operation of all its components including thresholds; '–': to be determined by the Minister.

Year	Applied to fishing year	Offset-year CPUE (kg/potlift)	Rule result: TAC (t)	TACC (t)	TAC (t)
2009	2010–11	0.794	293	164	293
2010	2011–12	1.027	293	164	293
2011	2012–13 (proposed)	1.597	322.3	–	–

4.4 Management Procedure for CRA 4

The 2005 stock assessment for CRA 4 (Breen *et al.* 2006) was used as the basis for an operating model that evaluated a large number of harvest control rules for this QMA (Breen & Kim 2006). This was done because the commercial fishery in this QMA was not catching the TACC and there was a need for a mechanism by means of which ACE (Annual Catch Entitlements) could be voluntarily removed from the fishery. This process of removal, known as "shelving", was used by the CRA 4 industry to set voluntary commercial catch limits for the 2007–08 and 2008–09 fishing years. This rule (rule E170) was adopted in March 2009 by the Minister of Fisheries. The rule (Figure 7) is specified as follows:

Eq. 2 $$TACC'_{y+1} = 500\left(\frac{I_y}{0.9}\right)^{1.4}$$

where $TACC'_{y+1}$ is the provisional TACC result from the rule and I_y is CPUE from the most recent AW season. There is no latent year; the maximum allowable annual change in TACC is 75% and the minimum change is 5%.

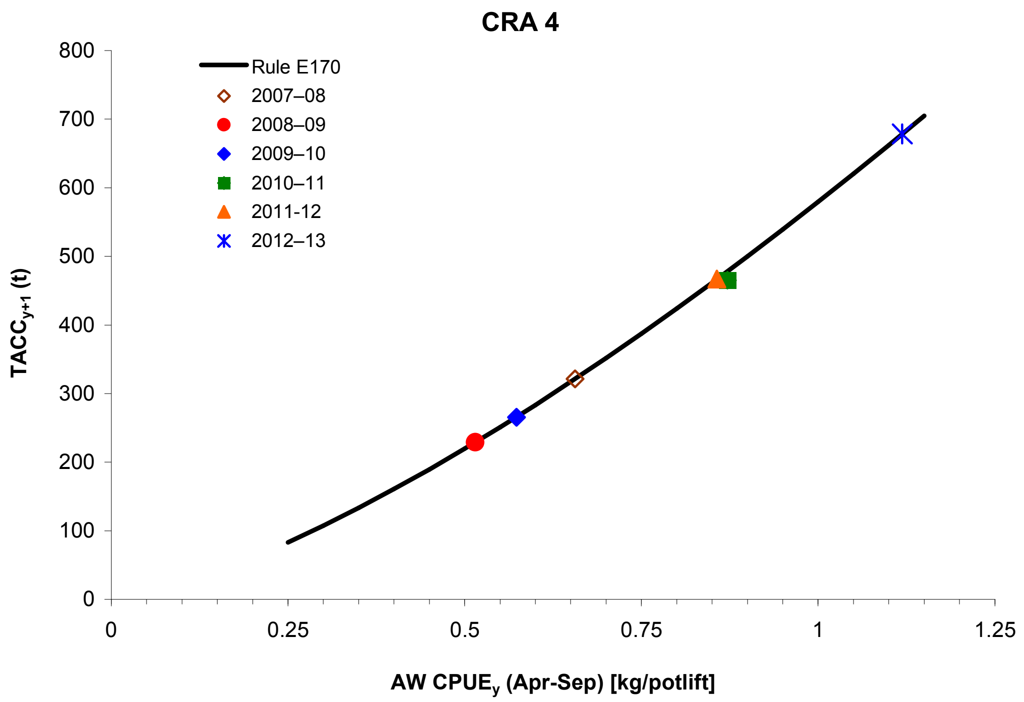


Figure 7: Graphic representation of the CRA 4 management procedure, plotting the catch limits in the next year as a function of CPUE in the current year and showing the CPUE values that generated the catch limit proposals for 2007–08, 2008–09, 2009–10, 2010–11, 2011–12, 2012–13.

The history of the CRA 4 management procedure is shown in Table 15. For 2009–10, the Minister set the CRA 4 TACC to 266 t under the rule, resulting in a TAC of 461 t after adding allowances of 195 t for non-commercial fisheries. For 2010–11, the increased CPUE of 0.871 produced a provisional TACC result of 477.6 t, which was limited by the maximum change threshold of 75% to 465.5 t. The CRA 4 industry chose to "shelve" some of this increase, and the Minister set a TACC of 415.6 after the statutory consultation. The TAC was determined by adding non-commercial allowances of 195 t. For 2011–12, the rule generated a proposed TACC of 466.9 t, which translated to a TAC of 661.9 t when the non-commercial allowances of 195 t were added (Table 15).

The most recent AW standardised CPUE estimate for CRA 4 is 1.119 kg/pot for the period 1 April to 30 September 2011.

The existing CRA 4 management procedure is scheduled to be replaced for the 2112–13 fishing year by a new MP based on offset year standardised CPUE. A new stock assessment (see Section 5.2) was used to set the operating model and exact form of the MP is currently under consultation. The details of the new CRA 4 MP will be reported next year.

Table 15: History of the CRA 4 management procedure, showing proposed limits to the commercial fishery in each of six years. The "operational limit" shows the level of voluntary shelving achieved for the 2007–08, 2008–09 and 2009–10 fishing years. "Rule result" is the result of the management procedure after operation of all its components including thresholds; '–': to be determined by the Minister.

Year	Applied to fishing year	AW CPUE (kg/potlift)	Rule result: TACC (t)	Operational limit (t)	TACC (t)	TAC (t)
2006	2007–08	0.656	321.1	339	577	771
2007	2008–09	0.515	228.9	240	577	771
2008	2009–10	0.573	265.9	266	266	461
2009	2010–11	0.871	465.5	–	415.6	610.6
2010	2011–12	0.857	466.9	–	466.9	661.9
2011[1]	2012–13 (awaiting new rule)					

4.5 Management Procedure for CRA 5

In 2010, a new management procedure was developed for CRA 5, using a new 2010 stock assessment as the basis for an operating model (Section 5.3) (Haist *et al.* 2011). The proposed 2010 MP was not accepted by the Minister. A new MP for CRA 5 based on the 2010 operating model is currently under consultation and its details will be reported next year.

4.6 Management Procedure for CRA 7

CRA 7 was managed from 1996 – 2007 using management procedures based on the observed CPUE in CRA 8, and from 2008 onwards using CPUE in CRA 7. There have been revisions to the MP operating in CRA 7 over the years. In 2007, separate management procedures were accepted by the Minister of Fisheries for CRA 7 and CRA 8 for the 2008–09 fishing year. From 2008-09 to 2011-12, CRA 7 was managed using a simple linear decision rule with no latent year, a minimum change threshold of 5% and a maximum change threshold of 50%. The history of this rule is shown in Table 16. For 2010–11, the TAC change was limited by the 50% maximum change threshold.

Table 16: History of the current CRA 7 management procedure, showing proposed limits to the commercial fishery in each of five years. "Rule result" is the result of the management procedure after operation of all its components including thresholds; '–': to be determined by the Minister.

Year	Applied to fishing year	Offset-year CPUE (kg/potlift)	Rule result: TAC (t)	TACC (t)	TAC (t)
2007	2008–09	1.439	143.9	123.9	143.9
2008	2009–10	2.09	209.0	189.0	209.0
2009	2010–11	0.803	104.5	84.5	104.5
2010	2011–12	0.957	95.7	75.7	95.7
2011	2012-13 (new proposed rule)	0.699	83.9	–	–-

In 2010, the CRA 7 industry requested exploration of a revised management procedure to reduce the volatility of TACC changes. Such a rule was developed but was not implemented in 2010. This new rule has a plateau of 120 t TAC between CPUE values of 1.0 and 2.0 kg/potlift, and increases linearly at the same slope above and below these values (Figure 3). The proposed rule has an asymmetric latent year: this means that the TAC can decrease in any year, but cannot increase if an increase or decrease was made to the TAC in the previous year. The minimum and maximum change thresholds are 10% and 50% respectively.

The Minister of Fisheries agreed that this revised MP should be used to recommend the 2012–13 CRA 7 TAC. The most recent offset-year standardised CPUE was 0.699 kg/potlift which, under this revised CRA 7 MP rule, would recommend a TAC of 83.9 t (Table 3, Figure 3).

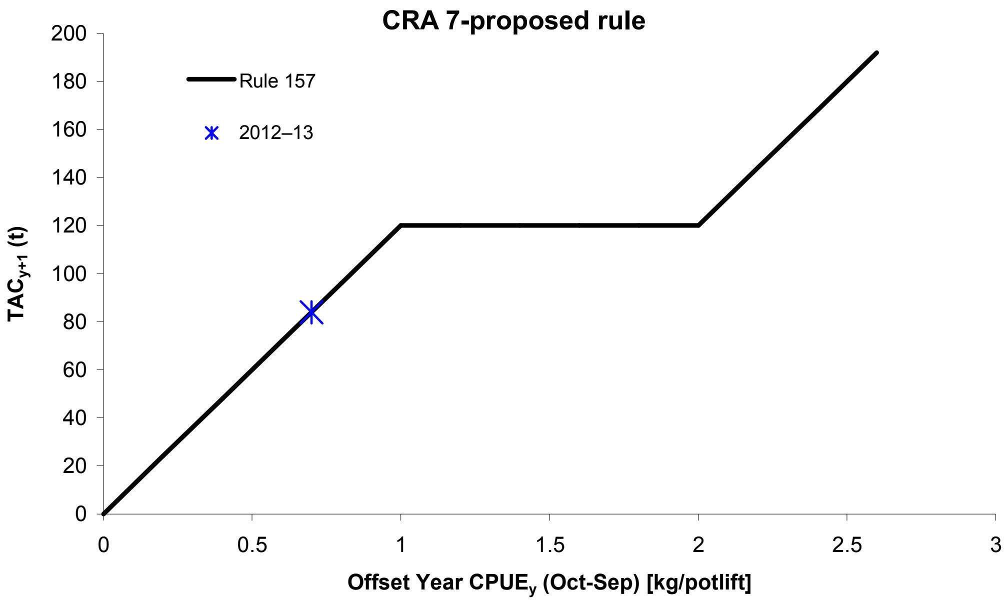


Figure 8: The revised CRA 7 harvest control rule, showing the result of its operation for 2012-13.

4.6 Management Procedure for CRA 8

CRA 8 has been managed since 1996 using management procedures based on the observed CPUE in the fishery. These have been revised several times, most recently in 2007, when separate management procedures were accepted by the Minister of Fisheries for CRA 7 and CRA 8 for the 2008–09 fishing year. The current management procedure uses the most recent offset-year standardised CPUE as input to generate a proposed TAC. There is no latent year; the minimum change threshold is 5% and the maximum change threshold is 50%.

The harvest control rule driving the CRA 8 management procedure is shown in Figure 9. TAC 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 (3.2 kg/potlift). The plateau affords stability of TACC, a performance quality requested by the CRA 8 commercial industry.

Formally, this rule is given by:

Eq. 3
$$TAC'_{y+1} = \begin{cases} \max\left(0, \left(1053 - 1.2\left(1.9 - I_y\right)\frac{1053}{1.9}\right)\right), & I_y < 1.9, \\ 1053, & 1.9 \le I_y \le 3.2, \\ 1053 + 0.16\left(I_y - 3.2\right)\frac{1053}{1.9}, & I_y > 3.2. \end{cases}$$

where TAC'_{y+1} is the rule's specified TAC for the next fishing year, before the operation of minimum and maximum change thresholds, and I_y is standardised CPUE from the most recent offset year.

The history of the current CRA 8 management procedure is shown in Table 17. The most recent offset-year standardised CPUE estimate was 2.947 kg/pot. This puts TAC on the plateau because it is less than 3.2 kg/potlift threshold at the upper end of the plateau. Under the CRA 8 management procedure, the TAC would remain at 1053 t.

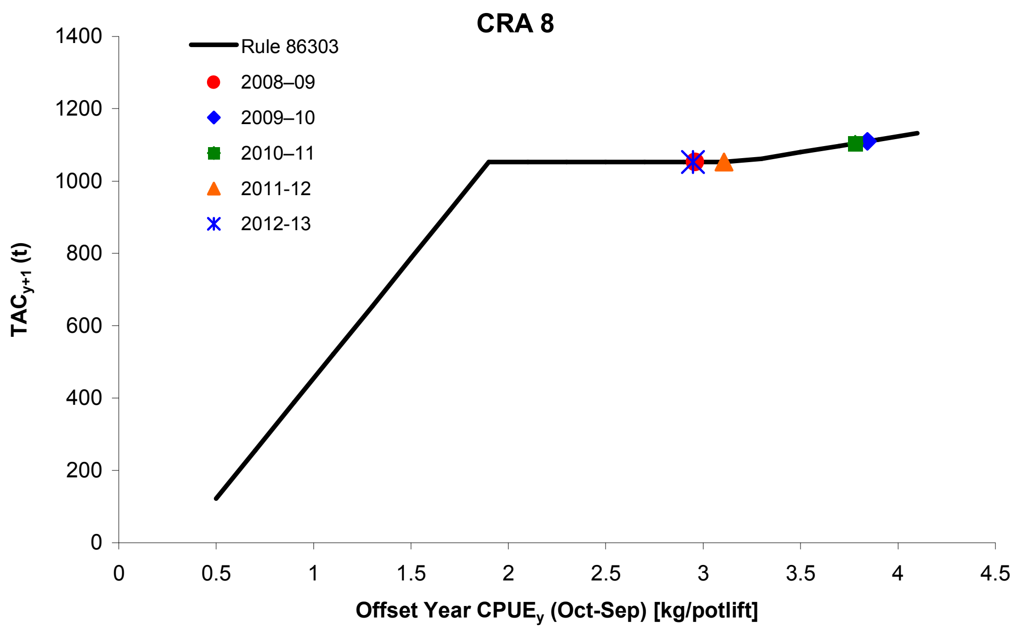


Figure 9: Graphic representation of the CRA 8 management procedure, plotting the TAC in the next year as a function of offset-year CPUE in the current year and showing the CPUE values which generated the TAC proposals for 2008–09, 2009–10, 2010–11, 2011-12 and 2012–13.

Table 17: History of the CRA 8 management procedure, showing proposed limits to the commercial fishery in each of five years. "Rule result" is the result of the management procedure after operation of all its components including thresholds; '–': to be determined by the Minister.

Year	Applied to fishing year	Offset-year CPUE (kg/potlift)	Rule result: TAC (t)	TACC (t)	TAC (t)
2007	2008–09	2.960	1053	966	1053
2008	2009–10	3.844	1110	1019	1110
2009	2010–11	3.781	1110	1019	1110
2010	2011–12	3.107	1053	1053	962
2011	2012–13 (proposed)	2.947	1053	–	–

5. STOCK ASSESSMENT

A new stock assessment was completed in 2011 for CRA 4. This section also reports 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 original and reflects the TAC, TACC and allowances that were current at the time each assessment was completed.

5.1 CRA 1 and CRA 2

This section reports assessments for *J. edwardsii* for CRA 1 and CRA 2 from the NSN substock taken from the 2002 Mid-year Plenary report (Sullivan & O'Brien 2002).

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

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

Significant catches occurred in the early part of the time series for CRA 1 and CRA 2. Different regulations existed at this time and pots were not required to have escape gaps. We therefore incorporated historical information for CRA 1 and CRA 2: a time series of sex-specific MLS regulations, time series of catch per day estimates for the 1960s and early 1970s, and some early size frequency data, including market sampling data. These data and their sources are listed in Table 18. It was possible to estimate recruitment deviations beginning in 1960.

Major changes made to the 2002 model were:
- The CV of the expected growth increment was changed to a sex-specific parameter.
- The catch dynamics were changed to operate in two parts during each 6-month period so that proportions-at-length could be calculated from the mid-season length structure. The dynamics of the SL and NSL fisheries (fisheries respecting or not respecting the size limit) were both improved by doing this.

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

a) **Recruitment**. Each year, new recruits are added equally for each sex and both seasons, into the smallest size classes, beginning with the autumn-winter season. The proportion of individuals entering each size class is modelled as a normal distribution with a mean size (32 mm) and standard deviation (2 mm), and is truncated at the smallest size class (30 mm). The magnitude of recruitment in a specific year is determined by the parameter for base recruitment and (except for the early years) a parameter representing the deviation from base recruitment. The vector of recruitment deviations is assumed to be normally distributed with a mean of zero. The years for which recruitment deviations were estimated were 1960 to 2001.
b) **Mortality**. Natural, fishing and handling mortalities are applied to each sex category (male, immature female and mature female) in each size class. Natural mortality is estimated, but assumed to be constant and independent of sex category and length. Fishing mortality is determined from observed catch and model biomass, modified by legal sizes, sex-specific vulnerabilities and selectivity curves. Fisheries that respect size limits (SL fisheries − legal commercial and recreational) are differentiated from those which do not (NSL fisheries − part of the illegal fishery plus the Mäori traditional fishery). It is assumed that size limits and the

prohibition of taking of berried females apply only to the SL fisheries. Otherwise, the selectivity and vulnerability functions are the same for the SL and NSL fisheries. Relative vulnerability is calculated by assuming that the males in the spring-summer season have the highest vulnerability and that the vulnerability of all other sex categories by season are equal to or less than the spring-summer males. Mature females have no legal vulnerability in the autumn-winter, when all are assumed to be ovigerous. The annual rate of SL fishing mortality is calculated as the ratio of catch to the SL biomass, where catch includes both the legal catch and the portion of NSL catch taken from the SL biomass. SL biomass is defined as the weight of males and females in the size classes above the MLS limits, adjusted for their relative vulnerability as defined above. Handling mortality rate is assumed to be proportional to legal fishing mortality at 10% of all lobsters that are released.

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

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

Model fitting

A total negative log likelihood function was minimised using AD Model Builder™. The model was fitted to standardised CPUE indices estimated by season from the 1979–80 to 2001–02 fishing years. The model was also fitted to an additional seasonal catch rate index based on daily catch and effort data for the period 1963 to 1973 (Annala & King 1983). A lognormal error structure was assumed and a catchability constant (q) was calculated analytically for each CPUE series.

The model was fitted to size data taken from commercial pots. These data were available either from research sampling conducted on commercial vessels or from voluntary logbooks maintained by rock lobster fishers in CRA 1 and CRA 2. Estimates of the seasonal size frequency were obtained by collating data that had been summarised by area/month strata and weighted by the commercial catch taken in each stratum, the number of lobsters measured and the number of days sampled. Size data from each source (research sampling or voluntary logbooks) were fitted separately. A fundamental assumption is that the size frequency data are representative of the commercial lobster catch. The size proportions within each season summed to one across all three sex categories: males, immature females, and mature females. This provides the model with seasonal estimates of the relative proportion by sex category in the catch.

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

A summary of the data used in each assessment, the data sources and the applicable years are provided in Table 18.

The parameters estimated in each model and the priors used are provided in Table 19. Fixed parameters and their values are given in Table 20. CPUE, the historical catch rate, the priors and the tagging data were weighted directly by a relative weighting factor. For CRA 1, we varied the weights to obtain standard deviations of standardised residuals for each data set that were close to one. For CRA 2 it was necessary to further increase the weight on CPUE data to obtain a credible fit.

Table 18: Data types and sources for the 2002 assessment s for CRA 1 and CRA 2. Year codes apply to the first 9 months of each fishing year, viz. 1998–99 is called 1998. NA – not applicable or not used; MFish - NZ Ministry of Fisheries; NZRLIC – Rock Lobster Industry Council.

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

Table 19: Parameters estimated and priors used in basecase assessments for CRA 1 and CRA 2. Prior type abbreviations: U – uniform; N – normal; L – lognormal.

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

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

Table 20: Fixed parameter values used in base case assessment for CRA 1 and CRA 2.

	CRA 1	CRA 2
Std dev of observation error of increment	2	2
Historical catch per day CV	0.30	0.30
Maximum exploitation rate	90%	90%
Current male size limit	54	54
Current female size limit	60	60
First year for recruitment deviations	1960	1960
Last year for recruitment deviations	2001	2001
Relative weight for length frequencies	50	18
Relative weight for CPUE	1	2
Relative weight for CR	0.6	1
Relative weight for tag-recapture data	0.5	1

Model projections

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

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

b) Samples from the joint posterior distribution of parameters were generated using the Markov chain – Monte Carlo procedure (MCMC) using the Hastings-Metropolis algorithm;
c) For each sample of the posterior, 5-year projections (encompassing the 2002–03 to 2006–07 fishing years) were generated by assuming the catches indicated in Table 21. Future annual recruitment was randomly sampled with replacement from the model's estimated recruitments from the period 1989−1998;
d) A marginal posterior distribution was found for each quantity of interest by integrating the product of the likelihood and the priors over all model parameters; the posterior distribution was described by the mean, median, and 5th and 95th percentiles.

Table 21: Catches (t) used in the five-year projections. Projected catches are based on the current TACC for CRA 1 and CRA 2, and the current estimates of recreational, customary and illegal catches.

Population modelled	Commercial	Recreational	Reported Illegal	Unreported Illegal	Customary
CRA 1	129.2	47.2	0	72	10
CRA 2	225.0	122.6	5	83	10

Performance indicators

The 2001 Plenary agreed to use a number of performance indicators as measures of the stock status for CRA 1 and CRA 2. These performance indicators were calculated using the current catch levels. The RLFAWG did not consider that virgin biomass or B_{MSY} were appropriate reference points, given the difficulty of accurately estimating these quantities. Therefore the assessment used performance indicators based on biomass levels for the ten years 1979 to 1988. This is the earliest period for which we have CPUE data and base case fits for both CRA 1 and CRA 2 suggested that biomass was relatively stable during this period. The Plenary agreed that this was an appropriate reference biomass level. Biomass in both stocks increased in the mid 1990s to higher levels than this reference level.

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

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

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

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

Stock assessment results: *Jasus edwardsii*, CRA 1

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

Base case results suggested that biomass decreased to a low point in 1973, increased through the early 1980s, declined again until the early 1990s (but not as low as in 1973), increased strongly in the late 1990s and then declined slightly (Figure 10). Exploitation rate peaked in the early 1970s near 30% for the spring-summer fishery, and are currently in the 7−12% range (Table 22).

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

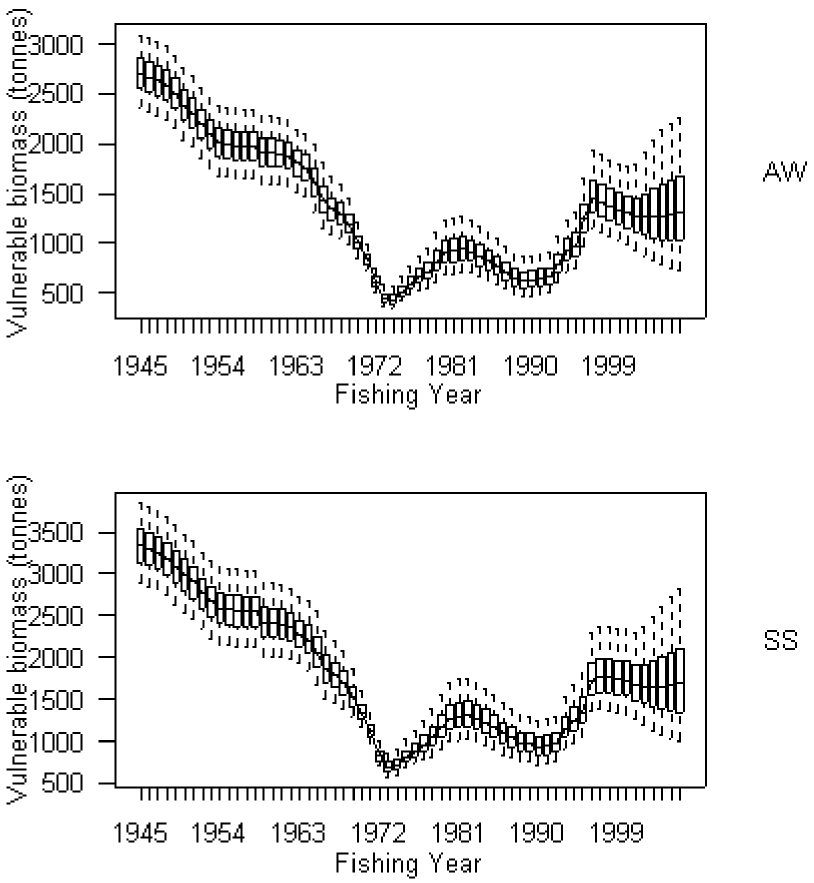


Figure 10: CRA 1: posterior trajectories of vulnerable biomass, for the AW (top) and SS (bottom) seasons, from the CRA 1 base case MCMC simulations. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.

Table 22: Summary statistics for performance indicators from posterior distributions from CRA 1. Biomass indicators are shown in t.

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

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

Stock assessment results: *Jasus edwardsii*, CRA 2

The base case assessment for CRA 2 was obtained by first making the standard deviations of standardised residuals from all data sets close to 1 by adjusting the relative weights for each data set. However, it was necessary to further increase the weight on CPUE data until a satisfactory fit to all data sets was achieved. As in the CRA 3 assessment last year the model appears to have trouble fitting the steep decline in CPUE after 1998: it expects more large lobsters to remain in the population and consequently expects CPUE to remain higher than was observed.

Base case results suggested that biomass decreased to a low point in 1977, increased to 1980, declined slowly through 1988, increased strongly to a peak in 1998 and then declined again (Figure 11). Seasonal exploitation rate peaked in the mid-1980s near 50% for the spring-summer fishery, and is currently in the 20–25% range.

A series of sensitivity trials suggested that the results were generally robust to these trials (based on MPD estimates). A set of retrospective analyses on the MPD fits showed a strong effect to removing data from 1999, the year when CPUE began to decrease strongly. Fits to the spring-summer CPUE did not change much, indicating the problem is probably caused by the 1999 autumn-winter CPUE data point. This retrospective model estimates a much higher M and higher biomass than in the base case and suggests that the model has difficulty in predicting the extent of the decline between 1999 and 2001 based solely on the data available up to 1999.

The assessment results (Table 23) are based on the posterior distributions of indicators. These were obtained from MCMC simulations − for CRA 2, five chains of 600 000 simulations each were started from the likelihood profile on Ln($R0$). Diagnostics were acceptable, and the results are based on 4950 samples remaining after the first 10 samples were discarded from each chain. Results suggest that vulnerable biomass is currently about 50% higher (0.05 and 0.95 quantiles were 30% to 70%) than in the reference period. At the current levels of catch and using recruitments sampled from 1989–98, the median expectation is that biomass will remain at current levels over five years, but with considerable uncertainty (0.05 and 0.95 quantiles were 35% to 170% of current biomass).

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

Table 23: Summary statistics for performance indicators from posterior distributions from CRA 2. Biomass indicators are shown in t.

	Basecase				Estimate male SS vulnerability				Alternative recreational catch trajectory			
Indicator	0.05	median	mean	0.95	0.05	median	mean	0.95	0.05	median	mean	0.95
$BALL_{79-88}$	1 592	1 656	1 657	1 723	1 443	1 499	1 499	1 561	1 625	1 699	1 699	1 773
$BRECT_{79-88}$	525	555	556	589	479	504	505	532	565	603	603	640
$BVULN_{79-88}$	391	412	413	435	362	380	381	400	414	440	440	465
$BALL_{02}$	1 807	2 170	2 176	2 571	1 578	1 997	1 997	2 428	1 886	2 292	2 296	2 723
$BRECT_{02}$	1 025	1 150	1 150	1 275	889	1 027	1 028	1 169	1 064	1 198	1 197	1 330
$BVULN_{02}$	527	619	621	716	485	588	589	696	547	647	648	750
$BALL_{07}$	1 284	2 122	2 135	3 037	1 144	2 004	2 017	2 911	1 264	2 190	2 202	3 191
$BRECT_{07}$	372	1 033	1 047	1 757	291	1 001	1 006	1 733	264	1 028	1 040	1 822
$BVULN_{07}$	199	614	631	1 117	173	612	621	1 101	153	604	621	1 142
$UNSL_{02}$ (%)	3.7	4.2	4.2	4.9	3.7	4.4	4.5	5.3	3.5	4.0	4.0	4.7
USL_{02} (%)	21.6	25.0	25.1	29.2	22.2	26.2	26.5	31.8	21.4	24.9	25.0	29.3
$UNSL_{06}$ (%)	2.8	4.4	4.8	8.4	2.8	4.4	5.1	9.9	2.7	4.3	4.9	9.3
USL_{06} (%)	15.2	25.7	30.0	59.3	15.4	26.2	31.8	73.1	15.2	26.2	31.8	72.1
$BVULN_{02}/BVULN_{79-88}$ (%)	130	150	150	171	129	154	155	181	127	146	147	169
$BVULN_{07}/BVULN_{02}$ (%)	34	99	101	170	33	104	104	176	26	93	94	167
$BVULN_{07}/BVULN_{79-88}$ (%)	48	149	153	271	46	161	163	290	35	137	141	258

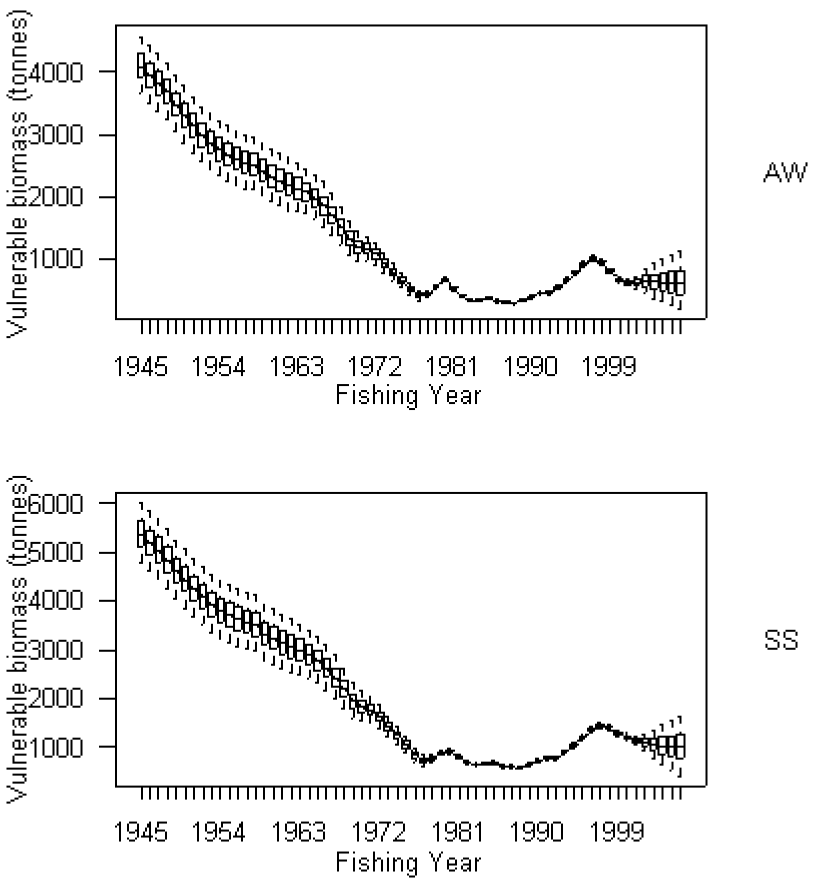


Figure 11: CRA 2: posterior trajectories of vulnerable biomass, for the AW (top) and SS (bottom) seasons, from the CRA 2 base case MCMC simulations. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.

5.2 CRA 3

This section reports assessments for *J. edwardsii* for CRA 3 from the NSC substock taken from the 2008 Mid-year Plenary report (Ministry of Fisheries 2008). This assessment used a single-stock version of the multi-stock length-based model (MSLM) (Haist *et al.* 2009). In a simple preliminary trial, the new model was able to reasonably match the MPD results from the 2004 CRA 3 assessment when fitted to the same data.

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

- tag-recapture data from 1975–1981 and from 1995–2006,
- standardised CPUE from 1979–2007,
- historical catch rate data from 1963–1973; and
- length frequency data from commercial catches (log book and catch sampling data) from 1989 to 2007.

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

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

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

The start date for the accepted model was 1945, with an annual time step through 1973 and then switching to a seasonal time step from 1974 onward: autumn/winter (AW), extending from April to September, and spring/summer (SS), extending from October to March. The last fishing year in the minimisations was 2007, and projections were made through 2012 (five years). Two selectivity epochs were modelled, with the change made in 1993 to capture regulation shifts for the pot escape gaps. Recruitment deviations were estimated from 1945 through 2004. Maximum vulnerability was assumed to be for males in the SS season. A marine reserve was modelled, beginning in 1999 and alienating 10% of the habitat. The model was fit to CPUE, the historical catch rate series, length frequency (LF) data and the two tag-recapture datasets. No pre-recruit index was fit, and the puerulus settlement index was fit in a separate randomisation trial.

A log-normal prior was specified for *M*, with mean 0.12 and c.v. of 0.4. A normal prior was specified for the recruitment deviations in log space, with mean 0 and standard deviation 0.4. Priors for all other parameters were specified as uniform distributions with wide bounds.

Other model options used in the reference case were:

- the dynamics option was set to instantaneous;
- selectivity was set to the double normal form used in previous assessments;
- movements were turned off;

- the relation between CPUE and biomass was fixed to linear;
- maturity parameters were fixed at values estimated outside the model;
- the growth c.v. was fixed to 0.5 to stabilise the analysis;
- the right-hand limb of the selectivity curve was fixed to 200 as in previous assessments;
- dataset weights were adjusted to attempt to obtain standard deviations of normalised residuals of 1.0 or medians of absolute residuals of 0.67.

The RLFAWG considered results from the mode of the joint posterior distribution (MPD) results and the results of 13 sets of MPD sensitivity trials:

- altering the specification of the growth transition period,
- varying the transition period between tag data sets,
- using finite dynamics instead of instantaneous,
- varying start year and initial exploitation rate,
- estimating the relation between CPUE and biomass,
- estimating the CV of predicted growth increments,
- estimating maturity parameters,
- fixing the size at maximum selectivity for females to 60,
- fixing M to 0.12 (the mean of the prior),
- removing data sets one at a time
- estimating the right-hand limb of selectivity for both sexes and epochs,
- ignoring the marine reserve,
- fitting to puerulus settlement data and
- adding uncertainty to NSL catches as requested by the WG

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

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

The RLFAWG agreed on a set of indicators. Some of these were based on beginning of season AW vulnerable biomass: the biomass legally and functionally available to the fishery, taking MLS, female maturity, selectivity-at-size and seasonal vulnerability into account. The limit indicator *Bmin* was defined as the nadir of the vulnerable biomass trajectory (using current MLS), 1945-2007. Current biomass, *B2008*, was taken as vulnerable biomass in AW 2008, and projected biomass, *B2012*, was taken from AW 2012.

A biomass indicator associated with *MSY* or maximum yield, *Bmsy*, was calculated by doing deterministic forward projections for 50 years, using the mean of estimated recruitments from 1979-2004. This period was chosen to represent the recruitments that were estimated from adequate data, and represents the best available information about likely long-term average recruitment. These *MSY* and *Bmsy* calculations are sensitive to the period chosen to represent the mean recruitment, which varies substantially over the range of the period available, causing variation in estimated *Bmsy*. It was agreed to hold the non size-limited (NSL) catches (customary and illegal) constant at their assumed 2007 values, to vary the SL fishery mortality rate *F* to maximise the annual size-limited (SL) catch, and to record the associated AW biomass.

MSY was the maximum yield (the sum of AW and SS “size-limited” [SL] catches) found by searching across a range of multipliers (from 0.1 to 2.5) on the AW and SS *F* values that were estimated for 2007 for the SL catch for each of the 3000 samples from the joint posterior distribution. The model used a Newton-Raphson algorithm to find the NSL fishery mortality rates. The AW vulnerable biomass associated with the *MSY* was taken to be *Bmsy*. If the *MSY* were still increasing with the highest *F* multiplier, the *MSY* and *Bmsy* obtained with that multiplier were used. The multiplier, *Fmult*, was also reported as an indicator. The *MSY* and *Bmsy* calculations were based on the growth parameters estimated from the second (1996–2006) tag dataset.

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

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

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

The posterior trajectory of vulnerable biomass by season from 1976 (Figure 12) shows a nadir near 1989, a strong increase in the 1990s followed by a sharp decrease, and variable projections with an decreasing median. The trajectory of biomass from 1945 to 1960 is difficult to explain as there were only low catches throughout this period; the model output shows low recruitments estimated for these years.

The assessment results are summarised in Table 24. *Bmsy* and *MSY* from the base case were calculated with growth estimates based on the later and slower growth dataset. Current biomass (2008) was above *Bmin* in 83% of runs, and the median result was 11% above *Bmin*. Current biomass was above *Bmsy* in less than 1% of runs, and the median result was half *Bmsy*. Current exploitation rate was about 55%.

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

Projected CPUE had a median of 0.5 kg/potlift, and only 20% of runs exceeded 0.75 kg/potlift. The mean *F* multiplier associated with *MSY* was about 75% of current *F*. These results suggest a stock that is near *Bmin* and well below *Bmsy*. Under current catches and recent recruitments the model predicted a 75% probability of biomass decrease over four years.

Projections were made with alternative levels of SL catch (commercial plus recreational) with the NSL catch (illegal and customary) held constant (Table 25). These were 5-year projections made in the same way as the base case projections described above, and were made at the request of the Plenary for the guidance of the NRLMG, stakeholders and MFish.

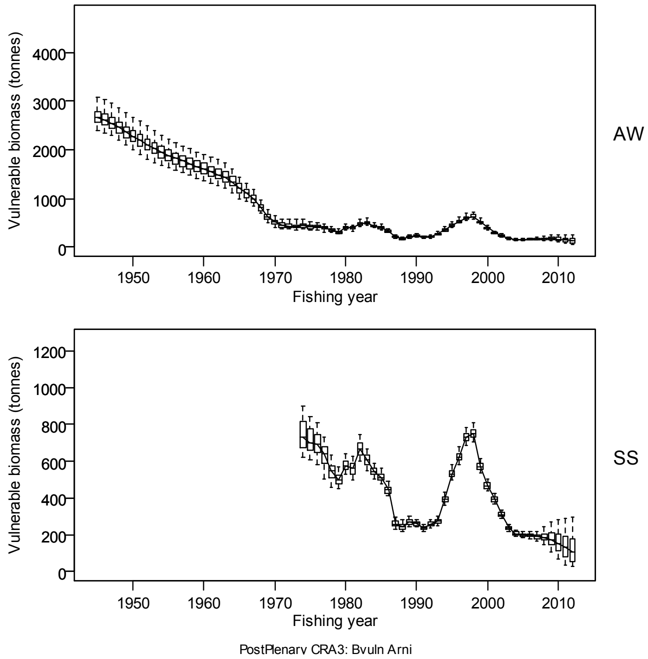


Figure 12: The posterior trajectory of vulnerable biomass, by season, from the CRA 3 base case McMC simulations, including the projections from 2008-12. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.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

Table 24: Quantities of interest to the CRA3 assessment from the model base case McMCs. USL is the exploitation rate that produces the size-limited catch. All biomass values are in tonnes and represent the beginning of season AW vulnerable biomass.

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

Table 25: Results of 5-year projections with alternative SL catch levels for CRA3.

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

5.3 CRA 4

This section reports an assessment for *J. edwardsii* for CRA 4 done 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 26.

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 26: 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.

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

Parameters estimated in each model and their priors are provided in Table 27. Fixed parameters and their values are given in Table 28. CPUE, the historical catch rate, proportions-at-length and tagging data were given relative weights directly by a relative weighting factor.

Table 27: Parameters estimated and priors used in basecase assessments for CRA 4. Prior type abbreviations: U – uniform; N – normal; L – lognormal.

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

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

Table 28: Fixed values used in base case assessment for CRA 4.

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

Model projections

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

a) Model parameters were estimated by AD Model Builder™ using maximum likelihood and the prior probabilities. The point estimates are called MPD (mode of the joint posterior) estimates;
b) Samples from the joint posterior distribution of parameters were generated with Markov chain - Monte Carlo (McMC) simulations using the Hastings-Metropolis algorithm; two million simulations were made, starting from the base case MPD, and 1000 samples were saved. From each sample of the posterior, 4-year projections (2011–2014) were generated with an assumed current-catch scenario (Table 29);
c) Future annual recruitment was randomly sampled with replacement from the model's estimated recruitments from 2002-11 (except for the no-puerulus sensitivity trial which resampled from 1998–2007).

Table 29: 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. Agreed indicators are summarised in Table 30. Base case results (Table 31) suggested that biomass decreased to a low point in 1991, then increased to a high in 1998 (Figure 13), 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 31). Projected biomass would decrease at the level of current catches over the next 4 years (Figure 13).

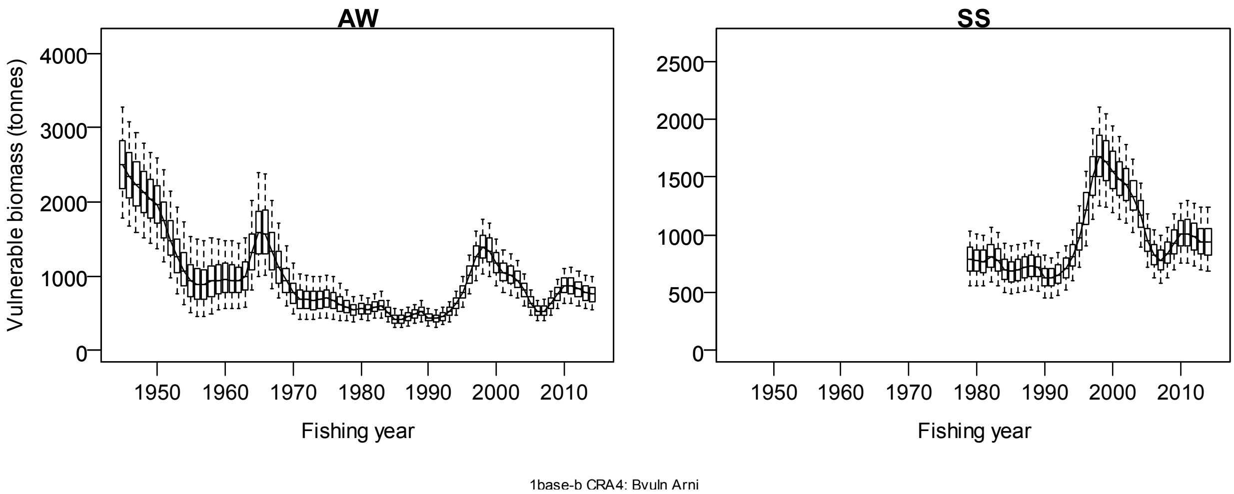


Figure 13: Posterior distributions of the CRA 4 base case McMC biomass vulnerable trajectory. Before 1979 there was a single time step, shown in AW. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th quantiles.

Table 30: Performance indicators used in the CRA 5 stock assessment

Reference points	
Bmin	The lowest beginning AW vulnerable biomass in the series
Bcurrent	Beginning of season AW vulnerable biomass for the year the stock assessment is performed
Bref	Beginning of AW season mean vulnerable biomass for 1979–88
Bproj	Projected beginning of season AW vulnerable biomass (ie, the year of stock assessment plus 4 years)
Bmsy	Beginning of season AW vulnerable biomass associated with MSY, calculated by doing deterministic forward projections with recruitment *R0* and current fishing patterns
MSY	Maximum sustainable yield (sum of AW and SS SL catches) found by searching a across a range of multipliers on F.
Fmult	The multiplier that produced *MSY*
SSBcurr	Current spawning stock biomass at start of AW season
SSBproj	Projected spawning stock biomass at start of AW season
SSBmsy	Spawning stock biomass at start of AW season associated with *MSY*
CPUE indicators	
CPUEcurrent	CPUE at *Bcurrent*
CPUEproj	CPUE at *Bproj*
CPUEmsy	CPUE at *Bmsy*
Performance indicators	
Bcurrent / Bmin	ratio of *Bcurrent* to *Bmin*
Bcurrent / Bref	ratio of *Bcurrent* to *Bref*
Bcurrent / Bmsy	ratio of *Bcurrent* to *Bmsy*
Bproj / Bcurrent	ratio of *Bproj* to *Bcurrent*
Bproj / Bref	ratio of *Bproj* to *Bref*
Bproj / Bmsy	ratio of *Bproj* to *Bmsy*
SSBcurr/SSB0	ratio of *SSBcurrent* to *SSB0*
SSBproj/SSB0	ratio of *SSBproj* to *SSB0*
SSBcurr/SSBmsy	ratio of *SSBcurrent* to *SSBmsy*
SSBproj/SSBmsy	ratio of *SSBproj* to *SSBmsy*
SSBproj/SSBcurr	ratio of *SSBproj* to *SSBcurrent*
USLcurrent	The current exploitation rate for SL catch in AW
USLproj	Projected exploitation rate for SL catch in AW
USLproj/USLcurrent	ratio of SL projected exploitation rate to current SL exploitation rate
Probabilities	
P(Bcurrent > Bmin)	probability *Bcurrent > Bmin*
P(Bcurrent > Bref)	probability *Bcurrent > Bref*
P(Bcurrent > Bmsy)	probability *Bcurrent > Bmsy*
P(Bproj > Bmin)	probability *Bproj > Bmin*
P(Bproj > Bref)	probability *Bproj > Bref*
P(Bproj > Bmsy)	probability *Bproj > Bmsy*
P(Bproj > Bcurrent)	probability *Bproj > Bcurrent*
P(SSBcurr>SSBmsy)	probability *SSBcurr>SSBmsy*
P(SSBproj>SSBmsy)	probability *SSBproj>SSBmsy*
P(USLproj>USLcurr)	probability SL exploitation rate *proj* > SL exploitation rate *current*
P(SSBcurr<0.2SSB0)	soft limit: probability *SSBcurrent* < 20% *SSB0*
P(SSBproj<0.2SSB0	soft limit: probability *SSBproj* < 20% *SSB0*
P(SSBcurr<0.1SSB0)	soft limit: probability *SSBcurrent* < 10% *SSB0*
P(SSBproj<0.1SSB0)	soft limit: probability *SSBproj* < 10% *SSB0*

A series of MCMC sensitivity trials was also made, including trials with low estimated vulnerability for immature females, exclusion of puerulus data, using a different lag (3 years) for fitting the puerulus data, fixed M, using a higher weight for the LF data and using an alternative recreational catch vector. The assessment results from the base case and sensitivity trials calculated as a series of agreed indicators (Table 30) are shown in Table 31.

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

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

Table 31: Assessment results for CRA5 – medians of indicators described in Table 30 from the base case and sensitivity trials; the lower part of the table shows the probabilities that events are true; biomass in t and CPUE in kg/potlift.

Indicator	basecase	lovuln	nopoo	poolag3	fixed*M*	hiLFwt	hiRecCat
Bmin	407	398	416	355	365	321	423
Bcurr	862	844	941	742	674	805	898
Bref	514	495	521	438	477	411	536
Bproj	751	727	770	607	571	663	831
Bmsy	377	385	374	343	547	416	408
MSY	680	655	676	662	532	610	715
Fmult	4.05	3.76	4.44	3.81	1.50	2.96	3.57
SSBcurr	2 615	809	2 496	1 826	1 513	1 999	2 654
SSBproj	2 796	829	2 457	1 690	1 576	2 147	2 864
SSBmsy	2 646	652	2 387	1 757	1 739	2 143	2 675
CPUEcurrent	0.91	0.91	1.01	0.91	0.91	0.95	0.91
CPUEproj	0.77	0.75	0.78	0.69	0.74	0.73	0.83
CPUEmsy	0.29	0.31	0.29	0.30	0.68	0.38	0.31
Bcurr/Bmin	2.12	2.11	2.27	2.08	1.87	2.52	2.11
Bcurr/Bref	1.68	1.70	1.82	1.69	1.42	1.96	1.68
Bcurr/Bmsy	2.30	2.20	2.56	2.15	1.26	1.94	2.21
Bproj/Bcurr	0.87	0.86	0.82	0.82	0.85	0.83	0.93
Bproj/Bref	1.46	1.47	1.49	1.38	1.22	1.61	1.56
Bproj/Bmsy	2.01	1.90	2.08	1.78	1.08	1.60	2.04
SSBcurr/SSB0	0.65	0.43	0.67	0.62	0.46	0.58	0.63
SSBproj/SSB0	0.69	0.44	0.65	0.57	0.48	0.62	0.68
SSBcurr/SSBmsy	0.98	1.24	1.04	1.04	0.87	0.93	0.99
SSBproj/SSBmsy	1.05	1.27	1.01	0.96	0.91	1.01	1.07
SSBproj/SSBcurr	1.07	1.03	0.96	0.92	1.04	1.08	1.08
USLcurrent	0.24	0.24	0.21	0.27	0.31	0.25	0.23
USLproj	0.30	0.31	0.30	0.38	0.40	0.34	0.25
USLproj/USLcurrent	1.28	1.29	1.38	1.39	1.29	1.36	1.07
P(*Bcurr*>*Bmin*)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P(*Bcurr*>*Bref*)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P(*Bcurr*>*Bmsy*)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P(*Bproj*>*Bmin*)	1.00	1.00	0.99	1.00	1.00	1.00	1.00
P(*Bproj*>*Bref*)	1.00	1.00	0.91	1.00	0.94	1.00	1.00
P(*Bproj*>*Bmsy*)	1.00	1.00	0.99	1.00	0.69	1.00	1.00
P(*Bproj*>*Bcurr*)	0.01	0.02	0.18	0.01	0.02	0.01	0.12
P(*SSBcurr*>*SSBmsy*)	0.39	1.00	0.64	0.71	0.01	0.13	0.45
P(*SSBproj*>*SSBmsy*)	0.73	1.00	0.52	0.35	0.10	0.53	0.79
P(*USLproj*>*USLcurr*)	1.00	1.00	0.91	1.00	1.00	1.00	0.83
P(*SSBcurr*<*0.2SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P(*SSBproj*<*0.2SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P(*SSBcurr*<*0.1SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P(*SSBproj*<*0.1SSB0*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Indicators based on SSBmsy

SSBmsy is biomass of mature females associated with *Bmsy*. The historical track of biomass versus fishing intensity is shown in Figure 14. 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 14 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.

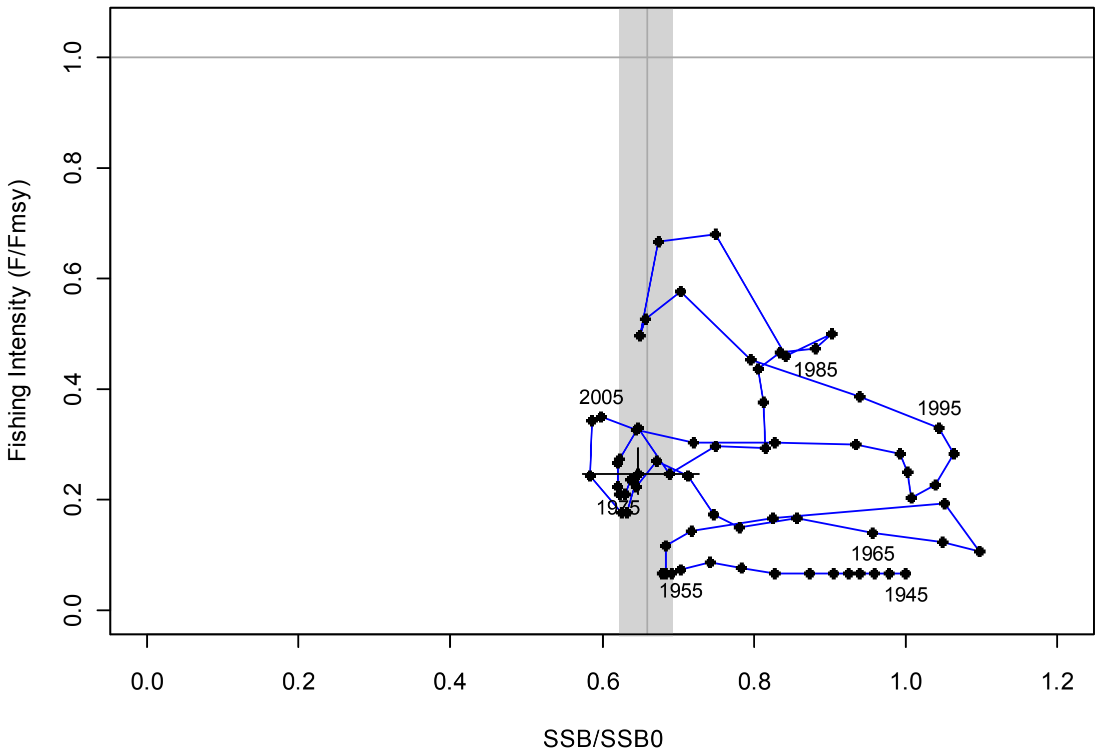


Figure 14: "Snail trail" that summarises the *SSB* history of the CRA 4 stock. The x-axis is spawning stock biomass *SSB* in year *y* as a proportion of the unfished spawning stock, *SSB0*. *SSB0* is constant for all years of a run, but varies through the 1000 runs. The y-axis is fishing intensity in 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.

5.4 CRA 5

Model structure

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

Significant catches occurred in the early part of the time series for CRA 5. Different MLS regulations existed at this time and pots were not required to have escape gaps. The model incorporated a time series of sex-specific MLS regulations. Data and their sources are listed in Table 32.

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

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

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

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

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

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

Model fitting

A total negative log likelihood function was minimised using AD Model Builder™. The model was fitted to historical catch rate, standardised CPUE and puerulus settlement data using lognormal likelihood. The model was fitted to proportions-at-length with multinomial likelihood and tag-recapture data with robust normal likelihood. For the CPUE and puerulus lognormal likelihoods, CVs for each index value were initially set at the standard error from the GLM analysis. Process error was subsequently added to these CVs so that the overall standard deviation of the standardised (Pearson) residuals was near 1.0. A fixed CV of 0.3 was used for the historical catch rate data. The robust normal likelihood was used for the tagging data so that data outliers (defined as observations with a standardised residual greater than 3.0) would be downweighted. Proportions-at-length, assumed to be representative of the commercial catch, were available from both observer catch sampling and voluntary logbooks; these were fitted separately. Data were summarised by area/month strata and weighted by the commercial catch taken in each stratum, the number of lobsters measured and the number of days sampled. Size data from each source (research sampling or voluntary logbooks) were fitted separately. Seasonal proportions-at-length summed to one across males, immature and mature females. Experiments (randomisation trials) were conducted to establish that puerulus settlement data contained a signal about recruitment.
In the base case, the model's options for fitting a non-linear relation between biomass and CPUE, having density-dependent growth, having a stock-recruit relation and having movements between stocks were all turned off. The base case was obtained by weighting CR, LFs and tags so that standard deviations of normalised residuals were close to 1; CPUE data were intentionally upweighted to force an acceptable fit and puerulus data were also upweighted. It was decided to fix the value of growth c.v. to that estimated in growth-only fits to the tagging data, and to put a prior on the growth shape parameters to avoid unrealistic curves. Recruitment deviations were estimated for the whole time series.

Parameters estimated in each model and their priors are provided in Table 33. Fixed parameters and their values are given in Table 34. 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 32: Data types and sources for the 2010 assessment for CRA 5. Year codes apply to the first 9 months of each fishing year, viz 1998-99 is called 1998. NA – not applicable or not used; MFish – NZ Ministry of Fisheries; NZRLIC – NZ Rock Lobster Industry Council.

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

Table 33: Parameters estimated and priors used in basecase assessments for CRA 5. Prior type abbreviations: U – uniform; N – normal; L – lognormal.

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

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

Table 34: Fixed values used in base case assessment for CRA 5.

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

Model projections

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

d) Model parameters were estimated by AD Model Builder™ using maximum likelihood and the prior probabilities. These point estimates are called MPD (mode of the joint posterior) estimates;
e) Samples from the joint posterior distribution of parameters were generated with Markov chain - Monte Carlo (MCMC) simulations using the Hastings-Metropolis algorithm; two million simulations were made, starting from the base case MPD, and 1000 samples were saved. From each sample of the posterior, 5-year projections (2010–2014) were generated with two agreed catch scenarios (Table 35).
f) Future annual recruitment was randomly sampled with replacement from the model's estimated recruitments from 2000–09 (except for the no puerulus sensitivity trial which resampled from 2000–06).

Vulnerable biomass in the assessment model was determined by the MLS, selectivity, relative sex and seasonal vulnerability and berried state for mature females. All mature females were assumed to be berried (and not vulnerable to the fishery) in AW and not berried (and vulnerable) in SS. Base case results suggested that biomass decreased to a low point in 1991, remained low through 1995, then increased (Figure 15). The current vulnerable stock size (AW) is about 3 times the reference biomass and the spawning stock biomass is well above B_{msy} (Table 36). However, projected biomass would decrease at the level of current catches over the next 4 years (Figure 15).

A series of MCMC sensitivity trials was also made, including exclusion of puerulus data, using a flat recreational catch vector, fixed M, fast growth found in an exploratory trial, density-dependent growth and estimated shape of the CPUE/biomass relation. The assessment results from the base case and sensitivity trials calculated as a series of agreed indicators (Table 36) are shown in Table 37 for the more aggressive of the two catch scenarios (Scenario 1, Table 35). Indicators from Scenario 2, with lower projected catches, are not reported.

Table 35: Catches (t) used in the five-year projections. Projected catches are based on the current TACC for CRA 5, and the current estimates of recreational, customary and illegal catches.

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

Table 36: Performance indicators used in the CRA 5 stock assessment.

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

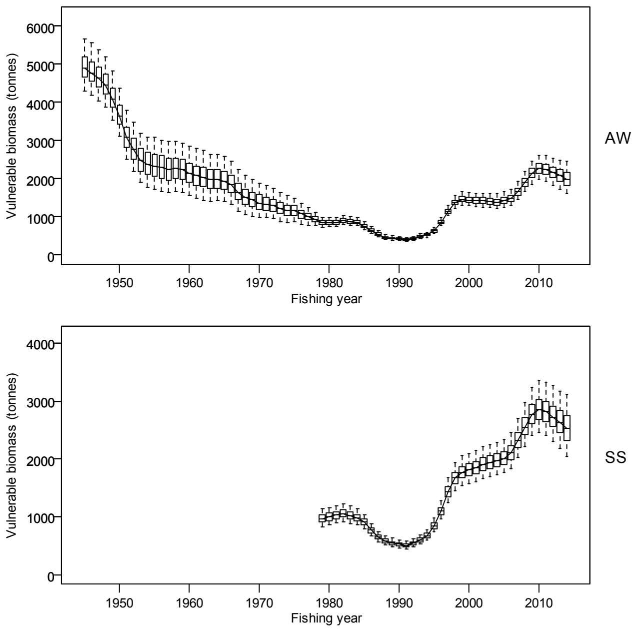


Figure 15: Posterior distributions of the base case McMC biomass vulnerable trajectory. Before 1979 there was a single time step, shown in AW. Projected catches were scenario 1 (Table 35). For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th quantiles.

Table 37: Assessment results – medians of indicators described in Table 36 from the base case and sensitivity trials under Scenario 1 catches (Table 35); the lower part of the table shows the probabilities that events are true.

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

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

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

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 16. 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 16 has been calculated using the 2009 fishing pattern.

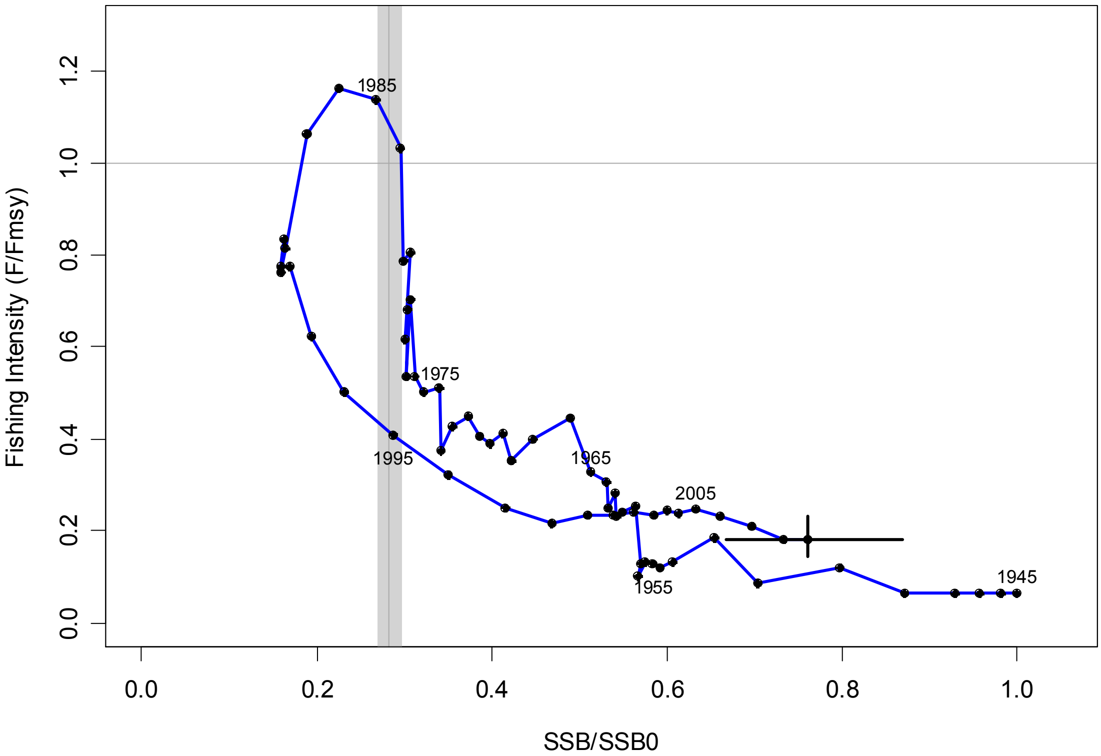


Figure 16: "Snail trail" that summarises the history of the CRA 5 fishery. The x-axis is the spawning biomass (SSB) as a proportion of B0 (SSB0); the y-axis is the ratio of the fishing intensity (F) relative to Fmsy. Each point is the median of the posterior distributions, and the bars associated with 2009 show the 90% confidence intervals. The vertical reference line shows SSBmsy as a proportion of SSB0, with the grey band indicating the 90% confidence interval. The horizontal reference line is Fmsy.

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

5.5 CRA 6

This section reports an assessment for *J. edwardsii* for CRA 6 from the CHI stock taken from the 1996 Mid-year Plenary report (Annala & Sullivan 1996).

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 new production model, which appeared to fit the observed data well. Both models assume a constant level of annual productivity which is independent of the standing stock and thus will not be affected by changes to the level of the standing stock. B_0 was estimated by both models to be about 20 000 t.

5.6 CRA 7 and CRA 8

This section reports assessments for *J. edwardsii* for CRA 7 and CRA 8 from the NSS substock taken from the 2006 Mid-year Plenary report (Ministry of Fisheries 2006).

New catch histories for each stock were developed within the Working Group and also various other assumptions agreed for recreational and customary catches. Input data to the model included tag recoveries for growth rates, standardised CPUE from 1979-2006, historical catch rate data from 1963-73 and length frequency data from commercial catches (log book and catch sampling data). The start date for the model was set at 1976 to improve the behaviour of the model (to overcome problems with the Hessian matrices).

The Working Group discussed the results from a proposed basecase and 5 sensitivity trials. The results were generally similar indicating that the model had explored the same general solution in all six runs. However, there were some differences in the indicators between the runs. Overall there appeared to be poor MCMC behaviour for all model runs.

A primary diagnostic is the appearance of the traces, simply the parameter value plotted against sample number. These should be well mixed and should not show a trend through the simulation. In the proposed basecase MCMC simulation, the *M* parameter shows a jump after about 900 samples from values between 0.02 and 0.03 up to values between 0.04 and 0.07. This problem is also seen in the running median, running percentile and moving mean plots. These should ideally show good stability through the simulation, but diagnostics for the estimated parameters in this run were not good.

Traces for the *M* parameter did not appear to cover the full range of values that are plausible. For example the MCMC only explored values in the range 0.02 to 0.07 while higher values are plausible. These diagnostics suggest that the MCMC is not properly converged, and that the behaviour of *M* is a prime suspect. Most other posteriors appear to be well-formed.

The proposed base case was not considered acceptable by the Working Group to report as the final assessment for these stocks. However, the Working Group considered that both stock are very likely to be above target levels. Both stocks show increasing CPUE to levels not seen since the 1980s. CPUE in CRA8 in 2006 (Figure 17) was well above the target set for the rebuilt stock (1.9 kg per potlift).

The Working Group agreed that, as no management measures were required in CRA 7 and CRA 8 for 2007, the assessment did not need to be completed before the planned November Plenary meeting (this meeting was subsequently cancelled). However, to allow the management strategy evaluation to be completed for CRA 7 and CRA 8 in 2007 an agreed basecase model will be required early next year. Alternative parameterisations or methodology may be needed to form a base operating model suitable for management strategy evaluation.

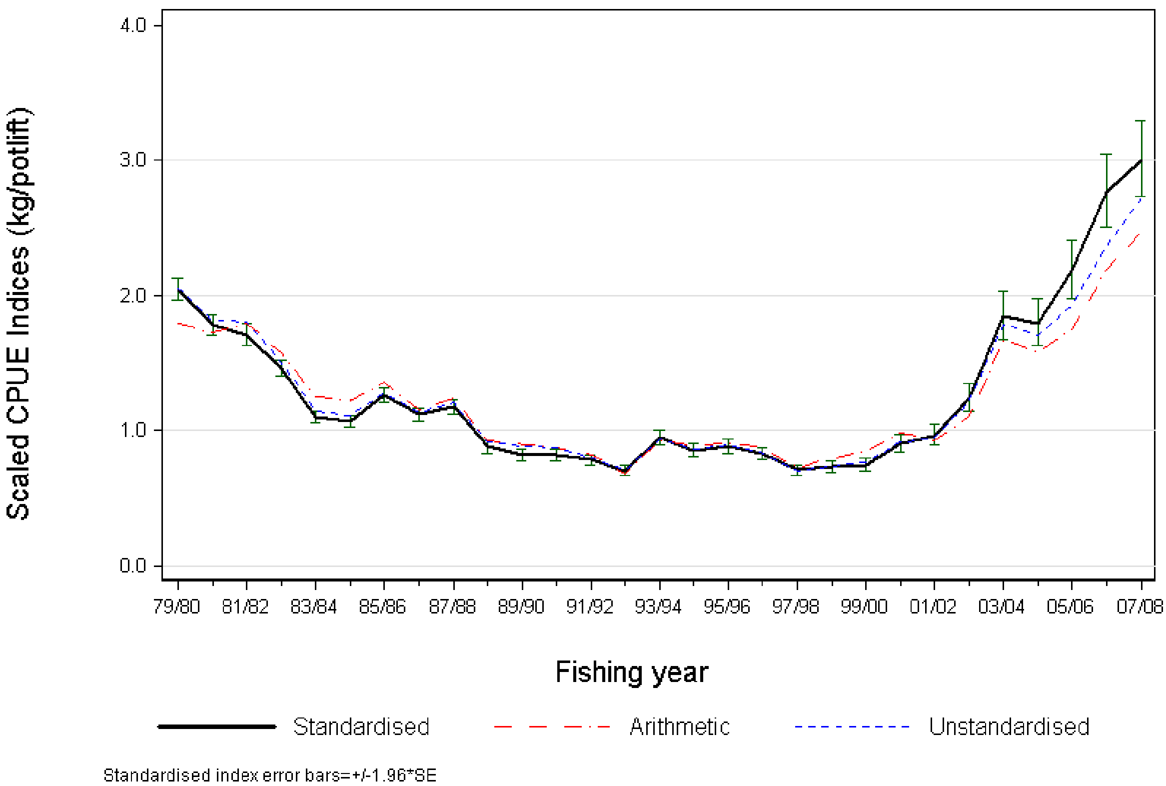


Figure 17: Annual CPUE indices for CRA 8: arithmetic (dashed line), unstandardised (dotted line), and standardised (bold line) ± 2 s.e. 1979–80 to 2007–08. The geometric mean for each series = 1.13 kg/potlift.

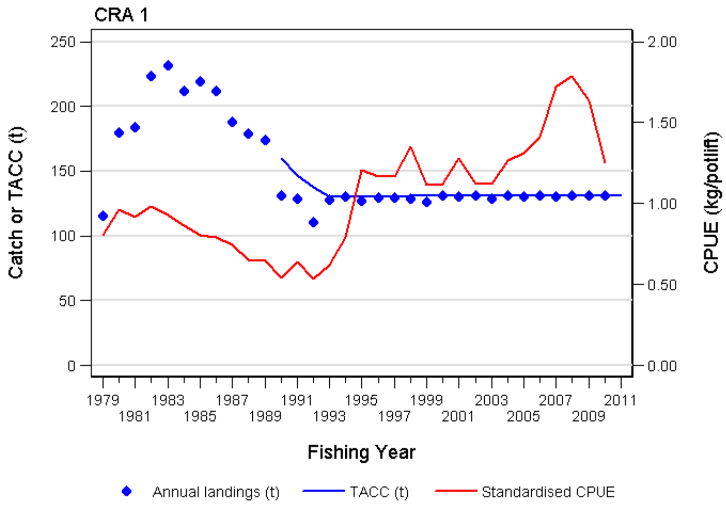
6. STATUS OF THE STOCKS

For the purposes of stock assessment and management, rock lobsters are assumed to constitute separate Fishstocks within each CRA QMA 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.

6.1 *Jasus edwardsii*, Northland (CRA 1) and Bay of Plenty (CRA 2)

CRA 1 Northland

Stock Status	
Year of Most Recent Assessment	2002
Assessment Runs Presented	Base case and 2 sensitivity runs
Reference Points	Target: Not established (reported against *Bref*) *Bref*: mean of beginning AW vulnerable biomass for the period 1979-88 Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default)
Status in relation to Target	Biomass in 2002 was 150% of *Bref*
Status in relation to Limits	Unlikely (< 60%) to be below the soft limit Very Unlikely (< 90%) to be below the hard limit
Historical Stock Status Trajectory and Current Status	



Annual landings, TACC and standardised CPUE for CRA1 from 1979 to 2010.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Standardised CPUE increased steadily from 2003 to 2008, but dropped 30% between 2008 and 2010.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	
Trends in Other Relevant Indicators or Variables	

Projections and Prognosis	
Stock Projections or Prognosis	5 year forward projections conducted in 2002 using 2002 levels of commercial, customary, non-commercial and illegal catches showed that the stock would remain at a similar level.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Bayesian length based model	
Main data inputs	CPUE, length frequency data, tagging data	
Period of Assessment	Latest assessment: 2002	Next assessment: Unknown
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty	Non-commercial catch	

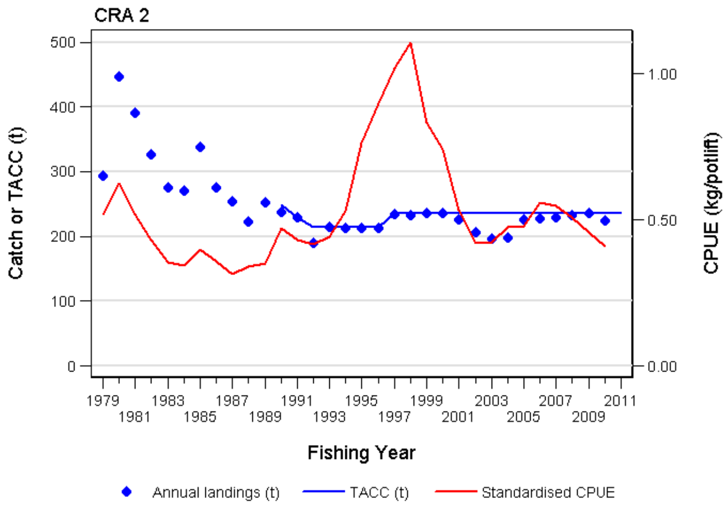
Qualifying Comments
CPUE rose nearly 50% after the 2002 assessment to the highest in the series in 2008, but has since dropped 30% from that peak.

Fishery Interactions

CRA 2 Bay of Plenty

Stock Status	
Year of Most Recent Assessment	2002
Assessment Runs Presented	Base case and 2 sensitivity runs
Reference Points	Target: Not established (reported against *Bref*) *Bref*: mean of beginning AW vulnerable biomass for the period 1979-88 Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default)
Status in relation to Target	Biomass in 2002 was 150% of *Bref*
Status in relation to Limits	Unlikely (< 60%) to be below the soft limit Very Unlikely (< 90%) to be below the hard limit

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA2 from 1979 to 2010.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Standardised CPUE dropped to below 0.5 kg/potlift in 2002 from the peak year in 1997. Since then CPUE has remained below 0.5 kg/potlift except for the three years 2006–2008.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	
Trends in Other Relevant Indicators or Variables	
Projections and Prognosis	
Stock Projections or Prognosis	5 year forward projections conducted in 2002 using 2002 levels of commercial, customary, non-commercial and illegal catches showed that the stock would remain at a similar level.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Bayesian length based model	
Main data inputs	CPUE, length frequency data, tagging data	
Period of Assessment	Latest assessment: 2002	Next assessment: Unknown
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty	Non-commercial catch	

Qualifying Comments
CPUE in the last 2 years has been below 0.5 kg/potlift and CPUE in 2010 is the lowest since the escape gap regulations changed in 1993.

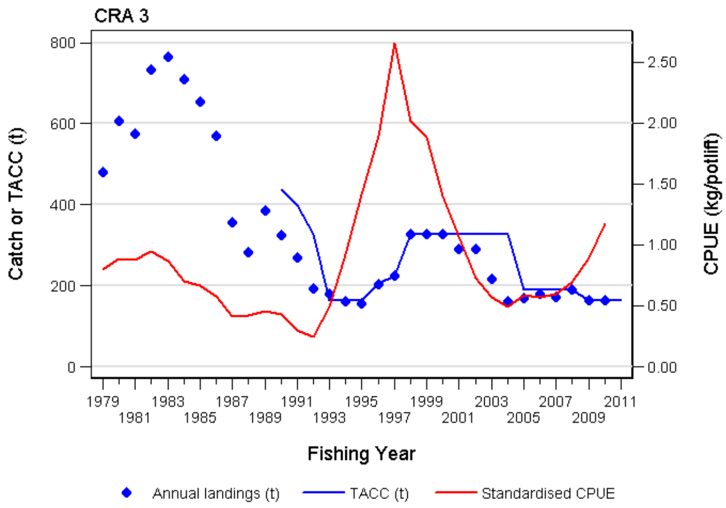
Fishery Interactions

6.2 *Jasus edwardsii*, Gisborne (CRA 3), Wairarapa – Hawkes Bay (CRA 4) and Marlborough - Kaikoura (CRA 5)

CRA 3 Gisborne

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	Base case and 13 MPD sensitivity runs
Reference Points	Target: reported against B_{MSY} B_{MSY}: AW vulnerable biomass associated with MSY (maximum SL catch summed across AW and SS) Limit: reported against B_{MIN} B_{MIN}: minimum AW vulnerable biomass, 1945–2007 Soft limit: 20% SSB_0 (default) Hard limit: 10% SSB_0 (default)
Status in relation to Target	Biomass in 2008 was about half B_{MSY}, with a 0% probability of being above B_{MSY}. Very Unlikely (< 10%) to be above B_{MSY}.
Status in relation to Limits	Biomass in 2008 was 11% above B_{MIN}, with an 18% probability of being below B_{MIN}. Unlikely (< 40%) to be below B_{MIN}. Status relative to hard and soft limits is unknown.

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA3 from 1979 to 2010.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass declined steadily from 1997 to 2003 and is increasing after several years of little change.
Recent Trend in Fishing Mortality or Proxy	
Other Abundance Indices	
Trends in Other Relevant Indicators or Variables	

Projections and Prognosis	
Stock Projections or Prognosis	5 year forward projections in 2009 under 2008 levels of commercial, customary, non-commercial and illegal catches showed that the stock would decrease by 25%.
Probability of Current Catch or TACC causing decline below Limits	Status relative to hard and soft limits at the end of the projection period is unknown.

Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Multi-stock length based model	
Main data inputs	CPUE, length frequency, tagging data	
Period of Assessment	Latest assessment: 2008	Next assessment: Unknown
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty	Future recruitment and growth rate	

Qualifying Comments
The quality of the 2008 Markov chain–Monte Carlo simulations was poor. The running quantile plots for many estimated parameters showed a drift through the run, suggesting poor convergence, and a trend to move well away from the MPD estimate.

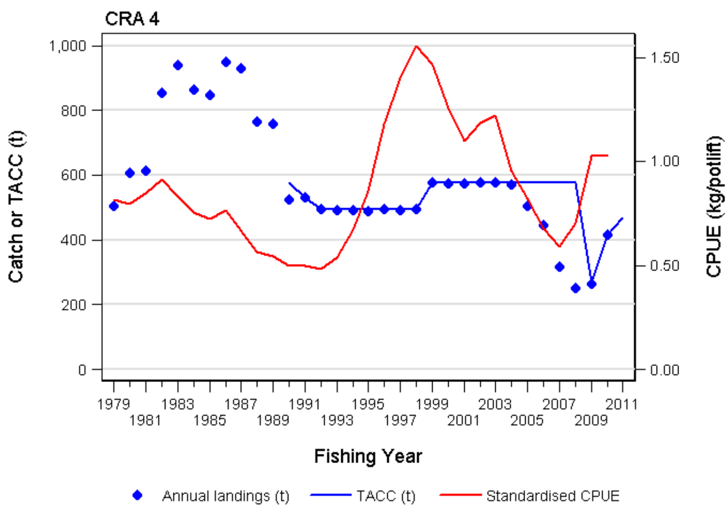
Recent developments in stock status
CPUE has been increasing since 2004. In 2011, the management procedure for CRA 3 proposed that the TAC be increased to 322.3 t because the standardised offset year CPUE was 1.597 kg/potlift, which is above the upper 1.08 kg/potlift threshold.

Fishery Interactions

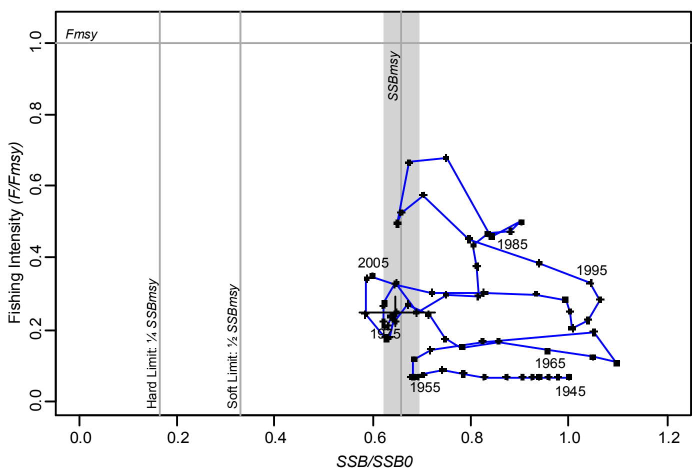
CRA 4 Wairarapa – Hawkes Bay

Stock Status	
Year of Most Recent Assessment	2011
Assessment Runs Presented	Base case and 6 MCMC sensitivity runs
Reference Point	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)
Status in relation to Target	Biomass in 2010 was about 1.7 times *Bref*. Virtually Certain (> 99%) to be above *Bref* SSB_{2010} = 0.98 SSB_{MSY}. About as Likely as Not (40-60%) to be above SSB_{MSY}
Status in relation to Limits	Exceptionally Unlikely (< 1%) to be below the soft and hard limits

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA4 from 1979 to 2010.



"Snail trail" that summarises the history of the CRA 4 fishery. The x-axis is the spawning biomass (*SSB*) as a proportion of SSB_0; the y-axis is the ratio of the fishing intensity (*F*) relative to F_{MSY}. Each point is the median of the posterior distributions, and the bars associated with 2010 show the 90% confidence intervals. The vertical reference lines shows SSB_{MSY} as a proportion of SSB_0 (with the grey band indicating the 90% confidence interval), the default soft limit: ½ SSB_{MSY} and the default hard limit: ¼ SSB_{MSY}. The horizontal reference line is F_{MSY}

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass decreased in two steps from a peak in 1997 to a low in 2007 but has increased over the three most recent years to a level similar to that observed in 2004.
Recent Trend in Fishing Mortality or Proxy	Fishing intensity increased from a low observed in 2007 but was well below F_{MSY} in 2010
Other Abundance Indices	None
Trends in Other Relevant Indicators or Variables	Recent average 14-year puerulus settlement index is low relative to the long-term (32-year) mean index.

Projections and Prognosis	
Stock Projections or Prognosis	4-year forward projections conducted in 2011 using 2010 levels of commercial, customary, non-commercial and illegal catches showed that the stock would decrease, but remain well above *Bref*. Virtually Certain (> 99%) to remain above *Bref.*
Probability of Current Catch or TACC causing decline below Limits	Exceptionally Unlikely (< 1%) to be below the soft and hard limits at the end of the projection period.

Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Bayesian length based model	
Main data inputs	CPUE, length frequency, tagging data, puerulus settlement indices	
Period of Assessment	Latest assessment: 2011	Next assessment: Unknown
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.	

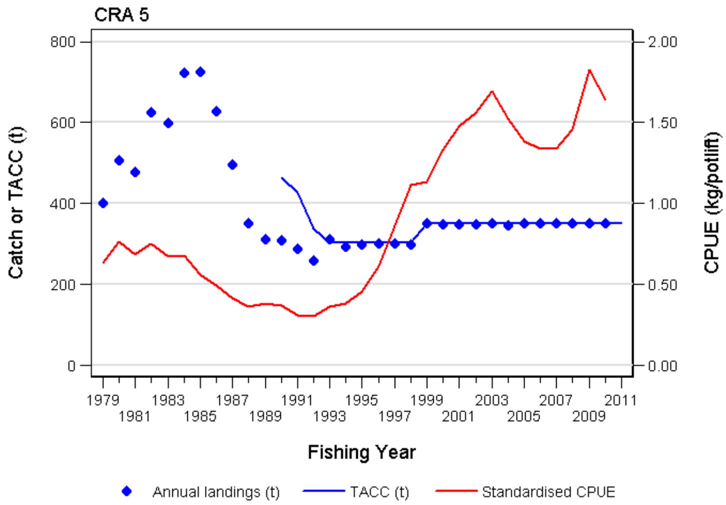
Qualifying Comments
A new management procedure has been developed, based on the 2011 assessment

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.

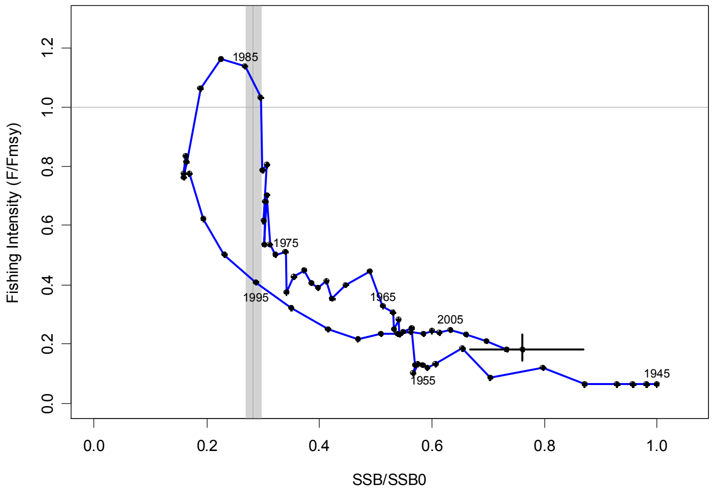
CRA 5 Marborough - Kaikoura

Stock Status	
Year of Most Recent Assessment	2010
Assessment Runs Presented	Base case
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)
Status in relation to Target	B_{2009} = 3.0 *Bref.* Virtually Certain (> 99%) to be above *Bref* SSB_{2009} = 4.6 SSB_{MSY}. Virtually Certain (> 99%) to be above SSB_{MSY}
Status in relation to Limits	Exceptionally Unlikely (< 1%) to fall below the soft and hard limits.

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA5 from 1979 to 2010



"Snail trail" that summarises the history of the CRA 5 fishery. The x-axis is the spawning biomass (*SSB*) as a proportion of B_0 (SSB_0); the y-axis is the ratio of the fishing intensity (*F*) relative to F_{MSY}. Each point is the median of the posterior distributions, and the bars associated with 2009 show the 90% confidence intervals. The vertical reference line shows SSB_{MSY} as a proportion of *SSB0*, with the grey band indicating the 90% confidence interval. The horizontal reference line is F_{MSY}

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE dropped 10% in 2010 from 2009, the highest level observed in the 32 year series after a short period of decline in the mid-2000s.
Recent Trend in Fishing Mortality or Proxy	Fishing mortality declined substantially after CRA 5 entered the QMS, and was at its lowest level in 2009 since that introduction. Fishing intensity in 2009 is equivalent to the level observed in 1952.
Other Abundance Indices	None
Trends in Other Relevant Indicators or Variables	The 2009 puerulus (settlement) index is about 1/3 average. However, average settlement over the past 10 years has been near the long-term average.

Projections and Prognosis	
Stock Projections or Prognosis	5 year forward projections from 2010 under 2009 levels of commercial, customary, illegal catches and 2 alternative recreational catches catch levels (155 t and 112 t) showed that the biomass would decrease, but remain well above *Bref* and B_{MSY}.

Probability of Current Catch or TACC causing decline below Limits	Exceptionally Unlikely (< 1%) to fall below the soft and hard limits at the end of the projection period.

Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Bayesian length based model	
Main data inputs	CPUE, length frequency, tagging data, puerulus data	
Period of Assessment	Latest assessment: 2010	Next assessment: Unknown
Changes to Model Structure and Assumptions	Revised growth model, addition of puerulus data.	
Major Sources of Uncertainty	Level of non-commercial catches, illegal catches, modelling of growth, estimation of productivity.	

Qualifying Comments
A management procedure has been developed that may be used to manage the fishery in the future.

Recent developments in stock status
CPUE dropped 10% in 2010 from 2009, the highest point in the series.

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

6.3 *Jasus edwardsii*, Chatham Islands (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 2009−10 fishing year (345 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.

6.4 *Jasus edwardsii*, Otago (CRA 7) and Stewart Island (CRA 8)

In 2006, CRA 7 and CRA 8 were modelled simultaneously as separate stocks within a new multi-stock model. The assessment was not finalised in the time available; however, both stocks showed increasing CPUE to levels not seen since the 1980s. CPUE in CRA8 in 2006 was well above the target set for the rebuilt stock (1.9 kg per potlift). This indicated that it was time to develop a management strategy designed to maintain stock biomass, and this was done in 2007.

In 2011 the management procedure for CRA 7 proposed a decrease in the TAC for CRA 7 to 69.9t for the 2012-13 fishing year. In 2011 the management procedure for CRA 8 proposed retention of the TAC at the 2011 level of 1053 t.

6.5 *Sagmariasus verreauxi*, PHC stock

The status of this stock is unknown.

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