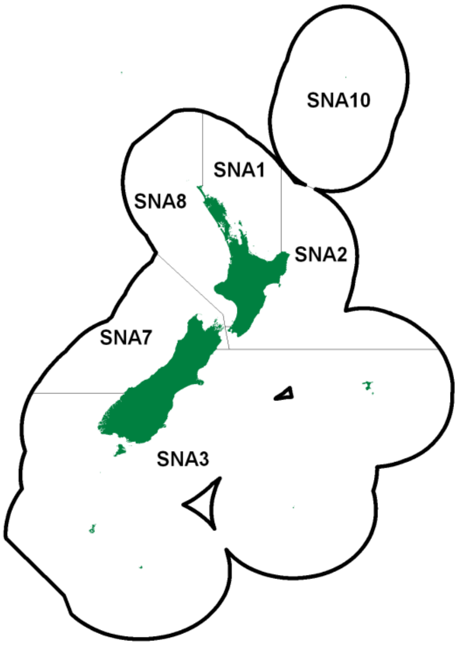
SNAPPER (SNA)

(*Pagrus auratus*)
Tamure, Kouarea



1. FISHERY SUMMARY

1.1 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 to over 6000 t for SNA 1, and from 1330 t to 1594 t for SNA 8 (Table 2).

In 1986-87, landings from the two largest Fishstocks (i.e., SNA 1 and SNA 8) were less than their respective TACCs (Table 2), but catches subsequently increased in 1987-88 to the level of the TACCs (Figure 1). Landings from SNA 7 remained below the TACC after introduction to the QMS, 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).

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

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 2011-12 and gazetted and actual TACCs (t) for 1986-87 to 2011-12. QMS data from 1986-present. [Continued on next page].

Fishstock	SNA 1		SNA 2		SNA 3		SNA 7		SNA 8	
QMAs	1		2		3,4,5,6		7		8,9	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983-84†	6 539	-	145	-	2	-	375	-	1 725	-
1984-85†	6 898	-	163	-	2	-	255	-	1 546	-
1985-86†	5 876	-	177	-	0	-	188	-	1 828	-
1986-87	4 016	4 710	130	130	0	30	257	330	893	1 330
1987-88	5 061	5 098	152	137	1	30	256	363	1 401	1 383
1988-89	5 793	5 614	210	157	1	30	176	372	1 526	1 508
1989-90	5 826	5 981	364	157	< 1	30	294	160	1 550	1 594
1990-91	5 315	6 002	427	157	< 1	31	160	160	1 658	1 594
1991-92	6 191	6 010	373	157	< 1	31	148	160	1 464	1 594
1992-93	5 423	4 904	316	252	2	32	165	160	1 543	1 500
1993-94	4 846	4 928	307	252	< 1	32	147	160	1 542	1 500
1994-95	4 831	4 938	307	252	< 1	32	150	160	1 434	1 500
1995-96	4 941	4 938	279	252	< 1	32	146	160	1 558	1 500
1996-97	5 049	4 938	352	252	< 1	32	162	160	1 613	1 500
1997-98	4 524	4 500	286	252	< 1	32	182	200	1 589	1 500
1998-99	4 411	4 500	283	252	3	32	142	200	1 636	1 500
1999-00	4 500	4 500	391	252	< 1	32	174	200	1 604	1 500
2000-01	4 347	4 500	360	252	< 1	32	156	200	1 630	1 500
2001-02	4 372	4 500	252	252	1	32	141	200	1 577	1 500
2002-03	4 484	4 500	334	315	< 1	32	187	200	1 558	1 500
2003-04	4 466	4 500	339	315	< 1	32	215	200	1 667	1 500
2004-05	4 641	4 500	399	315	< 1	32	178	200	1 663	1 500
2005-06	4 539	4 500	389	315	< 1	32	166	200	1 434	1 300
2006-07	4 429	4 500	329	315	< 1	32	248	200	1 327	1 300
2007-08	4 548	4 500	328	315	< 1	32	187	200	1 304	1 300
2008-09	4 543	4 500	307	315	< 1	32	205	200	1 344	1 300
2009-10	4 465	4 500	296	315	< 1	32	188	200	1 280	1 300
2010-11	4 516	4 500	320	315	< 1	32	206	200	1 312	1 300
2011-12	4 614	4 500	358	315	< 1	32	216	200	1 360	1 300

Table 2 [Continued].

Fishstock	SNA 10			
QMAs	10		Total	
	Landings	TACC	Landings§	TACC
1983-84†	0	-	9 153	-
1984-85†	0	-	9 228	-
1985-86†	0	-	8 653	-
1986-87	0	10	5 314	6 540
1987-88	0	10	6 900	7 021
1988-89	0	10	7 706	7 691
1989-90	0	10	8 034	7 932
1990-91	0	10	7 570	7 944
1991-92	0	10	8 176	7 962
1992-93	0	10	7 448	6 858
1993-94	0	10	6 842	6 883
1994-95	0	10	6 723	6 893
1995-96	0	10	6 924	6 893
1996-97	0	10	7 176	6 893
1997-98	0	10	6 583	6 494
1998-99	0	10	6 475	6 494
1999-00	0	10	6 669	6 494
2000-01	0	10	6 496	6 494
2001-02	0	10	6 342	6 494
2002-03	0	10	6 563	6 557
2003-04	0	10	6 686	6 557
2004-05	0	10	6 881	6 557
2005-06	0	10	6 527	6 357
2006-07	0	10	6 328	6 357
2007-08	0	10	6 367	6 357
2008-09	0	10	6 399	6 357
2009-10	0	10	6 230	6 357
2010-11	0	10	6 355	6 357
2011-12	0	10	6 547	6 357

† 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. § 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	7 550	4 500		2 600*	450
SNA 2	450	315	14	90	31
SNA 3		32.3			-
SNA 7	306	200	16	90	-
SNA 8	1 785	1 300	43	312	130
SNA 10		10			

* SNA 1 has a combined non-commercial allowance of 2 600 t.

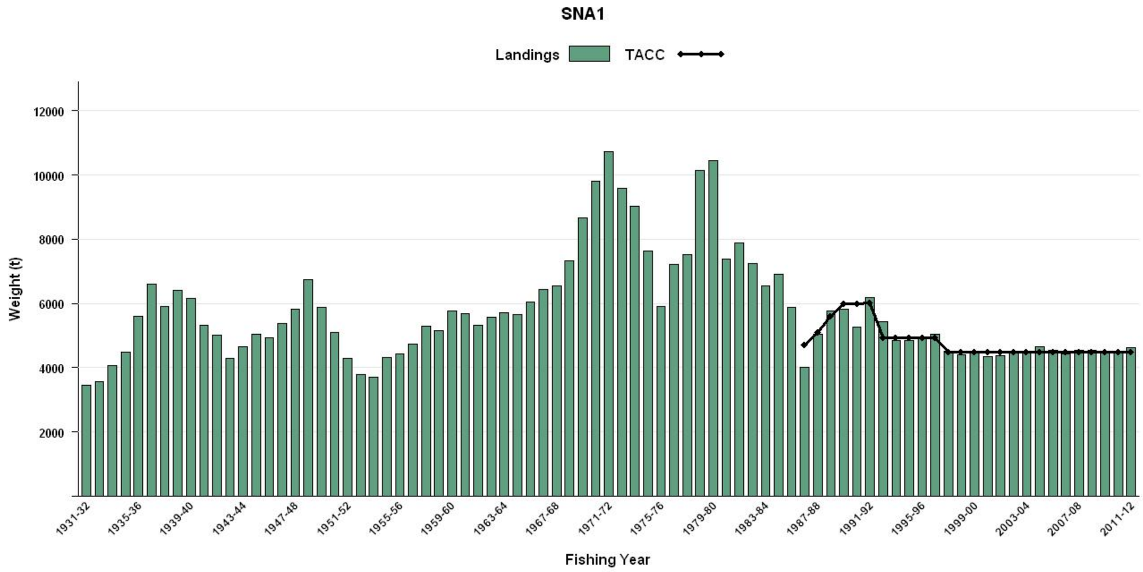
From 1 October 1997 the TACC for SNA 1 was reduced to 4500 t, within an overall TAC of 7550 t, while the TACC for SNA 7 was increased to 200 t within an overall TAC of 306 t. In SNA 2, the bycatch of snapper in the tarakihi, gurnard and other fisheries has resulted in overruns of the snapper TACC in 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. Although the 315 t TACC was substantially over-caught from 2002-03 to 2006-07, catches have since been closer to the TACC. 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 3 shows the TACs, TACCs and allowances for each Fishstock from 1 October 2004. All commercial fisheries have a minimum legal size (MLS) for snapper of 25 cm.

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.

Year	(a) Trawl	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	1 289	-	251	929
1970		31 789	676	2	131	543
1971		42 212	522	5	115	403
1972		49 133	1 444	1	225	1 217
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
Year	(b) Longline		Total Snapper	SNA 1	SNA 7	SNA 8
1975			1 510	761	-	749
1976			2 057	930	-	1 127
1977			2 208	1 104	-	1 104



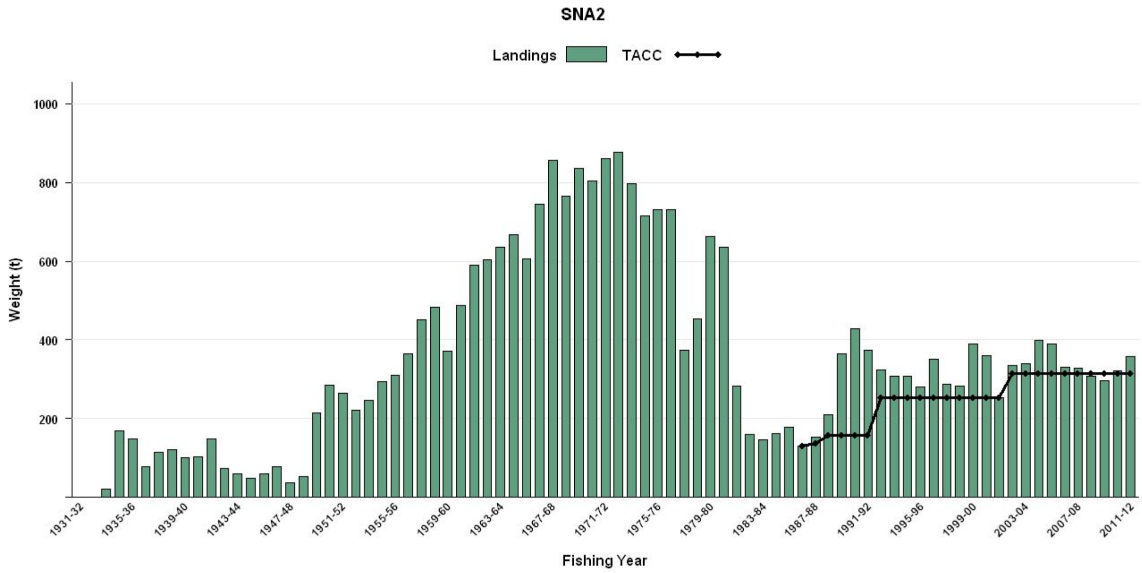
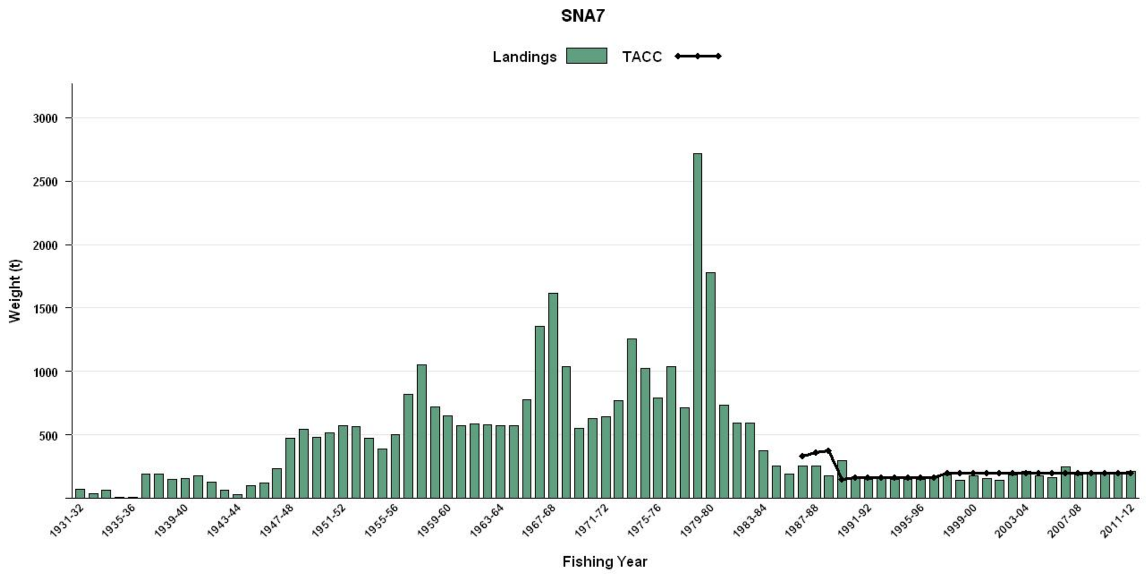


Figure 1: Historical landings and TACC for the four main SNA stocks. SNA1 (Auckland East) and SNA2 (Central East). [Continued on next page].



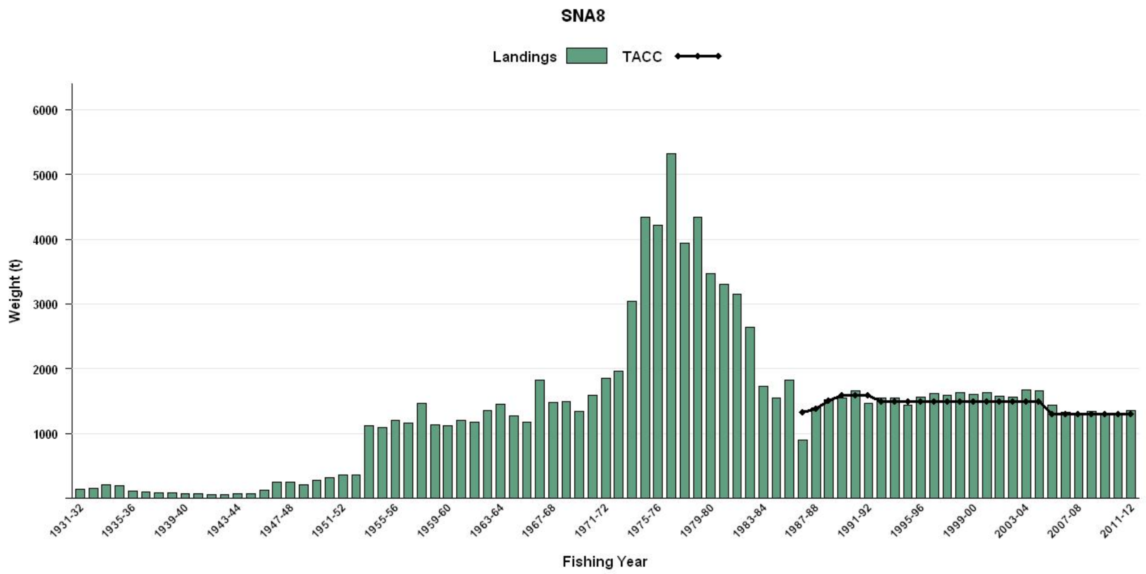


Figure 1 [Continued]: Historical landings and TACC for the four main SNA stocks. From top to bottom: SNA7 (Challenger) and SNA8 (Central Egmont).

1.2 Recreational fisheries

The snapper fishery is the largest recreational fishery in New Zealand. It is the major target species on the northeast and northwest coasts of the North Island and is targeted seasonally around the rest of the North Island and the top of the South Island. The allowances within the TAC for each Fishstock are shown in Table 3.

1.2.1 Management controls

The two main methods used to manage recreational harvests of snapper are minimum legal size limits (MLS) and daily bag limits. Both of these have changed over time (Table 5).

Table 5: Changes to minimum legal size limits and daily bag limits used to manage recreational harvesting levels in snapper stocks, 1985-2012.

Stock	MLS	Bag limit	Introduced
SNA 1	25	30	1/01/1985
SNA 1	25	20	30/09/1993
SNA 1	27	15	1/10/1994
SNA 1	27	9	1/10/1997
SNA 2	25	30	1/01/1985
SNA 2	27	10	1/10/2005
SNA 3	25	30	1/01/1985
SNA 3	25	10	1/10/2005
SNA 7	25	30	1/01/1985
SNA 7 (excl Marlborough Sounds)	25	10	1/10/2005
SNA 7 (Marlborough Sounds)	25	3	1/10/2005
SNA 8	25	30	1/01/1985
SNA 8 (FMA 9 only)	25	20	30/09/1993
SNA 8 (FMA 9 only)	27	15	1/10/1994
SNA 8	27	10	1/10/2005

1.2.2 Estimates of recreational harvest

There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and, offsite methods where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest were calculated using an onsite approach, a tag ratio method, in the mid 1980s (Table 6). A tonnes per tag ratio was obtained from commercial tag return data and this tonnage was multiplied by the number of tags returned by recreational fishers to estimate recreational harvest tonnages. 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 was 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.

The next method used to generate recreational harvest estimates was the offsite regional telephone and diary survey approach: 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 2002) and a rolling replacement of diarists in 2001 (Boyd & Reilly in press) allowed estimates for a further year (population scaling ratios and mean weights were not re-estimated). Other than for the 1991-92 MAF Fisheries South survey, the diary method used mean weights of snapper obtained from fish measured at boat ramps.

The harvest estimates provided by these telephone diary surveys are no longer considered reliable for various reasons. With the early telephone/diary method, fishers were 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 (and, hence, the harvest) is thereby under-estimated. Pilot studies for the 2000 telephone/diary survey suggested that this effect could occur when recreational fishing was established as the subject of the interview at the outset. Another equally serious cause of bias in telephone/diary surveys was that diarists who did not immediately record their day's catch after a trip sometimes overstated their catch or the number of trips made. There is some indirect evidence that this may have occurred in all the telephone/diary surveys (Wright *et al*. 2004).

Table 6: 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 (for the telephone/diary and panel survey catch estimates). Numbers and mean weights are not calculated in the tag ratio method. [Continued on next page].

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	-	-	**1 600**
Total	1994	Telephone/diary	3 804	871	**2 857**
East Northland	1996	Telephone/diary	684	1 039	711
Hauraki Gulf/Bay of Plenty	1996	Telephone/diary	1 852	870	1 611
Total	1996	Telephone/diary	2 540	915	**2 324**
East Northland	2000	Telephone/diary	1 457	1 154	1 681
Hauraki Gulf	2000	Telephone/diary	3 173	830	2 632
Bay of Plenty	2000	Telephone/diary	2 274	872	1 984
Total	2000	Telephone/diary	6 904	904	**6 242**
East Northland	2001	Telephone/diary	1 446	-[5]	1 669
Hauraki Gulf	2001	Telephone/diary	4 225	-[5]	3 507
Bay of Plenty	2001	Telephone/diary	1 791	-[5]	1 562
Total	2001	Telephone/diary	7 462	-[5]	**6 738**
Hauraki Gulf	2003-04	Aerial-access	-	-	1 334
East Northland	2004-05	Aerial-access	-	-	557
Hauraki Gulf	2004-05	Aerial-access	-	-	1 354
Bay of Plenty	2004-05	Aerial-access	-	-	516
Total	2004-05	Aerial-access	-	-	**2 419**
East Northland	2011-12	Aerial-access	-	-	718
Hauraki Gulf	2011-12	Aerial-access	-	-	2490
Bay of Plenty	2011-12	Aerial-access	-	-	546
Total	2011-12	Aerial-access	-	-	**3 754**
East Northland	2011-12	Panel survey[7]	686	1 266	869
Hauraki Gulf	2011-12	Panel survey[7]	2 215	1 022 / 987[6]	2 254
Bay of Plenty	2011-12	Panel survey[7]	691	956 / 1 003[6]	669
Total	2011-12	Panel survey[7]	3 592	1 025	**3 792**

Table 6 [Continued].

Stock	Year	Method	Number of fish (thousands)	Mean weight (g)	**Total weight (t)**
SNA 2	1993	Telephone/diary	28	1 282	**36**
	1996	Telephone/diary	31	1 282[2]	**40**
	2000	Telephone/diary	268	1 200[4]	**322**
	2001	Telephone/diary	144	-[5]	**173**
	2011-12	Panel survey[7]	55	1 027	**57**
SNA 7					
Tasman/Golden Bays	1987	Tag ratio	-	-	**15**
Total	1993	Telephone/diary	77	2 398[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**
Total	2005-06	Aerial-access	-	-	**42.6**
Total	2011-12	Panel survey[7]	110	799	**88**
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	1 020	**661**
Total	2001	Telephone/diary	1 111	-	**1 133**
Total	2007	Aerial-access	-	-	**260**
Total	2011-12	Panel survey[7]	557	770 / 1 255 / 1160[8]	**630**

[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
[6] Separate mean weight estimates were used for summer (1 October 2011 to 30 April 2012) and for winter (1 May to 30 September 2012)
[7] This surveys was still under review at the time that this report was written, but appears to provide plausible results
[8] Separate mean weight estimates were used for harbours (Kaipara and Manukau)/North coast (open coast fishery north of Tirua Point)/ South coast (open coast fishery south of Tirua point)

The recreational harvest estimates provided by the 2000 and 2001 telephone diary surveys are thought to be implausibly high, which led to the development of an alternative maximum count aerial-access onsite method that provides a more direct means of estimating recreational harvests for suitable fisheries. The maximum count aerial-access approach combines data collected concurrently from two sources: a creel survey of recreational fishers returning to a subsample of ramps throughout the day; and an aerial survey count of vessels observed to be fishing at the approximate time of peak fishing effort on the same day. The ratio of the aerial count in a particular area to the number of interviewed parties who claimed to have fished in that area at the time of the overflight was used to scale up harvests observed at surveyed ramps, to estimate harvest taken by all fishers returning to all ramps. The methodology is further described by Hartill *et al*. (2007).

This aerial-access method was first employed in the Hauraki Gulf in 2003–04 and was then extended to survey the wider SNA 1 fishery in 2004–05. This approach has subsequently been used to estimate recreational harvests from SNA 7 (2005-06 fishing year) and SNA 8 (2006-07). The Recreational and Snapper Working Groups both concluded that this approach provided reliable estimates of recreational harvest for these fish stocks.

In response to the cost and scale challenges associated with onsite methods, in particular the difficulties in sampling other than trailer boat fisheries, offsite approaches to estimating recreational fisheries harvest have been revisited. This led to the implementation of a national panel survey during the 2011-12 fishing year. The panel survey used face-to-face interviews of a random sample of New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information collected in standardised phone interviews.

1.2.2.1 SNA 1

The most recent aerial-access survey was conducted in QMA 1 in 2011–12 (Hartill *et al.* 2013), to independently provide harvest estimates for comparison with those generated from a concurrent national panel survey (excluding the Chatham Islands). The national panel survey was still under review at the time that this report was written, but both surveys appear to provide plausible results that corroborate each other, and are therefore considered to be broadly reliable. Harvest estimates provided by these surveys are given in Table 5, but the panel survey estimate should be regarded as provisional at this stage. Regional harvest estimates provided by the 2004–05 and 2011–12 aerial-access surveys were used to inform the 2013 stock assessment for SNA 1. Note that neither of these estimates includes catch taken on recreational charter vessels, or recreational catch taken under s111 general approvals.

1.2.2.2 SNA 8

In 2005, the Snapper Working Group 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. The estimate from the 2006-07 aerial overflight survey of the SNA 8 fishery (260 t) suggests that the assumed value of 300 t may have been the more plausible. There are potential sources of bias associated with the aerial-access estimate, both negative (a potential underestimation of the shore based harvest, especially to the south) and positive (over reporting of harvests by charter boat operators in a log book survey).

The recent national panel survey (excluding the Chatham Islands) was still under review at the time that this report was written, but appears to provide plausible results, and is therefore considered to be broadly reliable. The harvest estimate provided by this survey for SNA 8 is given in Table 5, but should be regarded as provisional at this stage. Note that this estimate does not include catch taken on recreational charter vessels, or recreational catch taken under s111 general approvals.

1.3 Customary non-commercial fisheries

Snapper form important fisheries for customary non-commercial, but the annual catch is not known.

1.4 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. These proportions were based on the black market trade in snapper and higher levels of under-reporting (to avoid tax) that existed prior to the introduction of the QMS. The 10% under-reporting post-QMS accounts for the practice of “weighing light” and the discarding of legal sized snapper.

1.5 Other sources of mortality

No estimates are available regarding the quantum of other sources of mortality on snapper stocks; although high-grading of longline fish and discarding of under-sized fish by all methods occurs. An at-sea study of the SNA 1 commercial longline fishery in 1997 (McKenzie 2000) found 6-10% of snapper caught by number were under 25 cm (MLS). Results from a holding net study indicate mortality levels amongst lip-hooked snapper caught shallower than 35 m were low.

Estimates for incidental mortality were based on other catch-at-sea data using an age-length structure model for longline, trawl, seine and recreational fisheries. In SNA1, estimates of incidental mortality for the year 2000 from longline were less than 3% and for trawl, seine and recreational fisheries between 7% and 11% (Millar *et al*. 2001). In SNA8, estimates of trawl and recreational incidental mortality were lower, mainly because of low numbers of 2 and 3 year old fish estimated in 2000.

In SNA 1, recreational fishers release a high proportion of their snapper catch, most of which is less than 27 cm (recreational MLS). An at sea study in 2006–07 recorded snapper release rates of 54.2% of the catch by trailer boat fishers and 60.1% of the catch on charter boats (Holdsworth & Boyd 2008). Incidental mortality estimated from condition at release was 2.7% to 8.2% of total catch by weight depending on assumptions used.

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.

Although all snapper undergo a female phase as juveniles, after maturity each individual functions as one sex (either male or female) during the rest of its life. Sexual maturity occurs at an age of 3-4 years and a length of 20-28 cm; and the sex ratio of the adult population is approximately 50:50. 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. Juvenile snapper (0+) are known to reach high abundances in shallow west and east coast harbours and estuaries around the northern half of the North Island and have also been observed in catches from trawl surveys conducted in shallow coastal waters around northern New Zealand, including Tasman and Golden Bays. Despite observations of spawning condition adults along the Wairarapa and Kapiti coasts, 0+ snapper have yet to be found in these areas. Young snapper disperse more widely into less sheltered coastal areas as they grow older. 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. (Francis 1993)

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 7.

Table 7: 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	MPI (unpub. data)
SNA 8	0.16	-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			MPI (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 (Gilbert *et al.* 2000).

New Zealand snapper are thought to comprise either seven or eight biological stocks based on: the location of spawning and nursery grounds; differences in growth rates, age structure and recruitment strength; and the results of tagging studies. These stocks comprise three in SNA 1 (East Northland, Hauraki Gulf and BoP), two in SNA 2 (one of which may be associated with the BoP stock), two in SNA 7 (Marlborough Sounds and Tasman/Golden Bay) and one in SNA 8. Tagging studies reveal that limited mixing occurs between the three SNA 1 biological stocks, with greatest exchange between BoP and Hauraki Gulf.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the 2013 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. An issue-by issue analysis is available in the 2012 Aquatic Environment and Biodiversity Annual Review (www.mpi.govt.nz/Default.aspx?TabId=126&id=1644).

4.1 Role in the ecosystem

Snapper are one of the most abundant demersal generalist predator found in the inshore waters of northern New Zealand (Morrison & Stevenson 2001, Kendrick & Francis 2002), and as such are likely to be an important part of the coastal marine ecosystem (Salomon et al. 2008). Localised depletion of snapper probably occurs within the key parts of the fishery (Parsons *et al.* 2009), and this has unknown consequences for ecosystem functioning in those areas.

4.1.1 Trophic interactions

Snapper are generalists, occupying nearly every coastal marine habitat less than 200 m deep. Owing to this generalist nature there is a large potential for a variety of trophic interactions to involve snapper. The diet of snapper is also diverse and opportunistic, largely feeding on crustaceans, polychaetes, echinoderms, molluscs and other fish (Godfriaux 1969, Godfriaux 1974). As snapper increase in size, harder bodied and larger diet items increase in importance (e.g. fish, echinoids, hermit crabs, molluscs and brachyuran crabs) (Godfriaux 1969, Usmar 2012). There is some evidence to suggest a seasonal component to snapper diet, with high proportions of pelagic items (e.g. salps and pelagic fish such as pilchards) observed during spring in one study (Powell 1937).

There is some evidence to suggest that snapper have the ability to influence the environment that they occupy in some situations. On some rocky reefs, recovery of predators inside marine reserves (including snapper and rock lobster, *Jasus edwardsii*) has led to the recovery of algal beds through predation exerted on herbivorous urchins (Babcock *et al.* 1999; Shears & Babcock 2002). Snapper competes with other species, overlap in diet is likely with a number of other demersal predators (e.g. tarakihi, red gurnard, trevally, rig, and eagle ray). The wide range of prey consumed by these species and differences in diet preference and habitat occupied, however, is likely to reduce the amount of competition overall (Godfriaux 1970, 1974). The importance of snapper as a food source for other predators is poorly understood.

4.1.2 Ecosystem Indicators

Tuck *et al.* (2009) used data from the Hauraki Gulf trawl survey series to derive fish-based ecosystem indicators using diversity, fish size, and trophic level. This trawl survey ran until 2000 and covers a key component of the distribution of snapper. The survey has not been conducted since, however, and the current inshore trawl surveys cover only the southern end of snapper distribution in New Zealand. Tuck et al. (2009) showed decreasing trends in the proportion of species with low resilience (from FishBase, Froese & Pauly 2000) and the proportion of demersal fish species in waters shallower than 50 m in the Hauraki Gulf. Several indices of fish diversity showed significant declines in muddy waters shallower than 50 m, especially in the Firth of Thames. Tuck et al. (2009) did not find size-based indicators as useful as they have been overseas, but there was some indication that the maximum size of fish has decreased in the Hauraki Gulf survey area, especially over sandy bottoms. Since 2008 routine measurement of all fish species in New Zealand trawl surveys has been undertaken and this may increase the utility of size-based indicators in the future.

4.2 Incidental catch (fish and invertebrates)

Most snapper taken in SNA 1 and 8, and some taken in SNA 7, is the declared target species, but some snapper is taken as a bycatch in a variety of inshore trawl and line fisheries. No summaries of the observed fish and invertebrate bycatch are currently available, so the best available information is from research fishing conducted in the areas where target fisheries take place. Although the gear used for these surveys may be different than that used in the fishery itself (e.g. smaller mesh cod ends are used in trawl surveys), they are conducted in the same areas and provide some insight as to the fish and invertebrate species likely to be caught in association with snapper.

More than 70 species have been captured in trawl surveys within SNA1 but catches are dominated by snapper. Kendrick and Francis (2002) noted the following species in more than 30% of tows by research vessels *Ikatere* and *Kaharoa*: jack mackerels (three species), John dory, red gurnard, sand flounder, leatherjacket, rig, eagle ray, lemon sole, and trevally (see also Langley 1995a, Morrison 1997, Morrison and Francis 1997, Jones *et al*. 2010). Smaller numbers of invertebrates are captured including green-lipped mussel, arrow squid, broad squid, octopuses, and scallop (Langley 1995a, Morrison 1997, Morrison and Francis 1997 and Jones *et al*. 2010). For SNA1, information on the bycatch associated with research longlining during tagging surveys is also available, although restricted to the inner and western parts of the Hauraki Gulf. The most common bycatch species in this area included: rig, school shark, hammerhead shark, eagle ray, stingrays, conger eel, trevally, red gurnard, jack mackerels, blue cod, John dory, kingfish, frostfish and barracouta (Morrison and Parsons unpublished data).

Trawl surveys targeting juvenile snapper in Tasman and Golden Bays have captured more than 50 finfish species. Common bycatch species (Blackwell & Stevenson 1997) were: spiny dogfish, red cod, barracouta, red gurnard, jack mackerel (three species), hake, blue warehou, tarakihi and porcupine fish. Invertebrates captured included sponges, green-lipped mussel, octopuses, arrow squid, nesting mussel, and horse mussel. Over 80 species have been captured in trawl surveys within SNA8. Red gurnard, jack mackerel (three species), trevally, barracouta, school shark, spiny dogfish, rig, John dory and porcupine fish were the most abundant finfish (Langley 1995b, Morrison 1998, Morrison & Parkinson 2001). Few invertebrates other than arrow squid were caught (Morrison & Parkinson 2001).

4.3 Incidental Catch (mammals, seabirds, turtles, and protected fish)

For protected species, capture estimates presented here include all animals recovered to the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds struck by a warp or caught on a hook but not brought onboard the vessel, Middleton & Abraham 2007, Brothers *et al.* 2010).

4.3.1 Marine mammal interactions

There were no observed captures of marine mammals in trawls targeting snapper between 2002-03 and 2011-12 but low observer coverage of inshore trawlers (average 0.85% in FMAs 1 and 9 over these years, Thompson & Abraham 2012) means that the frequency of interactions is highly uncertain. In these same years, there were no observed marine mammal captures in snapper longline fisheries where coverage has averaged 1.6% of hooks set (3.0 and 4.3% in the two most recent years).

4.3.2 Seabird interactions

There were only two observed captures of seabirds (one flesh-footed shearwater and one unidentified small bird) in trawls targeting snapper between 2002-03 and 2009-10 but low observer coverage of inshore trawlers (average 0.85% in FMAs 1 and 9 over these years, Thompson and Abraham 2012) means that the frequency of interactions is highly uncertain. The estimated number of seabird captures in the snapper bottom longline fishery declined from 3 436 in 2000-01 to 247–644 in 2003-04 (depending on the model used, Table 8, estimates from McKenzie & Fletcher 2006, Baird & Smith 2007, 2008, Abraham & Thompson 2010). The estimated number of captures between 2003-04 and 2006-07 appears to have been relatively stable at about 400–600 birds each year.

Between 2002–03 and 2011–12, there were 85 observed captures of birds in snapper longline fisheries (Table 9) but no estimates of total captures for the 2011-12 fishing year are yet available. The rate of capture varied between 0 and 0.1 birds per 1000 hooks observed, fluctuating without obvious trend. Seabirds observed captured in snapper longline fisheries were mostly fluttering shearwater (63%), flesh-footed shearwater (19%), and black (Parkinson's) petrel (14%), and all were taken in the Northland-Hauraki area (Table 10). These numbers should be regarded as only a general guide on the composition of captures because the observer coverage is low, is not uniform across the area, and may not be representative.

Table 8: Model based estimates of seabird captures in the SNA 1 bottom longline fishery from 1998-99 to 2006-07 (from McKenzie & Fletcher 2006 (for vessels under 28 m), Baird & Smith 2007, 2008, Abraham & Thompson 2010). Numbers in parentheses are 95% confidence limits or estimated CVs.

	Model based estimates of captures					
Fishing year	MacKenzie & Fletcher		Baird & Smith		Abraham & Thompson	
1998-99	1 464	(271 – 9 392)	–	–	–	–
1999-00	2 578	(513 – 13 549)	–	–	–	–
2000-01	3 436	(697 – 17 907)	–	–	–	–
2001-02	1 856	(353 – 11 260)	–	–	–	–
2002-03	1 583	(299 – 9 980)	–	–	739	(332 – 1 997)
2003-04	247	(51 – 1 685)	546	(c.v. = 34%)	644	(301 – 1 585)
2004-05	–	–	587	(c.v. = 42%)	501	(245 – 1 233)
2005-06	–	–	–	–	469	(222 – 1 234)
2006-07	–	–	–	–	457	(195 – 1 257)

Table 9: Number of tows by fishing year, observed, and estimated seabird captures in the snapper bottom longline fishery, 2002–03 to 2011–12. No. obs, number of observed hooks; % obs, percentage of hooks observed; Rate, number of captures per 1000 observed hooks. Estimates are based on methods described in Abraham *et al.* (2013) and are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002-03 to 2010-11 are based on data version 20120531 and preliminary estimates for 2011-12 are based on data version 20130304.

			Fishing effort	Observed captures		Estimated captures		
	All hooks	No. obs	% obs	Number	Rate	Mean	95% c.i.	% included
2002–03	13 661 602	0	0.0	0	-	580	314-857	100.0
2003–04	12 193 788	193 893	1.6	10	0.052	488	268-723	100.0
2004–05	11 510 191	250 985	2.2	13	0.052	420	227-618	100.0
2005–06	11 694 613	116 290	1. 0	12	0.103	355	196-527	100.0
2006–07	10 347 591	62 360	0.6	0	0	361	186-543	100.0
2007–08	9 048 572	0	0.0	0	-	312	160-474	100.0
2008–09	8 956 484	268 746	3.0	20	0.074	306	170-453	100.0
2009–10	11 022 455	485 668	4.4	30	0.062	347	196-508	100.0
2010-11	11 346 632	0	0.0	0	-	366	191-552	100.0
2011-12†	11 032 280	0	0.0	0	-	-	-	-

† Provisional data, no model estimates available.

Table 10: Number of observed seabird captures in the snapper longline fishery, 2002–03 to 2011–12, by species or species group. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR (from Richard and Abraham 2013 where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for snapper. Other data version 20130304.

Species	**Risk Ratio**	**Captures (Northland and Hauraki)**
Black petrel	Very high	28
Flesh footed shearwater	Very high	37
Pied shag	Very low	2
Black backed gull	-	1
Buller's shearwater	-	1
Fluttering shearwater	-	3
Red billed gull	-	1
Gannets	N/A	2
Unidentified seabird	N/A	12
Total	**N/A**	**85**

4.3.3 Sea turtle interactions

Between 2002-03 and 2011-12 there has been one observed capture of a green turtle across the snapper longline fishery occurring in the Northland and Hauraki fishing area. Observer records documented the green turtle as captured and released alive (Thompson *et al.* 2013).

4.4 Benthic interactions

A proportion of the commercial catch of snapper is taken using bottom trawls in Benthic Optimised Marine Environment Classification (BOMEC, Leathwick *et al.* 2009) classes A, C (northern shelf) and H (shelf break and upper-slope) (Baird & Wood 2012), and at least 90% of trawls occur shallower than 100 m depth (Baird *et al.* 2011, tabulating only data from TCEPR forms). Trawling for snapper, like trawling for other species, is likely to have effects on benthic community structure and function (e.g. Thrush *et al.* 1998, Rice 2006) and there may be consequences for benthic productivity (e.g. Jennings 2001, Hermsen *et al.* 2003, Hiddink *et al.* 2006, Reiss *et al.* 2009). These consequences are not considered in detail here but are discussed in the Aquatic Environment and Biodiversity Annual Review (2012).

4.5 Other considerations

4.5.1 Spawning disruption
Fishing within aggregations of spawning fish may have the potential to disrupt spawning behaviour and, for some fishing methods, may lead to reduced spawning success. No research has been conducted on disruption of snapper spawning, but aggregations of spawning snapper often receive high commercial and recreational fishing effort (Ministry for Primary Industries unpublished data). Areas likely to be important for snapper spawning include the Hauraki Gulf (Cradock Channel, Coromandel Harbour to the Firth of Thames, and between the Noises, Tiritiri Matangi and Kawau Islands (Zeldis & Francis 1998)), Rangaunu and Doubtless Bay, the Bay of Islands, eastern Bay of Plenty, and the coastal areas adjacent to the harbour mouths on the west coast such as the Manukau and Kaipara Harbours (Hurst *et al.* 2000).

4.5.2 Genetic effects
Fishing, environmental changes, including those caused by climate change or pollution, could alter the genetic composition or diversity of a species. Hauser et al. (2003) estimated genetic diversity and confidence limits for snapper in Tasman Bay and the Hauraki Gulf. They showed a significant decline of both mean heterozygosity and mean number of alleles in Tasman Bay, but only random fluctuations in the Hauraki Gulf. In Tasman Bay, there was a decrease in genetic diversity at six of seven loci examined, compared with only one in the Hauraki Gulf. Hauser et al. (2003) associated this decline with overfishing of the SNA 7 stock and estimated the effective population size in Tasman Bay as only 46–176 individuals between 1950 and 1998.

4.5.3 Habitat of particular significance to fisheries management
Habitat of particular significance for fisheries management (HPSFM) does not have a policy definition (Ministry of Fisheries, 2012) although work is currently underway to generate one. For juvenile snapper, it is likely that certain habitats, or locations, are critical to successful recruitment of snapper. Post settlement juvenile snapper (10-70 mm fork length) associate strongly with three-dimensional structured habitats in estuaries, harbours and sheltered coastal areas (such as beds of seagrass and horse mussels, Morrison unpublished data, Thrush *et al*. 2002, Parsons *et al*. in press). The reason for this association is currently unclear, but the provision of food and shelter are likely explanations. Some potential nursery habitats appear to contribute disproportionately to their area. The Kaipara Harbour in northern New Zealand contributes a disproportionately high proportion of successful recruits to the SNA 8 fishery (M. Morrison unpublished data) and a similar situation exists for snapper from Port Phillip Bay in Australia (Hamer *et al*. 2011). These habitats are subject to land-based stressors (Morrison *et al*. 2009) that may affect their production of juvenile snapper and recruitment to the SNA 8 fishery.

5. STOCK ASSESSMENT

Stock assessments for SNA 2, SNA 7 and SNA 8 were last completed in 2009, 2002 and 2005 respectively. Based on a preliminary assessment undertaken in 2012, a new assessment of SNA 1 was conducted in 2013. The next most recent assessment was undertaken in 2000.

5.1 SNA 1 (Auckland East)

5.1.1 Model structure
The model used for the 2013 assessment was written using CASAL (Bull et al. 2012) and is a development of the three-stock, three-area model used in the 2012 assessment (Francis & McKenzie draft a). The 2012 assessment was given a quality ranking of “2” due to lack of convergence of MCMCs and poor estimates of the extent of depletion in 1970. These problems have largely been resolved in the new assessment.

The model covered the time period from 1900 to 2013 (i.e., fishing years 1899–1900 to 2012–13), with two time steps in each year (Table 11).

The assessment explicitly modelled the movement of fish between areas and assumed a Home Fidelity (HF) movement dynamic. Under the HF movement, fish spawn in their home area and some move to other areas at other times of the year where they are subject to fishing. There were two sets of migrations: in time step 1, all fish returned to their home (i.e., spawning) area just before spawning; and in time step 2, some fish moved away from their home area into another area. This second migration may be characterised by a 3 x 3 matrix, in which the *ij*th element, p_{ij}, is the proportion of fish from the *i*th area that migrate to the *j*th area.

The model partitions the modelled population by age (ages 1–20, where the last age was a plus group), stock (three stocks, corresponding to the parts of the population that spawn in each of three subareas of SNA 1), area (the three subareas), and tag status (grouping fish into six categories – one for untagged fish, and one each for each of five tag release episodes). That is to say, at any point in time, each fish in the modelled population would be associated with one cell in a 20 x 3 x 3 x 6 array, depending on its age, the stock it belonged to, the area it was currently in and its tag status at that time. To avoid confusion about areas and stocks we use two-letter abbreviations (EN, HG, BP) for areas, and longer abbreviations (ENLD, HAGU, BOP) to denote stocks. As with previous snapper models (e.g., Gilbert et al 2000), this model did not distinguish fish by sex.

Table 11: Annual model time steps and the processes and observations used in each time step Note that the home area for a fish is where it spawns (and was recruited). Each year some fish migrate away from their home ground (in step 2) and then return home in step 1 of the following year.

Time step	Model processes (in temporal order)	Observations[2,3]
1	age incrementation, migration to home area, recruitment, spawning, tag release	
2	migration from home area, natural and fishing mortality[1]	biomass, length and age compositions, tag recapture

[1]Fishing mortality was applied after half the natural mortality
[2]The tagging biomass estimate was assumed to occur immediately before the mortality; all other observations occurred half-way through the mortality
[3]See Table 13 for more details of all observations

A total of 168 parameters were estimated in the base model (Table 12). The six migration parameters define the 3 x 3 migration matrix described above (there are only six parameters because the proportions in each row of the matrix must sum to 1). Selectivities were assumed to be age-based and double normal, and to depend on fishing method but not on area. Three selectivities were estimated for commercial fishing (for longline, single trawl, and Danish seine); one for the (single trawl) research surveys, and two for recreational fisheries (for before and after a change in recreation size limit in 1995). All priors on estimated parameters were uninformative except for the usual lognormal prior on year-class strengths (with coefficient of variation (CV) 0.6).

Year class strengths (YCS) were estimated as free parameters but only for years where there was at least one observation of catch-at-age. The YCS estimation period in the model was also the period over which the R0 parameter was also estimated. YCS estimation conformed to the Haist parameterisation in which the mean of the YCSs is constrained to 1 (Bull *et al.* 2012). For years where YCS could not be estimated as free parameters YCS was set to 1.

Table 12: Details of parameters that were estimated in the model

Type	Description	No. of parameters	Prior
R0	Mean unfished recruitment for each stock	3	uniform-log
YCS	Year-class strengths by year and stock	136[1]	lognormal[2]
Migration	Proportions migrating from home grounds	6	uniform
Selectivity	Proportion selected by age by a survey or fishing method	18	uniform
q	Catchability (for relative biomass observations)	5	uniform-log
		168	

[1]In the MPD run YCSs were estimated for years 1966–2007 for ENLD, 1951–2007 for HAGU, and 1971-2001 for BOP; in the MCMC run the most recent years, 2008–2012, were also estimated.
[2]With mean 1 and coefficient of variation 0.6

Some parameters were fixed, either because they were not estimable with the available data (notably natural mortality and stock-recruit steepness were fixed at values determined by the Working Group), or because they were estimated outside the model (Table 13). As in 2012, mean length at age was specified by yearly values (rather than a von Bertalanffy curve) because these values showed a strong trend for the older ages. Data were available for 1994–2010 for ENLD, and for 1990–2010 for HAGU and BOP. In each stock, mean lengths for earlier years were set to the average values over these years, and for later years (including projections) to the 2006–2010 average.

Table 13: Details of parameters that were fixed in the model

Natural mortality	0.075 y^{-1}
Stock-recruit steepness (Beverton & Holt)	0.85
Tag shedding (instantaneous rate, 1985 tagging)	0.486 y^{-1}
Tag detection (1985 and 1994 tagging)	0.85
Proportion mature	0 for ages 1-3, 0.5 for age 4, 1 for ages > 4
Length-weight [mean weight (kg) = a (length (cm))^b]	a = 4.467 x 10^{-5}, b = 2.793
Mean lengths at age	provided for years 1990-2010[1]
Coefficients of variation for length at age	0.10 at age 1, 0.20 at age 20
Pair trawl selectivity	a_1 = 6 y, σ_L = 1.5 y, σ_R = 30 y

[1]See text for details

The most important change from the model used in the 2012 assessment was that the catch history was revised and extended back to 1900, and it was assumed that each stock was at its unfished level (B_0) in 1900. Two other changes of consequence affected the tag-recapture data sets that were 'condensed' (i.e., the number of length classes in each data set was substantially decreased by combining adjacent length classes until each remaining length class contained at least 5 observed recaptures) and iteratively reweighted, together with the composition data sets (for details see Francis & McKenzie draft b). Other minor changes included dropping small fisheries (pro-rating their catches over the remaining fisheries in the same area) and removing priors on recreational selectivities.

Five types of observations were used in the base stock assessment (Table 14). These were the same as in the 2012 assessment (Francis & McKenzie draft a) except for the addition of 2012 data points for each of the CPUE time series and the recreational length compositions.

Table 14: Details of observations used in the stock assessment model

Type	Likelihood	Area[1]	Source	Range of years	No. of years
Absolute biomass	Lognormal	BOP	1983 tagging	1983	1
Relative biomass (CPUE or survey)	Lognormal	BOP	longline	1990-2011	22
		ENLD	longline	1990-2011	22
		HAGU	longline	1990-2011	22
		BOP	single trawl	1996-2011	16
		HAGU	research survey	1983-2001	13
Age composition	Multinomial	HAGU	longline	1985-2010	22
		BOP	longline	1990-2010	19
		ENLD	longline	1985-2010	18
		HAGU	Danish seine	1970-1996	11
		HAGU	research survey	1985-2001	10
		HAGU	single trawl	1975-1994	6
		BOP	single trawl	1990-1995	4
		BOP	research survey	1990-1996	3
		ENLD	research survey	1990	1
		BOP	Danish seine	1995	1
Length composition		BOP	recreational fishing	1991-2012[2]	14
		ENLD	recreational fishing	1991-2012[2]	14
		HAGU	recreational fishing	1991-2012[2]	14
		Area tagged[1]	**Year tagged**	**Areas recaptured[1]**	**Years recaptured**
Tag recapture	Binomials	ENLD	1983	ENLD, HAGU	1984, 1985
		HAGU	1983	ENLD, HAGU	1984, 1985
		ENLD	1993	ENLD, HAGU, BOP	1994, 1995
		HAGU	1993	ENLD, HAGU, BOP	1994, 1995
		BOP	1993	ENLD, HAGU, BOP	1994, 1995

[1]Areas are East Northland (ENLD), Hauraki Gulf (HAGU), and Bay of Plenty (BOP)

[2]All length composition data sets were split into pre-1995 (2 years) and post-1995 (11 years) because recreational selectivity was assumed to change in 1995

Data weighting

The approach to data weighting followed the methods of Francis (2011) except that a new method was used to weight the tag-recapture data (not discussed by Francis 2011) via the dispersion parameter (for details see Francis & McKenzie draft b). CVs on the various abundance data sets were defined *a priori* to be consistent with the most "plausible" fit the model was expected to achieve to the data (as agreed by the working group).

5.1.2 Catch History

Recreational catch

Direct estimates of annual recreational harvest from the three areas of SNA 1(East Northland, Hauraki Gulf and Bay of Plenty) are available from aerial-access surveys conducted in 2004-05 and 2011-12 (Table 5) (Hartill *et al*. 2007; MPI unpublished data).

The recreational catch history used in the previous 2012 stock assessment for SNA 1 was based commercial longline CPUE indices (1990 to 2011) scaled to the 2004-05 aerial-access estimates for each area of SNA 1. In 2012 the Working Group decided that commercial longline CPUE indices should not be used to inform recreational catch histories because the 2011-12 aerial-access harvest estimates were well above those predicted by the long line CPUE based approach used in 2012, particularly for the Hauraki Gulf. Instead the Working Group decided that an alternative creel survey based recreational kg per trip index provides a more realistic means of interpolating between the 2004–05 and 2011–12 aerial-access harvest estimates, in all three areas of SNA 1. Recreational kg per trip data are available for many of the years since 1991, especially since 2001, and these data explicitly take into account the 1995 changes to the recreational MLS and bag limits. These indices are based on creel survey data collected between January and April only. The geometric mean of the recreational kg per trip index over the period 2004–05 to 2011–12 was used to scale this index up to the level of the geometric mean of the two aerial-access harvest estimates. Exponential curves fitted to the recreational kg per trip index were used were used to provide interpolated catch estimates for years between 1990 and 2012 where no year index was available (Figure 2). The recreational harvest in 1970 was assumed to be 70% of the 1989-90 estimates in each area, with a linear increase in annual catch across the intervening years (Figure 2).

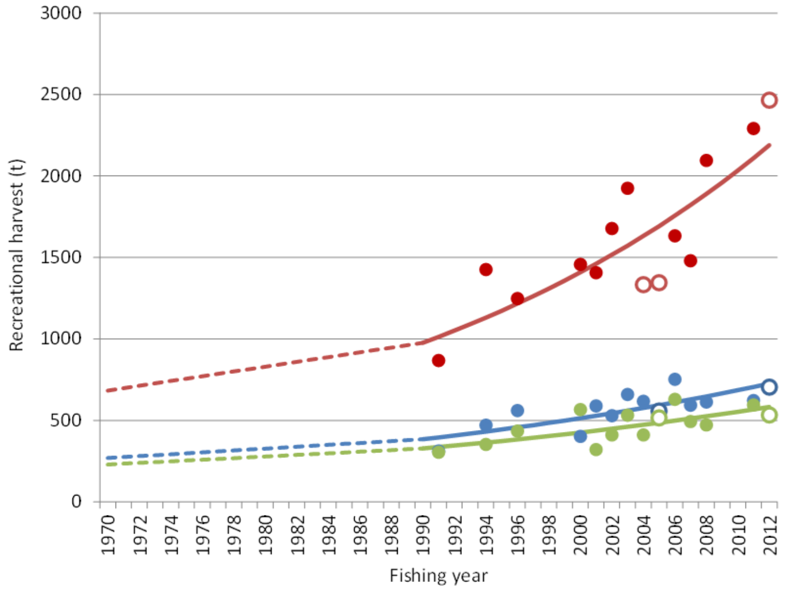


Figure 2: Recreational catch histories for the three areas of SNA 1 (Hauraki Gulf in red, East Northland in blue, and the Bay of Plenty in green). Open circles denote aerial-access survey estimates, closed circles denote recreational kg per trip indices scaled to the geometric mean of the aerial-access estimates, solid curved lines denote exponential fits to the scaled kg per trip indices which were used to predict harvests for those years for which creel survey data were not available, and dashed lines denote linear interpolations between 1990 and 1970 (when harvests were assumed to be at 70% of that predicted for 1990).

By choosing to scale recreational catch to the relative CPUE between years and scaling these estimates to the geometric mean of the two aerial surveys, the Working Group implicitly assumed that effort has remained constant throughout the period 1990–2012. Because recreational catch increased more rapidly than the BLL CPUE from 2007, the model estimated an increasing recreational exploitation rate in order to match the input catches. Increasing exploitation rates with fixed effort can only be resolved if recreational catchability also increased. The Working Group agreed that this was plausible even though relative recreational catchability must have increased by about 50% to account for the increased recreational catch estimates between 2005 and 2012. Projections also require the additional assumption that relative recreational catchability will remain at the values that were associated with the projected exploitation rate. The Working Group agreed to test the sensitivity of the projections to the catchability assumption by projecting forward using high and low recreational exploitation rate estimates: a) from 2013, the final model year, and b) from the average 1995–2005 exploitation rate, a period of relatively constant recreational catch incorporating the 2005 aerial catch estimate.

Recreational catch histories for each area for the period 1900 to 1970 were based on the average of two expert opinions of the harvest in 1900, provided by two regular members of the Marine Amateur Fishing Working Group. This averaged estimate was used to generate a linearly increasing recreational catch history for the period 1900 to 1970 (Figure 3).

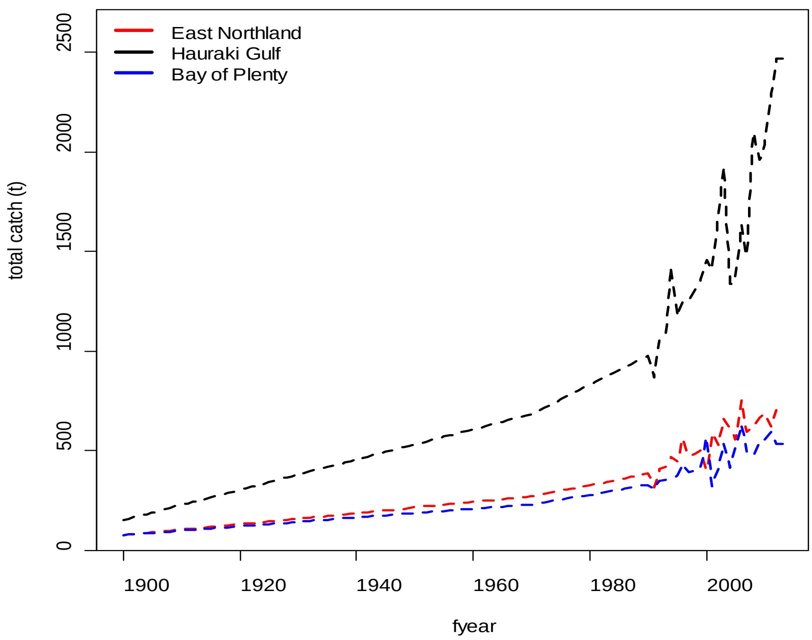


Figure 3: Assumed and derived recreational catch histories for the period 1900 to 2013, that were used in the 2013 SNA 1 assessment model.

The customary harvest is not known and no additional allowance is made beyond the recreational catch.

Commercial catch

The SNA 1 commercial catch histories for the various method area fisheries after 1989-90 were derived from the Ministry for Primary Industries (MPI) catch effort reporting database (*warehou*); catches for method and area between 1981-82 and 1989-90 were constructed on the basis of data contained in archived MPI databases.

Commercial catch histories for the period 1915 through 1982 were derived from two sources as follows:

- 1915–73: Annual Reports on Fisheries, compiled by the Marine Department to 1971 and the Ministry of Agriculture and Fisheries to 1973 as a component of their Annual Reports to Parliament published as Appendices to the Journal of the House of Representatives (AJHR). From 1931 to 1943 inclusive, data were tabulated by April–March years; these were equated with the main calendar year (e.g. 1931–32 landings are treated as being from 1931). From 1944 onwards, data were tabulated by calendar year.
- 1974–82: Ministry of Agriculture and Fisheries, Fisheries Statistics Unit (FSU) calendar year records published by King (1985). The available data grouped catches for all species comprising less than 1% of the port totals as “Minor species”. An FSU hardcopy printout dated 23 March 1984 held by NIWA was used to provide species-specific catches in these cases (although this had little effect for snapper given that it is typically a major species in SNA 1 ports).

No commercial catch records are available prior to 1915; therefore, for the purposes of the current assessment the 1915 catch totals were applied back to 1900.

The only information available on the spatial distribution of SNA 1 landings before 1983 comes from “The Wetfish Report” (Ritchie et al. 1975) in which snapper landings for old statistical areas were provided by year and month for the period 1960–1970. The boundaries of the old Statistical Areas 2, 3 and 4 are similar to those for the East Northland, Hauraki Gulf and Bay of Plenty substocks. However, Area 4 is smaller than the Bay of Plenty substock, whereas Area 2 is larger than East Northland and Area 3 is larger than Hauraki Gulf. Nevertheless, the match between old statistical areas and substock boundaries is likely close enough to use the catch split from “The Wetfish Report” to apportion SNA 1 landings among substocks. The percentage split by statistical area varied little over the 11-year period 1960–70:

Area 2: 17–20% (mean 19%)
Area 3: 54–59% (mean 56%)
Area 4: 22–29% (mean 25%).

The mean percentages for Areas 2, 3 and 4 were used to apportion 1960–70 SNA 1 landings among East Northland, Hauraki Gulf and Bay of Plenty respectively. In the absence of any information on the spatial distribution of catches before 1960, the same percentages were applied to SNA 1 landings for 1900–1959.

The historical SNA 1 commercial catch time-series was divided into four method fisheries: longline; single bottom trawl; pair bottom trawl; and Danish seine. Catches from “other” commercial methods (predominantly setnet) were not explicitly modelled but the catch totals were pro-rated across the fisheries in the same area. Information on specific catching methods becomes increasing less reliable prior to 1973 so the area catch method splits from the early 1970’s were applied back into to 1900.

As was done for the 2000 and 2012 assessments; commercial catch totals prior to the 1986 QMS year were adjusted upwards to account for an assumed 20% level of under-reporting. Catch totals post QMS were likewise scaled assuming 10% under-reporting (Figure 4 &5).

Estimation of foreign commercial landings

In the 1997-98 SNA 1 assessment (Davies 1999), the foreign (Japanese longline) catch was assumed to have occurred between 1960 and 1977, with cumulative total removals over the period at three alternative levels: 20 000 t, 30 000 t and 50 000 t. The assumed pattern of catches increased linearly to a peak in 1968 then declined linearly to 1977; the catch was split evenly between east Northland and the Hauraki Gulf/Bay of Plenty. For the current assessment the base case level of total foreign catch for the current between 1960 and 1977 was assumed to be 30 000 t, catch apportioned among the three substocks in the ratio 50% East Northland, 10% Hauraki Gulf and 40% Bay of Plenty and added to the domestic longline method totals.

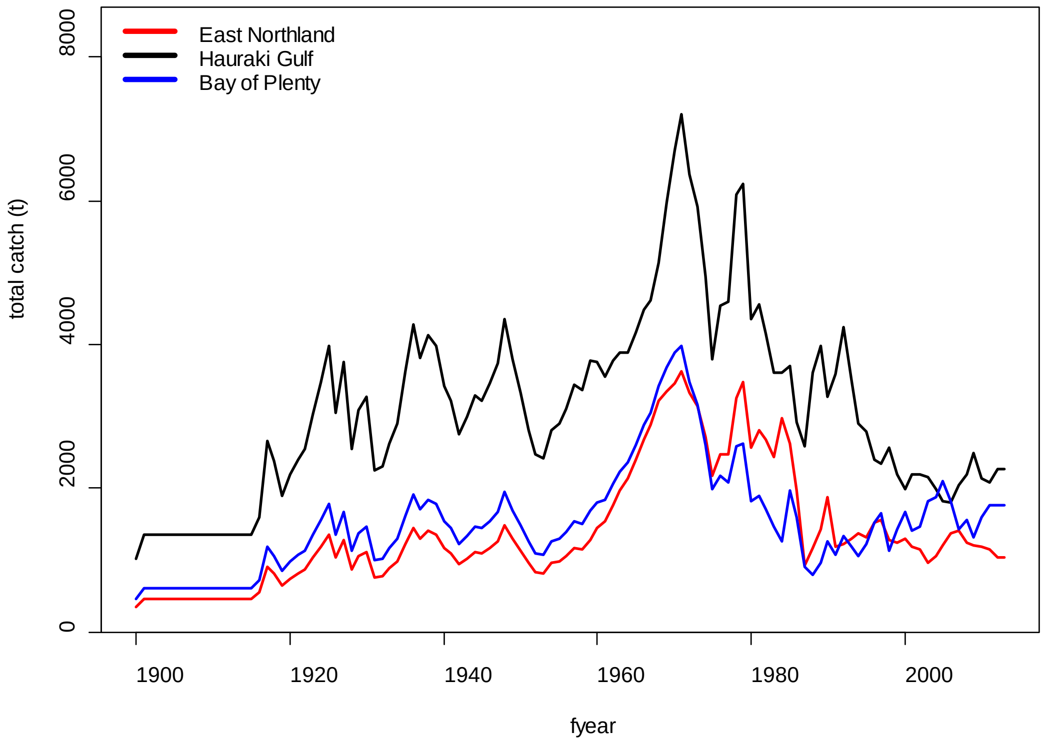


Figure 4: Commercial catch histories by area (adjusted for under-reporting) plus foreign catch used as input to the 2013 SNA 1 assessment model.

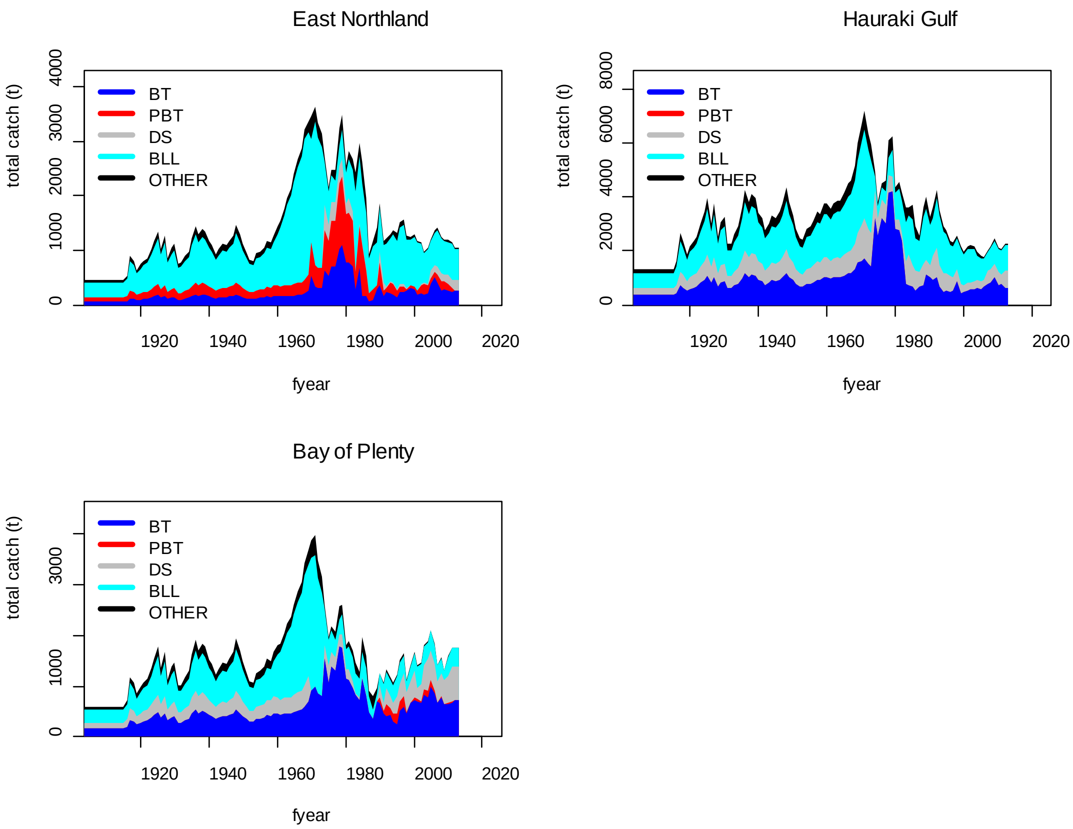


Figure 5: Commercial catch histories by method and area (adjusted for under-reporting) used as input to the 2013 SNA 1 assessment model.

5.1.3 Abundance indices

Trawl surveys

Trawl surveys were carried out in all three areas between the mid-1980s to 2000. Unfortunately, the only area for which a viable series of abundance estimates exists is the Hauraki Gulf. An index of relative numbers of fish surveyed from the Hauraki Gulf trawl survey series was fitted in the model and was assigned an overall CV of 0.15 (Table 14).

Longline CPUE

CPUE indices for the fishing years 1989-90 to 2011-12 were derived using data from bottom longline fisheries operating in the East Northland, Hauraki Gulf and Bay of Plenty areas within SNA1 (see also McKenzie & Parsons 2012). Data for years prior to 2007-08 were fisher daily amalgamated catch totals, i.e. catch per day. After 1 October 2007 longline fishers were required to report catch and effort on a per set or event basis. Combining the data required aggregating the more detailed post 2007 data at the daily catch level. The validity of doing this was explored by looking for discontinuities in the annual median number of hooks reported by the core vessels over the form change interval. It was concluded combining the two data series in a single analysis was appropriate.

Analysis was restricted to a subset of "core" vessels. The vessel selection process sought to:

- minimise number of vessels in the analysis;
- maximise proportion of total longline catch: threshold set at 60%;
- maximise number of years in the fishery;
- maximise number of trips per year average.

Standardised CPUE indices were derived as the coefficient of the year covariate in a log-linear regression model of daily log-catch (kg). Other variables offered to the model were vessel-id, target, month, statistical area, number of hooks and number of sets (refer McKenzie & Parsons 2012). Parameters selected by the model are given in Table 15.

Alternative analyses were undertaken, using more vessels, to include at least 80% of the total longline catch for the last five years. These analyses produced results consistent with those using fewer vessels and less of the catch suggesting the derived standardised indices were relatively insensitive to the core vessel selection and the proportion of the total longline catch included.

The pattern in nominal (unstandardised) longline CPUE shows increasing trends in all three areas (Figure 6). Increasing trends in the standardised CPUE indices are also seen in the Hauraki Gulf and Bay of Plenty areas, however, the increase in Hauraki Gulf abundance is less steep than the unstandardised indices (Figure 6). The difference between the standardised and unstandardised longline indices is most pronounced for East Northland with the standardised indices being much flatter (Figure 6).

Table 15: Parameters (covariates) selected in the log-linear model standardisation of daily log-catch from longline (log catch-per-day) and bottom trawl (log catch per unit tow) by area along with the proportion of variance explained (model R-square) by the addition of each successive term (model R-square).

Long Line

East Northland

parameter:	Fyear	log (number_of_hooks)	vessel	month	target
model R-square:	0.06	0.30	0.35	0.39	0.41

Hauraki Gulf

parameter:	Fyear	log (number_of_hooks)	vessel	month
model R-square:	0.08	0.34	0.44	0.49

Bay of Plenty

parameter:	Fyear	vessel	log (number_of_hooks)	target
model R-square:	0.07	0.43	0.53	0.57

Bottom Trawl

Bay of Plenty

parameter:	Fyear	target	vessel	depth	month	stat-area
model R-square:	0.01	0.10	0.15	0.17	0.19	0.21

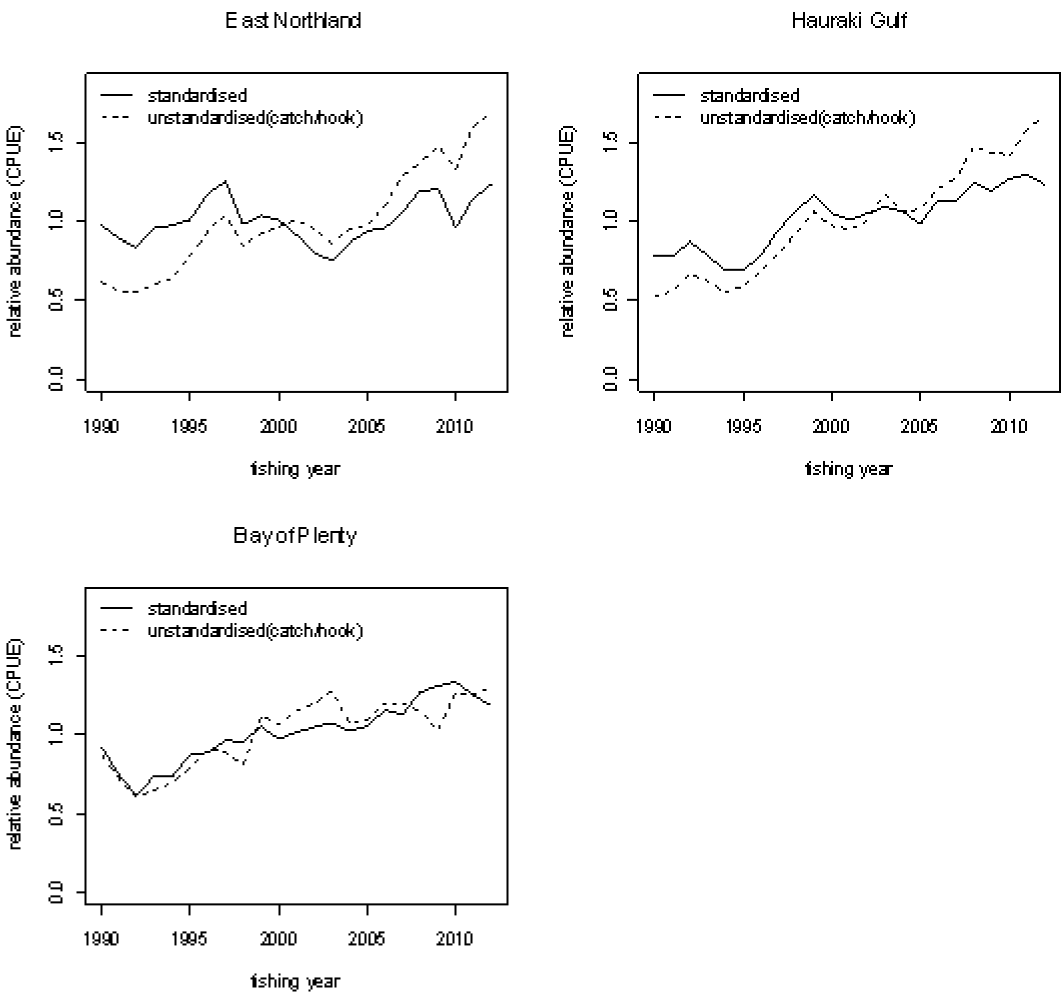


Figure 6: Longline CPUE indices of abundance (unstandardised & standardised) from 1990-2012 for the three component stocks of SNA 1

The area specific longline CPUE indices were fitted by the 2013 model, with each series assigned overall cv of 0.15.

Bay of Plenty single trawl CPUE

The Bay of Plenty single trawl CPUE data were available from fishing years 1989-90 to 20011-12 (23 year time series). However, three different catch effort form types have been in use during this period, partially limiting the temporal continuity of the series. Prior to the 1997-98 fishing year the majority of Bay of Plenty trawl fishers were using the less detailed daily CELR reporting forms. From 1995-96, however, a significant number of Bay of Plenty trawl fishers (>70%) were reporting on Trawl Catch Effort Processing Returns (TCEPR) that provide effort details as well as latitude and longitude information for each tow. From the 2007-08 fishing year many Bay of Plenty trawl fishers moved onto the new Trawl Catch Effort Return (TCER) forms. The TCER forms are largely identical to the TCEPR forms but require catch details of the top 8, not 5, species to be recorded. It was decided not to include the CELR data in the CPUE standardisations and only to include years where a high proportion of TCEPR and TCER data were available; specifically 1995-96 through 20011-12 fishing years (17 year time series).

As with the longline analysis both standardised and unstandardised CPUE indices were derived. In the unstandardised analysis CPUE was simply catch per tow, in the standardised analysis was log catch per tow (positive catches only). The following continuous effort variables were considered in the model selection (standardisation) process: Log (fishing duration); Log (net height); Log (net width); Log (gear depth); Log (engine power); Log (vessel length*depth*breadth). Categorical variables considered were: fishing-year (forced); month; season (4), vessel; and statistical-area.In the Bay of Plenty trawl fishery 98% of the snapper catch is taken targeting five main species: SNA, TRE, TAR, GUR and JDO). Therefore “target” was included in the standardisation as a six level categorical variable (five target species plus an “other” category) (refer McKenzie & Parsons 2012 for details). Parameters chosen by the standardisation procedure are given in Table 14.

The standardised CPUE indices suggest the Bay of Plenty trawl fishery experienced a slight increase in abundance between 1996 and 2008 and more recently from 2009-11 (Figure 7).

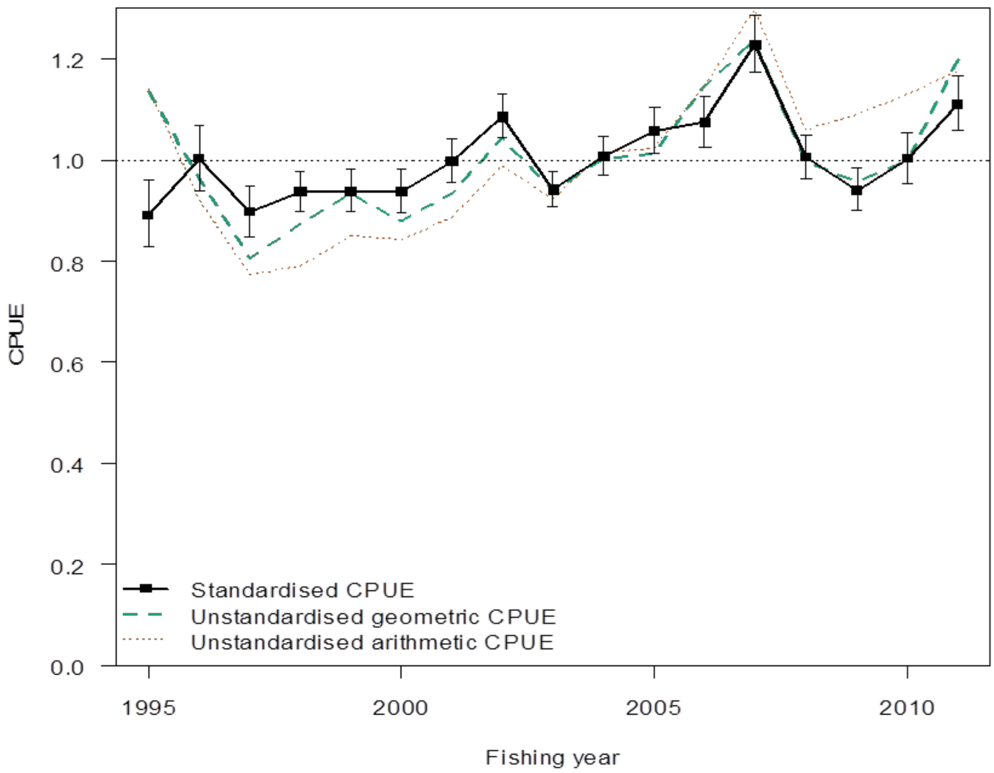


Figure 7: Single trawl CPUE indices of Bay of Plenty area abundance (unstandardised & standardised) from 1996-2012

The single trawl Bay of Plenty CPUE was fitted with assigned overall cv of 0.15 (section below; Table 14).

5.1.4 Catch at age and length observations

Commercial data

Catch-at-age observations from single trawl, Danish Seine and longline are available from the Bay of Plenty and Hauraki Gulf stocks; longline only for east Northland (Table 14).

Catch-at-age sampling since 1985 in East Northland shows a greater accumulation of fish older than 20 years than observed in the Hauraki Gulf or Bay of Plenty sub-stocks (Figures 8-10). The Bay of Plenty long line age composition is similar to SNA 8, with the fishery largely comprised of only 4-6 dominant age classes with few fish older than 20 years present in the catch samples (Figure 10).

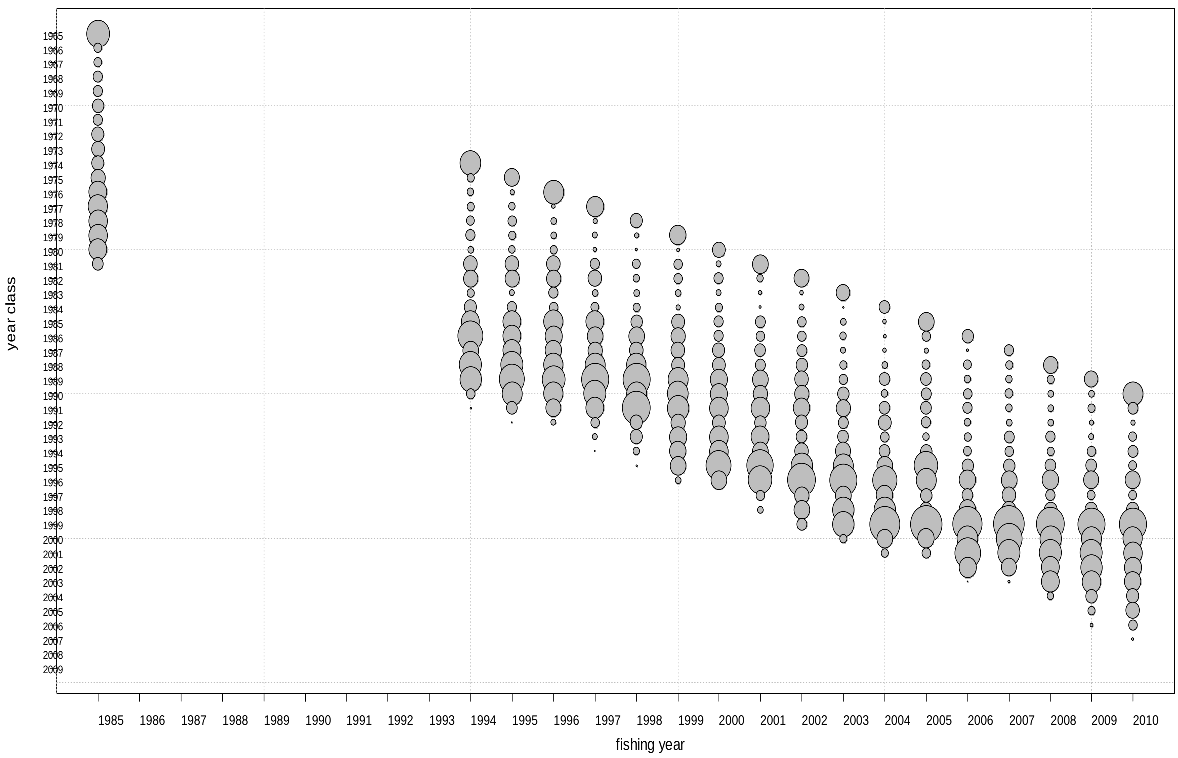


Figure 8: Relative year-class strength observed in the east Northland longline fishery 1984-85 - 2009-10. Year on the X-axis refers to the second part of the fishing year. The oldest year class is a 20+ group.

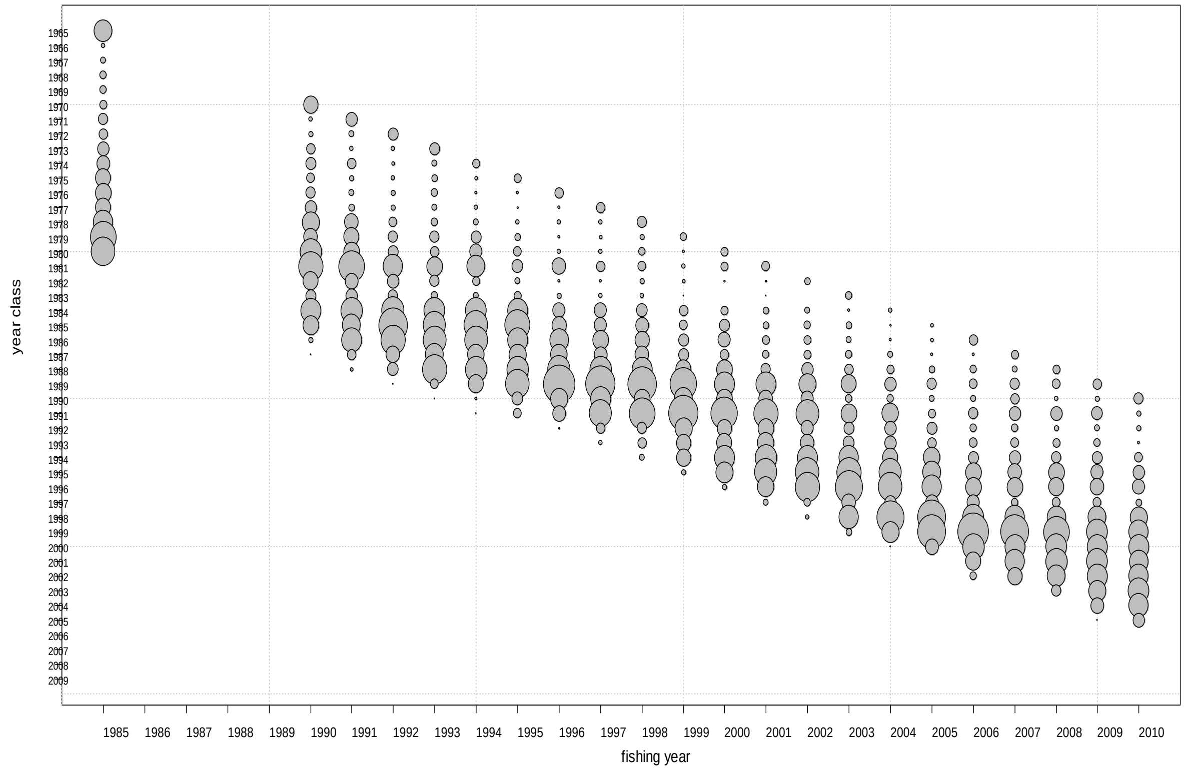


Figure 9: Relative year-class strength observed in the Hauraki Gulf longline fishery 1984-85 - 2009-10. Year on the X-axis refers to the second part of the fishing yearThe oldest year class is a 20+ group

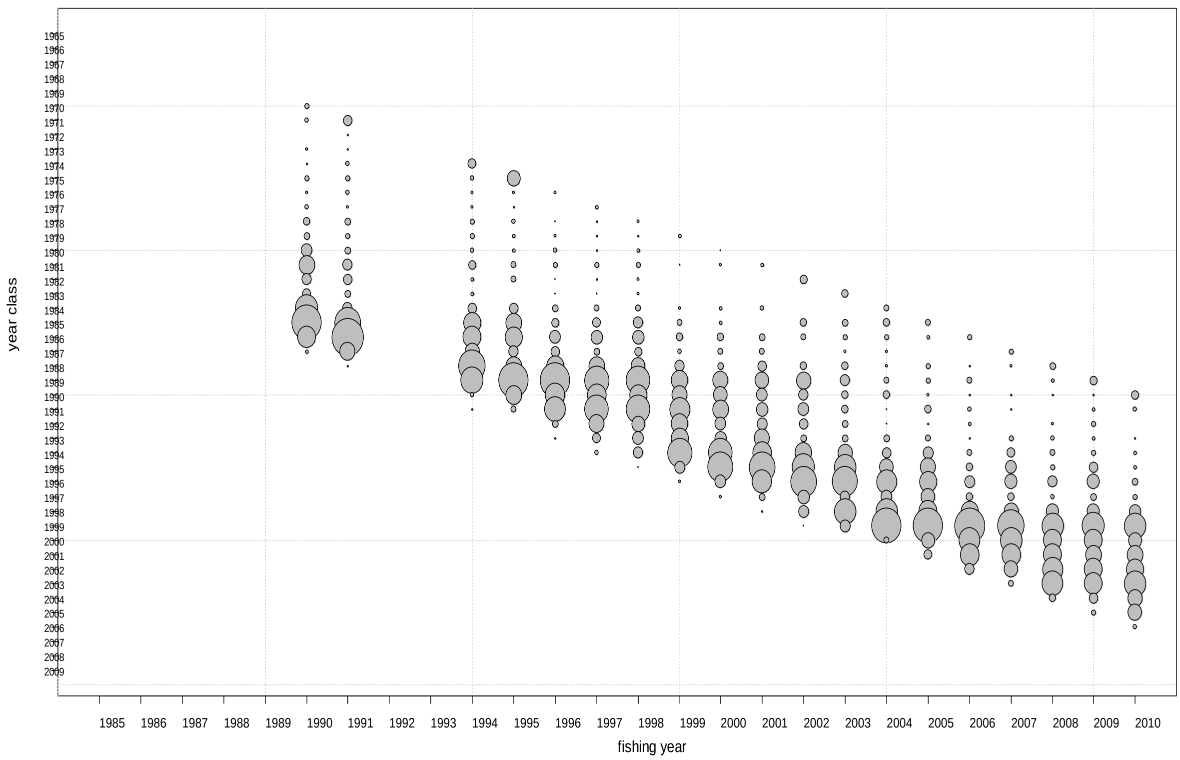


Figure 10: Relative year-class strength observed in the Bay of Plenty longline fishery 1990-91 - 2009-10. Year on the X-axis refers to the second part of the fishing year. The oldest year class is a 20+ group.

Recreational data
Observations of recreational catch at length are available for most years 1990, spanning the 1994 change in minimum legal size (Table 14).

Research Trawl data
Catch-at-age observations from research trawl surveys are available for most surveys and fitted in the model for all areas (Table 14).

5.1.5 Snapper 1983, 1985 and 1994 tagging programmes

Analysis of past snapper tagging programmes revealed a number of sources of bias that need to be accounted for if these data are to be used for assessment purposes. Data from the 1985 and 1994 tagging programmes were corrected for bias and input directly into the assessment model. Data from the 1983 Bay of Plenty tagging programme were unavailable. The published biomass estimate (6000 t Sullivan 1987) was fitted in the model as a point estimate but given a high cv (0.4) in recognition the likely inherent but unaccountable biases in the data.

Initial mortality
The release data were adjusted for initial mortality outside the model using methods given in Gilbert & McKenzie (1999).

Tag-loss
The effect of tag-loss was only an issue for the 1983 and 1985 tagging programmes where external tags were used. A revised estimate of tag loss was derived from a double-tagging experiment in 1985.

Trap avoidance
Trap avoidance was found to occur for both trawl and longline tagged fish (Gilbert and McKenzie 1999), the result of this was that released fish were less likely to be recaptured using the same method.

Trawl and longline methods were used to tag fish in both the 1985 and 1994 tagging programmes. The CASAL models used the scaling factors derived by Gilbert and McKenzie (1999) to adjust the tagging data for trap-avoidance.

Detection of recaptured tags
Because a fishery independent tag recovery process was used in the 1994 programme, a reliable estimate of tag under-detection was obtained. The model was provided this estimate to adjust the 1994 tag recovery data.

The recovery of tags in 1983 and 1984 programmes relied on fishers to voluntarily return tags. Estimates of under-reporting from these programmes are less precisely known but were assumed to be 15% (1988 Snapper Plenary Report).

Differential growth of tagged fish
There is evidence that tagged fish may stop growing for 6 months after tagging (Davies *et al*. 2006).The growth differential between tagged and untagged fish may bias results as the model will expect these fish to be larger than they are. As it was not possible to incorporate this source of bias in the model, it was assumed that, given the majority of tags recovered in both programmes came from the first year after release, growth bias would be minimal.

Spatial Heterogeneity
A primary objective when tagging fish for biomass estimation is to ensure homogeneous mixing of tags within each spatial stratum so that the probability of recovering a tagged fish is the same in all locations. Spatial heterogeneity impedes realisation of this objective. The potential bias caused by spatial heterogeneity may be high or low as it depends largely on the spatial distribution of recapture effort (i.e. fishing) within the spatial stratum. Heterogeneity was observed in both tagging programmes as mark rates varied amongst statistical areas and methods; and was most apparent in the 1994 Hauraki Gulf Danish seine catches (Gilbert & McKenzie 1999). The results of simulation

modelling using Hauraki Gulf data from the 1994 programme showed that under scenarios where the difference in the spatial mark-rates was high (up to 4-fold) and catch examination tonnages were spatially disproportionate, the level of bias (+/-) in the biomass estimate could be as high as 35% (Davies *et al.* 1999b). However for scenarios where fishing was more uniform across strata, the expected level of bias was likely to be only 10%. To further investigate potential bias introduced by heterogeneity in the 1994 tagging programme, fish tagged and released by the Hauraki Gulf Danish seine fishery were excluded from the analysis. This increased the 1995 Hauraki Gulf biomass estimate by 15%, from 30 000 t to 34 000 t (Davie *et al.* 1999a). Evidence for spatial heterogeneity in East Northland and the Bay of Plenty was much weaker than for the Hauraki Gulf (Gilbert & McKenzie (1999). For the 2013 stock assessment all tag recovery data are used, including Danish seine recoveries from the Hauraki Gulf.

5.1.6 Stock Assessment Results

Spawning biomass by stock and by area and for HAGUBOP

Two versions of spawning-stock biomass (SSB) are presented in the following results. The first, labelled "by stock", is calculated in the conventional way (in the model time step 1 – when spawning occurs and all fish are in their home grounds); the second, labelled "by area", is calculated half-way through the mortality in time step 2, when some fish are away from their home ground. The former is the usual SSB, but the latter is better estimated and may be more relevant for management purposes.

Some SSB results are also presented for the Hauraki Gulf and Bay of Plenty combined (labelled HAGUBOP by stock, or HGBP by area) because there is some doubt about the relationship between fish in these two areas.

Base model

The base model MPD achieved good fits to the abundance data and reasonably good fits to the composition data. The fit to the tag-recapture data was negatively affected by a conflict between these data and the age compositions which caused an imbalance in the fits to the tag-recapture data: the observed tag rate (the proportion of fish with tags) was greater than the expected rate in 23 of the 26 data sets. Although the expected rate lay within the 95% confidence bounds in all but three data sets, this result indicates that the model is unable to fit the tagging data well. Issues with the original tagging data and analyses have been identified elsewhere (Gilbert et al 1999; Davies et al 1999b).

All estimated spawning biomass trajectories show substantial reductions up to 1999 (for East Northland) or about 1988 (for other stocks and areas), and then some increase thereafter (Figure 11, upper panels). In terms of current biomass, both the stock BOP and area BP are estimated to be more depleted (3–10% B_0) than the other stocks and areas (15–30% B_0) (Table 15). However, for all stocks and areas current biomass is 30–68% higher than its minimum value (Table 16). Stock HAGU and area HG are estimated to contain a much greater tonnage of fish than the other stocks and areas, both over the period of the assessment (Figure 11, upper panels) and in their unfished state (Table 15). ENLD/EN and BOP/BP are estimated to have contained broadly similar tonnages 53 000 to 112 000 t) before the fishery started; which was estimated to be the larger depends on whether we are considering the biomass by stock or by area.

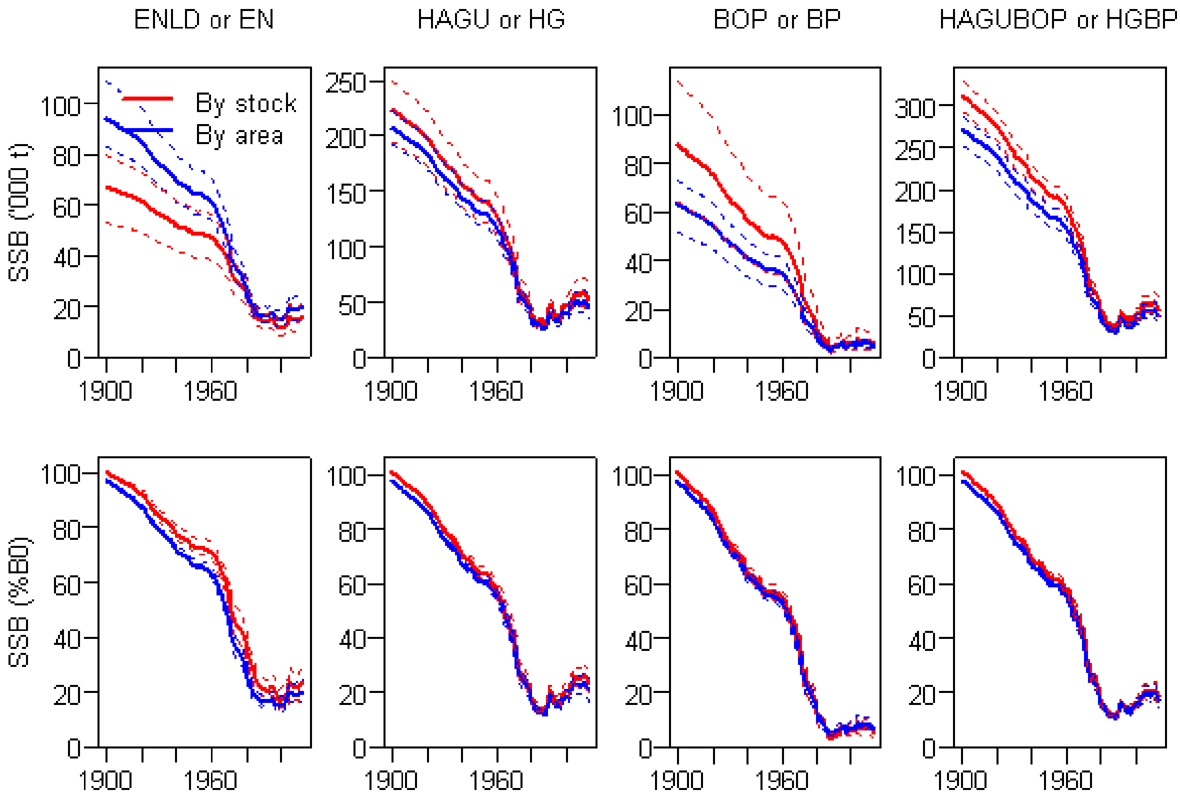


Figure 11: SSB trajectories by stock (red lines) and area (blue lines) from the base model. Solid lines are MCMC medians, broken lines are 95% confidence intervals.

Table 16: Base model estimates of unfished biomass (B_0) and current biomass (B_{2013} as $\%B_0$ and $\%B_{min}$) by stock and area. Estimates are MCMC medians with 95% confidence intervals in parentheses.

	B_0 ('000 t)	B_{2013} ($\%B_0$)	B_{2013} ($\%B_{min}$)[1]
By stock			
ENLD	66 (53, 79)	24 (18, 30)	137 (108, 176)
HAGU	220 (192, 246)	24 (19, 29)	168 (137, 206)
BOP	86 (63, 112)	6 (3, 9)	148 (104, 209)
HAGUBOP	306 (288, 325)	19 (15, 23)	167 (139, 201)
By area			
EN	96 (85, 111)	20 (16, 25)	130 (108, 159)
HG	211 (197, 227)	21 (17, 26)	167 (136, 204)
BP	64 (53, 74)	7 (5, 10)	145 (114, 185)
HGBP	276 (258, 292)	18 (15, 22)	165 (136, 199)

[1] B_{min} was taken as B_{1999} for ENLD and EN, and as B_{1988} for other stocks and areas

The majority of fish do not move away from their home grounds, with migration being most common for BOP fish and least common for ENLD fish (Table 17). Uncertainty in the proportion migrating is greatest for fish from BOP. The estimated proportion migrating from BOP to ENLD appears to be unrealistically high when compared to the observed movements of tagged fish.

In all areas current exploitation rates by method are estimated to be highest for the recreational fishery (Figure 12). Fishing intensity is estimated to be highest in BOP. For ENLD and HAGU fishing intensity declined from peaks in the 1980s, but has increased in the HAGU since 2007 (Figure 13). The fishing intensity for the HAGUBOP stock rose sharply from the early 1960s and reached a peak in the 1980s. It then declined by approximately 50% to 2007, but has since increased to 86% of the 1985 peak (Figure 13). Estimates of year-class strength are precise only for a relatively narrow range of years, particularly for ENLD and BOP, where catch-at-age data are sparser (Figure 14).

Table 17: Base case migration matrix (showing proportions of each stock migrating to each area in time step 2). Estimates are MCMC medians with 95% confidence intervals in parentheses.

Stock	Area EN		Area HG		Area BP	
ENLD	0.94	(0.89, 0.97)	0.05	(0.02, 0.10)	0.01	(0.00, 0.04)
HAGU	0.09	(0.05, 0.14)	0.87	(0.82, 0.91)	0.04	(0.02, 0.06)
BOP	0.17	(0.02, 0.36)	0.18	(0.07, 0.34)	0.63	(0.45, 0.83)

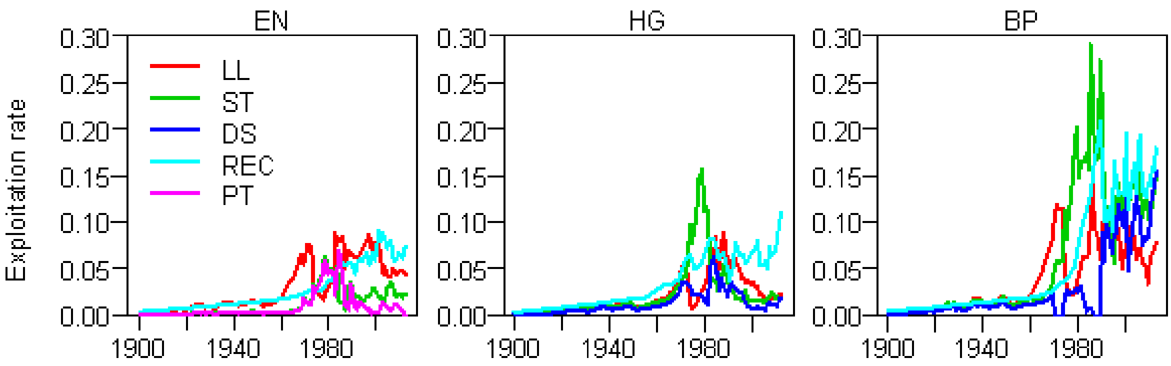


Figure 12: MPD estimates of exploitation rates by fishery and year.

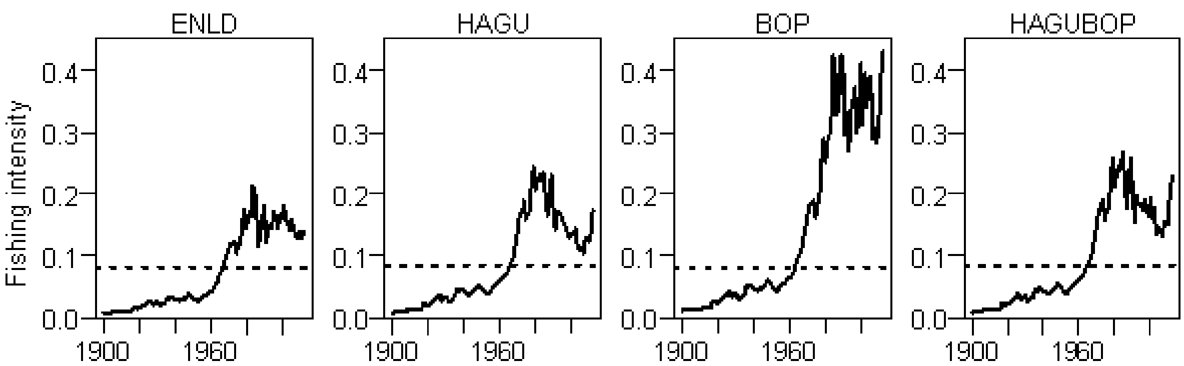


Figure 13: MPD estimates of fishing intensity by year and stock. Dotted lines show the intensity required to maintain the spawning biomass at 40%B_0 ($U_{40\%B0}$).

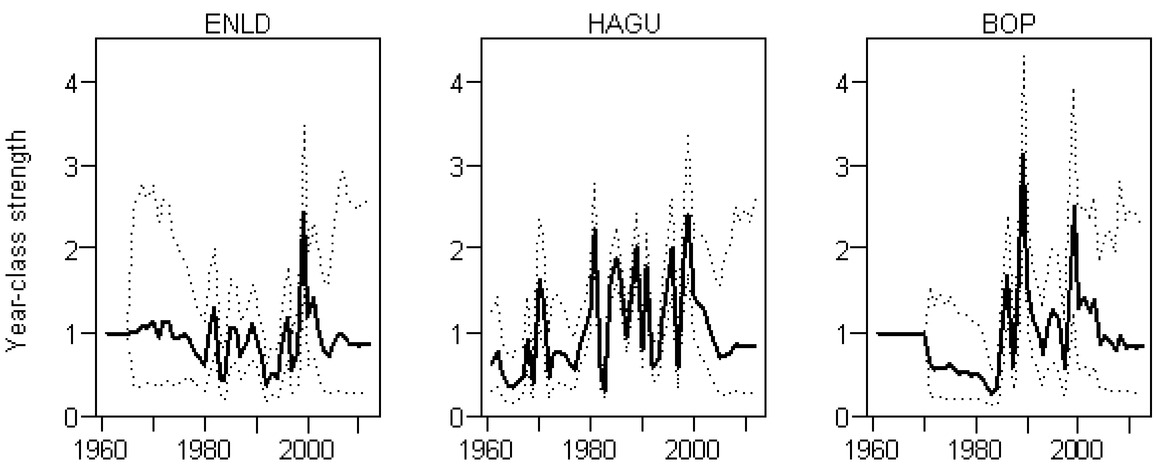


Figure 14: Estimated year-class strengths by year and stock (a value of 1 indicates that the year class has the strength predicted by the stock-recruit relationship). Estimates are MCMC medians (solid lines) and 95% confidence intervals (dotted lines).

No stock or area is at or above the target and none but the Bay of Plenty is below the hard limit. Probabilities of being below the soft limit range from 0.04 to 1.00 (Table 18).

Table 18: Probabilities, by stock and area, relating current biomass to the target (40%B_0) and limits (soft 20%B_0, and hard 10%B_0).

	ENLD/EN		HAGU/HG		BOP/BP		HAGUBOP/HGBP	
Probability	by stock	by area	by stock	by area	by stock	by area	by stock	by area
At or above target	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Below soft limit	0.12	0.52	0.04	0.34	1.00	1.00	0.74	0.89
Below hard limit	0.00	0.00	0.00	0.00	0.99	0.99	0.00	0.00

Sensitivity analyses

Many alternative models were constructed and run to determine the sensitivity of the assessment to various model assumptions (Francis & McKenzie draft b).

Some changes of assumptions had comparatively little effect on stock status. The following changes fall into this category: alternative levels of trap shyness and tag loss; allowing the initial (1900) biomass to differ from B_0; increasing the maximum age in the partition from 20 to 60; dropping tag-recapture data from Statistical Area 008 (the Bay of Plenty area closest to the Hauraki Gulf); and assuming that tagging in area BP occurred before HAGU fish in that area had returned home.

Two other alternative models were useful in demonstrating the sensitivity of the assessment to specific data sets. In one, the longline CPUE indices were replaced by their unstandardised values (which have quite different trends –see Figure 6), and in the other, the tag-recapture data were strongly down-weighted. In both cases there was a marked change in the estimated biomass trajectories; however, neither of these runs was considered to provide useful information on current stock status.

There are nine alternative models for which some results are presented (Table 19). Most of these alternative models are easily understood, but two merit more detailed description.

Table 19: Brief descriptions of nine alternative models run to determine sensitivity to various model assumptions.

Label	Description
catch-lo/hi	Use alternative lower and higher catch histories
sel-by-area[1]	Assume that fishery selectivity depends on area, as well as fishing method
reweight	Age and tag-recapture data reweighted to reduce imbalance in fit to tag-recapture data
M-lo/hi	Replace the assumed value of natural mortality, $M = 0.075\ y^{-1}$, with lower (0.05) and higher (0.10) values
steep-lo/hi	Replace the assumed value of stock-recruit steepness, 0.85, with lower (0.7) and higher (0.95) values
one-stock[1]	Replace the base three-stock (and three-area) model with 3 separate one-stock models: one for each area.

[1]MCMC runs were done for these sensitivities

The first, sel-by-area, was motivated by the observation that, for any given fishing method and year, the mean age (or mean length for recreational fisheries) of the catch was almost always lowest in area BP (Figure 15). In the base model this implied that the biomass was more depleted in BP than in the other areas because of the assumption that the selectivity of each fishing method is the same in all three areas. This assumption was removed in model sel-by-area (so a separate selectivity curve was estimated for each combination of fishing method and area). Sel-by-area was considered as an alternative base case but the overall stock status differed little from the base that was chosen when BOP and HG stock status results were combined.

The one-stock models were constructed because of uncertainty about stock structure and fish movement between areas. Although it is clear that fish spawn in all three areas and move between areas (as assumed in the base model) the complexity of this structure and movement is unlikely to be well represented in the base model. For example, the proportion of fish migrating between areas in the relatively few years of the tag-recapture data may not be representative of what happened in other years. Also, the assumptions that (a) all fish were in their home area at the time of tagging, and (b) all recaptures occurred during the period that migrating fish were away from home, are likely to be only approximately true. The one-stock models offer an alternative, and much simpler, way of analysing the available data. Each of these models may be thought of as being constructed from the base model in the obvious way, by removing the stock and area structures (and the associated migrations), and also the observations and fisheries that were associated with other areas. The only complicated part in this construction concerned the tag release and recapture observations (for details see Francis & McKenzie draft b).

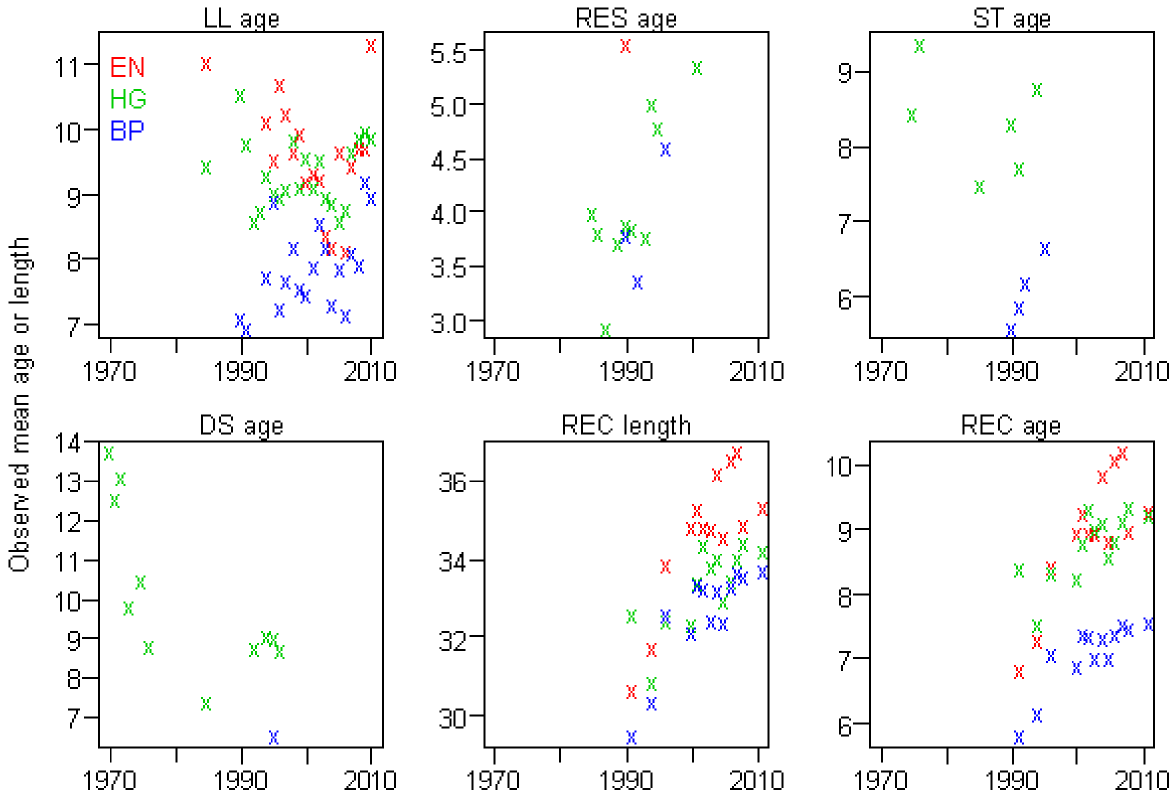


Figure 15: Observed mean age (for commercial fisheries and research surveys) or length (for recreational fisheries) by fishing method and area. In the bottom right-hand panel, the observed recreational mean lengths have been converted to ages using the mean length at age relationship (averaged over years 1994-2010) for each area.

Results of the sensitivity analyses are presented in terms of their effects on current status (Figure 16). Regardless of whether current status was measured by stock or by area, all models estimated the Bay of Plenty spawning biomass to be the most depleted, and most estimated that the Hauraki Gulf was least depleted. The greatest sensitivity was shown with model sel-by-area, which estimated much less depletion for the Bay of Plenty (current biomass was 14% B_0, compared to 6–7% B_0 in the base model), and model reweight, which estimated more depletion for the other areas. Estimates from sel-by-area were broadly similar to those from the one-stock models. Changes in both M and steepness had predictable effects (the same for all stocks and areas): lower values, which imply lower productivity, led to more depletion, and higher values to less depletion. Current status estimates were not very sensitive to alternative catch histories. Stock status was always slightly worse by stock than by area for Bay of Plenty, with the reverse being true for East Northland and Hauraki Gulf. Due to uncertainty about the relationship between BOP and HGU, stock status is also presented for the two stocks combined.

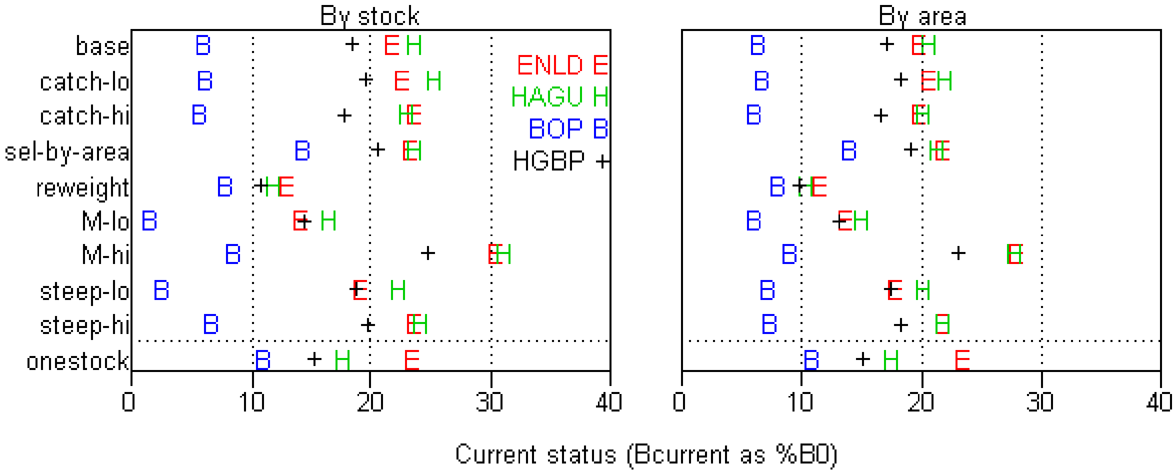


Figure 16: MPD estimates of current status (B_{2013} as $\%B_0$), by stock and area, for the base model and some sensitivity analyses. The horizontal broken line separates the one-stock estimates from the others as a reminder that there is no distinction between spawning biomass by stock and by area for these models.

5.1.7 Yield estimates and projections

Five-year projections of the base case were carried out under "status quo" conditions, which were taken to mean constant catches (equal to the 2012 and 2013 catches) for the commercial fisheries and constant exploitation rate (equal to the average of the 2008–2012 rates) for the recreational fisheries. In these projections, simulated year-class strengths (YCSs) were resampled from the 10 most recent reliably estimated YCSs (deemed to be 1995–2004). The simulated YCSs included both the recent YCSs that were not estimated (due to the lack of recent age composition data) in the MPD (2008–2012) as well as the five "future" YCSs (2013–2017).

With status quo catches the biomass is likely to continue to increase for all stocks and areas (Figure 17). These results changed only slightly when the future exploitation rate for the recreational fishery in HG was changed from 0.0779 (the average of the 2008–2012 rates) to 0.0648 (the average for 1995–2005) or 0.1089 (the rate for 2013). Projections from the one-stock and sel-by-area sensitivity models predicted increasing or near-stable biomass for all stocks and areas.

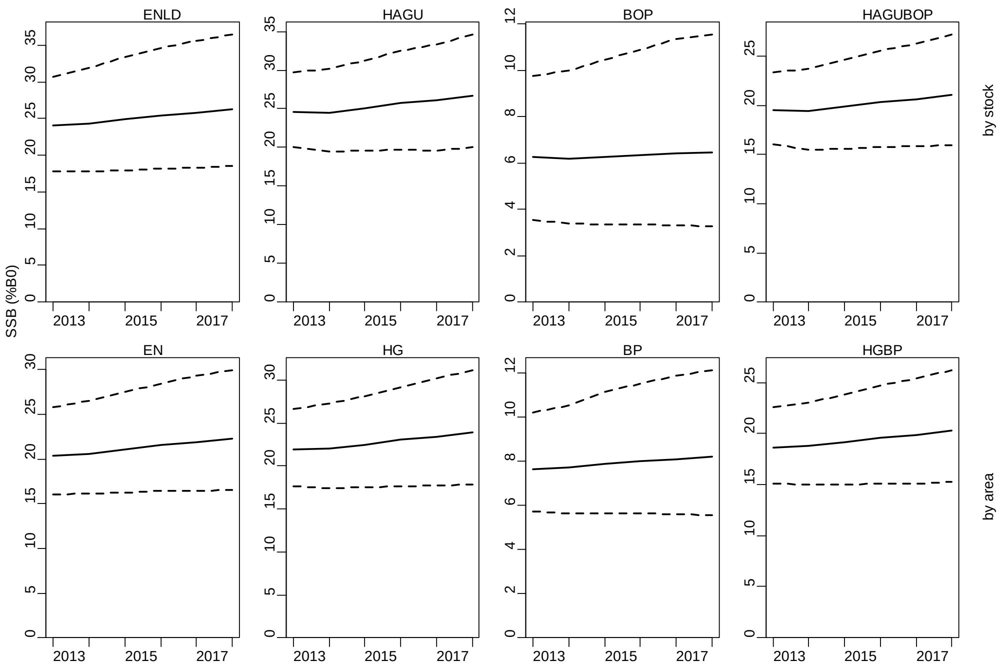


Figure 17: Projected spawning-stock biomass (SSB) by stock and by area. Estimates are MCMC medians (solid lines) and 95% confidence intervals (broken lines).

Deterministic B_{MSY}

Deterministic B_{MSY} was calculated as 25-26% B_0 for all individual stocks and areas and 30% for the combined Hauraki Gulf/Bay of Plenty. There are several reasons why B_{MSY}, as calculated in this way, is not a suitable target for management of the SNA 1 fishery. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge including perfect catch and biological information and perfect stock assessments (because current biomass must be known exactly in order to calculate target catch), a constant-exploitation management strategy with annual changes in TACs (which are unlikely to happen in New Zealand and not desirable for most stakeholders), and perfect management implementation of the TAC and catch splits with no under- or overruns. Second, it assumes perfect knowledge of the stock-recruit relationship, which is actually very poorly known. Third, it would be very difficult with such a low biomass target to avoid the biomass occasionally falling below 20% B_0, the default soft limit according to the Harvest Strategy Standard. Thus, the actual target needs to be above this theoretical optimum; but the extent to which it needs to be above has not been determined.

Results from the deterministic B_{MSY} calculations were used to determine the level of fishing that would maintain the spawning biomass at the interim target level of 40%B_0. This ranged from 19% to 59% of the 2013 level (Table 20).

Table 20: Estimated levels of fishing – expressed as multiples of 2013 exploitation rates – that would be required to maintain spawning biomass at 40%B_0.

ENLD	HAGU	BOP	HAGUBOP	
by stock	0.59	0.50	0.19	0.38
by area	0.55	0.46	0.21	0.38

5.1.8 Other factors

1. Uncertainty associated with some of the tagging assumptions is not explicitly incorporated into the model. Examples include confidence intervals on trap shyness, the duration of the mixing period, and clumping of recaptures (for example, higher recovery rates in 1994 Danish seine Hauraki Gulf catches).
2. A lack of recent catch-at-age data means that recent relative year class strengths were not available for projections of stock size. SNA1 is currently only sampled for catch-at-age every three years.

5.1.9 Research requirements

1. As there is uncertainty in the relationship between standardised CPUE and abundance, it is necessary to investigate options for fishery-independent abundance estimates, such as a new tagging study.
2. The utility of longline CPUE as an index of abundance should be investigated by comparing the series used for the stock assessment with alternative series modelled using finer-scale catch-at-age information collected since the introduction of new statutory forms (LCER) in 2007.
3. A better understanding of stock boundaries and movement dynamics in the Bay of Plenty and the Hauraki Gulf is required before these two areas may be reliably modelled as separate. The location of juvenile nursery areas, particularly in the Bay of Plenty, would also be useful in this regard.
4. The sensitivity of the model to all forms of bias and uncertainty in the 1985 and 1994 tagging data, in particular spatial heterogeneity and trap avoidance, needs to be investigated.
5. A detailed evaluation of the interaction between growth and selectivity in each stock/area should be undertaken.
6. The optimal frequency of catch-at-age monitoring should be evaluated. The current three year cycle constitutes a 2/3 reduction in the number of independent observations available for any given year-class over annual sampling (i.e. is a loss of precision), and also may delay, by up to three years, our first awareness of extreme recruitment events. If both SNA 1 stock assessments catch-at-age sampling are to be conducted on a three year cycle, it is important

that the assessment be timed for the year following the latest catch-at-age study. This would provide for more reliable projections.

5.2 SNA 2

Previous assessments of SNA 2 were done by Harley & Gilbert (2000) and Gilbert & Phillips (2003). A stock assessment for SNA 2 was done in 2009 (Langley 2010). The model incorporates seven years of catch at age data sampled from the commercial fishery between 1991-92 and 2007-08 and a standardised CPUE index for the bottom trawl fishery for the recent period of the fishery (1989-90 to 2008-09).

5.2.1 Model data sets

CPUE indices

A series of standardised indices were derived from the inshore trawl fishery for 1989-90 to 2008-09 (Kendrick & Bentley In press). These indices were accepted by the NINS WG; however, given that the indices are principally derived from a bycatch fishery, there are concerns that the indices are likely to be influenced by changes in regulations affecting the fishery. For example, the decline in the CPUE indices in the two most recent years may be attributable to changes in targeting behaviour caused by a considerable increase in the deemed value for SNA 2. Therefore, the resulting CPUE indices are unlikely to be a reliable index of abundance. In addition, the CPUE indices reveal a very large decline in the early years of the time series. These observations are inconsistent with the observed age frequency data from the fishery and the underlying population dynamic of the species.

Catch at age data

Seven years of age frequency data are available from the commercial fishery. There is considerable variability in the age compositions among years which is likely to be due, in part, to the sampling of the snapper bycatch from a number of different target fisheries. The age compositions are principally comprised of younger age classes and few old fish are sampled from the catch. Consequently, the age frequency distributions are likely to be uninformative regarding the cumulative impact of fishing mortality on the underlying population age structure. There are also concerns regarding the representative nature of the sampling and comparability of the ageing in earlier years.

Commercial catch

The pre-QMS catches are assumed to include a level of unreported catch (equivalent to 20%) of the reported catch. Following the introduction of the QMS, the unreported catch was assumed to be 10% of the reported catch in 1986 and then decline by 1% annually to 1996 and maintained at that level for the remainder of the model period.

Recreational catch

Four 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). The more recent recreational catch estimates (for 2000 and 2001) were substantially higher and were considered to be less reliable and consequently were not used.

Recreational catches from 1933-2008 were assumed using a step function that increased catches from 0 in 1933 by 5 t every 10 years with an annual catch of 45 t in the last decade. The assumed catch history was consistent with the lower estimates of recreational catch obtained in the 1990s.

Customary non-commercial catch

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

5.2.2 Model structure

A statistical, age-structured population model was implemented using the Stock Synthesis (Methot 2009). The model encompasses the 1933-2009 period. The model structure includes two sexes, 1-19 year age classes, and an accumulating age class for older fish (20+ years). The age structure of the population at the start of the model is assumed to be in an unexploited, equilibrium state.

The total annual catch is attributed to a single fishery and the CPUE indices represent an index of the vulnerable component of the population. There is considerable variability in the age frequency data among years and, consequently, these data were assigned a relatively low weight in the total objective function (sample size of 50).

Preliminary model runs revealed that the model was highly sensitive to the assumptions regarding fishery selectivity. Two initial scenarios were considered: full selectivity of the older age classes (logistic selectivity) or estimation of the age selectivity of the older age classes (double normal). The double normal selectivity resulted in a very low selectivity for the older age classes and a very optimistic current stock status, although this was largely attributable to the model estimating a large, cryptic component of the population.

It was considered that there was insufficient information content in the age frequency data to estimate the selectivity of the older age classes due to confounding with fishing mortality. On that basis, it was decided to adopt an externally derived selectivity function. The selectivity of the Bay of Plenty SNA 1 single bottom trawl fishery (Gilbert *et al.* 2000), modified to account for the more rapid growth of younger snapper in SNA 2, was applied to define the selectivity of the older age classes. The selectivity of the younger (1-5 year) age classes was based on the age-specific estimates of selectivity obtained from the double normal selectivity model.

It is important to note that the model results, particularly current stock status, are highly dependent on the selectivity function applied and, consequently, should be considered very uncertain. The model results were also highly sensitive to the relative weighting assigned the CPUE indices and the age frequency data. For this reason, the estimates of current stock status from the model are not reported. Nonetheless, other model stock indicators (particularly estimates of *MSY*) were less sensitive to the selectivity assumption and the model is likely to be more informative regarding estimates of yield.

Model assumptions:

- Natural mortality $M = 0.075\ y^{-1}$ or $0.06\ y^{-1}$,
- Deterministic recruitment for 1933-1984 and 2003-09 assuming no stock recruitment relationship. Recruitment deviates estimated for 1985-2002 assuming a standard deviation of the natural logarithm of recruitment (σ_R) equal 0.6,
- Fishery selectivity was temporally invariant and fixed based on an externally derived selectivity function.
- SNA 2 specific growth parameters (Table 20).

Two model runs are presented based on the alternative values assumed for natural mortality.

Model uncertainty was estimated using a Markov chain Monte Carlo (MCMC) approach. However, the model is highly constrained by the assumptions that the key parameters (selectivity, M, and growth) are known without error and, therefore, the level of uncertainty is greatly under-estimated. The resulting estimate of virgin, equilibrium recruitment (R_0) is largely dependent on the historical catch history.

Current stock status is unknown and therefore stock projections are not considered informative.

5.2.3 Results

The model fit to both the age composition data and the CPUE indices is poor. There is a clear conflict between the two data sources as evidenced by the fit to the most recent years' data; the model fits the recent decline in the CPUE indices only by estimating lower year class strengths than evident in the commercial age frequency observations. Conversely, the model is unable to fit to the strong decline in the CPUE indices in the early 1990s given the observed age compositions.

The biomass trajectory derived from the model displays a strong decline in biomass during the 1960s and 1970s concomitant with the higher levels of catch during the period (Figure 18). The estimated biomass trajectory is highly constrained throughout this period and during the preceding years due to structural assumptions of the model, principally the fixed selectivity, deterministic recruitment and fixed biological parameters. The model is essentially estimating a R_0 that is consistent with these assumptions and thereby yields a minimum level of virgin biomass necessary to support the historical catches under the assumptions of deterministic recruitment.

Table 20: The median and 5 and 95 percentiles of the marginal posterior distributions for SNA 2 model runs assuming different values for natural mortality (Steepness = 1). B_0 is the virgin biomass (mature female); B_{MSY} is biomass at *MSY*; *MSY* is maximum sustainable yield and includes under-reporting and non-commercial catch. The current stock status is very uncertain and, consequently, not reported (see text for details).

Run	B_0	B_{MSY}	*MSY*	B_{MSY}/B_0
M 0.075	8,669 (8,583-8,816)	1,650 (1,634-1,678)	496 (491-505)	0.190 (0.190-0.190)
M 0.06	9,228 (9,166-9,314)	1,798 (1,786-1,815)	443 (440-447)	0.195 (0.195-0.195)

The fishing mortality rates derived from the model in the more recent period are determined, in part, by the observed age composition and the assumed selectivity function. Consequently, the assumed selectivity function has considerable influence on the estimates of current stock status. Further, given the conflict between the data sources, the relative weighting of the CPUE and age frequency data is also highly influential. On that basis, estimates of current stock status are not considered reliable and it is not possible to make conclusions regarding current stock status from the assessment models.
Nonetheless, for the range of model options investigated, the estimates of *MSY* are comparable. This is attributable to the similar estimates of R_0 (and therefore B_0) among the various model options. Again, the estimates of virgin biomass are consistent with the minimum biomass levels necessary to support the catch history during the period prior to the mid 1980s.

5.2.4 Yield Estimates and projections

Maximum Sustainable Yield (*MSY*)
The two models yielded median values of *MSY* of 496 t and 443 t for the higher (*M* = 0.075) and lower (*M* = 0.06) natural mortality scenarios, respectively. The *MSY* estimates are highly constrained due to the structural assumptions of the model and the confidence intervals do not represent the high uncertainty associated with the yield estimates. These yield estimates are likely to be conservative as they are based on estimates of R_0 that approach the minimum level of (deterministic) recruitment necessary to support the historical catches from the stock. Conversely, the models will over-estimate yields to the extent that the historical catches have been over-estimated i.e. the allowance for 20% over-catch of the reported catch.

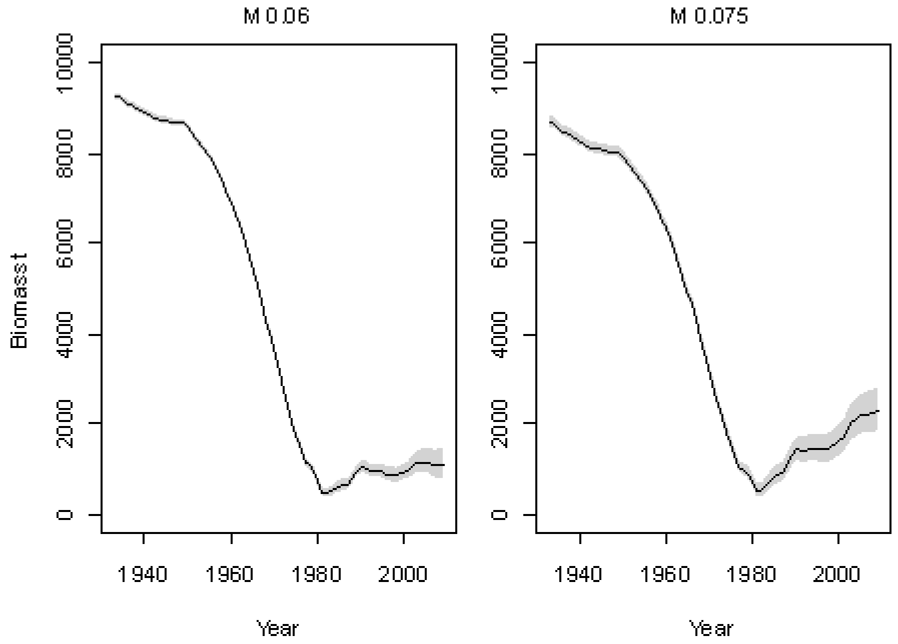


Figure 18: Biomass (median and 90 percentiles of the posterior distribution) for SNA 2 with the alternative assumptions of lower (0.06) and higher (0.075) natural mortality. Biomass is defined as mature, female biomass.

5.3 SNA 7 (Challenger)

5.3.1 Stock Assessment

A stock assessment of SNA 7 was undertaken in 2002 (Gilbert & Phillips 2002) (see 2008 Plenary for details). This assessment was externally reviewed in 2006. Based on that review, the Snapper Working Group concluded (25 September 2006) that the model was depicting the 2001 SNA 7 biomass at an unrealistically high level (100-200% B_{MSY}) and rejected the results of the assessment. This was largely a result of the model using long-term historical catch (since 1930s) to estimate initial biomass. The historical catch data indicated that the initial biomass was large and that the associated productivity would be expected to be high under average recruitment. Based on the 1986-88 tag estimate of absolute biomass and low catches, the stock was assumed to have collapsed, and the TACC was reduced. Current catch levels are below the expected level of productivity predicted by the model, which suggests that the stock should be rebuilding. This prediction has not been corroborated by catches or other information external to the model.

At that time the Working Group concluded that an assessment should not be repeated for SNA 7 until a reliable index of abundance is available.

5.3.2 Index of Abundance

A characterisation of the SNA 7 fishery identified three fisheries operating in Tasman Bay/Golden Bay that could potentially provide indices of abundance (Hartill & Sutton 2011). These were the trawl fisheries targeting SNA, FLA, and BAR. Although standardised indices derived from all three fisheries showed a high degree of interannual variability, the general long-term trend was broadly the same,. The characterisation suggested that all three fisheries could potentially interact with different components of the wider stock, both spatially and temporally. The Southern Inshore Working Group suggested that catch data from all three fisheries should be combined into a single model that explicitly considered the manner in which these fisheries might interact with the components of the Tasman Bay/Golden Bay snapper stock. The resulting combined fishery CPUE index was considered to be the most plausible index of abundance available for SNA 7 (Hartill & Sutton 2011). This analysis was updated and developed further by Langley (2013).

This CPUE analysis was updated and refined by Langley (2013). The data set was updated to include data from 2009-10 to 2011-12, while maintaining the equivalent model structure for the lognormal GLM. In addition, a binomial model was implemented to model the incidence of snapper catch in the BT(MIX) fishery. The binomial indices increased considerably over the last few years following an increase in the proportion of fishing events that caught snapper while targeting flatfish and barracouta. The annual delta-lognormal indices were derived from combining the lognormal and binomial indices.

A range of alternative CPUE indices were derived using different catch and effort data sets and model configurations. The resulting CPUE indices from the range of model options were comparable. The delta lognormal (all years) model was considered the preferred CPUE index for the stock on the basis that it incorporated all available information from the fishery. The confidence intervals for the individual indices were computed using a bootstrapping procedure (Figure 19).

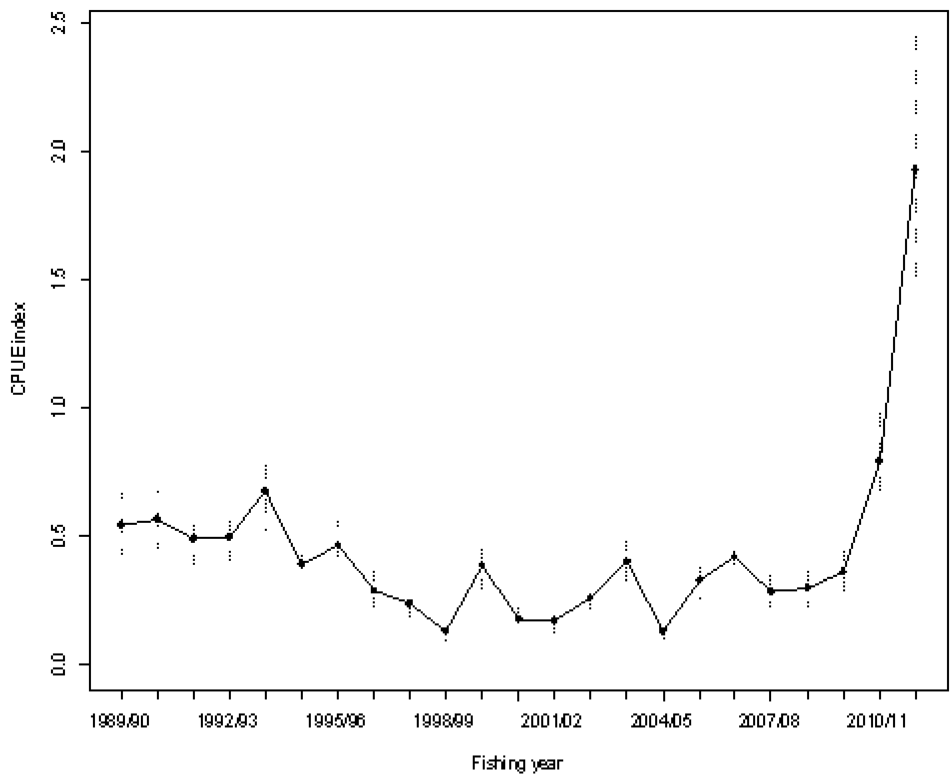


Figure 19: Relative CPUE indices derived from the delta lognormal (all years) model for the combined single trawl fishery. The vertical lines represent the 95% confidence intervals. The confidence intervals were derived using a bootstrapping procedure.

The Working Group accepted the delta lognormal (all years) index for monitoring the SNA 7 fishery. This index is also generally comparable with the trend in CPUE indices derived independently from the SNA7 BPT trawl fishery. Both sets of indices exhibit a very strong increase in CPUE over the last 5 years, but particularly during the 2010-11 and 2011-12 fishing seasons. Standardised CPUE from the single trawl and pair trawl fisheries is estimated to have increased during 2008-09 to 2011-12 by 450% and 700%, respectively.

The fine-scale trawl catch and effort data collected from the fishery from 2007-08 onwards reveal no obvious temporal changes in the operation of the fishery that might contribute towards the recent large increase in the CPUE indices. Further, the CPUE indices obtained from the standardised CPUE analysis of these recent data are comparable to the indices derived from the longer-term CPUE models (all years).

It is reasonable to conclude that the recent increase in the CPUE indices is partly driven by a recent period of strong recruitment. The analysis of the SNA 7 size grade data is generally consistent with this assertion, with an increase in the proportion of smaller fish in the catch from 2008-09 onwards. There is also supporting information from the time series of Tasman Bay/Golden Bay *Kaharoa* trawl surveys which have caught higher numbers of juvenile snapper in recent years (pers. comm. Michael Stevenson, NIWA).

Bentley & Langley (in press) developed an age structured simulation model for SNA 7 as model for the evaluation of potential management procedures for the fishery. The model was implemented in the Stock Synthesis software (Methot 2005). The formulation of the model was similar to the SNA 7 stock assessment model previously implemented by Harley and Gilbert (2000). Many of the historical data sets included in the operating model were sourced directly from Harley & Gilbert (2000) rather than the original source materials. A number of additional data sets were also incorporated in the current analysis and these are described in more detail below.

The simulation model for this study to incorporates the CPUE index in Figure x and SNA 7 size grade data from fish processing sheds to enable an evaluation of these data within the framework of the population dynamics of the stock. It is not intended for the results of the simulation modelling to be considered as a formal stock assessment of SNA 7, but this model places the current trends in a historical context and indicates that the recent increase in biomass was lower than the CPUE index suggests.

For the base model run (CPUE c.v. 15%), the model provides a reasonable fit to the CPUE indices with the exception of the last year. For 2012, the estimated stock biomass is substantially lower than the corresponding CPUE index (Figure y). Nonetheless, the model attempts to fit the increase in stock abundance via the estimation of an exceptionally strong 2007 year class (Figure 20).

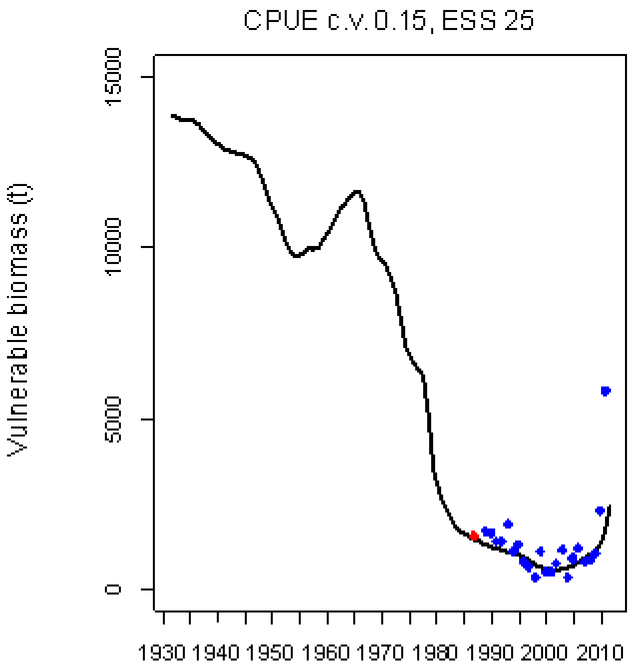


Figure 20: Biomass trajectories for one of the base simulation model runs fitting the CPUE (blue points) and the recent size grade data: h = 0.95; m = 0.075 and SigmaR = 0.6. The red point represents the biomass estimate from the SNA 7 tagging programme.

Given what we know about snapper population dynamics the most reasonable explanations for the recent large increases in recent CPUE are substantial increases in recruitment or catchability. There has been a substantial increase in the proportion of small fish in the trawl survey and some evidence of good recruitment from the size grade data.

The available *in situ* sea temperature data were examined and, while there was some indication of warmer water temperatures in spring 2011-12, there was no indication that the prevailing sea conditions were likely to have caused substantial increases in catchability. However, given the very short time-series of sea temperature data available and the lack of other alternative environmental indicators (e.g. current flow) it is not possible to dismiss the potential for some exogenous influence on the catchability of snapper in recent years.

While there is evidence that the stock abundance has increased in the last two years, the extent of the rebuild relative to the B_{MSY} benchmark, is unknown. A formal stock assessment is required to make a definitive statement regarding the current stock status of SNA 7.

5.4 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 1931-04.

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 1965-74 was assumed to be 2000 t per year,
- YCS was estimated for the 1971-00 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.

Catch at age

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, 1991-04.

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.

Year class strength (YCS)

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 21). 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 21: 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 1974-91 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 21). 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.

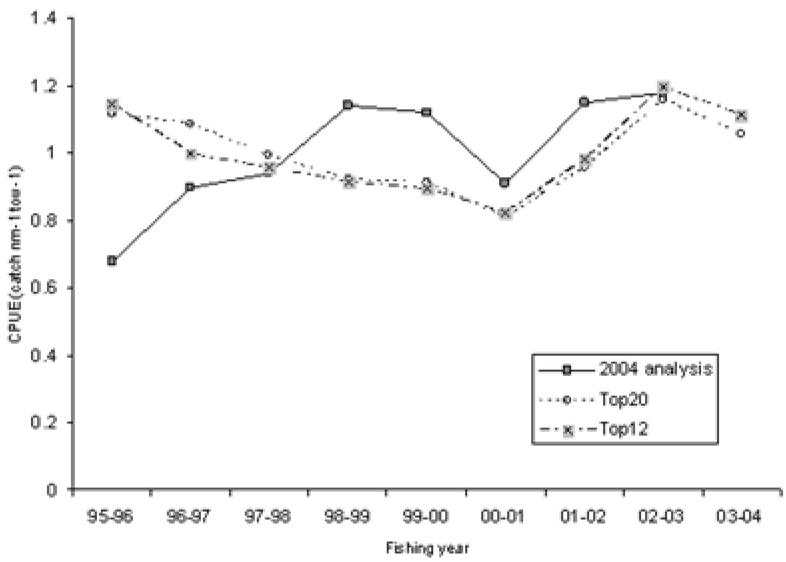


Figure 21: Single trawl CPUE indices of catch per n. mile used in the 2004 and 2005 assessments.

2002 Tagging program biomass

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 22. 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 22: Estimated population biomass.

Stratum name		Biomass (t)
	< 75 m	≥ 75 m
Ninety Mile Beach	685	104
Kaipara	887	135
Manukau	3 465	526
North Taranaki	2 131	324
South Taranaki	1 897	288
Total		10 442
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 9505 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 two tagging programmes, the Working Group 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 22. 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 23). The list of priors assumed for model parameters is given in Table 24. 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 23: 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 24: Assumed model priors.

Parameter	Prior	Specification
Mean recruitment, R_0	Uniform-log	Range = (10^4, 10^8)
Year class strengths (1971-00)	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

Alternative model runs

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.

Results

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 1989-04 length-at-age data give greater weights-at-age than the 1975-79 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 1975-79 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 25 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 25: 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 22). 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.

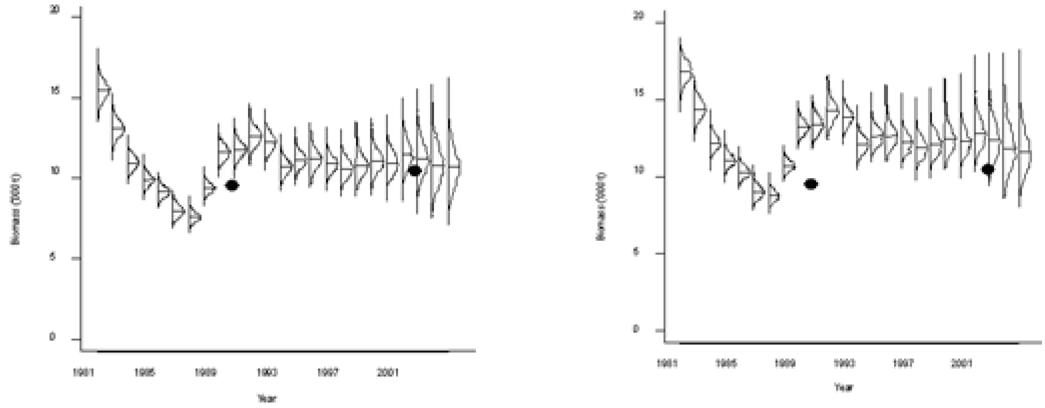


Figure 22: Posterior distributions of the biomass trajectories for the SNA 8 model estimates assuming historical recreational catch of 300 t (left panel) and 600 t (right panel) with the tagging programme estimates of biomass (solid circles).

Estimates of yield and projections

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 (F_{rec}); and secondly, assuming a constant catch capped at the level assumed for 1990-2004 (R_{cap}). 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 23) 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 (F_{rec}) 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 (R_{cap}) 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 26, and Figure 24). The rate of increase was slightly lower for F_{rec} options (constant recreational exploitation rate, Figure 24a and 24c) compared to the R_{cap} projection options (constant recreational catch, Figure 24b and 24d). The rate of rebuilding varied widely depending upon the assumed future TACC.

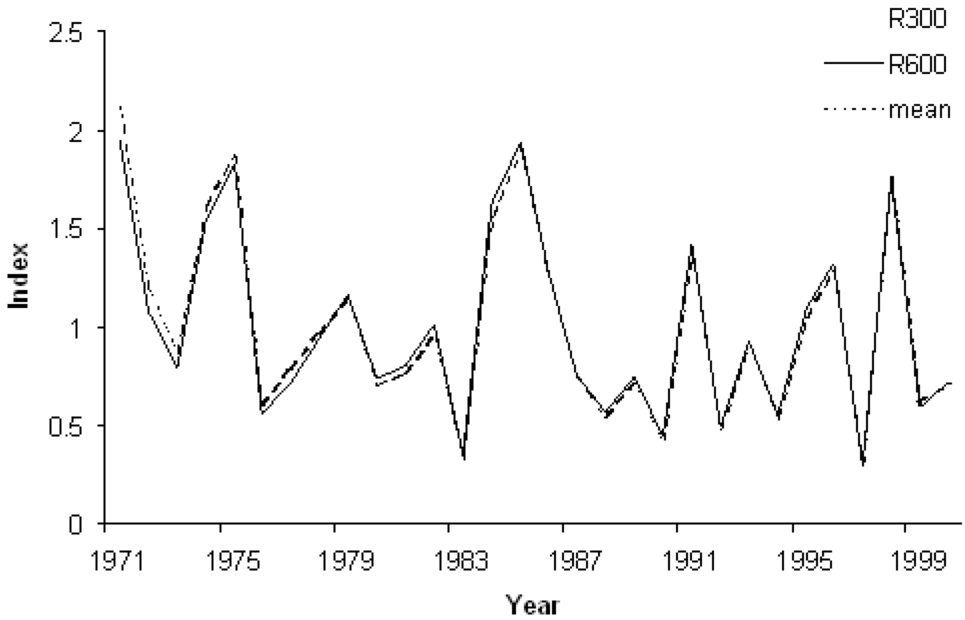


Figure 23: SNA 8 Base case model MPD estimates of the relative strengths of the 1971 to 2000 year classes.

Under the F_{rec} 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.

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.

Table 26: 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	1.7	1.29	2.13	1	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	1.1	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	-	2010
500	10 929	17 747	1.63	1.3	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

(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	1.3	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	1.1	0.7	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	2.2	1.77	2.7	1	-	2010
500	11 676	17 346	1.49	1.19	1.84	1	1 013	2014
1 000	11 729	14 596	1.24	0.93	1.57	0.9	856	2021
1 250	11 710	13 106	1.11	0.8	1.43	0.71	767	>2025
1 375	11 702	12 419	1.05	0.75	1.39	0.59	726	>2025

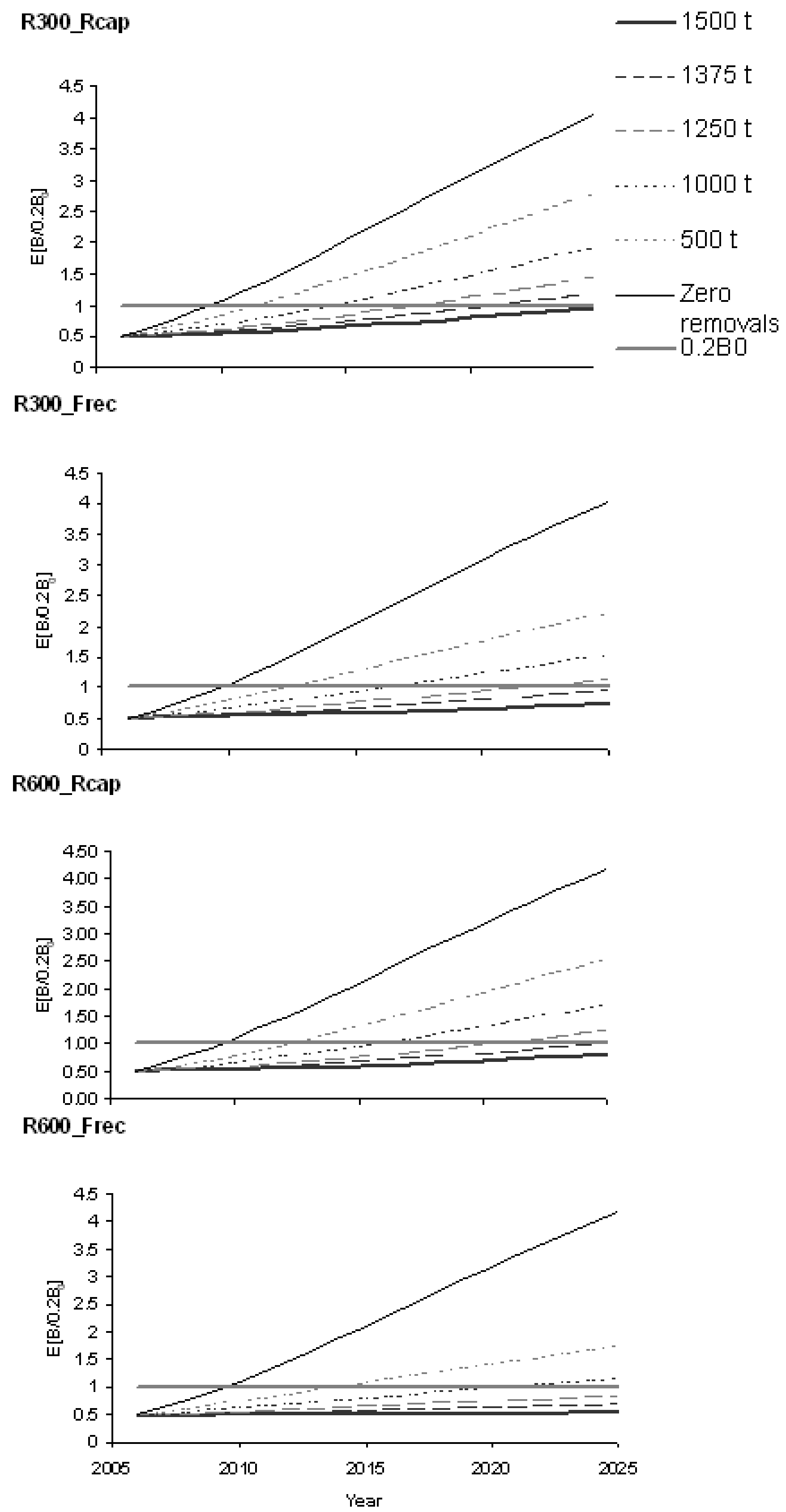


Figure 24: Mean of expected biomass relative to 20% of virgin biomass (B_0) forecast to 2025 for the R300 and R600 models under two alternative options for recreational catch: Frec, constant annual exploitation rate at the MPD level estimated in 2004; and, Rcap, constant annual catch of 300 or 600 t 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.

6. STATUS OF THE STOCKS

Stock Structure Assumptions

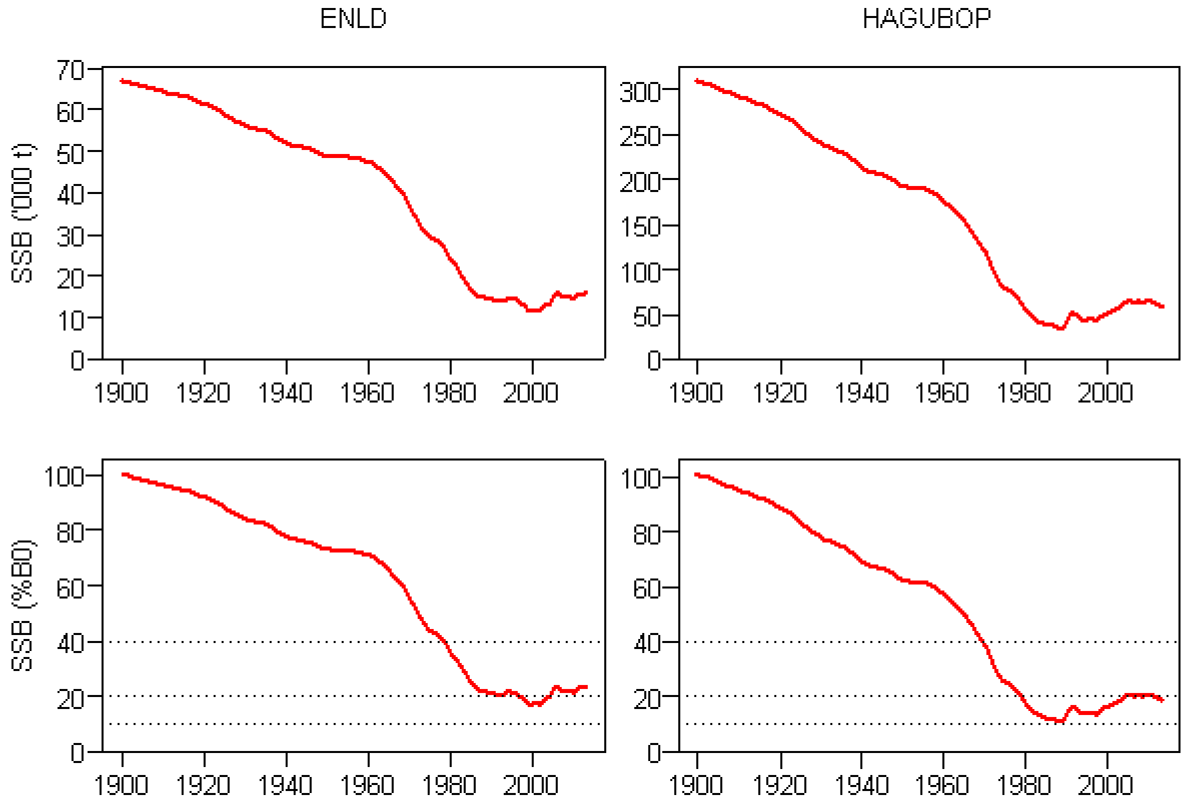
New Zealand snapper are thought to comprise either seven or eight biological stocks based on the location of spawning and nursery grounds; differences in growth rates, age structure and recruitment strength; and the results of tagging studies. These stocks are assumed to comprise three in SNA 1 (East Northland, Hauraki Gulf and Bay of Plenty), two in SNA 2 (one of which may be associated with the Bay of Plenty stock), two in SNA 7 (Marlborough Sounds and Tasman/Golden Bay) and one in SNA 8. Tagging studies reveal that limited mixing occurs between the three SNA 1 biological stocks, with greatest exchange between the Bay of Plenty and Hauraki Gulf.

- **SNA 1**

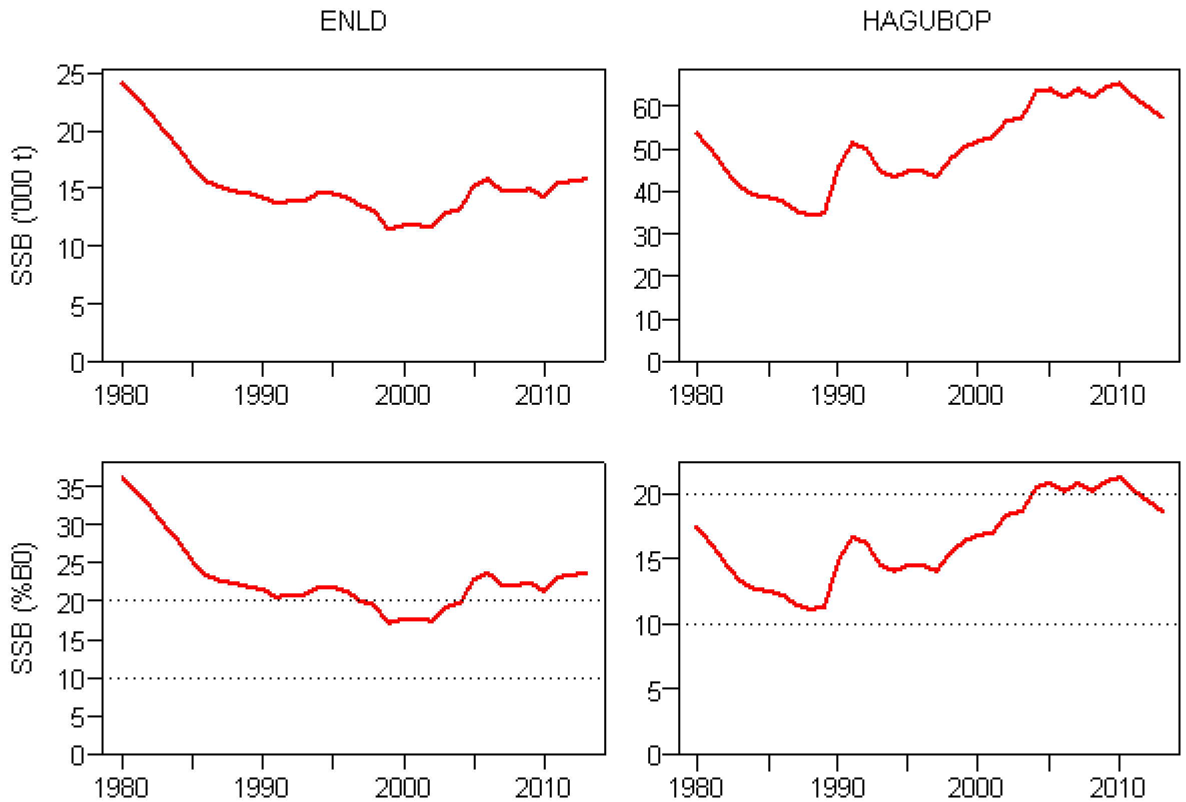
The 2013 assessment was based on three stocks: East Northland, Hauraki Gulf and Bay of Plenty; however, results for Hauraki Gulf and the Bay of Plenty are combined in the summaries below due to uncertainties about movement of the two stocks between the two areas.

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	Base case models (M = 0.075, h = 0.85) for East Northland and the Hauraki Gulf and Bay of Plenty to 2012-13
Reference Points[3]	Interim target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $U_{40\%B0}$
Status in relation to Target	East Northland B_{2013} was estimated to be 24% B_0; Very Unlikely (< 10%) to be at or above the target Hauraki Gulf + Bay of Plenty B_{2013} was estimated to be 19% B_0; Very Unlikely (< 10%) to be at or above the target
Status in relation to Limits	East Northland B_{2013} is About as Likely as Not (40-60%) to be below the soft limit B_{2013} is Very Unlikely (< 10%) to be below the hard limit Hauraki Gulf + Bay of Plenty B_{2013} is About as Likely as Not (40-60%) to be below the soft limit B_{2013} is Very Unlikely (< 10%) to be below the hard limit
Status in relation to Overfishing	East Northland Overfishing is Likely (> 60%) to be occurring Hauraki Gulf+Bay of Plenty Overfishing is Likely (> 60%) to be occurring

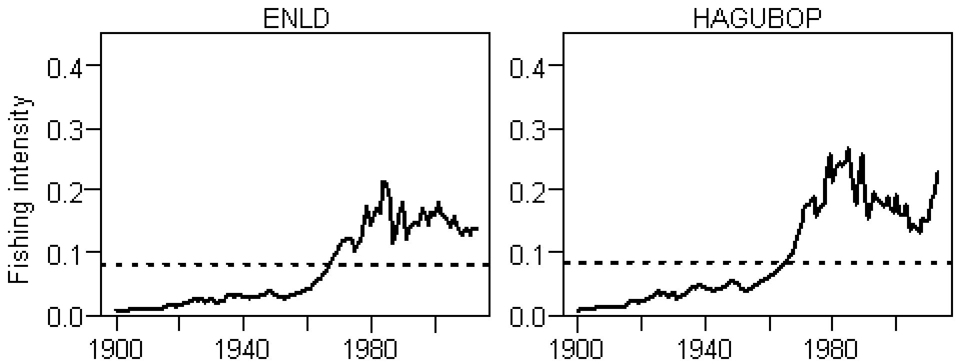
Historical Stock Status Trajectory and Current Status



MCMC base model SSB and status trajectories by stock (dotted lines indicate target (40% B_0**), soft limit (20%** B_0**) and hard limit (10%** B_0**)).**



MCMC base model SSB and status trajectories by stock, for the period since 1980 (dotted lines indicate soft limit (20% B_0**) and hard limit (10%** B_0**))**

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	East Northland Stock biomass was estimated to have experienced a long steep decline from about 1960 to 1985, and has fluctuated without trend since then. Hauraki Gulf+Bay of Plenty Stock biomass was estimated to have experienced a long steep decline from about 1960 to about 1988, after which it gradually increased to 2010 and then declined slightly.
Recent Trend in Fishing Mortality or Proxy	 East Northland The fishing intensity for this stock rose sharply from the early 1960s, reached a peak in the early 1980s, and has since declined slightly. Hauraki Gulf + Bay of Plenty The fishing intensity for this stock rose sharply from the early 1960s and reached a peak in the 1980s. It then declined by approximately 50% to 2007, but has since increased to 86% of the 1985 peak.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Model five year projections using recent catches for the commercial fleet and recent exploitation rates for the recreational fishery from the MCMCs predict increasing SSBs in East Northland and in the Hauraki Gulf-Bay of Plenty combined.
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits (5 years)	Soft limit East Northland: Very Unlikely (< 10%) Hauraki Gulf + Bay of Plenty: Unlikely (< 40%) Hard limit East Northland: Very Unlikely (< 10%) Hauraki Gulf + Bay of Plenty: Very Unlikely (< 10%)
Probability of Current Catch or TAC causing Overfishing to continue or to commence	East Northland Current catch is Very Likely (> 90%) to cause overfishing to continue Hauraki Gulf + Bay of Plenty Current catch is Very Likely (> 90%) to cause overfishing to

	continue	
Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Quantitative stock assessment.	
Assessment Method	Spatially-disaggregated, 3-stock, age-structured, single-sex model undertaken in CASAL	
Assessment Dates	Latest assessment: 2013	Next assessment: 2016
Overall assessment quality rank	1 - High Quality	
Main data inputs (rank)	- Proportions-at-age from the commercial fisheries, and historic trawl surveys	1 – High Quality
	- Proportions-at-length from the recreational fishery	1 – High Quality
	- Estimates of biological parameters (e.g. growth, age-at-maturity and length/weight)	1 – High Quality
	- Standardised longline CPUE indices	1 – High Quality
	- Standardised single trawl for the BoP	1 – High Quality
	- Estimates of recreational harvest	1 – High Quality
	- Commercial catch	1 – High Quality
	- Tag-based biomass estimates (BoP - 1983)	2 – Medium or Mixed Quality: data no longer available
	- Data from tagging experiments in 1985 (HG, EN)	1 – High Quality
	- Data from tagging in 1994 (all areas)	1 – High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	- Catch history extended back to 1900 and stocks assumed to be at B_0 in 1900 - tag-recapture data sets condensed and reweighted	
Major Sources of Uncertainty	1. Stock structure and degree of exchange between BoP and HG 2. Conflict between catch-at-age and tagging data 3. Relationship between standardised longline CPUE and abundance, as the methodology may not account for perceived changes in fishing behaviour 4. Temporal trends in growth rate	

Qualifying Comments
Working Group and Plenary members had difficulty reaching consensus on the reliability of the assessment. Some members felt the assessment was robust to uncertainties, while others were concerned that alternative assumptions could affect outcomes about stock status.

Fishery Interactions
Main QMS bycatch species are trevally, red gurnard, John dory and tarakihi. Incidental captures of sea turtles and seabirds occur in the bottom longline fisheries, including black petrel, that are ranked as at very high risk in the Seabird Risk Assessment.[1]

[1] The risk was defined as the ratio of the estimated annual number of fatalities of birds due to bycatch in fisheries to the Potential Biological Removal (PBR), which is an estimate of the number of seabirds that may be killed without causing the population to decline below half the carrying capacity. Richard and Abraham (2013).

- **SNA 2**

Stock Status	
Year of Most Recent Assessment	2010
Assessment Runs Presented	Two model runs, both with a steepness fixed at 1, are reported with alternative values of natural mortality and a fixed fishery selectivity function.
Reference Points	Target: Not established but B_{MSY} assumed Soft Limit: 20% B_0 (HSS default) Hard Limit: 10% B_0 (HSS default)
Status in relation to Target	Unknown
Status in relation to Limits	Soft: Unlikely (< 40%) Hard: Unlikely (< 40%)
Historical Stock Status Trajectory and Current Status	
Due to the unreliability of the assessment no figure is displayed.	
Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	For the range of model runs investigated, estimates of *MSY* (443-496 t) are higher than the recent catch levels (376 t). By inference, the stock biomass would be expected to have increased slowly over the last decade if recruitment has been maintained at or above long-term average levels.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	The broad range of ages present in the catch suggests that the stock is unlikely to be at very low levels.

Projections and Prognosis	
Stock Projections or Prognosis	Given that the catch is below the range of *MSY* estimates, it is Likely that biomass would increase at current catch levels provided that recruitment is maintained at or above average levels.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Unlikely (< 40%)

Assessment Methodology		
Assessment Type	Level 1- Quantitative Stock Assessment	
Assessment Method	Bayesian statistical catch at age model implemented in Stock Synthesis	
Main data inputs	- Proportions at age data from the commercial fishery - Estimates of biological parameters (e.g., *M*, growth, age-at-maturity and length/weight) - Commercial catch - Standardised single trawl CPUE index of abundance - Estimates of recreational harvest - Estimates of commercial over catch	
Period of Assessment	Latest assessment: 2010	Next assessment: to be determined
Changes to Model Structure and Assumptions	The previous assessment was done in 2002. The 2010 model includes three additional years of catch-at-age data from the commercial fishery and a series of CPUE indices (1989/90-2008/09). The most crucial difference between the two assessments	

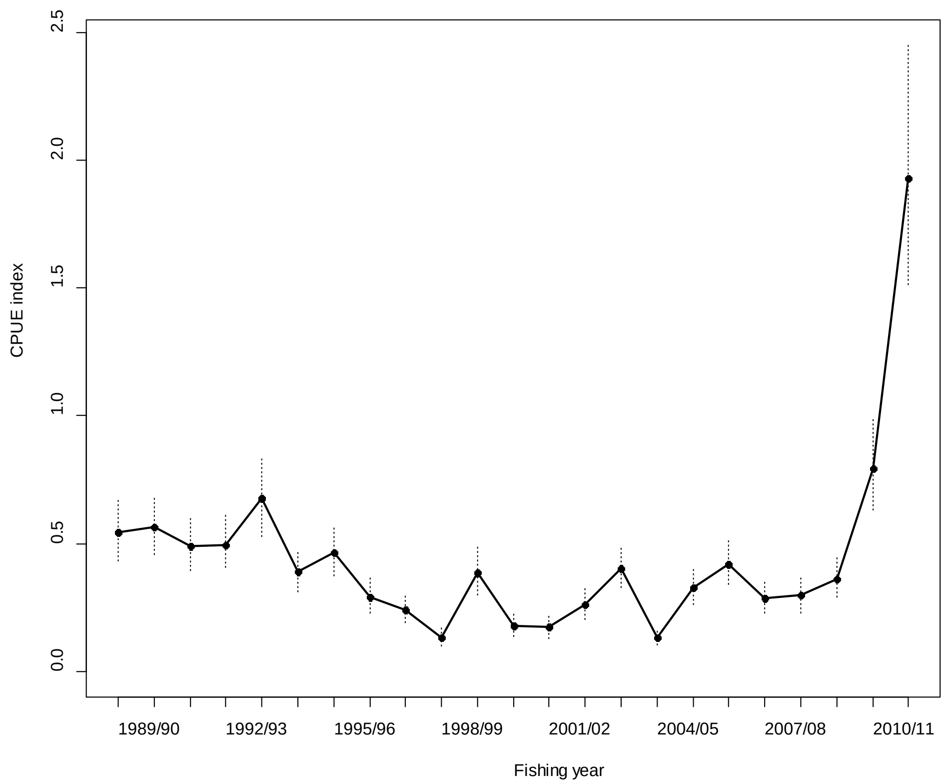
	is the assumptions relating to the selectivity of the commercial fishery. The previous assessment assumed logistic selectivity (full selectivity for older age classes) while the current assessment assumed a fixed dome-shaped selectivity.
Major Sources of Uncertainty	– There is a high degree of uncertainty regarding the assumed selectivity function for the commercial fishery. Furthermore, selectivity of the commercial fishery is likely to have changed over the history of the fishery. – The CPUE indices are unlikely to represent a reliable index or abundance. – The catch-at-age data do not track year classes well and may not be representative of the catch. – The values of M have been derived from other snapper stock and may not be appropriate for SNA 2. – There is uncertainty regarding the catch history prior to the introduction of the QMS. – There is assumed to be no stock-recruitment relationship.

Qualifying Comments
There is a high level of uncertainty associated with the assessment, with the result that stock status and projections cannot be reliably determined. However, estimates of *MSY* were robust to the range of assumptions investigated but are dependent on the assumptions regarding historical catch. For the range of model scenarios considered, estimates of *MSY* were higher than the recent and current levels of catch. Despite the limitations of the catch-at-age data, the broad range of ages present in the catch suggests that the stock is unlikely to be at very low levels.

Fishery Interactions
Snapper is a bycatch of the main inshore fisheries within SNA 2, principally the red gurnard and tarakihi bottom trawl fisheries. The operation of these fisheries is constrained by the SNA 2 TACC.

- **SNA 7**

Stock Status	
Year of Most Recent Assessment	20112013
Assessment Runs Presented	A CPUE index that combined the snapper catch and effort from trawl fisheries directed at SNA, FLA and BAR in Tasman and Golden Bays
Reference Points	Target: Not established but B_{MSY} assumed Soft Limit: 20% B_0 (HSS default) Hard Limit: 10% B_0 (HSS default)
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown

Historical Stock Status Trajectory and Current Status

Relative CPUE indices derived from the delta lognormal (all years) model for the combined single trawl fishery. The vertical lines represent the 95% confidence intervals. The confidence intervals were derived using a bootstrapping procedure Langley (2013).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE generally declined to 2001, after which it fluctuated without trend until 2009/10 when it increased markedly in the next two years.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	In 2009 the West Coast South Island trawl survey caught a large number of small snapper (1+). It was suggested at the time that this was an indication of a large recruitment event. It is likely that this high recruitment is responsible to an unknown extent for the increases in CPUE.
Trends in Other Relevant Indicators or Variables	Catch-at-age collected in 2003-04 and 2006-07 lacked fish over 8 years old, which were relatively common in earlier samples collected between 1997 and 2001. The current level of commercial catch is 25% of the average catch from 1945-80.

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

Qualifying Comments
The impact of the current young age structure of the population on spawning success is unknown

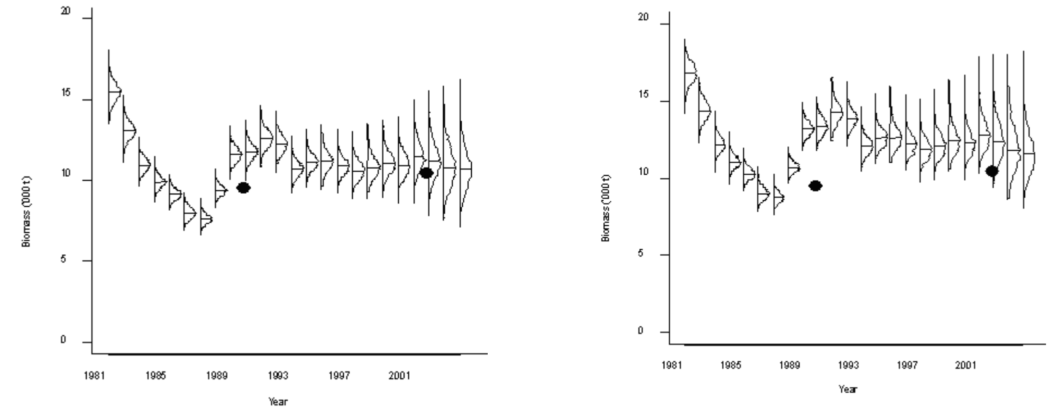
Fishery Interactions
Snapper target fisheries have bycatch of flatfish, red cod, gurnard, tarakihi and small amounts of barracouta and warehou.

- **SNA 8**

Stock Structure Assumptions
Tagging, genetic and morphological studies have revealed that snapper off the west coast of the North Island (i.e., SNA 8) comprise a separate biological unit.

Stock Status	
Year of Most Recent Assessment	2005
Assessment Runs Presented	Given the uncertainty in estimates of recreational harvest, two alternate model runs 1) recreational harvest of 300 t and 2) recreational harvest of 600 t.
Reference Points	Target: Not established but B_{MSY} (20% B_0) assumed Soft Limit: 20% B_0 (HSS default) Hard Limit: 10% B_0 (HSS default)
Status in relation to Target	R300 B_{2004} estimated to be 9.8% B_0, Very Unlikely (< 10%) to be at or above the target R600 B_{2004} estimated to be 10% B_0, Very Unlikely (< 10%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Likely (> 90%) to be below (in 2005) Hard Limit: About as Likely as Not (40-60%)

Historical Stock Status Trajectory and Current Status



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

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	Unknown

Trends in Other Relevant Indicators or Variables	Recent catch-at-age sampling shows that the age structure in the fishery has changed little over the last 20 years averaging around 6 years (this is the lowest average of all the snapper stocks). The fishery is held up in most years by only 4-5 dominant age classes with a negligible accumulation of biomass beyond 20 years. Given the current age structure the stock would be very vulnerable to recruitment failure extending more than 2-3 years in duration.

Projections and Prognosis	
Stock Projections or Prognosis	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 predicted 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.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Unlikely (< 40%)

Assessment Methodology		
Assessment Type	Level 1 - Quantitative Stock Assessment	
Assessment Method	Age-structured Bayesian stock assessment implemented with CASAL software	
Main data inputs	- Proportions at age data from the commercial fisheries, recreational fishery and historic trawl surveys. - Estimates of biological parameters (e.g., growth, age-at-maturity and length/weight). - Standardised single trawl CPUE index of abundance. - Sea Surface temperatures - Estimates of recreational Harvest - Commercial catch - Two tag-based biomass estimates	
Period of Assessment	Latest assessment: 2005	Next assessment: Unknown
Changes to Model Structure and Assumptions	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-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.
Major Sources of Uncertainty	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 because extra weight was given 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.

Qualifying Comments
An aerial overflight survey in 2007 estimated recreational harvest to be 260 t, thereby suggesting the 600 t run was less plausible than the 300 t estimate. All SNA 8 stock assessments have assumed steepness is 1.0 (no stock recruitment relationship), which given the stocks low biomass relative to B_0 is a questionable assumption. Alternative values of steepness have not been investigated for SNA 8.

Fishery Interactions
The primary species caught in association with snapper in bottom trawl fisheries are trevally, red gurnard, John dory and tarakihi.

Yield estimates, TACCs and TACs for the 2011-12 fishing year are summarised in Table 27.

Table 27: Summary of yield estimates (t), TACCs (t) and reported landings (t) for the most recent fishing year.

Fish stock	QMA	*MCY*	CAY_{99-00}	*MSY*	2011-12 Actual TACC	2011-12 Commercial landings
SNA 1	1	9 911	8 712	10 050	4 500	4 614
SNA 2	2	-	-	440-500	315	358
SNA 3	3, 4, 5 & 6	-	-	-	32	< 1
SNA 7	7	-	-	850	200	216
SNA 8	8, 9	-	-	-	1 300	1 360
SNA 10	10	-	-	-	10	0
Total					6 357	6 547

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