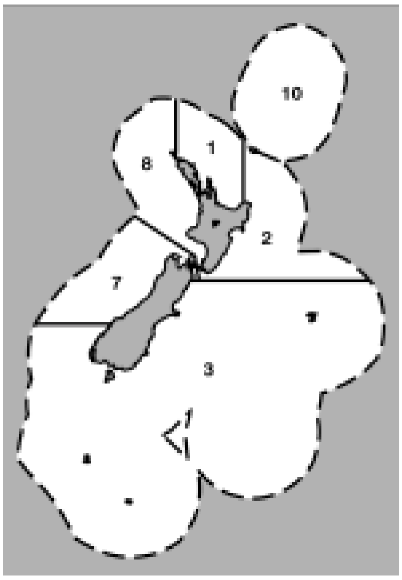
SNAPPER (SNA)

(*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). In the 1980s an increasing proportion of the 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. Subsequent decisions by the Quota Appeal Authority saw the TACCs increase, in the case of SNA 1 from 4710 t to over 6000 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 (the deemed penalty value was incurred for about 400 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 since 1987–88. The snapper catches from these fisheries declined from 80% of the total snapper catch in 1992–93 to 56% in 1993–94. However, despite the efforts of fishers to minimise by-catch, the SNA 2 TACC continues to be over-caught.

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.

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	3 465	0	69	140	1961	5 318	589	583	1 178
1932	3 567	0	36	159	1962	5 582	604	582	1 352
1933	4 061	21	65	213	1963	5 702	636	569	1 456
1934	4 484	168	7	190	1964	5 643	667	574	1 276
1935	5 604	149	10	108	1965	6 039	605	780	1 182
1936	6 597	78	194	103	1966	6 429	744	1 356	1 831
1937	5 918	114	188	85	1967	6 557	856	1 613	1 477
1938	6 414	122	149	89	1968	7 333	765	1 037	1 491
1939	6 168	100	158	71	1969	8 674	837	549	1 344
1940	5 325	103	174	76	1970	9 792	804	626	1 588
1941	5 003	148	128	62	1971	10 737	861	640	1 852
1942	4 279	74	65	57	1972	9 574	878	767	1 961
1943	4 643	60	29	75	1973	9 036	798	1 258	3 038
1944	5 045	49	96	69	1974	7 635	716	1 026	4 340
1945	4 940	59	118	124	1975	5 894	732	789	4 217
1946	5 382	77	232	244	1976	7 220	732	1 040	5 326
1947	5 815	36	475	251	1977	7 514	374	714	3 941
1948	6 745	53	544	215	1978	10 128	454	2 720	4 340
1949	5 866	215	477	277	1979	10 460	662	1 776	3 464
1950	5 107	285	514	318	1980	7 370	636	732	3 309
1951	4 301	265	574	364	1981	7 872	283	592	3 153
1952	3 795	220	563	361	1982	7 242	160	591	2 636
1953	3 703	247	474	1 124	1983	6 256	160	544	1 814
1954	4 316	293	391	1 093	1984	7 141	227	340	1 536
1955	4 442	309	504	1 202	1985	6 774	208	270	1 866
1956	4 742	365	822	1 163	1986	5 969	255	253	959
1957	5 285	452	1 055	1 472	1987	4 532	122	210	1 072
1958	5 154	483	721	1 128	1988	5 082	165	193	1 565
1959	5 778	372	650	1 114	1989	5 816	227	292	1 571
1960	5 697	487	573	1 202	1990	5 757	429	200	1 551

The 1931–1943 years are April-March but from 1944 onwards are calendar years. 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. 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. 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 1999–00 and gazetted and actual TACCs (t) for 1986–87 to 1999–00

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†	6 539	–	145	–	2	–	375	–	1 725	–	0	–	9 153	–
1984–85†	6 898	–	163	–	2	–	255	–	1 546	–	0	–	9 228	–
1985–86†	5 876	–	177	–	0	–	188	–	1 828	–	0	–	8 653	–
1986–87‡	4 016	4 710	130	130	0	30	257	330	893	1 330	0	10	5 314	6 540
1987–88‡	5 061	5 098	152	137	1	30	256	363	1 401	1 383	0	10	6 900	7 021
1988–89‡	5 793	5 614	210	157	1	30	176	372	1 526	1 508	0	10	7 706	7 691
1989–90‡	5 826	5 981	364	157	< 1	30	294	160	1 550	1 594	0	10	8 034	7 932
1990–91‡	5 315	6 002	427	157	< 1	31	160	160	1 658	1 594	0	10	7 570	7 944
1991–92‡	6 191	6 010	373	157	< 1	31	148	160	1 464	1 594	0	10	8 176	7 962
1992–93‡	5 423	4 904	316	252	2	32	165	160	1 543	1 500	0	10	7 448	6 858
1993–94‡	4 846	4 928	307	252	< 1	32	147	160	1 542	1 500	0	10	6 842	6 883
1994–95‡	4 831	4 938	307	252	< 1	32	150	160	1 434	1 500	0	10	6 723	6 893
1995–96‡	4 941	4 938	279	252	< 1	32	146	160	1 558	1 500	0	10	6 924	6 893
1996–97‡	5 049	4 938	352	252	< 1	32	162	160	1 613	1 500	0	10	7 176	6 893
1997–98‡	4 524	4 500	286	252	< 1	32	182	200	1 589	1 500	0	10	6 583	6 494
1998–99‡	4 411	4 500	283	252	2.5	32	142	200	1 636	1 500	0	10	6 475	6 494
1999–00‡	4 500	4 500	391	252	< 1	32	174	200	1 604	1 500	0	10	6 669	6 494
2000–01‡	4 347	4 500	360	252	< 1	32	156	200	1 630	1 500	0	10	6 496	6 494

† 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

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 3). 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 3: 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	3 092	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 the 1998 assessment the start year for the SNA 1 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 tonnes. 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 from 1965 to 1974. An annual catch level of 2000 tonnes was assumed. Trawl catches from 1967–77 and longline catch from 1975–77 were assumed to be at the reported levels.

(b) Recreational fisheries

Estimates of recreational catch for snapper in 1996 are available (Table 4) from the 1996 national telephone and diary survey (Bradford 1998). The mean weight of snapper was estimated from the fish measured at boatramps throughout 1996.

Table 4: Recreational catch estimates (t) of snapper for 1996. The number of fish was estimated from the diary reports of catch scaled up to the total population in each area

	Number of fish	**Mean weight (g)**	**Total catch Tonnes**
SNA 1			
East Northland	684 000	1039	711
Hauraki Gulf/ Bay of Plenty	1 852 000	870	1 611

		Total	2 322
SNA 2	31 000		40
SNA 7	74 000		177
SNA 8	271 000		236

Estimates of recreational catch in earlier years for most areas are available based on the results of tagging programmes (Table 5) or regional telephone and diary surveys in MAF Fisheries South (1991–92), Central (1992–93) and North (1993–94) regions (Teirney et al. 1997). Estimates of the annual recreational catch of snapper by Fishstock are available by combining the results of these surveys.

Table 5: Recreational catch estimates in numbers (millions) and weight (t) of snapper and recreational catch expressed as a percentage of total catch by all sectors

(a)		**Tagging programme estimates**	**Recreational catch (t)**	**% of total catch**
Auckland East (SNA 1)	–	Bay of Plenty, 1984	400	30
		Hauraki Gulf, 1985	830	20
		East Northland, 1985	370	17
		TOTAL	1 600	21
Challenger (SNA 7)	–	Tasman/Golden Bay, 1987	15	8
West coast				
North Island (SNA 8)	–	1991	250	13

(b)	**Telephone and diary survey estimates Number (millions)**	**Recreational catch (t)**	**% of total catch**
SNA 1	3.77	2850–3250	37–40
SNA 2	0.03	40	11
SNA 7	0.08	70	30
SNA 8	0.36	300–420	16–21

Mean weight was based on boatramp survey for SNA 1, SNA 7 and SNA 8, and from diary estimated weights for SNA 2.

In 1997 the Minister made an allowance of 2600 t for all non-commercial users within the SNA 1 TAC.

(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. Sensitivity to this assumption in the assessments was tested using a higher value (40%) prior to 1986.

(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 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 $M = 0.06 \text{ yr}^{-1}$ 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 assessment for SNA 1 and 8. Further analyses will be completed to determine the best estimate for snapper.

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 2 & 7	0.06			Sullivan (unpubl. data)
SNA 1 & 8	0.075			Hilborn and Starr (unpubl. analysis)
2. Weight = a (length)^b (Weight in g, length in cm forklength)				
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 and Sullivan (1994)
SNA 2	0.061	-5.42	68.85	NIWA (unpubl. analysis)
SNA 7	0.122	-0.71	69.6	MAF (unpublished data)
SNA 8	0.160	-0.11	66.7	Gilbert and Sullivan (1994)
4. Age at recruitment (years)				
SNA 1*	4 (39%) 5 (100%)			Gilbert et al. (in prep.)
SNA 7	3			MAF (unpublished data)
SNA 8	3			Gilbert and 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 assessments of snapper stocks have not been updated in 2001, but results from earlier years are presented for each stock.

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 boatramp 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*=10735), 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 *Amax* 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, *Amax*, 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	Estimated no. of 1 yr olds

	(°C)	(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	3.11 #

* The 1+ snapper are about 23 months old at the time of the trawl surveys
‡ First five values corrected for low catchability
# Preliminary result from November 2000 survey

(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 c.v.s 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 decreases 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 substock 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 substock these were longline, single trawl, Danish seine, other commercial, and recreational. For the East Northland substock, 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_tR), 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 c.v.s 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 c.v. corresponding to the estimated proportion at age. It will therefore underestimate the c.v. 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 *c.v.*, $\sigma_{C@A} = c\sqrt{n}$ was assumed, where c is the sampling c.v. 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 *c.v.*, $\sigma_{C@A}$ 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.
- 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 $P(B_{20} > B_{1999})$

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

2. Probability of stock rebuild $P(B_{20} > B_{MSY})$

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 $E(B_{20} / B_{MSY})$

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.

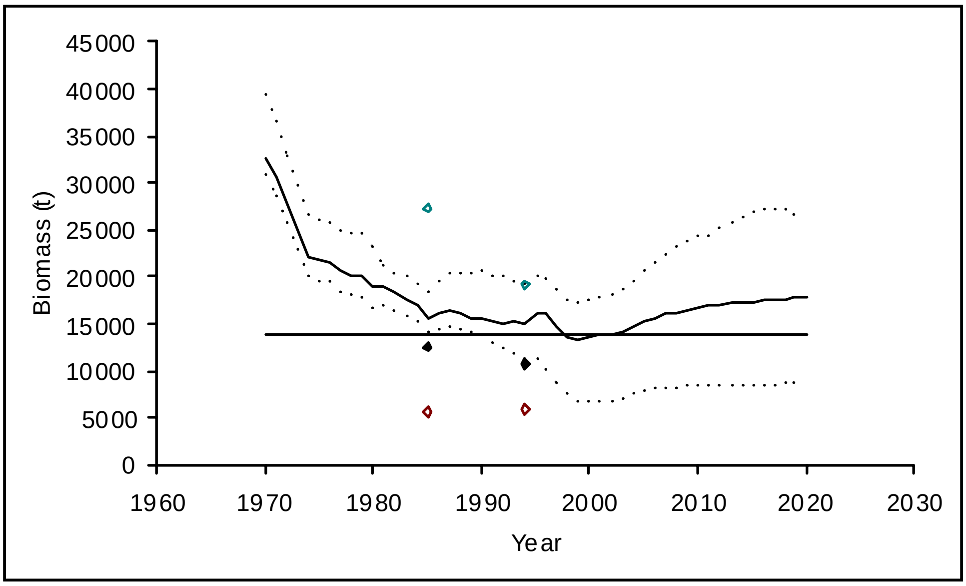


Figure 1: East Northland maximum likelihood stock biomass trajectory for base case (thick line) with 90% confidence intervals for each year's biomass estimated by parametric bootstrap (dashed lines), and the estimated base case B_{MSY} level (thin line). The biomass estimates from the two tagging programmes 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	2 057	0.49	1.29
Low weight *CPUE* ($\sigma = 3$)	65 300	13 500	11 500	0.85	0.115	2 015	0.49	1.16
Low weight *C@A* ($\sigma = 20$)	65 300	14 200	11 800	0.83	0.117	2 059	0.49	1.15
$M = 0.06\ y^{-1}$	75 900	15 700	11 800	0.75	0.100	1 966	0.44	0.97
$M = 0.09\ y^{-1}$	59 800	13 200	19 100	1.14	0.130	2 149	0.53	1.54
No trap avoidance bias	69 400	14 200	16 300	1.15	0.115	2 128	0.49	1.52
No constraint on Z pre 70	61 400	12 700	11 600	0.91	0.091	1 893	0.64	1.11
Free *C@A* and CPUE σ	72 100	14 800	19 700	1.33	0.115	2 208	0.49	1.74
Fix Selectivities LL	70 000	13 700	15 700	1.14	0.115	2 096	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).

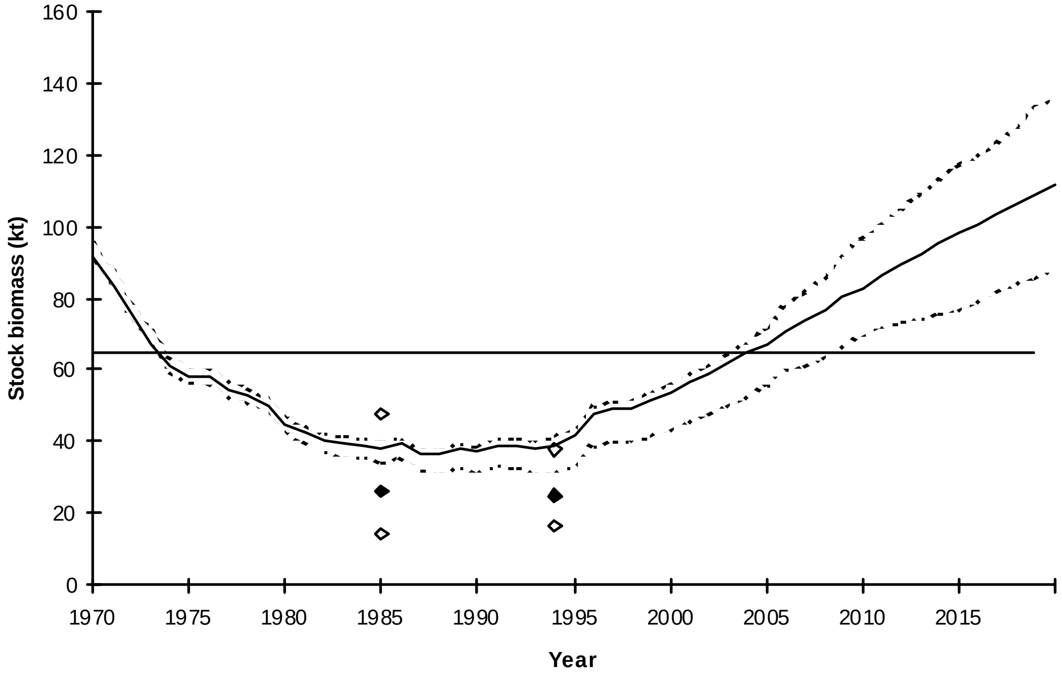


Figure 2: Hauraki Gulf/Bay of Plenty maximum likelihood stock biomass trajectory for base case (thick line) with 90% confidence intervals for each year's biomass estimated by parametric bootstrap (dashed lines), and the estimated base case B_{MSY} level (thin line). The biomass estimates from the two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

Table 13: 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	7 993	0.33	1.73
$M = 0.06\ y^{-1}$	329 700	76 200	40 800	0.54	8 014	0.28	1.33
$M = 0.09\ y^{-1}$	246 200	57 500	56 400	0.98	8 127	0.36	1.95
Low weight *C@A* ($\sigma = 20$)	280 600	66 700	35 800	0.54	8 197	0.29	1.48
Low weight *CPUE* ($\sigma = 3$)	280 000	64 000	50 700	0.79	7 971	0.32	1.72
CPUE & tag indices omitted	281 000	65 000	53 700	0.83	8 055	0.33	1.76
No trap avoidance bias	280 000	64 300	50 300	0.78	7 971	0.32	1.70
Fixed 1985 & 1994 selectivities	291 200	63 200	61 400	0.97	7 676	0.32	1.82
YCS based on SST	274 600	63 800	42 500	0.67	7 887	0.32	1.57
$Z_1 \geq M, Z_2 \geq M$	260 400	70 000	41 100	0.67	7 526	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 = 2 000 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 = 7 911 t

Estimation of Current Annual Yield (CAY)

The CAY was calculated by multiplying the start of year biomass in 1999–00 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 1999–00 was 13 494 t

$CAY_{99–00}$ = 2 008 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 1999–00 was 54 063 t.

$CAY_{99–00}$ = 6 704 t

Maximum Sustainable Yield (MSY)

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

East Northland

MSY = 2 057 t

The range in Table 11 is 1 893 to 2 208 t.

Hauraki Gulf/Bay of Plenty

MSY = 7 993 t

The range in Table 13 is 7 526 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

4.3 SNA 2

4.3.1 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, local air temperature has been used to estimate a relationship with year class strength (YCS) as an alternative to the base case model where YCS's are estimated 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).

Catches from 1932–1992 were assumed. A step function was used to model catches for the years where observations were not available. It was assumed that catches increased from 0 by 5 t every 10 years

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.

4.3.2 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/Golden Bay (SNA 7) assessment and is based on Harley & Gilbert (2000). The data used for model fitting for SNA 2 does not include any abundance estimate. Fitting was to the small number of recent proportions at age datasets. This limited the number of free parameters for which we could obtain good estimates.

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). The air temperature data was available to estimate recruitment over this period.

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 represent mean recruitment, which determines virgin biomass,
- 1970–1997 YCS estimated individually, remainder as a function of air temperature
- Age at full commercial selectivity estimated (5.0 y) and left hand limb estimated (3.6 y), right hand limb fixed = 500 y.
- where p is the proportion at age and n is the sample size,
- non-commercial catch was projected forward at the 1996 value (40 t),
- in the deterministic projections commercial catch was projected forward at the 1997–98 catch including assumed under-reporting (260 t),
- Bayesian posteriors were obtained where recruitment was randomly resampled from the estimated YCS's and total catches of 300, 500 or 700 t,

Model Projections

To assess management strategies, the model was projected into the future and the performance of alternative constant catch levels was assessed. The model was projected forward deterministically to 2011 using the MLE parameter values and assumed constant annual catches. Recruitment was randomly resampled 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 used in the SNA 7 assessment. 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.

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 with a 80/30 split between the two methods. Total catches projected were 300, 500 and 700 t. The following performance indicators were derived:

$P(B_{2001} > B_{MSY})$ and $P(B_{2011} > B_{MSY})$

4.3.3 Results

For all runs, the current biomass was near or somewhat below B_{MSY} and is predicted to increase to well above this by 2011 at the current catch level, except for runs where the natural mortality was low (Table 15). We discount the possibility of very low (age independent) natural mortality for snapper. Run 1 (base case) and Run 6 (YCS as a function of temperature) predict increases in biomass to remain above B_{MSY} at the end of a ten year projection period (Table 16 and Figure 3).

As with the Tasman/Golden Bay (SNA 7) assessment, the MCMC simulation appeared not to converge for runs where YCS's were independently estimated. This is probably due to high correlations in estimated parameters (Figure 4). For Run 6, which involves the restrictive assumption that recruitment is a function of temperature, the MCMC is likely to have converged (Figure 4). Run 6 predicted biomass estimates are optimistic, and the MLE's biomass variables fall near the centre of their corresponding marginal distributions.

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 6. It is attained at an exploitation rate of about 10.5% of start of year, recruited biomass at B_{MSY} (4 487 t for Run 1, and 4 354 t for Run 6).

MSY = 478 t for Run 1, and 454 t for Run 6

This estimate includes non-commercial catch and 10% under-reporting of commercial catches.

Table 15: Model specifications, MLE's and 5 and 95 percentiles of the marginal Bayesian posterior for SNA 2 under various model assumptions. 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 2001; B_{2011} is the biomass at the start of 2011.

Run	Description	B_0 (kt)	B_{MSY} (kt)	B_{2001} (kt)	B_{2011} (kt)	*MSY* (t)	$B_{2001}/B_{\mathrm{MSY}}$
1	Base case*; MLE	19.1	4.5	4.0	6.8	478	0.89
	Base case; Posterior	19.9, 25.8	4.7, 6.1	4.3, 10.5	7.2,15.1	495, 641	0.89, 1.75
2	Commercial proportions at age weight = 1.0	19.0	4.5	4.3	7.4	479	0.98
3	Commercial proportions at age weight = 20.0	19.4	4.6	4.1	6.8	482	0.90
4	Recruitment weighting = 2.0	19.0	4.5	4.3	7.3	480	0.96
5	YCS estimated	17.8	4.2	3.1	5.2	450	0.73
6	All YCS function of temperature	18.4	4.4	3.7	5.9	453	0.90
	YCS function of temperature; Posterior	18.2, 19.0	4.3, 4.5	3.1, 4.7	5.1, 7.3	446, 465	0.73, 1.11
7	YCS 1963–1997	18.4	4.3	3.8	6.0	462	0.87
8	*M* fixed at 0.06 y^{-1}	20.6	5.0	2.3	4.9	432	0.46
9	*M* fixed at 0.09 y^{-1}	17.9	4.1	5.9	9.2	527	1.45
10	Estimated *M* (0.037 y^{-1}), YCS function of temperature	23.2	5.6	0.7	0.1	333	0.12
11	50% selectivity at age 25 y	20.5	4.2	4.4	7.6	498	1.04
12	Estimated selectivity	20.3	4.2	4.2	7.4	495	1.00

Table 16: Bayesian posterior probabilities for SNA 2 Run 1 (base case) and Run 7 (YCS estimated by air temperature) with resampled recruitment and various annual TAC's (assumed to be caught exactly), with 30% taken by non–commercial.

Run	TAC	P(B_{2001}<B_{MSY})	90% CI for $B_{2001}/B_{\mathrm{MSY}}$	P(B_{2011}<B_{MSY})	90% CI for $B_{2011}/B_{\mathrm{MSY}}$
1	300	0.14	0.89, 1.86	0.00	1.43, 2.65
	500	0.14	0.87, 1.79	0.03	1.06, 2.29
	700	0.15	0.88, 1.79	0.26	0.67, 2.01
	TAC	P(B_{2001}<B_{MSY})	90% CI for $B_{2001}/B_{\mathrm{MSY}}$	P(B_{2011}<B_{MSY})	90% CI for $B_{2011}/B_{\mathrm{MSY}}$
6	300	0.78	0.74, 1.11	0	1.19, 1.65
	500	0.77	0.74, 1.16	0.52	0.76, 1.27
	700	0.77	0.74, 1.12	0.99	0.31, 0.87

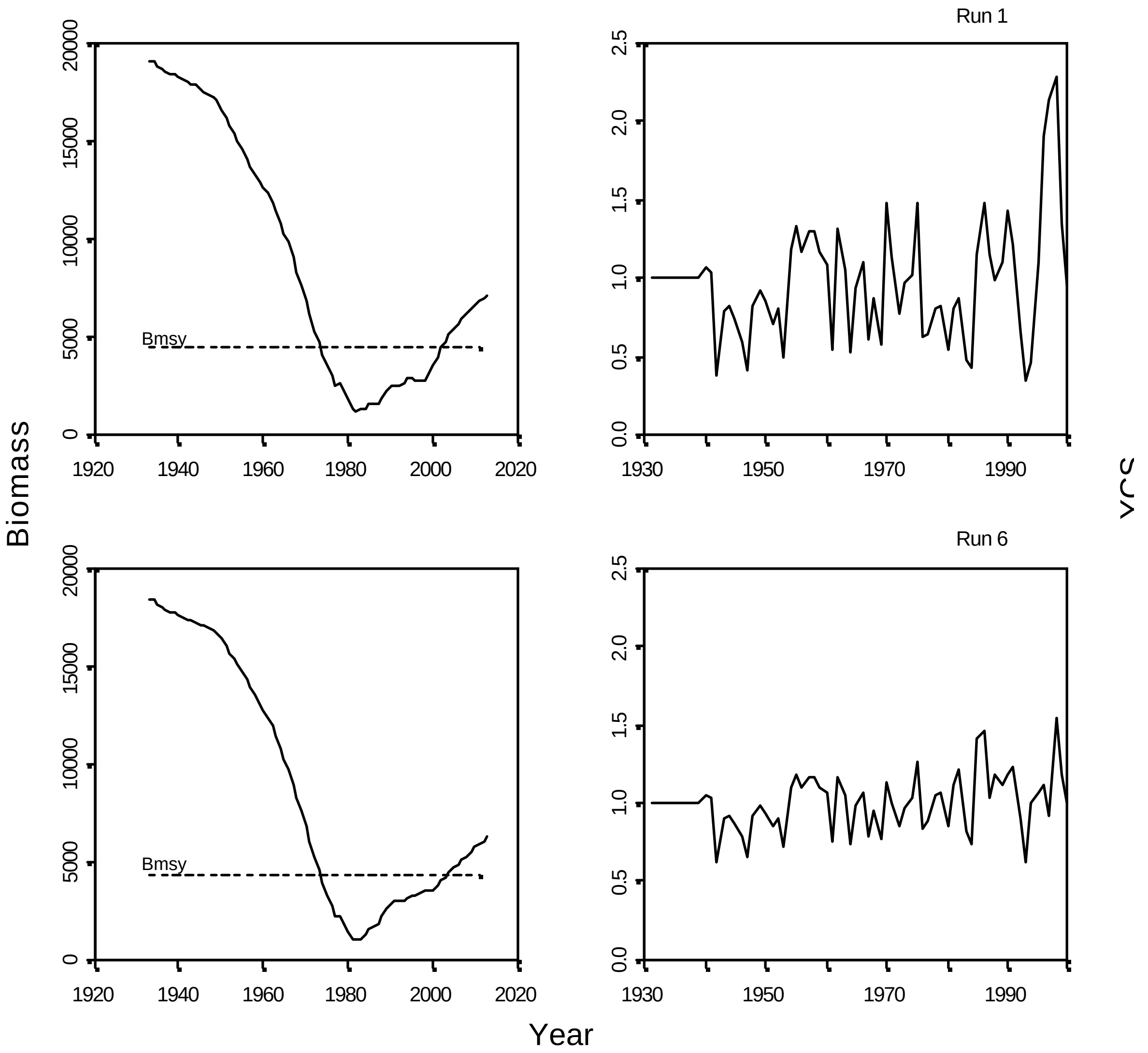


Figure 3: MLE biomass trajectories and YCS estimates for Runs 1 & 6, SNA 2 from 1933 to the 2000–01 fishing year, with projections to 2010–11 assuming constant recruitment and an annual catch of 300 t (80% commercial). B_{MSY} is shown.

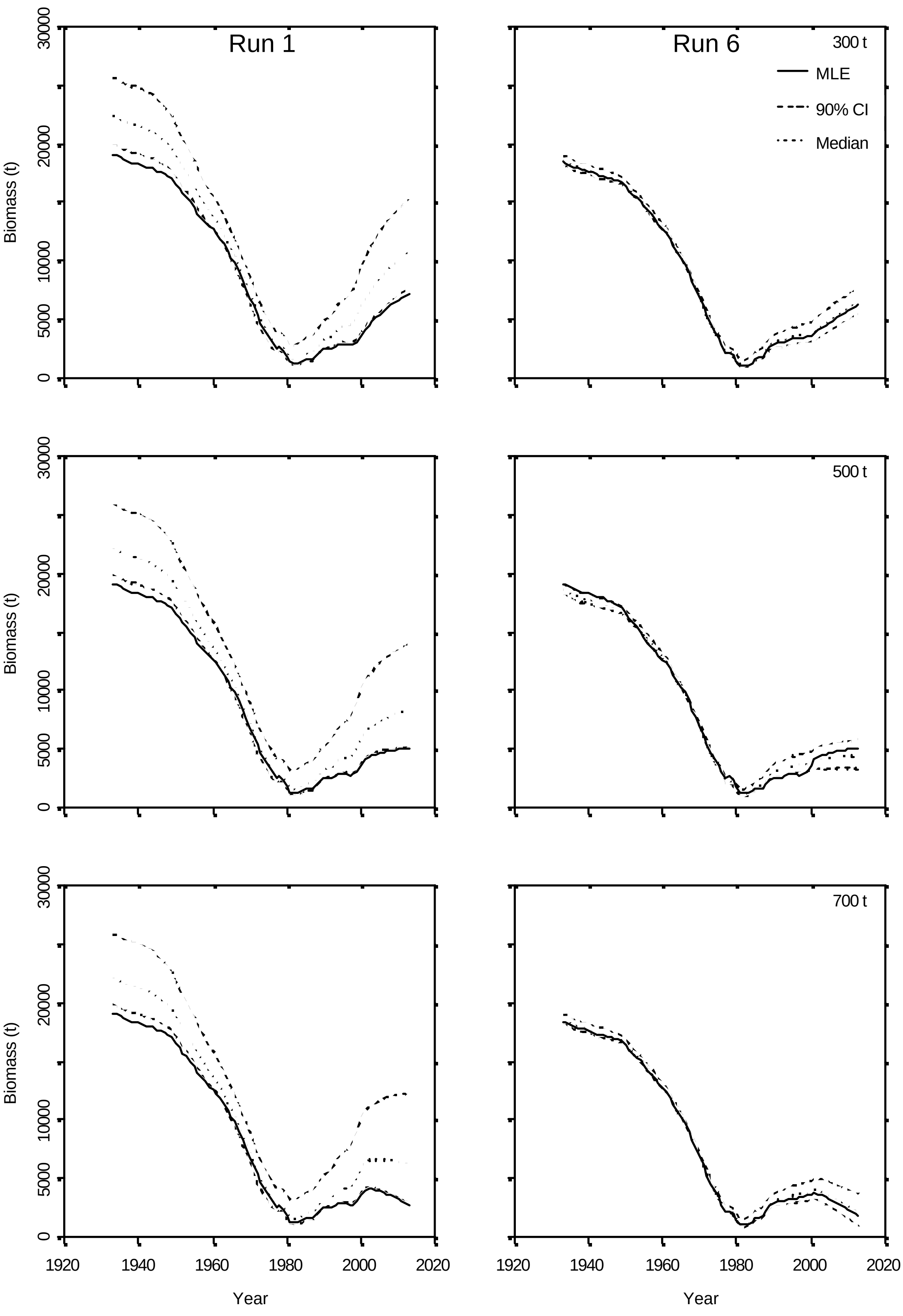


Figure 4: Projected biomass with 90% posterior distribution confidence intervals for SNA 2, Run 1 (base case) and Run 6 (YCS function of air temperature) under three levels of total annual catch (assuming 80% commercial).

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 (TGGB) region comparable to the Leigh SST series for the Hauraki Gulf. Instead, local air temperature has been used to estimate a relationship with year class strength (YCS) as an alternative to the base case model where YCS's are estimated 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 the TBGB region 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 and 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 and Golden Bays snapper fishery. 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. This model was similar to that used in other snapper stock assessments. It was based on that of Harley & Gilbert (2000), 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 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. The consequence was that their virgin biomasses tended to be lower and their projections 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
- Age at full commercial selectivity estimated (4.0 y) and left hand limb estimated (2.85 y), right hand limb fixed = 500 y.
- Research selectivity was flat (=1 for all ages).,
- where p is the proportion at age and n is the sample size,
- non-commercial catch was projected forward at the 1996 value (84 t),
- in the deterministic projections commercial catch was projected forward at the 1997–98 catch including assumed under-reporting (185 t),
- Bayesian posteriors were obtained where recruitment was randomly resampled from the estimated YCS's and total catches of 270, 500 or 700 t,
- the standard deviation parameter in the tagging biomass likelihood was fixed.

Model Projections

To assess management strategies, the model was projected into the future and the performance of alternative constant catch levels was assessed. The model was projected forward deterministically to 2011 using the MLEs. Recruitment was randomly resampled 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 with a 70/30 split between the two methods. Total catches projected were 270, 500 and 700 t. The following performance indicators were derived:

$P(B_{2001} > B_{MSY})$ and $P(B_{2011} > B_{MSY})$

4.3.3 Results

A Tasman Bay/Golden Bay stock assessment is presented that reaches similar, but somewhat more optimistic, conclusions to 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). Run 1 (base case) and Run 7 (YCS as a function of temperature) are expected to increase and remain above B_{MSY} at the end of a ten year projection period (Table 18 and Figure 1).

Harley & Gilbert (2000) were not able to obtain an MCMC simulation that converged for runs where YCS's were independently estimated (Figure 5). We are uncertain whether we solved this problem and our resulting Bayesian posterior distributions may not be valid. Our conclusions are therefore largely based on MLE's rather than posterior distributions. The base case posterior distribution that suggested that there might have been a large volume of parameter space that had high likelihood and that gave higher current biomasses than the MLE, whereas the volume of parameter space that had high likelihood and where current biomasses were near that of the MLE was much lower. This conclusion remains tentative. For Run 7, which involves the restrictive assumption that recruitment is a function of temperature, the MCMC is likely to have converged (Figure 6). Here the estimates are less optimistic (but still very optimistic), but the MLE's for biomass variables fall near the centre of their corresponding marginal distributions.

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} (9 102 t for Run 1, and 7 422 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: Tasman Bay/Golden Bay estimates (t) under various model assumptions and 5 and 95 percentiles of the marginal Bayesian posterior for Runs 1 and 7: B_0 is virgin biomass, B_{MSY} is biomass that supports MSY, B_{2001} and B_{2011} are biomasses in 2000–01 and 2010–11, MSY is maximum sustainable yield and includes overruns. Biomasses are at start of year.

Run	Description	B_0 (kt)	B_{MSY} (kt)	B_{2001} (kt)	B_{2011} (kt)	MSY (t)	$B_{2001}/B_{\mathrm{MSY}}$
1	Base case*; MLE	34.9	9.1	22.8	25.7	855	2.50
	Base case; Posterior	36.4, 46.2	9.4, 16.0	24.6, 37.3	27.3, 39.9	890, 1095	2.3, 2.7
2	50% selectivity at age 25 and 3	39.6	9.6	25.4	28.1	928	2.63
3	Estimated M (0.055 y^{-1})	33.4	8.5	12.2	15.7	656	1.43
4	Mean recruitment 1931–1997	34.9	9.1	22.8	25.7	855	2.50
5	YCS 1980–1997	28.9	7.6	15.9	18.6	704	2.10
6	YCS 1970–1997	39.1	10.2	20.7	23.2	958	2.03
7	All YCS function of temperature	28.4	7.4	15.9	18.3	694	2.14
	All YCS function of temperature; Posterior	27.9, 29.3	7.2,7.6	15.1, 16.9	16.6, 20.2	679, 712	2.07,2.21
8	All YCS estimated	28.4	7.0	16.4	19.1	695	2.20
9	M fixed at 0.06 y^{-1}	33.6	8.6	14.7	18.3	702	1.71
10	M fixed at 0.09 y^{-1}	37.1	12.5	31.1	32.0	1015	2.48
11	Commercial proportions at age weighting=4.0	33.3	8.7	18.9	21.9	816	2.17
12	Commercial proportions at age weighting=0.25	36.2	9.4	25.5	28.5	886	2.71
13	Tagging biomass c.v. = 0.2	30.4	7.9	16.4	19.6	745	2.07
14	Tagging biomass c.v. = 1.0	37.2	9.7	25.8	28.6	909	2.66

Table 18: Bayesian posterior probabilities and 90% confidence intervals for base case (Run 1) and YCS estimated by temperature (Run 7) assuming constant recruitment and various annual TAC's (assumed to be caught exactly), with 30% taken by non-commercial

Run	TAC	$P(B_{2001}<B_{\mathrm{MSY}})$	90% CI for $B_{2001}/B_{\mathrm{MSY}}$	$P(B_{2011}<B_{\mathrm{MSY}})$	90% CI for $B_{2011}/B_{\mathrm{MSY}}$
1	270	0	2.32, 2.72	0	2.48, 3.01
	500	0	2.32, 2.73	0	2.21, 3.15
	700	0	2.32, 2.74	0	2.12, 3.02
7	270	0	2.08, 2.21	0	2.45, 2.67
	500	0	2.08, 2.21	0	2.06, 2.46
	700	0	2.08, 2.21	0	1.85, 2.29

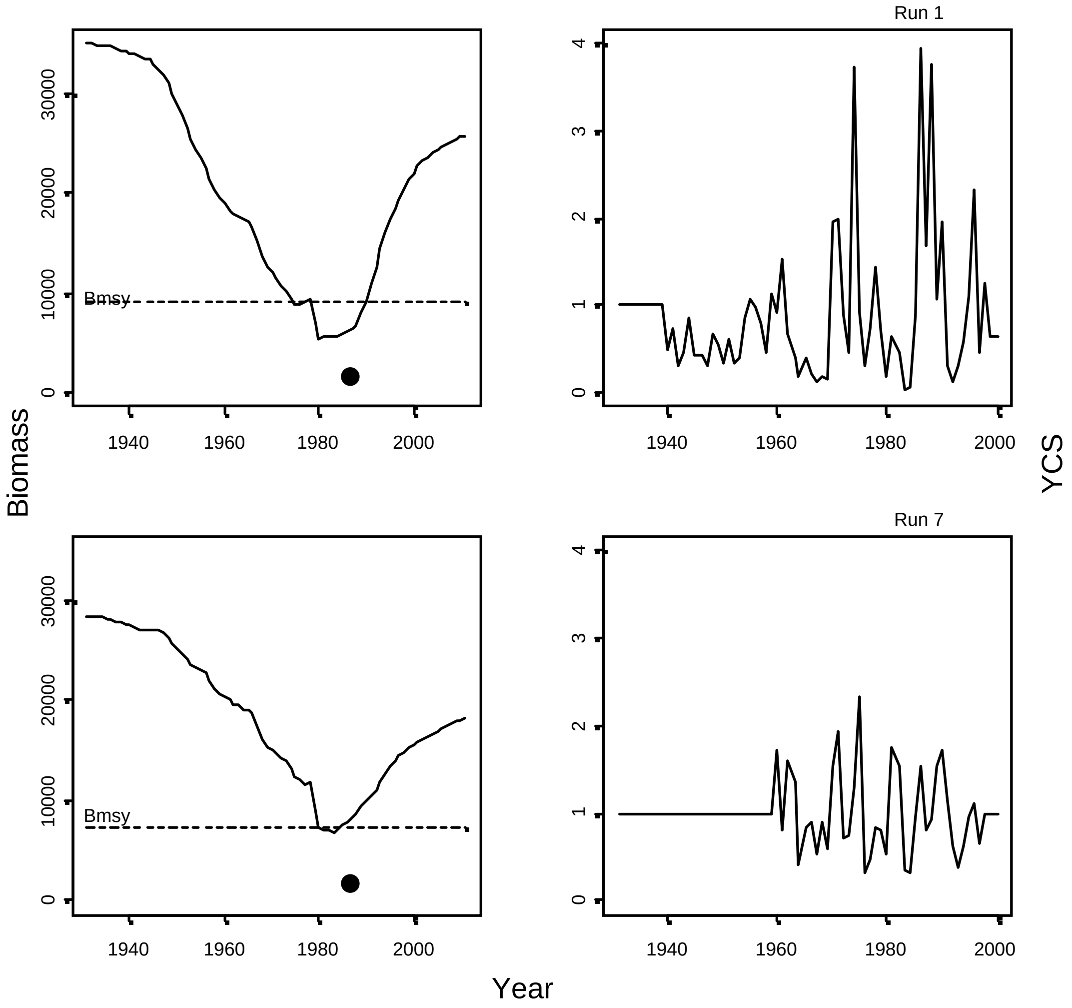


Figure 5: **Tasman Bay/Golden Bay maximum likelihood stock biomass trajectory (thick line) for base case (Run 1) and YCS estimated by temperature (Run 7), estimated B_{MSY} level (thin line) and tagging programme biomass estimate (●)**

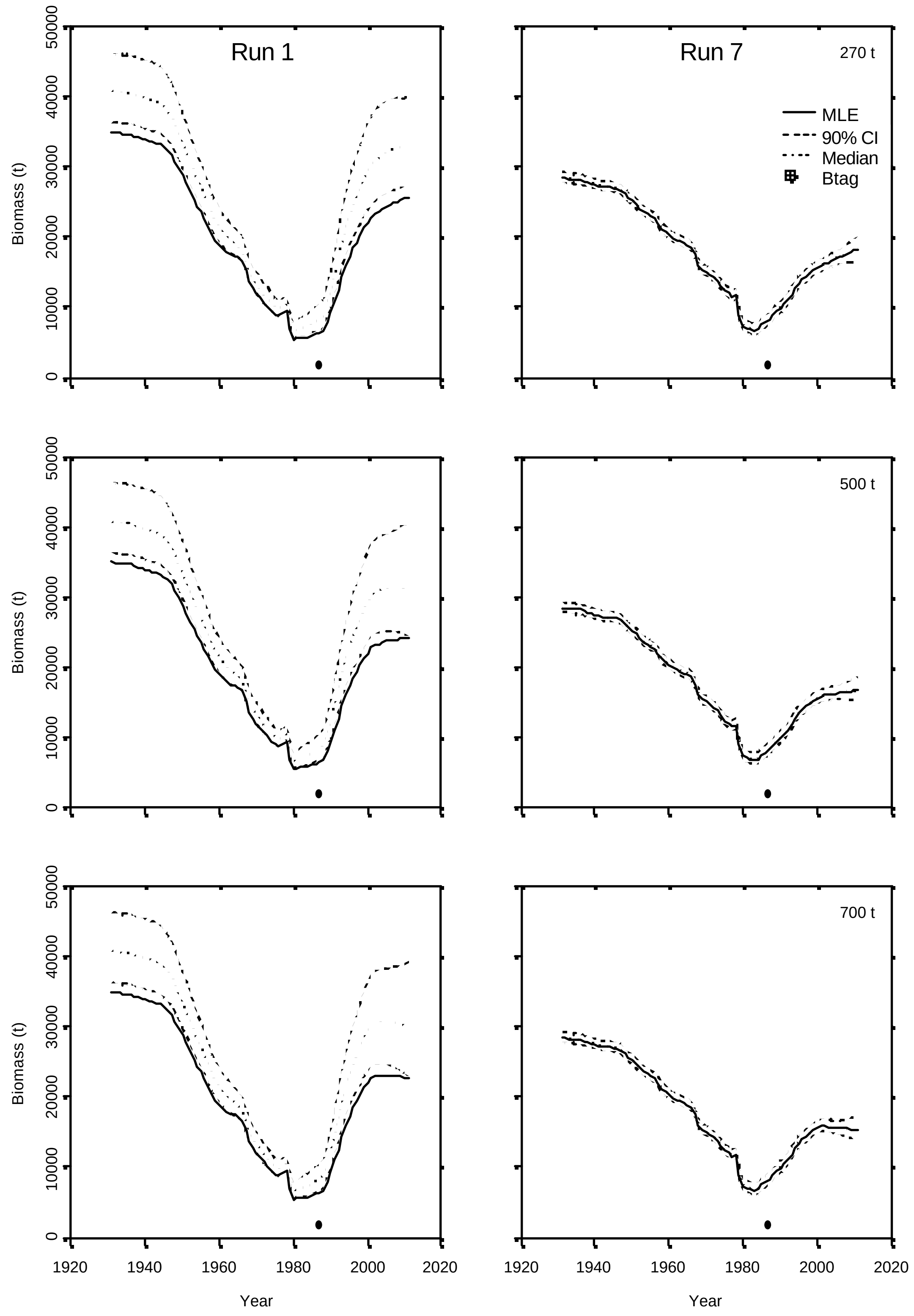


Figure 6: Biomass trajectories with 90 percentiles of the posterior distribution for TBGB, Run 1 (base case) and Run 7 (YCS function of air temperature) under three levels of total annual catch (assuming 70% commercial).

4.4 SNA 8 (Auckland West/Central West)

A revised assessment of SNA 8 was completed in 2000 using:

- an additional year's information on catch and catch at age (single trawl 1998–99);
- a new CPUE time series from 1990–99 for the single trawl fishery;
- separate catchability coefficients for the 2+ and 3+ trawl survey recruitment indices;

Provision was made for under-reporting of the commercial catch (20% before 1987 and 10% since the QMS was introduced) and additional Japanese catch (longline) from 1960 to 1974 was assumed at the level of 2000 t per year.

The projections of biomass to 1999–00 have been modelled assuming commercial catch at the TACC level of 1500 t (plus 10% overrun). Assumptions have been made for the impact of changes to the daily bag limit and the increase in minimum legal size in the recreational fishery.

Recreational catch

Recreational catch estimates are not available prior to 1990. The catch history assumed by Gilbert & Sullivan (1994) has been used for years up to 1989. For more recent years the results of telephone and diary surveys are available. The estimate of recreational catch from the 1996 national diary survey in the SNA 8 stock was 236 t (Table 4). Earlier estimates were available from the tagging program carried out in 1990 and from the North region telephone and diary survey in 1994 (Table 5). The recreational catch since 1990 was modelled such that the average of the observed catches in 1990, 1994 and 1996 (290 t) was taken from the stock each year for which no estimate was available (1991 to 1993 and 1995, 1997). For years after 1997 the catch was assumed to be at a constant exploitation rate equal to the recreational fishing mortality estimated for 1996. The vulnerability of 3 year olds to the recreational method was adjusted to account for the introduction of the increased minimum legal size to 27 cm for the recreational sector in 1994. This adjustment had 50% of the 3 year olds vulnerable to recreational fishing mortality being landed, while the remaining 50% were released with 80% survival. Similarly the total recreational fishing mortality was reduced in 1995 to account for the reduction in the total bag limit from 20 to 15 from 1 October 1994. The selection pattern used for recreational catch was based on the 1985 tagging programme results from SNA 1.

Selectivity-at-Age

Estimates of selectivity-at-age for the single trawl and pair trawl methods were calculated from the results of the 1990 tagging programme. The patterns obtained suggested implausibly high selectivity of the single trawl method for fish less than 8 years of age, and selectivities of fish older than 8 years were poorly estimated for both single and pair trawl methods. Selectivity-at-age estimates were assumed that reflected the general pattern indicated from the tagging programme results (Table 17). The estimates of selectivity-at-age for the recreational method derived from the 1985 east Northland/Hauraki Gulf tagging programme were employed.

Table 17: Assumed SNA 8 selectivity-at-age estimates for the longline, single and pair trawl methods

Age	**Single Trawl**	**Pair Trawl**	**Longline**
3	1.25	0.60	1.00
4	1.25	0.73	1.00
5	1.25	0.87	1.00
6 to 20	1.00	1.00	1.00

(a) Estimates of fishery parameters and abundance

Model Assumptions:

- natural mortality assumed to be 0.075 yr^{-1} (sensitivity tests of 0.06 and 0.09)
- the unexploited population in 1931 calculated using constant annual recruitment was assumed to represent virgin stock biomass
- level of under-reporting for domestic commercial catch was 20% pre-1987 and 10% after 1987

- recreational catch up to 1989 used the recreational catch history given in Gilbert & Sullivan (1994) and from 1990 to 1997 used the mean of the estimates from 1990, 1994 and 1996
- Japanese catch from longline in the period 1965–74 was assumed to be 2000 t per year
- a selectivity pattern was assumed for each gear type modified from the initial estimates from the 1990 tagging programme
- catch at age data had a weighting of sigma = 10, the tag estimate was assigned a CV of 0.1 and the trawl survey data a CV of 0.3. Both trawl CPUE series were assigned CVs of 1.0
- 1971–94 represents the period of mean recruitment, i.e., average YCS=1.0
- YCS for the 1995–99 was derived from a SST-recruitment relationship.
- year class strength (YCS) estimates for the 1971–94 year classes (24 parameters)

Year class strength (YCS)

The age structured model was constructed to estimate constant annual recruitment (number of 1 year old fish entering the fishable stock) from 1928 to 1970. Year class strength for 1971 to 1994 were estimated from catch at age data and trawl survey indices (Table 20). The annual recruitments were estimated as indices relative to the constant recruitment estimate and the average for 1971–94 was defined to represent the mean recruitment. These parameters were determined by a maximum likelihood fit to two series of observed trawl CPUE data, trawl catch at age data, trawl survey recruitment indices (1984–94 excluding 1990) and a tagging estimate of absolute biomass in 1990. In fitting to the trawl survey recruitment indices (Table 18), separate catchability coefficients were estimated for the 2+ and 3+ indices so as to account for age-specific differences in the vulnerability of snapper to research trawl gear. The unexploited population in 1931 was estimated from the constant annual recruitment parameter from which equilibrium virgin biomass was calculated.

Satellite sea surface temperature (SST) data was available for the west coast North Island from 1982–99. A log-linear regression between estimated YCS for the years 1982–94 and SST was derived within the model. Using this relationship YCS for the years 1995 to 1999 was predicted.

Table 18: SNA 8 trawl survey estimates of relative year class strength with the ages at which individual year classes were sampled

Year Class	Index	*c.v.*	Age Surveyed
1984	0.82	0.27	3+
1985	2.73	0.28	2+
1986	0.78	0.10	3+
1987	0.67	0.20	2+
1988	0.18	0.37	3+
1989	0.96	0.32	2+
1990	–	–	–
1991	1.27	0.15	3+
1992	0.79	0.26	2+
1993	0.93	0.31	3+
1994	0.89	0.20	2+

CPUE analyses

A time series of annual pair trawl CPUE indices (catch per day) for the period 1974 to 1991 for SNA 8 was obtained by Vignaux (1993). An analysis of pair and single CPUE data covering the period 1989–90 through 1998–99 was undertaken in 1999. For the recent analysis, data were summarised according to a wide range of variables including year, vessel-pair, target species, trip, date, fishing statistical area, trawl duration and power. The effort term adopted was catch per trawl tow. Pair trawl data was analysed as two series: a complete fishery series, i.e., including all data; and a subset series using the Sanford fleet data only. All the Sanford data except for the most recent two years were manually checked for errors. Computer methods were used to screen all other data.

The trends evident in the single trawl and pair trawl indices differed. The two pair trawl indices differed with respect to the degree of decline, whereas the single trawl indices indicated a slight decline followed by a moderate increase in the most recent three years. The population model fit to the pair trawl series was poor but fitted reasonably well to the single trawl index. The snapper stock assessment Working Group rejected both the all-data and Sanford pair trawl indices on the basis that they likely contained duplication errors. The Working Group accepted the single trawl index for input to the model (Table 19).

Table 19: CPUE abundance indices and standard errors from SNA 8 single trawl fishery

Year	CPUE	S.E.
1990	1.13	0.03
1991	1.16	0.03
1992	1.04	0.03
1993	0.86	0.02
1994	0.79	0.02
1995	0.82	0.02
1996	0.89	0.02
1997	1.14	0.02
1998	1.08	0.02
1999	1.22	0.02

1990 Tagging Program Biomass

The recalculated estimate of absolute biomass of SNA 8 from the 1990 tagging programme was input to the model. After correcting for sources of bias, the revised estimate 9 505 t; a CV of 0.1 was assumed.

(b) Results

The stock assessment model indicates that the current recruited biomass is less than the B_{MSY} reference point and is expected to increase slowly over the next ten years (Table 21). It is not expected to exceed the B_{MSY} reference point at the end of a 20-year projection period. However, the assessment diagnostics indicate that this conclusion is likely to be highly dependent on the initial model assumptions, including the relative weighting of the various input data sources used to fit the model. The model appeared to be highly robust to the assumptions made and this was due partly to the constraint exerted by the assumed relative weight assigned to the various input data. The working group concluded that further work was required to investigate the high degree of certainty that appears to be a characteristic of this model. Therefore, the results of the sensitivity tests of this model to various assumptions and estimates of uncertainty are not reported because further investigations are to be carried out on the effects of different relative weighting of the input data. The working group noted that a substantial tagging programme is planned for this stock in 2002–03 which should help resolve some of the uncertainties which exist in this assessment.

Table 20: Estimates of year class strength for SNA 8 used in the basecase assessment

Year	Year class strength
1971	1.19
1972	0.77
1973	0.86
1974	1.72
1975	1.78
1976	0.29
1977	0.38
1978	1.43
1979	0.98
1980	0.55
1981	0.81
1982	1.25
1983	0.41
1984	1.36
1985	2.19
1986	1.32
1987	0.74
1988	0.24
1989	0.50
1990	0.17
1991	0.83
1992	0.87
1993	1.36
1994	2.02

Table 21: Biomass and yield estimates for SNA 8. B_0 is virgin stock biomass. B_{99}, B_{00} and B_{MSY} are start of year biomasses for 1998–99, 1999–00 and biomass producing maximum sustainable yield (MSY), respectively. B_{99}/B_{MSY} is the ratio of current (1998–99) biomass to B_{MSY}. CSP_{00} is the predicted current surplus production in 1999–00 under the annual recruitment estimated within the model

	B_0 t	B_{99} t	B_{00} t	B_{MSY} t	B_{99}/B_{MSY}	MSY t	CSP_{00} t
Model	108 000	9241	9359	27 800	0.33	2 700	2000

(c) Estimation of Maximum Constant Yield (MCY)

MCY was estimated from the equation MCY = CSP, as the stock is below B_{MSY}. CSP is the equilibrium current surplus production from the model described above.

MCY = 2231 t

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.

(d) Estimation of Current Annual Yield (CAY)

CAY was calculated from the Baranov catch equation under the base case. F_{ref} was set equal to F_{MSY}. At B_{MSY} the catch to start-year biomass ratio F_{MSY} is 9.8%.

$CAY_{99–00}$ = 917 t

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.

(e) Other yield estimates and stock assessment results

Maximum Sustainable Yield (MSY)

MSY was calculated as the maximum catch that could be sustained by the stock in equilibrium. This is achieved with a catch to biomass ratio of 9.8% at B_{MSY}.

MSY = 2727 t

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.

5. STATUS OF THE STOCKS

SNA 1

The current 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

For all runs, the current biomass was near or somewhat below B_{MSY} and would increase to well above this by 2011 at the current catch level, except for runs where the natural mortality was low. We discount the possibility of very low (age independent) natural mortality for snapper. The model used a full catch history and was fitted to four years of proportions at age estimates. The model estimates must be treated with some caution. We conclude that a catch somewhat higher than the current catch (e.g. 400 t) would likely be sustainable and result in an increase in the stock size towards B_{MSY}.

SNA 7

From the modelling results it is very likely that the stock had been growing in size, is well above B_{MSY} (i.e. above 24% B_0), and would continue to increase even if future catches were substantially larger than those currently being taken

SNA 8

Model results indicate that the SNA 8 stock is most likely below the B_{MSY} reference point. However, the working group also concluded that the model cannot provide reliable estimates of stock status relative to B_{MSY} and that the model estimates of uncertainty are not realistic. The working group also notes that a substantial tagging programme is planned for this stock in 2000–01 which should help resolve some of the uncertainties which exist in this assessment.

Summary of yield estimates (t), TACCs (t) and reported landings (t) for the most recent fishing year

Fishstocks	QMA	MCY	CAY$_{99-00}$	MSY	1999–00 TACC	1999–00 Commercial landings
SNA 1	1	9911	8712	10050	4500	4500
SNA 2	2	370	–	–	252	391
SNA 3	3, 4, 5 & 6	–	–	–	32	< 1
SNA 7	7	650	930	650	200	174
SNA 8	8, 9	2231	917	2700	1500	1604
SNA 10	10	–	–	–	10	0
Total					6494	6 669

6. FOR FURTHER INFORMATION

Annala, J. H. & Sullivan, K. J. (Comps.) 1997: Report from the Fishery Assessment Plenary, May 1997: stock assessments and yield estimates. 381 p. (Unpublished report held in NIWA library, Wellington.)

Bradford, E. 1998: Harvest estimates from the 1996 national marine fishing surveys. N.Z. Fisheries Assessment Research Document 98/16. 27 p.

Davies, N.M. 1997: Assessment of the west coast snapper (Pagrus auratus) stock (SNA 8) for the 1996–97 fishing year. N.Z. Fisheries Assessment Research Document 97/12. 47 p.

Davies, N.M., Gilbert, D.J. & Sullivan K.J. (in prep.): Assessment of the SNA 1 stock for the 1996–97 fishing year. Draft N.Z. Fisheries Assessment Research Document.

Davies, N.M., Walsh, C., & Hartill, B. 1993: Estimating catch at age of snapper from west coast and Hauraki Gulf fisheries, 1992–93. Northern Fisheries Region Internal Report No.17. 58 p. (Draft report held by MAF Fisheries North Region, Auckland.)

Francis, M.P. 1993: Does water temperature determine year class strength in New Zealand snapper (Pagrus auratus, Sparidae)? Fisheries Oceanography 2(2): 65–72.

Francis, M.P., Langley, A.D., & Gilbert, D.J. 1995: Snapper recruitment in the Hauraki Gulf. N.Z. Fisheries Assessment Research Document 95/17. 26 p.

Harley, S.J.; Gilbert, D.J. (2000). Assessment of the Tasman and Golden Bays snapper fishery for the 1999–2000 fishing year. *New Zealand Fisheries Assessment Report 2000/28*. 42 p.

Gilbert, D.J.; Taylor, P.R. (2001). The relationships between snapper (Pagrus auratus) year class strength and temperature for SNA 2 and SNA 7. New Zealand Fisheries Assessment Report 2001/64. 33 p.

Gilbert D.J & McKenzie, J.R. 1999: Sources of bias in biomass estimates from tagging programmes in the SNA 1 snapper (*Pagrus auratus*) stock *NZ Fisheries Assessment Research Document 99/16*. 47 p.

Gilbert, D.J. & Sullivan K.J. 1994: Stock assessment of snapper for the 1992–93 fishing year. N.Z. Fisheries Assessment Research Document 94/3. 37 p.

Maunder, M.N. & Starr, P.J. 1995: Validating the Hauraki Gulf snapper pre-recruit trawl surveys and temperature recruitment relationship using catch at age analysis with auxiliary information. Draft N.Z. Fisheries Assessment Research Document.

Paul, L. J. 1976: A study on age, growth and population structure of the snapper, *Chrysophrys auratus* in Hauraki Gulf, *N.Z. Fish. Res. Bull. Ministr. Agric. Fish., N.Z. 13*: 63 p.

Sullivan, K.J. 1985: Snapper. *In* Colman, J.A., McKoy, J.L., and Baird, G.G. (Comps. and Eds.) 1985: Background papers for the 1985 Total Allowable Catch recommendations, pp. 187–214. (Unpublished report, held in MAF Fisheries Greta Point library, Wellington.)

Sullivan, K.J., Hore, A.J., & Wilkinson, V.H. 1988: Snapper. *In* Baird, G.G., and McKoy, J.L. Papers from the workshop to review fish stock assessments for the 1987–88 New Zealand fishing year, pp. 251–275. (Unpublished report, held in MAF Fisheries Greta Point library, Wellington.)

Sylvester, T. 1995: Initial results of the Northern boat ramp survey. Seafood New Zealand, February 1995. pp. 11–13.

Teirney, L.D., Kilner, A.R., Millar, R.B., Bradford, E., & Bell, J.D. 1997: Estimation of recreational harvests from 1991–92 to 1993–94. N.Z. Fisheries Assessment Research Document 97/15. 43 p.

Vignaux, M. 1993: Catch per unit of effort (cpue) analysis of the SNA 8 snapper fishery. N.Z. Fisheries Assessment Research Document 93/2. 12 p.