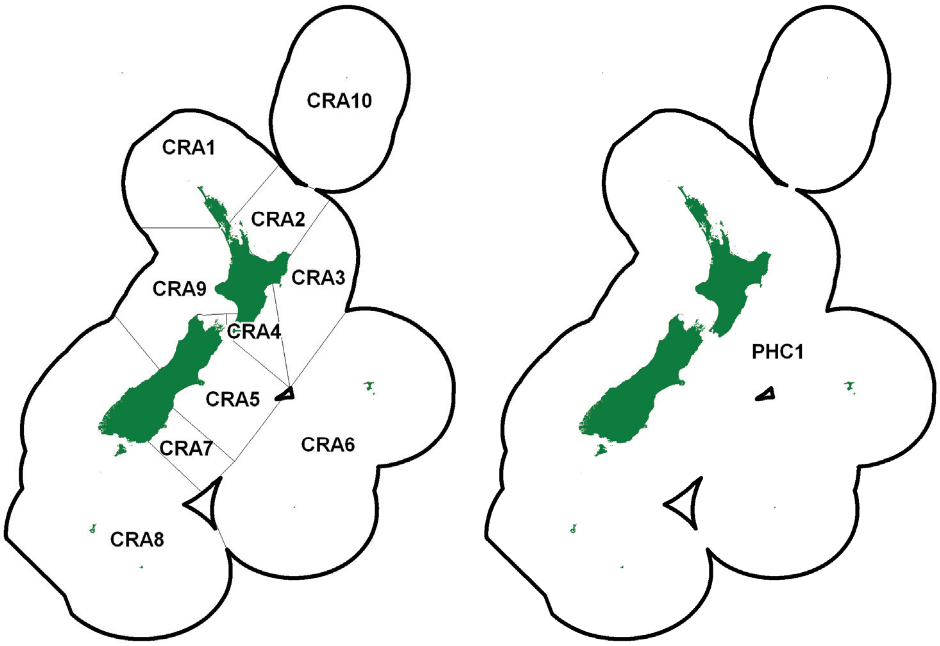
ROCK LOBSTER (CRA and PHC)

(*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 continued operation of the NSS Decision Rule resulted in increases to the CRA 7 and CRA 8 TACCs in both 2008–09 and 2009–10 (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 and 2008, followed by a decrease in the CRA 4 TACC from 577 t to 266 t for the 2009–10 fishing year (Table 1). The TACC for CRA 3 was also decreased from 190 t to 164 t for the 2009–10 fishing year. The NSI TACC for rock lobster in 2009–10 is 2 402 t, a decline from the 2008–09 value of 2 621 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. Figure 1 shows historical landings and TACC values for all CRA stocks.

The MLS in the commercial fishery for red rock lobster is based on tail width (TW), except in the Otago fishery. For Otago (CRA 7), the MLS 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.

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.

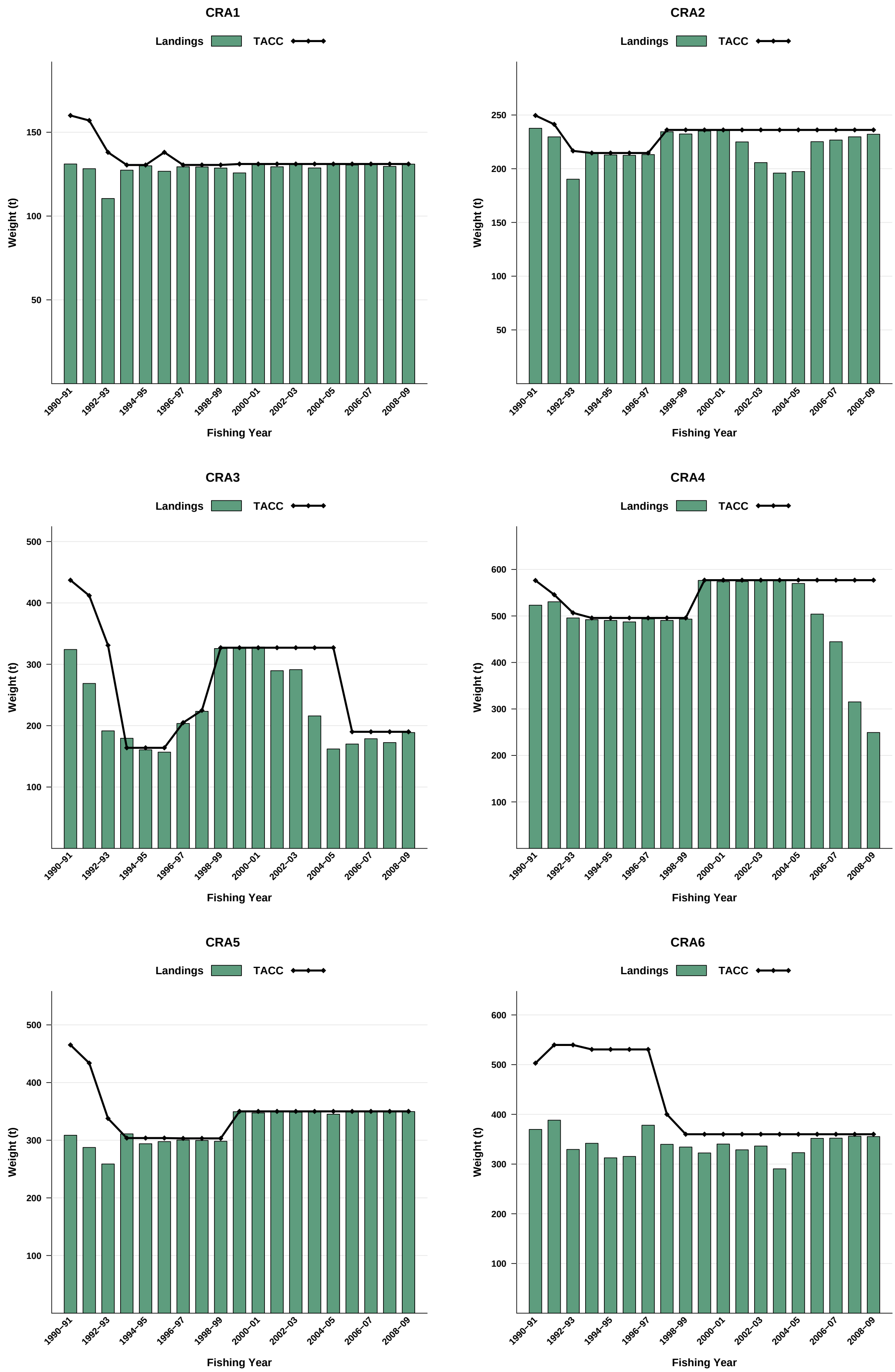


Figure 1: Historical landings and TACC for the 9 main CRA stocks and PHC 1. **[Continued on next page]…**

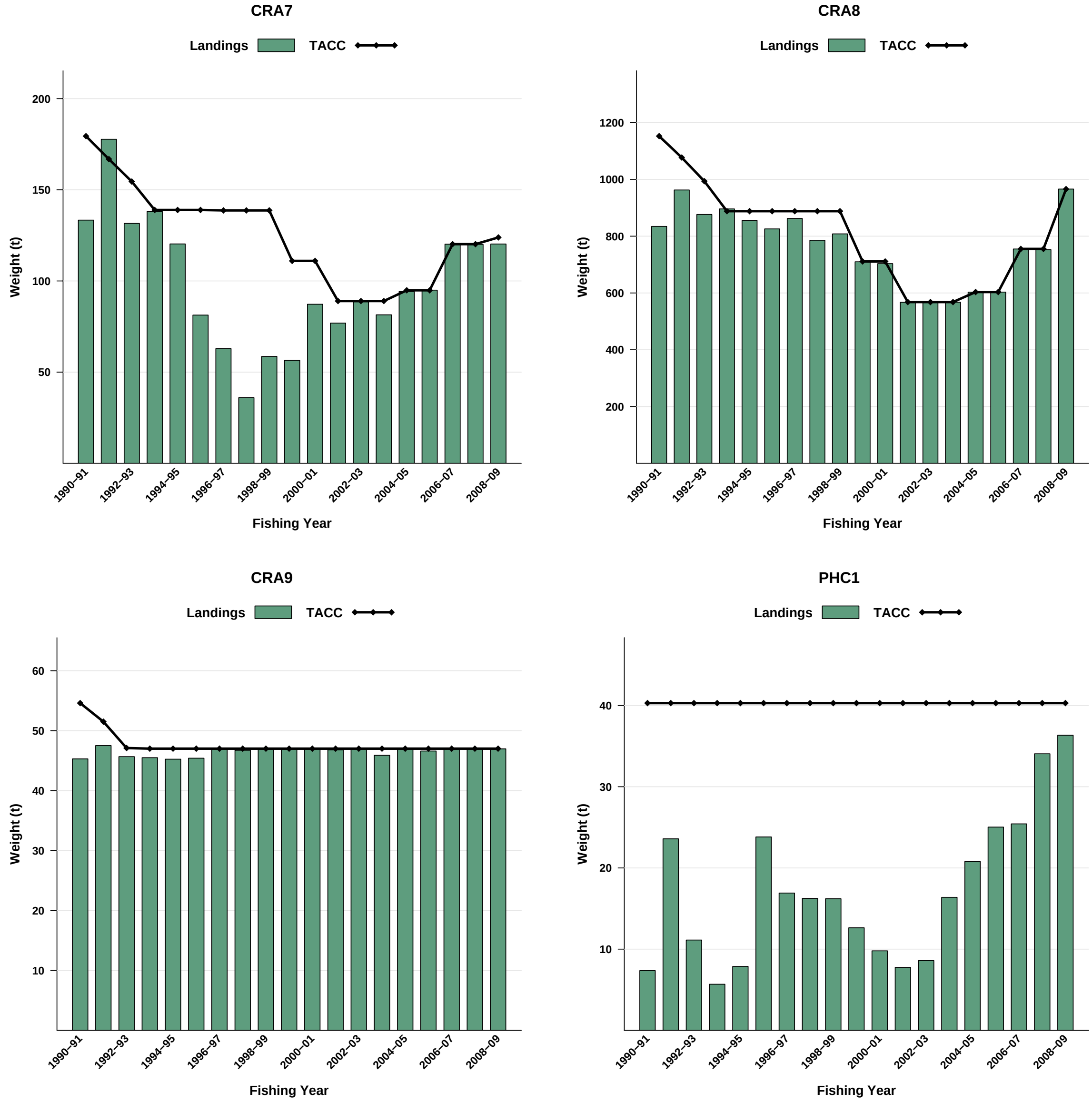


Figure 1 [Continued]: Historical landings and TACC for the 9 main CRA stocks and PHC 1.

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).

	CRA 1			CRA 2			CRA 3			CRA 4		
Fishing Year	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC
1990–91	131.1	160.1	–	237.6	249.5	–	324.1	437.1	–	523.2	576.3	–
1991–92	128.3	146.8	–	229.7	229.4	–	268.8	397.7	–	530.5	529.8	–
1992–93	110.5	137.4	–	190.3	214.6	–	191.5	327.5	–	495.7	495.7	–
1993–94	127.4	130.5	–	214.9	214.6	–	179.5	163.7	–	492.0	495.7	–
1994–95	130.0	130.5	–	212.8	214.6	–	160.7	163.7	–	490.4	495.7	–
1995–96	126.7	130.5	–	212.5	214.6	–	156.9	163.7	–	487.2	495.7	–
1996–97	129.4	130.5	–	213.2	214.6	–	203.5	204.7	–	493.6	495.7	–
1997–98	129.3	130.5	–	234.4	236.1	452.6	223.4	224.9	379.4	490.4	495.7	–
1998–99	128.7	131.1	–	232.3	236.1	452.6	325.7	327.0	453.0	493.3	495.7	–
1999–00	125.7	131.1	–	235.1	236.1	452.6	326.1	327.0	453.0	576.5	577.0	771.0
2000–01	130.9	131.1	–	235.4	236.1	452.6	328.1	327.0	453.0	573.8	577.0	771.0
2001–02	130.6	131.1	–	225.0	236.1	452.6	289.9	327.0	453.0	574.1	577.0	771.0
2002–03	130.8	131.1	–	205.7	236.1	452.6	291.3	327.0	453.0	575.7	577.0	771.0
2003–04	128.7	131.1	–	196.0	236.1	452.6	215.9	327.0	453.0	575.7	577.0	771.0
2004–05	130.8	131.1	–	197.3	236.1	452.6	162.0	327.0	453.0	569.9	577.0	771.0
2005–06	130.5	131.1	–	225.2	236.1	452.6	170.1	190.0	319.0	504.1	577.0	771.0
2006–07	130.8	131.1	–	226.7	236.1	452.6	178.7	190.0	319.0	444.6	577.0	771.0
2007–08	129.6	131.1	–	229.7	236.1	452.6	172.4	190.0	319.0	315.2	577.0	771.0
2008–09	131.0	131.1	–	232.1	236.1	452.6	188.8	190.0	319.0	249.3	577.0	771.0
2009–10	N/A	131.1	–	N/A	236.1	452.6	N/A	164.0	293.0	N/A	266.0	461.0

	CRA 5			CRA 6			CRA 7			CRA 8		
Fishing Year	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC	Catch	TACC	TAC
1990–91	308.6	465.2	–	369.7	518.2	–	133.4	179.4	–	834.5	1152.4	–
1991–92	287.4	426.8	–	388.3	503.0	–	177.7	164.7	–	962.7	1054.6	–
1992–93	258.8	336.9	–	329.4	503.0	–	131.6	153.1	–	876.5	986.8	–
1993–94	311.0	303.2	–	341.8	530.6	–	138.1	138.7	–	896.1	888.1	–
1994–95	293.9	303.2	–	312.5	530.6	–	120.3	138.7	–	855.6	888.1	–
1995–96	297.6	303.2	–	315.3	530.6	–	81.3	138.7	–	825.6	888.1	–
1996–97	300.3	303.2	–	378.3	530.6	–	62.9	138.7	–	862.4	888.1	–
1997–98	299.6	303.2	–	338.7	400.0	480.0	36.0	138.7	–	785.6	888.1	–
1998–99	298.2	303.2	–	334.2	360.0	370.0	58.6	138.7	–	808.1	888.1	–
1999–00	349.5	350.0	467.0	322.4	360.0	370.0	56.5	111.0	131.0	709.8	711.0	798.0
2000–01	347.4	350.0	467.0	342.7	360.0	370.0	87.2	111.0	131.0	703.4	711.0	798.0
2001–02	349.1	350.0	467.0	328.7	360.0	370.0	76.9	89.0	109.0	572.1	568.0	655.0
2002–03	348.7	350.0	467.0	336.3	360.0	370.0	88.6	89.0	109.0	567.1	568.0	655.0
2003–04	349.9	350.0	467.0	290.4	360.0	370.0	81.4	89.0	109.0	567.6	568.0	655.0
2004–05	345.1	350.0	467.0	323.0	360.0	370.0	94.2	94.9	114.9	603.0	603.4	690.4
2005–06	349.5	350.0	467.0	351.7	360.0	370.0	95.0	94.9	114.9	603.2	603.4	690.4
2006–07	349.8	350.0	467.0	352.1	360.0	370.0	120.2	120.2	140.2	754.9	755.2	842.2
2007–08	349.8	350.0	467.0	356.0	360.0	370.0	120.1	120.2	140.2	752.4	755.2	842.2
2008–09	349.7	350.0	467.0	355.0	360.0	370.0	120.3	123.9	143.9	966.0	966.0	1 053
2009–10	N/A	350.0	467.0	N/A	360.0	370.0	N/A	189.0	209.0	N/A	1 019	1 110

	CRA 9			Total		
Fishing Year	Catch	TACC	TAC	Catch[1]	TACC[1]	TAC[1]
1990–91	45.3	54.7	–	2 907.4	3 793.0	–
1991–92	47.5	50.2	–	3 020.9	3 502.9	–
1992–93	45.7	47.0	–	2 629.9	3 201.9	–
1993–94	45.5	47.0	–	2 746.2	2 912.1	–
1994–95	45.2	47.0	–	2 621.5	2 912.1	–
1995–96	45.4	47.0	–	2 548.6	2 912.1	–
1996–97	46.9	47.0	–	2 690.5	2 953.1	–
1997–98	46.7	47.0	–	2 584.2	2 864.1	1 312.0
1998–99	46.9	47.0	–	2 726.0	2 926.8	1 275.6
1999–00	47.0	47.0	–	2 748.5	2 850.2	3 442.6
2000–01	47.0	47.0	–	2 795.9	2 850.2	3 442.6
2001–02	46.8	47.0	–	2 593.0	2 685.2	3 277.6
2002–03	47.0	47.0	–	2 591.1	2 685.2	3 277.6
2003–04	45.9	47.0	–	2 451.5	2 685.2	3 277.6
2004–05	47.0	47.0	–	2 472.3	2 726.4	3 318.8
2005–06	46.6	47.0	–	2 475.8	2 589.4	3 184.8
2006–07	47.0	47.0	–	2 604.8	2 766.6	3 362.0
2007–08	47.0	47.0	–	2 472.3	2 766.6	3 362.0
2008–09	47.0	47.0	–	2 639.1	2 981.0	3 576.5
2009–10	N/A	47.0	–	N/A	2 762.2	3 362.6

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 near 1.0 kg per potlift, increasing again in 2008–09 to a mean of 1.26 kg/potlift (Table 2).

Table 2: Reported commercial landings (t) to 31 March 2009 and CPUE (kg/potlift) for Jasus edwardsii NSI and CHI stocks, and NSN, NSC and NSS substocks, for the 1979–80 to 2008–09 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 2008–09 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 2008–09 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	359	0.71	837	0.76	873	2.18	2 116	1.03	356	1.53
2008–09	363	0.71	788	0.89	1 086	2.92	2 284	1.26	355	1.50

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 0.97 kg per potlift. CPUE levels in CRA 1 and CRA 2 differ: CRA 1 maintained higher catch rates 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 at that level over the three 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 and is now nearly 3.0 kg per potlift in the most recent fishing year (Table 2). Catches are relatively low in CRA 7 compared with those in the other QMAs, but CPUE has been rising in both CRA 7 and CRA 8, with CPUE currently at the highest level in both QMAs since recording began (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 to below 2 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, and since increased to 1.5 kg/potlift in 2007–08 and 2008–09. 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	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09
CRA 1	1.09	1.17	1.30	1.20	1.22	1.23	1.14	1.32	1.64	1.57
CRA 2	0.71	0.71	0.56	0.44	0.43	0.43	0.47	0.54	0.53	0.53
CRA 3	1.56	1.19	0.95	0.73	0.62	0.52	0.62	0.58	0.60	0.71
CRA 4	1.27	1.26	1.06	1.09	1.14	1.00	0.88	0.65	0.60	0.71
CRA 5	1.00	1.16	1.27	1.26	1.39	1.26	1.17	1.18	1.19	1.28
CRA 6	1.19	1.15	1.15	1.16	1.10	1.21	1.35	1.44	1.53	1.50
CRA 7	0.22	0.35	0.46	0.52	0.58	0.75	1.12	1.56	1.31	1.69
CRA 8	0.84	0.98	0.92	1.10	1.67	1.58	1.75	2.19	2.47	3.22
CRA 9	0.87	0.93	0.82	1.11	1.63	2.14	2.22	1.94	1.85	1.75

***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 in 2007–08 and 2008–09 (Table 4).

Table 4: Reported landings of *Sagmariasus verreauxi* from 1990–91 to 2008–09. Data from QMR or MHR (after 1 Oct 2001).

Year	Landings (t)	Year	Landings (t)
1990–91	7.4	2000–01	9.8
1991–92	23.6	2001–02	7.8
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	34.1
1998–99	16.2	2008–09	36.3
1999–00	12.6		

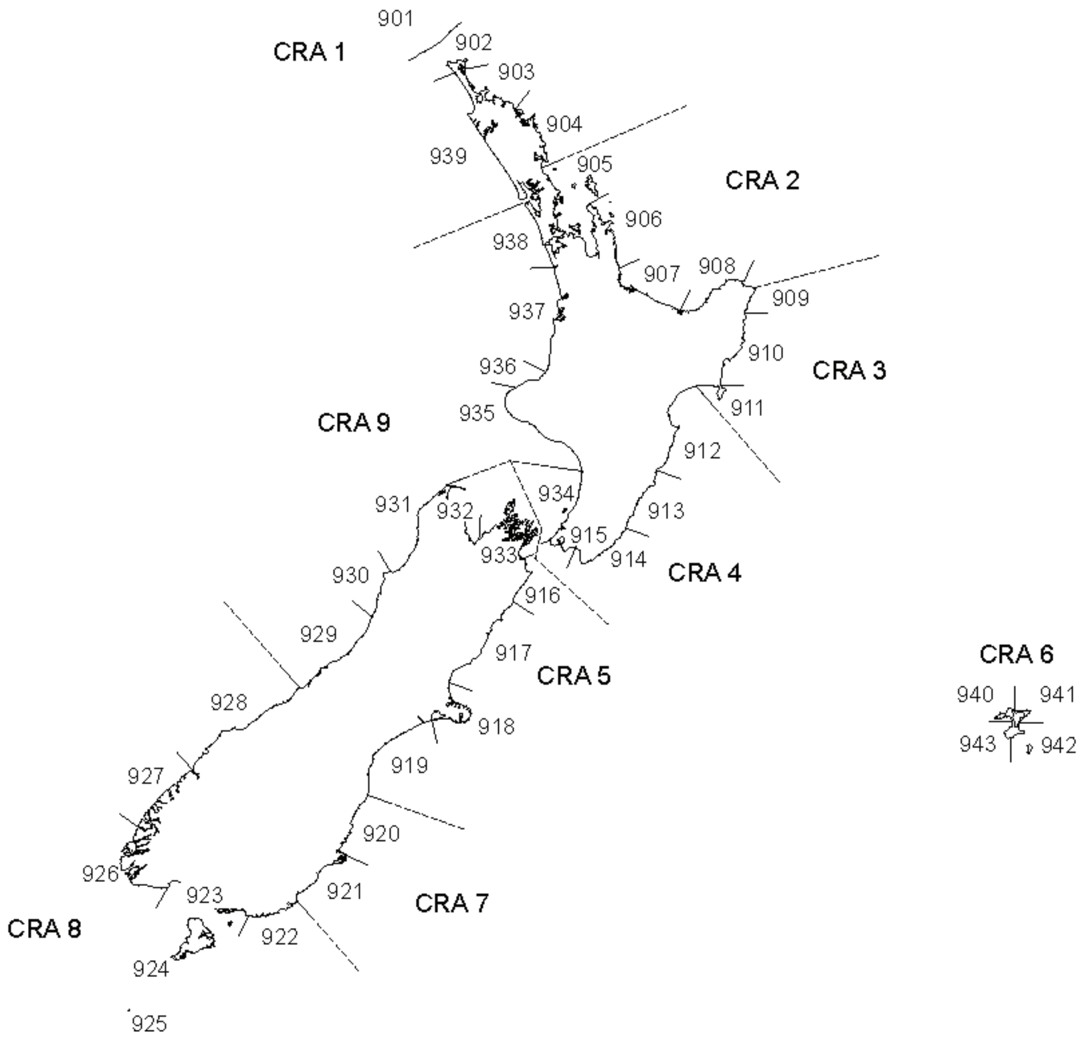


Figure 2: Rock lobster statistical areas as reported on CELR forms.

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 2). 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	03/04	04/05	05/06	06/07	07/08	08/09
1	901	–	3.56	3.20	2.96	3.48	4.00
1	902	3.30	2.06	2.37	–	2.46	1.69
1	903	0.73	1.08	0.86	1.33	1.47	1.19
1	904	0.37	0.57	–	–	0.62	–
1	939	0.83	0.70	0.57	0.86	1.08	1.29
2	905	0.53	0.56	0.51	0.60	0.57	0.60
2	906	0.36	0.38	0.46	0.51	0.54	0.44
2	907	0.46	0.47	0.46	0.56	0.61	0.82
2	908	0.44	0.43	0.42	0.55	0.43	0.48
3	909	0.87	0.82	0.79	0.97	1.00	1.04
3	910	0.58	0.53	0.58	0.47	0.60	0.71
3	911	0.60	0.42	0.59	0.60	0.50	0.57
4	912	1.13	0.77	0.59	0.55	0.62	0.68
4	913	1.40	1.21	0.94	0.74	0.69	0.80
4	914	1.20	1.11	0.93	0.55	0.44	0.56
4	915	1.01	0.76	0.81	0.67	0.78	0.85
4	934	–	–	–	1.50	0.86	–
5	916	2.67	2.38	2.19	2.09	2.09	2.41
5	917	1.19	1.06	1.18	1.22	1.34	1.44
5	918	1.38	1.37	1.85	–	–	1.68
5	919	–	–	–	–	–	–
5	932	–	–	–	–	–	–
5	933	1.08	0.89	0.72	0.72	0.72	0.74
6	940	1.12	1.12	1.21	1.23	1.37	1.35
6	941	0.74	0.88	0.90	1.00	1.13	1.31
6	942	1.36	1.49	1.65	1.89	1.96	1.63
6	943	0.94	1.00	1.49	1.91	1.39	1.44
7	920	0.49	0.53	0.94	1.34	1.13	1.66
7	921	1.93	1.32	1.81	2.02	1.99	2.02
8	922	–	–	–	–	–	–
8	923	2.57	2.45	4.25	2.07	4.16	3.32
8	924	2.38	2.00	3.00	4.04	3.18	3.17
8	925	1.57	1.13	–	–	2.87	–
8	926	2.12	1.96	2.21	2.63	2.28	2.93
8	927	1.59	1.72	1.17	1.72	2.89	3.69
8	928	1.01	1.41	1.68	2.13	5.33	6.69
9	929	–	–	–	–	–	–
9	930	–	–	–	–	–	–
9	931	1.65	–	–	2.94	–	–
9	935	2.20	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	30.417	Ramped from 1945; after 1979, the "best recreational catch" was scaled by the ratio of the annual standardised CPUE 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] Kim et al. (2004); [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 two 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] Kim et al. (2004); [6] Breen et al. (2007)

1.3 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.

1.4 Illegal catch

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

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

	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					0	75												
2002		72		82	0	75	9	51		40		10		1		18		1
2003					0	89.5												
2004							10	30										

Table 10: Export discrepancy estimates by year for all of New Zealand (McKoy, pers. comm.). The QMA export discrepancy catch is calculated using the proportion of the reported QMA commercial catch relative to the total NZ commercial catch $\left(C_y\right)$ starting with the total NZ export discrepancy for that year $\left(I_y\right)$: $\left(I_{q,y} = I_y * C_{q,y} / C_y\right)$. 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 $\left(P_q\right)$ relative to the reported QMA commercial catches $\left(C_{q,y}\right)$ is used in each CRA QMA to estimate illegal catches prior to 1990: $\text{Illegal}_{q,y} = P_q * C_{q,y} \quad \text{if } y < 1974 \text{ or } \left(y > 1980 \text{ and } y < 1990\right)$.

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

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

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

1.5 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.

2. BIOLOGY

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

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

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

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

Table 11: Values used for some biological parameters.

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

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

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

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

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

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

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

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

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

Growth modelling

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

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

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

For CRA 3, tag recapture data are available from 1975–1981 and 1995–2006. Equivalent data are also available from a PhD project (Freeman 2008) from areas outside the Te Tapuwae o Rongokako marine reserve near Gisborne, and these data were used, with permission, in the 2008 stock assessment. It was discovered that CRA 3 growth rates based on the 1995–2006 data were significantly lower than those based on the 1975–1981 data. There is no obvious reason for the change in growth rates and an analysis of the CRA 5 tag recaptures did not show this decrease. Growth estimation in the 2008 assessment treated the older and newer data as two discrete data sets, and estimated growth for these periods separately.

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 12 provides the standardised settlement indices from all sites except Chalky.

Table 12: Puerulus settlement indices for CRA 3. 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	
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 banding, size at onset of maturity in females, migratory behaviour, fishery catch and effort patterns, phyllosoma abundance patterns and puerulus settlement levels. These observations led to division of the 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 CRA 4, CRA 7 and CRA 8 management procedures for the 2010–11 fishing year, based on CPUE data extracted in September and November 2009.

4.1 Data preparation procedures

For decision rule analyses, the data were extracted using 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 fishing year (or period for CRA 4) as explanatory variables. The data were restricted to the appropriate QMAs for each analysis and all data were used except for coded vessel number 4548, which has been consistently dropped from the NSN analysis. 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.

The NSN and NSC decision rules use annual standardised CPUE indices based on the fishing year. The CRA 7 and CRA 8 management procedures both use the most recent annual standardised CPUE estimates from CRA 7 or CRA 8 respectively where the year used as the basis for these rules is offset by 6 months relative to the rock lobster fishing year. The CPUE index used in the rule is based on the most recent AW season and the preceding SS season (whereas the rock lobster fishing year comprises the SS season and the preceding AW season). This is called the “offset year”. 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).

The CRA 4, CRA 7 and CRA 8 analyses follow the suggestion of Francis (1999) and calculate “canonical” coefficients and standard errors for each year, allowing the calculation of standard errors for every coefficient, including the base year coefficient. A further refinement is to scale each standardised index by the geometric mean of the simple arithmetic CPUE indices (the summed catch divided by summed effort for each fishing 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 Rule 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 a "significant" decrease in the CPUE for a given year relative to 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 3). There were four consecutive years of decrease between 1998–99 and 2002–03, but this trend ended in 2003–04 and standardised indices since then have increased, with the exception of 2008–09 which has dropped to a level similar to that seen in 2006–07. The increase and recent decrease in the NSN series relative to the 2003–04 fishing year extend to both components of the NSN (CRA 1 and CRA 2). Figure 4 shows that the standardised index and the simple arithmetic mean show similar trends and that both are above the low abundance levels observed in the late 1980s and early 1990s.

Under the NSN decision rule, the 2008–09 CPUE is significantly above the 1992–93 CPUE (Table 13).

Table 13: Decision rule indices for 1992–93 and 2008–09 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).

Substock	1992–93 Index	1992–93 Lower	1992–93 Upper	2008–09 Index	2008–09 Lower	2008–09 Upper	Result
NSN	0.968	0.936	1.001	1.574	1.509	1.641	*
NSC	0.395	0.388	0.403	0.972	0.944	1.000	*

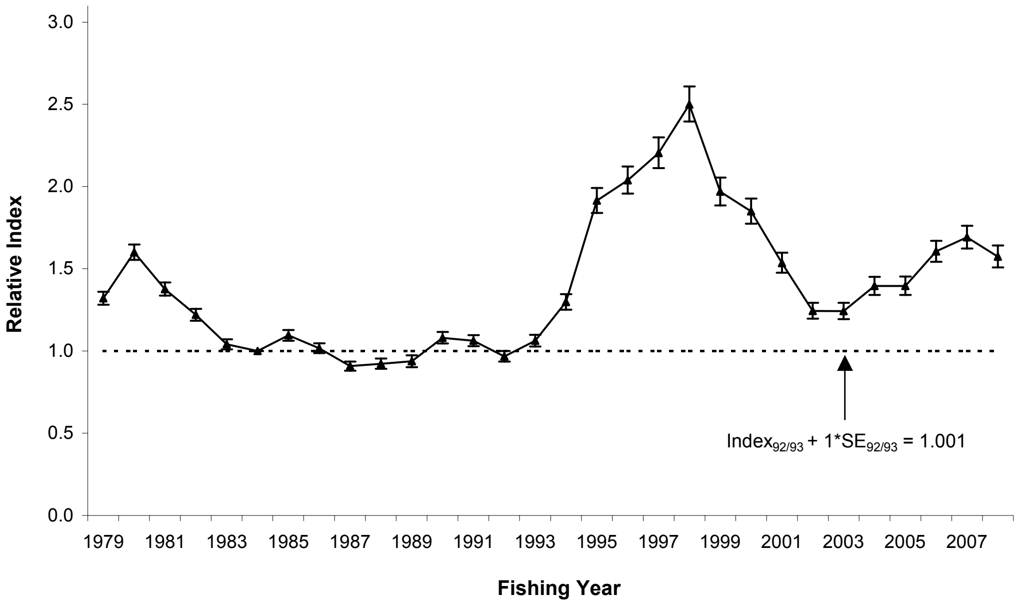


Figure 3: Values of the year index from the standardised CPUE analysis for the NSN substock showing plus and minus one standard error for each year. Horizontal line shows the upper bound of the 1992–93 standardised index which is the threshold for triggering this decision rule. Each year index is relative to the 1984-85 fishing year (the year with the lowest standard error).

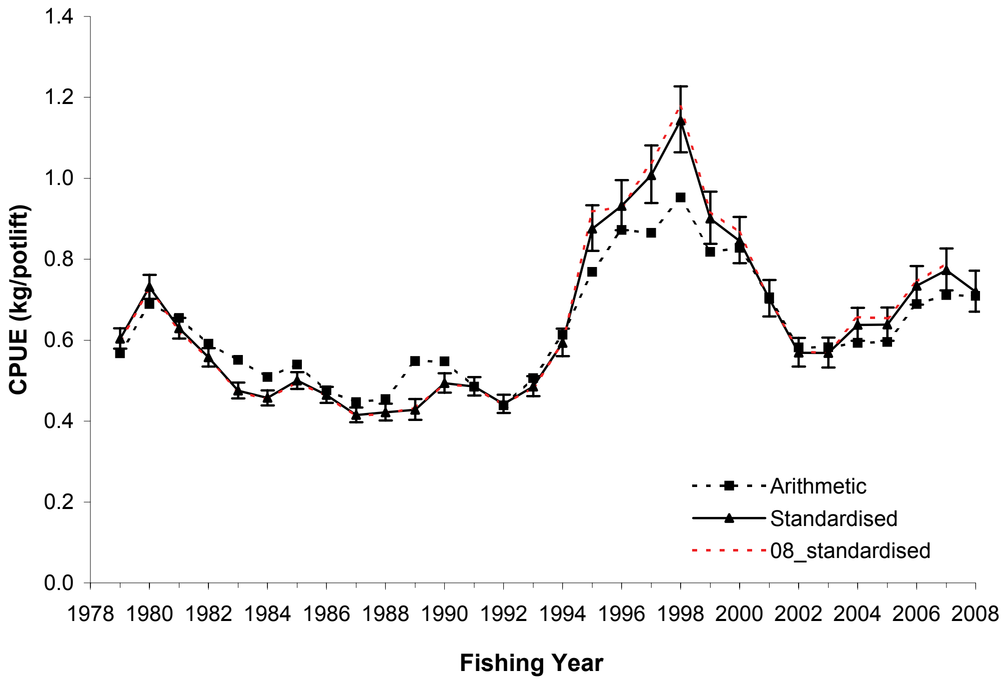


Figure 4: Values for the NSN standardised annual CPUE indices compared with the mean arithmetic annual CPUE (sum of annual catch divided by sum of potlifts). The standardised series is scaled to the geometric mean of the arithmetic annual CPUE (kg/potlift). Also shown is the equivalent standardised series calculated in September 2008.

NSC

As in the NSN substock, standardised CPUE for the NSC substock increased steadily between the 1992–93 and 1998–99 fishing years (Figure 5). Since then, there was a continuous decline in CPUE to a level about 50% below the 1998–99 peak, reached in 2007–08. This decline occurred in all three components of the NSC (CRA 3, CRA 4 and CRA 5), although CRA 4 was the only QMA which showed a declining trend for the entire period to 2007–08. CRA 5 began its decline from a peak only in 2003–04 while CRA 3 and CRA 4 started declining sooner. All three QMAs show an increase in CPUE for 2008–09 (Table 3).

Figure 6 compares the standardised index with the simple arithmetic mean, with both showing similar trends and remaining above the low abundance seen in 1992–93. The unstandardised index is lower than the standardised index for this substock, probably reflecting the switch to a winter fishery where catch rates are generally lower. The standardisation model interprets high catch rates in these winter months as indicative of higher abundance.

Under the decision rule, the 2008–09 CPUE is significantly above the 1992–93 CPUE (Table 13).

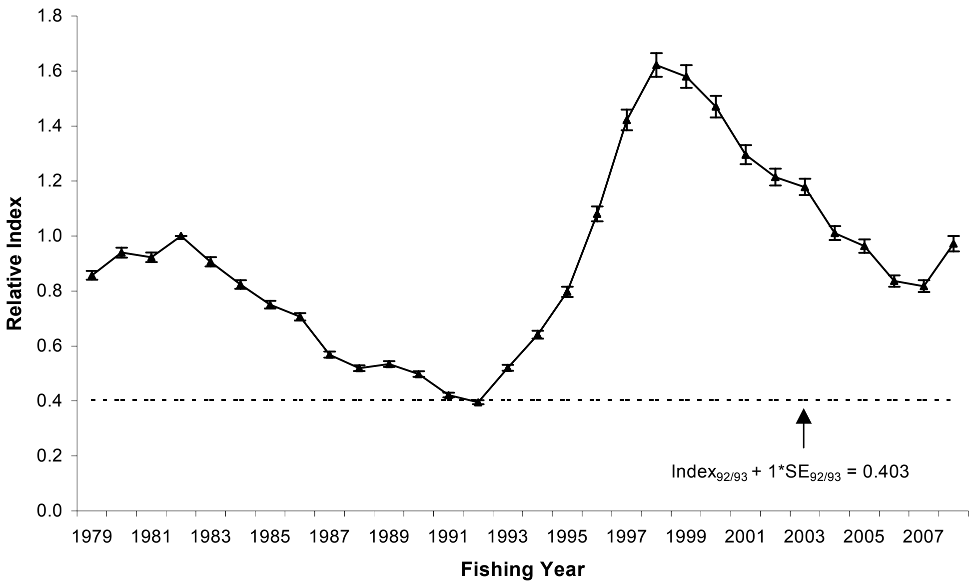


Figure 5: Values of the year index from the standardised CPUE analysis for the NSC substock showing plus and minus one standard error for each year. Horizontal line shows the upper bound of the 1992–93 standardised index which is the threshold for triggering this decision rule. Each year index is relative to the 1982–83 fishing year (the year with the lowest standard error).

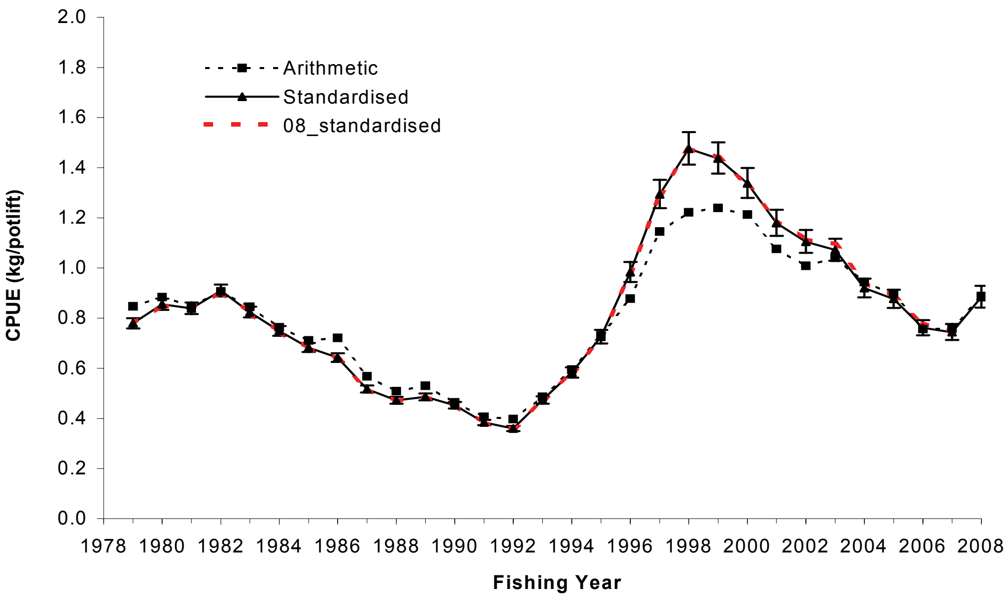


Figure 6: Values for the NSC standardised annual CPUE indices compared with the mean arithmetic annual CPUE (sum of annual catch divided by sum of potlifts). The standardised series is scaled to the geometric mean of the arithmetic annual CPUE (kg/potlift). Also shown is the equivalent standardised series calculated in September 2008.

4.3 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 used to evaluate a large number of rules informing a management procedure 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 to set a limit above which ACE (Annual Catch Entitlements) could be removed from the fishery. This process of removal, known as "shelving", was used to set voluntary commercial catch limits for the 2007–08 and 2008–09 fishing years (Table 14). This rule was adopted in March 2009 by the Minister of Fisheries, who set the CRA 4 TACC to 266 t under the rule, resulting in a TAC of 461 t after adding allowances for non-commercial fisheries.

Table 14: 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 compliance with the voluntary limit imposed for the 2007–08 and 2008–09 fishing years.

Year	Applied to fishing year	AW CPUE	Rule result	Operational limit
2006	2007–08	0.656	321.1	339
2007	2008–09	0.515	228.9	240
2008	2009–10	0.573	265.9	266

The rule as accepted by the Minister of Fisheries, E170 (Figure 7), is specified as follows:

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

where *TACC* is the proposed catch limit and *I* is standardised CPUE from the most recent AW season. There is no latent year; the maximum allowable annual change in TACC is 75% and the minimum change is 5%.

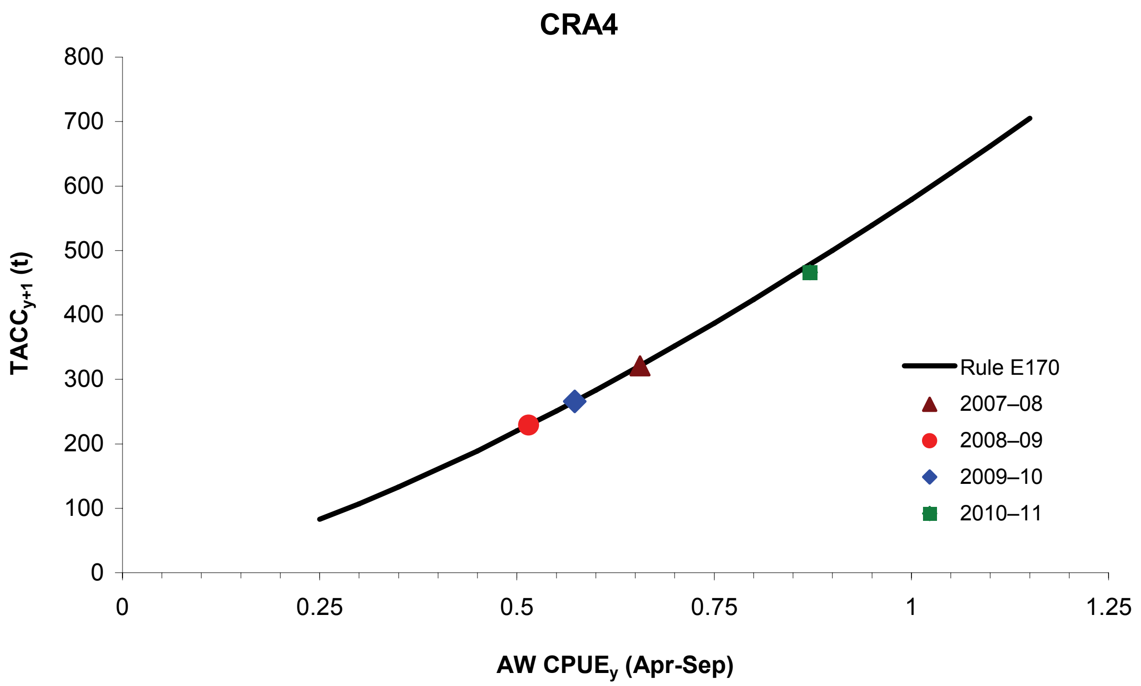


Figure 7: Graphic representation of the CRA 4 management procedure, plotting the catch limits in the next year as a function of CPUE in the current year and showing the CPUE values which generated the limit proposals for 2007–08, 2008–09, 2009–10 and 2010–11

The current TACC for CRA 4 is 266 t. The most recent AW standardised CPUE estimate for CRA 4 is 0.871 kg/pot for the period 1 April 2009 to 30 September 2009. Under the equation above for the CRA 4 management procedure, this would give a TACC of 477.59 t. This would represent an increase of 79.5%. However, the maximum change allowed under the rule is ±75%, thus the proposed TACC becomes 465.500 t under the CRA 4 management procedure.

4.4 Management Procedures for CRA 7 and CRA 8

Since 1996, both CRA 7 and CRA 8 have been managed using decision rules based on the observed CPUE in the fishery. These management procedures 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, beginning with the 2008–09 fishing year.

Both management procedures use the recent standardised CPUE estimates as input, based on the offset year from 1 October to 30 September. Both management procedures generate a proposed TAC in every year (as long as the change is greater than ±5%) which contrasts with the previous NSS procedure that incorporated a "latent year", whereby changes could not be made in two consecutive years.

The rule which drives the CRA 7 management procedure is shown in Figure 8. This rule gives 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 1 April–31 March fishing year and I_y is standardised CPUE from the most recent 12 months, 1 October to 30 September. The proposed TAC for 2010–11 is modified from the above equation by the rule component which limits rule changes to no more than ±50% in any year.

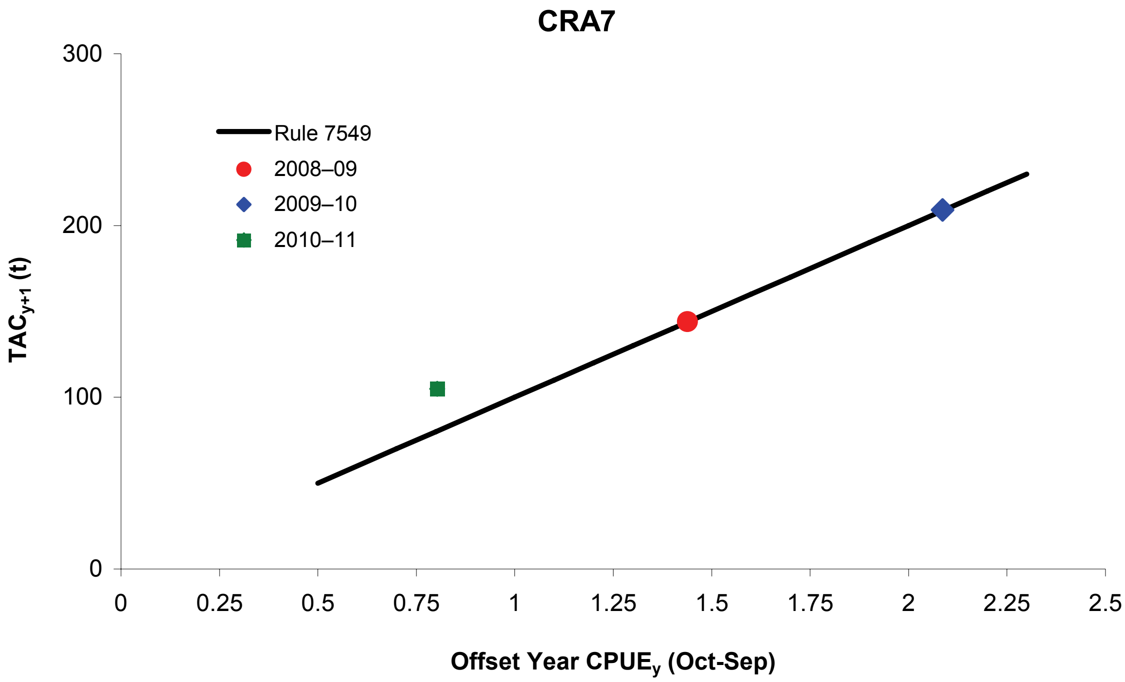


Figure 8: Graphic representation of the CRA 7 management procedure, plotting the TAC in the next year as a function of CPUE in the current year and showing the CPUE values which generated the TAC proposals for 2008–09, 2009–10 and 2010–11.

The rule driving the CRA 8 management procedure is shown in Figure 9. This rule gives a TAC which is a complex function of CPUE: TAC is constant over a wide range of CPUE; decreasing at a faster rate than CPUE when CPUE is below a threshold and increasing more slowly when CPUE is above a threshold. The plateau affords stability of TACC that was a high desideratum of the CRA 8 commercial industry.

Formally, this rule is given by:

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

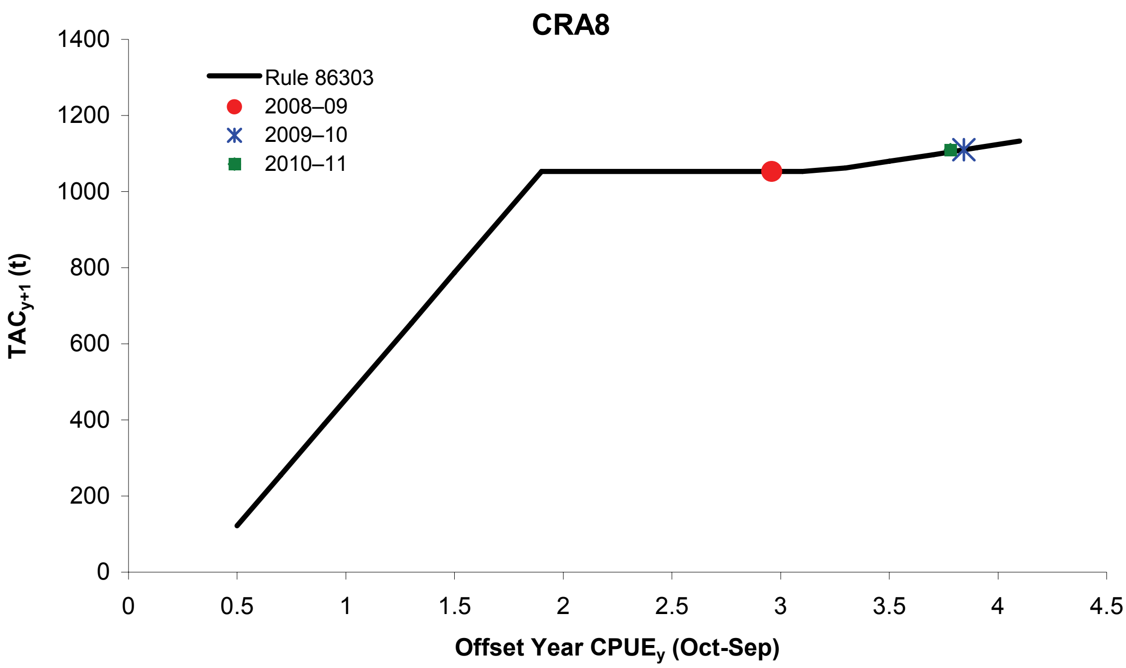


Figure 9: Graphic representation of the CRA 8 management procedure, plotting the TAC in the next year as a function of CPUE in the current year and showing the CPUE values which generated the TAC proposals for 2008–09, 2009–10 and 2010–11.

Implementation of CRA 7 and CRA 8 harvest control rules for 2008

The current TAC for CRA 7 is 209 t. The most recent annual standardised CPUE estimate for CRA 7 is 0.803 kg/pot for the period 1 October 2008 to 30 September 2009. Under the equation above for the CRA 7 management procedure, this gives a TAC of 80.300 t. This represents a decrease of 61.6%. However, the maximum change allowed under the rule is ±50%, thus the proposed TAC becomes 104.500 t under the CRA 7 management procedure.

Industry have proposed to vary the CRA 7 management procedure to have a multiplier of 80 rather than 100. Under this proposal, the equation above would give a provisional TAC of 64.24, representing a decrease of 69.3%. However, the maximum change allowed under the rule is ±50%, thus the proposed TAC would become 104.500 t under the proposed revised CRA 7 management procedure.

The current TAC for CRA 8 is 1 110 t. The most recent annual standardised CPUE estimate for CRA 8 is 3.781 kg/pot for the period 1 October 2008 to 30 September 2009. Under the equation above for the CRA 8 management procedure, this gives a TAC of 1 104.519 t. This represents a decrease of 0.5%. However, the minimum change allowed under the rule is ±5%, thus the proposed TAC remains unchanged under the CRA 8 management procedure.

4.5 Development of the CRA 3 management procedure

In 2009, the stock assessment team was asked by the National Rock Lobster Management Group to design and evaluate management procedures for CRA 3. This work used the 2008 stock assessment of CRA 3 (Starr et al. 2009; Breen et al. 2009) as a starting point; in particular, the stock assessment model used in 2008 was used as the basis for the operating model used to conduct MPEs.

The 2008 stock assessment was updated with one additional year's catch data from the Monthly Harvest Reports and one additional year's CPUE data based on an extract obtained in May 2009 (Table 15). Standardisation was for seasonal CPUE (see Bentley et al. 2005), using explanatory variables period, month and statistical area. Total deviance explained was 47%. Both AW and SS CPUE increased about 13% from the previous year (Table 15).

Table 15: Standardised seasonal CPUE for the last two years used in the updated stock assessment for CRA 3.

Fishing year	AW	SS
2007–08	0.596	0.569
2008–09	0.677	0.644

Length frequency data were not updated, and all other model assumptions, modelling choices and inputs were unchanged. The model fit was similar to that obtained in 2008.

As well as the base case operating model, three other operating models were used in the MPEs. A “high recruitment” model projected recruitment based on the past 20 years, 1986–2005, instead of the 10 years used in the base case. Recruitments in the past 10 years are low compared with previous ones and adding another 10 years to the base period increased average recruitment substantially.

Another operating model used the faster growth estimates from the pre-1996 tag-recapture data instead of the later set in the base case. A third alternative operating model was fitted to a data set that assumed an historical illegal catch vector that was half that assumed in the base case.

Productivity of the base case operating model was low. The relation between average catch and average CPUE suggested that the base case model would produce a maximum average catch near 160 t, but at the adjusted *Bref* only about 110 t. This productivity is lower than the catch and CPUE history of the fishery might suggest, but recruitment and growth have both declined. Both the higher recruitment and higher growth models had much higher catches from any level of abundance, and their effects were additive.

The observed estimated offset-year CPUE for 2008–09 is outside the distribution of model predictions. Because of this and the very high uncertainty associated with future recruitment patterns, rules were evaluated on the basis of both their base case performance and their high recruitment model performance (particularly the average catch and average 5-year catch). This allowed a search for rules that were safe in poor recruitment conditions but that exploited good recruitment.

Several thousand harvest control rules were defined and evaluated. Many were “screened out” because they had more than 5% of years with biomass less than *Bmin* or more than 50% of runs with biomass less than adjusted *Bref* in year 10, etc. After working with the most promising examples, a set of “final candidates” was made and these were presented to the RLFAWG and the CRA 3 Forum. Times to median rebuild were not very different amongst these nine rules. Average catches were similar, but minimum commercial catches showed considerable contrast among the rules. No other indicator showed as much contrast among the rules. Between the base case and the high recruitment models, rebuild times were much shorter in the latter, catches were higher and CPUE was higher after 10 years.

Note: a decision on the management procedure for this fishery had not been finalised when this report was completed (late November 2009).

5. STOCK ASSESSMENT

This section reports stock assessment results reported in 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.

5.1 CRA 1 and CRA 2

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

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

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

Significant catches occurred in the early part of the time series for CRA 1 and CRA 2. Different MLS regulations existed at this time and pots were not required to have escape gaps. We therefore incorporated historical information for CRA 1 and CRA 2: a time series of sex-specific MLS regulations, time series of catch per day estimates for the 1960s and early 1970s, and some early size frequency data, including market sampling data. These data and their sources are listed in Table 15. 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 15.

Table 15: 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; RLIC – 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	RLIC	1993	2002
Historical tag recovery data	MFish various	1975	1986
Current tag recovery data	RLIC & 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 16). Fixed parameters and their values are given in (Table 17). 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 16: 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 17: 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 18. 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 18: 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. $BVULN_{02}/BVULN_{79\text{–}88}$
2. $BVULN_{07}/BVULN_{02}$
3. $BVULN_{07}/BVULN_{79\text{–}88}$
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: $BVULN_{79\text{–}88}$ is defined as the mean of beginning AW vulnerable biomass from 1979 through 1988.

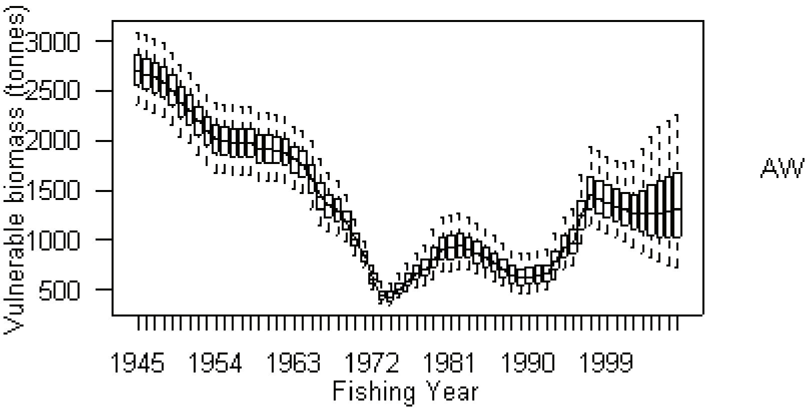
$USL_{02,AW}$ is the exploitation rate for catch taken from the SL vulnerable biomass in the autumn-winter season of 2002–03, and $USL_{06,AW}$ is the exploitation rate for catch taken from the SL vulnerable biomass in the autumn-winter season of 2006–07, the last year of projections. $UNSL_{02,AW}$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

Stock assessment results: Jasus edwardsii, CRA 1

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

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

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



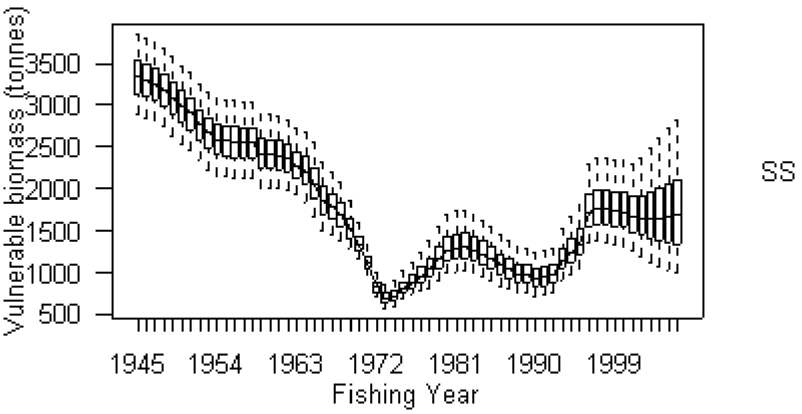


Figure 10: CRA 1: posterior trajectories of vulnerable biomass, for the AW (top) and SS (bottom) seasons, from the CRA 1 base case MCMC simulations. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.

Table 19: 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 19). The exploitation rates estimated in this sensitivity trial are very similar to the exploitation rates estimated by the base case.

Stock assessment results: *Jasus edwardsii*, CRA 2

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

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

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

The assessment results (Table 20) 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 20: 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 20), 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.

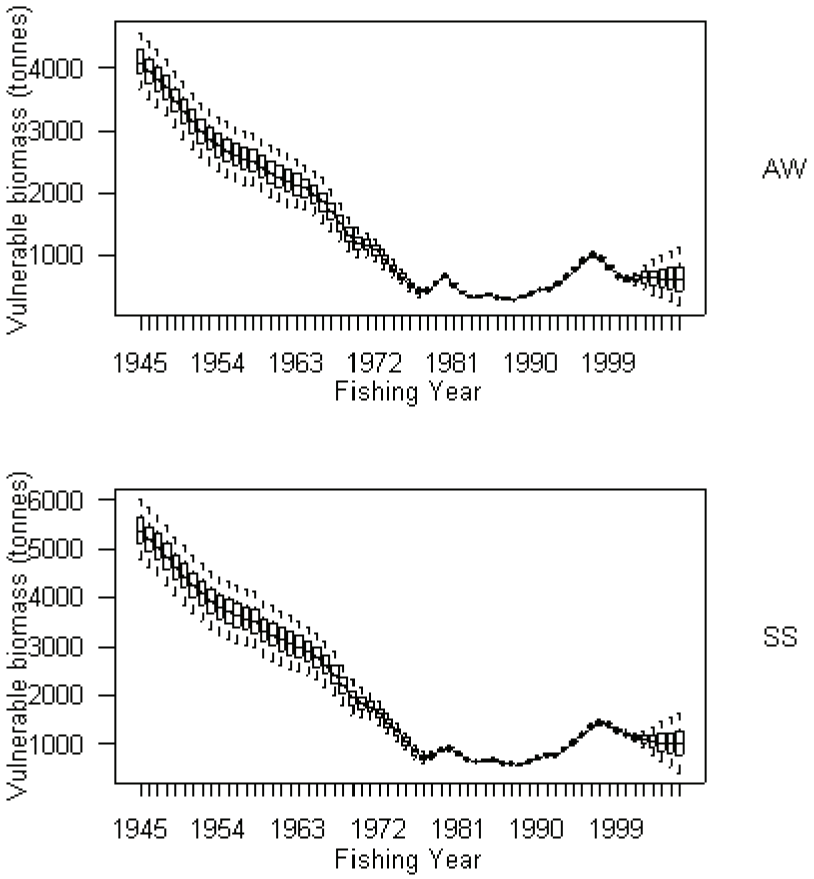


Figure 11: CRA 2: posterior trajectories of vulnerable biomass, for the AW (top) and SS (bottom) seasons, from the CRA 2 base case MCMC simulations. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.

5.2 CRA 3

This section reports assessments for *J. edwardsii* for CRA 3 from the NSC substock taken from the 2008 Mid-year Plenary report (Ministry of Fisheries 2008).

A multi-stock length-based model (MSLM) (Haist et al. 2009) was developed in 2006 as an extension to the length-based model previously used for rock lobster stock assessments. MSLM changed the growth model used to make predicted increments in tag-recapture data, and extended the model in several ways:

- MSLM allows several regions to be modelled simultaneously: separate parameters can be estimated for each region or common parameters can be estimated and shared by the regions;
- dynamics allow for movement among regions;
- fishing mortality dynamics can be finite (as in the older model) or instantaneous;
- density-dependent growth can be modelled;
- the time step can be variable;
- a stock-recruit relation can be modelled;
- the fishery selectivity sub-model has two options;
- likelihoods have a variety of options.

This model was used as a single-stock model for the 2008 assessment of CRA 3. 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 model 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 itself 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 and to vary the SL fishery mortality rate *F* to maximise the annual size-limited (SL) catch, and to record the associated AW biomass.

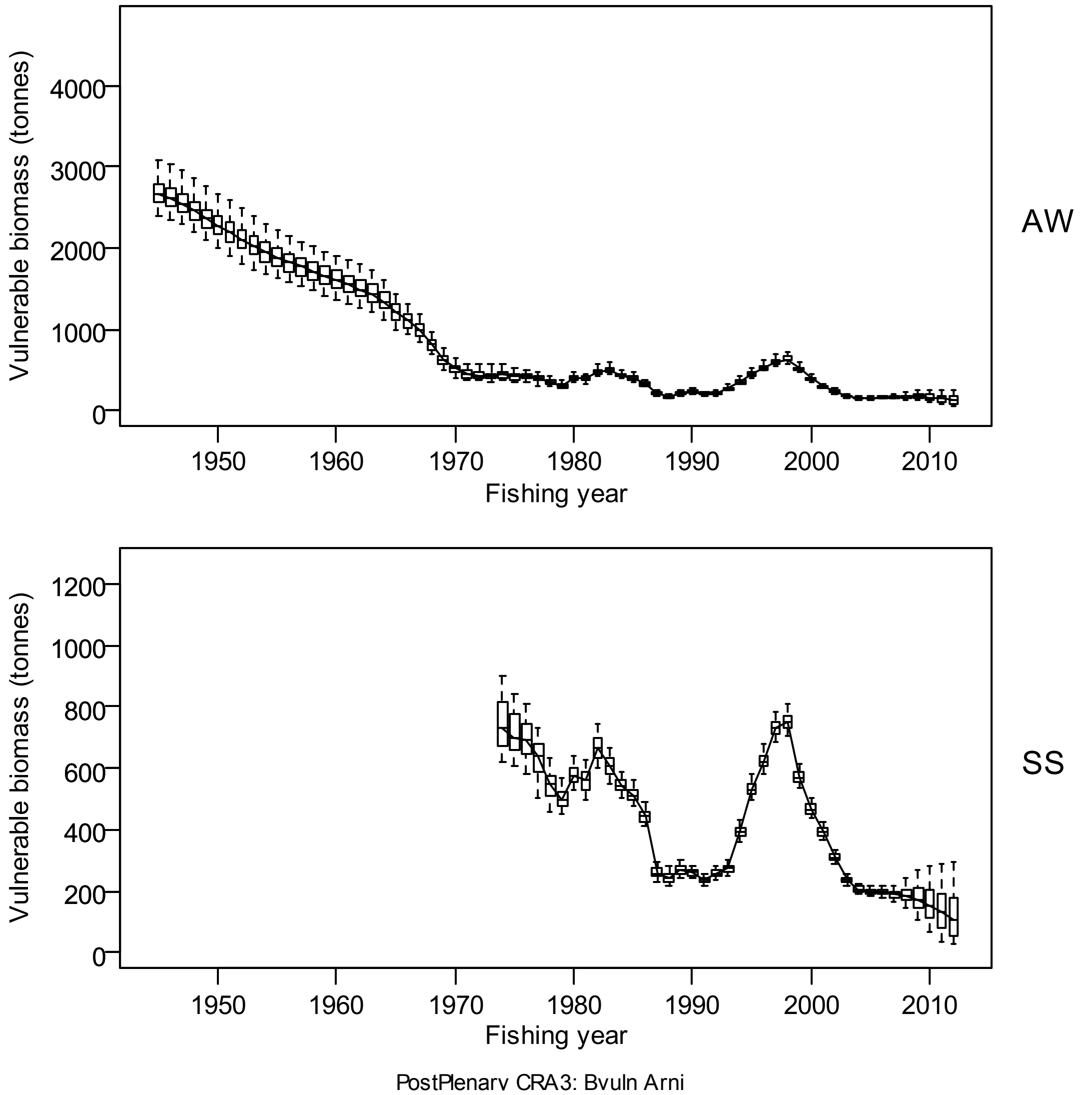


Figure 12: The posterior trajectory of vulnerable biomass, by season, from the CRA 3 base case McMC simulations, including the projections from 2008-12. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.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

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

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

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

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

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

The assessment results are summarised in Table 21. *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 21: 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 22). 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 22: 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%

5.3 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 23. For this assessment it was observed that few tag-recapture data involved larger lobsters.

Table 23: 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 RLIC: 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 RLIC	1986	2003	33
Tag recovery data	NZ RLIC & 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 24. Fixed parameters and their values are given in Table 25.

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 24: 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	–	–
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 25: 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 26. 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 26). For both sets of projections, the current split of AW and SS was used.

Table 26: 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 27.

Table 27: 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 (Tables 15 and 16) 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 13). 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 25). Recent exploitation rates appear to be around 20-30% of the vulnerable biomass (Table 28).

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

Indicator	5%	Median	95%
$\boldsymbol{B_{ref}}$	393	478	580
$\boldsymbol{B_{min}}$	278	360	455
$\boldsymbol{B_{current}}$	677	855	1068
$\boldsymbol{U_{current}}$	21%	25%	30%
$\boldsymbol{B_{proj}}$	426	808	1331
$\boldsymbol{U_{proj}}$	18%	27%	45%
$\boldsymbol{B_{current}/B_{ref}}$	1.50	1.78	2.12
$\boldsymbol{B_{current}/B_{min}}$	1.94	2.37	2.95
$\boldsymbol{B_{proj}/B_{ref}}$	0.92	1.68	2.73
$\boldsymbol{B_{proj}/B_{current}}$	0.57	0.94	1.39
$\boldsymbol{B_{proj}/B_{min}}$	1.23	2.24	3.67
$\boldsymbol{U_{proj}/U_{current}}$	0.76	1.11	1.67
$\boldsymbol{P(B_{proj} < B_{current})}$	60%		
$\boldsymbol{P(B_{proj} < B_{ref})}$	7%		
$\boldsymbol{P(B_{proj} < B_{min})}$	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 28. 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 28) 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%).

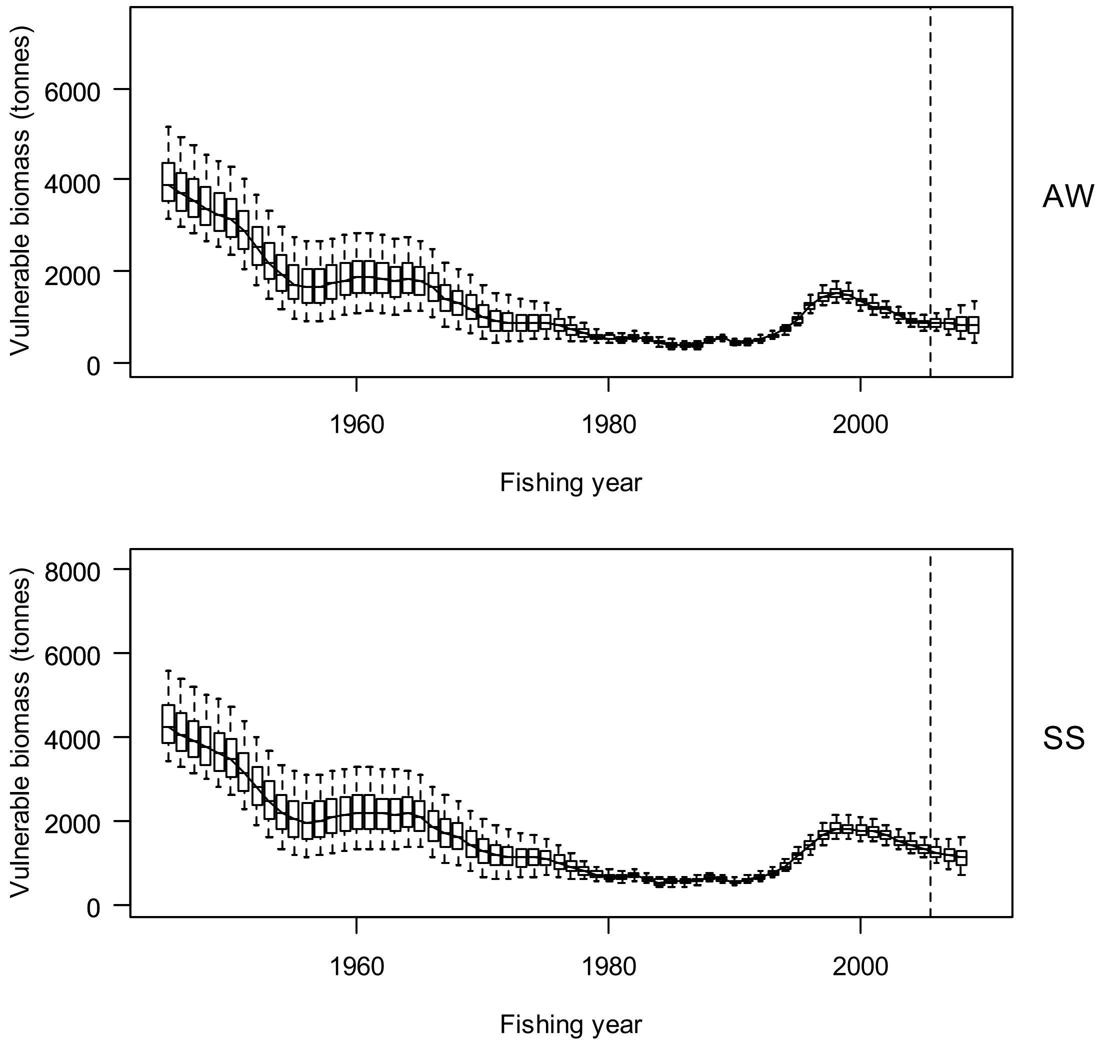


Figure 13: Posterior trajectories of vulnerable biomass, for the AW (top) and SS (bottom) seasons, from the CRA 4 base case MCMC simulations. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles. 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 28. 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.

5.4 CRA 5

Model structure

This section reports an assessment for *J. edwardsii* for CRA 5 from the NSC substock taken from the 2003 Mid-year Plenary report (Sullivan 2003).

The size-based model used in 2002, which was fully described by Starr *et al.* (2003), was revised and improved for the 2003 assessment. The model is fitted to three series of catch rate indices from different periods, and to size frequency and tagging data.

An important structural feature of the model is the division of the year into two seasons (autumn-winter (AW): April to September, and spring-summer (SS): October to March). This captures 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 5. Different MLS regulations existed at this time and pots were not required to have escape gaps. We therefore incorporated historical information for CRA 5: 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 29.

Major changes made to the 2003 model were: fitting to pre-recruit indices; estimation of recruitment deviations for all years through 1999; the generalised form of the growth model with shape parameter; direct estimation of catchability rather than calculating it; the use of true lognormal likelihood including the constants; addition of a switch assigning maximum seasonal vulnerability to any sex/season combination; and addition of a surplus production calculation.

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 1945 to 1999.

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 is assumed to be constant and independent of sex 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 regulations over time (for instance, changes in escape gap regulations) can be modelled by estimating separate selectivity parameters appropriate to each period of the fishery).

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 2002–03 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) and a pre-recruit index series from the catch sampling. A lognormal error structure was assumed for abundance indices and a normal error structure was assumed for tag-recapture data and proportions-at-length.

A summary of the data used in each assessment, the data sources and the applicable years are provided in Table 29.

Table 29: Data types and sources for the 2002 assessments for CRA 4 and 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; RLIC – 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
Pre-recruit index	MFish and RLIC	1993	2002
Historical proportions-at-size	Various	1974	1984
Observer proportions-at-size	MFish	1986	2002
Logbook proportions-at-size	RLIC	1994	2002
Current tag recovery data	RLIC & MFish	1996	2002
Historical MLS regulations	Annala (1983), MFish	1945	2002
Escape gap regulation changes	Annala (1983), MFish	1945	2002

The model was fitted to size data (proportions-at-length) 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. 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.

The parameters estimated in each model and the priors used are provided in Table 30. Fixed parameters and their values are given in Table 31. CPUE, the historical catch rate, pre-recruit data, the proportions-at-length and tagging data were weighted directly by a relative weighting factor. For CRA 5, we varied the weights to obtain standard deviations of standardised residuals for each data set that were close to one.

Table 30: Parameters estimated and priors used in basecase assessments for CRA 4 and CRA 5. 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
LogqI	U	1-25	–	–
LogqCR	U	1-25	–	–
LogqPRI	U	1-25	–	–
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	0.01-2.0	–	–

	Prior Type	Bounds	Mean	CV
TW at 50% probability female maturity	U	30–80	–	–
(TW at 95% probability female maturity) – (TW at 50% probability female maturity)[2]	U	0–60	–	–
Relative vulnerability: males autumn-winter [3]	U	0-1	–	–
Relative vulnerability: males spring-summer	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

[1] Normal in logspace = lognormal (bounds equivalent to –10 to 10)
[2] CRA 5 only
[3] Relative vulnerability of immature females in autumn-winter was fixed at one

Table 31: Fixed values used in basecase assessment for CRA 5

	CRA 5
Std dev of observation error of increment	1
Std dev of historical catch per day	0.30
Std dev of pre-recruit index	0.30
Maximum exploitation rate	90%
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	1999
Relative weight for length frequencies	29
Relative weight for CPUE	1.52
Relative weight for CR	2.4
Relative weight for PRI	0.18
Relative weight for tag-recapture data	0.28
Projected SL catch (t)	447
Projected NSL catch (t)	62

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 the Markov chain - Monte Carlo procedure (McMC) using the Hastings-Metropolis algorithm; For each sample of the posterior, 5-year projections (encompassing the 2003–04 to 2007–08 fishing years) were generated by assuming the catches indicated in Table 32.

c) 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 32: 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.

Population modelled	Commercial	Recreational	Reported Illegal	Unreported Illegal	Customary
CRA 5	350	99	3	49	10

Performance indicators

The 2001 Plenary agreed to use a number of performance indicators as measures of the status and risk for CRA 5. Subsequent assessments have continued this agreement. The Working Group 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 4 and CRA 5 suggest that biomass was relatively stable during this period. In 2001 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. $BVULN_{03}/BVULN_{79\text{-}88}$
2. $BVULN_{08}/BVULN_{03}$
3. $BVULN_{08}/BVULN_{79\text{-}88}$
4. $UNSL_{02,AW}$
5. $USL_{02,AW}$
6. $UNSL_{07,AW}$
7. $USL_{07,AW}$

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, $BVULN_{03}$, is defined as the start-of-season vulnerable biomass on 1 April 2003, the beginning of the autumn-winter season for the 2003-04 fishing year. Similarly, projected vulnerable biomass $BVULN_{08}$ is defined as the start-of-season vulnerable biomass on 1 April 2008, the beginning of the autumn-winter season for the 2008–2009 fishing year. Vulnerable biomass was also calculated for the reference period: $BVULN_{79\text{-}88}$ 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 $USL_{07,AW}$ is the exploitation rate for catch taken from the SL vulnerable biomass in the autumn-winter season of 2007-08, the last year of projections. $UNSL_{02,AW}$ and $UNSL_{07,AW}$ are similarly defined except that they describe the exploitation rate for catch taken from the NSL vulnerable biomass.

Stock assessment results: *Jasus edwardsii*, CRA 5

The base case assessment for CRA 5 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, an initial McMC trial using a fit which had standard deviations of normalised residuals (sdnrs) close to 1 had a poor trace. This was solved by reducing slightly the weight on the CPUE and CR data sets which produced an McMC with a better trace and sdnrs close to 1.

Base case results suggested that biomass decreased to a low point in the late 1980s, remained low through 1995, then increased (Figure 14). Seasonal exploitation rate peaked in 1985 at over 80% for the spring-summer fishery, and is currently near 30% for the catch limited by size limit and berried female restrictions in the autumn-winter and much lower (about 10%) in the spring-summer fishery.

A series of sensitivity trials on the MPD estimate suggested that the results were generally robust to these trials. Sensitivities with alternative non-commercial catch estimates showed that projected biomass was more affected by differences in their trend, rather than their magnitude. A set of retrospective analyses on the MPD fits did not change estimates of biomass or exploitation rate a great deal.

Table 33: Summary statistics for performance indicators from posterior distributions from CRA 5. Biomass indicators are shown in tonnes.

	Basecase			
	0.05	median	mean	0.95
$BALL_{79\text{-}88}$	3744	3918	3929	4151
$BRECT_{79\text{-}88}$	708	776	778	855
$BVULN_{79\text{-}88}$	517	555	557	606
$BALL_{03}$	4475	5281	5341	6394
$BRECT_{03}$	2314	2555	2562	2827
$BVULN_{03}$	966	1102	1106	1261
$BALL_{08}$	3928	5610	5676	7659
$BRECT_{08}$	1516	2364	2424	3494
$BVULN_{08}$	472	930	969	1586
$UNSL_{03}$ (%)	1.5%	1.7%	1.7%	2.0%
USL_{03} (%)	25.7%	29.4%	29.5%	33.5%
$UNSL_{07}$ (%)	1.3%	1.8%	1.9%	2.5%
USL_{07} (%)	22.7%	35.6%	37.3%	57.8%
$BVULN_{03}/BVULN_{79\text{-}88}$ (%)	176.9%	197.9%	198.5%	221.1%
$BVULN_{08}/BVULN_{03}$ (%)	44.5%	84.3%	87.2%	139.4%
$BVULN_{08}/BVULN_{79\text{-}88}$ (%)	85.5%	167.4%	173.7%	282.8%
$P(BVULN_{08}<BVULN_{03})$	0.692			

The assessment results (Table 33) are based on the posterior distributions of indicators. These were obtained from MCMC simulations - a single chain of 2 million was made and 10 000 samples were taken. The first 1000 were discarded to improve the diagnostics, which were accepted by the Working Group. Results suggest that the 2003 vulnerable biomass is currently about 198% (0.05 and 0.95 quantiles 77% to 121%) of the vulnerable biomass during the 1979-88 reference period (Figure 14). At the 2002-03 levels of catch and using recruitments sampled from 1989-98, the probability of the vulnerable biomass in 2008 being lower than the vulnerable biomass in 2003 is 0.69. However, the decrease is not expected to be large. The median expectation is that biomass will decrease to 84% of 2002-03 biomass over five years, but with considerable uncertainty (44% to 139% of current biomass).

The projections rely on an assumption that recruitment would be similar, on average, to that in the period 1989–98 and with variability as seen in those ten years. No sensitivity tests were conducted using alternative recruitment assumptions such as the puerulus settlement data. The settlement data for NSC to the end of 2002 show that there was a strong settlement pulse in the early 1990s, followed by lower settlement up to 1999. From 2000 there has been a recovery in settlement levels, with 2001 and 2002 near the long-term average.

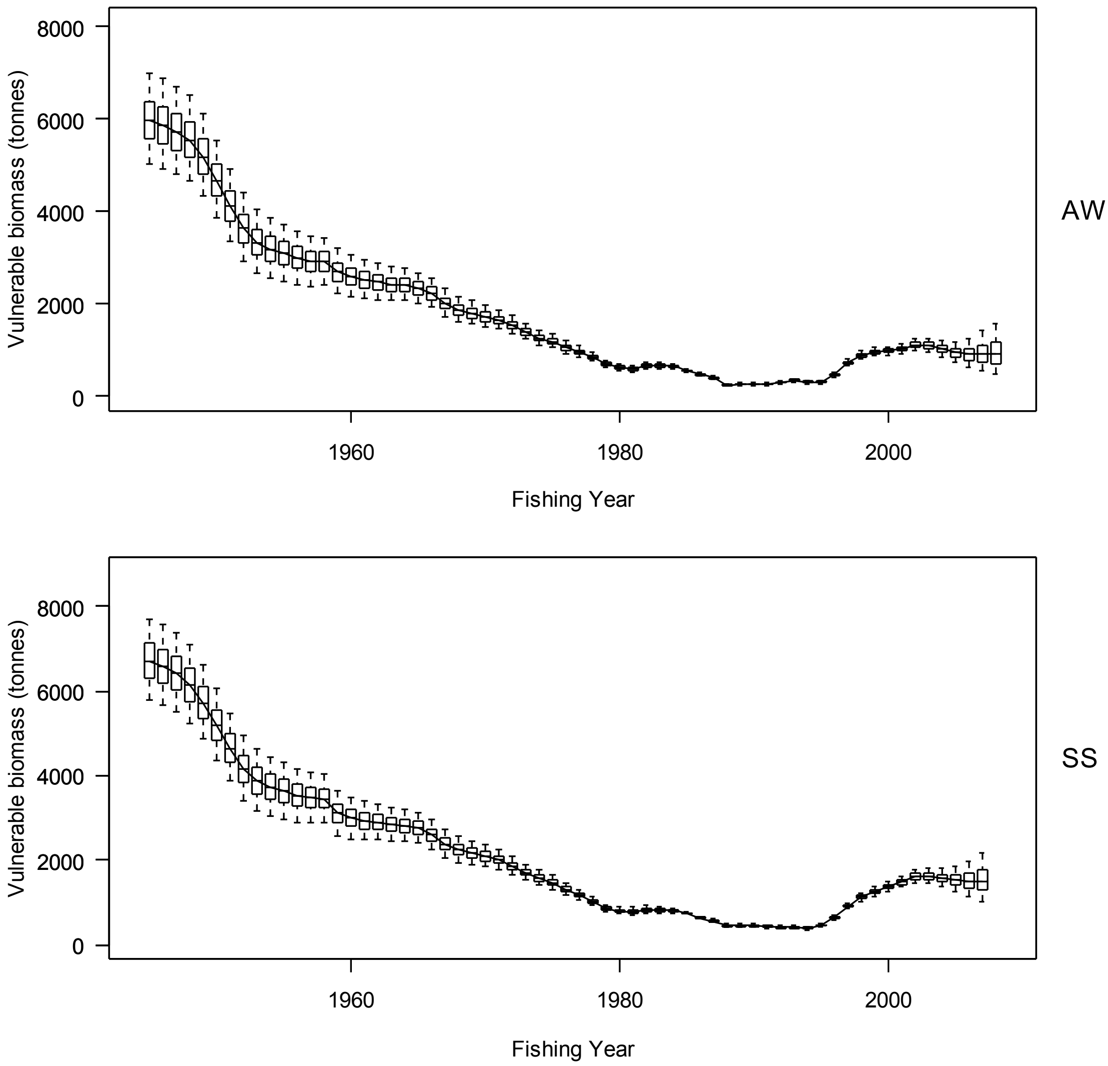


Figure 14: CRA 5: posterior trajectories of vulnerable biomass, for the AW (top) and SS (bottom) seasons, from the CRA 5 base case MCMC simulations. For each year the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.

5.5 CRA 6

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

Alternative methods have been used to assess the CHI stock. These include a simple depletion analysis presented to the Working Group in previous years and a new production model, which appeared to fit the observed data well. Both models assume a constant level of annual productivity which is independent of the standing stock and thus will not be affected by changes to the level of the standing stock. B_0 was estimated by both models to be about 20 000 t.

5.6 CRA 7 and CRA 8

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

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

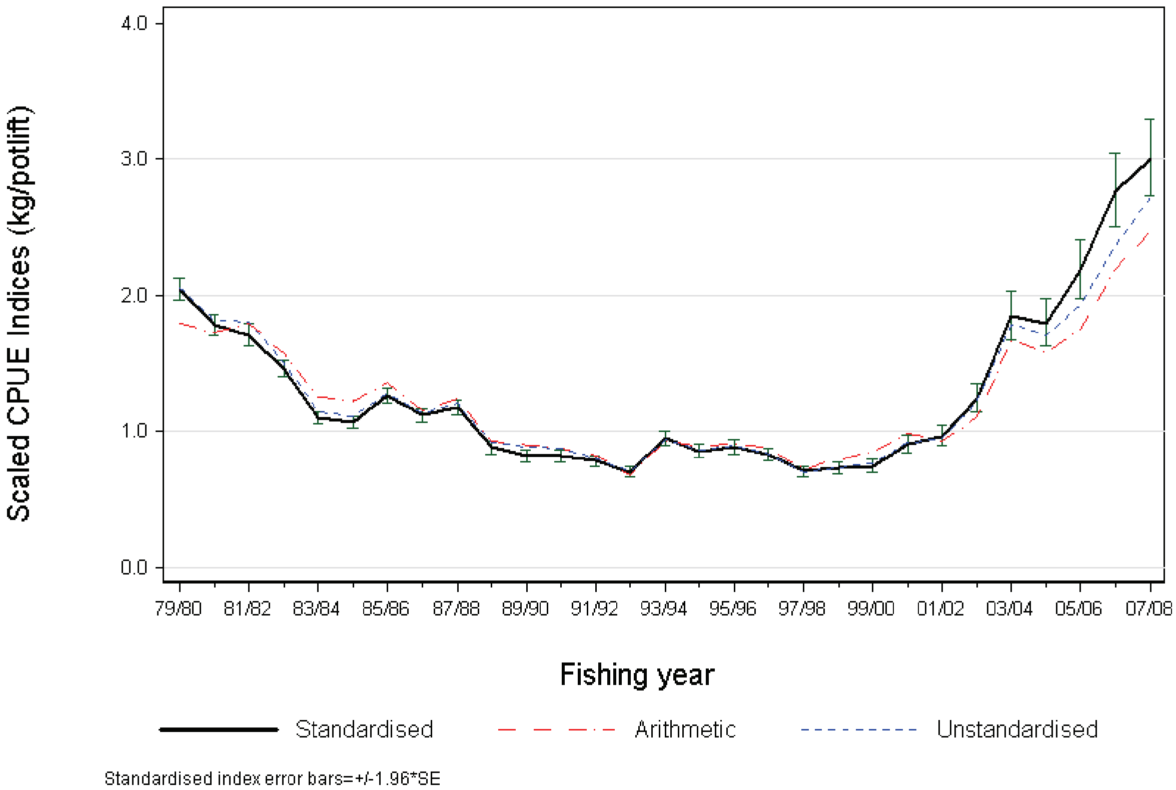


Figure 15: Annual CPUE indices for CRA 8: arithmetic (dashed line), unstandardised (dotted line), and standardised (bold line) ± 2 s.e. 1979–80 to 2007–08. The geometric mean for each series = 1.13 kg/potlift.

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 15) 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.

6. YIELD ESTIMATES

6.1 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.

6.2 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.

7. STATUS OF THE STOCKS

7.1 *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	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	
Historical Stock Status Trajectory and Current Status	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
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	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Hard Limit:

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 has increased in 2007 and 2008 above the 2002 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	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	
Historical Stock Status Trajectory and Current Status	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
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		
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Hard Limit:	
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 is similar to the 2002 level

Fishery Interactions

7.2 *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 Stock is 11% above B_{min}	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has declined since1999 and has a 25% probability of increase by 2012 under the current TAC
Recent Trend in Fishing Mortality or Proxy	
Other Abundance Indices	
Trends in Other Relevant Indicators or Variables	

Projections and Prognosis	
Stock Projections or Prognosis	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Hard Limit:

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
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	Mean of beginning AW vulnerable biomass for the period 1979-88
Status in relation to Target	Biomass in 2005 was about 1.8 times reference level
Status in relation to Limits	
Historical Stock Status Trajectory and Current Status	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has declined since1999 but is well above reference level
Recent Trend in Fishing Mortality or Proxy	
Other Abundance Indices	
Trends in Other Relevant Indicators or Variables	

Projections and Prognosis	
Stock Projections or Prognosis	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Hard Limit:

Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Bayesian length based model (Starr et al 2003)	
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 declined since 2005

Fishery Interactions

CRA 5

Stock Status	
Year of Most Recent Assessment	2003
Assessment Runs Presented	Base case and sensitivity runs
Reference Point	Mean of beginning AW vulnerable biomass for the period 1979-88
Status in relation to Target	Biomass in 2003 was about twice reference level
Status in relation to Limits	
Historical Stock Status Trajectory and Current Status	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is above reference level
Recent Trend in Fishing Mortality or Proxy	
Other Abundance Indices	
Trends in Other Relevant Indicators or Variables	

Projections and Prognosis		
Stock Projections or Prognosis		
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Hard Limit:	
Assessment Methodology		
Assessment Type	Level 1 Quantitative Assessment model	
Assessment Method	Bayesian length based model (Starr et al 2003)	
Main data inputs	CPUE, length frequency, tagging data	
Period of Assessment	Latest assessment: 2003	Next assessment: Unknown
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty		

Qualifying Comments

Recent developments in stock status
CPUE is similar to the 2003 level

Fishery Interactions

7.3 *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 2009 the 2007 management procedure for CRA 7 triggers a decrease in the TAC for CRA 7 to 104.5t for the 2010-11 fishing year. The results of the decision rule for CRA 8 estimates a decrease of 0.5% in TAC. However, the minimum change allowed under the rule is ±5%, thus the proposed TAC remains unchanged under the CRA 8 management procedure for the 2010–11 fishing year.

7.4 *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 2008–09 fishing year (355 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.

7.5 *Sagmariasus verreauxi*, PHC stock

The status of this stock is unknown.

Table 34: 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	2008–09 TACC	2008–09 Landings	2009–10 TACC	2009–10 TAC
CRA 1	Northland	–	131.1	131.0	131.1	–
CRA 2	Bay of Plenty	–	236.1	232.1	236.1	452.6
CRA 3	Gisborne	–	190.0	188.8	164.0	293.0
CRA 4	Wairarapa–Hawke Bay	–	577.0	249.3	266.0	461.0
CRA 5	Canterbury–Marlborough	–	350.0	349.7	350.0	467.0
CRA 6	Chatham Islands	300–380	360.0	355.0	360.0	370.0
CRA 7	Otago	–	123.9	120.3	189.0	209.0
CRA 8	Southern	–	966.0	966.0	1 019.0	1 110.0
CRA 9	Westland–Taranaki	–	47.0	47.0	47.0	–
CRA 10	Kermadec	–	0.0	0.0	0.0	–
Total			2 981.0	2 639.1	2 762.2	3 362.6
PHC 1	All QMAs	18	40.3	36.3	40.3	–

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