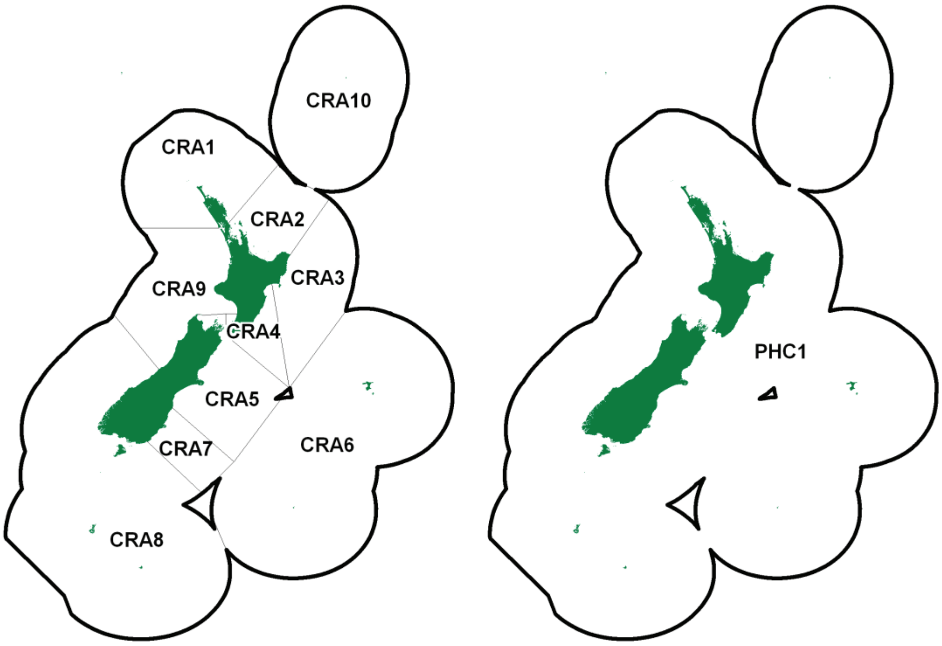
ROCK LOBSTER (CRA and PHC)

(*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 NSI stock into three substocks:
- 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

CRA 9 has not been assigned to a substock. Since 2001, assessments have generally been carried out at the Fishstock level, i.e. for CRA 1, CRA 2 etc.

Time series of commercial landings and catch per unit effort (CPUE) data are provided for stocks NSI, NSN, NSC, NSS and CHI for comparison with earlier years. The fishing year runs from 1 April to 31 March.

The NSI stock is composed of the CRA QMAs 1–5 and 7–9, each being a separate Fishstock with a separate TACC. The sum of the TACCs for the NSI stock was set at 3 275 t for the year commencing 1 April 1990. This total was reduced in each year until 1993–94 to reach 2 382 t (taking into account some increases in individual ITQs resulting from appeals over catch histories by fishers). The total TACC for the NSI stock then fluctuated at a level of 2 300 to 2 400 t to the 2005–06 season, when the NSI TACC dropped to 2 229 t through a reduction to the CRA 3 TACC from 327 t to 190 t (Table 1). The CRA 3 TAC dropped at the same time from 453 t to 319 t. The total NSI TACC increased in 2006–07 to 2 407 t through increases to the CRA 7 and CRA 8 TACCs from the operation of the NSS Decision Rule in 2005. The operation of the NSS Decision Rule resulted in increases to the CRA 7 and CRA 8 TACCs in both 2008–09 and 2009–10, followed by a 50% drop in the CRA 7 TACC and no change to the CRA 8 TACC for 1 April 2010 (Table 1). CRA 4 stakeholders took voluntary reductions in their effective TACC by agreeing to a shelving of ACE (annual catch entitlement) in both 2007–08 (to 340 t) and 2008–09 (to 250 t). The Ministry adopted a formal management procedure (MP) for CRA 4 in 2009, which decreased the CRA 4 TACC from 577 t to 266 t for the 2009–10 fishing year and increased the TACC to 417 t for 1 April 2010 (Table 1) (The increase would have been larger under the MP but the Minister of Fisheries opted to forego part of the increase based on recommendations from a number of stakeholders, including CRA 4 commercial fishermen). The TACC for CRA 3 was also decreased from 190 t to 164 t for the 2009–10 fishing year. The Minister adopted a formal MP for CRA 3 in 2010, which resulted in no TACC change for 1 April 2010. The NSI TACC for rock lobster in 2010–11 is 2 447 t, a slight increase over the 2009–10 value of 2 4702 t.

The TACC for the CHI stock (CRA 6) was set at 518 t in 1990 but increased through appeals to 531 t by the beginning of the 1993–94 fishing year (Table 1). The CHI TACC was subsequently reduced to 400 t in 1997–98 and to 360 t in 1998–99. CRA 10 comprises the Kermadec Islands, and has a nominal TACC of 0.086 t. The TACC for PHC increased from 27 t in 1990 to its current value of 40.3 t at the beginning of the 1993–94 fishing year following appeals.

TACs (Total Allowable Catch including 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. **Error! Reference source not found.** 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 is a tail length (TL) of 127 mm, which has applied to both sexes during the period 21 June to 19 November, the primary commercial season. The starting date for the CRA 7 commercial fishing season was changed to 1 June on 1 October 2009. 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.

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. Commercial fishers in 2008–09 and 2009–10 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 2009 and 2010.

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.

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

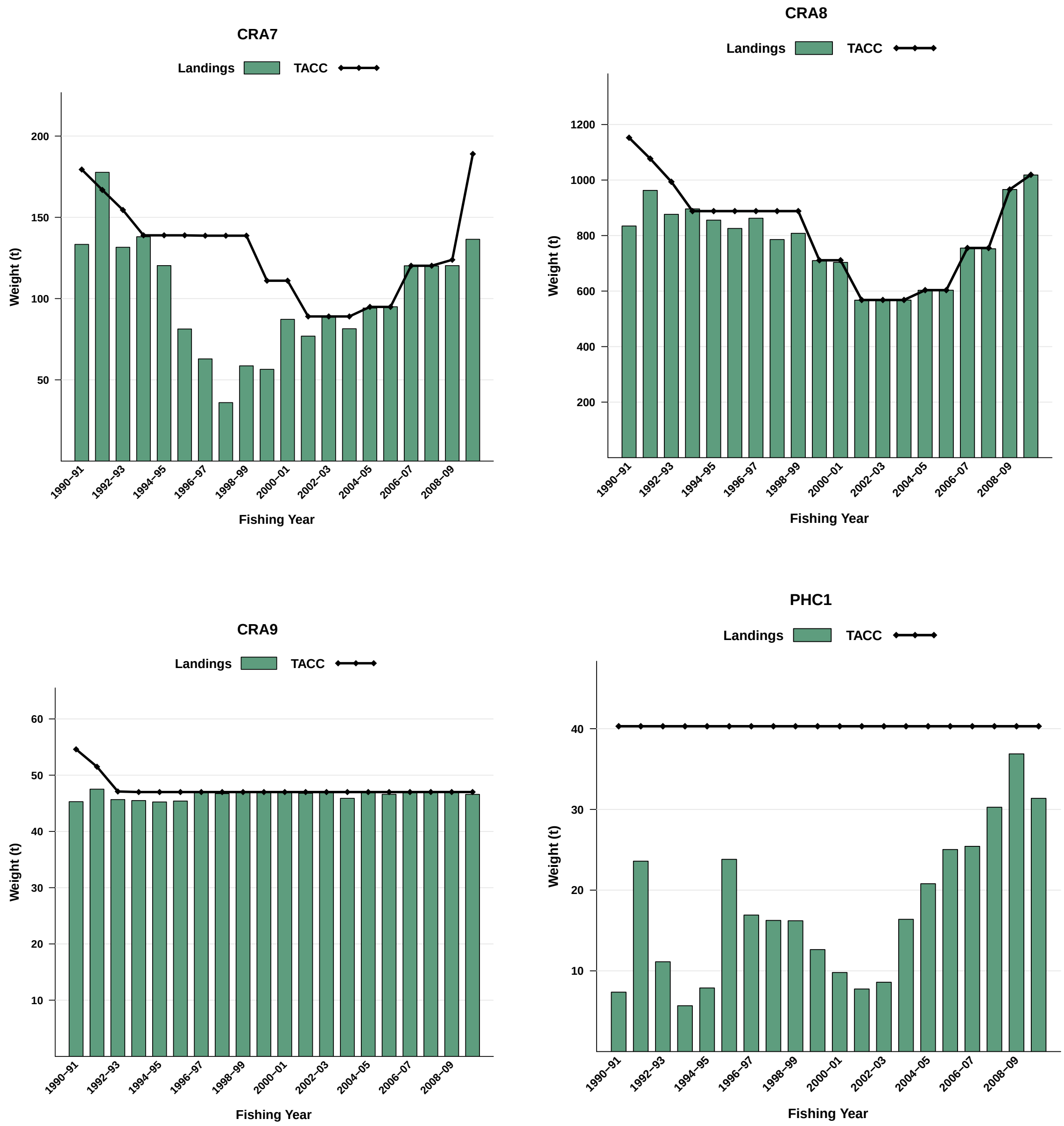


Figure 1 [Continued]: Historical landings and TACC for the 9 main CRA stocks and PHC 1.

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). In recent years, landings reported by LFRRs have been close to the QMR totals (Table 2 in Starr 2009).

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).

Fishing	CRA 1			CRA 2			CRA 3			CRA 4		
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	–	235.0	236.1	452.6	164.0	164.0	293.0	262.0	266.0	461.0
2010–11	N/A	131.1	–	N/A	236.1	452.6	N/A	164.0	293.0	N/A	415.6	610.6

Fishing	CRA 5			CRA 6			CRA 7			CRA 8		
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	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	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	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	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	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	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	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	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	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	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	344.8	360.0	370.0	136.5	189.0	209.0	1018.3	1019.0	1110.0
2010–11	N/A	350.0	467	N/A	360.0	370.0	N/A	84.5	104.5	N/A	1019.0	1110.0

Fishing	CRA 9			Total		
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	–	2688.1	2762.2	3362.6
2010–11	N/A	47.0	–	N/A	2807.3	3407.7

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

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 quickly 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 makes no attempt to link 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 revised 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, indicating that the problem has not been completely solved by this approach. In these instances, the method is modified by dropping all data for the vessel in the month with zero landings and 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 arithmetic CPUE estimates in Tables 2 and 3 have been subjected to the same error screening as those used for standardised CPUE analysis. For arithmetic estimates, CPUE is calculated from the sum of catch divided by the sum of pots for each stock, sub-stock or CRA Fishstock by fishing year.

Another potential problem with assuming CPUE indices are proportional to abundance has been identified by the RLFAWG Group. 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. The practice has become more prevalent in recent years, especially in areas where rock lobster abundance has increased. The RLFAWG agreed to identify this issue for further investigation.

***Jasus edwardsii*, NSI stock**
NSI landings were relatively stable from about 1960 until the late 1980s, when they declined (Table 2). CPUE was around 1.0 kg per potlift in the late 1970s and early 1980s, and decreased slowly until the late 1980s. Catch per pot lift in NSI declined to 0.48 kg in 1992–93 and has since recovered to levels above 1.0 kg per potlift in 2008–09 (1.26) and 2009–10 (1.33) (Table 2).

Table 2: Reported commercial landings (t) to 31 March 2010 and CPUE (kg/potlift) for *Jasus edwardsii* NSI and CHI stocks, and NSN, NSC and NSS substocks, for the 1979–80 to 2009–10 fishing years. Sources of data: catch and CPUE data from 1979–80 to 1985–86 from the QMS-held FSU data; catch data from 1986-87 to 2009–10 from QMR or MHR reports held by the Ministry of Fisheries (total catches in 1986–87 and 1987–88 have been divided among substocks using the FSU data because the QMR did not report individual CRA QMAs in those years); CPUE data from 1986–87 to 1988–89 from the QMS-held FSU data; CPUE data from 1989–90 to 2009–10 from the CELR data held by the Ministry of Fisheries corrected for actual landings. See Booth et al. (1994) for a discussion of problems with the QMS-held FSU data.

	NSI Substocks						NSI Total		CHI	
Fishing	NSN (CRA1 & 2)		NSC (CRA3, 4 & 5)		NSS (CRA7 & 8)		CRA 1–5 & CRA 7–9		CRA6	
Year	Landings	CPUE	Landings	CPUE	Landings	CPUE	Landings	CPUE	Landings	CPUE
1979–80	408	0.57	1 386	0.85	2 129	1.58	4 012	1.06	400	2.33
1980–81	626	0.69	1 719	0.88	1 761	1.49	4 203	1.02	356	2.18
1981–82	574	0.66	1 664	0.85	1 663	1.48	3 973	0.99	465	2.19
1982–83	549	0.59	2 213	0.91	1 632	1.35	4 453	0.96	472	1.78
1983–84	506	0.55	2 303	0.85	1 634	1.09	4 514	0.87	548	1.73
1984–85	482	0.51	2 294	0.76	1 741	1.09	4 598	0.82	492	1.35
1985–86	556	0.54	2 227	0.71	2 185	1.21	5 048	0.83	604	1.41
1986–87	486	0.48	2 144	0.72	1 927	1.07	4 650	0.79	580	1.66
1987–88	442	0.45	1 781	0.57	1 961	1.12	4 277	0.72	448	1.48
1988–89	401	0.45	1 399	0.51	1 262	0.80	3 087	0.58	450	1.40
1989–90	427	0.55	1 457	0.53	1 352	0.80	3 262	0.62	318	1.34
1990–91	369	0.55	1 156	0.46	968	0.75	2 538	0.56	370	1.38
1991–92	358	0.49	1 087	0.41	1 140	0.82	2 633	0.54	388	1.29
1992–93	301	0.44	946	0.40	1 008	0.62	2 300	0.48	329	1.14
1993–94	342	0.51	983	0.49	1 034	0.87	2 404	0.61	342	1.07
1994–95	343	0.61	945	0.60	976	0.79	2 309	0.67	313	1.07
1995–96	339	0.77	942	0.73	907	0.76	2 233	0.75	315	1.09
1996–97	343	0.87	997	0.88	925	0.74	2 312	0.83	378	1.02
1997–98	364	0.87	1 013	1.15	822	0.66	2 246	0.87	339	0.88
1998–99	361	0.95	1 117	1.22	867	0.71	2 392	0.94	334	1.17
1999–00	361	0.82	1 252	1.24	766	0.73	2 426	0.96	322	1.19
2000–01	366	0.83	1 249	1.21	791	0.81	2 453	0.98	343	1.15
2001–02	356	0.71	1 213	1.08	649	0.81	2 264	0.91	329	1.15
2002–03	336	0.58	1 216	1.01	656	0.94	2 255	0.89	336	1.16
2003–04	325	0.58	1 142	1.04	649	1.31	2 161	0.99	290	1.10
2004–05	328	0.59	1 077	0.94	697	1.36	2 149	0.96	323	1.21
2005–06	356	0.60	1 024	0.90	698	1.62	2 124	0.97	352	1.35
2006–07	358	0.69	973	0.76	875	2.07	2 253	0.99	352	1.44
2007–08	360	0.71	837	0.76	873	2.18	2 116	1.03	356	1.53
2008–09	363	0.71	789	0.89	1 086	2.91	2 285	1.26	355	1.50
2009–10	366	0.66	776	1.12	1 155	2.45	2 343	1.33	345	1.36

Jasus edwardsii, NSN substock

Landings in the NSN substock were high in the early 1980s but CPUE was less than 1.0 kg per potlift. Both measures gradually declined into the early 1990s. Catch per pot lift was around 0.7 kg in the early 1980s but the period from 1986–87 to 1992–93 had catch rates around 0.5 kg (Table 2). From 1994, CPUE increased to levels considerably higher than those observed at the beginning of the time series, peaking in 1998–99 at 0.95 kg per potlift. CPUE levels in CRA 1 and CRA 2 differ: CRA 1 maintained high catch rates (above 1.5 kg/potlift in most recent 3 fishing years) since the late 1990s, while CRA 2 declined to less than 0.5 kg/potlift in 2002–03 and has since remained near that level (Table 3). The combined NSN catch rate increased from 0.6 to 0.7 kg per potlift in 2006–07 and has remained near that level over the four most recent fishing years.

Jasus edwardsii, NSC substock

Landings in the NSC substock were very high to the mid 1980s, exceeding 2 000 t for five fishing years in succession. During that time, CPUE dropped from 0.9 kg/potlift to 0.7 kg/potlift (Table 2). Commercial catches then gradually decreased to below 1 000 t and CPUE dropped to below 0.5 kg per potlift by the early 1990s. From 1993–94, CPUE increased to a peak of 1.24 kg/potlift in 1999–2000 (Table 2). CPUE dropped to near 1.0 kg per potlift in 2002–03, and dropped to 0.76 kg/potlift in 2006–07 and 2007–08. This was still higher than the levels observed from 1987–88 to 1995–96. CPUE increased to 0.89 in the most recent year. Trends in CPUE have differed between the three component QMAs in the NSC, with CRA 3 CPUE peaking in 1997–98, CRA 4 in 1998–99, and CRA 5 in 2003–04 (Table 3).

Jasus edwardsii, NSS substock

Catches and CPUE were high for this substock: greater than 1 500 t per fishing year, with CPUE well over 1.0 kg per potlift throughout most of the 1980s. However, both measures gradually declined during that period, dropping below 1 000 t and below 1.0 kg per potlift by the early- to mid-1990s (Table 2). CPUE has been increasing since 1997–98, nearly reaching 3.0 kg per potlift in 2008–09 and above 2.0 kg/potlift in the most recent four fishing years (Table 2). Catches are relatively low in CRA 7 compared with those in the other QMAs, CPUE rose in both CRA 7 and CRA 8 up to 2009–10, with CPUE dropping by 40% in CRA 7 while remaining the same in CRA 8 (Table 3).

Jasus edwardsii, Westland/Taranaki (CRA 9)

Catch per pot lift fluctuated near 0.9 kg per potlift between 1998–99 and 2001–02, then increased to above 2 kg per potlift in 2004–05 and 2005–06, and has since decreased slowly to near 1.6 kg per potlift (Table 3).

Jasus edwardsii, CHI stock

CPUE in the CHI fishery was higher than in the other New Zealand CRA areas in the 1980s (Table 2). However, CPUE since the mid-1980s has declined to levels similar to those in other CRA QMAs (Table 3). CPUE dropped to 1.1 kg/potlift in 2003–04, increased to 1.5 kg/potlift in 2007–08 and 2008–09 and dropped to 1.4 kg/potlift in 2009–10. Landings were around 400 to 500 t per fishing year in the 1980s but fell below 400 t per year in the 1990s. The reasons for the decline in catch and in CPUE are unknown. Size frequencies of lobsters in the landed catch have changed little since the beginning of this fishery.

Table 3: Estimated arithmetic CPUE (kg/potlift) for each CRA quota management area for the ten 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).

										Fishing year
QMA	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10
CRA 1	1.17	1.30	1.20	1.22	1.23	1.14	1.32	1.64	1.57	1.63
CRA 2	0.71	0.56	0.44	0.43	0.43	0.47	0.54	0.53	0.53	0.49
CRA 3	1.19	0.95	0.73	0.62	0.52	0.62	0.58	0.60	0.71	0.85
CRA 4	1.26	1.06	1.09	1.14	1.00	0.88	0.65	0.60	0.71	1.02
CRA 5	1.16	1.27	1.26	1.39	1.26	1.17	1.18	1.19	1.28	1.44
CRA 6	1.15	1.15	1.16	1.10	1.21	1.35	1.44	1.53	1.50	1.36
CRA 7	0.35	0.46	0.52	0.58	0.75	1.12	1.56	1.31	1.69	1.02
CRA 8	0.98	0.92	1.10	1.67	1.58	1.75	2.19	2.47	3.20	3.11
CRA 9	0.93	0.82	1.11	1.63	2.14	2.22	1.94	1.85	1.75	1.64

Sagmariasus verreauxi, PHC stock

QMS-reported catches of the PHC stock halved between 1998–99 and 2001-02 but have since increased to near the TACC since 2007–08 (Table 4).

Table 4: Reported landings of *Sagmariasus verreauxi* from 1990–91 to 2009–10. Data from QMR or MHR (after 1 Oct 2001).

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

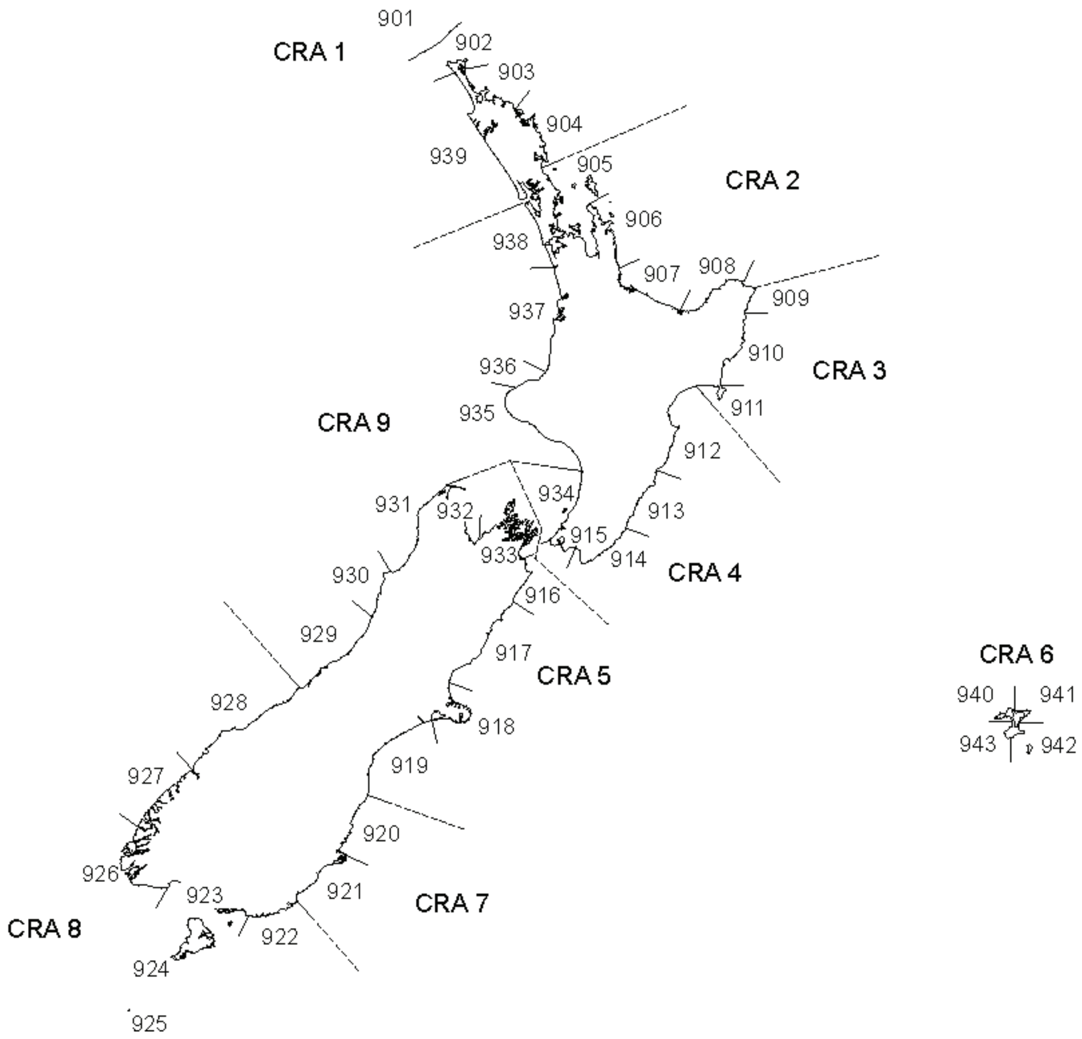


Figure 1: Rock lobster statistical areas as reported on CELR forms.

Jasus edwardsii CPUE by statistical area

Table 5 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 1). The values of CPUE and the trends in the fisheries vary within and between CRA areas.

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 6.

Table 5: 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	04/05	05/06	06/07	07/08	08/09	09/10
1	901	3.56	3.20	2.96	3.48	3.99	3.50
1	902	2.06	2.37	–	2.46	1.69	2.35
1	903	1.08	0.86	1.33	1.47	1.19	0.90
1	904	0.57	–	–	0.62	–	–
1	939	0.70	0.57	0.86	1.08	1.28	2.05
2	905	0.56	0.51	0.60	0.57	0.60	0.53
2	906	0.38	0.46	0.51	0.54	0.44	0.40
2	907	0.47	0.46	0.56	0.61	0.82	0.69
2	908	0.43	0.42	0.55	0.43	0.48	0.45
3	909	0.82	0.79	0.97	1.00	1.04	1.19
3	910	0.53	0.58	0.47	0.60	0.71	0.90
3	911	0.42	0.59	0.60	0.50	0.57	0.70
4	912	0.77	0.59	0.55	0.62	0.68	0.75
4	913	1.21	0.94	0.74	0.69	0.80	1.05
4	914	1.11	0.93	0.55	0.44	0.56	1.11
4	915	0.76	0.81	0.67	0.78	0.83	1.25
4	934	–	–	1.50	0.86	–	–
5	916	2.38	2.19	2.09	2.09	2.41	2.20
5	917	1.06	1.18	1.22	1.34	1.44	2.01
5	918	1.37	1.85	–	–	1.68	–
5	919	–	–	–	–	–	–
5	932	–	–	–	–	–	–
5	933	0.89	0.72	0.72	0.72	0.74	0.76
6	940	1.12	1.21	1.23	1.37	1.35	1.08
6	941	0.88	0.90	1.00	1.13	1.31	1.16
6	942	1.49	1.65	1.89	1.96	1.63	1.61
6	943	1.00	1.49	1.91	1.39	1.44	1.23
7	920	0.53	0.94	1.34	1.13	1.66	0.80
7	921	1.32	1.81	2.02	1.99	2.02	1.73
8	922	–	–	–	–	–	1.12
8	923	2.45	4.25	2.07	4.16	3.32	–
8	924	2.00	3.00	4.04	3.18	3.17	4.13
8	925	1.13	–	–	2.87	–	–
8	926	1.96	2.21	2.63	2.28	2.92	2.60
8	927	1.72	1.17	1.72	2.89	3.65	4.09
8	928	1.41	1.68	2.13	5.33	6.25	4.22
9	929	–	–	–	–	–	–
9	930	–	–	–	–	–	–
9	931	–	–	2.94	–	–	–
9	935	2.44	1.98	1.69	1.77	2.39	–
9	936	–	–	–	–	–	–
9	937	–	1.58	–	–	–	–
9	938	–	–	–	–	–	–

Table 6: 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

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

Table 7: 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 8.

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	2005	46.709	Ramped from 1945; constant from 1979	20	Constant from 1945
CRA 5 [4]	1945	2003	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 CPUE	10	Constant from 1945
CRA 6 [5]	–	–	–	Not used	–	–
CRA 7 [6]	1976	2006	4.514	Constant from 1976	1	Constant from 1976
CRA 8 [6]	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] Breen et al. (2006); [4] see Section XX; [6] Breen et al. (2007)

Table 8: 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	MFish Compliance estimate
CRA 5 [4]	Mean of 1994 and 1996 recreational survey estimates in numbers X 1994/96 SS mean weight from catch sampling	By WG agreement
CRA 6 [5]	Not used	Not used
CRA 7 [6] CRA 8 [6]	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 were 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] Breen et al. (2006); [4] see Section XX; [6] Breen et al. (2007)

1.3 CRA 5 recreational catch

Recreational catch estimates were required for the 2010 CRA 5 assessment. The RLFAWG considered that reports of increased recreational activity in CRA 5 coupled with an increasing trend in abundance made it unlikely that recreational catches have remained constant over time. For this reason, the RLFAWG agreed to use a catch trajectory that reflected the increasing abundance of lobster in this QMA (Figure 2).

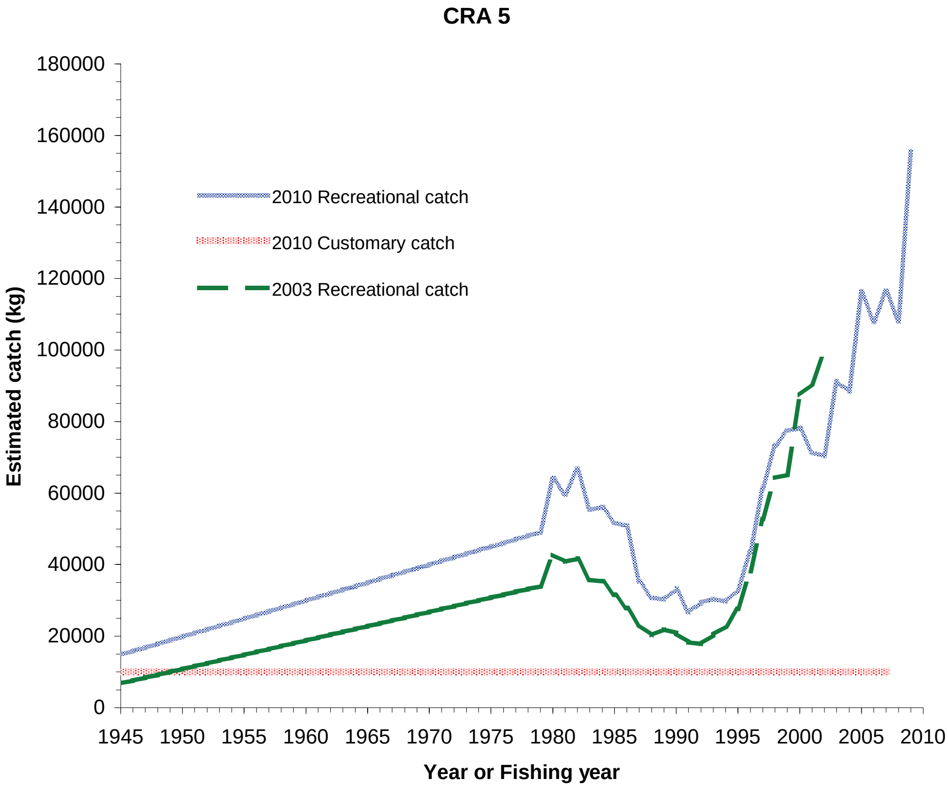


Figure 2. Recreational (blue) and customary (pink) catch trajectories (kg) for the 2010 stock assessment of CRA 5. Also plotted is the recreational catch trajectory used for the 2003 CRA 5 stock assessment (green dash). Section 111 catches have been added to the 2010 recreational catch trajectory. In 2010, recreational catches were made proportional to the Area 917 unstandardised 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 5 recreational catches (see minutes of the meeting 22 September 2010):

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

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

$$W_{1945} = 0.2 * W_{1979}$$

$$W_i = W_{i-1} + \frac{(W_{1979} - W_{1945})}{(1979 - 1945)} \quad \text{if } i > 1945 \,\&\, i < 1979$$

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

$CPUE_i =$ Area 917 spring/summer CPUE from 1979 to 2009

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

This algorithm is similar to that adopted by the RLFAWG for the 2003 CRA 5 stock assessment, except that the spring/summer (SS) standardised CPUE indices for all of CRA 5 were used in 2003. The RLFAWG preferred to use the unstandardised CPUE only from Area 917 because this is the region (Kaikoura) where most recreational catch from CRA 5 is taken. The mean number of lobsters from the 1994 and 1996 surveys was 54,000 and the mean weight of legal lobsters in the SS, estimated from the commercial sampling data, was 0.563 kg. The resulting recreational catch trajectory (Figure 2) showed a strong increasing trend since the mid-1990s, exceeding 100 t since 2005 and exceeding 150 t in 2009. Mean recreational catch for 1945 to 2009 was 41 t and since 1979 was 58 t before adding the Section 111 catch.

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 10 t (CRA 8) (Table 9)

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

Fishing Year	CRA1	CRA2	CRA3	CRA4	CRA5	CRA6	CRA7	CRA8	CRA9
1992-93	5								
1999-2000					8				
2000–01	3				30				
2001–02	111	227	136	648	465		77	253	5
2002–03	489	609	495	2,660	1,960		152	1,954	907
2003–04	2,221	1,025	372	3,399	2,907	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
Maximum	5,016	1,370	2,253	3,706	6,244	538	1,688	10,721	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. Table 7 presents the customary catch estimates used in all recent rock lobster stock assessments and Table 8 presents the rationale used when setting the levels presented in Table 7. 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 10) and catch which is outside of the MFish catch reporting system (columns labelled ‘NR’ in Table 10). Table 10 shows all the available illegal catch estimates by CRA QMA. When these data are used in stock assessments, missing cells are filled in by interpolation (for missing years) or by extrapolation (to extend the series after 2004–05). The illegal catches for these filled-in years are apportioned between the ‘R’ and ‘NR’ categories within each QMA (q) using the mean proportion $r_q = \sum R_{q,y} \Big/ \sum I_{q,y}$, where $R_{q,y}$ is the “reported” (‘R’) catch for those years with 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 10: 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.

	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										

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

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

Illegal catch estimates prior to 1990 have been derived from unpublished estimates of discrepancies between reported catch totals and total exported weight (Table 11; 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 11). 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 3. 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 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.

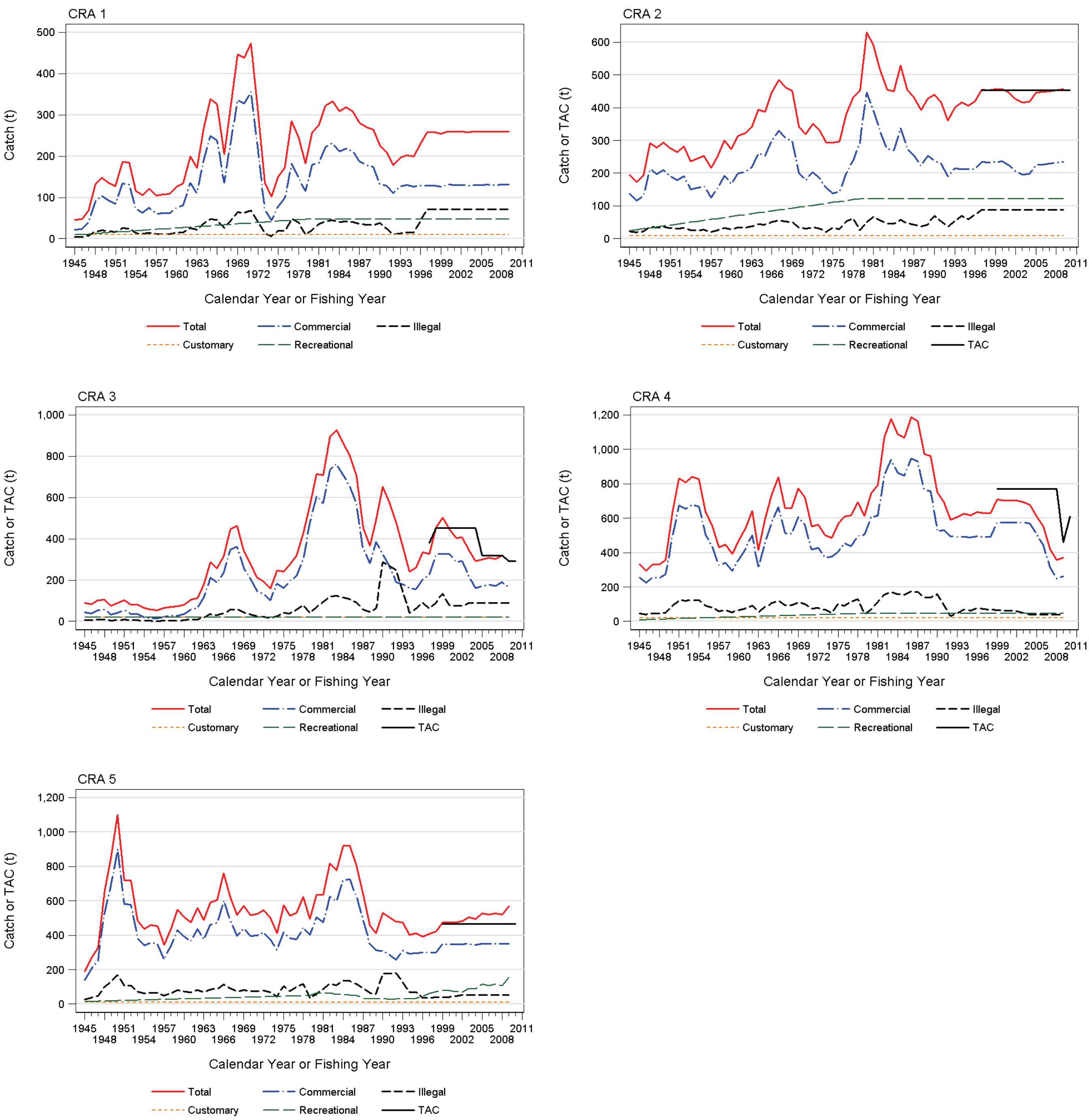


Figure 3: Catch trajectories (t) from 1945 to 2010 for CRA 1 to CRA 5, showing current best estimates for commercial, recreational, customary and illegal categories. Also shown is the sum of these four catch categories and the TAC (t) if it exists. Note that calendar year catches are plotted from 1945 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.

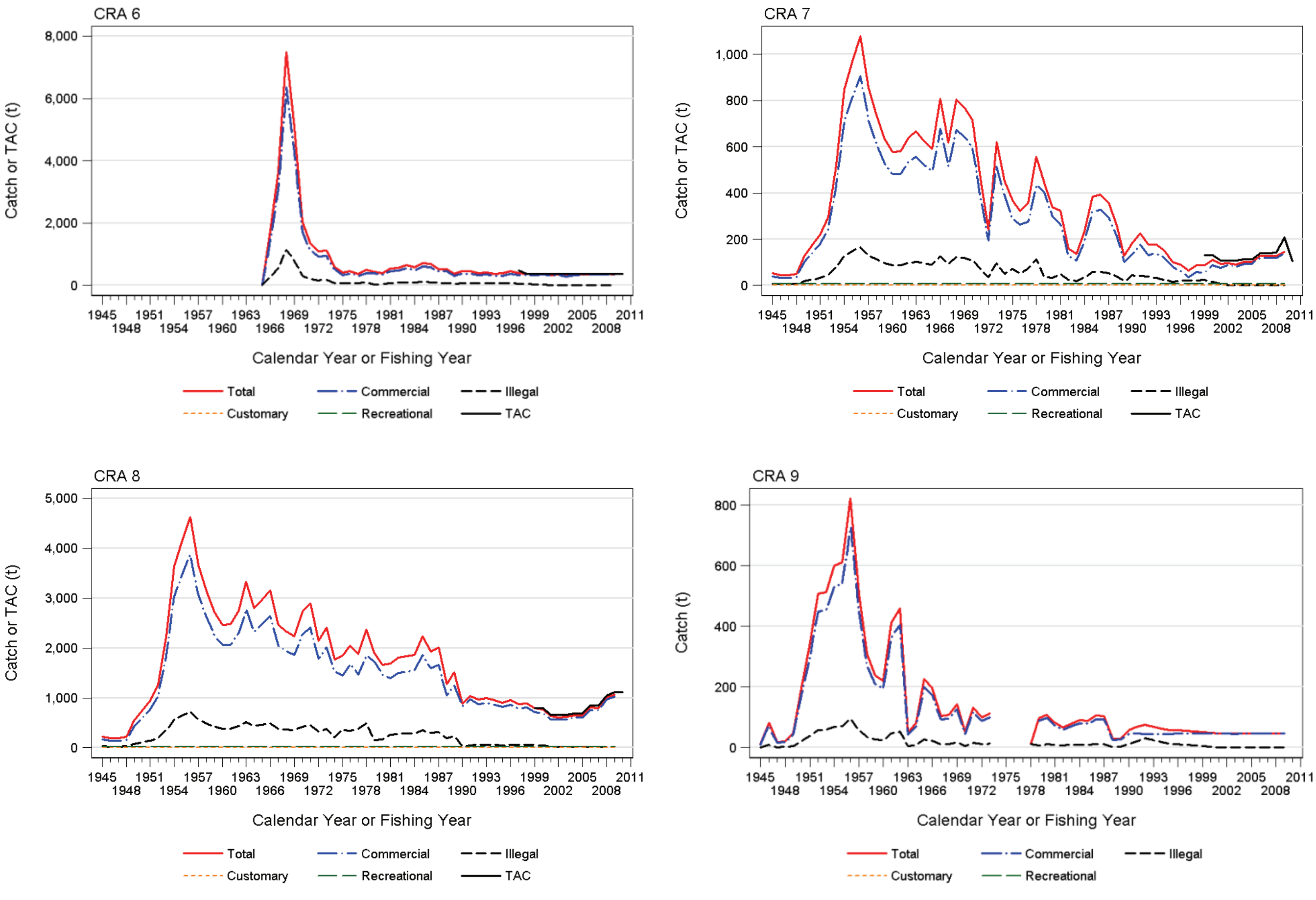


Figure 3 (cont.): Catch trajectories (t) from 1945 to 2010 for CRA 6 to CRA 9, showing current best estimates for commercial, recreational, customary and illegal categories. Also shown is the sum of these four catch categories and the TAC (t) if it exists. No catch estimates are available for CRA 9 from 1974 to 1978. 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.

2. BIOLOGY

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

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

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

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

Table 12: Values used for some biological parameters.

1. Natural mortality (M) [1]

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

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

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

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

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

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

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

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

Growth modelling

The primary 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.

For CRA 5 , tag recapture data for the 2010 assessment were available from 1975–1985 and 1997–2007. Comparisons of the estimated CRA 5 growth rate based on tagging made in the the earlier period with the modern period did not reveal any major change in growth rate similar to that discovered for CRA 3 (Breen et al. 2009).

Settlement indices

Annual levels of puerulus settlement have been estimated since 1979 or later at sites in Gisborne, Castlepoint, Napier, Wellington, Kaikoura, Moeraki, Halfmoon Bay, Chalky Inlet and Jackson Head. Table 13 provides the standardised settlement indices from all sites except Chalky.

Table 13: Puerulus settlement indices. Source: J. Forman & A. McKenzie, NIWA. Blanks indicate that no sampling was done, whereas a zero indicates a lack of observed settlement.

Year	Gisborne	Napier	Castlepoint	Kaikoura	Moeraki	Halfmoon	Jackson
1979		0.80					
1980		1.43		0		0.55	
1981		1.93		1.50		2.66	
1982		0.94		0.04		0.12	
1983		1.17	1.42	1.20		1.43	

Year	Gisborne	Napier	Castlepoint	Kaikoura	Moeraki	Halfmoon	Jackson
1984		0.39	1.37	0.35		0.12	
1985		0.18	0.88	0.49		0	
1986			0.51	0.15		0.03	
1987			1.70	1.71		0.51	
1988		1.42	0.99	0.76		0.07	
1989		1.02	1.52	1.26		0.17	
1990		1.08	0.94	0.42	0.25	0.14	
1991	1.46	2.18	1.96	8.36	0	0.27	
1992	2.09	2.30	2.45	9.73	0.05	0.20	
1993	1.78	1.82	1.51	4.88	0	0	
1994	2.79	1.37	0.95	1.31	0	0.36	
1995	1.09	1.02	0.90	1.54	0.04	0.10	
1996	1.01	1.62	1.31	1.15	0.37	0.10	
1997	1.05	1.24	1.15	2.43	0.24	0.17	
1998	1.46	1.06	1.70	3.19	0.22	0.08	
1999	0.10	0.28	0.34	2.14	0.05	0.08	0.84
2000	0.95	0.64	0.56	1.88	1.29	0.38	0.78
2001	1.14	1.36	0.77	0.70	0.84	0.55	0.93
2002	1.11	1.08	0.69	1.84	0.34	0.42	3.33
2003	2.24	1.25	0.77	7.87	2.59	1.12	1.72
2004	0.77	1.05	0.65	2.72	0.18	0.04	0.32
2005	2.48	1.22	1.18	3.54	0.05	0	3.99
2006	0.37	0.57	0.65	2.95	0.04	0.04	0.44
2007	0.30	1.00	0.90	1.99	0.02	0.14	0.49
2008	0.70	0.57	0.89	3.73	0.07	0.03	0.31

3. STOCKS AND AREAS

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

Subdivision of the NSI stock on other than genetic grounds has been considered (Booth & Breen 1992; Bentley & Starr 2001). There are geographic discontinuities in the prevalence of antennal b]anding, 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 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).

Although considered separately for stock assessment purposes, the CHI stock (CRA 6) also appears to be genetically the same as the NSI stock. It may depend upon the NSI stock as a source of recruitment, but changes in abundance within the CHI stock are unlikely to affect the NSI stock.

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 NSN and NSC rock lobster decision rules and the existing CRA 3, CRA 4, CRA 7 and CRA 8 management procedures for the 2011-12 fishing year, based on CPUE data extracted in November 2010 and standardised as described below.

The NSN and NSC decision rules are just that; they are not proper management procedures because they have not been simulation-tested and they do not specify catch limits. They were developed in 1994 and have been evaluated every year since then without being triggered. Proper operational management procedures have now been developed for all three substocks of the NSC. Once a management procedure is adopted for CRA 5, then the NSC decision rule will become obsolete. The NSN decision rule is currently the only formal monitoring for CRA 1 and CRA 2, because no assessments have been done in these QMAs since 2002.

4.1 Data preparation

Data were extracted, groomed with method “B4” (Bentley et al. 2005) and aggregated by fishing year, month, rock lobster statistical area and vessel. The standardisation procedure (Maunder & Starr 1995; Bentley et al. 2005) uses month, statistical area and year (or period for CRA 4) as explanatory variables. Each QMA analysis was done separately and all data were used except for coded vessel number 4548, which has been consistently dropped from the NSN analysis.

The NSN and NSC decision rules use annual standardised CPUE indices based on the fishing year. The decision rule comparisons for the NSN and NSC are based on the exponents of year coefficients calculated by the regression model, which uses ln(catch/potlifts) as the dependent variable and bases the test for a significant change on the calculated standard error for each coefficient. The coefficients in these regressions are calculated relative to the fishing year with the smallest standard error.

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 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.

4.2 Decision Rules for NSN and NSC

The decision rule described by Breen *et al.* (1994) was modified by the National Rock Lobster Management Group (NRLMG) for the NSN and NSC substocks to allow consideration of TAC increases. The original decision rule required that a substock be assessed whenever a “standardised CPUE analysis” (Maunder & Starr 1995) showed CPUE for a given year to be significantly lower than the CPUE estimate for 1992–93. A year index is considered “significantly different” from the 1992–93 year index if their standard-error bars do not overlap.

NSN

The standardised CPUE for the NSN substock increased steadily between the 1992–93 and 1998–99 fishing years (Figure 5). There were four consecutive years of decrease between 1998–99 and 2002–03, but this trend reversed after 2003–04, increasing for the next four years to a minor peak in 2007–08. The index has now declined for two consecutive years. Under the NSN decision rule, the 2009–10 CPUE is significantly above the 1992–93 CPUE (Table 14).

Table 14: Decision rule indices for 1992–93 and 2009–10 fishing years (1 April to 31 March) for the NSN and NSC substocks. The index is the year effect from a standardised CPUE analysis using 1984–85 and 1982–83 as base years for the NSN and NSC respectively. The table also shows the upper and lower bounds, which are the index plus and minus one standard error respectively. The final column indicates the significance of change between the two years (* = significant increase), based on a comparison of the 2009–10 lower bound (bold) with the 1992–93 upper bound (grey boxes).

Substock	1992–93 Index	1992–93 Lower	1992–93 Upper	2009–10 Index	2009–10 Lower	2009–10 Upper	Result
NSN	0.968	0.936	1.001	1.571	**1.506**	1.639	*
NSC	0.395	0.388	0.403	0.972	**0.945**	1.001	*

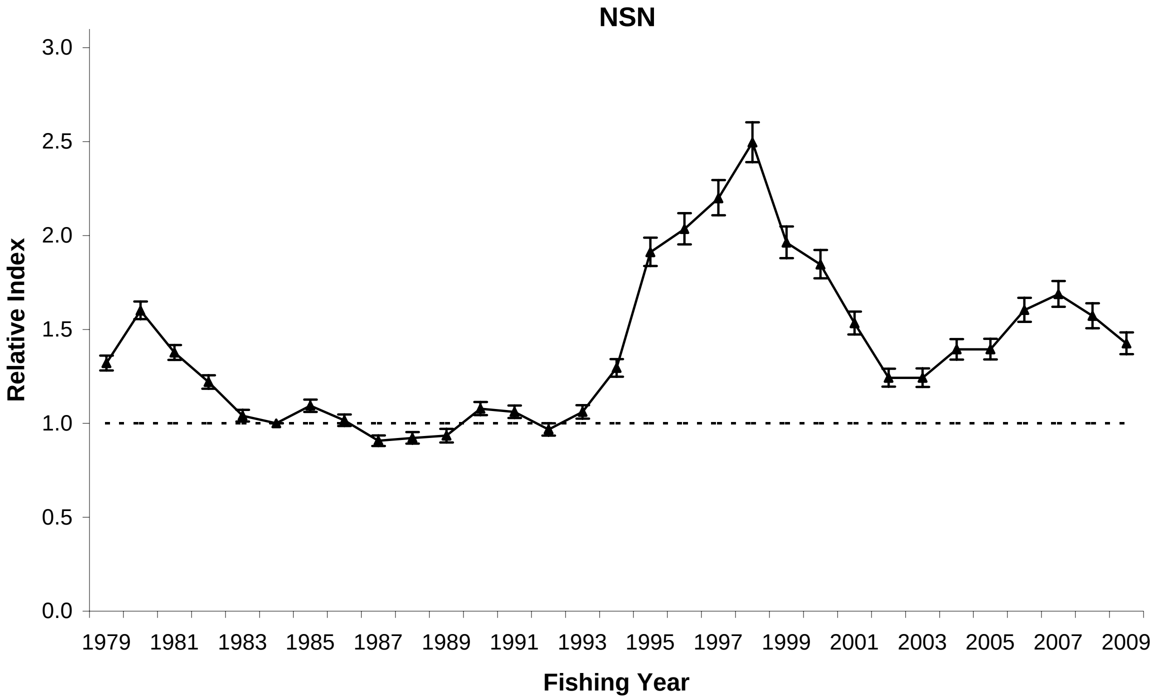


Figure 5: Values of the year index from the standardised CPUE analysis for the NSN substock showing plus and minus one standard error for each year. Horizontal line shows the index+ 1*S.E. upper bound of the 1992–93 standardised index (grey box: Table 144), which is the threshold for triggering this decision rule. Each year index is relative to the 1984-85 fishing year (the year with the lowest standard error).

NSC

As in the NSN substock, standardised CPUE for the NSC substock increased steadily between the 1992–93 and 1998–99 fishing years (Figure). After reaching the 1998 peak, there was a continuous decline in CPUE to a level about 50% below the 1998–99 peak, reached in 2007–08. CPUE has recovered strongly in the two years since 2007–08. Under the decision rule, the 2009–10 CPUE is significantly above the 1992–93 CPUE (Table 144).

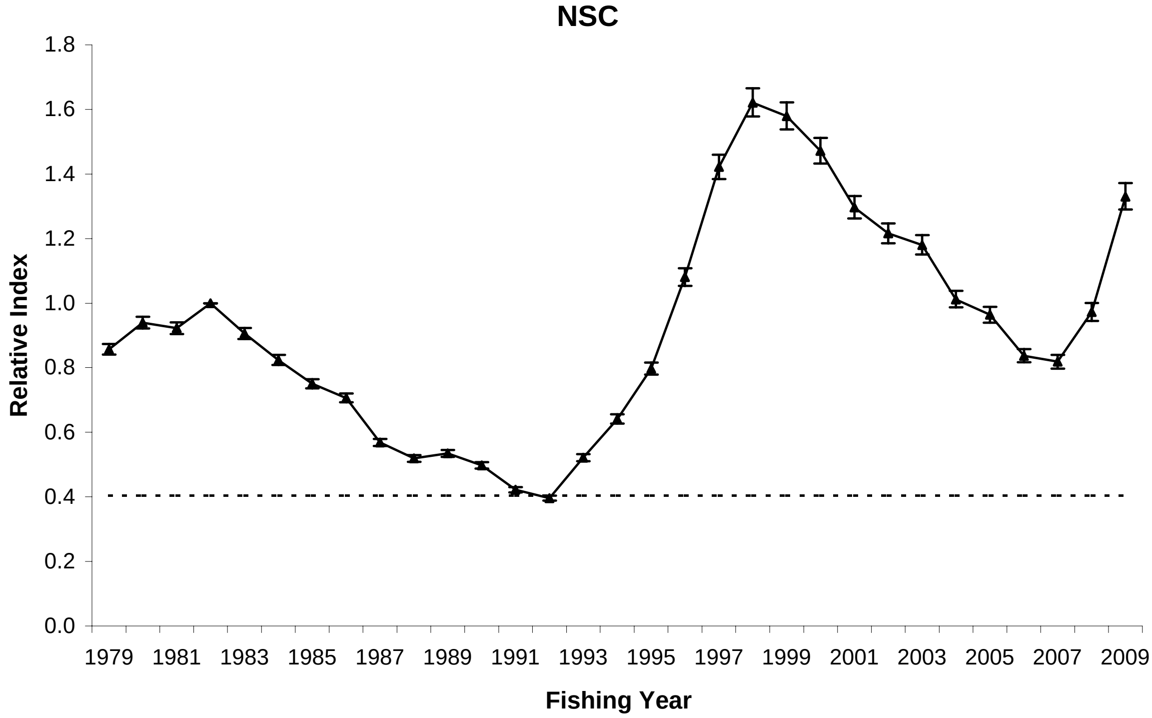


Figure 6: Values of the year index from the standardised CPUE analysis for the NSC substock showing plus and minus one standard error for each year. Horizontal line shows the index+ 1*S.E. upper bound of the 1992–93 standardised index (grey box: Table 144) which is the threshold for triggering this decision rule. Each year index is relative to the 1982–83 fishing year (the year with the lowest standard error).

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:

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

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

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

6. After the initial fixed TAC expires, if the procedure results in a TAC that does not change by more than 5%, no change will be made; and if the procedure results in a TAC that changes by more than 10%, the TAC will be changed by 10% only. The relation between CPUE and provisional TAC (before minimum and maximum change limits operate, and ignoring the initial fixed TAC) is illustrated in Figure .

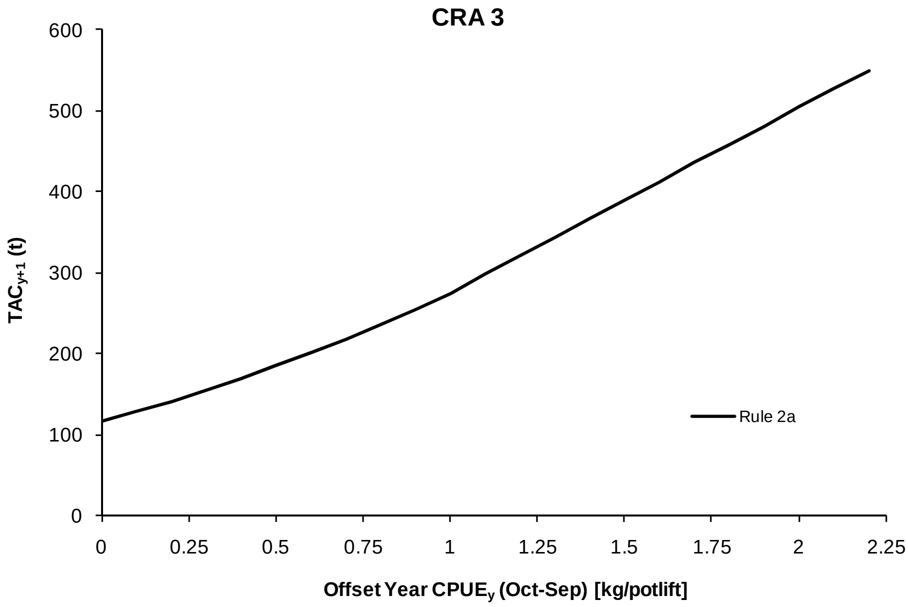


Figure 7: The CRA 3 management procedure, showing the provisional TAC as a function of CPUE.

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 (15).

Table 15: 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 (proposed)	1.027	293	–	–

In November 2010, the standardised offset-year CPUE was 1.027 kg/potlift. Under the management procedure, the proposed TAC would remain at 293 t because the CPUE remains above the 0.75 kg/potlift threshold and below the 1.08 kg/potlift threshold.

4.4 Management Procedure for CRA 4

The most recent stock assessment for CRA 4, completed in 2005 (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 8), is specified as follows:

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

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%.

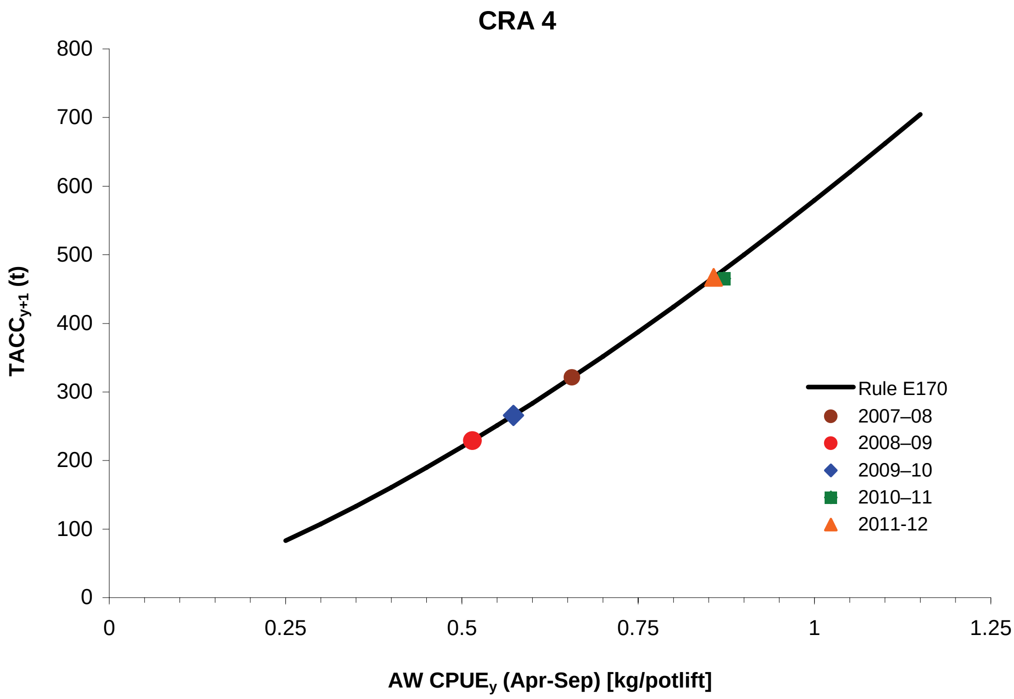


Figure 8: Graphic representation of the CRA 4 management procedure, plotting the catch limits in the next year as a function of CPUE in the current year and showing the CPUE values that generated the catch limit proposals for 2007–08, 2008–09, 2009–10, 2010–11 and 2011–12.

The history of the CRA 4 management procedure is shown in Table 16. 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.

Table 16: History of the CRA 4 management procedure, showing proposed limits to the commercial fishery in each of three years. The "operational limit" shows the level of voluntary shelving achieved for the 2007–08 and 2008–09 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 (proposed)	0.857	466.9	–		–

The most recent AW standardised CPUE estimate for CRA 4 is 0.857 kg/pot for the period 1 April to 30 September 2010. Under the CRA 4 management procedure, the TACC would be 466.9 t.

4.5 Management Procedure for CRA 5

In 2010, a new management procedure was developed for CRA 5, using a 2010 stock assessment as the basis for an operating model (Haist et al. in prep). Elements of a voluntary ACE-shelving rule adopted by the CRA 5 industry in 2009 (Breen 2009) were incorporated into the proposed new management procedure. Note: a decision on the management procedure for this fishery had not been finalised when this report was completed (late November 2009).

4.6 Management Procedure for CRA 7

Since 1996, CRA 7 has been managed using management procedures, based on the observed CPUE in CRA 8 until 2007, then CPUE in CRA 7 since then. These have been revised over the years, 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 current harvest control rule for the CRA 7 management procedure gives provisional TAC as a simple function of CPUE. The rule is:

$$TAC'_{y+1} = 100 I_y$$

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 this rule is shown in Table 17. For 2010–11, the TAC change was limited by the 50% maximum change threshold. The operation of this rule for 2011–12 using the 2009–10 offset-year CPUE results in a TAC of 95.7 t (Figure 9).

Table 17: History of the current CRA 7 management procedure, showing proposed limits to the commercial fishery in each of four 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 (proposed under current MP)	0.957	95.7	–	––

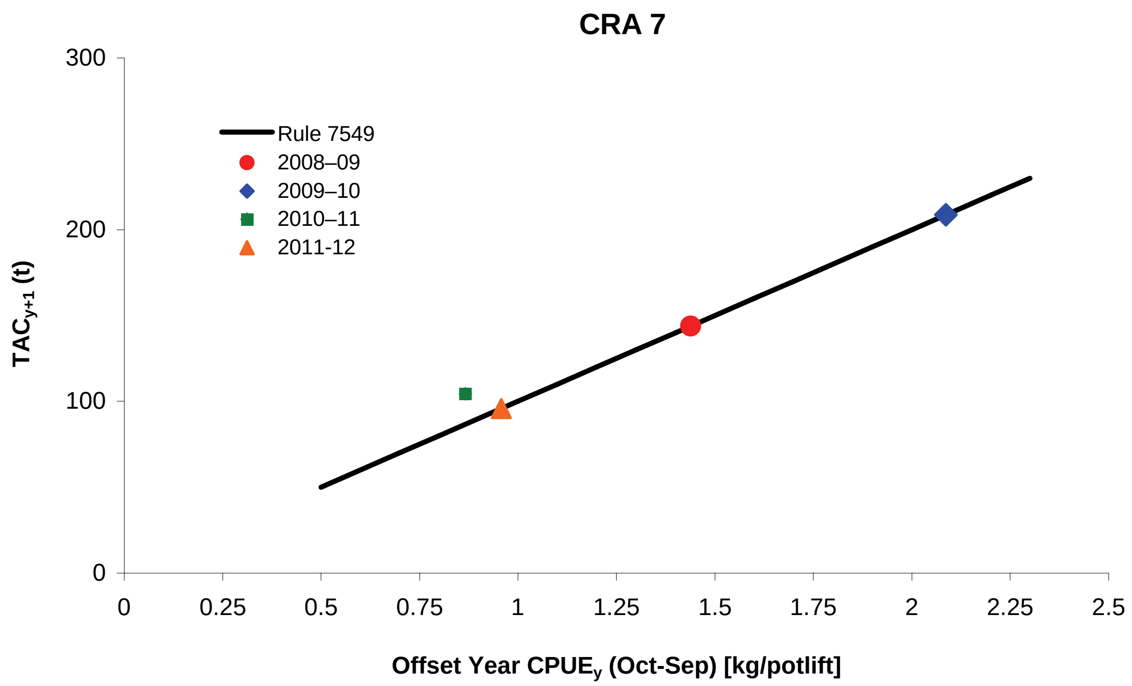


Figure 9: Graphic representation of the current CRA 7 management procedure, plotting the catch limits in the next year as a function of CPUE in the current year and showing the CPUE values which generated the limit proposals for 2008–09, 2009–10, 2010–11 and 2011–12.

In 2010, the CRA 7 industry requested exploration of a revised management procedure to reduce the apparent volatility of TACC. Note: any decision to chnage the management procedure for this fishery had not been finalised when this report was completed (late November 2009).

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 in every year. 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 10. 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:

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

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.

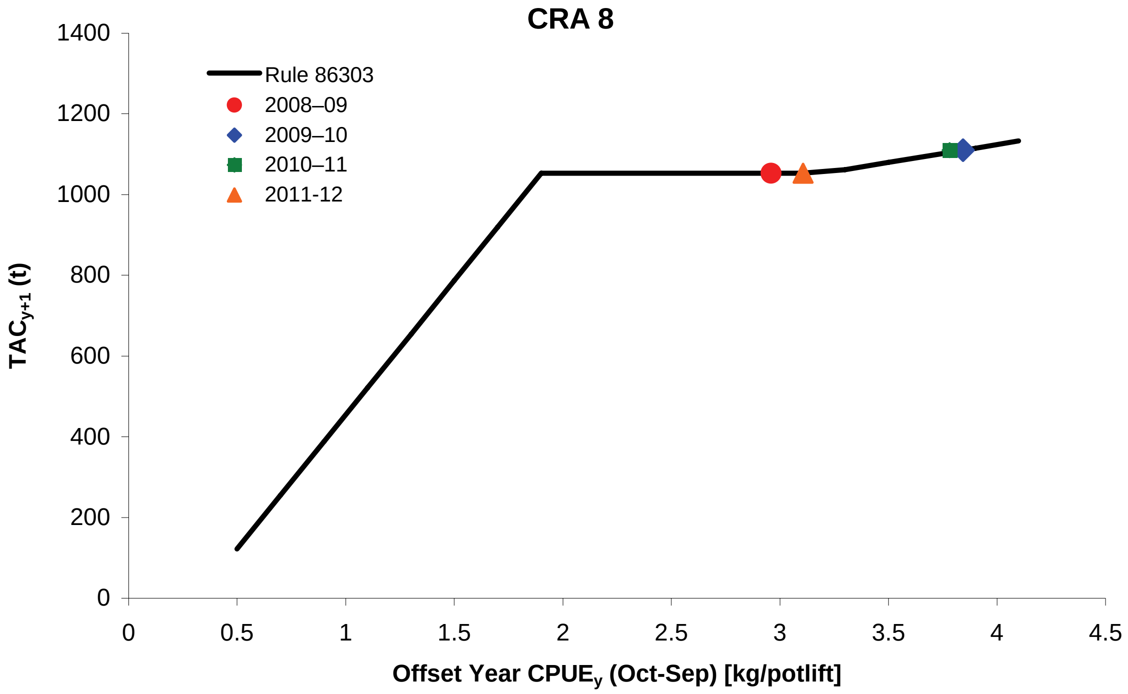


Figure 10: Graphic representation of the CRA 8 management procedure, plotting the TAC in the next year as a function of offset-year CPUE in the current year and showing the CPUE values which generated the TAC proposals for 2008–09, 2009–10, 2010–11 and 2011-12.

The history of the current CRA 8 management procedure is shown in Table . In 2009, the offset-year CPUE gave a provisional TAC that was a small decrease, but the decrease was less than the minimum change threshold of 5%, so no change was made.

Table 18: History of the CRA 8 management procedure, showing proposed limits to the commercial fishery in each of four 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 (proposed)	3.107	1053	–	–

The most recent annual standardised CPUE estimate for CRA 8 is 3.107 kg/pot for the period 1 October 2009 to 30 September 2010. Under the CRA 8 management procedure, the TAC would be 1053 t.

5. ENVIRONMENTAL EFFECTS OF FISHING

This section is new for the November 2010 Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of the rock lobster fisheries; a more detailed summary from an issue-by issue perspective will be available in the Ministry's Aquatic Environment Plenary that is under development.

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

5.1 Role in the ecosystem

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

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

Published scientific observations support predation upon rock lobsters by octopus (Brock *et al.* 2003), blue cod, groper, southern dogfish (Pike 1969) and seals (Yaldwyn 1958, cited in Kensler 1967). Anecdotal information supports predation upon rock lobsters by. rig (M. Francis *pers. comm.*).

5.2 Incidental catch (fish and invertebrates)

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

5.3 Incidental catch (seabirds and mammals)

Recovery of shags from lobster pots has been documented. One black shag (*Phalacrcorax carbo*) of 41 recovered dead from a Wairarapa banding study was found drowned in a crayfish pot hauled up from 12m depth (Sim and Powlesland 1995). Two Pitt Island shags (*Stictocarbo featherstoni*) were also recovered dead from lobster pots on a Chatham Island crayfish boat for 6 months from October 1997 to March 1998 (Bell and Bell 2000).

From January 2000 to August 2010, there were nine entanglements of eight humpback whales attributed to commercial or recreational rock lobster pots from the area within CRA5 from the Conway River north to Mangamaunu, which includes the Kaikoura Peninsula (DoC Unpublished report to Te Korowai, September 2010). No mortalities were observed, although mortalities are likely to be caused by prolonged entanglement, and therefore might not be observed within the same area. CRA 5 commercial fishermen work to a voluntary code of practice to avoid entanglements; this is awaiting endorsement from the Department of Conservation and Te Korowai. The commercial fishermen also cooperate with the Department of Conservation to assist releases when entanglements do occur.

5.4 Benthic interactions

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

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

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

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

5.5 Other considerations

There is no published information concerning ghost fishing by rock lobster pots in New Zealand, although since 1993 using pots with escape gaps has been compulsory in order to lessen the impact of potential ghost fishing. Ghost fishing occurs when lost gear continues to catch and kill animals.

Variable results have been seen with ghost fishing experiments internationally using lobster pots and, given differences in fishing techniques and species involved, the application of these studies to New Zealand is questionable. The loss to the fishery from retention or cannibalism in unbaited traps was estimated at a third or more of lobsters in or entering pots in a Maine study (Sheldon and Dow 1975). Contrastingly, lobster mortality was estimated at a maximum of 4% of entry into unbaited pots in Hawaii (Parrish and Kazama 1992). A study of ghost fishing of baited creels for Norway lobster concluded that once the initial bait was consumed, escape of captured lobsters was high and lost creels would cease to fish (Adey *et al*. 2008).

No habitats of particular significance to fisheries management have been defined for this fishery. An area near North Cape is, however, currently closed to packhorse lobster fishing to mitigate sub-legal handling disturbance in this area. This closure was generated due to the smaller sizes of animals there and results from a tagging study that showed movement away from this area into nearby fished areas (Booth 1979).

6. STOCK ASSESSMENT

A new stock assessment was completed in 2010 for CRA 5. This section also reports stock assessment results for other stocks from earlier Mid-Year Plenary documents. The text has not been updated from the original and reflects the TAC, TACC and allowances that were current at the time each assessment was completed.

6.1 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 Mregulations 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 14. 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 149.

Table 149: 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

The parameters estimated in each model and the priors used are provided in (Table 150). Fixed parameters and their values are given in (Table 21). 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 150: 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 21: Fixed parameter values used in basecase 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 22. 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 22: 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 41). Exploitation rate peaked in the early 1970s near 30% for the spring-summer fishery, and are currently in the 7–12% range.

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.

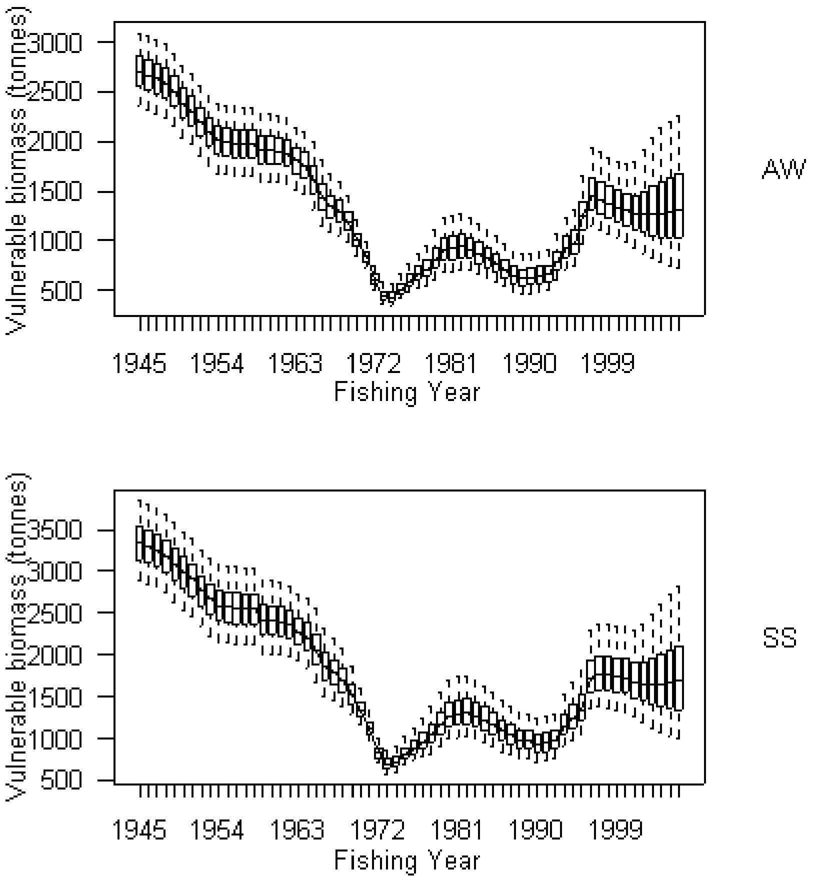


Figure 41: CRA 1: posterior trajectories of vulnerable biomass, for the AW (top) and SS (bottom) seasons, from the CRA 1 base case MCMC simulations. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.

Table 23: 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 (Table). 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 12). 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 24) 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).

Table 24: 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

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 (Table 24), 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.

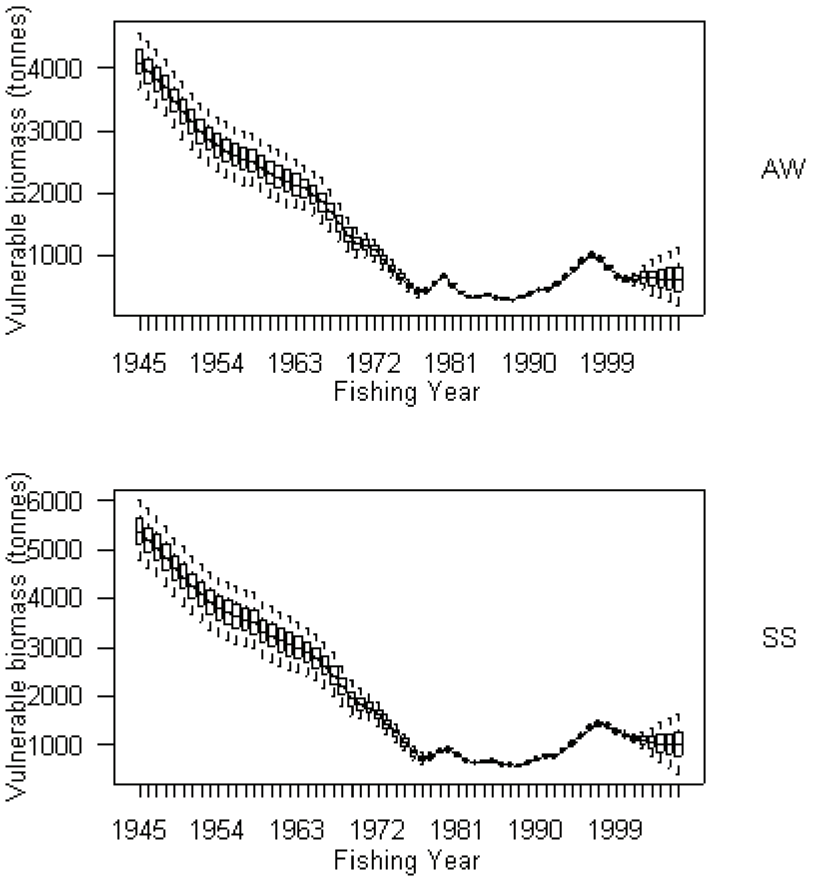


Figure 12: CRA 2: posterior trajectories of vulnerable biomass, for the AW (top) and SS (bottom) seasons, from the CRA 2 base case MCMC simulations. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.

6.2 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.

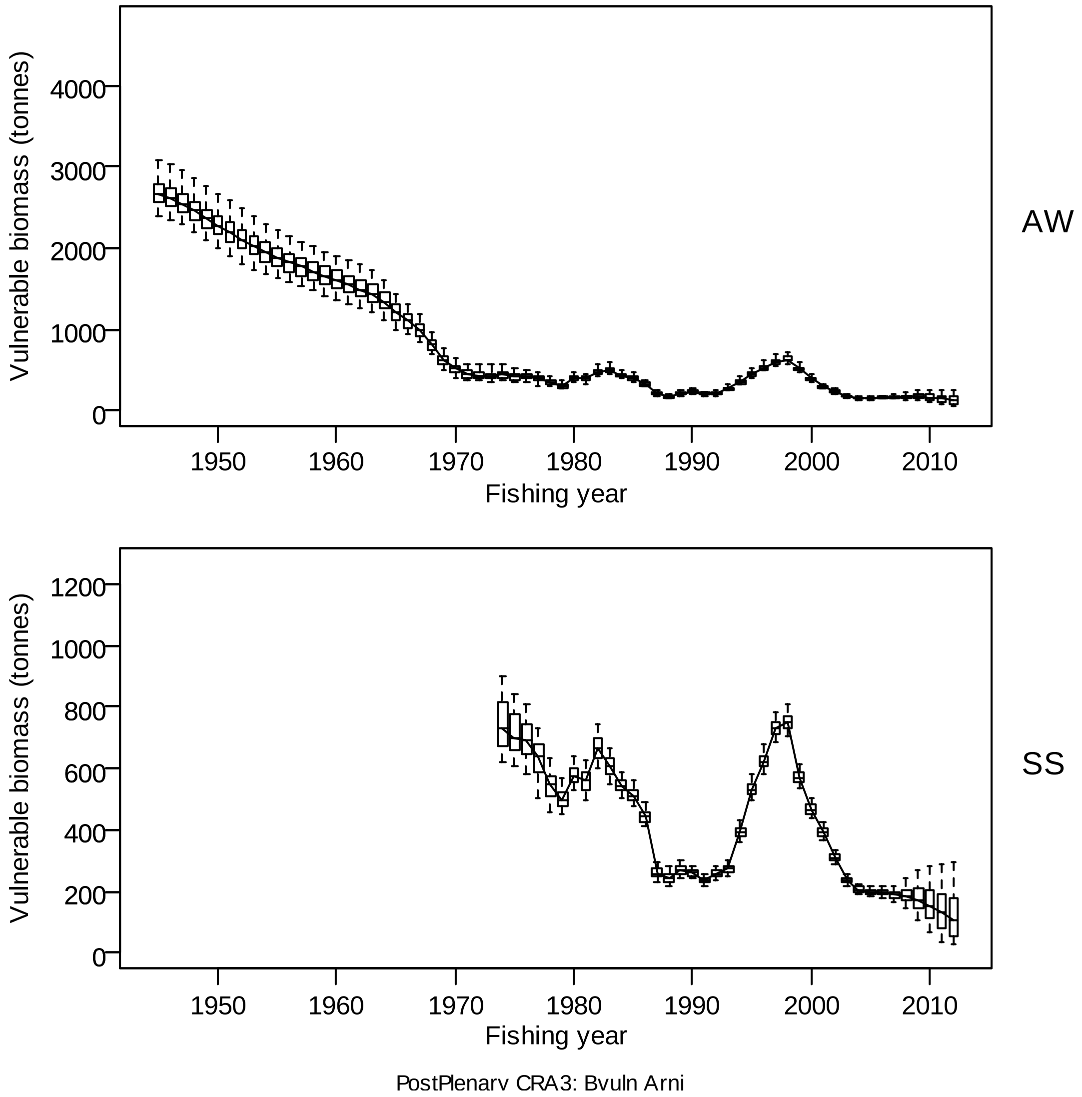


Figure 13: The posterior trajectory of vulnerable biomass, by season, from the CRA 3 base case McMC simulations, including the projections from 2008-12. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.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

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

Table 25: Quantities of interest to the assessment from the model base case McMCs. USL is the exploitation rate that produces the size-limited catch. All biomass values are in tonnes and represent the beginning of season AW vulnerable biomass.

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

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

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

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

Projections were made with alternative levels of SL catch (commercial plus recreational) with the NSL catch (illegal and customary) held constant (Table 26). These were 5-year projections made in the same way as the base case projections described above, and were made at the request of the Plenary for the guidance of the NRLMG, stakeholders and MFish.

Table 26: Results of 5-year projections with alternative SL catch levels.

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

6.3 CRA 4

This section reports an assessment for *J. edwardsii* for CRA 4 from the NSC substock taken from the 2005 Mid-year Plenary report (Sullivan et al. 2005).

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

A CRA 4 TAC was first set in April 1999 and remains at 771 tonnes. In that decision, the TACC was increased from 495.7 tonnes to 577 tonnes, based on a stock assessment made in 1998. Before 1999, the TACC had remained unchanged since April 1993. Within the TAC, allowances were made of 85 t for amateur and 35 t for customary catches, and an implicit allowance of 74 t for illegal catch. A stock assessment was made for CRA 4 in 2003 which did not result in any adjustment to the TAC or TACC.

The TACC of 577 t is distributed amongst 89 quota share owners. The fleet comprised an estimated 64 vessels (Starr 2009) in the 2003–04 commercial season, most operating from coastal bases in isolated rural areas. The CRA 4 commercial catch has a landed value of more than $18 million, based on the average landed value, and supports several processing and export operations in Napier and Wellington, Auckland and Canterbury.

The recreational catch history is unknown but was assumed as described in section 1 above, based on the 1994 and 1996 recreational surveys. Most recreational catch is taken in summer by potting and diving.

A comprehensive stock monitoring programme has been established in the CRA 4 fishery. There is a long time series of intensive catch sampling data from Napier, Castlepoint, Cape Palliser, and the Wellington south coast. This series was extended in 2004-05 with 35 samples (days), and 45 samples are planned for 2005-06. Tag recapture data are being routinely reported by commercial fishermen, and 4000 lobsters will be tagged in CRA 4 in 2005-06.

The seasonal CPUE for the 2005 autumn-winter period was estimated using a projection regression model fitted to partial season data (Rock Lobster Working Group document 2005/02). This projection model predicts the seasonal CPUE index using the pattern of historical CPUE indices compared to accumulated partial season data. This model was accepted by the Working Group because it showed good historical prediction performance. The autumn-winter and spring-summer catches for 2005 were also estimated from partial reported data, including allowing an expected overall shortfall of about 35 t from the TACC. Some length frequency data were also available for the 2005 autumn-winter season. The use of these partial year data allowed the extension of the assessment model to the end of 2005 and moved the start of the projection period to the autumn-winter of 2006.

Model structure

The length-based model, used in 2002 (Starr et al. 2003), 2003 (Kim et al. 2004) and 2004 (Haist et al. 2005), was used without major revision for the 2005 assessment. The model was fitted to two series of catch rate indices from different periods, and to size frequency and tag-recapture data. The model has three sex categories: male, immature female and mature female, and estimates a maturation schedule for females.

In the model, a year is divided into two seasons: autumn-winter (AW): April through September, and spring-summer (SS): October through March. This captures several biological processes: season- and sex-specific moult patterns, differential seasonal vulnerability between sexes, and a reduction in vulnerability of mature females greater than the MLS in the AW season because of their egg-bearing status. Seasonal structure is important to incorporate because, in the mid 1990s, several fisheries changed from predominantly SS fisheries to AW fisheries that caught mostly male lobsters (this trend has been partially reversed in some areas, including CRA 4).

Significant catches occurred in CRA 4 during the early part of the time series. Different MLS regulations existed in the past and escapement regulations have changed. We therefore incorporate historical information for CRA 4: time series of historical catches, sex-specific MLS regulations and catch per day estimates for the 1960s and early 1970s. Data and their sources are listed in Table 23.

The initial population in 1945 is assumed to be in equilibrium with base 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 AW season. The proportion of individuals recruiting to each size class is modelled as a normal distribution with a mean of 32 mm and a standard deviation of 2 mm. This distribution is truncated at the smallest size class in the model (30 mm). Recruitment in a specific year is the product of the base recruitment parameter and an annual deviation parameter. The vector of recruitment deviations is assumed to be normally distributed with assumed standard deviation 0.4. The years for which recruitment deviations were estimated were 1945 to 2003, with the last deviation also applied to 2004 and 2005 in minimisations.

b) **Mortality**. Natural, fishing and handling mortalities are applied to numbers in every sex/size class. Estimated natural mortality is assumed to be independent of sex, year and length. Fishing mortality is determined from observed catch and model biomass, modified by legal sizes, sex-specific seasonal vulnerabilities and size-specific selectivity curves.

   Fisheries that respect size limits (SL fisheries – legal commercial and recreational) are differentiated from those which do not (NSL fisheries – most of the illegal fishery plus the Mäori customary fishery). It is assumed that size limits and the prohibition of taking berried females apply only to the SL fisheries. Otherwise, selectivity and seasonal vulnerability functions are the same for the SL and NSL fisheries. Relative vulnerability is calculated by assuming that a specified sex in a specified season has the highest vulnerability and estimating the relative vulnerability for other sex/season combinations. 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 regulations over time (for instance, changes in escape gap regulations) are modelled by estimating separate selectivity parameters appropriate to each period of the fishery. For the CRA 4 assessment, the shape of the right-hand part of the curve was assumed to be flat.

d) **Growth and maturity**. For each sex in each season, a growth transition matrix specifies the probability of an individual remaining in the same size class or growing into a different size class. Maturity for females is estimated as a two-parameter logistic curve from the maturity-at-size information in the size frequency data, but for the CRA 4 assessment there were few immature females in the data, reflecting a small size at maturity, and one maturity parameter was assumed.

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 1979–80 through to the autumn-winter of 2005–06 fishing years. The index for the most recent period (AW 2005) was estimated using a regression method which predicts the seasonal CPUE based on partial in-season data (up to July 2005) (working group paper RLWG2005/02). 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 for abundance indices and a normal error structure for tag-recapture data and proportions-at-length.

The model was fitted to size data (proportions-at-length) taken from commercial pots, data obtained from research sampling conducted on commercial vessels. Voluntary logbooks were maintained by only one rock lobster fisherman in CRA 4 and were not considered sufficiently representative of the whole fishery to be included as input to the assessment. Estimates of the seasonal size frequency 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. A fundamental assumption is that the size frequency data are representative of the commercial lobster catch. Size proportions within each season are normalised to one across all three sex categories, providing the model with seasonal estimates of the relative proportion-at-size by sex.

Tag-recapture data come from all tagging projects conducted. Because the numbers of recoveries of small and large lobsters were limited, the CRA 4 tag data were augmented with an equal number of records from CRA 3 and CRA 5, after first establishing that the growth rates within the sizes of overlap in the data were similar.

A summary of data used, data sources and the applicable years are provided in Table 27. For this assessment it was observed that few tag-recapture data involved larger lobsters.

Table 27: Data types and sources for the 2005 assessment for CRA 4. Year codes apply to the first 9 months of each fishing year, viz. 1998–99 is called 1998. MFish: NZ Ministry of Fisheries; NZ NZRLIC: Rock Lobster Industry Council. –: not applicable.

Data type	Data source	Begin year	End year	Number
Historical catch rate	Annala & King (1983)	1963	1973	21
CPUE	FSU & CELR	1979	2005 (AW)	53
Observer proportions-at-size	MFish and NZ NZRLIC	1986	2003	33
Tag recovery data	NZ NZRLIC & MFish	1998	2004	2146
Historical MLS regulations	Annala (1983), MFish	1945	2004	–
Escape gap regulation changes	Annala (1983), MFish	1945	2004	–

The parameters estimated and the priors used are provided in Table 28. Fixed parameters and their values are given in Table .

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

Table 16: Parameters estimated and priors used in basecase assessments for CRA 4. Prior type abbreviations: U– uniform; N – normal; L – lognormal.

	Prior Type	Lower bound	Upper bound	Mean	CV
Log R_0 (ln 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
LogqI	U	-25	0	–	–
LogqCR	U	-25	2	–	–
Increment at TW=50 (male & female)	U	1	8	–	–

	Prior Type	Lower bound	Upper bound	Mean	CV
Difference between increments at TW=80, TW=50	U	0.001	30	–	–
Shape of length-growth increment relation	U	0.1	20	–	–
Relative sex/season vulnerability: [2]	U	0	1	–	–
Shape of ascending limb of vulnerability ogive	U	1	50	–	–

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

Table 29: Fixed values used in basecase assessment for CRA 4.

Quantity	CRA 4
Common error component (sigma tilde)	0.1108
(TW at 95% probability female maturity) – (TW at 50% probability female maturity)	20 mm
Shape parameter for biomass-CPUE relation	1
Minimum std dev of growth increment	1 mm
Std dev of observation error of increment	2.68 mm
Growth CV (male and female)	0.5
Shape of descending limb of vulnerability ogive	200
Std dev of historical catch per day	0.30
Maximum exploitation rate per season	90%
Handling mortality	10%
Process error for CPUE	0.25
Process error for historical catch rate	0.3
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	2003
Relative weight for length frequencies	1.25
Relative weight for CPUE	0.317
Relative weight for CR	0.5
Relative weight for tag-recapture data	0.5
Sex-season with maximum vulnerability	male (AW)

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 by AD Model Builder™ 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 a Markov chain – Monte Carlo procedure (MCMC) and the Hastings-Metropolis algorithm;

c) For each sample of the posterior, 3-year projections (encompassing the 2006–07 to 2009–10 fishing years) were generated by assuming the catches indicated in Table 17. Future annual recruitment was randomly sampled with replacement from the model's estimated recruitments from the period 1994–2003;

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.

At the request of the RLWG, projections were made with both our “best estimate” of future catch - comprising the TACC plus the current estimates of non-commercial catch and with the allowances specified in the TAC (Table 17). For both sets of projections, the current split of AW and SS was used.

Table 17: Catches (t) used in the 3-year projections for CRA 4. Two sets of projected catches were used: one based on the TACC and the current “best” estimates of recreational, customary and illegal catches; the other based on the allowances in the TAC. The “reported illegal” catches are subtracted from the legal commercial catch.

	Size-limited (SL) catch			Not size-limited (NSL) catch			
Catch category	Commercial	Recreational	Total	Reported illegal	Unreported illegal	Customary	Total
“Best” estimate of catch	571	47	618	5	35	20	60
TAC allowances	567	85	652	10	64	35	109

Performance indicators

The assessment used several performance indicators based on biomass and exploitation rate, all using beginning season biomass legally available and vulnerable to the fishery (e.g. above MLS and non-berried females) in the autumn-winter season (vulnerable biomass). The minimum biomass indicator, B_{min}, varies between MCMC draws, so it is not possible to define a single year as the expected minimum biomass. Current biomass, $B_{current}$, is taken from the autumn-winter season of 2006 because the assessment extends to the end of 2005 (see above). Projected biomass, B_{proj}, is taken from the autumn-winter season of 2009. A list of the projection performance indicators is provided in Table 181.

Table 181: Performance indicators for the 2004 CRA 4 stock assessment projections

B_{ref}	mean of AW vulnerable biomass from 1979–88
B_{min}	nadir of AW vulnerable biomass
$B_{current}$	2006 AW vulnerable biomass
$U_{current}$	AW exploitation rate on the SL biomass in 2005
B_{proj}	2009 AW biomass
U_{proj}	AW exploitation rate on the SL biomass in 2008
$B_{current}/B_{ref}$	ratio: current biomass to reference biomass
$B_{current}/B_{min}$	ratio: current biomass to minimum biomass
B_{proj}/B_{ref}	ratio: projected biomass to reference biomass
$B_{proj}/B_{current}$	ratio: projected biomass to current biomass
B_{proj}/B_{min}	ratio: projected biomass to minimum biomass
$U_{proj}/U_{current}$	ratio: projected exploitation rate to current exploitation rate
$P\left(B_{proj} < B_{current}\right)$	probability projected biomass is less than current biomass
$P\left(B_{proj} < B_{ref}\right)$	probability projected biomass is less than reference biomass
$P\left(B_{proj} < B_{min}\right)$	probability projected biomass is less than minimum biomass

Stock assessment results - *Jasus edwardsii*, CRA 4

The base case assessment chosen for CRA 4 (Table 32) resulted from extensive exploration of about 200 alternative runs. Initially, the various datasets were given natural weightings by trying to obtain standard deviations of normalised residuals (sdnr) from all data sets that were close to 1. However, in most cases this resulted in poor fits to the CPUE data; also some key parameters were estimated at their bounds and the maximum exploitation bound was reached. By upweighting the CPUE data, better fits to the recent CPUE were obtained. However, these model runs were not robust to small changes in model structure assumptions and both the length frequency data and the tag data showed a greater than expected number of very large residuals. Satisfactory runs were found by downweighting the length frequency and tag data and fixing the common error component (instead of fitting this value) so that the model was able to fit the data more freely. The chosen basecase gave a value of approximately 1 for the sdnr for CPUE, decreased the number of large residuals in the length frequency and tag data and the maximum exploitation rate stayed below 0.9. The WG noted that there was more uncertainty with this assessment than indicated by the basecase outputs because of the sensitivity shown to the data weighting.

Base case results suggested that the index biomass decreased to stable but low levels throughout the 1980s and early 1990s (Figure 14). This period coincided with the largest catches from the QMA in the mid-1980s. However, catches and apparent productivity had declined by the early 1990s. The biomass then increased strongly to a peak in 1998 and has since declined. Exploitation rate peaked in the 1990 spring-summer season, but the base case and most of the sensitivity runs did not reach the assumed maximum exploitation rate (Table). Recent exploitation rates appear to be around 20-30% of the vulnerable biomass (Table 19).

Three MCMC sensitivity trials were made, including a) a “domed” trial where the right-hand limb of the selectivity function was estimated, allowing it to descend to obtain a better fit to the data; b) a trial where a non-linear fit was allowed to the CPUE data; and c) a trial where the non-commercial catches were arbitrarily doubled. Three retrospective MCMC sensitivity trials were also done, stepping backward one year at a time from 2004 to 2002 and refitting the model to the remaining data. These sensitivities investigated the major uncertainties in the basecase assessment.

Table 19: Summary statistics for performance indicators from posterior distributions from the CRA 4 basecase assessment. Biomass indicators are shown in tonnes.

Indicator	5%	Median	95%
B_{ref}	393	478	580
B_{min}	278	360	455
$B_{current}$	677	855	1068
$U_{current}$	21%	25%	30%
B_{proj}	426	808	1331
U_{proj}	18%	27%	45%
$B_{current}/B_{ref}$	1.50	1.78	2.12
$B_{current}/B_{min}$	1.94	2.37	2.95
B_{proj}/B_{ref}	0.92	1.68	2.73
$B_{proj}/B_{current}$	0.57	0.94	1.39
B_{proj}/B_{min}	1.23	2.24	3.67
$U_{proj}/U_{current}$	0.76	1.11	1.67
$P\left(B_{proj} < B_{current}\right)$	60%		
$P\left(B_{proj} < B_{ref}\right)$	7%		
$P\left(B_{proj} < B_{min}\right)$	2%		

None of the three sensitivity trials resulted in any major differences in stock status, with the non-linear CPUE trial being the most similar to the basecase. The “domed” sensitivity was slightly more optimistic and the “double non-commercial catch” trials was slightly more pessimistic than the basecase, but neither trial provided results which were qualitatively different from those shown in Table 19. The retrospective sensitivities were robust to the removal of the data, with little change in the results over the period investigated.

The assessment results (Table 19) are based on the posterior distributions of indicators. These were obtained from the MCMC simulations – a single chain of 4 million was made and 2000 samples were taken. They suggest that the current vulnerable biomass is currently two to three times B_{min} (0.05 and 0.95 quantiles were 94% to 195% greater than B_{min}) and 78% greater than B_{ref} (50% to 112% greater). Using the “best” estimate of current catches and using historical recruitments sampled from 1994–2003, the median expectation is that biomass will decrease by 6% over three years, but with wide bounds (-43% to +39% of current biomass). The probability of a decrease was 60%, however, the probability of going below the reference biomass is low (7%) as is the probability of going below the minimum biomass (2%).

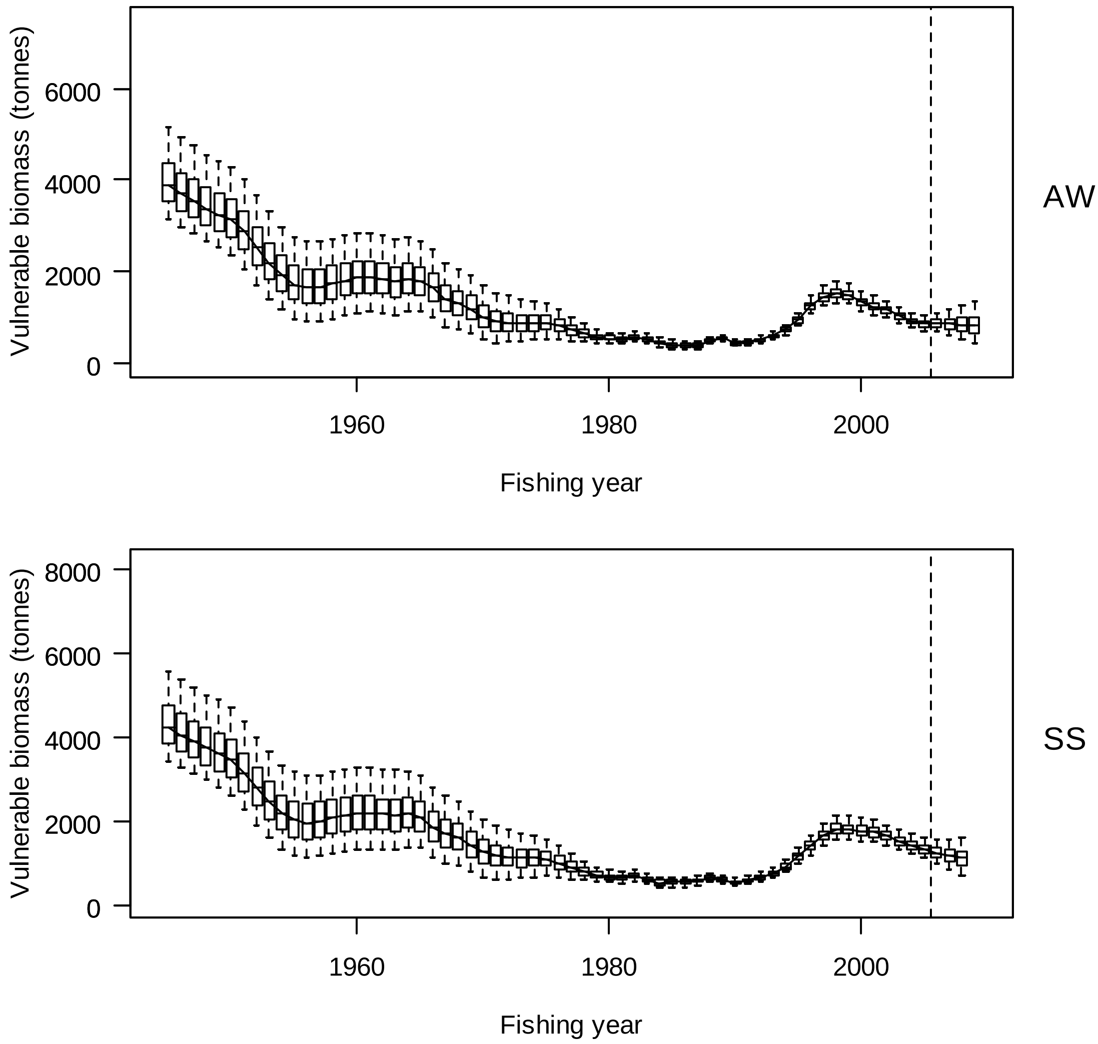


Figure 14: Posterior trajectories of vulnerable biomass, for the AW (top) and SS (bottom) seasons, from the CRA 4 base case MCMC simulations. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles. The vertical dashed line shows the beginning of the projection period.

The projections based on the sensitivity trials were also very similar to the basecase, with the “double non-commercial catch” trial giving the same probabilities of decline and exceeding the reference biomass levels as shown in Table 19. The “domed” projections were slightly more optimistic, with only a 50% probability of decline and almost no chance of exceeding the reference biomass levels. The projections rely on an assumption that recruitment would be similar, on average, to that in the 1994–2003 period and with variability as seen in those ten years.

6.4 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 20.

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 (Table 20) and puerulus settlement data using lognormal likelihood. The model was fitted to proportions-at-length with multinomial likelihood and tag-recapture data with robust normal likelihood. For the CPUE and puerulus lognormal likelihoods, CVs for each index value were initially set at the standard error from the GLM analysis. Process error was subsequently added to these CVs so that the overall standard deviation of the standardised (Pearson) residuals was near 1.0. A fixed CV of 0.3 was used for the historical catch rate data. The robust normal likelihood was used for the tagging data so that data outliers (defined as observations with a standardised residual greater than 3.0) would be downweighted. Proportions-at-length, assumed to be representative of the commercial catch, were available from both observer catch sampling and voluntary logbooks; these were fitted separately. Data were summarised by area/month strata and weighted by the commercial catch taken in each stratum, the number of lobsters measured and the number of days sampled. Size data from each source (research sampling or voluntary logbooks) were fitted separately. Seasonal proportions-at-length summed to one across males, immature and mature females. Experiments (randomisation trials) were conducted to establish that puerulus settlement data contained a signal about recruitment.

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

Table 20: Data types and sources for the 2010 assessment for CRA 5. Year codes apply to the first 9 months of each fishing year, viz 1998-99 is called 1998. NA – not applicable or not used; MFish – NZ Ministry of Fisheries; NZRLIC – NZ Rock Lobster Industry Council.

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

Parameters estimated in each model and their priors are provided in Table 21. Fixed parameters and their values are given in Table 35. 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 21: 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 35: 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

	CRA 5
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:

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

b) Samples from the joint posterior distribution of parameters were generated with Markov chain - Monte Carlo (MCMC) simulations using the Hastings-Metropolis algorithm; 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 22);

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

Table 22: Catches (t) used in the five-year projections. Projected catches are based on the current TACC for CRA 5, and the current estimates of recreational, customary and illegal catches.

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

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

Base case results suggested that biomass decreased to a low point in 1991, remained low through 1995, then increased (Figure 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 38). However, projected biomass would decrease at the level of current catches over the next 4 years (Figure 5)..

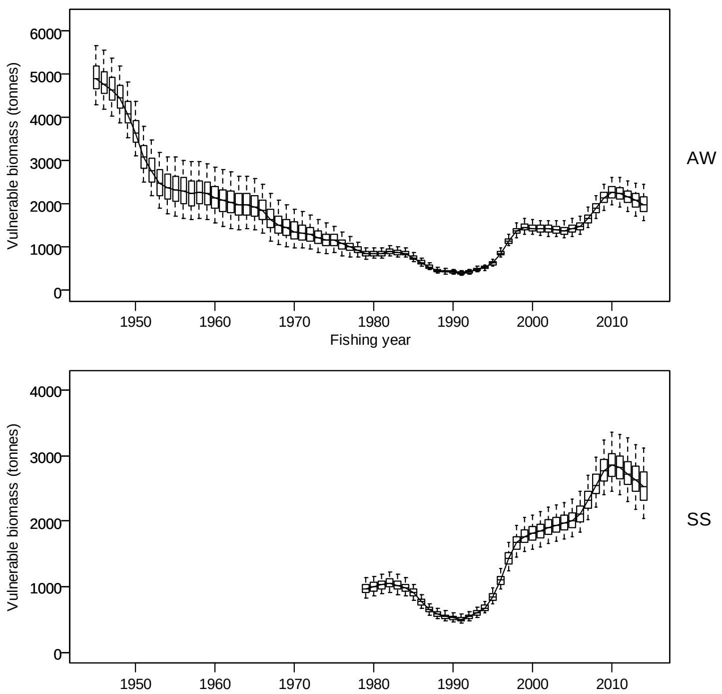


Figure 15: Posterior distributions of the base case McMC biomass vulnerable trajectory. Before 1979 there was a single time step, shown in AW. Projected catches were scenario 1 (Table 22). For each year the horizontal

line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th quantiles.

Table 37. Performance indicators used in the CRA 5 stock assessment

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

A series of MCMC sensitivity trials was also made, including exclusion of puerulus data, using a flat recreational catch vector, fixed M, fast growth found in an exploratory trial, density-dependent growth and estimated shape of the CPUE/biomass relation. The assessment results from the base case and sensitivity trials calculated as a series of agreed indicators (Table 37) are shown in Table for the more aggressive of the two catch scenarios (Scenario 1, Table 22). Indicators from Scenario 2, with lower projected catches, are not reported.

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

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

Table 38: Assessment results – medians of indicators described in Table 37 from the base case and sensitivity trials under Scenario 1 catches (Table 22); 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

	base	no puerulus	flat rec. catch	fixed M	fast growth	d-d growth	non-linear CPUE
Bcurr/Bmsy	4.62	4.62	5.54	3.10	2.53	2.88	2.82
Bproj/Bmin	4.91	6.15	5.15	5.51	3.60	5.23	2.23
Bproj/Bcurr	0.88	1.09	0.91	0.95	0.81	0.92	0.78
Bproj/Bref	2.60	3.27	2.75	2.92	1.89	2.57	1.45
Bproj/Bmsy	4.03	5.01	5.03	2.96	2.07	2.66	2.19
USLcurrent	0.122	0.122	0.101	0.145	0.327	0.184	0.187
USLproj	0.131	0.105	0.104	0.139	0.401	0.188	0.239
USLproj/USLcurrent	1.08	0.86	1.03	0.97	1.23	1.03	1.27
Fmult	5.47	5.41	9.51	2.73	4.05	2.97	3.14
P(Bref>Bmsy)	1.000	1.000	1.000	0.568	0.890	0.570	1.000
P(Bcurr>Bmin)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(Bcurr>Bref)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(Bcurr>Bmsy)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(Bproj>Bmin)	1.000	1.000	1.000	1.000	1.000	1.000	1.000
P(Bproj>Bcurr)	0.075	0.787	0.092	0.289	0.162	0.093	0.025
P(Bproj>Bref)	1.000	1.000	1.000	1.000	0.979	1.000	0.991
P(Bproj>Bmsy)	1.000	1.000	1.000	1.000	0.986	1.000	1.000
P(USLproj>USLcurr)	0.804	0.110	0.663	0.360	0.794	0.652	0.960
P(SSBcurr<0.2SSB0)	0	0	0	0	0	0	0
P(SSBproj<0.2SSB0)	0	0	0	0	0	0	0

Indicators based on *SSBmsy*
SSBmsy is biomass of mature females associated with B_{MSY}. The historical track of biomass versus fishing intensity is shown in **Error! Reference source not found.**. 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 **Error! Reference source not found.** has been calculated using the 2009 fishing pattern.

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

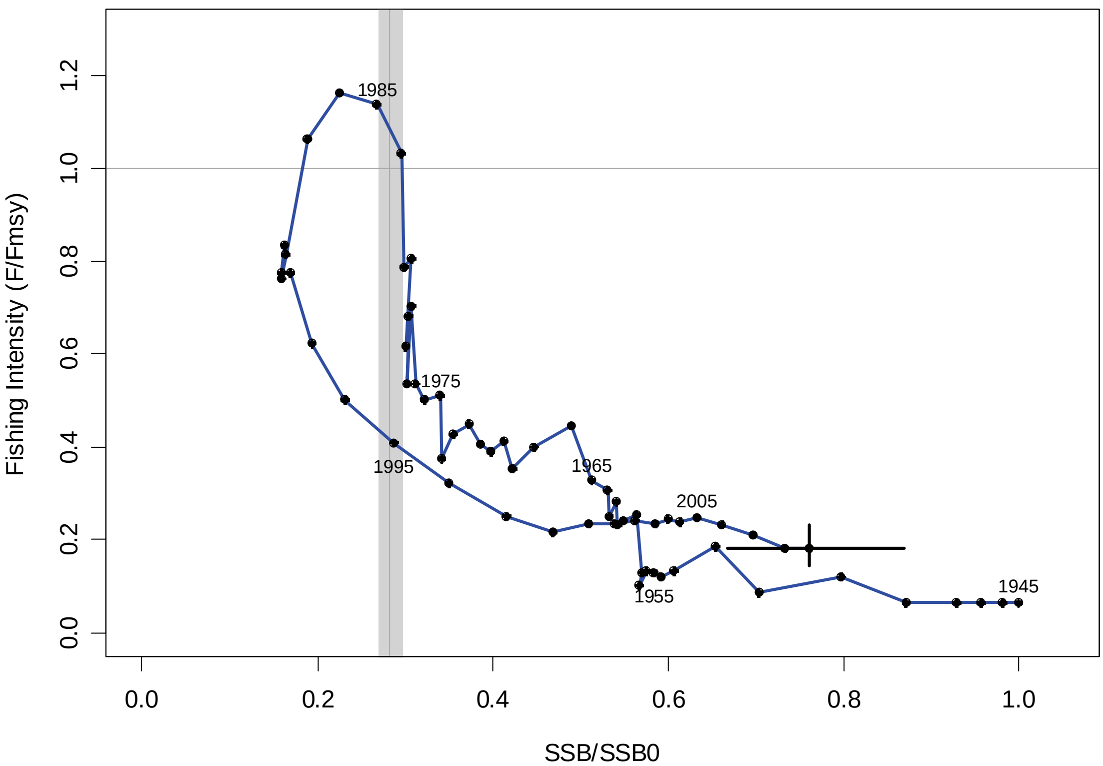


Figure 16: "Snail trail" that summarises the history of the CRA 5 fishery. The x-axis is the spawning biomass (SSB) as a proportion of B0 (SSB0); the y-axis is the ratio of the fishing intensity (F) relative to Fmsy. Each point is the median of the posterior distributions, and the bars associated with 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.

6.5 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.

6.6 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).

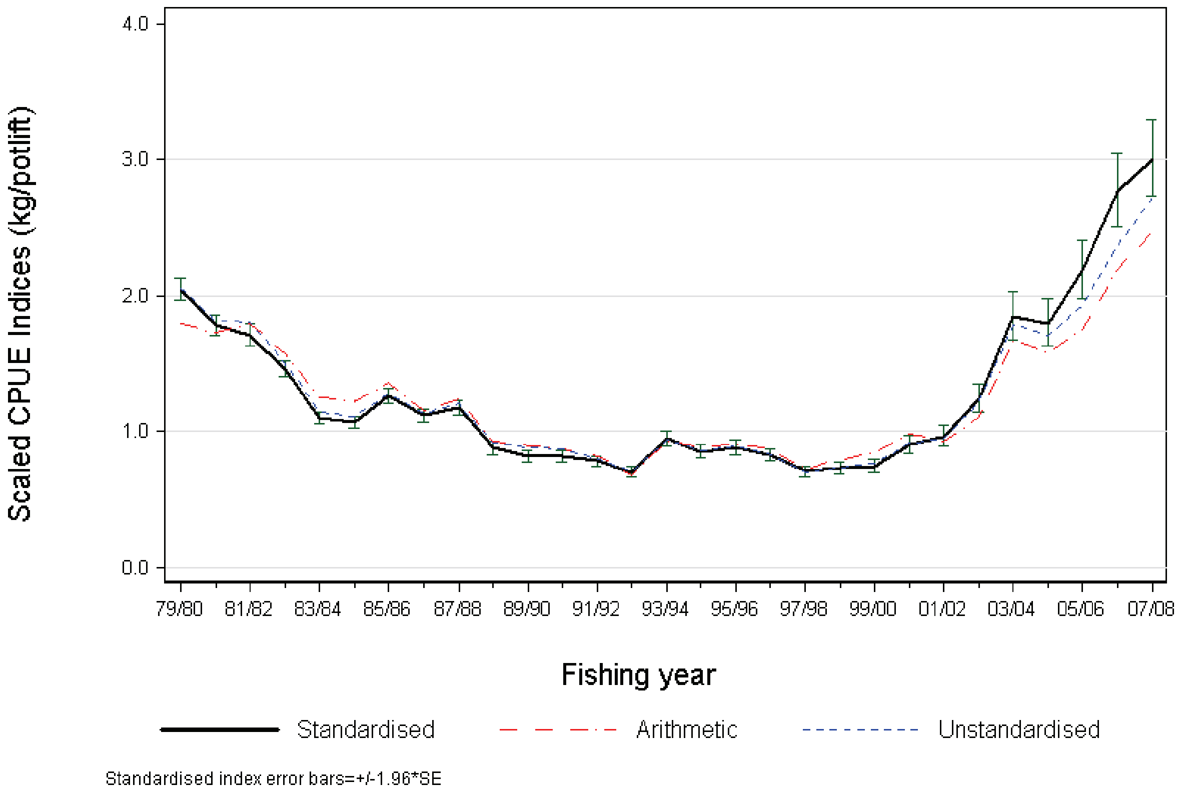


Figure 17: Annual CPUE indices for CRA 8: arithmetic (dashed line), unstandardised (dotted line), and standardised (bold line) ± 2 s.e. 1979–80 to 2007–08. The geometric mean for each series = 1.13 kg/potlift.

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 basecase was not considered acceptable by the Working Group to report as the final assessment for these stocks. However, the Working Group did not consider there was any current sustainability concern with these stocks. 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.

7. YIELD ESTIMATES

7.1 Estimation of Maximum Constant Yield (MCY)

***Jasus edwardsii*, all stocks**

MCY was not estimated.

***Sagmariasus verreauxi*, PHC stock**

MCY was estimated using the equation $MCY = cY_{av}$ (Method 4). Mean annual landings for 1979–96 were 20.0 t. The best estimate of *M* is 0.1, so the value of *c* was set at 0.9.

$$MCY = cY_{av} = 0.9 * 20 = 18 \text{ t}$$

It is not possible to assess the level of risk to the stock of harvesting the population at the estimated MCY value.

7.2 Estimation of Current Annual Yield (CAY)

***Jasus edwardsii*, all stocks**

CAY was not estimated for any stock.

***Sagmariasus verreauxi*, PHC stock**

CAY was not estimated because no biomass estimates are available for this stock.

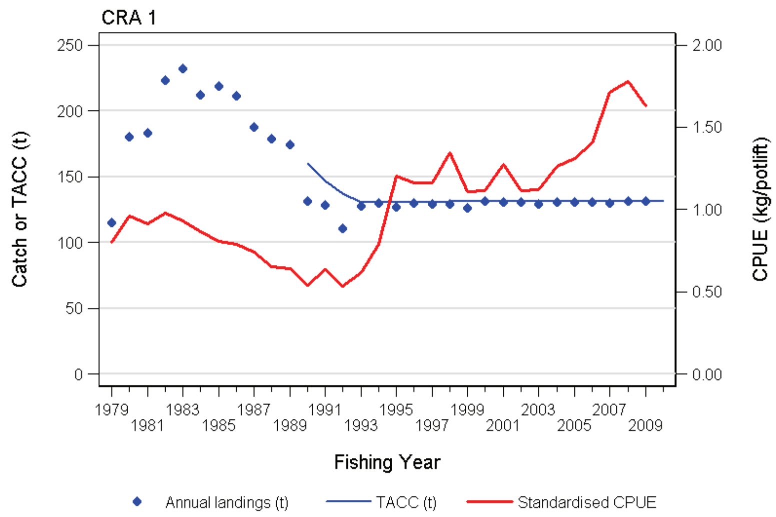
8. STATUS OF THE STOCKS

8.1 *Jasus edwardsii*, NSN substock

CRA 1 Northland

Stock Status	
Year of Most Recent Assessment	2002
Assessment Runs Presented	Base case and 2 sensitivity runs
Reference Point	- *Bref*: mean of beginning AW vulnerable biomass for the period 1979-88
Status in relation to Target	Biomass in 2002 was 150% of reference biomass
Status in relation to Limits	Unknown

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA1 from 1979 to 2009.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Standardised CPUE increased steadily from 2003 to 2008, but dropped in 2009
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 under 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

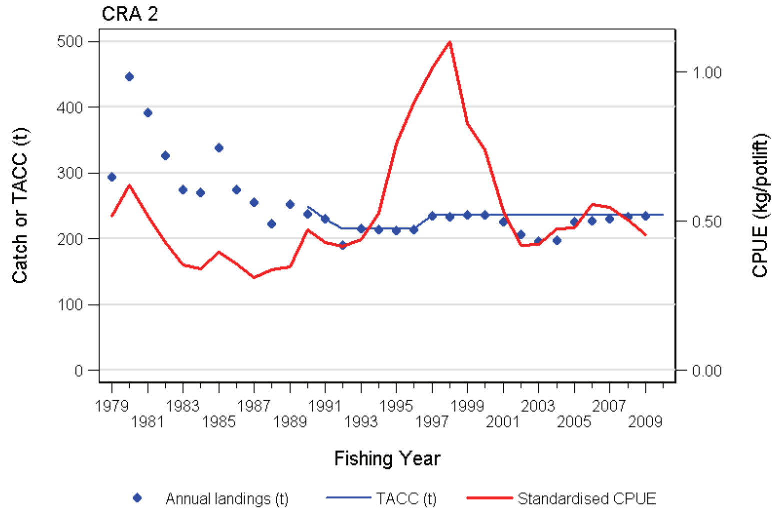
Recent developments in stock status
CPUE in the last 3 years is well above the 2002 level, and the stock is well above the target (reference) level.

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 Point	- *Bref*: mean of beginning AW vulnerable biomass for the period 1979-88
Status in relation to Target	Biomass in 2002 was 150% of reference biomass
Status in relation to Limits	Unknown

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA2 from 1979 to 2009.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Standardised CPUE dropped to below 0.5 kg/potlift from the peak year in 1997. Since then CPUE has remained relatively constant around this level but has declined in the most recent 2-3 years
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 under 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
Recent developments in stock status
CPUE increased from 2002 to 2007 but has since decreased back to the 2002 level.

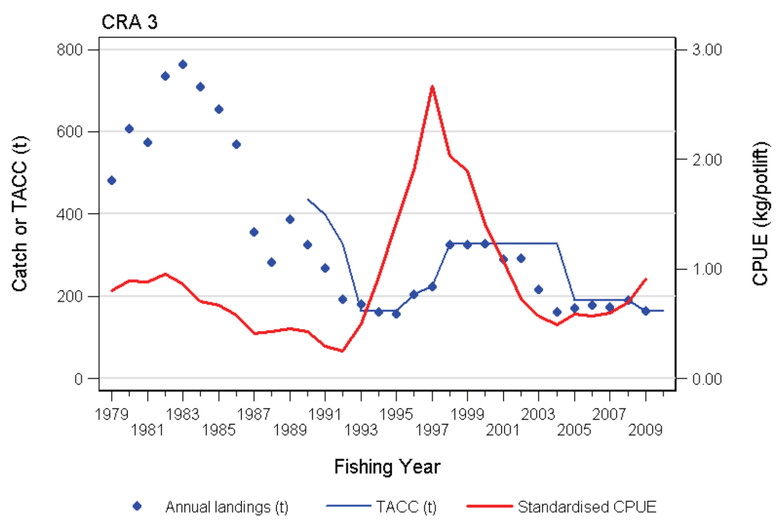
Fishery Interactions

8.2 *Jasus edwardsii*, NSC substock

CRA 3 Gisborne

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	Base case and 13 MPD sensitivity runs
Reference Point	B_{MSY}
Status in relation to Target	Biomass in 2008 was about half B_{MSY}, with a 0% probability of being above B_{MSY}
Status in relation to Limits	Biomass in 2008 was 11% above B_{min}, with an 82% probability of being above B_{min}

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA3 from 1979 to 2009.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass declined steadily from 1997 to 2003 and may now be 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 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	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Multi-stock length based model (Haist et al 2009)	
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	

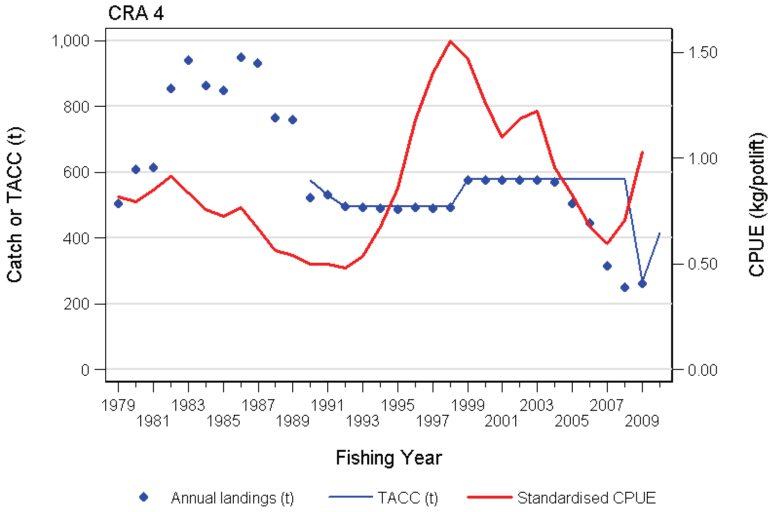
Qualifying Comments
The quality of the 2008 Markov chain–Monte Carlo simulations was not high. The running quantile plots for many estimated parameters showed a drift through the run, suggesting poor convergence, and a trend to move well away from the MPD estimate.

Recent developments in stock status
CPUE has been increasing since 2004. In 2010 the management procedure for CRA 3 proposed that the TAC would remain at 293 t because the CPUE remains above the 0.75 kg/potlift threshold and below the 1.08 kg/potlift threshold.
Fishery Interactions

CRA 4 Wairarapa – Hawke Bay

Stock Status	
Year of Most Recent Assessment	2005
Assessment Runs Presented	Base case and 3 MCMC sensitivity runs
Reference Point	- *Bref*: mean of beginning AW vulnerable biomass for the period 1979-88
Status in relation to Target	Biomass in 2005 was about 1.8 times the reference level
Status in relation to Limits	Unknown

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA4 from 1979 to 2009.

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 in the two most recent years
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 under 2005 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, tagging data	
Period of Assessment	Latest assessment: 2005	Next assessment: Unknown
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty		

Qualifying Comments

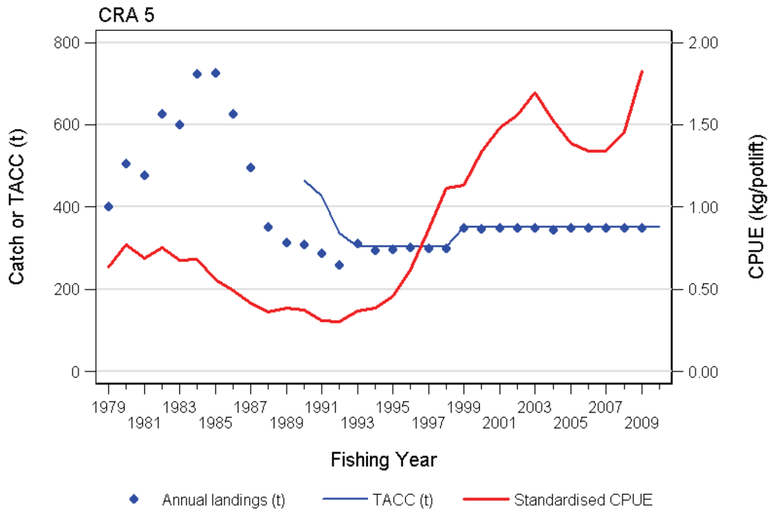
Recent developments in stock status
CPUE has increased in the last 2 years. In 2010 the management procedure for CRA 4 proposed a TACC of 466.9 t based on the most recent AW CPUE estimate of 0.857 kg/pot.

Fishery Interactions

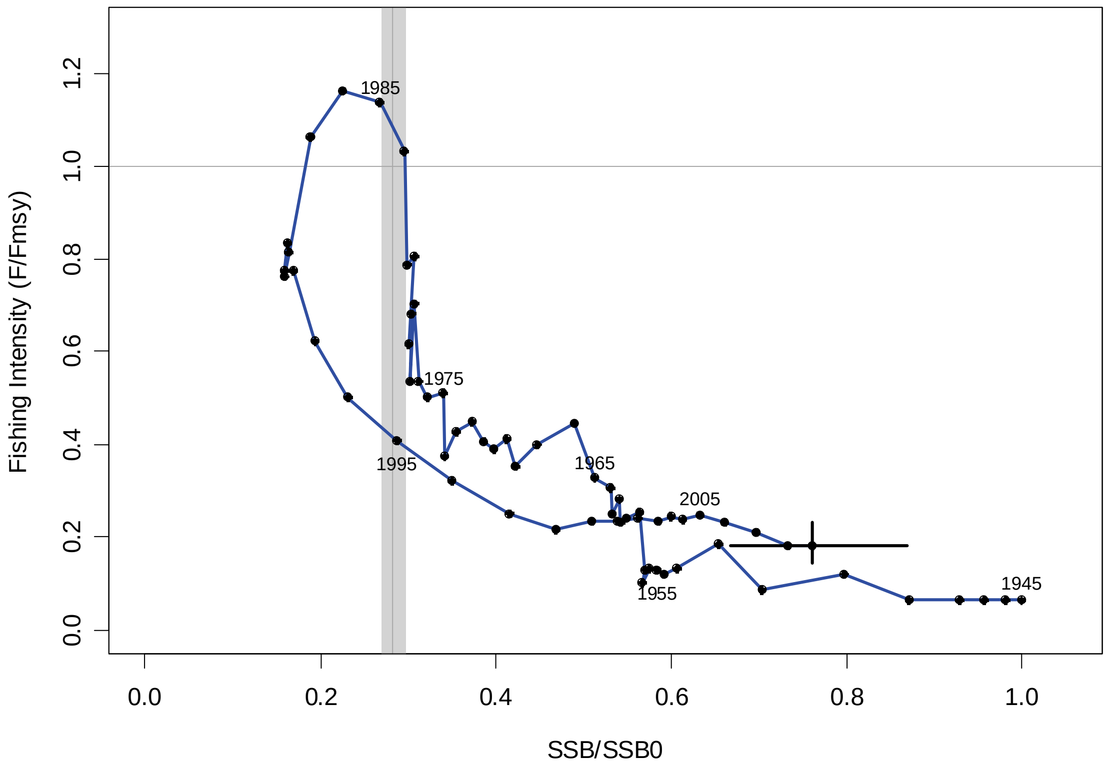
CRA 5

Stock Status	
Year of Most Recent Assessment	2010
Assessment Runs Presented	Base case
Reference Points	- *Bref*: mean of beginning AW vulnerable biomass for the period 1979-88 - *SSBmsy*: mature female biomass associated with B_{MSY} - Soft limit: 0.2 *SSB0* - Hard limit: 0.1 *SSB0*
Status in relation to Target	*Bcurrent* = 3.0 *Bref* (vulnerable AW biomass) *SSBcurrent* = 4.6 SS*Bmsy*
Status in relation to Limits	*P(SSBcurr*<0.2 *SSB0)* = 0 *P(SSBcurr*<0.1 *SSB0)* = 0

Historical Stock Status Trajectory and Current Status



Annual landings, TACC and standardised CPUE for CRA5 from 1979 to 2009.



"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*.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE is at the highest level in the 31 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 is currently at its lowest level. Current fishing intensity is equivalent to the level observed in 1952.
Other Abundance Indices	None
Trends in Other Relevant	The 2009 puerulus (settlement) index is about 1/3 average.

Indicators or Variables	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 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 the target reference levels.	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: *P(SSBproj<0.2SSB0)* = 0 Hard Limit: *P(SSBproj<0.1SSB0)* = 0	
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 also been developed that may be used to manage the fishery in the future.

Recent developments in stock status
Stock size is currently well above all reference points and fishing mortality appears to be low

Fishery Interactions
Potting is the main method of targeting rock lobster and is usually assumed to have very little direct impact 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.

8.3 *Jasus edwardsii*, NSS substock

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 2010 the 2007 management procedure for CRA 7 proposed a decrease in the TAC for CRA 7 to 95.7t for the 2011-12 fishing year. For CRA 8 the management procedure proposed an increase in TAC to 1053 t.

8.4 *Jasus edwardsii*, CHI stock

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.

8.5 *Sagmariasus verreauxi*, PHC stock

The status of this stock is unknown.

Table 23: Summary of yield estimates (t), TACCs and TACs (t), and reported 2007-08 commercial landings. The yield estimates for CRA 6 are the range of yield estimates from a simple production model. ('–', not available).

Fishstock	QMA	Yield Estimate	2009–10 TACC	2009–10 Landings	2010–11 TACC	2010–11 TAC
CRA 1	Northland	–	131.1	130.9	131.1	–
CRA 2	Bay of Plenty	–	236.1	235.0	236.1	452.6
CRA 3	Gisborne	–	164.0	164.0	164.0	293.0
CRA 4	Wairarapa–Hawke Bay	–	266.0	262.0	415.6	610.6
CRA 5	Canterbury–Marlborough	–	350.0	349.9	350.0	467.0
CRA 6	Chatham Islands	300–380	360.0	344.8	360.0	370.0
CRA 7	Otago	–	189.0	136.5	84.5	104.5
CRA 8	Southern	–	1 019.0	1 018.3	1 019.0	1 110.0
CRA 9	Westland–Taranaki	–	47.0	46.6	47.0	–
CRA 10	Kermadec	–	0.0	0.0	0.0	–
Total			2 762.2	2 688.0	2 807.3	3 407.7
PHC 1	All QMAs	18	40.3	36.3	40.3	–

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