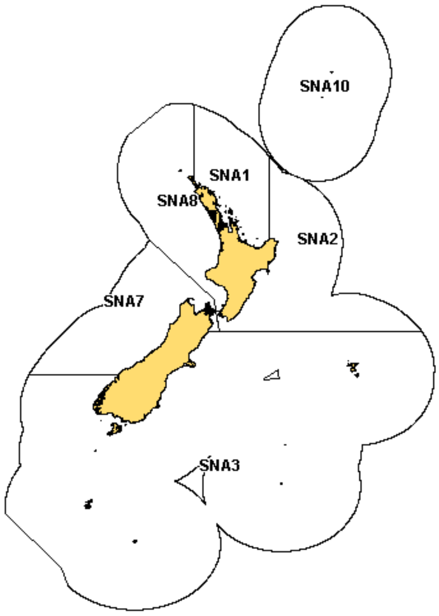
SNAPPER (SNA)

(*Pagrus auratus*)



1. FISHERY SUMMARY

(a) Commercial fisheries

The snapper fishery is one of the largest and most valuable coastal fisheries in New Zealand. The commercial fishery, which developed last century, expanded in the 1970s with increased catches by trawl and Danish seine. Following the introduction of pair trawling in most areas, landings peaked in 1978 at 18 000 t (Table 1). Pair trawling was the dominant method accounting for on average 75% of the annual SNA 8 catch from 1976 to 1989. In the 1980s an increasing proportion of the SNA 1 catch was taken by longlining as the Japanese "iki jime" market was developed. By the mid 1980s catches had declined to 8500–9000 t, and some stocks showed signs of overfishing. The fisheries had become more dependent on the recruiting year classes as stock size decreased. With the introduction of the QMS in 1986, TACCs in all Fishstocks were set at levels intended to allow for some stock rebuilding. Decisions by the Quota Appeal Authority saw TACCs increase, in the case of SNA 1 to over 6000 t, and for SNA 8 from 1330 t to 1594 t (Table 2).

In 1986–87, landings from the three largest Fishstocks were less than their respective TACCs (Table 2), but catches subsequently increased in 1987–88. However, landings from SNA 7 continued to fall below the TACC, and in 1989–90 the TACC was reduced to 160 t. Changes to TACCs that took effect from 1 October 1992 resulted in a reduction for SNA 1 from 6010 t to 4904 t, an increase for SNA 2 from 157 t to 252 t, and a reduction for SNA 8 from 1594 t to 1500 t. The TACC for SNA 1 was exceeded in the 1992–93 fishing year by over 500 t. Some of this resulted from carrying forward of up to 10% under-runs from previous years by individual quota holders, but most of this over-catch was not landed against quota holdings (deemed penalties were incurred for about 400 t).

From 1 October 1997 the TACC for SNA 1 was reduced to 4500 t, within an overall TAC of 7550 t, while the TACC for SNA 7 was increased to 200 t within an overall TAC of 306 t. In SNA 2, the bycatch of snapper in the tarakihi, gurnard and other fisheries has resulted in overruns of the snapper TACC in all years from 1987–88 up to 2000–01. From 1 October 2002, the TACC for SNA 2 was increased from 252 to 315 t, within a total TAC of 450 t. Table 3 shows the TACs, TACCs and allowances for each Fishstock from 1 October 2004.

From 1 October 2005 the TACC for SNA 8 was reduced to 1300 t within a TAC of 1785 t to ensure a faster rebuild of the stock.

Table 1: Reported landings (t) for the main QMAs from 1931 to 1990.

Year	SNA 1	SNA 2	SNA 7	SNA 8	Year	SNA 1	SNA 2	SNA 7	SNA 8
1931	3465	0	69	140	1961	5318	589	583	1178
1932	3567	0	36	159	1962	5582	604	582	1352
1933	4061	21	65	213	1963	5702	636	569	1456
1934	4484	168	7	190	1964	5643	667	574	1276
1935	5604	149	10	108	1965	6039	605	780	1182
1936	6597	78	194	103	1966	6429	744	1356	1831
1937	5918	114	188	85	1967	6557	856	1613	1477
1938	6414	122	149	89	1968	7333	765	1037	1491
1939	6168	100	158	71	1969	8674	837	549	1344
1940	5325	103	174	76	1970	9792	804	626	1588
1941	5003	148	128	62	1971	10 737	861	640	1852
1942	4279	74	65	57	1972	9574	878	767	1961
1943	4643	60	29	75	1973	9036	798	1258	3038
1944	5045	49	96	69	1974	7635	716	1026	4340
1945	4940	59	118	124	1975	5894	732	789	4217
1946	5382	77	232	244	1976	7220	732	1040	5326
1947	5815	36	475	251	1977	7514	374	714	3941
1948	6745	53	544	215	1978	10 128	454	2720	4340
1949	5866	215	477	277	1979	10 460	662	1776	3464
1950	5107	285	514	318	1980	7370	636	732	3309
1951	4301	265	574	364	1981	7872	283	592	3153
1952	3795	220	563	361	1982	7242	160	591	2636
1953	3703	247	474	1124	1983	6256	160	544	1814
1954	4316	293	391	1093	1984	7141	227	340	1536
1955	4442	309	504	1202	1985	6774	208	270	1866
1956	4742	365	822	1163	1986	5969	255	253	959
1957	5285	452	1055	1472	1987	4532	122	210	1072
1958	5154	483	721	1128	1988	5082	165	193	1565
1959	5778	372	650	1114	1989	5816	227	292	1571
1960	5697	487	573	1202	1990	5757	429	200	1551

Notes:

1. The 1931-1943 years are April-March but from 1944 onwards are calendar years.
2. The "QMA totals" are approximations derived from port landing subtotals, as follows: SNA 1, Mangonui to Whakatane; SNA 2 Gisborne to Wellington/Makara; SNA 7, Marlborough Sounds ports to Greymouth; SNA 8 Paraparaumu to Hokianga.
3. Before 1946 the "QMA" subtotals sum to less than the New Zealand total because data from the complete set of ports are not available. Subsequent minor differences result from small landings in SNA 3, not listed here.
4. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.

Table 2: Reported landings (t) of snapper by Fishstock from 1983–84 to 2005–06 and gazetted and actual TACCs (t) for 1986–87 to 2005–06.

Fishstock	SNA 1		SNA 2		SNA 3		SNA 7		SNA 8		SNA 10			
QMAs	1		2		3,4,5,6		7		8,9		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings§	TACC
1983–84†	6539	–	145	–	2	–	375	–	1725	–	0	–	9153	–
1984–85†	6898	–	163	–	2	–	255	–	1546	–	0	–	9228	–
1985–86†	5876	–	177	–	0	–	188	–	1828	–	0	–	8653	–
1986–87‡	4016	4710	130	130	0	30	257	330	893	1330	0	10	5314	6540
1987–88‡	5061	5098	152	137	1	30	256	363	1401	1383	0	10	6900	7021
1988–89‡	5793	5614	210	157	1	30	176	372	1526	1508	0	10	7706	7691
1989–90‡	5826	5981	364	157	< 1	30	294	160	1550	1594	0	10	8034	7932
1990–91‡	5315	6002	427	157	< 1	31	160	160	1658	1594	0	10	7570	7944
1991–92‡	6191	6010	373	157	< 1	31	148	160	1464	1594	0	10	8176	7962
1992–93‡	5423	4904	316	252	2	32	165	160	1543	1500	0	10	7448	6858
1993–94‡	4846	4928	307	252	< 1	32	147	160	1542	1500	0	10	6842	6883
1994–95‡	4831	4938	307	252	< 1	32	150	160	1434	1500	0	10	6723	6893
1995–96‡	4941	4938	279	252	< 1	32	146	160	1558	1500	0	10	6924	6893
1996–97‡	5049	4938	352	252	< 1	32	162	160	1613	1500	0	10	7176	6893
1997–98‡	4524	4500	286	252	< 1	32	182	200	1589	1500	0	10	6583	6494
1998–99‡	4411	4500	283	252	3	32	142	200	1636	1500	0	10	6475	6494
1999–00‡	4500	4500	391	252	< 1	32	174	200	1604	1500	0	10	6669	6494
2000–01‡	4347	4500	360	252	< 1	32	156	200	1630	1500	0	10	6496	6494
2001–02‡	4372	4500	252	252	1	32	141	200	1577	1500	0	10	6342	6494
2002–03‡	4484	4500	334	315	<1	32	187	200	1558	1500	0	10	6563	6557
2003–04‡	4466	4500	339	315	<1	32	215	200	1667	1500	0	10	6686	6557
2004–05‡	4641	4500	399	315	<1	32	178	200	1663	1500	0	10	6881	6557
2005–06‡	4530	4500	389	315	<1	32	166	200	1434	1500	0	10	6519	6557

† FSU data. SNA 1 = stat areas 1–10; SNA 2 = stat areas 11–16; SNA 3 = stat areas 18–32; SNA 7 = stat areas 17, 33–36, 38; SNA 8 = stat areas 37, 39–48.

‡ QMS data.

§ Includes landings from unknown areas before 1986–87.

Table 3: TACs, TACCs and allowances (t) for snapper by Fishstock from 1 October 2005.

Fishstock	TAC	TACC	Customary allowance	Recreational allowance	Other mortality
SNA 1	7550	4500	*	*	450
SNA 2	450	315	14	90	31
SNA 3		32.3			-
SNA 7	306	200	16	90	-
SNA 8	1785	1300	43	312	130
SNA 10		10			

* SNA 1 has a combined non-commercial allowance of 2600 t.

Foreign fishing

Japanese catch records and observations made by New Zealand naval vessels indicate significant quantities of snapper were taken from New Zealand waters from the late 1950s until 1977. There are insufficient data to quantify historical Japanese catch tonnages for the respective snapper stocks. However, trawl catches have been reported by area from 1967 to 1977, and longline catches from 1975 to 1977 (Table 4). These data were supplied to the Fisheries Research Division of MAF in the late 1970s, however, the data series is incomplete, particularly for longline catches.

Table 4: Reported landings (t) of snapper from 1967 to 1977 by Japanese trawl and longline fisheries. NA – not available.

(a) Trawl

Year	Trawl catch (all species)	Total snapper trawl catch	SNA 1	SNA 7	SNA 8
1967	3092	30	NA	NA	NA
1968	19 721	562	1	17	309
1969	25 997	1289	–	251	929
1970	31 789	676	2	131	543
1971	42 212	522	5	115	403
1972	49 133	1444	1	225	1217
1973	45 601	616	–	117	466
1974	52 275	472	–	98	363
1975	55 288	922	26	85	735
1976	133 400	970	NA	NA	676
1977	214 900	856	NA	NA	708

(b) Longline

Year	Total Snapper	SNA 1	–	SNA 8
1975	1510	761	–	749
1976	2057	930	–	1127
1977	2208	1104	–	1104

In 1997 the sensitivity of the SNA 1 and SNA 8 assessments to the assumed level of Japanese catch was investigated. Higher assumed levels of catch generally resulted in higher estimates of virgin biomass and mean recruitment. In SNA 1 the start year for the assessment model is 1970 which reduces the importance of the assumptions concerning Japanese catch.

Japanese catch was assumed to have occurred between 1960 and 1977, with cumulative total removals over the period at 30 000 t. The pattern of annual catches was assumed to increase linearly to a peak in 1968 (reaching 2202 t) then decline linearly to 1978 (zero). The catch was split evenly between East Northland and the Hauraki Gulf/Bay of Plenty.

For SNA 8, Japanese longline catch was assumed to be at a constant annual removal each year for 1965-1974. An annual catch level of 2000 t was assumed. Trawl catches for 1967-77 and longline catch for 1975-77 were assumed to be at the reported levels

(b) Recreational fisheries

The snapper fishery is the largest recreational fishery in New Zealand. It is the major target species on both coasts of the North Island. The allowances within the TAC for each Fishstock are shown in Table 3.

Nationally the snapper bag limit for amateur fishers was set at 30 per person and minimum legal size (MLS) at 25 cm in January 1985. This bag limit was retained until 30 September 1993 when a new limit of 20 per person was applied in FMA 1 and 9. Following further consideration on snapper bag limits in northern New Zealand, against the backdrop of sustainability measures required for the overall fishery in SNA 1 and SNA 8, differential bag limits were introduced for SNA 1 and SNA 8 stocks on 30 October 1995. In FMA 9 (the northern part of SNA 8) between Tirua Point and North Cape, the bag limit was set at 15, whereas the limit in SNA 1 was set at 9 and the size limit in both FMA 1 and 9 was raised to 27 cm for amateur fishers only. In FMA 8 (the southern part of SNA 8) and in SNA 2 the bag limit is 10 per person per day with a MLS of 27 cm. Around the South Island (most of SNA 3 and SNA 7) the snapper bag limit is 10 per person per day and the MLS is 25 cm.

The tag ratio method gave the first estimates of recreational catch (Table 5). A tonnes per tag ratio was obtained from commercial tag returns and this was applied to the recreational returns to estimate catch. Regional telephone and diary surveys gave later estimates: MAF Fisheries South (1991–92), Central (1992–93) and North (1993–94) regions (Teirney et al., 1997). Estimates for 1996 came from a national telephone and diary survey (Bradford, 1998). Another national telephone and diary survey was carried out in 2000 (Boyd & Reilly, in press a) and a rolling replacement of diarists in 2001 (Boyd & Reilly, in press b) allowed estimates for a further year (population scaling ratios and mean weights were not re-estimated). The diary method used mean weights of snapper obtained from fish measured at boat ramps.

Table 5: Recreational catch estimates for snapper stocks. Totals for a stock are given in bold. The telephone/diary surveys ran from December to November but are denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys. Numbers and mean weights are not calculated in the tag ratio method.

Stock	Year	Method	Number of fish (thousands)	Mean weight (g)	Total weight (t)
SNA 1					
East Northland	1985	Tag ratio	-	-	370
Hauraki Gulf	1985	Tag ratio	-	-	830
Bay of Plenty	1984	Tag ratio	-	-	400
Total	**1985**[1]	**Tag ratio**			**1600**
Total	**1994**	**Telephone/diary**	**3804**	**871**	**2857**
East Northland	1996	Telephone/diary	684	1039	711
Hauraki Gulf/ Bay of Plenty	1996	Telephone/diary	1852	870	1611
Total	**1996**	**Telephone/diary**	**2540**	**915**	**2324**
East Northland	2000	Telephone/diary	1457	1154	1681
Hauraki Gulf	2000	Telephone/diary	3173	830	2632
Bay of Plenty	2000	Telephone/diary	2274	872	1984
Total	**2000**	**Telephone/diary**	**6904**	**904**	**6242**
East Northland	2001	Telephone/diary	1446	-[5]	1669
Hauraki Gulf	2001	Telephone/diary	4225	-[5]	3507
Bay of Plenty	2001	Telephone/diary	1791	-[5]	1562
Total	**2001**	**Telephone/diary**	**7462**	-[5]	**6738**
SNA 2	**1993**	**Telephone/diary**	**28**	**1282**	**36**
	1996	**Telephone/diary**	**31**	**1282**[2]	**40**
	2000	**Telephone/diary**	**268**	**1200**[4]	**322**
	2001	**Telephone/diary**	**144**	-[5]	**173**
SNA 7					
Tasman/Golden Bays	1987	Tag ratio	-	-	15
Total	**1993**	**Telephone/diary**	**77**	**2398**[3]	**184**
Total	**1996**	**Telephone/diary**	**74**	**2 398**	**177**
Total	**2000**	**Telephone/diary**	**63**	**2 148**	**134**
Total	**2001**	**Telephone/diary**	**58**	-[5]	**125**
SNA 8					
Total	**1991**	**Tag ratio**	**-**	**-**	**250**
Total	**1994**	**Telephone/diary**	**361**	**658**	**238**
Total	**1996**	**Telephone/diary**	**271**	**871**	**236**
Total	**2000**	**Telephone/diary**	**648**	**1020**	**661**
Total	**2001**	**Telephone/diary**	**1111**	**-**	**1133**

[1] The Bay of Plenty programme was carried out in 1984 but is included in the 1985 total estimate
[2] Mean weight obtained from 1992–93 boat ramp sampling
[3] Mean weight obtained from 1995–96 boat ramp sampling
[4] Mean weight obtained from 1999–2000 commercial landed catch sampling
[5] The 2000 mean weights were used in the 2001 estimates

Several potential causes of bias have been identified for the recreational catch estimates. The three most serious are described:

- The tag ratio method requires that all tagged fish caught by recreational fishers are recorded, or at least that the under-reporting rate of recreational fishers is the same as that of commercial fishers. This was assumed, although no data were available to test the assumption. If the recreational under-reporting rate were greater than that of the commercial fishers a negative bias would result. In SNA 8 there was evidence that many tags recovered by commercial fishing were reported as recreational catch, which would give a positive bias to estimates.
- In the telephone/diary method fishers are recruited to fill in diaries by way of a telephone survey that also estimates the proportion of the population that is eligible (likely to fish). A "soft refusal" bias in the eligibility proportion arises if interviewees who do not wish to co-operate falsely state that they never fish. The proportion of eligible fishers in the population is thereby under-estimated. The 2000 telephone/diary survey (pilot studies) demonstrated that this effect occurred when recreational fishing was established as the subject of the interview at the outset. It established that soft refusals were highly likely to have biased all the previous telephone/diary surveys. A correction would be required to overcome this bias in the pre-2000 estimates.
- Another equally serious cause of bias in telephone/diary surveys was identified. This was the potential for diarists who did not immediately record their day's catch after a trip to overstate their catch or even to overstate the number of trips they had made. There is some indirect evidence that this may have occurred in all the telephone/diary surveys (Wright et al., 2004).

The Recreational Technical Working Group concluded that the harvest estimates from the diary surveys should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and, c) the 2000 and 2001 estimates are implausibly high for many important fisheries.

In 2005, the Snapper WG and Plenary considered recreational catches from SNA 8. Two alternative levels were assumed for the recreational catch from 1990 to 2004, either 300 t or 600 t. The Plenary considered these values were likely to bracket the true average level of catch in this period.

(c) Maori customary fisheries

Snapper form important fisheries for Maori, but the annual catch is not known.

(d) Illegal catch

No new information is available to estimate illegal catch. For modelling SNA 1 and SNA 8 an assumption was made that non-reporting of catch was 20% of reported domestic commercial catch prior to 1986 and 10% of reported domestic commercial catch since the QMS was introduced. This was to account for all forms of under-reporting.

(e) Other sources of mortality

No quantitative estimates are available regarding the impact of other sources of mortality on snapper stocks; high-grading of longline fish and discarding of under-sized fish by all methods occurs.

2. BIOLOGY

Snapper are demersal fish found down to depths of about 200 m, but are most abundant in 15–60 m. They are the dominant fish in northern inshore communities and occupy a wide range of habitats, including rocky reefs and areas of sand and mud bottom. They are widely distributed in the warmer waters of New Zealand, being most abundant in the Hauraki Gulf.

Snapper are serial spawners, releasing many batches of eggs over an extended season during spring and summer. The larvae have a relatively short planktonic phase which results in the spawning grounds corresponding fairly closely with the nursery grounds of young snapper. Young fish school in shallow water and sheltered areas and move out to deeper water in winter. The fish disperse more widely as they grow older. They first reach maturity from 20 to 28 cm fork length at 3–4 years of age. Large schools of snapper congregate before spawning and move on to the spawning grounds, usually in November-December. The spawning season may extend to January-March in some areas and years before the fish disperse, often inshore to feeding grounds. The winter grounds are thought to be in deeper waters where the fish are more widespread.

Water temperature appears to play an important part in the success of recruitment. Generally strong year classes in the population correspond to warm years, weak year classes correspond to cold years.

Growth rate varies geographically and from year to year. Snapper from Tasman Bay/Golden Bay and the west coast of the North Island grow faster and reach a larger average size than elsewhere. Snapper have a strong seasonal growth pattern, with rapid growth from November to May, and then a slowing down or cessation of growth from June to September. They may live up to 60 years or more and have very low rates of natural mortality. An estimate of M = 0.06 yr^{-1} was made from catch curves of commercial catches from the west coast North Island pair trawl fishery in the mid-1970s. These data were re-analysed in 1997 and the resulting estimate of 0.075 yr^{-1} has been used in the base case assessments for SNA 1, 2, and 7 (and SNA 8 up to 2004). In the 2005 assessment for SNA 8, natural mortality was estimated within the model.

Estimates of biological parameters relevant to stock assessment are shown in Table 6.

Table 6: Estimates of biological parameters.

Fishstock	Estimate			Source
1. Instantaneous rate of natural mortality (*M*)				
SNA 1, 2 & 7	0.075			Hilborn & Starr (unpub. analysis)
SNA 8	0.051 or 0.054			estimated within model
2. Weight = a(length)^b (Weight in g, length in cm fork length)				
All	a = 0.04467	b = 2.793		Paul (1976)
3. von Bertalanffy growth parameters				
	Both sexes combined			
	K	t_0	L_∞	
SNA 1	0.102	-1.11	58.8	Gilbert & Sullivan (1994)
SNA 2	0.061	-5.42	68.9	NIWA (unpub. analysis)
SNA 7	0.122	-0.71	69.6	MAF (unpub. data)
SNA 8	0.160	-0.11	66.7	Gilbert & Sullivan (1994)
4. Age at recruitment (years)				
SNA 1*	4 (39%) 5 (100%)			Gilbert et al. (2000)
SNA 7	3			MAF (unpub. data)
SNA 8	3			Gilbert & Sullivan (1994)

* For years when not estimated

3. STOCKS AND AREAS

There are no new data that would alter the stock boundaries given in previous assessment documents.

Separation of stocks has previously been on the basis of genetic studies and other biological information. The location of spawning grounds, differences in growth rates between areas and the results of tagging studies suggest that 6 or 7 stock units may exist. Although individual fish have recorded some long-distance movements, tagging studies show that generally movement is localised.

For the purpose of this assessment for SNA 1, the Bay of Plenty was combined with the Hauraki Gulf, because of the high level of mixing seen in the recovery of tagged snapper. Up to 30% of the tag recoveries from fish tagged in the Bay of Plenty in the 1994 tagging programme were recovered in the Hauraki Gulf. As there was little mixing between East Northland and Hauraki Gulf snapper, East Northland was assessed as a separate sub-stock.

4. STOCK ASSESSMENT

The SNA8 assessment was updated in 2005. The other assessments of snapper stocks reported here were completed in 2000 (SNA1) and in 2002 (SNA 2 and SNA 7).

4.1 SNA 1 (Auckland East)

4.1.1 Estimates of recreational catch, selectivity and abundance indices

(a) Recreational catch

The 1996 catch estimates were not considered to be directly comparable to estimates from the tagging programme or the 1993–94 survey (Table 5). The reasons are that an increase in snapper minimum legal size (MLS) was introduced in 1994 and a reduction in the bag limit was introduced in 1995. Catch estimates for 1996 were therefore adjusted upward before being combined with the two other values. Catch totals were firstly scaled up to account for an assumed 8% reduction in catch due to the bag limit decrease. This 8% reduction in catch was estimated from the distribution of bag sizes in the 1994 boat ramp survey. Secondly, an allowance was considered for the numbers of 25 and 26 cm fish which are no longer landed. The length frequency section of the 1996 catch less than 27 cm was replaced by the length frequency portion of the 1994 recreational catch, scaled so that the numbers at 27 cm were the same. This added numbers of fish at 25 and 26 cm to the length distribution of the catch for 1996. The adjusted 1996 length frequency catch was then converted to weight via the length weight relationship (Table 6). These two corrections allow an estimate to be made of what the recreational catch would have been if the management measures had not been introduced (Table 7).

The Working Group acknowledged there was uncertainty concerning the interpretation of these catch levels. The mean of the three estimates was taken to represent the average catch each year from 1970 to 1997. The adjusted 1996 catch estimate was used in the calculation of the mean.

Table 7: Annual recreational catch estimates (tonnes) for SNA 1 used in the modelling.

Year	Source	East Northland	Hauraki Gulf/Bay of Plenty	Total
1985	1985 tagging programme	370	1230	1600
1994	1994 North diary survey	723	2071	2794
1996	1996 National diary survey	711	1611	2322
Adjusted 1996		799	1817	–
Mean value 1985, 1994 and 1996 (adjusted)		631	1706	–

In years where an estimate is available the catch was assumed to be at that level, but in all other years the mean value was used. The following assumptions were made in respect to recreational catch estimates input to the stock assessment models:

(i) The effect of the size limit change to 27 cm (1 December 1994) was included by assuming that all fish 5 years and older were legal sized fish, but that 4 year old fish were returned to the water. The survival of 4-year-olds returned to the water was assumed to be 80%.
(ii) For years after 1996 recreational fishing mortality (*F*) was assumed to remain at the rate estimated for 1996.
(iii) No allowance was made for further management controls in years after 1 October 1995.

(b) Selectivity Estimates

Selectivity-at-length curves were estimated from the 1985 and 1994 tagging data for longline, single trawl, Danish seine, other commercial, and recreational methods. The last two were estimated for 1985 only. Variations in growth rates may cause annual variations in selectivity-at-age even if selectivity-at-length is constant. Hence, an age-length key based on data pooled over several years and throughout SNA 1 was used to convert the 1985 length data to mean selectivity-at-age curves. The age-length data came from Hauraki Gulf 1984–85 and 1989–90 to 1997–98 (*n*=10 735), Bay of Plenty 1989–90 to 1991–92 and 1993–94 to 1997–98 (*n*=6456), and East Northland 1989–90 to 1990–91 and 1992–93 to 1997–98 (*n*=5386). They were normalised to 1 for the selectivity of 8-year-olds.

It was assumed that selectivity-at-age was constant before 1987 (the start of the QMS) and again after 1987 and the 1985 and 1994 selectivity estimates were applied to each period correspondingly. The single estimates for other commercial and recreational selectivities were applied throughout. As an alternative to the estimated values, selectivity curves before and after 1987 for single trawl, Danish seine and longline were fitted in the models. Three parameters σ_{left}, σ_{right} and A_{max} were derived to describe the selectivity of each method. The left- and right-hand limbs of two different normal density functions were joined at an arbitrary age, A_{max}, and scaled to be one at this age. The fitted selectivity curves fitted the data significantly better than the curves estimated from tagging and were used for the base case estimates.

(c) Abundance indices

(i) Temperature-recruitment relationship

The relationship between abundance estimates of 1+ snapper in the Hauraki Gulf trawl surveys (Table 8) and the Leigh water temperature has previously been used to predict year class strength (YCS) in the SNA 1 sub-stocks (Francis et al., 1995). The catch at age data and the trawl survey indices have been fitted inside the model to determine the YCS (r_t) for each year from 1967 to 1997.

Table 8: Estimated number of 1+ snapper (birth date of January 1) in trawlable areas from Hauraki Gulf spring trawl surveys.

Year class	Mean Feb–Jun water temp (°C)	Estimated no. of 1 yr olds (millions)*
1983	17.25	1.24 ‡
1984	18.28	3.64 ‡
1985	18.79	5.08 ‡
1986	19.03	5.78 ‡
1987	17.98	2.61 ‡
1988	18.54	3.92
1989	19.30	10.04
1990	19.05	–
1991	18.10	3.47
1992	17.32	1.22
1993	17.68	1.39
1994	18.30	–
1995	19.24	–
1996	18.77	5.18
1999	19.60	3.40

* The 1+ snapper are about 23 months old at the time of the trawl surveys.
‡ First five values corrected for low catchability.

(ii) Biomass estimates

Snapper 1984 and 1995 tagging programmes

The 1985 and 1994 tagging biomass estimates are important observational inputs to the age-structured population models used to assess the status of SNA 1 (Annala et al., 1998; Davies et al., 1999). It is therefore necessary to identify sources of error in these estimates. Data from both tagging programme have been reassessed to (a) account for gear specific bias and (b) to incorporate greater uncertainty from spatial heterogeneity because evidence of both types of bias has been found in tagging data (Gilbert & McKenzie, 1999).

The heterogeneity in mark rates on a small spatial scale is most probably due to inadequate mixing of tagged fish. There was also a reduction in gear specific recovery probability, when release and recapture methods are the same, i.e., trap avoidance.

Revised estimates of biomass from the 1985 tagging programme were calculated following a detailed review of the tag-recapture database and the calculations to correct for direct sources of bias including trap avoidance. The reported recaptures were corrected to exclude recreational recaptures that were misidentified with respect to recapture method. The adjustment for tag loss in recaptures was improved to include this source of bias during the first month of the recapture phase. Recaptures with unknown release information were included in the tag-recapture sample. Consequently, the revised estimates (ignoring gear-specific bias) of biomass for the Hauraki Gulf and East Northland sub-stocks in 1985 are 24 853 t and 16 689 t respectively. Relative to the estimates that were input to the SNA 1 assessment carried out in 1998, these are 6.0% and 6.7% higher for the Hauraki Gulf and East Northland respectively.

Employing the revised detection success rate estimate for tagged fish in the 1994 tagging programme, increased the biomass estimates by 2.8% to produce the revised estimates of 29 115 t and 14 082 t for the Hauraki Gulf/Bay of Plenty and East Northland sub-stocks respectively. The corresponding revised estimate after excluding recaptures from Danish seine catches in the Hauraki Gulf was 35 249 t for the Hauraki Gulf/Bay of Plenty sub-stock.

Adjusting for gear-specific bias for the longline and trawl methods reduced the estimates of biomass. For the 1985 programme this adjustment resulted in 17.0% and 25.3% decreases in the revised estimates of biomass for the Hauraki Gulf and East Northland sub-stocks to 20 619 t and 12 463 t respectively.

For the 1994 programme the adjustment for gear-specific bias results in 23.0% and 24.5% decreases in the revised estimates of biomass for the Hauraki Gulf/Bay of Plenty and East Northland sub-stocks to 22 432 t and 10 634 t respectively. The corresponding decrease for the Hauraki Gulf/Bay of Plenty sub-stock excluding Danish seine recaptures from the Hauraki Gulf sample was 28.2%, from 35 249 t to 25 302 t.

Insufficient spatial information associated with tag-recapture data is available from either tagging programme to adjust the biomass estimates for bias due to spatial heterogeneity in the distribution of tagged fish in the population. In the 1994 programme, the Danish seine recaptures showed particularly pronounced mark rate anomalies and this was assumed to be due to spatial heterogeneity. Despite excluding this data, the derived estimates may still be biased. Given there is likely to be unquantifiable spatial bias in both biomass estimates the Working Group recommended that for the 1999 assessment the relative CVs on the 1985 and 1994 estimates be increased to 0.4 and 0.3 respectively.

Longline CPUE Index

Standardised CPUE indices were calculated for the SNA 1 longline fisheries for the 1989–90 to 1997–98 fishing years based on the method described in Vignaux (1994). This was a stepwise multiple log-linear regression of “successful” sets i.e., sets with a non-zero catch (these were more than 99% of reported sets). Variables were included in the models if they increased its explanation of variance by greater than 0.5%. CPUE was defined as log(kg/set) with number of hooks supplied as a variable to the model. Only vessels which fished “regularly and a lot” were included with vessel identifier supplied as a variable to the model. Only records that targeted snapper were included. Separate analyses were run for a) East Northland, b) Hauraki Gulf, and c) Bay of Plenty.

The year effects from the standardised CPUE are taken to be indices of relative abundance (Table 9) The East Northland and Hauraki Gulf indices show little change over time, varying between -17 and +18 % from their 1989–90 values. The Bay of Plenty index decreased by 40% between 1989–90 and 1991–92, improved abruptly in 1992–93 and has continued to increase to 20% above its 1989–90 value.

Table 9: Relative year effects for the regression of log(kg/set) of vessel subsets from the standardised CPUE analyses.

	East Northland			Hauraki Gulf			Bay of Plenty		
Year	***n***	**CPUE**	**2s.e.**	***n***	**CPUE**	**2s.e.**	***n***	**CPUE**	**2s.e.**
1989–90	916	1.00	0.00	1077	1.00	0.00	117	1.00	0.00
1990–91	1162	0.92	0.06	1268	0.93	0.05	431	0.71	0.10
1991–92	1171	0.86	0.06	1374	1.00	0.05	481	0.62	0.09
1992–93	990	1.01	0.07	1491	0.90	0.05	434	0.99	0.14
1993–94	1097	0.85	0.06	1449	0.83	0.04	604	0.96	0.13
1994–95	1374	0.92	0.06	1622	0.88	0.05	721	0.97	0.13
1995–96	1248	1.11	0.07	1409	0.92	0.05	600	1.12	0.15
1996–97	1431	1.18	0.08	1184	1.09	0.06	703	1.10	0.15
1997–98	1013	0.94	0.07	955	1.12	0.07	413	1.20	0.18

4.1.2 Model Structure

The Hauraki Gulf/Bay of Plenty and East Northland stocks were modelled separately using a slightly revised version of the age-structured population models described by Davies et al. (1999), similar to the stock synthesis model of Methot (1990). The models for each sub-stock are similar in the following respects.

The models have age classes from 4 to 20 years. The final age class is an aggregate of the fish older than 19 years. The population is updated annually, with partial recruitment occurring at age 4 at the beginning of the year according to a year-specific factor. Parameters did not vary by sex and natural mortality was constant for all ages. Fishing mortalities were age and method specific. Five separate fishing methods were included in the model. For the Hauraki Gulf/Bay of Plenty sub-stock these were longline, single trawl, Danish seine, other commercial, and recreational. For the East Northland sub-stock, pair trawl replaced Danish seine. Von Bertalanffy and length-weight parameters were used in the calculation of catch weights and biomass. All fish at an age were modelled to be the same length and weight.

The following observations were input to the models: trawl survey recruitment indices and SST; catch at age data; tagging programme estimates of absolute biomass; fishing method selectivities (these were also estimated within the model); and total annual removals (commercial, non-commercial, illegal). Estimation was by maximum likelihood with likelihood terms for the trawl survey recruitment indices (Hauraki Gulf/Bay of Plenty only), the catch at age estimates, the longline CPUE time series and the stock biomass estimates. Total fishing mortality was apportioned between the methods according to observed catches and the selectivity-at-age curves.

Yield per recruit analyses were carried out to obtain equilibrium yield estimates under the same assumptions as the models. It is assumed that the maximum sustainable yield (MSY) occurs at the maximum yield per recruit ($F = F_{max}$). B_{MSY} is defined as the start of year biomass producing the maximum yield with fixed selectivities for each method and fixed proportions of the catch for each method (including recreational fishing) based on the 1998–99 year. Results are expressed relative to virgin start of year biomass (B_0). The yield per recruit and its maximum depends on the allocation of the total catch amongst the methods, because yield is affected by the selectivity curves. The maximum was defined for a catch allocated amongst methods (including recreational) in the same proportions as for 1998–99.

Hauraki Gulf/Bay of Plenty

The numbers at age of an initial non-virgin population in 1970 were determined by mean recruitment, R, and two total mortality parameters, one relating to fish of ages 4 to 19 years, Z_1, and the other for the aggregate age class of fish over 19 years, Z_2. The population was projected from 1970 to 2020. The model estimated R, Z_1, Z_2, and the trawl survey proportionality constant, q. For 1980-92, the annual recruitments, R_t (= $r_t R$), were estimated as free parameters. The slope of the SST recruitment relationship, β, was estimated by linear regression of these log(R_t) on SST. Hence the R_t were predicted for other years. The intercept of the SST recruitment relationship, α, was obtained from the constraint that the mean r_t for the years 1967-99 equal 1. This period defined mean virgin recruitment. Log-normal error was assumed for the CPUE biomass indices, the tagging biomass estimates, the catch at age data and the trawl survey recruitment indices. Standard deviations assumed for the log-normal distributions (approximately equal to CVs in the natural scale) were:

1 CPUE biomass index, $\sigma_E = 0.35$
2 Tagging biomass estimates, $\sigma_B = 0.4$ for 1985 and 0.3 for 1994
3 Catch at age, $\sigma_C = c\sqrt{n}$ (see below)
4 Trawl survey recruitment indices, $\sigma_R = 0.3$.

Catch at age estimates for several methods in the same year were sometimes based on the same age length key. To allow for this lack of independence, the standard deviation for each proportion at age was scaled by the square root of the number of methods in the year, $\sqrt{n}$. The variable, c, was the CV corresponding to the estimated proportion at age. It will therefore underestimate the CV for the 1969–70 to 1972–73 data because they were from single rather than multiple landings. Therefore, $\sqrt{n}$ was set to 4 to reduce their weighting.

For each of the four observation types, a further factor that scales the standard deviations, so that the residuals best fit the spread of the assumed log-normal model can be estimated. This was done for the CPUE and the catch at age data in the base case, but not for the tagging biomass estimates (two observations) or recruitment indices (11 observations). In many of the sensitivity fits, the scaling factor for the catch at age data was arbitrarily fixed at 5 or 20 to reduce their influence.

Model Assumptions:

- Natural mortality $M = 0.075$ y^{-1} (sensitivity tests used 0.06 and 0.09 y^{-1}),
- recruitment in the years 1967-99 was assumed to represent mean recruitment, which determines virgin biomass,
- selectivity curves were estimated where catch at age data existed (sensitivity test used tagging programme estimates),
- for catch at age data a CV, $\sigma_{C@A} = c\sqrt{n}$ was assumed, where c is the sampling CV for the proportion at age and n is the number of gear types in a year based on the same age-length-key,
- non-commercial catch was projected forward at the fishing mortality estimated for 1995–96, but the catch was not allowed to exceed 1800 t,
- commercial catch was projected forward equal to 75% of the 1998–99 SNA 1 TACC and apportioned to the various methods in the same ratio as the 1997–98 fishing year,
- in deterministic projections beyond 1999, (the last year class predicted by SST), recruitment was set at R,
- in stochastic projections, recruitment was obtained by resampling the R_t (1967-99) with replacement.
  - recreational catch from 1970 to 1997 was constant at a mean level of 1706 t per year (a sensitivity test used the recreational catch history given in Gilbert & Sullivan (1994) which is lower overall),
  - Japanese catch after 1970 was based on a total of 15 000 t from 1960-77,
  - Z_1 was constrained to exceed M and Z_2 was constrained to lie between 0.04 y^{-1} and Z_1,
  - the standard deviation parameters in the tagging biomass likelihood and the trawl survey recruitment likelihood functions were fixed,
  - in stochastic projections, recruitment was alternatively obtained by resampling sequences of R_t corresponding to *el Niño* oscillations (varying between 2–5 years) with replacement.

East Northland

An initial non-virgin population in 1970 was determined by mean recruitment, R, and a total mortality parameter, Z. The population was projected from 1970 to the present with given commercial and recreational catches, and given values for natural mortality, growth, and gear-specific selectivity. Recruitment was determined by 18 annual year class strength indices (1976-93) and as a function of SST for the years up to 1975 and 1992-99.

Twenty-three parameters were estimated in the model: 18 year class strengths (1976-93), mean recruitment, R, and total mortality pre-1970, Z, and a three parameter double normal curve describing post QMS longline selectivity.

Parameters α and β were determined as functions of the logarithms of the year class strength parameters by linear regression. The regression was carried out for each set of trial values of year class strength during the log likelihood minimisation. The recruitment series $\{r_t\}$ was then made up of the 18 year class parameters and the year class strengths predicted by SST for the other years (1911-75, 1994-99). This series was normalised so that the mean of the final combined series was 1 for 1970-99.

Model parameters were estimated by fitting to the catch at age time series, the recent nine year CPUE time series and tagging programme absolute biomass estimates for 1985 and 1994 using a search routine to minimise the logarithm of the likelihood. Standard errors assumed for the log-normal distributions were:

1 CPUE index $\sigma_{CPUE} = 0.35$
2 Tagging biomass estimates, $\sigma_B = 0.4$ for 1985 and 0.3 for 1994
3 Catch at age, $\sigma_C = c$.

For each of the three observation types, a further factor that scales the standard deviations, so that the residuals best fit the spread of the assumed log-normal model can be estimated. This was done for the CPUE and the catch at age data in the base case, but not for the tagging biomass estimates (two observations). In many of the sensitivity fits, the scaling factor for the catch at age data was arbitrarily fixed at 5 or 20 to reduce their influence.

Model Assumptions:

- Natural mortality $M = 0.075\ y^{-1}$ (sensitivity tests used 0.06 and 0.09 y^{-1}),
- recruitment in the years 1970-99 was assumed to represent mean recruitment, which determines virgin biomass,
- selectivity curves were estimated where catch at age data existed (sensitivity test used tagging programme estimates),
- for catch at age data a CV, $\sigma_{C@A}$ was assumed,
- non-commercial catch was projected forward at the fishing mortality estimated for 1995–96, but the catch was not allowed to exceed 800 t,
- commercial catch was projected forward equal to 25% of the 1998–99 SNA 1 TACC and apportioned to the various methods in the same ratio as the 1997–98 fishing year,
- in deterministic projections beyond 1999, (the last year class predicted by SST), recruitment was set at R,
- in stochastic projections, recruitment was obtained by resampling the R_t (1967-99) with replacement,
- Pre-1970 total mortality constrained by $Z \geq M + 0.04$ (a sensitivity test had Z constrained by $Z \geq M$),
- Observations of catch at age for year classes 1976-1993 (minimum of three observations per year class),
- recreational catch from 1970 to 1997 was 631 t per year,
- Japanese catch after 1970 was based on a total of 15 000 t from 1960-77,
- Leigh sea surface temperature series used to fit recruitment indices for years before 1976 and after 1993,
- Catch at age data from 1985 was fitted in the model to estimate the pre-1970 year classes 1965-1969 and a plus group,
- Pre-QMS selectivities for longline, single and pair trawl methods were derived from 1985 tagging data and used to calculate method-specific fishing mortality prior to 1986. Selectivity estimates for longline single and pair trawl were derived from 1995 tagging data and used to estimate method-specific post-QMS fishing mortality. After convergence, the model was refitted to

estimate post-QMS longline selectivity (3 parameter double normal function). A sensitivity of fixed post QMS selectivity on longline was also investigated, and

- Relative MLE weighting (sigma) on CPUE, 1985 and 1994 biomass estimates and catch at age was 1:1:5 (sensitivities: low CPUE (3:1:5); low C@A (1:1:20); estimated variance CPUE and C@A).

Model projections

The fitted models were projected to 2020. Commercial catch for the projection period was assumed to be at the TACC level of 4500 t (plus 10% overrun), with the catch split in the proportion 0.25:0.75 between East Northland and Hauraki Gulf/Bay of Plenty. Projected catches were apportioned between commercial methods according to the method-specific proportions of the reported catch in 1997–98 for each sub-stock. For the purposes of projecting the recreational catch, assumptions have been made for the impact of changes to the daily bag limit and the increase in minimum legal size. Recreational catch was also capped, assuming that future management measures would constrain it at 2600 t. Hauraki Gulf/Bay of Plenty and East Northland were capped at 1800 t and 800 t, the proportion corresponding to the 1996 recreational estimates. Annual year class strengths predicted from SST-recruitment relationships for the years 1992 to 1999 were used to calculate absolute recruitment to 2003 for each model. Constant recruitment equal to the estimated mean absolute recruitment was assumed for other years to 2020 in the deterministic base case and sensitivity runs.

Bootstrap estimation procedures were employed to estimate uncertainty in model estimates of biomass and yield. In this approach, distributions of model estimates were calculated from a large number of conditional parametric bootstraps. Pseudo-replicates of catch at age, trawl survey recruitment indices and tagging programme absolute biomass estimates were generated according to the error structures specified in the maximum likelihood estimators. These data were then used to estimate the model parameters. The distribution of model estimates is used to describe the uncertainty in these quantities. For each bootstrap run, stochastic recruitment for the years 2004 to 2020 was generated by randomly selecting with replacement from the 1967-1999 year class strength estimates obtained from within that run.

Fishery Performance Indicators

The following fishery performance indicators were used to report the results of the projections with the status quo TACC and either a capped or uncapped recreational catch:

1. Probability of stock increase $P(B_{2020} > B_{1999})$

The probability that the start of year biomass in 2020 will be above the current biomass level.

2. Probability of stock rebuild $P(B_{2020} > B_{MSY})$

The probability that the start of year biomass in 2020 will be above the biomass level B_{MSY}. B_{MSY} is defined as the biomass producing the maximum yield with fixed selectivities for each method and fixed proportions of the catch for each method (including recreational fishing) based on the 1997–98 year.

3. Expected stock status $E(B_{2020}/B_{MSY})$

The expected start of year biomass in 2020 relative to B_{MSY}.

4.1.3 Results

East Northland

The base case East Northland stock assessment indicates that the current recruited biomass is at about the B_{MSY} reference point and is expected to exceed B_{MSY} at the end of the twenty year projection period (with 67% probability; Table 10; Figure 1).

This conclusion is robust to all sensitivities investigated, except when a low natural mortality was investigated, where the stock status is about 75% of B_{MSY}, increasing to near B_{MSY} in twenty years (Table 11). Other sensitivities, including high values for natural mortality, different weightings between the various data sources, whether or not trap avoidance was included in the tagging biomass estimates, and estimated or fixed selectivities, estimate that the current biomass is either near or above the B_{MSY} reference point and will increase to above B_{MSY} in the next twenty years.

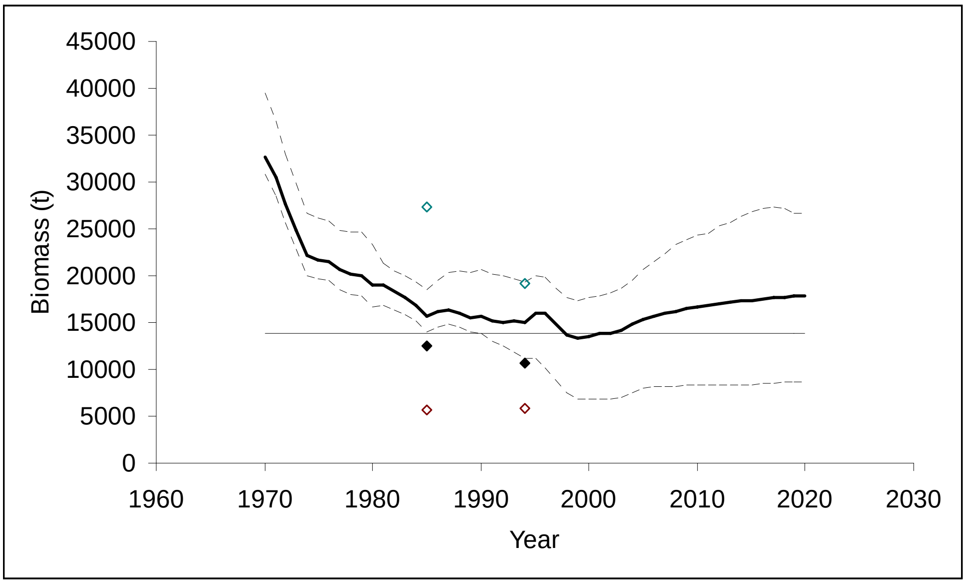


Figure 1: East Northland maximum likelihood stock biomass trajectory for base case (thick line) with 90% confidence intervals for each year's biomass estimated by parametric bootstrap (dashed lines), and the estimated base case B_{MSY} level (thin line). The biomass estimates from the two tagging programmes are plotted (♦) with their assumed 95% confidence intervals (hollow diamonds).

Table 10: East Northland bootstrap performance indicators (corrected for bias).

Performance Indicators	**Estimate**
Probability of stock increase, P[$B_{20} > B_{1999}$]	0.95
Probability of stock rebuild, P[$B_{20} > B_{MSY}$]	0.67
Expected stock status, E[B_{20} / B_{MSY}]	1.22

Table 11: East Northland model parameters and estimates of start of year biomass (t) and yield (t): virgin biomass (B_0), biomass that supports maximum sustainable yield (B_{MSY}), and biomass in 1998–99 (B_{99}). Maximum sustainable yield (MSY) includes overruns (t) (see text for explanation of sensitivity runs).

Description	B_0	B_{MSY}	B_{99}	B_{99}/B_{MSY}	*Z*	*MSY*	B_{70}/B_0	B_{20}/B_{MSY}
Base case	66 700	13 800	13 300	0.96	0.115	2057	0.49	1.29
Low weight *CPUE* ($\sigma = 3$)	65 300	13 500	11 500	0.85	0.115	2015	0.49	1.16
Low weight *C@A* ($\sigma = 20$)	65 300	14 200	11 800	0.83	0.117	2059	0.49	1.15
$M = 0.06$ y^{-1}	75 900	15 700	11 800	0.75	0.100	1966	0.44	0.97
$M = 0.09$ y^{-1}	59 800	13 200	19 100	1.14	0.130	2149	0.53	1.54
No trap avoidance bias	69 400	14 200	16 300	1.15	0.115	2128	0.49	1.52
No constraint on Z pre 70	61 400	12 700	11 600	0.91	0.091	1893	0.64	1.11
Free *C@A* and CPUE σ	72 100	14 800	19 700	1.33	0.115	2208	0.49	1.74
Fix Selectivities LL	70 000	13 700	15 700	1.14	0.115	2096	0.47	1.53

Hauraki Gulf

The base case Hauraki Gulf/Bay of Plenty stock assessment indicates that the current recruited biomass is less than the B_{MSY} reference point but is expected to exceed B_{MSY} at the end of the twenty year projection period (with 100% probability; Table 12; Figure 2). This conclusion is robust to all sensitivities investigated, including high and low values for natural mortality, different weightings between the various data sources, whether or not trap avoidance was included in the tagging biomass estimates, estimated or fixed selectivities, and using temperature to predict all recruitments (Table 13).

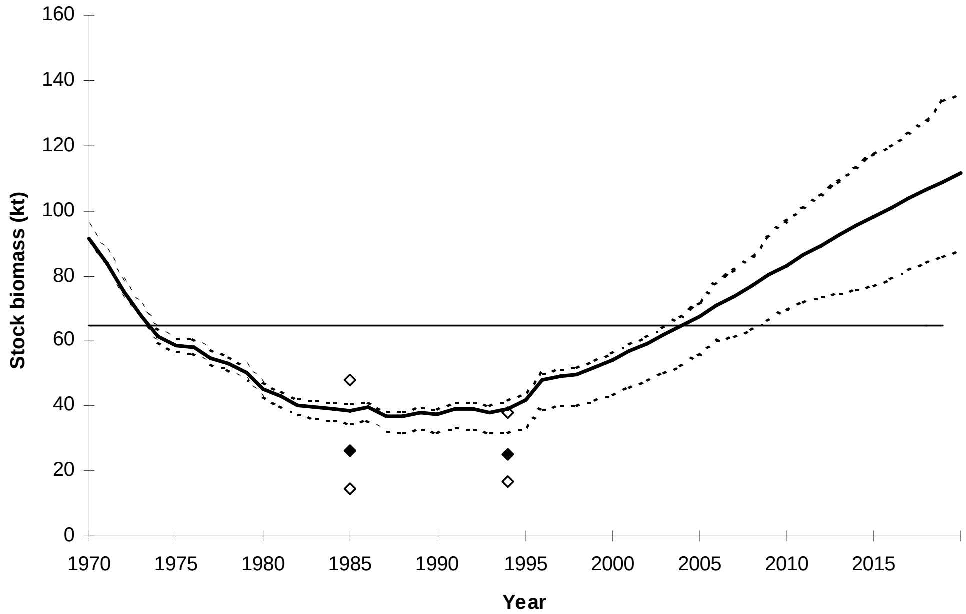


Figure 2: Hauraki Gulf/Bay of Plenty maximum likelihood stock biomass trajectory for base case (thick line) with 90% confidence intervals for each year's biomass estimated by parametric bootstrap (dashed lines), and the estimated base case B_{MSY} level (thin line). The biomass estimates from the two tagging programmes are plotted (♦) with their assumed 90% confidence intervals (hollow diamonds).

Table 12: Hauraki Gulf/Bay of Plenty bootstrap estimates of performance indicators.

Performance indicator	Estimate
Probability of stock increase, P[$B_{20} > B_{1999}$]	1.00
Probability of stock rebuild, P[$B_{20} > B_{MSY}$]	1.00
Expected stock status, E[B_{20} / B_{MSY}]	1.76

Table13: Hauraki Gulf/Bay of Plenty estimates (t): B_0 is virgin biomass, B_{MSY} is biomass that supports MSY, B_{70}, B_{99} and B_{20} are biomasses in 1969–70, 1998–99, and 2019–20, MSY is maximum sustainable yield and includes overruns. Biomasses are at start of year. Likelihood weightings, σ,multiply the assumed standard deviations for Catch at age.

Description	B_0	B_{MSY}	B_{99}	B_{99}/B_{MSY}	MSY	B_{70}/B_0	B_{20}/B_{MSY}
Base case	279 200	64 400	51 700	0.80	7993	0.33	1.73
$M = 0.06$ y^{-1}	329 700	76 200	40 800	0.54	8014	0.28	1.33
$M = 0.09$ y^{-1}	246 200	57 500	56 400	0.98	8127	0.36	1.95
Low weight *C@A* ($\sigma = 20$)	280 600	66 700	35 800	0.54	8197	0.29	1.48
Low weight *CPUE* ($\sigma = 3$)	280 000	64 000	50 700	0.79	7971	0.32	1.72
CPUE & tag indices omitted	281 000	65 000	53 700	0.83	8055	0.33	1.76
No trap avoidance bias	280 000	64 300	50 300	0.78	7971	0.32	1.70
Fixed 1985 & 1994 selectivities	291 200	63 200	61 400	0.97	7676	0.32	1.82
YCS based on SST	274 600	63 800	42 500	0.67	7887	0.32	1.57
$Z_1 \geq M$, $Z_2 \geq M$	260 400	70 000	41 100	0.67	7526	0.38	1.46

4.1.4 Yield Estimates

Estimation of Maximum Constant Yield (MCY)

These estimates include non-commercial catch and are based on commercial catch history with under-reporting which is assumed to continue at 10% in future years.

East Northland

MCY was estimated for the base case from the equation MCY = CSP as the stock is below B_{MSY}.

MCY = 2000 t

Hauraki Gulf/Bay of Plenty

MCY was estimated for the base case from the equation MCY = CSP as the stock is below B_{MSY}. CSP is the equilibrium surplus production at the 1998–99 biomass.

MCY = 7911 t

Estimation of Current Annual Yield (CAY)

The CAY was calculated by multiplying the start of year biomass in 1999–2000 in the model by F_{ref}. F_{ref} was set equal to F_{max}. These estimates include non-commercial catch and are based on commercial catch history with under-reporting which is assumed to continue at 10% in future years.

East Northland

In the base case F_{max} corresponds to a catch to biomass ratio of 14.9% and the start of year biomass in 1999–2000 was 13 494 t

$CAY_{99–00}$ = 2008 t

Hauraki Gulf/Bay of Plenty

In the base case F_{max} corresponds to a catch to biomass ratio of 12.4% and the start of year biomass in 1999–2000 was 54 063 t.

$CAY_{99–00}$ = 6704 t

Maximum Sustainable Yield (MSY)

MSY was calculated as the maximum catch that could be sustained by the stock in equilibrium.

East Northland

MSY = 2057 t

The range in Table 11 is 1893 to 2208 t.

Hauraki Gulf/Bay of Plenty

MSY = 7993 t

The range in Table 13 is 7526 to 8 197 t.

Table 14: Yield estimates for East Northland and Hauraki Gulf/Bay of Plenty (t).

	MCY	CAY_{99-00}	MSY
East Northland	2000	2008	2057
Hauraki Gulf/Bay of Plenty	7911	6704	7993

4.2 SNA 2

A new assessment model for SNA 2 was developed in 2002, which incorporates four years of catch at age data sampled from this fishery between 1991–92 and 1999–2000. A Bayesian analysis was attempted together with a set of sensitivities to determine a range of plausible assessments based on the available data.

4.2.1 Estimates of fishery parameters and abundance

(a) Recruitment

There is evidence for a temperature recruitment relationship in SNA 2 (Gilbert & Taylor, 2001). There is no long-term time series of SST for the Hawke Bay or Wairarapa Coast region comparable to the Leigh SST series for the Hauraki Gulf. Instead, air temperature from the Nelson Park, Napier climatological station has been used to predict year class strength (YCS) as an alternative to estimating YCS's as free parameters.

(b) Recreational catch

Two estimates of recreational catch are available for the SNA 2 fishery. Estimates were obtained by way of a diary survey in 1992–93 and 1996, and cover the whole of the SNA 2 fishery (Bradford, 1998; Teirney et al., 1997).

Recreational catches from 1932-1992 were assumed using a step function that increased catches from 0 by 5 t every 10 years.

(c) Customary catch

No estimates are available on the levels of Maori customary catch. It has been assumed that the recreational catch estimates include a portion of the catch representing the customary take.

4.2.2 Model Structure

The stock assessment of SNA 2 is the first to be based on a fitted population model. The model used has similar structure as the Tasman Bay/Golden Bay (SNA 7) assessment and is based on Harley & Gilbert (2000). The data used for model fitting does not include any abundance estimate but includes a small number of recent proportions at age datasets. This limited the number of free parameters for which good estimates can be obtained.

The model begins in 1933 and assumes that the population was then in a virgin state. The stock was heavily exploited prior to 1970 and the total catch history is available. For these reasons it was considered more appropriate to model the stock from its virgin state in the form of a Total Catch History model (Gilbert, 1994). Air temperature data was available to estimate recruitment over this period.

Base case model assumptions:
- natural mortality $M = 0.075\ y^{-1}$ (sensitivity tests used 0.06 and 0.09 y^{-1}),
- recruitment in the years 1970-97 was assumed to equal virgin recruitment,
- 1970-97 YCS's were estimated individually, 1940-69 YCS's were estimated as a function of air temperature and the remainder were set to 1 (virgin recruitment),

- left and right limbs of commercial selectivity curves were defined by normal density functions. Age at full selectivity was fixed (selectivity = 1.0 at 5.0 y), left hand limb was estimated (= 0.5 at 3.6 y), and right hand limb was fixed (= 0.5 at 500 y),
- non-commercial catch was projected forward at the 1996 value (40 t).

Model Projections

The model was projected to 2006 both deterministically and stochastically to determine the status of the stock under alternative constant catch levels. Future catches incorporated commercial catch (with 10% under-reporting) plus non-commercial catch. Two scenarios of total catches were investigated in projections, 317 t (2000–01 TACC + 10% + 40 t non-commercial) and 436 t (2000–01 landings + 10% + 40 t non-commercial). B_{MSY} is the equilibrium biomass that supports the deterministic maximum catch defined in Section 4.3.4.

In the deterministic projection the maximum likelihood estimates (MLE's) were used and mean recruitment applied in future years. Stochastic projections were performed by sampling from the posterior distribution and projecting forward with recruitment randomly resampled with replacement from the estimated YCSs.

A Bayesian framework was used to derive estimates of uncertainty in management quantities and for the calculation of performance indicators. The procedures were the same as those used by Maunder (1998) and involved the use of the Markov Chain Monte Carlo (MCMC) procedure from AD Model Builder, (© Otter Research). All priors were chosen to be non-informative uniform distributions, so the mode of the joint posterior distribution was the MLE. Samples from the joint posterior distribution of the parameters were taken and the marginal posterior distribution determined by integrating the product of the likelihood and the priors over all model parameters.

4.2.3 Results

The model was fitted only to the available four years of proportions at age data. As no indices of biomass are available, model estimates must be treated with caution. In both Run 1 (base case) and Run 6 (which uses air temperature to estimate YCS), the MLE and the lower 5% bound of the posterior distribution estimate that the current (2000–01) biomass is about 90%B_0, except for the Run 6 posterior, which is less optimistic. Both the deterministic MLE projections and the Bayesian projections (lower 5% of the posterior distributions) estimate that the stock size will increase at the two catch levels investigated. The deterministic projections for Runs 1 and 6 estimate that the biomass in 2005–06 will be above B_{MSY} (Table 15 and Figure 3).

The estimated joint posterior distributions for Runs 1 and 6 are unsatisfactory due to problems with model structure. For Run 1, the model allows the mean YCS in 1940-69 to differ more than is considered to be reasonable from the mean YCS for 1970-97 (which equals virgin recruitment). For Run 6, the model parameterisation did not allow a complete exploration of the uncertainty in recruitment variation. However, the lower bounds of these two posterior distributions are likely to be more reliable as they are constrained by the catch history and the available data. For these reasons, the lower bounds of the posterior distributions and the associated MLE estimates are reasonably similar.

A number of sensitivities were investigated based on MLE's. These sensitivities included alternative weightings of the proportion at age data, a higher weight on the recruitment YCS, different assumed values for *M*, and a descending limb on the selectivity to the commercial fishery. For these sensitivity runs, except the one where the natural mortality was assumed to be lower than in the base case, the current biomass was estimated to be between 90% and 150% of B_{MSY} (Table 16).

Table 15: The 5 and 95 percentiles of the marginal posterior distributions for SNA 2 for Runs 1 and 6 with resampled recruitment under two total annual catch scenarios 317 t and 436 t. B_0 is the virgin biomass; B_{MSY} is biomass at *MSY*; B_{2001} is the biomass at the start of 2000–01, etc. *MSY* is maximum sustainable yield and includes under-reporting and non-commercial catch.

Run	Description	Total catch (t)	B_0 (kt)	B_{MSY} (kt)	B_{2001} (kt)	B_{2006} (kt)	*MSY* (t)	B_{2001}/B_{MSY}	B_{2006}/B_{MSY}
1	Base case	317	19.9, 25.8	4.7, 6.1	4.3, 10.5	5.6, 12.8	495, 641	0.9, 1.9	1.2, 2.3
		436				4.9,12.7			1.0, 2.1
6	All YCS function of temperature	317	18.2, 19.0	4.3, 4.5	3.2,5.0	4.0, 6.1	446, 465	0.7, 1.1	0.9, 1.4
		436				3.3, 5.4			0.8, 1.2

Table 16: Model specifications and MLE's for SNA 2 under various assumptions. Projections assume total catch continues at 2000–01 TACC + 10% + non-commercial. *N* is the number of estimated parameters; B_0 is the virgin biomass; B_{MSY} is biomass at *MSY*; B_{2001} is the biomass at the start of 2000–01, etc. *MSY* is maximum sustainable yield and includes under-reporting and non-commercial catch. Run numbers are those used in Gilbert & Phillips (2002).

Run	Description	*N*	B_0 (kt)	B_{MSY} (kt)	B_{2001} (kt)	B_{2006} (kt)	*MSY* (t)	B_{2001}/B_{MSY}
1	Base case; MLE	30	19.1	4.5	4.0	5.4	478	0.9
2	Commercial proportions at age weight = 1.0	30	19.0	4.5	4.3	6.3	479	1.0
3	Commercial proportions at age weight = 20.0	30	19.4	4.6	4.1	5.7	482	0.9
4	Recruitment weighting = 2.0	30	19.0	4.5	4.3	6.2	480	1.0
6	All YCS function of temperature	3	18.4	4.4	3.7	4.7	453	0.9
8	*M* fixed at 0.06 y^{-1}	30	20.6	5.0	2.3	3.3	432	0.5
9	*M* fixed at 0.09 y^{-1}	30	17.9	4.1	5.9	8.0	527	1.5
11	50% selectivity at age 25 y	30	20.5	4.2	4.4	6.3	498	1.0

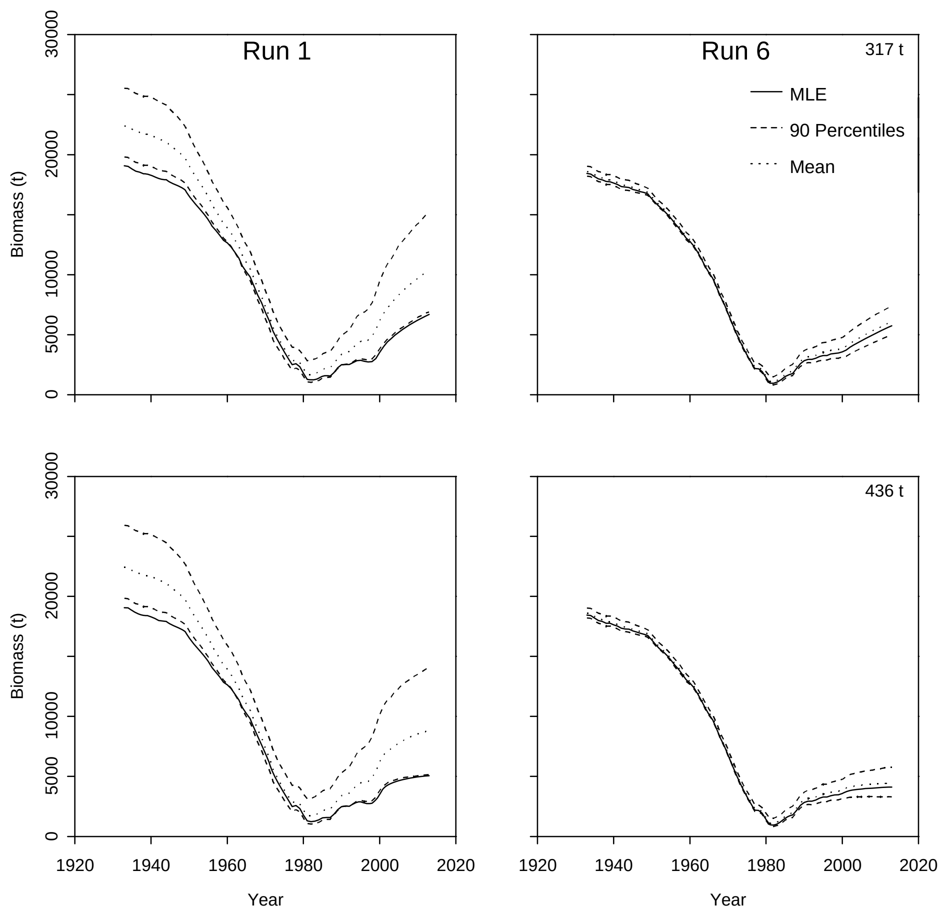


Figure 3: Projected biomass with 90 percentiles of the posterior distribution for SNA 2, Run 1 (base case) and Run 6 (YCS function of air temperature) under two total annual catch scenarios (TAC + 10% + 40 t non-commercial = 317 t and 2000–01 landings + 10% + 40 t non-commercial = 436 t).

4.2.4 **Yield** *Estimates*

Maximum Sustainable Yield (MSY)

For Run 1 and Run 6, the MLE and the lower 5% bound of the posterior distribution estimate the MSY to be between 446 and 495 t. The mean and upper bounds of the posterior distributions for Runs 1 and 6 are unreliable for the reasons discussed in the previous section. The deterministic maximum catch that could be sustained by the stock in equilibrium is attained at an exploitation rate of about 10.5% of start of year, recruited biomass at B_{MSY}.

These estimates include non-commercial catch and an allowance for 10% under-reporting of commercial catches.

4.3 SNA 7 (Challenger)

4.3.1 Estimates of fishery parameters and abundance

(a) Recruitment

There is evidence for a temperature recruitment relationship in SNA 7 (Annala & Sullivan, 1997). There is no long-term time series of SST for the Tasman Bay/Golden Bay region comparable to the Leigh SST series for the Hauraki Gulf. Instead, air temperature from the Appleby climatological station has been used to predict YCS as an alternative to estimating YCS's as free parameters.

(b) Recreational catch

Three estimates of recreational catches are available for the SNA 7 fishery. The first estimate from the 1987 tag-recapture programme did not include recreational catches from the Marlborough Sounds as no tagging took place there. The 1992–93 and 1996 estimates were obtained by way of a diary survey and cover the whole of the SNA 7 fishery (Teirney et al., 1997; Bradford, 1998).

To make all three estimates comparable, the last two observations were re-estimated to calculate catches for Tasman Bay/Golden Bay only. While three estimates of recreational catch are available, catches must be estimated (guessed) for the years between the three observations and for the period 1931-1987. It is quite likely that with constant fishing effort the recreational landings would have increased, due to increases in stock size. However, given the increasing holidaymaker presence in the area during the summer, it is possible that fishing effort has also increased over time.

No estimates are available on the levels of Maori customary catch. It has been assumed that the recreational catch estimates include a portion of the catch representing the customary take.

(c) Abundance indices

During 1986-1988, an extensive tag-recapture programme was carried out in Tasman Bay/Golden Bay and the stock biomass was estimated to be 1576 t. Results from the 1987 programme were revised to correct for: (1) growth during the recovery period; (2) natural mortality at 0.075 y^{-1} (previously 0.06 y^{-1}); and (3) tag loss during the recapture phase.

The new estimate was 1544 t. The possible effects of spatial heterogeneity in mark rates and gear specific avoidance by tagged fish were not included in the revised analysis. It is likely that the revised estimate is quite imprecise.

4.3.2 Model Structure

An age-structured model with gear specific selectivity at age was used to model the Tasman Bay/Golden Bay snapper fishery. This model was similar to that used in other snapper stock assessments, and was based on that of Harley & Gilbert (2000). The numbers of fish at age in each successive fishing year are calculated by subtracting catch and natural mortality, and by incrementing the age of each cohort. Annual recruitment is introduced into the first age class each year.

The present assessment contains the latest proportions at age data, includes improvements to the population model, and uses weightings for the proportions at age data that better reflect the sampling precision. Here, mean recruitment is obtained by taking the arithmetic mean of year class strengths over a specified period. Because Harley & Gilbert (2000) used the geometric mean, which is invariably lower, their surplus production during the modelled period was substantially greater than that for the virgin stock and for the projections. Consequently, virgin biomass estimates tended to be lower, and projected biomass less optimistic.

The annual fishing mortality for commercial and recreational fishing had different age-specific selectivity patterns. Fish 30 years and older were aggregated in a plus group, natural mortality was assumed to be constant over time and age, and a von Bertalanffy growth equation and length-weight relationship were used to describe growth.

The model begins in 1931 and assumes that the population was then in a virgin state. The stock was heavily exploited prior to 1970 and the catch at age data extends back over a longer period than for any of the northern snapper fisheries. For these reasons it was considered more appropriate to model the stock from its virgin state in the form of a Total Catch History model (Gilbert, 1994). The air temperature data was available to estimate recruitment over this period.

The model was fitted to: commercial proportions at age data, research trawl survey proportions at age data, estimates of proportion at age in 1987 from the tag-recapture programme, and 1987 biomass estimate from the tag-recapture programme.

Model Assumptions:

- natural mortality $M = 0.075$ y^{-1} (sensitivity tests used 0.06 and 0.09 y^{-1}),
- recruitment in the years 1960-97 was assumed to represent mean recruitment, which determines virgin biomass,
- 1960-1997 YCS estimated individually, remainder as a function of air temperature,
- Left and right limbs of commercial selectivity curves were defined by normal density functions. Age at full selectivity was estimated (selectivity = 1.0 at 4.0 y), left hand limb estimated (= 0.5 at 2.85 y) and right hand limb fixed (= 0.5 at 500 y),
- research selectivity was flat (= 1.0 for all ages),
- non-commercial catch was projected forward at the 1996 value (84 t),
- the standard deviation parameter in the tagging biomass likelihood was fixed at 0.4.

Model Projections

To assess management strategies, the model was projected to 2006 and the performance of alternative constant catch levels was assessed. The model was projected forward deterministically using the MLE and constant recruitment equal to the mean, and stochastically by sampling from the posterior distribution with recruitment randomly resampled with replacement from the estimated YCS's. Projections performed to estimate uncertainty are described in the section below.

Fishery Performance Indicators

A Bayesian framework was used to derive estimates of uncertainty in management quantities and for the calculation of performance indicators. The procedures were the same as those used by Maunder (1998) and involved the use of the Markov Chain Monte Carlo (MCMC) procedure from AD Model Builder, (© Otter Research). All priors were chosen to be non-informative uniform distributions, so the mode of the joint posterior distributions was the MLE. Samples from the joint posterior distribution of the parameters were taken and the marginal posterior distribution determined by integrating the product of the likelihood and the priors over all model parameters. This allowed modes, medians and 90% confidence intervals to be estimated for the parameters of interest (e.g., biomass, YCS, mean recruitment).

Fishery performance indicators were determined by projecting a sample from the posterior distribution forward into the future with constant catches and recruitment. Future catches incorporated commercial catch and under-reporting plus non-commercial landings set at 2001 levels (304 t). The following performance indicators were derived:

$$P(B_{2001} > B_{MSY}) \text{ and } P(B_{2006} > B_{MSY})$$

4.3.3 Results

The stock assessment results are similar to, but somewhat more optimistic, than those of Harley & Gilbert (2000). The base case and all of the sensitivity runs put the stock above B_{MSY}, as did the 1999 assessment (Table 17). Biomass in Run 1 (base case) and Run 7 (YCS as a function of temperature) is expected to increase and remain above B_{MSY} at the end of a six-year projection period (Table 18 and Figure 4). Results are given in more detail in Gilbert & Phillips (2002).

Harley & Gilbert (2000) were not able to obtain an MCMC simulation that converged for runs where YCS's were independently estimated. It is uncertain whether this problem has been solved. For Run 1, the MLE for B_{2001} falls in the extreme left-hand tail of its estimated posterior distribution. As for SNA 2, the likelihood profile and estimated posterior for B_{2001} appear inconsistent. This suggests that the posterior may not be valid. However both the corresponding likelihood profile and posterior distribution indicate that the current biomass is highly likely to be more than double B_{MSY}. While moderate ranges of absolute values for virgin and current biomass appear to be consistent with the data, low values are not. For Run 7, which involves the restrictive assumption that recruitment is a function of temperature, the MCMC is likely to have converged. The estimated posterior distribution is quite similar in shape and location to the likelihood profile for B_{2001}. Here the estimates are slightly less optimistic, but the current biomass is still highly likely to be more than double B_{MSY} and to increase in the future under current catches (Table 19).

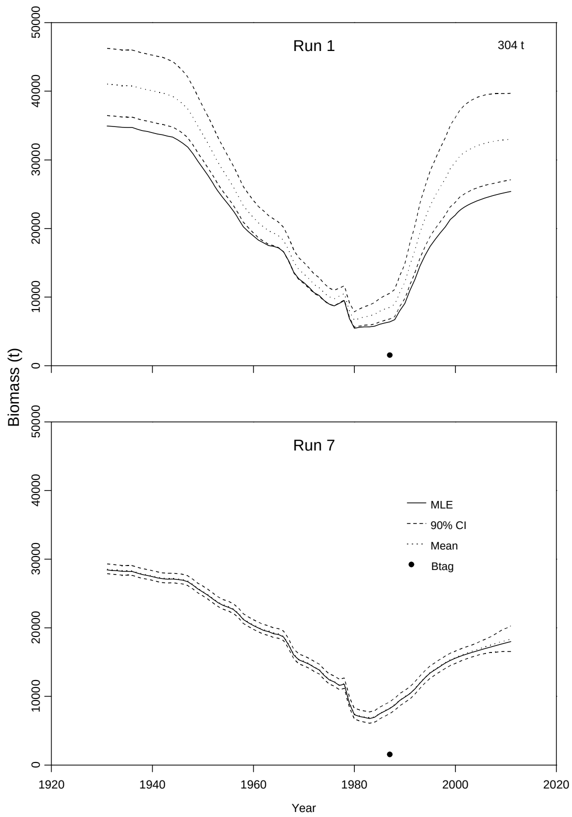


Figure 4: Biomass trajectories with 90 percentiles of the posterior distribution for Tasman Bay/Golden Bay, Run 1 (base case) and Run 7 (YCS function of air temperature) for the 2000–01 TACC (assumed to be taken with 10% overrun + 84 t non-commercial)

4.3.4 Yield Estimates

Maximum Sustainable Yield (MSY)

MSY was calculated as the deterministic maximum catch that could be sustained by the stock in equilibrium for Runs 1 and 7. It is attained at an exploitation rate of 9.4% of start of year, recruited biomass at B_{MSY} (9102 t for Run 1, and 7422 t for Run 7).

MSY = 855 t for Run 1, and 694 t for Run 7

These estimates include non-commercial catch and the assumed 10% under-reporting of commercial catches.

Table 17: Model specifications and MLE's for Tasman Bay/Golden Bay under various assumptions. Projections assume total catch continues at 2000–01 TACC + 10% + non-commercial. *N* is the number of estimated parameters; *LIKE* is the total negative log-likelihood; B_0 is the virgin biomass; B_{MSY} is biomass at *MSY*; B_{2001} is the biomass at the start of 2000–01, etc. *MSY* is maximum sustainable yield and includes overruns. Run numbers are those used in Gilbert & Phillips (2002).

Run	Description	*N*	*LIKE*	B_0 (kt)	B_{MSY} (kt)	B_{2001} (kt)	B_{2006} (kt)	*MSY* (t)	B_{2001}/B_{MSY}
1	Base case*; MLE	41	3977	34.9	9.1	22.8	24.5	855	2.5
2	50% selectivity at age 25 and 3	40	4015	39.6	9.6	25.4	26.8	928	2.6
7	All YCS function of temperature	3	4416	28.4	7.4	15.9	17.0	694	2.1
9	*M* fixed at 0.06 y^{-1}	41	3971	33.6	8.6	14.7	16.7	702	1.7
10	*M* fixed at 0.09 y^{-1}	41	3986	37.1	12.5	31.1	32.0	1015	2.5
11	Commercial proportions at age weighting = 4.0	41	2135	33.3	8.7	18.9	20.5	816	2.2
12	Commercial proportions at age weighting = 0.25	41	11231	36.2	9.4	25.5	27.6	886	2.7

Table 18: Means and percentiles of the marginal posterior distributions for Tasman Bay/Golden Bay for Runs 1 and 7. Projections assume total catch continues at 2000–01 TACC + 10% + non-commercial. B_0 is the virgin biomass; B_{MSY} is biomass at *MSY*; B_{2001} is the biomass at the start of 2000–01, etc. *MSY* is maximum sustainable yield and includes overruns.

Run	Description	B_0 (kt)	B_{MSY} (kt)	B_{2001} (kt)	B_{2006} (kt)	*MSY* (t)	B_{2001}/B_{MSY}
1	Base case; posterior mean	41.0	12.0	29.7	32.4	939	2.5
	Base case; 5 and 95 percentiles	36.4, 46.2	9.4, 16.0	24.6, 37.3	26.3, 39.5	890, 1095	2.3, 2.7
7	All YCS function of temperature; posterior mean	28.5	7.5	16.0	17.2	695	2.1
	All YCS function of temperature; 5 and 95 percentiles	27.9, 29.3	7.2, 7.6	15.1, 16.9	16.3, 18.3	679, 712	2.1, 2.2

Table 19: Bayesian posterior probabilities for Tasman Bay/Golden Bay Run 1 (base case) and Run 7 (YCS function of temperature) with resampled recruitment for the 2000–01 TACC (assumed to be taken with 10% overrun + 84 t non-commercial).

Run	Total catch (t)	P(B_{2006}>B_{MSY})	90 percentiles for B_{2001}/B_{MSY}	P(B_{2006}>B_{MSY})	90 percentiles for B_{2006}/B_{MSY}
1	304	1	2.14, 2.72	1	2.44, 2.90
7	304	1	2.07, 2.21	1	2.22, 2.42

4.4 SNA 8 (Auckland West/Central West)

A revised assessment of SNA 8 was completed in 2005 including updated observations on:

- method-specific catch weights to 2003–04;
- catch-at-age for commercial pair and single trawl in 2003–04; and,
- single trawl CPUE time series from 1996-2004 incorporating tow duration as the unit of effort from core vessels in the fleet.

New information added to the 2005 assessment included:

- single trawl catch-at-age 1974 to 1976;
- pair trawl catch-at-age with recalculated observations for 1974 to 1976; 1978 to 1980;
- mean size-at-age 1975, 1976 and 1979;
- pair trawl catch-at-sea length frequency in 1986; and,
- boat ramp samples of recreational length frequency in 1991, 1994, 1996 and 2000.

Using this new information assisted the estimation of selectivities-at-length for the single trawl, pair trawl and recreational fishing methods, and natural mortality. A revised time series of observed and assumed mean size-at-age was input to the model for the period 1931-2004.

(a) Estimates of fishery parameters and abundance

The assessment model was written using CASAL (Bull et al., 2004). It was age-based but included approximations for length-based selectivities. It models the SNA 8 exploitation history by maximising the likelihood fit to a time series of observations. Bayesian estimates for the fitted parameters were the means of the estimated marginal posterior distributions; priors were specified for key model parameters such as R_0 (mean recruitment), q (catchability coefficient), selectivity at length, natural mortality and year class strengths. For particular types of observations the model incorporates process error as defined by Bull et al. (2004). Stochastic projections of the model to 2025 were undertaken to assess the probability of population increase and the decline in annual harvest proportions under alternative future catch levels.

Model assumptions:

- an equilibrium unexploited population in 1931, calculated using constant annual recruitment, was assumed to represent virgin stock biomass,
- the level of under-reporting for domestic commercial catch was 20% before 1987 and 10% after 1987,
- Japanese longline catch in the period 1965-1974 was assumed to be 2000 t per year,
- YCS was estimated for the 1971-2000 year classes (30 parameters),
- 1971-2000 represented mean recruitment, i.e., average year class strength (YCS) = 1.0,
- the catch at age fit assumed a multinomial distribution,
- CPUE, trawl survey YCS indices, and tag-recapture biomass and population proportions at length were fitted assuming log-normal distributions,
- 1990 and 2002 tag-recapture estimates were fitted as absolute biomass and proportions-at-length assuming log-normal distributions,
- the CVs assumed for the 1990 and 2002 absolute biomass estimates were 0.3 and 0.2 respectively,
- selectivity-at-length was estimated for the single trawl, pair trawl and recreational methods as independent parameters; time-variant recreational selectivities were specified to take account of changed minimum legal size (MLS) from 25 cm to 27 cm in October 1994;
- selectivity-at-length for the longline method was assumed to be constant at a value of 1.0.

<u>Catch at age</u>

Catch at age information from the Ministry of Fisheries stock monitoring programme was available for the following methods and years:

- pair trawl 1974-76, 1978-80, 1986-87, 1989-90, 2000-04,
- single trawl 1974-76, 1991-2004.

For the period 1974 to 1980, estimates were calculated as the mean catch-at-age weighted by the catches taken in each season sampled in that year.

<u>Year class strength (YCS)</u>

The age structured model was constructed to estimate constant annual recruitment (number of 1-year-old fish entering the stock) from 1928 to 1970. Year class strength information came from catch at age data and trawl survey indices (Table 20). Separate catchability coefficients were estimated for the

2+ and 3+ indices to account for differences in vulnerability. The annual YCS's were estimated as indices relative to the average recruitment for 1971-2000.

Table 20: SNA 8 trawl survey indices of relative year class strength with the ages at which individual year classes were sampled.

Survey year	Year class	Index	CV	Age surveyed
1987	1984	0.82	0.27	3+
	1985	2.73	0.28	2+
1989	1986	0.78	0.10	3+
	1987	0.67	0.20	2+
1991	1988	0.18	0.37	3+
	1989	0.96	0.32	2+
1994	1991	1.27	0.15	3+
	1992	0.79	0.26	2+
1996	1993	0.93	0.31	3+
	1994	0.89	0.20	2+
1999	1996	1.90	0.13	3+
	1997	0.29	0.19	2+

Recreational catch

Recreational catch estimates range between 236 and 1133 t (Table 5). The uncertainty in these estimates discussed above, means that their utility is mainly limited to identifying a plausible range. The Working Group agreed to use two alternative recreational catch scenarios that were deemed to represent the upper and lower bounds of average recreational catch. For the lower catch scenario an annual recreational catch of 300 t was assumed between 1990 and 2004. For the higher catch scenario the 1990 to 2004 value was 600 t. For both scenarios the 1931 catch was assumed to be 20% of the 1990 catch and the intermediate year catches were determined by linear interpolation. These two recreational catch scenarios were used in the alternative stock assessments presented below. No additional catch is assumed for customary catch above either recreational level.

CPUE analyses

A time series of annual pair trawl CPUE indices (catch per day) for 1974-1991 for SNA 8 was derived by Vignaux (1993). The recent time series of single and pair trawl catch and effort data cover the period 1989–90 through 2003–04. There was a shift to more detailed reporting forms in 1994–95. To use the data prior to this year, a coarser unit of effort must be defined over the whole time series that limits the resolution of a descriptive effort variable. In past analyses the unit used was catch per tow (Davies et al., 1999). Davies et al. found that there were significant differences between pair and single trawl CPUE after 1989–90. The Snapper Working Group rejected the pair trawl index after 1990–91 on the grounds that it possibly contained duplicated effort data.

For the 2004 assessment a time series of single trawl CPUE indices was calculated using the recent detailed catch-effort data reported since 1994–95. The effort term was catch per nautical mile derived from "tow speed" and "tow duration". Covariates in the general linear model included: a length/breadth/depth (LBD) parameter representing vessel-power; month; stat-area; and target. Zero catches were included in the GLM by the addition of 1 kg to all recorded catch estimates. The index derived from the GLM fit is given in Figure 5.

This series was updated to 2003–04 for the 2005 assessment and a GLM standardisation was undertaken using the same parameters as in 2004. The data showed a decreasing trend in the proportion of zero catches which the WG felt was important to include in the standardised model. Various methods were attempted to include this information, such as adding a constant to the zero catches or using a combined model where the zero catches were modelled separately based on a binomial distribution and then combining the binomial model with the lognormal model (positive catch data) using a delta method. The former approach resulted in unacceptable model diagnostics and the delta method showed that the effect of adding the trend in proportion zero catch was relatively minor compared to the trend obtained from the positive catch data. Consequently the WG recommended not including the zero catch data in the GLM fits but that this issue could be explored more fully in future assessments.

The WG also requested that the LBD parameter previously used to describe vessel fishing power be replaced by an individual categorical "vessel" variable and that the analysis be restricted to vessels which had been active in the fishery for at least three years. This data selection resulted in the construction of two datasets describing the catch and effort data for the top 20 and the top 12 catching vessels.

The updated single trawl GLM index showed a shallow decreasing trend from 1995–96 to 2000–01 followed by a general increase to 2003–04 (Figure 5). The Working group considered these indices were more appropriate than the analysis used to generate the 2004 series, given that the 2005 analysis was based on data from core vessels only and that the model diagnostics were acceptable. There was virtually no difference between the year indices based on the data from the top 20 or the top 12 vessels and the WG adopted the series based on the top 12 vessels to include in the SNA 8 assessment model.

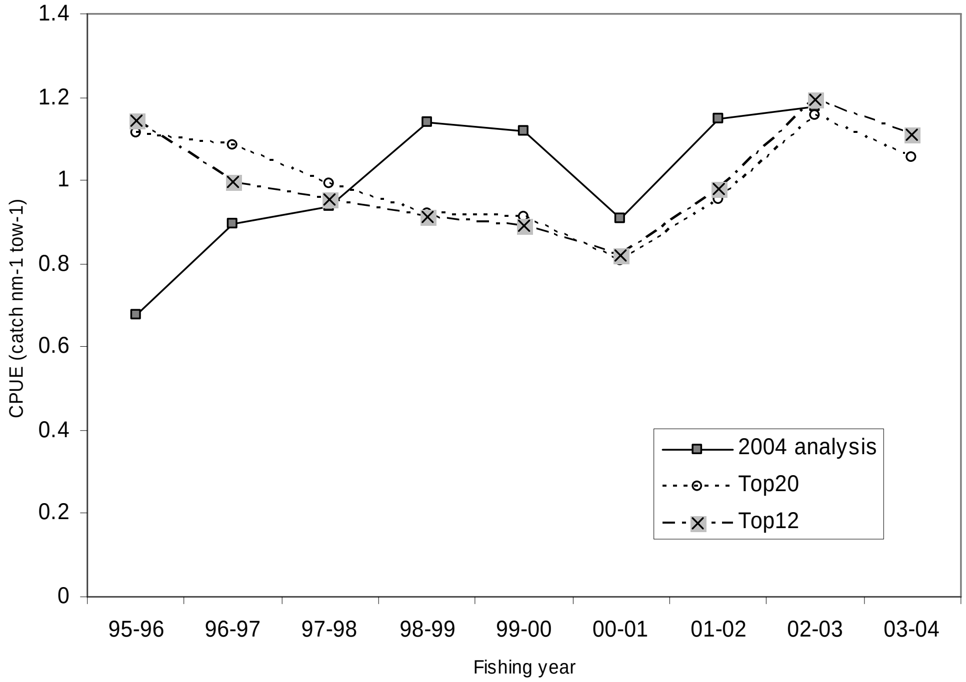


Figure 5: Single trawl CPUE indices of catch per n. mile used in the 2004 and 2005 assessments.

<u>2002 Tagging Program Biomass</u>

A tag-recapture programme was carried out in 2002 and 2003 to estimate recruited population size in SNA 8. In February 2002, 22854 fish were tagged with internal passive integrated transponder tags. Fish 20 cm and larger were tagged from 335 trawl tows distributed from Ninety Mile Beach to South Taranaki, out to a depth of 75 m. SNA 8 was divided into five inshore strata (less than 75 m) and five adjacent offshore strata. Fish were not tagged from the offshore strata because of the likely high mortality rate of snapper that are caught in deeper water. It was assumed that fish would mix between inshore and offshore strata. Some fish under 25 cm were tagged to allow the estimation of the growth rate of recruiting fish. Commercial landings were scanned for tags between October 2002 and July 2003. The fishing location of each landing or part-landing was recorded. The primary data were therefore the release location and size of each fish tagged; the location, date, weight and a length frequency sample of each part-landing that was scanned; and a unique identifier (tag number) and length for each recaptured fish.

Ancillary data were required to allow the estimation of initial (immediate post-tagging) mortality, scanner failure rates and the difference between the growth rates of tagged and untagged fish. Length frequency samples taken during the release phase were also used to improve the precision of the estimates of numbers at length. Evidence obtained from double-tagged fish showed that tag deterioration and tag loss did not occur over the duration of the experiment.

Estimation

Maximum likelihood was used to estimate the recruited population size as a vector of numbers at length in each of the ten strata in February 2002. A model was developed to calculate the binomial likelihood of a tagged fish being either recaptured or not recaptured in each scanned landing. Likelihoods for initial survival, movement, growth of fish and scanner failure were included. Binomial likelihoods were also calculated for the numbers of survivals from three initial mortality experiments (in 1992, 1994 and 2002) where tagged fish were retained in a holding net for two weeks. The probability of a tagged fish being detected by each scanner was calculated from a series of tag seeding trials. A normal likelihood involving the growth of untagged fish was calculated from sample proportions by age and length from commercial landings and research trawl survey samples. Multinomial likelihoods were also obtained for length frequency samples taken during the release and the recapture phases.

A total of 103 parameters were estimated. These were: 16 numbers at length parameters for each inshore/offshore pair of strata; a North/South movement parameter; two growth parameters for tagged fish and two for untagged fish; a phase parameter for growth seasonality; a parameter for growth variability; five scanner success rate parameters; three initial survival rate parameters; four release phase selectivity parameters and four recapture phase (commercial fishery) selectivity parameters.

The population in each stratum between 15 and 80 cm was obtained by interpolating between adjacent pairs of the 16 numbers at length parameters. The numbers of fish between 15 and 24 cm was estimated to account for the recruitment of fish below 25 cm into the population in the period from February 2002 (tag release) to October 2002 to July 2003 (recapture period).

Because fish were not tagged from the offshore strata there was a confounding of inshore/offshore movement and the offshore population size. The populations in the offshore strata were therefore assumed to have the same proportions at length as the adjacent inshore strata and two non-estimated parameters were also required: inshore/offshore movement and the proportion of fish whose home stratum was offshore.

Each fish had a hypothetical home stratum. The probability that a fish would, at any time, be in another stratum was a constant function of how far that stratum was from the home stratum, dependent on the two movement parameters. Thus the model did not allow net movement over time. Inshore and offshore movement was equally likely and northerly and southerly movement was equally likely. The probability of movement more than one stratum north or south declined as a power function of the movement parameter. Impermeable boundaries were assumed at the north of the Ninety Mile Beach stratum and at the south of South Taranaki.

Results

The estimated biomass in each stratum is given in Table 21. A substantial fraction of the total biomass (37%) comes from fish above 55 cm in length. The CV of the recruited population biomass estimate was 0.12. The estimated numbers per centimetre length class have CVs that fall from 0.24 at 25 cm to a minimum of 0.06 in the mid-30's and then rise to exceed 0.30 at 66 cm, based on the estimated Hessian matrix. Estimates in adjacent length classes are highly correlated with correlation coefficients exceeding 0.85 above 31 cm. CASAL does not at present contain any multivariate likelihood function with covariances. To simply ignore these high correlations would give these data excessive weighting.

Table 21: Estimated population biomass.

Stratum name	**Biomass (t)**	
	<75 m	**≥75 m**
Ninety Mile Beach	685	104
Kaipara	887	135
Manukau	3465	526
North Taranaki	2131	324
South Taranaki	1897	288
Total		10442
CV of total		0.12

The estimate of biomass from the 1990 tagging programme in SNA 8 was recalculated. After correcting for sources of bias, the revised estimate was 9 505 t; a CV of 0.18 was assumed. The programme also provided estimates of the recruited population length composition. The CVs assumed for these (0.11 to 0.48) were double those derived from the 2002 programme.

After consideration of the low CVs estimated from the 2 tagging programmes the WG agreed to fit the absolute biomass estimates and proportions at length for the 1990 and 2002 tagging data in both alternative runs, but to increase the CVs of the absolute biomass estimate to 0.3 for the 1990 programme and to 0.2 for the 2002 value.

Mean weight-at-age estimates

Comparison of mean weight at age data from the age samples over time indicated that, on average, fish at the same age were heavier in the 1990s than in the 1970s. It is not known what has caused this change in mean weight-at-age, but it is possible that it results from density-dependence or from changes in the mean temperature. This shift in mean weight at age has important implications for the calculation of the B_0 and B_{MSY} reference points because they will differ, depending on which set of mean weight at age are used. The WG agreed to calculate all biomass levels prior to 1980 using the mean weight at age derived from the 1975-79 catch-at-age samples. Biomass levels after 1989 used the post-1989 mean weight-at-age estimates. Biomass levels in the period from 1980 to 1988 used a mean weight at age values calculated from the mean of the two sets of available estimates. This means in the model that B_0, based on the 1931 initial equilibrium biomass, has been calculated using the mean weight-at-age levels appropriate to the 1970s.

Revised selectivity estimates from tagging.

Length-based selectivity curves for single and pair trawl were obtained from the tagging estimator model, primarily from the recapture phase length frequencies. Both had steeply declining right hand limbs with 50% selectivity at 49.2 and 54.1 cm respectively. Although these estimates were consistent with the lower recapture rates of larger fish, previous estimates and other data in the population model suggested shallower declines, especially for pair trawl. In the population model runs single and pair trawl length-based selectivities were estimated as independent parameters, with the tagging selectivity estimates defining the means of informed priors. Alternative recreational length-based selectivities before and after 1994 were estimated to take account of the effect of a change in the minimum legal size (MLS) from 25 cm to 27 cm in October 1994. Knife-edge left hand limbs and the join parameters corresponding to the MLS values were assumed, with the right hand limbs of the selectivity functions being estimated.

Assumed error and priors

The level of observational and process error (see Bull et al., 2004) assumed for fitting to the observational data is given in Table 21. Process error was added to CPUE, trawl survey recruitment indices (TSI), and boat ramp length frequency data. The level of process error for CPUE was set such that the total CV was approximately 0.2 to 0.3. Process error for TSI and boat ramp length frequency data was added to reduce the relative weight of these observations in the overall model fit (Table 22). The list of priors assumed for model parameters is given in Table 23. The uniform prior for YCS was deliberately chosen to overcome a problem with the YCS parameterisation for calculating Bayesian estimates using the MCMC algorithm; the impact of this on the assessment has not been determined.

The natural weighting for the observations fitted in the model is that which produces a standard deviation for the standardised residuals that is close to 1.0. This was not the weighting used in the SNA 8 model. A lower weighting was assigned to the catch-at-age data and pair trawl length frequency data (low effective sample sizes) to maintain the relative weight of the tagging programme estimates in the overall model fit.

Table 22: Observation error assumed for data input to the SNA 8 model (effective sample size = N, coefficient of variation =CV), and process error assumed.

Observation type	Observation error	Process error	Error type
Catch at age pair trawl post-1986	N = 13 to 63	0	Multinomial
Catch at age single trawl post-1991	N = 13 to 72	0	Multinomial
Catch at age pair trawl 1974-80	N = 8 to 86	0	Multinomial
Catch at age single trawl 1974-76	N = 7 to 35	0	Multinomial
CPUE pair trawl 1974-1991	CV range = 0.07 - 0.67	0.2	Log-normal
CPUE single trawl 1996-2004	CV range = 0.023 – 0.047	0.2	Log-normal
Tag biomass 1990	CV = 0.3	0	Log-normal
Observation type	**Observation error**	**Process error**	**Error type**
Tag biomass 2002	CV = 0.2	0	Log-normal
Tag population proportions at length 1990	CV range = 0.11 - 1.28	0	Log-normal
Tag population proportions at length 2002	CV range = 0.06 – 0.76	0	Log-normal
Trawl survey 2+ year class strength index	CV range = 0.19 - 0.32	0.2	Log-normal
Trawl survey 3+ year class strength index	CV range = 0.10 - 0.37	0.4	Log-normal
Boat ramp recreational catch length frequency	N = 100	N = 60	Multinomial
Pair trawl catch-at-sea length frequency 1986	N = 10	0	Multinomial

Table 23: Assumed model priors.

Parameter	Prior	Specification
Mean recruitment, R_0	Uniform-log	Range = (10^4, 10^8)
Year class strengths (1971-2000)	Uniform	Range = (0.01, 20.0)
Catchability coefficients (CPUE and trawl survey indices), q_1, q_2, q_3, q_4	Uniform-log	Range = (10^{-9}, 3.0)
Selectivity (all double-normal) – single and pair trawl	Normal	Means = tag 2002 estimates (6 parameters) CVs range = 0.11 - 0.63
Selectivity (all double-normal) – recreational	Normal	Means = 12 cm above Ljoin (2 parameters) CV = 0.5
Natural mortality, *M**	Log-normal	Mean = 0.075, CV = 0.5

* M was fixed in the MCMC for both runs at the value estimated in the MPD

<u>Alternative model runs</u>

A range of alternative models were explored to test the sensitivity of the model to alternative assumptions concerning the value of natural mortality, assumed catch history and the information obtained from the tagging programmes. The WG finally agreed on two runs that differed only in the level of recreational catch assumed (either 300 t or 600 t from 1990 to 2004). Both runs fit the tag-recapture data from 1990 and 2002 as absolute biomass estimates plus proportions at length.

(b) <u>Results</u>

As the weights at age vary over the time period of the model it is necessary to determine what population parameters should be used in defining the virgin biomass. The 1989–2004 length-at-age data give greater weights-at-age than the 1975–1979 data. It was inferred that these increased growth rates were a result of density dependence rather than of a positive relationship with mean water temperature. The WG agreed that virgin stock biomass (B_0) should therefore be defined as that resulting from mean recruitment and the 1975–1979 mean weights-at-age and is equal to the modelled 1931 biomass.

The model estimates of natural mortality were 0.051 and 0.054, depending on which level of recreational catch was assumed. These estimates are lower than the value (0.075) assumed in previous SNA 8 assessments, based on the catch-at-age data collected in the 1970's, but analysed independent of the assessment model. The model fit to the observations was significantly improved when estimating natural mortality compared to a model fit when assuming a fixed value of 0.075. The effect of lower estimates of natural mortality is to reduce the estimates of mean recruitment and the stock productivity.

The mean of the posterior distributions and 90% credible intervals for B_0 and B_{04} are shown in Table 24 for the alternative runs. A higher B_0 estimate was obtained for the run that assumed higher recreational catch (R600), but stock status was similar. This range for B_0 is not considered to adequately describe the full uncertainty in B_0 for a number of reasons:

- the model may be described as a "total catch history model", so the time series of historical catches strongly determines the estimate of B_0. The alternative recreational catch history resulted in a higher estimate of B_0 but with similar levels of uncertainty. There is further substantial uncertainty in the assumed catch history for Japanese longline catch, commercial catch overruns and the pattern of recreational catches.
- There are a large number of observations to which the model was fitted over the period 1974 to 2004. Amongst these the catch-at-age data in the 1970's has moderate leverage on the estimates of R_0 and M. An evident constraint on the model biomass is that it remains above zero in the mid-1980s while at the same time fits the absolute abundance estimates from the later tagging programmes. Throughout this period, 1986 to 1990, there was strong agreement in the model fit to six of the data types. The model fits to these data serves to constrain the estimates of R_0 and M, and, hence, B_0.
- The model trajectory differed somewhat from the recent CPUE index. However the observed indices were within a narrow range (0.9 to 1.2) and the fit was consistent with the CV's.

Table 24: Mean of posterior distributions of biomass for the SNA 8 model using recreational catch levels of 300 t (R300) and 600 t (R600). B_0 is virgin stock biomass. B_{04} is the start of year biomass for 2003–04, and B_{04}/B_0 is the ratio of 2003–04 biomass to B_0. The 90% credible intervals were derived from the marginal posterior distributions for the Base case. The biomass units are 1000 t.

Model run	B_0	5%	95%	B_{04}	5%	95%	B_{04}/B_0	5%	95%
R300	110	108	112	10.8	8.5	13.4	9.8%	7.8%	12.1%
R600	117	114	119	11.7	9.2	14.6	10.0%	8.0%	12.5%

The Working Group discussed the use of appropriate reference points for reporting the stock status of SNA8. Because the model uses variable growth curves through the calculation period, B_{MSY} will vary depending on the assumed growth rate and how growth might vary with stock size. For instance, if a constant mean size-at-age equal to that for 1931–2004 was used, B_{MSY} = 18.3% B_0. Alternatively, if the 1989–2004 mean size-at-age were used, B_{MSY} = 17.5% B_0. Ideally, a functional relationship defining density dependent growth would be used to calculate the SNA 8 B_{MSY} but the functional relationship of size-at-age with density is not defined and was not possible to model in the time available. Based on exploratory modelling of density-dependent growth, the Working Group adopted 20% B_0, where B_0 is the Base case model estimate of biomass in 1931, as the definition for B_{MSY}. Under the mean size-at-age for 1931–2004 the catch to biomass ratio at B_{MSY} was 0.098.

Bayesian posterior estimates for the model parameters were derived from MCMC chains of 3.2 million (R300) and 2.6 million (R600) iterations (Figure 6). It was necessary to hold M constant at the MPD values (0.051 and 0.054) to produce convergence of the MCMC. The MCMC traces for the two main model runs showed no obvious signs of non-convergence.

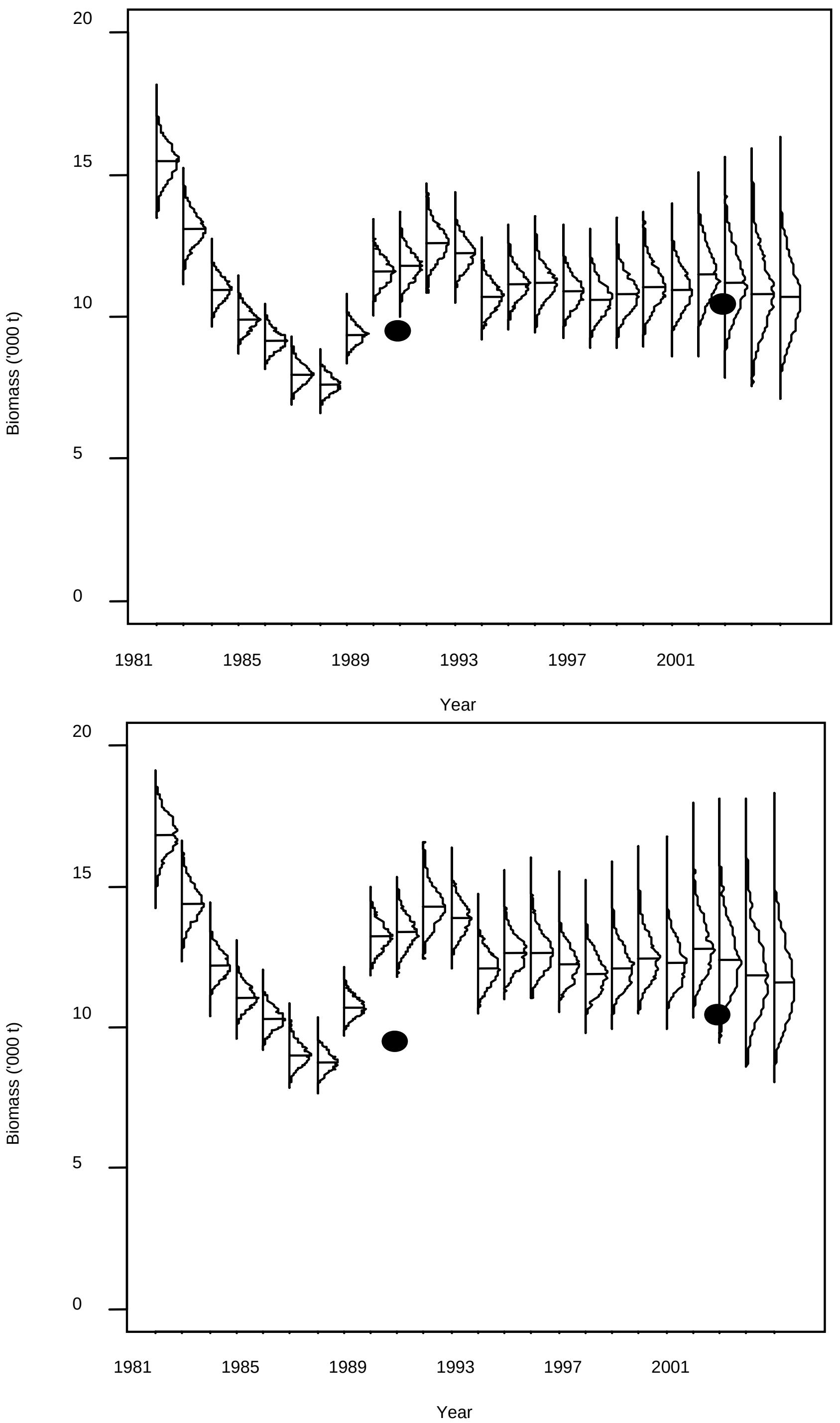


Figure 6: Posterior distributions of the biomass trajectories for the SNA 8 model estimates assuming historical recreational catch of 300 t (top panel) and 600 t (bottom panel) with the tagging programme estimates of biomass (solid circles).

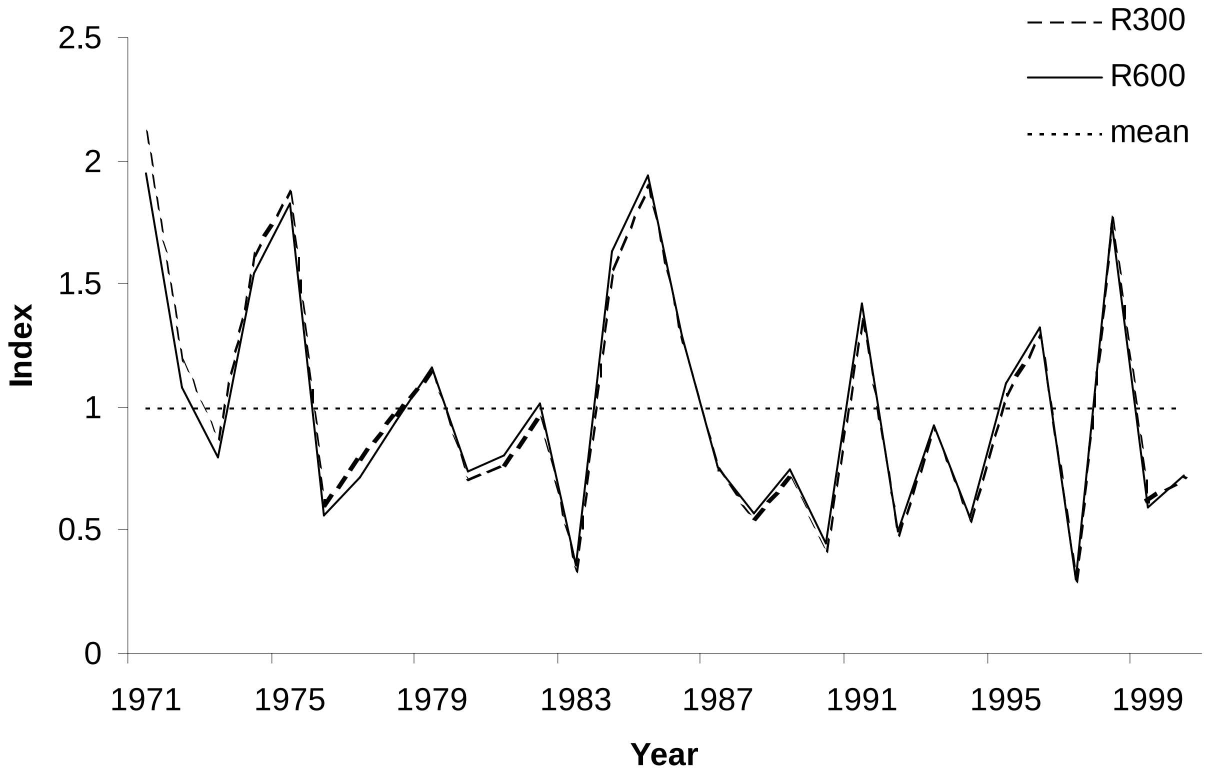


Figure 7: SNA 8 Base case model MPD estimates of the relative strengths of the 1971 to 2000 year classes.

<u>Projections</u>

Projections of population biomass have been modelled assuming future commercial catch over the range 500 to 1500 t, with a 10% overrun component. Two options were investigated for future recreational catch in projections: firstly, assuming a constant recreational exploitation rate at the level estimated in the model in 2004 (Frec); and secondly, assuming a constant catch capped at the level assumed for 1990-2004 (Rcap). Two alternative levels were assumed for the recreational catch from 1990 to 2004, either 300 t or 600 t. The WG considered these values were likely to bracket the true average level of catch in this period. The impact of the increase in minimum legal size (MLS) in the recreational fishery has been incorporated into the model assumptions. A projection was also investigated that included zero future removals (commercial or non-commercial) from the population in all years. This was to determine the maximum rate of rebuilding possible for the population.

The posteriors of the model parameters were sampled for projections while assuming stochastic recruitments (by randomly resampling with replacement the year class strengths (Figure 7) in each draw), and constant commercial catches. Constant mean size-at-age using the 1989–2004 mean was assumed. At each catch level, simulations were carried out, projecting forward to 2025. For projections assuming future annual recreational exploitation rates are constant (Frec) the value was estimated from the model MPD value (i.e. the recreational catch to absolute biomass ratio in 2004). In this case the commercial catch was assumed to be constant at the alternative levels, however, the recreational catch varied as stock size and age structure changed. For projections assuming constant future recreational catch (Rcap) this did not occur.

Under all future recreational catch options and at alternative levels of future TACC the stock is predicted to increase on average (Table 25, and Figure 8). The rate of increase was slightly lower for Frec options (constant recreational exploitation rate, Figure 8a and 8c) compared to the Rcap projection options (constant recreational catch, Figure 8b and 8d). The rate of rebuilding varied widely depending upon the assumed future TACC.

Table 25: SNA 8: Projection estimates for the R300 and R600 model runs under two alternative options for recreational catch: a) constant proportional recreational catch (*Frec*) equivalent to the proportional recreational harvest in 2005; and b) constant annual recreational catch (*Rcap*). Estimates are shown for a range of future TACCs and for a projection under zero removals, i.e. TACC = 0 t and zero recreational catch. B_{05} and B_{10} are start of year biomasses for 2004–05, and 2009–10, respectively. P(B_{10}>B_{05}) is the probability of B_{10} exceeding B_{05} and E( ) denotes expected value. The 90% credible interval for B_{10}>B_{05} were derived from the marginal posterior distributions. CR_{2010} is recreational catch in 2010. E(B_y) denotes the year B_{MSY} is expected to be reached.

(a) R300_Rcap

TACC	E(B_{05}) (t)	E(B_{10}) (t)	B_{10}/B_{05} Expected	5%	95%	P(B_{10}> B_{05})	E(CR_{2010})	Year when E(By) = B_{MSY}
500	10 891	18 538	1.70	1.29	2.13	1.00	300	2011
1 000	10 882	15 266	1.39	0.99	1.81	0.94	300	2014
1 250	10 869	13 709	1.25	0.83	1.67	0.84	299	2018
1 375	10 866	12 876	1.17	0.74	1.59	0.74	297	2021
1 500	10 904	12 206	1.10	0.71	1.51	0.64	296	>2025

(b) R300_Frec

TACC	E(B_{05}) (t)	E(B_{10}) (t)	B_{10}/B_{05} Expected	5%	95%	P(B_{10}> B_{05})	E(CR_{2010})	Year when E(By) = B_{MSY}
0	10 929	23 614	2.18	1.77	2.68	1.00	-	2010
500	10 929	17 747	1.63	1.30	2.01	0.96	561	2012
1 000	10 901	14 746	1.35	1.02	1.71	0.96	472	2016
1 250	10 913	13 288	1.21	0.84	1.57	0.83	426	2022
1 375	10 929	12 556	1.14	0.79	1.48	0.75	401	>2025
1 500	10 906	11 778	1.07	0.73	1.43	0.61	376	>2025

(c) R600_Rcap

TACC	E(B_{05}) (t)	E(B_{10}) (t)	B_{10}/B_{05} Expected	5%	95%	P(B_{10}> B_{05})	E(CR_{2010})	Year when E(By) = B_{MSY}
500	11 693	18 429	1.57	1.17	2.01	0.99	600	2012
1 000	11 713	15 353	1.30	0.87	1.74	0.88	599	2016
1 250	11 683	13 781	1.17	0.76	1.58	0.73	596	2020
1 375	11 676	13 087	1.10	0.70	1.53	0.64	591	>2025
1 500	11 695	12 337	1.04	0.67	1.46	0.53	583	>2025

(d) R600_Frec

TACC	E(B_{05}) (t)	E(B_{10}) (t)	B_{10}/B_{05} Expected	5%	95%	P(B_{10}> B_{05})	E(CR_{2010})	Year when E(By) = B_{MSY}
0	11 730	25 592	2.20	1.77	2.70	1.00	-	2010
500	11 676	17 346	1.49	1.19	1.84	1.00	1 013	2014
1 000	11 729	14 596	1.24	0.93	1.57	0.90	856	2021
1 250	11 710	13 106	1.11	0.80	1.43	0.71	767	>2025
1 375	11 702	12 419	1.05	0.75	1.39	0.59	726	>2025
1 500	11 700	11 799	1.00	0.70	1.32	0.48	690	>2025

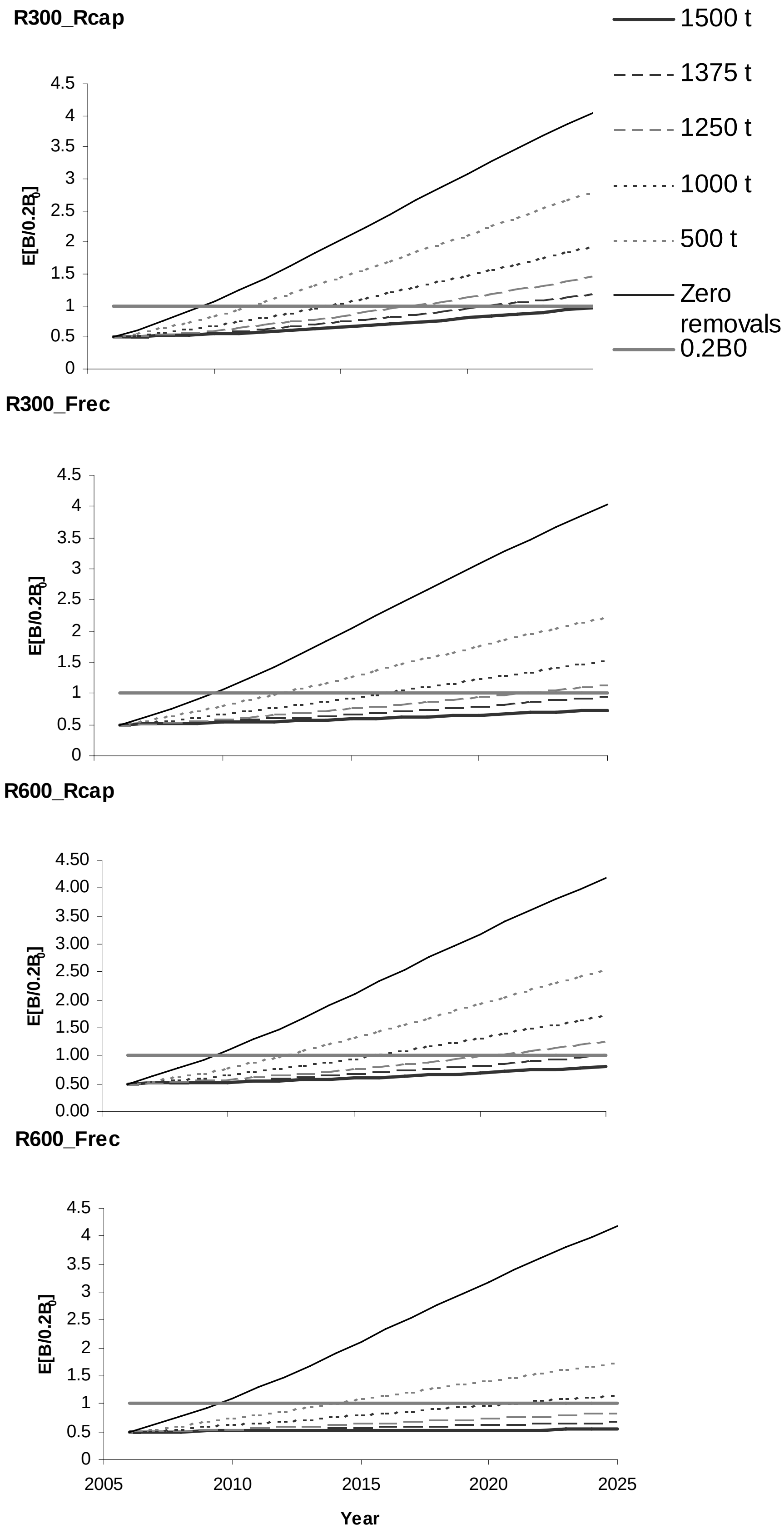


Figure 8: Mean of expected biomass relative to 20% of virgin biomass (B0) forecast to 2025 for the R300 and R600 models under two alternative options for recreational catch: Frec, constant annual exploitation rate at the MPD level estimated in 2004; and, Rcap, constant annual catch of 300 or 600 t respectively. For each model option a range of future TACC levels were investigated (500 to 1500 t), and compared to an option for zero removals from the population.

Under the Frec projection option, recreational take increases as the stock increases but is mediated by the domed recreational selectivity curve. The high proportion of young fish in the population after a period of rapid rebuild gives recreational fishers higher catches for the same effort. Under the slower rebuild the young fish make up a relatively smaller fraction of the population leading to relatively smaller recreational catch.

In summary the SNA 8 stock is predicted to increase under any future TACC level and alternative recreational catch assumptions. However, with a TACC of 1500 t the rate of rebuild is very slow.

(c) Estimation of Maximum Constant Yield (MCY)

Estimates of MCY were not calculated.

(d) Estimation of Current Annual Yield (CAY)

Estimates of CAY were not calculated.

(e) Other factors that may modify assessment results

The WG considered that there were a number of other factors that should be considered in relation to the stock assessment results presented here for SNA 8. The current assessment produces very precise results, which are the product of the available data and various model assumptions. However, many of the model assumptions may be violated to some extent. Some of the more important considerations are:

- the tagging estimates may be biased;
- the MPD residuals are not consistent with the statistical assumptions of the model and give extra weight to the tagging estimates;
- natural mortality is not known exactly (as was assumed in the MCMCs);
- the catch history is uncertain with regard to Japanese longline catch and commercial catch overruns in addition to recreational catch.

A full exploration of these factors has not been performed. Additional sensitivity runs taking account of these factors would produce a greater range of uncertainty than is present in the current assessment.

5. STATUS OF THE STOCKS

No new stock assessments are presented for snapper stocks. The assessments from earlier years are summarised below.

SNA 1

These stocks were last assessed in 2000. The status of the two sub-stocks differs.

East Northland

The base case East Northland stock assessment indicates that the current recruited biomass is at about the B_{MSY} reference point and is expected to exceed B_{MSY} at the end of the twenty-year projection period (with 67% probability). This conclusion is robust to all sensitivities investigated, except when a low natural mortality was investigated. Even in this sensitivity, the stock is expected to increase to near B_{MSY} at the end of the projection period.

Hauraki Gulf/Bay of Plenty

The base case Hauraki Gulf/Bay of Plenty stock assessment indicates that the current recruited biomass is less than the B_{MSY} reference point but is expected to increase over the next twenty years under the current TACC and estimated levels of recreational and unreported catch. It is expected to exceed the B_{MSY} reference point at the end of the projection period (with 100% probability). This conclusion is robust to all sensitivities investigated.

For SNA 1 as a whole, catches at the level of the TAC will allow the stock to increase over the next 20 years.

SNA 2

An assessment model was fitted to four years of proportions at age data in 2002. As there are no indices of biomass available, model estimates must be treated with caution. For almost all runs, the current biomass was estimated to be near to or somewhat below B_{MSY} but was projected to increase towards B_{MSY} by 2006 at the current catch level (436 t).

SNA 7

An assessment was completed in 2002 for this stock. Model results indicated that the stock should have rebuilt substantially since the low levels of the early 1980s. However, there are no current indices of abundance for this stock to verify the results from the assessment model; only catch at age data is available for recent years.

The MLEs for B_{2001} for the base case and all of the sensitivity runs are well above B_{MSY}. The large reduction in catches from the mid-1980's and the long period that cohorts persist in the recent catch at age data are reflected in model estimates of a rebuilding stock. The results indicate the stock would continue to increase even if future catches were substantially larger than those currently being taken.

SNA 8

The 2005 stock assessment indicated that current biomass (start of year 2004–05) was between 8% and 12% B_0 and the biomass was predicted to slowly increase at the TACC level of 1500 t. However, from 1 October 2005 the TACC was reduced to 1300 t to ensure a faster rebuild of the stock. At this TACC level the rebuild to B_{MSY} (20%B_0) occurred after 2018 in all cases assuming either constant recreational effort, or capped recreational catch at the alternative levels of 300 t or 600 t per year. Rebuilding tended to be slower for runs that allowed the recreational catch to rise with increasing biomass.

Yield estimates, TACCs and TACs for the 2005/06 fishing year are summarised in Table 26.

Table 26: Summary of yield estimates (t), TACC's (t) and reported landings (t) for the most recent fishing year.

Fish stock	QMA	MCY	CAY_{99-00}	MSY	2005-06 Actual TACC	2005-06 Commercial landings
SNA 1	1	9 911	8 712	10 050	4500	4530
SNA 2	2	–	–	440-500	315	389
SNA 3	3, 4, 5 & 6	–	–	–	32	<1
SNA 7	7	–	–	850	200	166
SNA 8	8, 9	–	–	–	1500	1434
SNA 10	10	–	–	–	10	0
Total					6557	6519

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