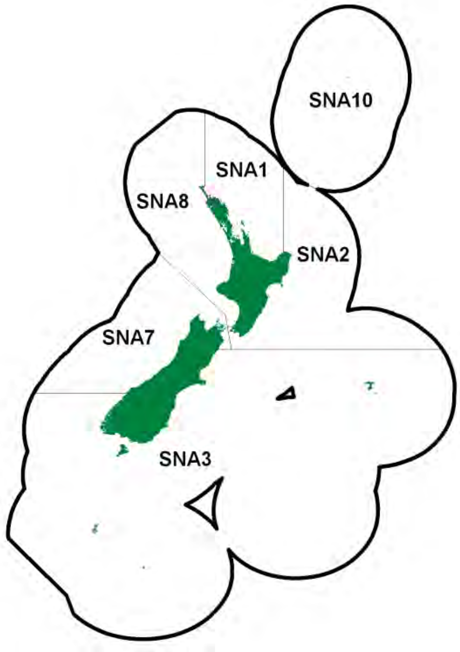
SNAPPER (SNA)

(*Chrysophrys auratus*)
Tamure, Kouarea



1. FISHERIES SUMMARY

1.1 Commercial fisheries

Snapper fisheries are one of the largest and most valuable coastal fisheries in New Zealand. The commercial fisheries, which began their development in the late 1800s, 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 17 500 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 by the fishing year 1990–91, and from 1330 t to 1594 t for SNA 8 by 1989–90 (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 4938 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. [Continued on next page]

Year	SNA 1	SNA 2	SNA 7	SNA 8	Year	SNA 1	SNA 2	SNA 7	SNA 8
1931–32	3 355	0	69	140	1961	5 887	481	583	1 178
1932–33	3 415	0	36	159	1962	6 502	495	582	1 352
1933–34	3 909	18	65	213	1963	6 967	504	569	1 456
1934–35	4 317	113	7	190	1964	7 269	541	574	1 276
1935–36	5 387	106	10	108	1965	7 991	471	780	1 182
1936–37	6 369	48	194	103	1966	8 762	619	1 356	1 831
1937–38	5 665	64	188	85	1967	9 244	695	1 613	1 477
1938–39	6 145	77	149	89	1968	10 328	650	1 037	1 491

Table 1: [Continued]

Year	SNA 1	SNA 2	SNA 7	SNA 8	Year	SNA 1	SNA 2	SNA 7	SNA 8
1939–40	5 918	76	158	71	1969	11 318	687	549	1 344
1940–41	5 100	80	174	76	1970	12 127	665	626	1 588
1941–42	4 791	110	128	62	1971	12 709	717	640	1 852
1942–43	4 096	53	65	57	1972	11 291	716	767	1 961
1943–44	4 456	43	29	75	1973	10 450	676	1 258	3 038
1944	4 909	37	96	69	1974	8 769	586	1 026	4 340
1945	4 786	42	118	124	1975	6 774	681	789	4 217
1946	5 150	59	232	244	1976	7 743	751	1 040	5 326
1947	5 561	25	475	251	1977	7 674	308	714	3 941
1948	6 469	40	544	215	1978	9 926	365	2 720	4 340
1949	5 655	172	477	277	1979	10 273	569	1 776	3 464
1950	4 945	229	514	318	1980	7 274	554	732	3 309
1951	4 173	205	574	364	1981	7 714	247	592	3 153
1952	3 665	176	563	361	1982	7 089	135	591	2 636
1953	3 581	203	474	1 124	1983	6 539	145	544	1 814
1954	4 180	211	391	1 093	1984	6 898	163	340	1 536
1955	4 323	254	504	1 202	1985	5 876	177	270	1 866
1956	4 615	278	822	1 163	1986	5 969	130	253	959
1957	5 129	325	1 055	1 472	1987	4 016	152	210	1 072
1958	5 007	369	721	1 128	1988	5 038	210	193	1 565
1959	5 607	286	650	1 114	1989	5 754	364	292	1 571
1960	5 889	389	573	1 202	1990	5 826	428	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.
5. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings.

Table 2: Reported landings (t) of snapper by Fishstock from 1983–84 to present and gazetted and actual TACCs (t) for 1986–87 to present. QMS data from 1986–present. [Continued on next page]

Fishstock	SNA 1		SNA 2		SNA 3		SNA 7		SNA 8	
FMAs	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	< 1	32	257	330	893	1 331
1987–88	5 038	5 098	152	137	1	32	256	363	1 401	1 383
1988–89	5 754	5 614	210	157	< 1	32	176	372	1 527	1 508
1989–90	5 826	5 981	364	157	< 1	32	294	151	1 551	1 594
1990–91	5 273	6 002	428	157	< 1	32	160	160	1 659	1 594
1991–92	6 176	6 010	373	157	< 1	32	148	160	1 459	1 594
1992–93	5 427	4 938	324	252	< 1	32	165	160	1 543	1 500
1993–94	4 847	4 938	307	252	< 1	32	147	160	1 542	1 500
1994–95	4 857	4 938	308	252	< 1	32	150	160	1 436	1 500
1995–96	4 938	4 938	280	252	< 1	32	146	160	1 558	1 500
1996–97	5 047	4 938	351	252	< 1	32	162	160	1 613	1 500
1997–98	4 525	4 500	286	252	< 1	32	182	200	1 589	1 500
1998–99	4 412	4 500	283	252	2	32	142	200	1 636	1 500
1999–00	4 509	4 500	390	252	< 1	32	174	200	1 604	1 500
2000–01	4 347	4 500	360	252	< 1	32	156	200	1 631	1 500
2001–02	4 374	4 500	252	252	1	32	141	200	1 577	1 500
2002–03	4 487	4 500	334	315	< 1	32	187	200	1 558	1 500
2003–04	4 469	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	1 345	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	1 313	1 300
2011–12	4 614	4 500	358	315	< 1	32	216	200	1 360	1 300
2012–13	4 457	4 500	310	315	< 1	32	211	200	1 331	1 300
2013–14	4 459	4 500	313	315	< 1	32	210	200	1 275	1 300
2014–15	4 479	4 500	271	315	< 1	32	210	200	1 272	1 300
2015–16	4 408	4 500	321	315	< 1	32	189	200	1 328	1 300
2016–17	4 620	4 500	373	315	< 1	32	263	250	1 334	1 300
2017–18	4 567	4 500	373	315	< 1	32	263	250	1 288	1 300
2018–19	4 437	4 500	364	315	< 1	32	257	250	1 293	1 300
2019–20	4 460	4 500	330	315	< 1	32	289	250	1 347	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
2012–13	0	10	6 309	6 357
2013–14	0	10	6 256	6 357
2014–15	0	10	6 232	6 357
2015–16	0	10	6 247	6 357
2016–17	0	10	6 590	6 407
2017–18	0	10	6 490	6 407
2018–19	0	10	6 351	6 407
2019–20	0	10	6 425	6 407

† FSU data. SNA 1 = Statistical Areas 001–010; SNA 2 = Statistical Areas 011–016; SNA 3 = Statistical Areas 018–032; SNA 7 = Statistical Areas 017, 033–036, 038; SNA 8 = Statistical Areas 037, 039–048. § Includes landings from unknown areas before 1986–87.

From 1 October 1997 the TACC for SNA 1 was reduced to 4500 t, within an overall TAC of 7550 t, and 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, red gurnard, and other fisheries 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 t to 315 t, within a total TAC of 450 t. Nevertheless the 315 t TACC has regularly been over-caught since, except in the fishing years 2008–09 to 2009–10 and 2012–13 to 2014–15. 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. In 2016–17, the TAC for SNA 7 was increased from 306 t to 545 t, including an increase in the TACC from 200 t to 250 t. The SNA 7 TACC was increased again in 2020–21 to 350 t. Table 3 shows the TACs, TACCs, and allowances for each Fishstock from 1 October 2020. All commercial fisheries have a minimum legal size (MLS) for snapper of 25 cm.

Table 3: TACs, TACCs, and allowances (t) for snapper by Fishstock from 1 October 2020.

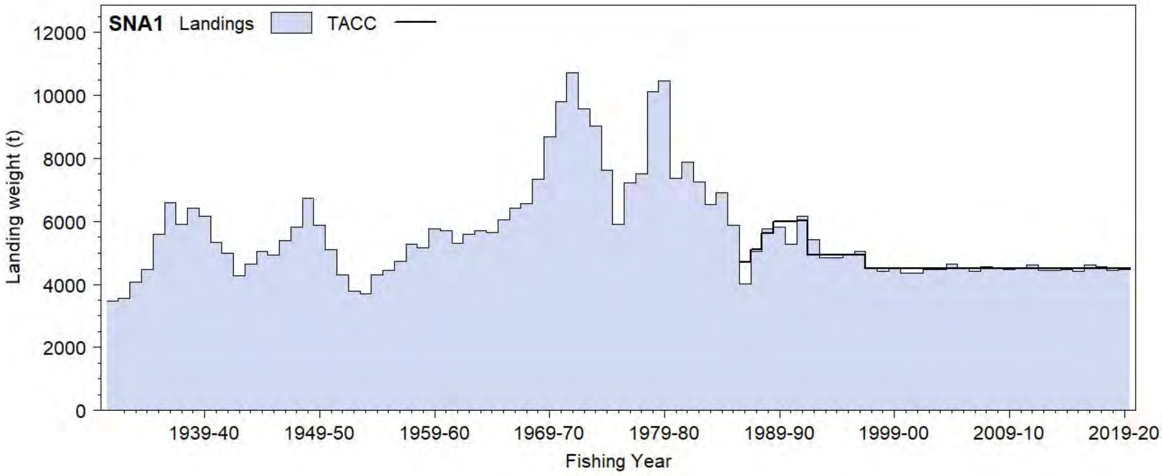
Fishstock	TAC	TACC	Customary allowance	Recreational allowance	Other mortality
SNA 1	8 050	4 500	50	3 050	450
SNA 2	450	315	14	90	31
SNA 3		32	–	–	–
SNA 7	645	350	20	250	25
SNA 8	1 785	1 300	43	312	130
SNA 10		10	–	–	–

Foreign fishing

Japanese catch records and observations made by New Zealand naval vessels indicate that significant quantities of snapper were taken from New Zealand waters by Japanese vessels 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



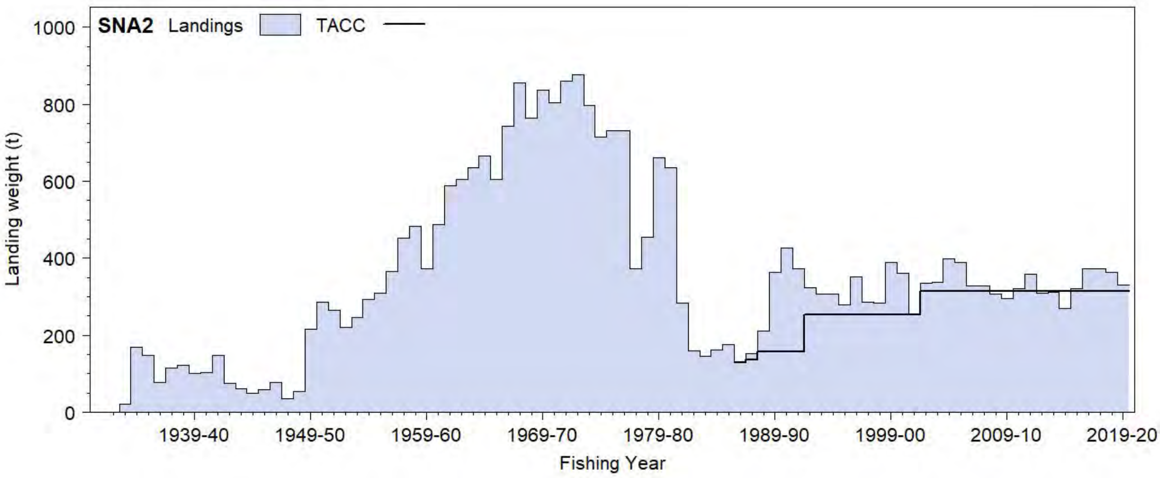
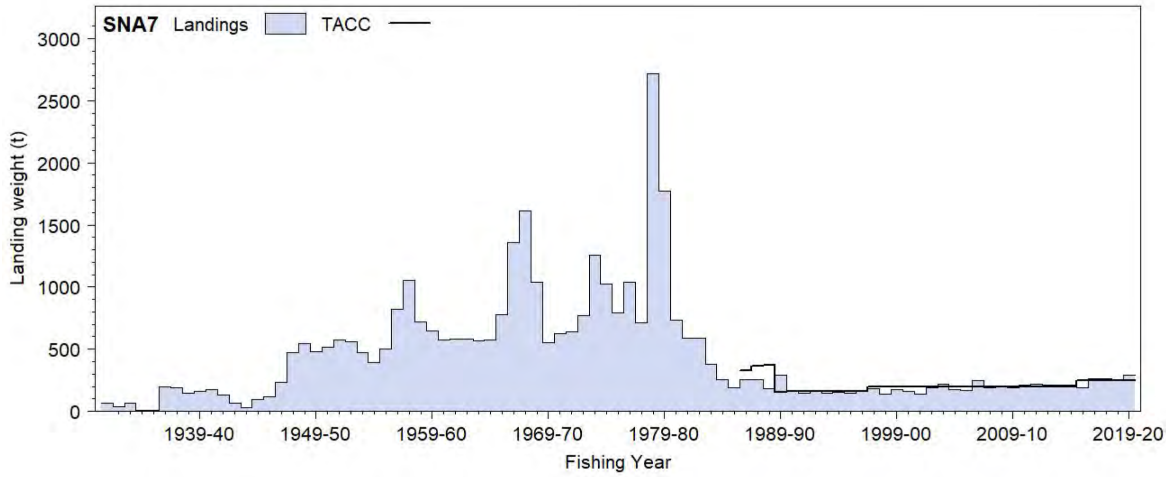


Figure 1: Total reported landings and TACCs for the four main SNA stocks. From top: SNA 1 (Central East) and SNA 2 (Central East). [Continued on next page]



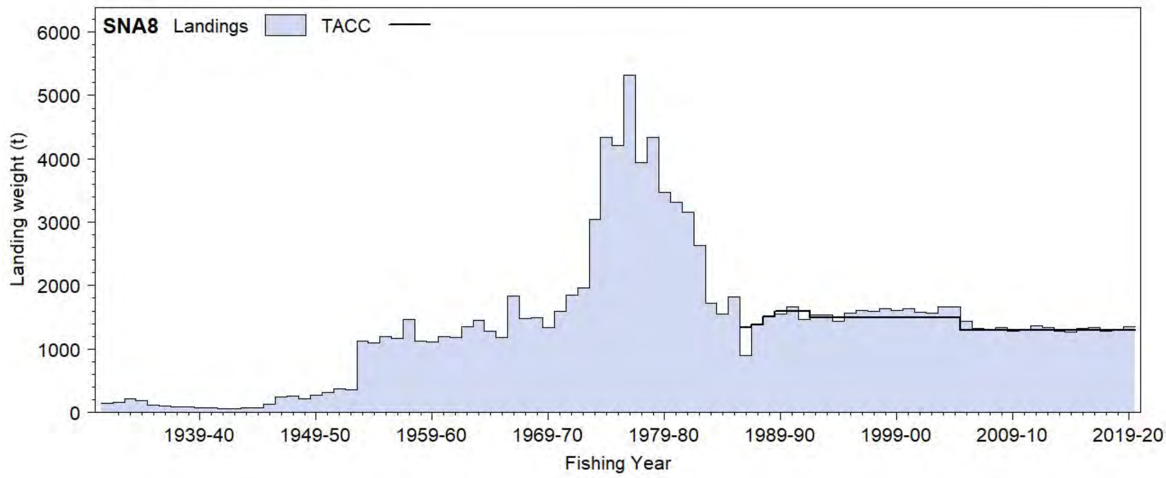


Figure 1: [Continued] Total reported landings and TACC for the four main SNA stocks. From top to bottom: SNA 7 (Challenger) and SNA 8 (Central Egmont).

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 current 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 have changed over time (Table 5). The number of hooks permitted on a recreational longline was reduced from 50 to 25 in 1995.

Table 5: Changes to minimum legal size limits (MLS) and daily bag limits used to manage recreational harvesting levels in snapper stocks, 1985–2014. [Continued on next page]

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	13/10/1995
SNA 1	30	7	1/04/2014
SNA 2	25	30	1/01/1985
SNA 2	27	10	1/10/2005

Table 5 [Continued]

Stock	MLS	Bag limit	Introduced
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 for SNA 1, 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 during the 1991 tag recapture phase, 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 et al 2004) allowed estimates for a further year (population scaling ratios and mean weights were not re-estimated in 2001). 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 the 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).

The recreational harvest estimates provided by the 2000 and 2001 telephone/diary surveys are thought to be implausibly high for many species including snapper, 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 and was used in 2011–12 and 2017–18 to corroborate concurrent national panel surveys. This approach has also been used to estimate recreational harvests from SNA 7 (2005–06 and 2015–16 fishing years) and SNA 8 (2006–07). The Marine Amateur Fisheries and Snapper Working Groups both concluded that this approach generally 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 (Wynne-Jones et al 2014). The panel survey used face-to-face interviews of a random sample of 30 390 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 was collected in computer-assisted standardised phone interviews. This national panel survey was repeated during the 2017–18 fishing year (Wynne-Jones et al 2019).

1.2.2.1 SNA 1

Aerial-access surveys were conducted in FMA 1 in 2011–12 and 2017–18 (Hartill et al 2013, 2019) to independently provide harvest estimates for comparison with those generated from concurrent national panel surveys (excluding the Chatham Islands). Both surveys appear to have provided plausible results that corroborate each other and are therefore considered to be broadly reliable. Harvest estimates provided by these surveys are given in Table 6. 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. Web camera/creel survey monitoring (see Table 6a) suggests that the recreational harvest of snapper in SNA 1 can vary greatly between years. The overall trend across all three regions of SNA 1 suggests a decline in the recreational harvest in the years following 2011–12, that was mostly driven by declining catch rates in the Hauraki Gulf. This was followed by a period of increasing recreational harvest in recent years, from 2015–16.

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. Includes charter boat catch and panel survey estimates of s111 catches. [Continued on next page]

Stock	Year	Method	Number of fish (thousands)	Mean weight (g)	Total weight (t)	CV
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/BoP	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	0.09

Table 6 [Continued]

Stock	**Year**	**Method**	**Number of fish (thousands)**	**Mean weight (g)**	**Total weight (t)**	**CV**
SNA 1						
East Northland	2004–05	Aerial-access	–	–	557	0.13
Hauraki Gulf	2004–05	Aerial-access	–	–	1 345	0.10
Bay of Plenty	2004–05	Aerial-access	–	–	516	0.10
Total	2004–05	Aerial-access	–	–	**2 419**	**0.06**
East Northland	2011–12	Aerial-access	–	–	718	0.14
Hauraki Gulf	2011–12	Aerial-access	–	–	2490	0.08
Bay of Plenty	2011–12	Aerial-access	–	–	546	0.12
Total	2011–12	Aerial-access	–	–	**3 754**	**0.06**
East Northland	2011–12	Panel survey	718	1 266	909	0.12
Hauraki Gulf	2011–12	Panel survey	2 350	1 022 / 987[6]	2 381	0.11
Bay of Plenty	2011–12	Panel survey	714	956 /1 003[6]	691	0.12
Total	2011–12	Panel survey	3 884	1 025	**3 981**	**0.08**
East Northland	2017–18	Aerial-access	–	–	720	0.10
Hauraki Gulf	2017–18	Aerial-access	–	–	2 068	0.07
Bay of Plenty	2017–18	Aerial-access	–	–	680	0.10
Total	2017–18	Aerial-access	–	–	**3 467**	**0.05**
East Northland	2017–18	Panel survey	587	1 351	793	**0.10**
Hauraki Gulf	2017–18	Panel survey	1 443	1 162/1 189	1 684	**0.10**
Bay of Plenty	2017–18	Panel survey	571	1 116/1 205	**650**	**0.12**
Total	2017–18	Panel survey	2 601	1 202	**3 127**	**0.07**
SNA 2						
Total	1993	Telephone/diary	28	1 282	**36**	**–**
Total	1996	Telephone/diary	31	1 282[2]	**40**	**–**
Total	2000	Telephone/diary	268	1 200[4]	**322**	**–**
Total	2001	Telephone/diary	144	–[5]	**173**	**–**
Total	2011–12	Panel survey	55	1 027	**57**	**0.25**
Total	2017–18	Panel survey	83	1 117	**93**	**0.24**
SNA 7						
Tasman Bay /Golden Bay	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	–	–	**43**	**0.17**
Total	2011–12	Panel survey	110	799	**89**	**0.17**
Total	2015–16	Aerial-access	–	–	**83**	**0.18**
Total	2017–18	Panel survey	98	1 505	**147**	**0.16**
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**	**0.10**
Total	2011–12	Panel survey	557	770 /1 255 / 1 160[7]	**630**	**0.16**
Total	2017–18	Panel survey	707	–	**892**	**0.12**

[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] 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).

Table 6a: Recreational catch estimates (t) for snapper in different parts of the SNA 1 stock area calculated from web camera and creel monitoring at key ramps combined with aerial-access estimates for each area in 2004–05 and 2006–07 (Hauraki Gulf only) and 2011–12 and 2018–19 (all areas within SNA 1).

Year	East Northland	CV	Hauraki Gulf	CV	Bay of Plenty	CV	Total SNA 1	CV
2004–05	730	0.14	1 216	0.13	605	0.15	2 551	0.08
2006–07	–	–	1 224	0.16	–	–	–	–
2011–12	689	0.13	2 772	0.09	596	0.18	4 057	0.07
2012–13	679	0.15	1 718	0.09	273	0.21	2 671	0.07
2013–14	540	0.12	876	0.13	216	0.19	1 632	0.08
2014–15	511	0.14	735	0.11	223	0.25	1 469	0.08
2015–16	647	0.13	657	0.15	171	0.19	1 475	0.09
2016–17	649	0.13	649	0.12	385	0.19	1 683	0.08
2017–18	751	0.13	1 037	0.11	623	0.16	2 410	0.08
2018–19	1 030	0.09	1 312	0.09	376	0.13	2 718	0.06

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 which are included in the estimate). The 2011–12 and 2017–18 national panel surveys provided plausible results and are considered to be broadly reliable and suggest that catch is increasing. Web camera/ creel survey monitoring in SNA 8 started in late 2011 and has found no general trend in fishing effort, but a gradual fluctuating increase in catch rates and hence harvest, since that time. No estimates of absolute catch have yet been developed from these data.

1.2.3 Monitoring harvest

In addition to estimating absolute harvests, a system to provide relative estimates of harvest over time for key fishstocks has been designed and implemented for some key recreational fisheries. The system uses web cameras to continuously monitor trends in trailer boat traffic at key boat ramps. This monitoring is complemented by creel surveys that provide estimates of the proportion of observed boats that were used for fishing, and of the average harvest of snapper and kahawai per boat trip. These data are combined to provide relative harvest estimates for SNA 1.

Trends inferred from this monitoring programme were initially very similar to that inferred from aerial-access harvest estimates in the Hauraki Gulf in 2004–05, 2006–07, and 2011–12, but the camera/creel snapper harvest estimate for the Hauraki Gulf in 2017–18 is substantially lower than concurrent aerial-access and national panel surveys estimates for the same year (Table 6a cf. Table 6). This difference appears to be due to a recent substantial increase in recreational fishing effort and catch around expanding mussel farms in the Firth of Thames, coinciding with a lesser increase in effort in the north-western Hauraki Gulf. Additional creel survey monitoring has been initiated to monitor changes in the recreational fishery in these areas, which had not been adequately monitored from boat ramps in the Auckland metropolitan area up until 2019–20. These estimates show that the recreational snapper harvest varies substantially more than would be expected if catches were related only to stock abundance; this suggests that changes in localised availability to recreational fishers can also have a marked effect on the recreational harvest. Web camera monitoring is continuing, and the coverage is being progressively extended to other FMAs.

1.3 Customary non-commercial fisheries

Snapper form important fisheries for customary non-commercial, but the annual catch is not known. The information on Māori customary harvest under the provisions made for customary fishing is limited (Table 6b). It is likely that Māori customary fishers utilise the provisions under recreational fishing regulations. Customary reporting varies within SNA 8. Large areas of SNA 8 are gazetted under the Fisheries (Kaimoana Customary Fishing) Regulations 1998 which require reporting on authorisations. In the areas not gazetted, customary fishing authorisations issued would be under the Fisheries (Amateur

Fishing) Regulations 2013, where there is no requirement to report. The numbers reported in Table 6b may be underestimated.

Table 6b: Customary approvals in SNA 8 from 2005 to 2020.

Year	Quantity approved (kg)	Reported actual quantity harvested (kg)	Number of authorisations issued
2005	130		
2006	220		3
2007	250	70	3
2008	30	30	
2009	950	651	5
2010	5 457	3 176	7
2011	4 910	2 950	15
2012	3 340	2 494	6
2013	4 887	2 965	16
2014	19 030	6 136	31
2015	16 025	5 186	19
2016	11 270	5 578	28
2017	1 510	1 133	13
2018	790	608	9
2019	18 270	912	46
2020	5 800	Current year	15

1.4 Illegal catch

No new information is available to estimate illegal catch. For modelling SNA 1, SNA 7, 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-size snapper.

1.5 Other sources of mortality

No estimates are available regarding the amount 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 SNA 1 commercial longline fisheries in 1997 (McKenzie 2000) found that 6–10% of snapper caught by number were under 25 cm (MLS). Results from a holding net study indicate that 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 SNA 1, estimates of incidental mortality for the year 2000 from longlines were less than 3% and for trawl, seine, and recreational fisheries between 7% and 11% (Millar et al 2001). In SNA 8, 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 was 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, and Tasman Bay and Golden Bay. 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 off 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, 7, and 8.

The growth rates of snapper in SNA 1 and SNA 8 have also varied over time. For SNA 8, growth rates were considerably higher during the 1980s and 1990s compared with the 1970s and more recent period (from mid-2000s). The SNA 8 growth parameters in Table 7 were derived from age-length observations from the early 1990s and, hence, represent the period of higher growth rates. The temporal variation in growth may indicate density-dependence in the growth rates of snapper, at least in SNA 1 and SNA 8, given the historical exploitation patterns of those stocks. There was no apparent variation in the growth rates of snapper in SNA 7. 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, & 8	0.075			Hilborn & Starr (unpub. analysis)
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 (1990s)	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

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 Bay of Plenty (BoP)), two in SNA 2 (one of which may be associated with the BoP stock), two in SNA 7 (Marlborough Sounds and Tasman Bay/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.

Tagging studies in SNA 7 (1986/87) and SNA 8 (1990) revealed reciprocal movements of snapper between Tasman Bay/Golden Bay and South Taranaki Bight, although the scale of the movement is likely to be relatively low, especially given the observed differences in the age structure of snapper sampled from the two areas. Tagging studies in SNA 8 have shown considerable movements of fish between South Taranaki Bight and the area north of Cape Egmont. However, recent *Kaharoa* trawl surveys indicate some differences in the age structure of snapper between the two areas which may suggest a degree of spatial stratification of the SNA 8 stock.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was last updated from the 2018 Fisheries Assessment Plenary. An issue-by-issue analysis is available in the Aquatic Environment and Biodiversity Annual Review 2019–20 (Fisheries New Zealand 2020), online at https://www.mpi.govt.nz/dmsdocument/40980-aquatic-environment-and-biodiversity-annual-review-201920). The following sections were updated in 2021: 4.3.2, 4.3.4, and 4.4. Some tables in these sections have not been updated because data were unavailable at the time of publication.

4.1 Role in the ecosystem

Snapper are one of the most abundant demersal generalist predators 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 fisheries (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. Because of this generalist nature there is a large potential for a variety of trophic interactions to involve snapper. The diet of snapper is diverse and opportunistic and largely includes 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 can 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 series 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 Bycatch (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 observed fish and invertebrate bycatch in snapper target fisheries 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 SNA 1, but catches are dominated by snapper. Kendrick & 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 & 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 & Francis 1997, and Jones et al 2010). For SNA 1, 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 & Parsons, NIWA, unpublished data).

Trawl surveys targeting juvenile snapper in Tasman Bay and Golden Bay 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 SNA 8. 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 capture of protected species (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 captures

There were two observed captures of New Zealand fur seals in trawls targeting snapper between 2002–03 and 2017–18, but historically low observer coverage of inshore trawlers (average 6.98% in FMAs 1 and 9 between 2002–03 and 2017–18, but averaging 20.51% between 2013–14 and 2017–18) (data retrieved on 24 May 2021 from https://psc.dragonfly.co.nz/2019v1/released/new-zealand-fur-seal/inshore-trawl/all-vessels/eez/2002-03-2017-18/) means that the frequency of captures is highly uncertain. In the same time period, there were no observed marine mammal captures in snapper longline fisheries, when coverage has averaged 2.18% of hooks set (4.5 and 3.1% in the two most recent years) (data retrieved 24 May 2021 from https://psc.dragonfly.co.nz/2019v1/released/new-zealand-fur-seal/snapper-longline/all-vessels/eez/2002-03-2017-18/).

Observers recorded two dolphin deaths during snapper trawling in 2016–17: one common dolphin from off the North Island east coast and one bottlenose dolphin from the Northland-Hauraki Gulf area (Abraham et al 2021).

4.3.2 Seabird interactions and captures

There have been nine observed captures of seabirds (3 flesh-footed shearwater, 3 black petrel, 2 shearwaters that were not identified further, and 1 common diving petrel) and 28 observed deck strikes (11 common diving petrels, 10 grey-faced petrel, 2 Buller's shearwater, 1 flesh-footed shearwater, 1 New Zealand white-faced storm petrel, 1 cape petrel, 1 black petrel, and 1 Cook's petrel) in trawls targeting snapper between 2002–03 and 2017–18, but historically low observer coverage of inshore trawlers (average 6.98% in FMAs 1 and 9 between 2002–03 and 2017–18, but averaging 20.51% between 2013–14 and 2017–18) means that the frequency of interactions is highly uncertain. (Data given above were accessed on 24 May 2021 from https://psc.dragonfly.co.nz/2019v1/released/birds/inshore-trawl/all-vessels/eez/2002-03-2017-18/.)

The estimated number of total incidental captures of all seabirds in the snapper bottom longline fishery declined from 3436 in 2000–01 to 247–644 in 2003–04 (depending on the model used, Table 8, estimates from MacKenzie & Fletcher 2006, Baird & Smith 2007, 2008, Abraham & Thompson 2011a). 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 2017–18, there were 156 observed captures of birds in snapper bottom longline fisheries (Table 9). Estimates of the mean total seabird captures from 2002–03 to 2017–18 vary from 831 to 350 based on a consistent capture rate. The rate of capture varied between 0.0 and 0.1 birds per 1000 hooks observed, fluctuating without obvious trend. Seabirds observed captured in snapper longline fisheries were mostly flesh-footed shearwater (53%) and black (Parkinson's) petrel (24%), and the majority were taken in the Northland-Hauraki area (88%) (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.

The snapper target bottom longline fishery contributes to the total risk posed by New Zealand commercial fishing to seabirds (Table 11). The two species to which the fishery poses the most risk are black petrel and flesh-footed shearwater, with this target fishery posing 0.4421 and 0.2166 of PST, respectively (Table 11). The black petrel is assessed at very high risk from commercial fishing in New Zealand waters, and the flesh-footed shearwater is assessed at high risk from commercial fishing in New Zealand waters (Richard et al 2020).

Table 8: Model based estimates of seabird captures in the SNA 1 bottom longline fishery from 1998–99 to 2006–07 (from MacKenzie & Fletcher 2006 (for vessels under 28 m), Baird & Smith 2007, 2008, Abraham & Thompson 2011a). Numbers in parentheses are 95% confidence limits or estimated CVs.

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	(CV = 34%)	644	(301–1 585)
2004–05	–	–	587	(CV = 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 2017–18. The 2018-19 and 2019-20 data were unavailable at the time of publication. 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 by Abraham et al (2016) and Abraham & Richard (2017, 2018) and are available via https://data.dragonfly.co.nz/psc. Observed and estimated protected species captures in this table derive from the PSC database version PSCV4. [Continued on next page]

	Fishing effort			Observed captures		Estimated captures		
	All hooks	No. obs	% obs	Number	Rate	Mean	95% c.i.	% included
2002–03	13 728 642	0	0.0	0	–	831	609–1 102	100.0
2003–04	12 267 547	187 282	1.5	10	0.05	706	520–936	100.0
2004–05	11 543 911	244 692	2.1	13	0.05	622	464–823	100.0
2005–06	11 696 613	116 288	1.0	12	0.10	526	383–697	100.0
2006–07	10 349 991	62 360	0.6	0	0.00	510	371–682	100.0
2007–08	9 047 826	0	0.0	0	–	460	333–617	100.0
2008–09	8 979 950	318 274	3.5	25	0.08	473	347–629	100.0
2009–10	11 041 505	634 145	5.7	30	0.05	504	373–669	100.0
2010–11	11 343 682	0	0.0	0	–	537	392–724	100.0
2011–12	11 037 036	0	0.0	0	–	483	351–651	100.0
2012–13	10 505 560	366 120	3.5	2	0.01	453	330–606	100.0
2013–14	11 122 814	747 597	6.7	47	0.06	456	345–595	100.0
2014–15	10 844 232	0	0.0	0		386	278–517	100.0
2015–16	10 617 551	337 125	3.2	7	0.02	364	266–493	100.0
2016–17	10 757 966	486 700	4.5	4	0.01	363	262–485	100.0
2017–18	10 417 487	327 091	3.1	14	0.04	350	253–471	100.0

Table 10: Number of observed seabird captures in the snapper longline fishery, 2002–03 to 2017–18, by species or species group. The 2018-19 and 2019-20 data were unavailable at the time of publication. The risk category is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Population Sustainability Threshold, PST (from Richard et al 2017, where full details of the risk assessment approach can be found). Observed and estimated protected species captures in this table derive from the PSC database version PSCV4, www.data.dragonfly.co.nz/psc.

Taxa	Risk category	Northland and Hauraki	Bay of Plenty	West Coast North Island	Taranaki
Black petrel	Very high	38	0	0	0
Flesh-footed shearwater	High	67	8	0	7
Northern giant petrel	Medium	1	0	0	0
Pied shag	Negligible	2	0	0	0
Fluttering shearwater	Negligible	6	0	0	0
Sooty shearwater	Negligible	1	0	0	0
Australasian gannet	Negligible	2	0	0	0
Buller's shearwater	Negligible	13	0	1	0
Southern black-backed gull	Negligible	5	0	0	0
Petrels	–	2	0	0	1
Total other birds	–	138	9	1	8

Table 11: Risk ratio of seabirds predicted by the risk assessment for the snapper target bottom longline fishery and all fisheries included in the risk assessment, 2006–07 to 2016–17, showing seabird species with a risk ratio of Very High or High; estimates at a fishery-specific level were not available for other species. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Population Sustainability Threshold, PST (from Richard et al 2017, where full details of the risk assessment approach can be found). The DOC threat classifications are given by (Robertson et al 2017 at http://www.doc.govt.nz/documents/science-and-technical/nztcs19entire.pdf).

		Risk ratio			
Species name	PST (mean)	SNA target bottom longline	Total	Risk category	DOC Threat Classification
Black petrel	447	0.4421	1.23	Very high	Threatened: Nationally Vulnerable
Flesh-footed shearwater	1 450	0.2166	0.49	High	Threatened: Nationally Vulnerable

4.3.3 Sea turtle captures

Between 2002–03 and 2014–15 there was one observed capture of a green turtle in the snapper bottom longline fishery occurring in the Northland and Hauraki fishing area. Observer records documented the green turtle as captured and released alive (Fisheries New Zealand unpublished data). In the same period, there were no captures of turtles in the snapper trawl fishery.

4.3.4 Protected fish captures

White pointer sharks (*Carcharodon carcharias*, also known as great white shark) were protected in New Zealand waters in 2007 under the Wildlife Act 1953, but they are incidentally caught in commercial and recreational fisheries (Francis & Lyon 2012). Fishers have reported catching a total of 24 white pointer shark individuals in snapper trawls since 2009, 4 of which were dead upon capture, 5 were released alive but injured, and the remainder were released alive. Little is known about the survival of released individuals, but it is assumed to be low.

4.4 Benthic interactions

The spatial extent of seabed contact by trawl fishing gear in New Zealand's EEZ and Territorial Sea has been estimated and mapped for all trawl fisheries combined (Baird & Mules 2021). This most recent analysis provides an assessment of the inshore trawl footprint was for the period 2007–08 to 2018–19 (Baird & Mules 2021).

A total of almost 43 700 bottom contacting tows have targeted snapper between 2007–08 and 2018–19. Annual numbers fluctuated around 4000 tows per year up to 2012–13 but have declined to around 3000 since 2015–16 (Baird & Mules 2021). The total aggregate area fished between 2007–08 and 2018–19 was 49 250 km^2. This has mostly (67%) been within SNA 1, where annual aggregate area fished declined from around 3000 km^2 (2007–08 to 2012–13) to 2100 km^2 (2016–17), before increasing to around 3200 km^2 (2017–18 and 2018–19). Annual area fished within SNA 2 and SNA 7 has fluctuated around 350 km^2; whereas in SNA 8, the annual area fished declined from 1300 km^2 in 2007–08 to 480 km^2 by 2010–11 and has fluctuated around this level since this time (Baird & Mules 2021).

A proportion of the commercial catch of snapper is taken using bottom trawls in Benthic Optimised Marine Environment Classification (BOMEC, Leathwick et al 2012) 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 data from TCEPR forms). Trawling for snapper, like trawling for other demersal 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 et al 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 2019–20 (Fisheries New Zealand 2020).

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 or species, 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 (Fisheries New Zealand 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 Manukau Harbour and Kaipara Harbour (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. Bernal-Ramírez 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. Bernal-Ramírez et al (2003) associated this decline with overfishing of the SNA 7 stock and estimated the effective population size in Tasman Bay declined to a low level 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 for Primary Industries 2013). 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, Thrush et al 2002, Morrison et al 2009, 2014a, b). 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. For example, the Kaipara Harbour in northern New Zealand contributed to more than 75% of the recruits to the SNA 8 fishery in 2003 (Morrison, NIWA, unpublished data, Morrison et al 2009) 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, Lowe et al 2015) that may affect the survival of juvenile snapper and hence recruitment to the SNA 8 fishery. It should, however, be noted that recruitment over the last decade has been exceptionally good, suggesting that environmental factors affecting egg and larval survival in the ocean have had greater influence on the number of fertilised eggs surviving to adulthood.

5. RECRUITMENT, ENVIRONMENTAL VARIABILITY, AND CLIMATE CHANGE

This section was last updated in May 2021.

Recruitment dynamics are challenging to assess or predict because of the many underlying drivers that vary over time and space. Stock size, demographic and trait composition, condition and distribution of spawning fish, and the spatio-temporal dynamics of trophic and environmental interactions all influence recruitment processes. Annual variations in snapper recruitment have considerable impact on this fishery and improved understanding of the influence of environmental variables on recruitment patterns would be very useful for the future projection of stock size under different climate change scenarios and different environmental conditions.

New Zealand waters are becoming warmer and more acidic due to the emission of anthropogenic carbon dioxide (Law et al 2018a, 2018b). Recruitment success of New Zealand snapper has been highly correlated with warmer conditions (Francis 1993, Harley & Gilbert 2000, Zeldis et al 2005, Dunn et al 2009, Langley 2015, Garg 2020). Snapper recruitment fluctuations may significantly influence biomass where: 1) a series of weak or strong year classes occur in adjacent years, 2) a population is heavily fished and thus more easily dominated by younger year classes, or 3) a population is near the geographic limit of its range and is dominated by a few year classes due to irregular recruitment; each of which has occurred in at least one snapper stock in New Zealand (Francis 1993).

Recruitment in SNA 7 and SNA 8 has been above average in recent years (Langley 2020a, 2020b). Some spatial differences in year class strength (YCS) patterns are evident across different stocks, but appear to be reasonably well correlated, which may be a result of each stock showing similar responses to broad climatic phenomena, such as the Southern Oscillation Index (SOI) (Francis & Mackenzie 2015). Stock assessments have estimated high levels of recruitment in SNA 7 and SNA 8 between 2006 and 2019 (Langley 2015, 2020a, 2020b), which may possibly be linked to increasing water temperatures. It should nevertheless be noted that the relationship between recruitment and water temperature is unlikely to be linear, with growth and recruitment decreasing after reaching an optimum thermal maxima for Australian snapper populations (Fowler & Jennings 2003, Murphy 2013). It is unclear what the thermal maxima will be for snapper in New Zealand.

In SNA 7, recruitment has been shown to be positively correlated with air temperature (Harley & Gilbert 2000). Strong year classes have also been linked to positive SOI conditions, whereas weak year classes have been linked to negative SOI conditions (Langley 2015). More recently, Garg (2020) examined environment-recruitment relationships for SNA 1 (1970–2007) and SNA 7 (1982–2012) using generalised linear models based on annual recruitment estimates from stock assessment models that incorporated age data from otolith samples. The most variation in YCS was explained by the mean autumn (April–June) SST in SNA 1 and by mean annual SOI in SNA 7, and the Interdecadal Pacific Oscillation accounted for the second greatest amount of variation in both SNA 1 and SNA 7. These findings were consistent with Francis (1993), who concluded that water temperature appears to play an important part in the success of recruitment, with strong year classes in the population generally corresponding to warm years, and weak year classes to cold years. As well as finding a positive correlation between YCS and SST, Dunn et al (2009) also found a positive correlation between YCS and SOI for SNA 1.

A recent study found that fishing and environmental factors initially promote individual fish growth of snapper, but regional-scale wind and temperature may also increase the sensitivity of stocks to environmental change (Morrongiello et al 2021).

Temperature-recruitment relationships are typically non-linear, and studies on snapper in South Australia have shown a reduction in recruitment after temperatures rose above 25 °C (Fowler & Jennings 2003). In Western Australia, snapper growth is greatest at mid latitudes with more moderate temperatures, and lowest at the northern limit of the geographical range for snapper, where temperatures are at their highest (Wakefield et al 2017). In South Australia, biochronology work has found an optimal temperature maximum of 18–20 °C for growth in snapper, and temperatures greater than this result in slower growth rates (Martino et al 2019), which was also in support of optimum growth conditions for juvenile snapper ascertained from aquaculture experimental studies (Fielder et al 2005). The Hauraki Gulf is currently experiencing temperatures near 20 °C, but the optimal temperature range for snapper stocks in New Zealand is unknown (Parsons et al 2020). Recent Hauraki and Bay of Plenty trawl surveys which monitored snapper recruitment and compared it to SST show that the estimated year class strength of 1+ and 2+ snapper in the Hauraki Gulf 2019 survey was well above the long-term average, whereas in the Bay of Plenty, YCSs were well above average (1+) and about average (2+) (see Parsons & Bian in prep).

Several causal mechanisms may result in the increased production of prey and a faster larval growth rate of snapper (Murphy 2013). Zeldis et al (2005) found that wind-driven upwelling caused increased flux of shelf water into the Hauraki Gulf, resulting in greater primary productivity, prey abundance, and higher larval snapper survival.

Ocean acidification (OA) has been shown to have a variable influence on snapper larvae. Although higher temperature and carbon dioxide levels may positively impact growth and survival of snapper larvae, this effect may be countered by the negative effects of elevated carbon dioxide on metabolic rates and swimming performance (McMahon et al 2020a, 2020b). Modelling the overall effect from both OA and warming on snapper populations estimated a 29% reduction to a 44% increase in fishery yield and therefore remains highly uncertain (Parsons et al 2020).

Cummings et al (2021) assessed the vulnerability of New Zealand's snapper fishery to projected environmental change as 'moderate' and outlined the following potential outcomes of increased sea temperatures: 1) southward range expansion, 2) change in distribution of predators, competitors, parasites, and disease, and 3) toxicity and decreased dissolved oxygen due to harmful algal blooms. In recent years, snapper populations appear to have been increasing, in some areas substantially, suggesting that environmental conditions are currently favourable for snapper recruitment and survival.

6. STOCK ASSESSMENT

An assessment of SNA 1 was conducted in 2013, following a preliminary assessment undertaken in 2012. An assessment for SNA 7 was conducted in 2015 and updated in 2018 and 2020. An assessment for SNA 8 was conducted in 2020 and finalised in 2021.

6.1 SNA 1 (Auckland East)

6.1.1 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 2015a). 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 were largely resolved in the 2013 assessment.

The 2013 assessment model covered the time period from 1900 to 2013 (i.e., fishing years 1899–1900 to 2011–12, with two time steps in each year (Table 12).

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 × 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, at any point in time, each fish in the modelled population would be associated with one cell in a 20 × 3 × 3 × 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 12: 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 13). The six migration parameters define the 3 × 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) of 0.6).

Table 13: Details of parameters that were estimated in the model.

Type	Description	No. of parameters	Prior
R_0	Mean unfished recruitment for each stock	3	uniform-log
YCS	Year-class strengths by year and stock	1 361	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)	$^5/_{168}$	uniform-log

[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.

Year class strengths 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 R_0 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.

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 14). 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 14: 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]	$a = 4.467 \times 10^{-5}$, $b = 2.793$
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, $\sigma_L = 1.5$ y, $\sigma_R = 30$ y

[1]See text for further 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 2015b). Other minor changes included dropping small fisheries (prorating 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 15). These were the same as in the 2012 assessment (Francis & McKenzie 2015a) except for the addition of 2012 data points for each of the CPUE time series and the recreational length compositions.

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 2015b). The 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).

Table 15: Details of observations used in the stock assessment model. [Continued on next page]

Type	Likelihood	Area[1]	Source	Range of years	No. of years
Absolute biomass	Lognormal	BOP	1983 tagging	1983	1
Relative biomass (CPUE)	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

Type	Likelihood	Area[1]	Source	Range of years	No. of years
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

Table 15 [Continued]

Type	Likelihood	Area[1]	Source	Range of years	No. of years
Age composition	Multinomial	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

Type	Likelihood	Area tagged[1]	Year tagged	Areas recaptured[1]	Years
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.

6.1.2 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 6) (Hartill et al 2007, Fisheries New Zealand unpublished data).

The recreational catch history used in the previous 2012 stock assessment for SNA 1 was based on 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 longline CPUE based approach used in 2012, particularly for the Hauraki Gulf. Instead the Working Group decided that an alternative creel survey based recreational kilogram 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 kilogram 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 kilogram 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 kilogram per trip index 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).

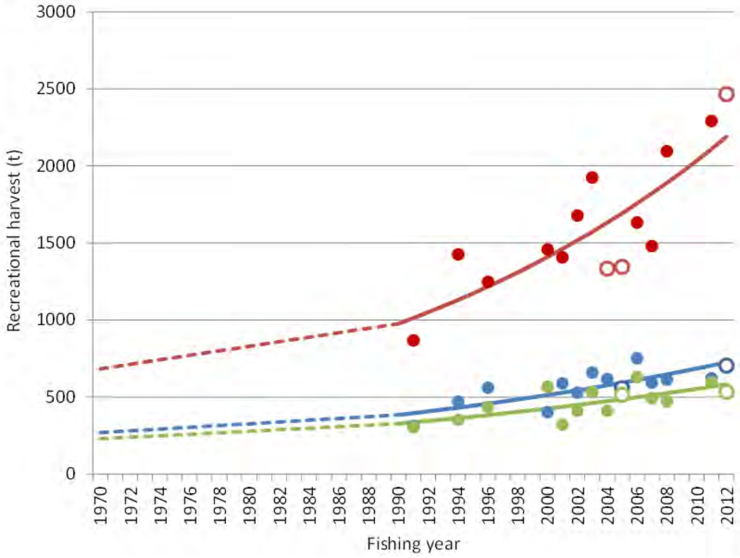


Figure 2: Recreational catch histories for the three areas of SNA 1 (Hauraki Gulf in red, East Northland in blue, and the Bay of Plenty in green). Open circles denote aerial-access survey estimates, closed circles denote recreational kilogram per trip indices scaled to the geometric mean of the aerial-access estimates, solid curved lines denote exponential fits to the scaled kilogram 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).

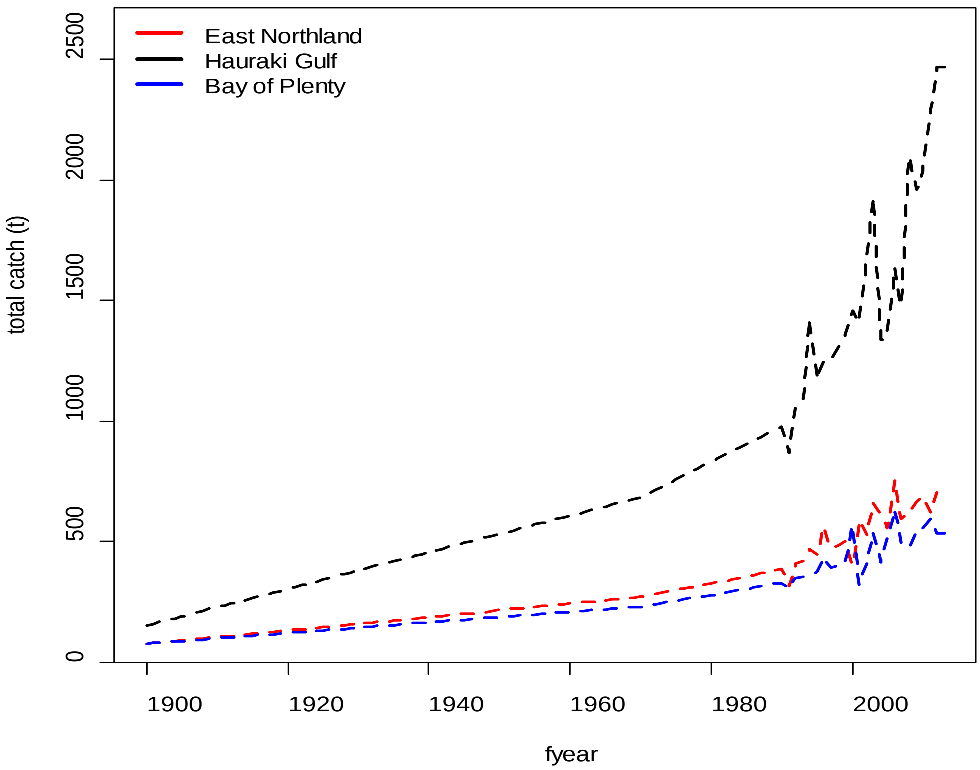


Figure 3: Assumed and derived recreational catch histories for the period 1900 to 2013 that were used in the 2013 SNA 1 assessment model.

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 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 Fisheries Working Group. This averaged estimate was used to generate a linearly increasing recreational catch history for the period 1900 to 1970 (Figure 3).

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 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 Fisheries New Zealand databases.

Commercial catch histories for the period 1915 through to 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. 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 to be 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 (BLL), single bottom trawl (BT), pair bottom trawl (BPT), and Danish seine (DS). Catches from 'other' commercial methods (predominantly set net) were not explicitly modelled but the catch totals were prorated 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 1970s were applied back 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 (Figures 4 and 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 2013 assessment, the base case level of total foreign catch for the period 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.

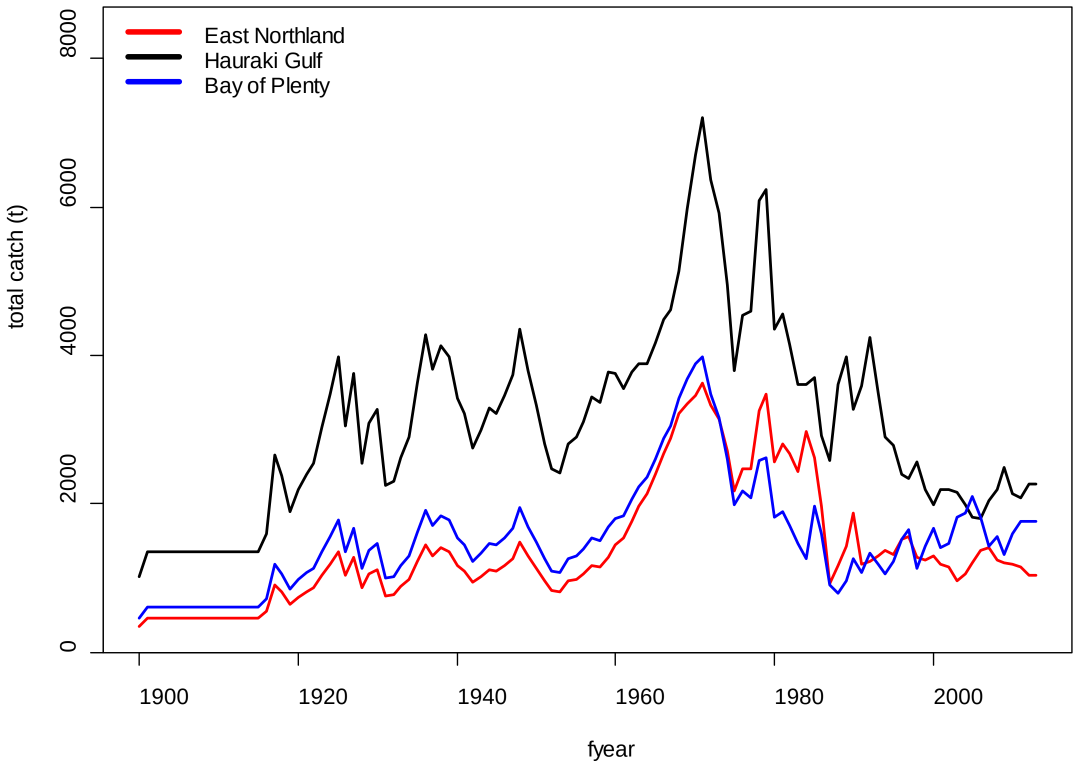


Figure 4: Commercial catch histories by area (adjusted for under-reporting) plus foreign catch used as input to the 2013 SNA 1 assessment model.

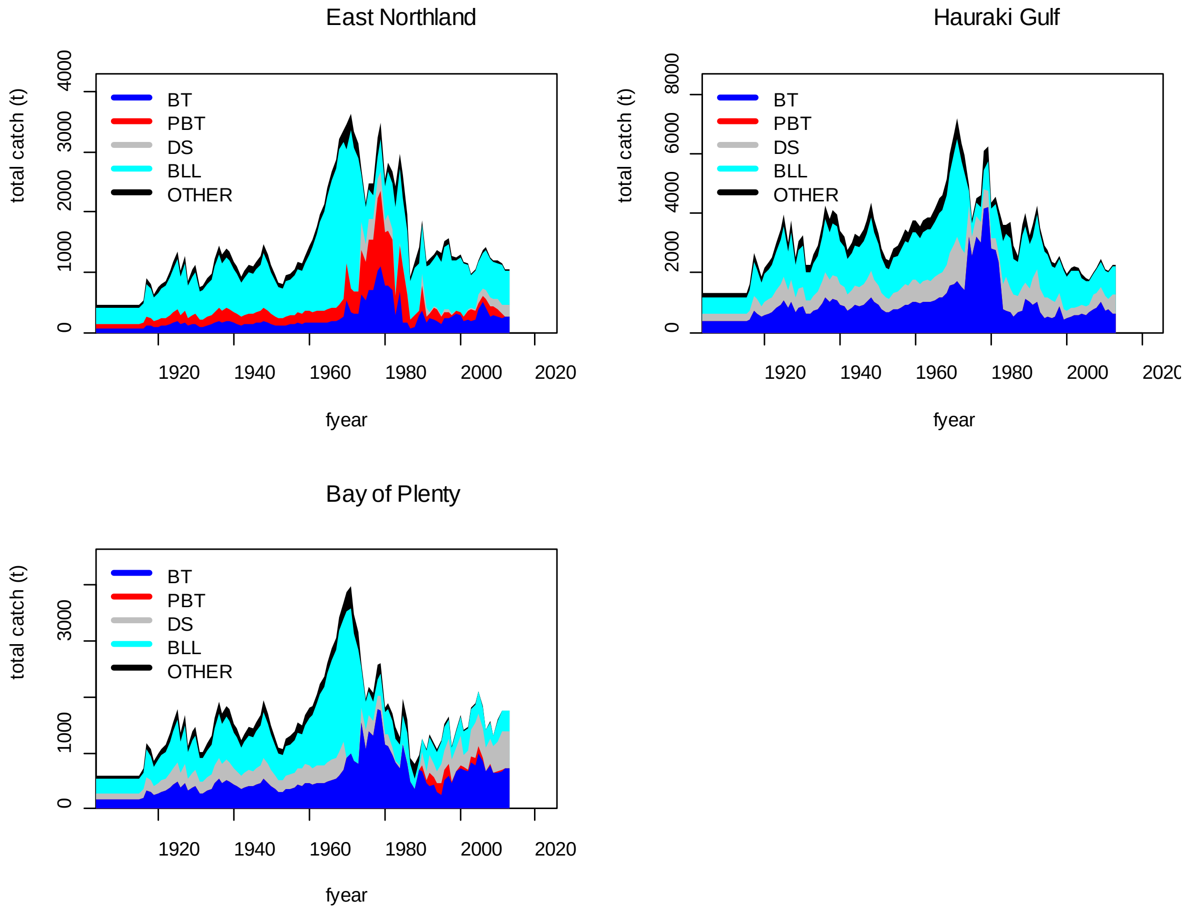


Figure 5: Commercial catch histories by method and area (adjusted for under-reporting) used as input to the 2013 SNA 1 assessment model.

6.1.3 Abundance indices

Trawl surveys

Trawl surveys were carried out in all three areas between the mid-1980s and 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 (see Table 15).

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 SNA 1 (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. To combine the data, the more detailed post 2007 data were aggregated 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 that 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 the number of vessels in the analysis;
- maximise the proportion of total longline catch: threshold set at 60%;
- maximise the number of years in the fishery; and
- maximise the average number of trips per year.

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 16.

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 that 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 16: 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-squared) by the addition of each successive term (model R-squared).

	Parameter	Fyear	Number of hooks (log)	Vessel	Depth	Month	Target	Stat area
Longline								
East Northland	model R-squared	0.06	0.3	0.35	–	0.39	0.41	–
Hauraki Gulf	model R-squared	0.08	0.34	0.44	–	0.49	–	–
Bay of Plenty	model R-squared	0.07	0.53	0.43	–	–	0.57	–
Bottom Trawl								
Bay of Plenty	model R-squared	0.01	–	0.15	0.17	0.19	0.1	0.21

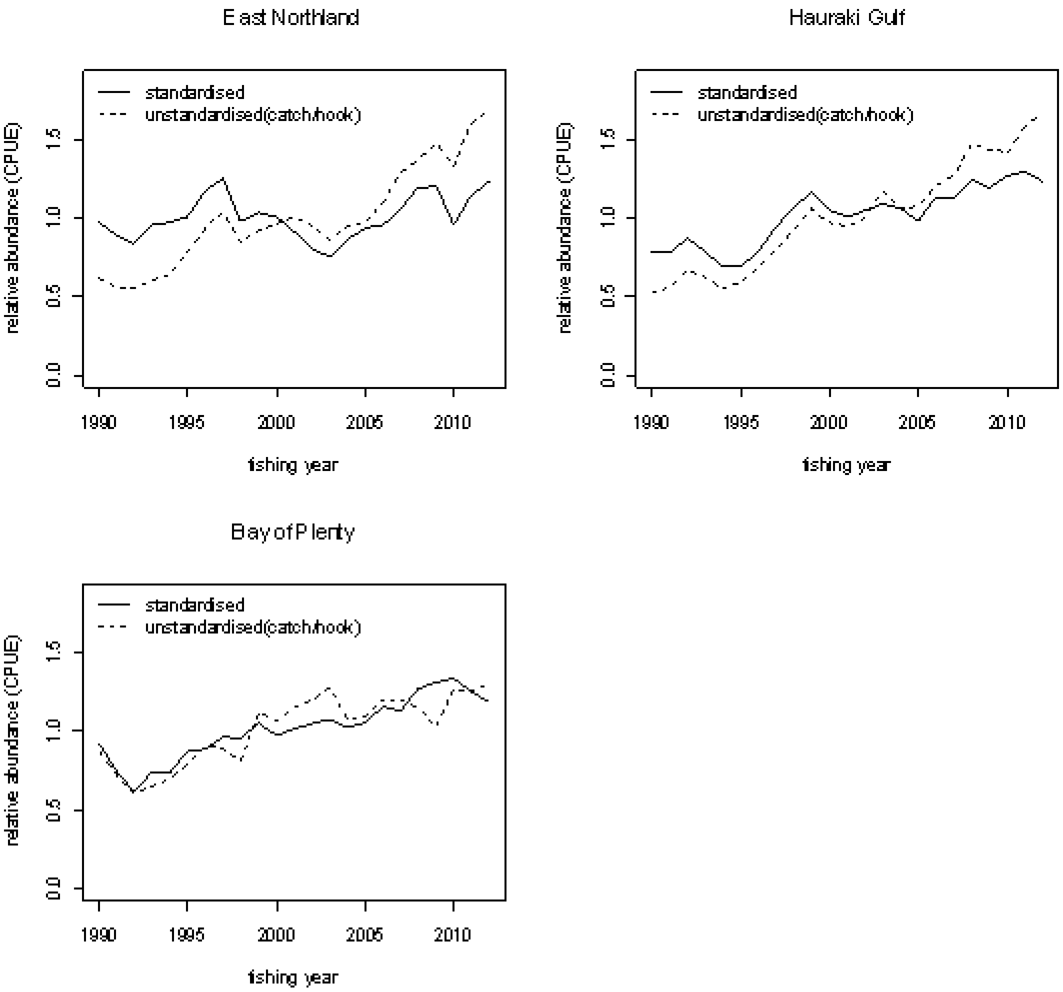


Figure 6: Longline CPUE indices of abundance (standardised and unstandardised) from 1990–2012 for the three component stocks of SNA 1.

The area specific longline CPUE indices were fitted by the 2013 model, with each series assigned an 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 2011–12 (a 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 1995–96 fishing year, most Bay of Plenty trawl fishers used the less detailed daily CELR reporting forms. From 1995–96, however, a significant number of Bay of Plenty trawl fishers (over 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 eight, not five, 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 the 1995–96 to 2011–12 fishing years (a 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 CPUE 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 when 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 16.

The standardised CPUE indices suggest that the Bay of Plenty trawl fishery experienced a slight increase in abundance between 1996 and 2008 and more recently from 2010–11 (Figure 7).

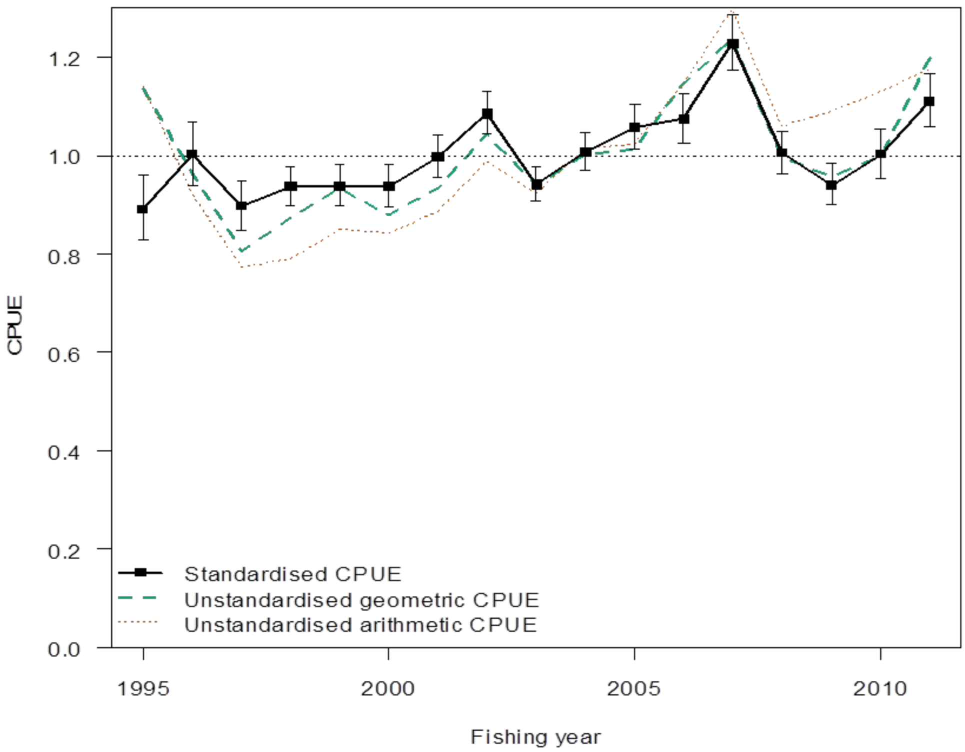


Figure 7: Single trawl CPUE indices of Bay of Plenty area abundance (standardised and unstandardised) from 1996–2012. Note: 1995 is the 1995-96 fishing year in this plot.

The single trawl Bay of Plenty CPUE was fitted with an assigned overall CV of 0.15 (see Table 15).

6.1.4 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 (see Table 15).

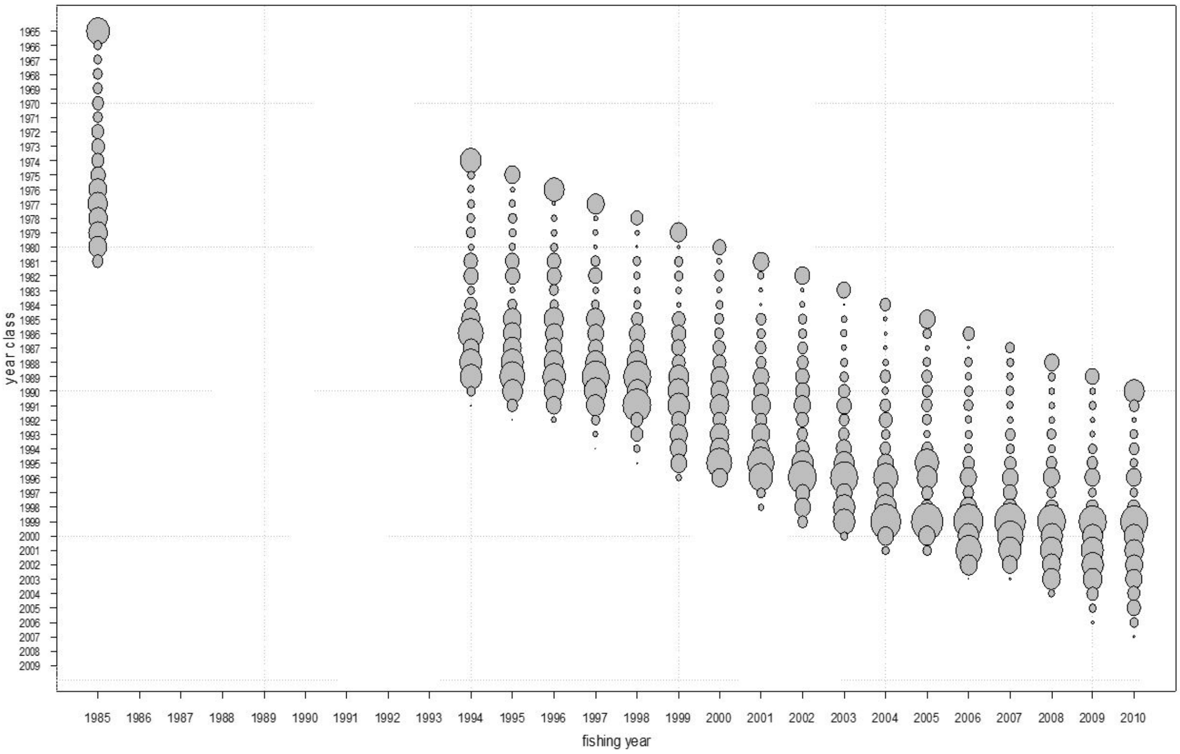


Figure 8: Relative year-class strength observed in the East Northland longline fishery 1984–85 to 2009–10. Year on the x-axis refers to the second part of the fishing year. The oldest year class is a 20+ group.

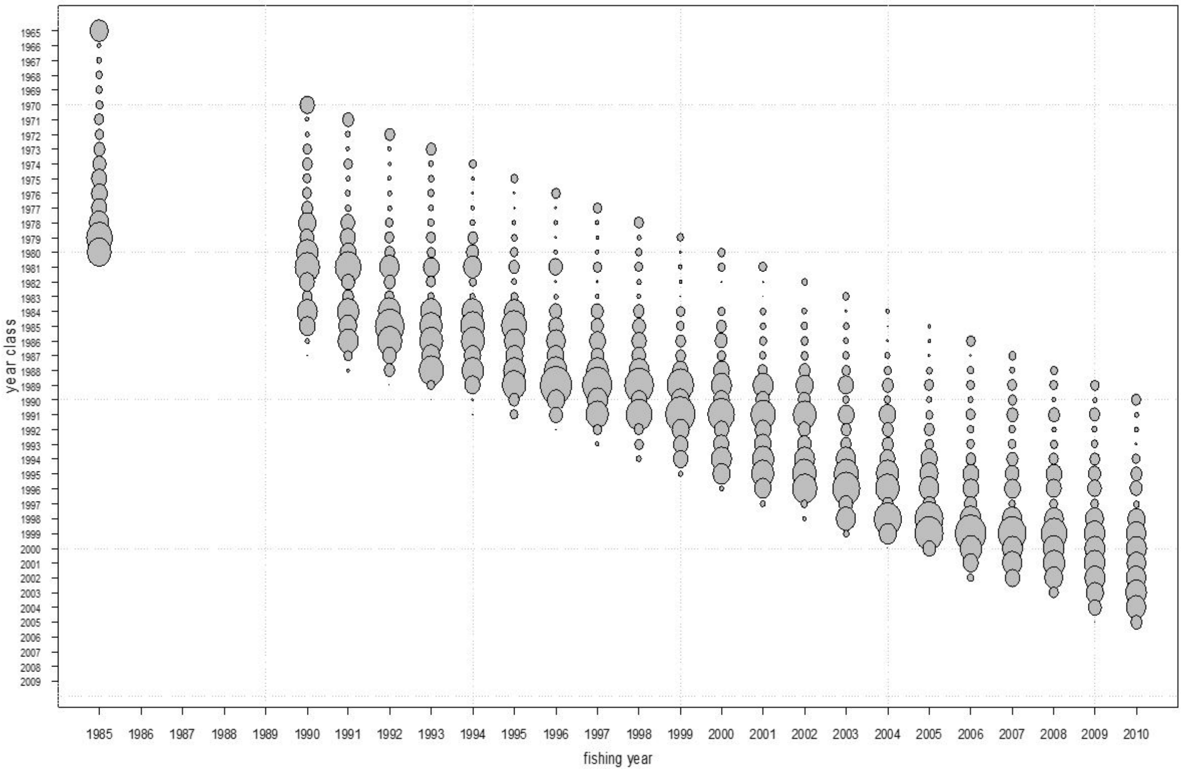


Figure 9: Relative year-class strength observed in the Hauraki Gulf longline fishery 1984–85 to 2009–10. Year on the x-axis refers to the second part of the fishing year. The oldest year class is a 20+ group.

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 longline age composition is similar to that for SNA 8, with the fishery largely comprising only 4–6 dominant age classes with few fish older than 20 years present in the catch samples (Figure 10).

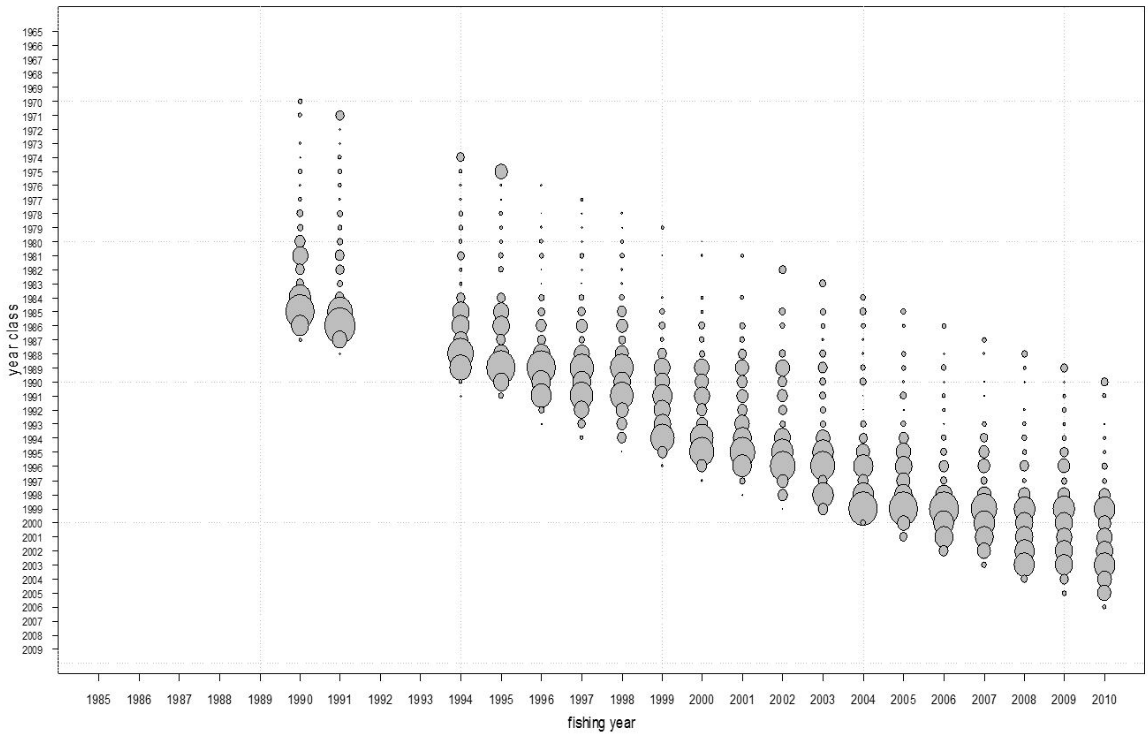


Figure 10: Relative year-class strength observed in the Bay of Plenty longline fishery 1990–91 to 2009–10. Year on the x-axis refers to the second part of the fishing year. The oldest year class is a 20+ group.

Recreational data

Observations of recreational catch at length are available for most years after 1990, spanning the 1994 change in minimum legal size (see Table 15).

Research Trawl data

Catch-at-age observations from research trawl surveys are available for most surveys and fitted in the model for all areas (see Table 15).

6.1.5 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 et al 1988) was fitted in the model as a point estimate but given a high CV (0.4) in recognition of 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 by 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 & 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 & McKenzie (1999) to adjust the tagging data for trap avoidance.

Detection of recaptured tags

Because a fisheries-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 because the model will expect these fish to be larger than they are. Because it was not possible to incorporate this source of bias in the model, it was assumed that, given that 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 because it depends largely on the spatial distribution of recapture effort (i.e., fishing) within the spatial stratum. Heterogeneity was observed in both tagging programmes because 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 (positive or negative) 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 (Davies 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.

6.1.6 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 17). However, for all stocks and areas current biomass is 30–68% higher than its minimum value (Table 17). 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 17). ENLD/EN and BOP/BP are estimated to have contained broadly similar tonnages (53 000 t to 112 000 t) before the fisheries started; which was estimated to be the larger depends on whether the biomass is considered by stock or by area.

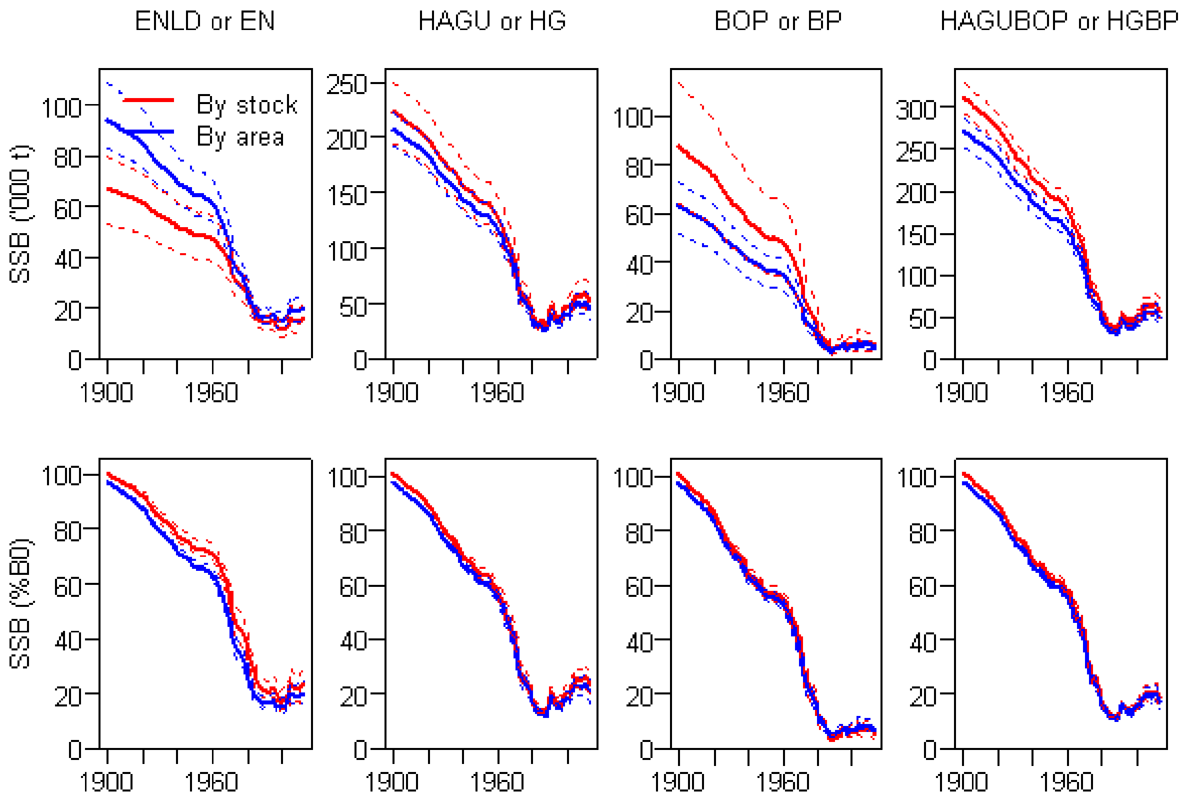


Figure 11: *SSB* trajectories by stock (red lines) and area (blue lines) from the base model. Solid lines are MCMC medians, broken lines are 95% confidence intervals.

Table 17: 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.

Most fish do not move away from their home grounds, with migration being most common for BOP fish and least common for ENLD fish (Table 18). 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 with the observed movements of tagged fish.

Table 18: 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)

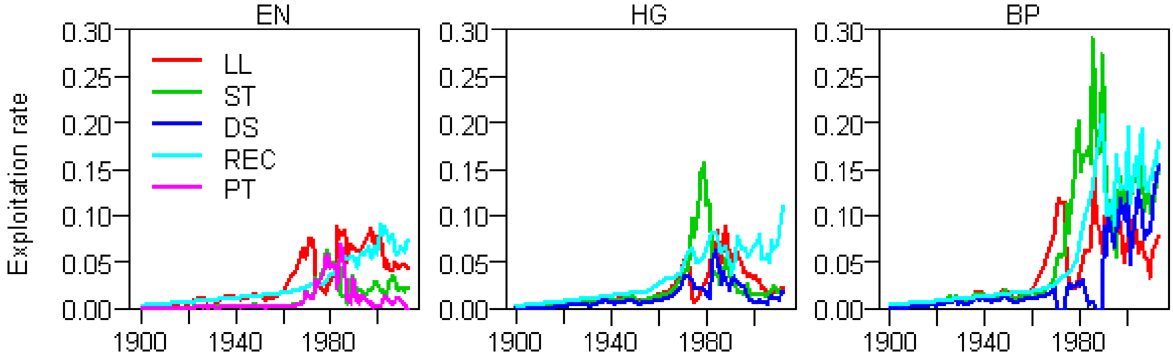


Figure 12: MPD estimates of exploitation rates by fishery and year.

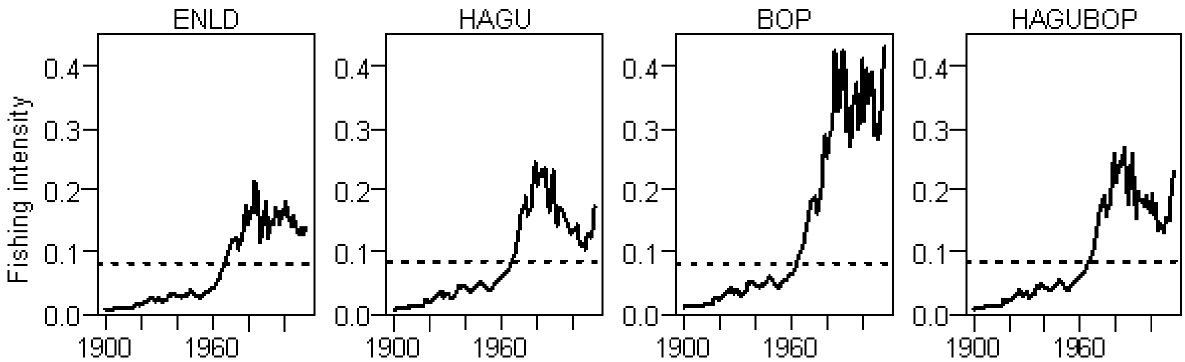


Figure 13: MPD estimates of fishing intensity by year and stock. Dotted lines show the intensity required to maintain the spawning biomass at 40% *B0 (U40%B0)*.

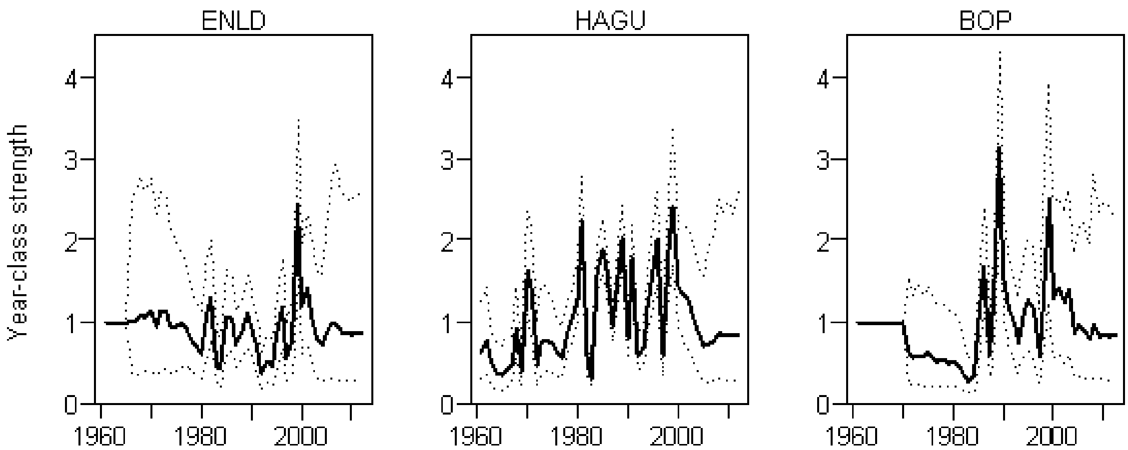


Figure 14: Estimated year-class strengths by year and stock (a value of 1 indicates that the year class has the strength predicted by the stock-recruit relationship). Estimates are MCMC medians (solid lines) and 95% confidence intervals (dotted lines).

In all areas current exploitation rates by method are estimated to be highest for the recreational fisheries (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).

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 19).

Table 19: 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 2015b).

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 20). Most of these alternative models are easily understood, but two merit more detailed description.

Table 20: 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 that 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 2015b).

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 models 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 with 6–7% B_0 in the base model), and model re-weight, 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.

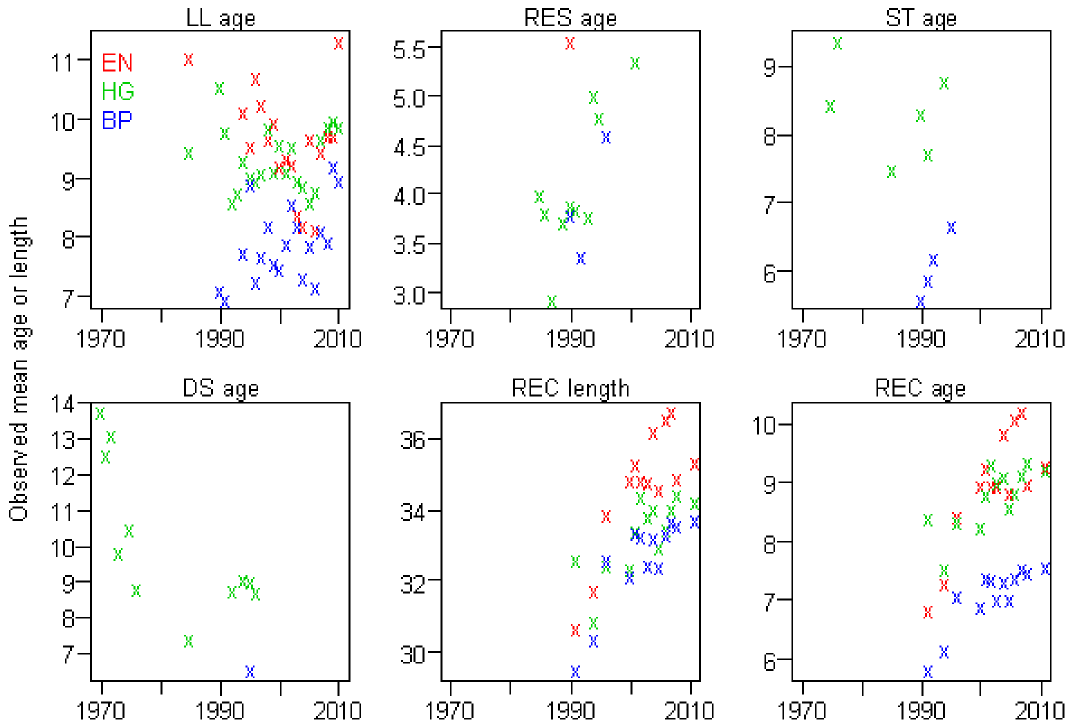


Figure 15: Observed mean age (for commercial fisheries and research surveys) or length (for recreational fisheries) by fishing method and area. In the bottom right-hand panel, the observed recreational mean lengths have been converted to ages using the mean length at age relationship (averaged over years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

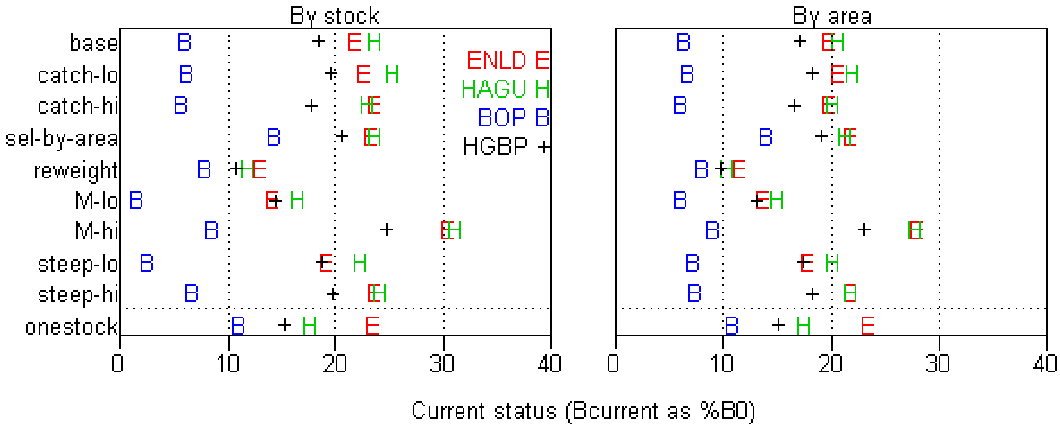


Figure 16: MPD estimates of current status (B_{2013} as %B_0), by stock and area, for the base model and some sensitivity analyses. The horizontal broken line separates the one-stock estimates from the others as a reminder that there is no distinction between spawning biomass by stock and by area for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

6.1.7 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 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.

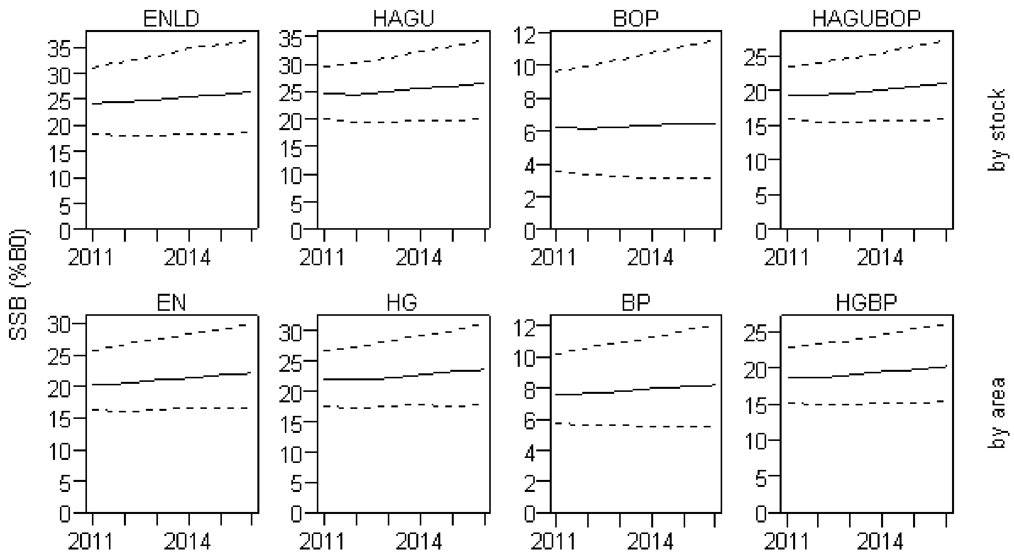


Figure 17: Projected spawning-stock biomass (*SSB*) by stock and by area. Estimates are MCMC medians (solid lines) and 95% confidence intervals (broken lines).

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 fisheries. 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-runs 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 21).

Table 21: 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

6.1.8 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. SNA 1 is currently only sampled for catch-at-age every three years.

6.1.9 Future research considerations

1. Because there is uncertainty in the relationship between standardised CPUE and abundance, it is necessary to investigate options for fisheries-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 two thirds 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.

6.1.10 Longline CPUE update

The 2013 stock assessment of SNA 1 incorporated CPUE indices for the fishing years 1989–90 to 2011–12 derived from the bottom longline fisheries operating in the East Northland, Hauraki Gulf, and Bay of Plenty areas within SNA 1 (section 5.1.3). The CPUE analyses were updated in 2016 to include data to 2014–15 (three additional years) (Langley 2016).

The updated CPUE indices were very similar to the corresponding CPUE indices included in the 2013 stock assessment. For each of the three fisheries areas, the most recent CPUE indices (2012–13 to 2014–15) (Figure 18) were broadly comparable with the CPUE indices from the preceding five years (i.e., 2007–08 to 2011–12).

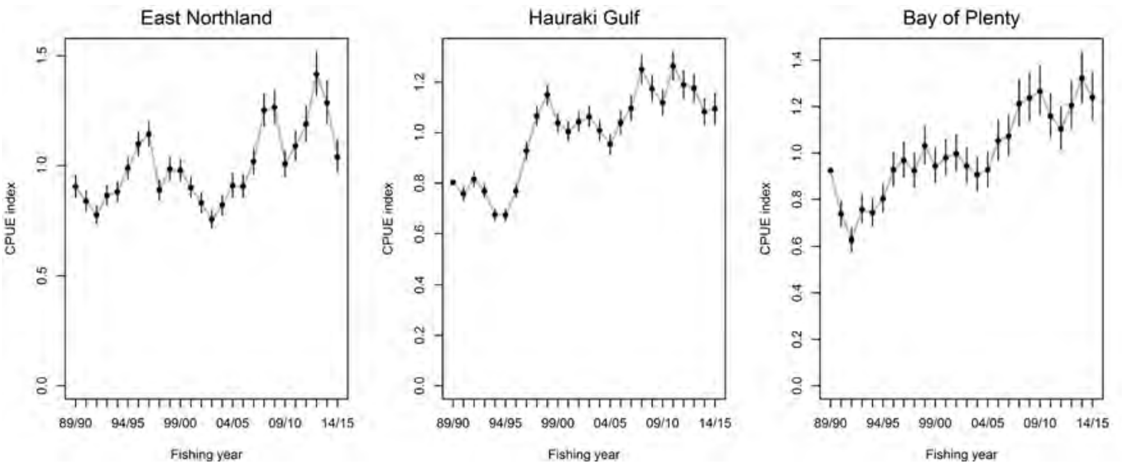


Figure 18: Longline CPUE indices (and 95% confidence intervals) updated to include 1989–90 to 2014–15 fishing years.

6.2 SNA 2

A full quantitative stock assessment was completed for SNA 2 in 2009 (Langley 2010). This assessment is not reported here because it assumed that SNA 2 comprised a single biological stock and the Plenary gave it a quality ranking of ‘2’ at the time of review. Subsequent catch-at-age sampling (Walsh et al 2012) found evidence for two sub-stocks within SNA 2: a northern stock located between Mahia Peninsula and Cape Runaway, and a southern stock occurring within Hawke Bay. In 2017 standardised CPUE indices for the two sub-stocks were derived using data from the mixed target bottom trawl fishery for the recent period of the fishery (2001–02 to 2015–16).

6.2.1 Standardised CPUE

In 2017, Schofield et al (2018a) completed a standardised CPUE analysis for the two sub stocks of SNA 2 using commercial catch and effort data from the bottom trawl fishery. Two data series were considered: vessel-day records from TCER, TCELR, and CELR (pre 2008) forms aggregated using the Langley method (Langley 2014); and tow by tow records from TCER and TCELR forms. The analysis included tows targeting snapper, trevally, tarakihi, and red gurnard and was limited to Hawke Bay and north, because there were very limited catches of snapper in the southern and eastern areas of SNA 2.

Due to changes in regulations and reporting behaviour between 1989–90 and 2001–02, data from this period were excluded from the analysis. Throughout this period the SNA 2 TACC was consistently over-caught, in 2000 Annual Catch Entitlement was introduced, in 2001 differential deemed values were introduced, and in 2002 the SNA 2 TACC was increased to 325 t.

The boundary between the northern and southern sub-stocks was assumed to lie off the southern tip of Mahia Peninsula, splitting Statistical Area 013 into Eastern and Western sub-areas at 177.87° E. A classification partitioning model was used to allocate catch and effort reported from Statistical Area 013 on CELR forms to one of the two sub-stocks, trained using the high-resolution data available since 2007. The partition tree used landing port for the primary split and then target species as a secondary split when landing port was not Auckland, Gisborne, or Tauranga. Actual area (013W or 013E) was correctly assigned for 88.9% of records in the training dataset.

A Generalised Linear Modelling (GLM) approach was applied to model the occurrence of snapper catches (presence/absence) and the magnitude of positive snapper catches. The dependent variable of the catch magnitude CPUE models was the natural logarithm of catch. For the positive catch CPUE models, a Weibull error structure was adopted following an evaluation of alternative distributions. The presence/absence of snapper catch was modelled based on a binomial distribution. The range of potential explanatory variables included vessel, fishing year, month, location, depth, target species, trawl speed, trawl distance, and trawl duration.

For the northern sub-stock snapper occurred in approximately 70% of vessel-days; occurrence had a generally increasing trend from 2002 to 2008 and then a slightly decreasing trend from 2008 to 2016.

The southern sub-stock had positive catches in around 50% of vessel-days between 2002 and 2007 then a steady decline to 20% occurrence in 2016. Trends in occurrence for the tow-based series were broadly consistent taking into account the reporting of the top eight species in the TCER data, as opposed to the top five species in the vessel-day series.

The positive catch indices for northern sub-stock were stable from 2002 to 2004, declined from 2005 to 2009, and have since fluctuated without trend. The southern sub-stock positive catch indices increased from 2002 to 2004, then declined until 2010, from which point they have been stable. The tow-based series from both sub-stocks follow the vessel-day series.

The combined series for the northern sub-stock increased from 2002 to 2006, declined from 2006 to 2010, then gradually increased from 2010 to 2016. The southern sub-stock also increased from 2002 to 2006, then declined substantially from 2007 to 2010. There was an uplift in 2012 and 2013 but the index subsequently showed a gradual decrease to 2016.

The NINS WG adopted the combined vessel day CPUE indices as indices of abundance for the SNA 2 sub-stocks (22 June 2017). These indices were updated in 2018 (Schofield et al 2018b) to include data to 30 September 2017. The indices in each area showed a noticeable increase in abundance in 2017.

6.2.2 Catch at age data

Seven years of age frequency data were available from the commercial fisheries for the 2009 assessment. There was considerable variability in the age compositions among years, likely to be due, in part, to the sampling of the snapper bycatch from a number of different target fisheries. The age compositions were principally composed of younger age classes and few old fish were sampled from the catch. There are concerns regarding the representative nature of the sampling and comparability of the ageing in earlier years.

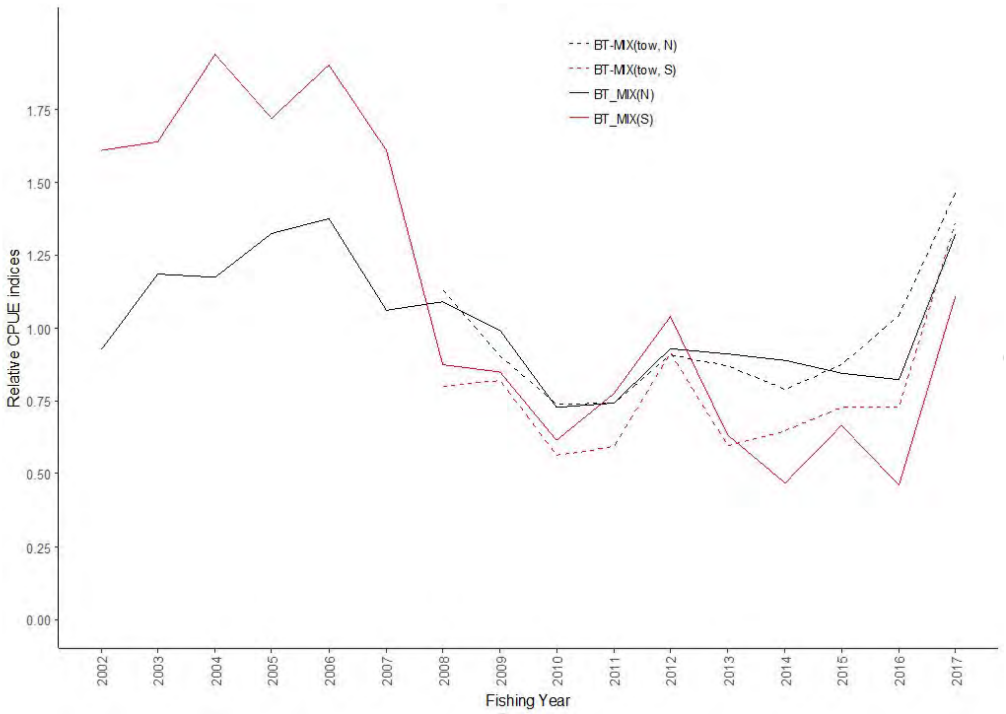


Figure 19: Comparison of standardised combined catch per unit effort (CPUE) indices for the northern and southern sub-stocks of SNA 2 from bottom trawling targeting gurnard, snapper, tarakihi, and trevally combined over all form types (BT_MIX), and more recently from data based on TCEPR/ TCER (BT_MIX(tow)) format data only (Schofield et al 2018b). Both series are scaled relative to the geometric mean of the years they have in common. Fishing years are labelled according to the second calendar year, e.g., 2002 = 2001–02. In both standardisation models a Weibull error distribution was assumed for positive catches.

A further commercial catch sampling programme was conducted in the 2007–08 and 2008–09 fishing years (Walsh et al 2012). The study found evidence for two sub-stocks within SNA 2: a northern stock located between Mahia Peninsula and Cape Runaway, and a southern stock within Hawke Bay. Walsh et al (2012) demonstrated that although strong year classes were consistent between stocks, a range of year classes were present in the northern area (similar to the eastern Bay of Plenty), whereas the southern area was dominated by a few strong year classes. Snapper from the southern sub-stock grew considerably faster than those from the northern sub-stock weighing 60–50% more at any given age.

6.3 SNA 7 (Challenger)

A stock assessment of SNA 7 was undertaken in 2002 (Gilbert & Phillips 2003) following an initial assessment conducted by Harley & Gilbert (2000). These assessments incorporated a long time series of historical catch and the magnitude of the overall catch produced estimates of virgin stock biomass that were relatively large. The stock assessment was externally reviewed in 2006. Based on that review, the Snapper Working Group concluded (25 September 2006) that the estimates of recent stock biomass from the assessment model were unrealistically high and the assessment was not suitable for management of the fisheries. The Working Group concluded that a further SNA 7 assessment should not be conducted until a reliable index of abundance was available for the stock.
The development of a time series of CPUE indices from the SNA 7 trawl fishery (Hartill & Sutton 2011) enabled a stock assessment to be conducted. An initial model was configured that was similar in structure to the earlier assessment and many of the historical data sets were sourced directly from Harley & Gilbert (2000). The model results were accepted as a preliminary assessment by the 2014 Plenary and further refined in 2015 (Langley 2015).

Over the subsequent years, additional data were collected from the fisheries and the assessment was updated again in 2018 (Langley 2018) and 2020 (Langley 2020a).

6.3.1 Model data sets

CPUE indices
The recent stock assessments of SNA 7 have incorporated a time series of CPUE indices as a primary index of stock abundance. The CPUE indices are based on catch and effort data from the Tasman Bay/Golden Bay trawl fishery targeting snapper, flatfish, red gurnard, and, to a lesser extent, barracouta during October–April. Successive analyses have updated and refined the CPUE indices and the current time series includes the 1989–90 to 2018–19 fishing years. The accepted CPUE indices are based on catch and effort data aggregated by vessel fishing day. A GLM approach was applied to separately model the probability of catching snapper (binomial model) and the magnitude of positive (non-zero) snapper catch (lognormal model). A combined series of CPUE indices (delta-lognormal) were derived from the annual coefficients of the two models.

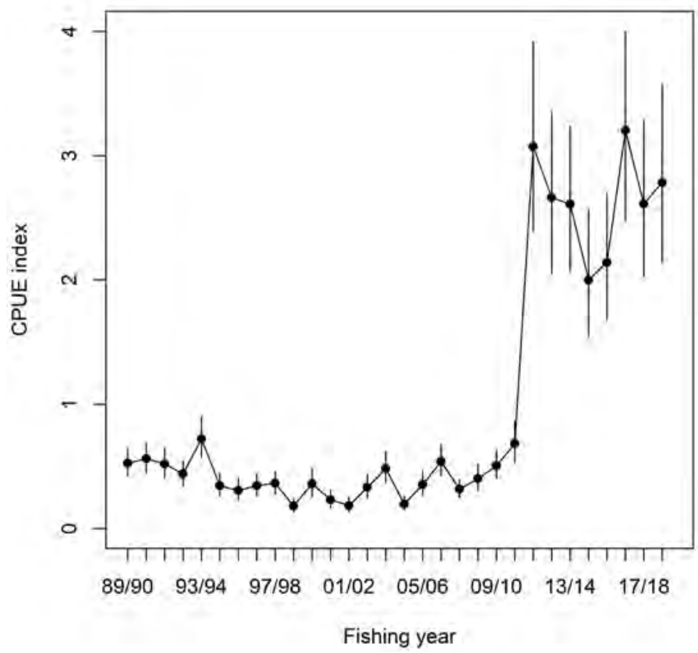


Figure 20: Relative CPUE indices derived from the delta lognormal (all years) model for the combined single trawl fishery. The vertical lines represent the 95% confidence intervals. The confidence intervals were derived using a bootstrapping procedure.

The time series of CPUE indices are relatively constant during 1989–90 to 2010–11, increase considerably in 2011–12 (by 450%), and remain at the higher level during the subsequent years (Figure 20). An investigation of the fine-scale trawl catch and effort data collected from the fishery from 2007–08 onwards revealed no obvious spatio-temporal changes in the operation of the fishery that might have contributed 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 with the indices derived from the longer-term CPUE models (all years).

Trawl survey
The West Coast South Island inshore trawl survey also encompasses the Tasman Bay/Golden Bay area, although prior to 2017 the survey had not included the shallower areas (less than 20 m) that support most of the snapper catch. Trawl survey biomass estimates of recruited snapper in 2015, 2017, and 2019 (core area) revealed a larger increase (over 10-fold) in relative abundance compared with the CPUE indices.

The trawl survey biomass estimates were not included in the assessment model because the survey time series did not encompass the entire distribution of snapper in the Tasman Bay/Golden Bay area. Further, the detailed analysis of the commercial catch and effort data revealed that the relative increase in snapper catch rates was higher in the deeper areas of Tasman Bay/Golden Bay (i.e., core survey area). This indicated that the current series of trawl survey biomass estimates (from the core survey area) may over-estimate the extent of the increase in snapper biomass (positively biased).

The 2017 and 2019 surveys were extended to include the 10–20 m depth range of Tasman Bay/Golden Bay. The age compositions of snapper from these two recent trawl surveys are considered to represent an unbiased estimate of the age composition of the snapper population and, on that basis, were incorporated in the stock assessment model. The 2019 trawl survey (core + SNA) age composition was dominated by 1-year old fish, indicating relatively strong recent recruitment (the 2017 year class).

Other model data
The other main data inputs included in the 2020 stock assessment model are, as follows:

- Commercial catch history (1931–2018) apportioned by pair trawl (BPT) and single trawl (BT) fishing methods. The annual catches include an additional 20% allowance for under-reported catch prior to the introduction of the QMS in 1986 and a 10% allowance for the subsequent years (Figure 21).
- Recreational catch history (see below for details).
- Commercial age frequency data: BPT from pre QMS era (N=5) and BT from QMS era (N=9).
- An estimate of 1987 stock biomass from a tag release-recovery programme (N=1) (Kirk et al 1988).
- Age compositions of snapper in Tasman Bay/Golden Bay sampled by the 2017 and 2019 *Kaharoa* trawl surveys (core area) augmented by length compositions from the earlier surveys for which age compositions were not available (2007, 2011, 2013, and 2014).
- An age composition of snapper in Tasman Bay/Golden Bay sampled by the 2019 *Kaharoa* trawl survey (core + SNA area) and the length composition from the 2017 survey.
- Length compositions from the recreational fishery (2005, 2011, 2015–2017) obtained from boat ramp interviews.

The recreational catch history was formulated based on estimates of recreational catch from 1987, 2005–06, 2011–12, 2015–16, and 2017–18 (Figure 21). The point estimates were used to determine estimates of recreational exploitation rates in each year based on the annual estimates of biomass from preliminary model runs. Exploitation rates were interpolated between successive recreational catch estimates to determine annual estimates of recreational catch from 1987 to 2016. The 2018–19 recreational catch was estimated using the 2017–18 exploitation rate. For the period prior to 1987, the exploitation rate was extrapolated, declining by 10% per annum, to the early 1960s when a lower threshold of 10 t per annum was attained.

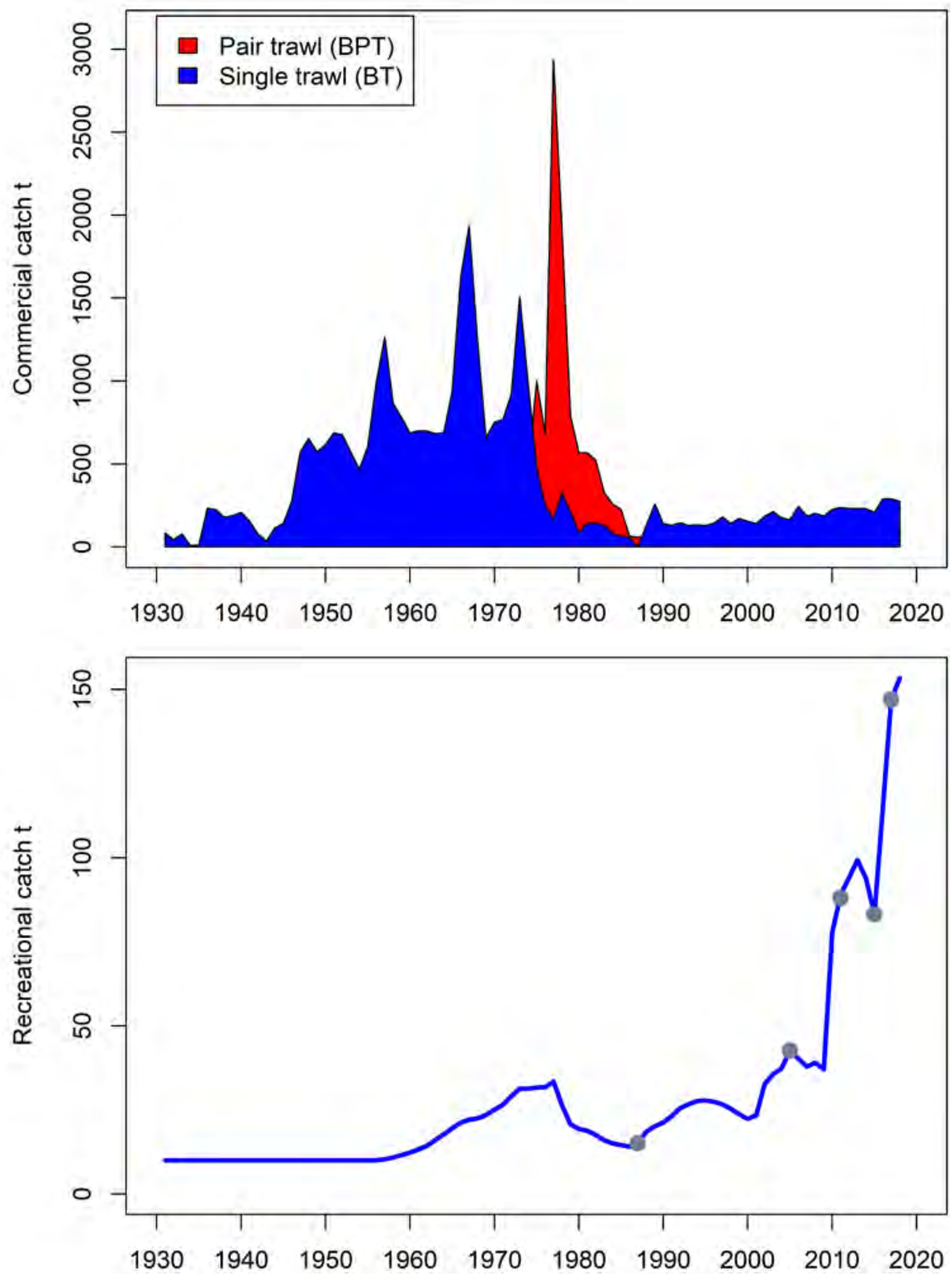


Figure 21: Commercial (top) and recreational catch histories for SNA 7 included in the stock assessment models. The commercial catch history includes an allowance for 20% unreported catch prior to the QMS and 10% allowance in the subsequent years. The grey points represent the survey estimates of recreational catch.

Model structure and assumptions

A statistical age-structured population model for SNA 7 was implemented using Stock Synthesis (Methot & Wetzell 2013). The main model structural assumptions for the base model option are as follows:

- The initial population (1931) is in an unexploited, equilibrium state and assumes two sexes and 30 age classes, including a plus group. The model data period is 1931–2018 (the 2018 model year represents the 2018–19 fishing year).
- Recruitment for 1931–1949 is at the equilibrium level (with a Beverton-Holt stock-recruitment relationship, SRR, steepness of 0.95); recruitment deviates are estimated for 1950–2017. Recruitment for 2018 was assumed based on the average level of recruitment from the stock-recruitment relationship.
- Commercial fisheries selectivities are age-based and temporally invariant.
- Selectivities for the commercial BPT and BT fisheries have full selection for all recruited age classes (parameterised using a logistic selectivity function).

- Age based selectivity for the *Kahaora* trawl survey (core area) is parameterised using a logistic selectivity function. The single age composition from the 2019 core + SNA survey area was fitted with a separate logistic selectivity function.
- The selectivity of the recreational fishery is length-based and parameterised using a double normal function. Selectivity is configured with three time blocks (pre-2013, 2013–2015, and 2016 onwards) to account for the increase in the catch of larger fish by the longline method in the intermediate period.
- All CPUE indices were assigned a CV of 25% (based on RMSE from preliminary model runs).
- The tag biomass estimate was assumed to represent the proportion of the stock biomass that had recruited to the commercial BPT fishery in 1987. The tag biomass estimate was assigned a CV of 30% following Harley & Gilbert (2000). The moderate CV was adopted to reflect concerns regarding the reliability of the tag biomass estimate.
- Relative weightings (ESS) of the age composition were informed following the approach of Francis (2011); the BPT age compositions were assigned an Effective Sample Size (ESS) of 8.5, BT age an ESS of 10, trawl survey age and length compositions an ESS of 10. Recreational length compositions were assigned an ESS of 1.0.

Initial model options assumed a steepness of 0.90 for the SRR. However, the results of MCMC sampling revealed that a subset of the MCMC chains estimated annual recruitments that were very low and insufficient to support the subsequent catches resulting in the stock crashing during the mid-late 2000s. This effect was ameliorated for a model sensitivity with a higher value of steepness of 0.95. This sensitivity run was subsequently elevated to become the new base case. The lower value of steepness (0.90) was retained as a model sensitivity.

Table 22: Details of parameters that were fixed in the base model.

Natural mortality	0.075 y^{-1}
Stock-recruit steepness (Beverton & Holt)	0.95
Std deviation of rec devs (sigmaR)	1.5
Proportion mature	0 for ages 1–2, 1 for ages > 2
Length-weight [mean weight (kg) = a (length (cm))^b]	a = 4.467 × 10-5, b = 2.793
Growth parameters	k=0.122, $L\infty$ = 69.6, Length1=13.1
Coefficients of variation for length-at-age	0.075

Table 23: Estimated parameters for the base model and model sensitivities.

Parameter	Number of parameters	Parameterisation, priors, constraints
LnR_0	1	Uniform, uninformative
Rec devs (1950–2017)	68	SigmaR 1.5
Selectivity BPT commercial	2	Logistic
Selectivity BT commercial	2	Logistic
Selectivity trawl survey core	2	Logistic
Selectivity trawl survey core+SNA	2	Logistic
Selectivity tag	–	Equivalent to commercial 1
Selectivity Recreational	8	Double normal
CPUE q	1	Uniform, uninformative

For the base model option, the model biomass approximates the point estimate of the 1987 recruited biomass from the tagging programme (Figure 22). The model also provides a good fit to the time series of CPUE indices to 2010. Stock biomass is predicted to have increased considerably from 2010 (2010–11 fishing year) following the overall magnitude of the increase in CPUE indices. However, the fits to the individual CPUE indices from 2011–12 to 2018–19 are relatively poor (Figure 22).

The recent increase in the CPUE series is consistent with strong recruitment in recent years. This is evident from the dominant 2007 year class in the 2013–14 and 2016–17 age compositions and, correspondingly, the model estimates a very strong 2007 year class to fit the CPUE and age composition data (Figure 23). The model also estimates that the 2010 year class is of above average strength. The 2019 trawl survey (core + SNA) age composition was dominated by 1-year old fish and correspondingly the model estimated an exceptionally strong 2017 year class, although the magnitude of the recruitment estimate is extremely uncertain.

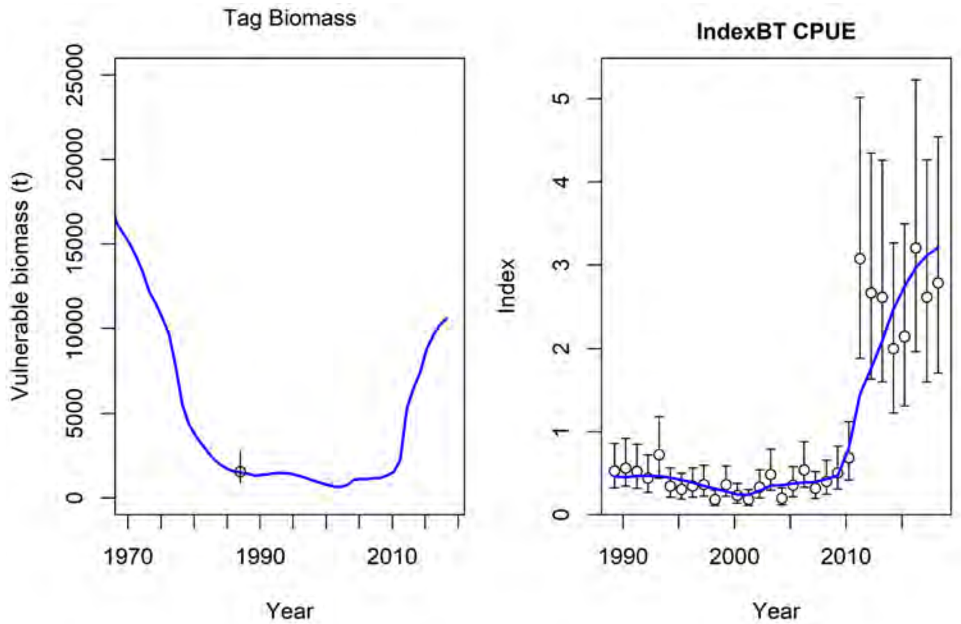


Figure 22: Biomass trajectories (MPD) for the base model option presenting the fit to the tag biomass estimate (left panel) and the CPUE indices (right panel). The point represents the biomass estimate from the 1987 tagging programme with the lognormal confidence interval (for an assumed CV of 0.30).

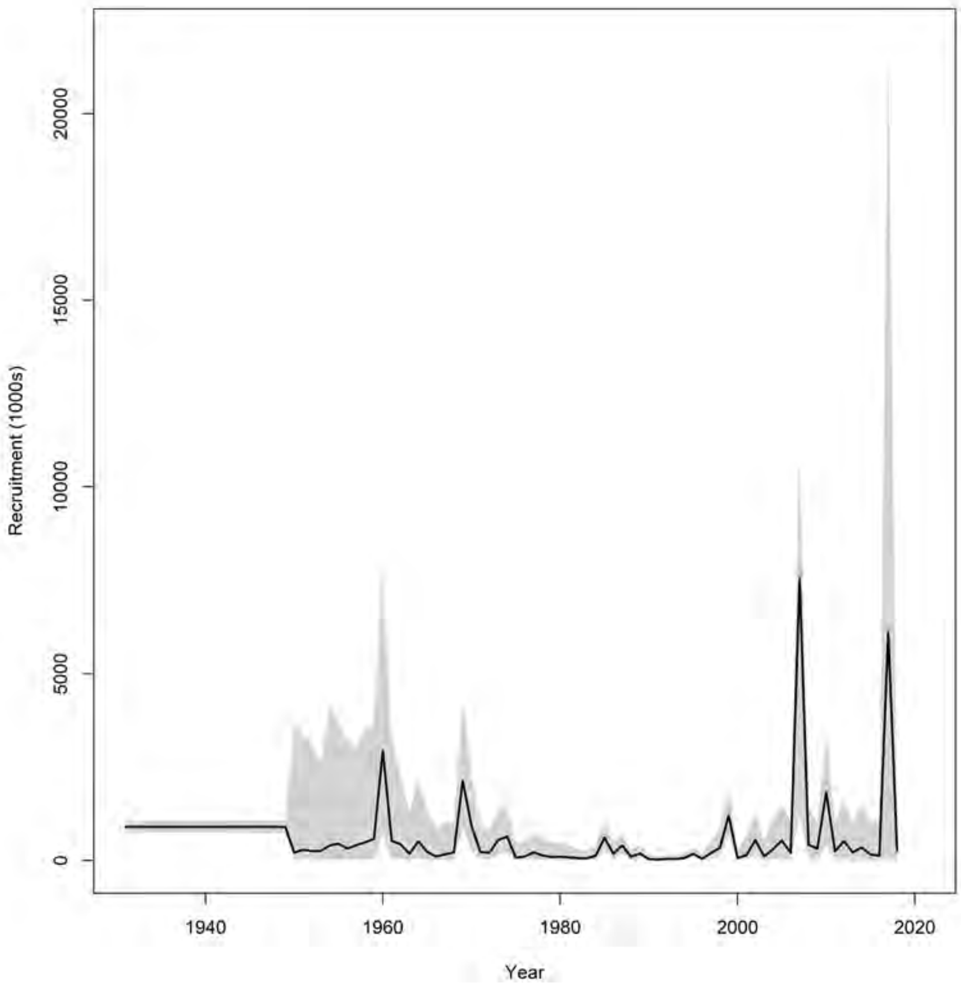


Figure 23: Annual recruitment for the base model (MCMC results). Recruitment deviates were estimated for 1950–2017. The line represents the median and the shaded area represents the 95% credible interval.

The model fits to individual age compositions from the recent years were relatively poor, indicating a degree of conflict with the CPUE indices. A range of model trials was conducted to investigate the relative influence of the individual data sets. These trials revealed that estimates of recent biomass were relatively insensitive to the weighting of the age composition data relative to the CPUE indices, although higher weighting of the commercial age composition data yielded slightly more optimistic estimates of stock status.

The base model provides estimates of current stock status that are quite uncertain, primarily due to the uncertainty associated with the estimates of the strength of recent recruitment (from 2007, 2010, and 2017 year classes). It was considered that the high degree of uncertainty in the base model adequately represented the overall uncertainty in stock status. On that basis, a limited range of additional model sensitivities were conducted to investigate the influence of key assumptions in the estimation of stock status. The final set of model sensitivities included a lower value of SRR steepness (0.90 compared with 0.95), a lower value of natural mortality (0.06 compared with 0.075), and a lower value of variation in the recruitment deviates (sigmaR 1.0 compared with 1.5) (Table 24). The sensitivity of the model results to the most recent strong year class (2017) was evaluated by excluding this year class from the estimated series of recruitment deviates (which is effectively the same as assuming this year class is of average size). The sensitivities were treated as single changes from the base model.

Table 24: Description of model sensitivities.

Sensitivity run	Description
NatMort sensitivity	$M = 0.06$
RecDev variation sensitivity	sigmaR = 1.0
Recruitment 2017	Recdev 1950-2016
Steepness 0.90	$h = 0.90$

Stock status (current 2018 = 2018/19 fishing year and forecast to 2024) for the SNA 7 spawning biomass was reported relative to the default hard limit of 10% SB_0 and the default soft limit of 20% SB_0 and interim target biomass level of 40% SB_0. Fishing mortality (2018) was reported relative to the corresponding interim target biomass level, i.e., $F_{SB40\%}$. The interim target biomass level was proposed at the SINS WG and was based on the default value for a low productivity stock as described by the Harvest Strategy Standard.

For the base model, biomass is estimated to have increased considerably from 2010 and the current (2018) biomass is well above the soft limit (20% SB_0). There is considerable uncertainty in the magnitude of the recent increase in biomass, although the stock is estimated to be at about the interim target biomass level (40% SB_0) (Figure 24a, Table 25). The model sensitivities estimated current stock status that bracketed the base model estimates – less optimistic current stock status from the lower natural mortality and lower steepness sensitivities and more optimistic stock status for the lower SigmaR sensitivity. The exclusion of the 2017 year class from the recruitment deviates resulted in a somewhat lower estimate of current stock status (Figure 24b). Stock status was relatively insensitive to the slightly lower alternative value of steepness, although the lower bound was poorly determined resulting in a higher probability of being below the hard and soft limits.

The MCMCs for the other lower productivity options also included a small subset of samples that crashed during the last 10 years of the model period, resulting in a very low confidence bound for the estimate of current biomass and related stock status metrics. As previously noted, those samples are not representative of current stock status and are a function of the stock productivity assumptions for each option. Consequently, the lower bound of the confidence interval is not considered to be reliably determined for those options and the corresponding probability of being below the hard and soft limits will be slightly over estimated.

For all model options, current rates of fishing mortality are well below the corresponding fishing mortality threshold ($F_{SB40\%}$) (Figure 25, Table 25).

Table 25: Estimates of current (2018–19) and virgin spawning biomass (t) (median and the 95% confidence interval from the MCMCs) and probabilities of current biomass being above specified levels and probability of fishing mortality being below the level of fishing mortality associated with the interim target biomass level.

Model option	SB_0	SB_{2018}	SB_{2018}/SB_0	Pr(SB_{2018} > X% SB_0)		
				40%	20%	10%
Base	15 624	6 347	0.406	0.534	0.965	0.983
	(13 066–18 479)	(2 574–9 473)	(0.167–0.589)			
NatMort sensitivity	16 928	5 905	0.352	0.265	0.919	0.958
	(14 719–19 486)	(19–8 609)	(0.001–0.506)			
Recruit sensitivity	14 841	5 864	0.391	0.465	0.95	0.97
	(12 899–17 335)	(951–8 593)	(0.066–0.567)			
SigmaR sensitivity	11 107	5 847	0.530	0.836	0.933	0.948
	(9 637–12 757)	(7–8 771)	(0.001–0.774)			
Steepness sensitivity	16 150	6 348	0.392	0.468	0.905	0.945
	(13 367–19 242)	(1–9 480)	(0–0.594)			

	$F_{SB40\%}$	$F_{2018}/F_{SB40\%}$	Pr(F_{2018} < $F_{SB40\%}$)
Base	0.056	0.598	
	(0.039–0.059)	(0.398–1.394)	0.941
NatMort sensitivity	0.048	0.76	
	(0.035–0.050)	(0.51–6.174)	0.821
Recruit sensitivity	0.056	0.674	
	(0.037–0.059)	(0.452–3.866)	0.880
SigmaR sensitivity	0.055	0.679	
	(0.037–0.059)	(0.432–8.562)	0.847
Steepness sensitivity	0.055	0.617	
	(0.041–0.057)	(0.402–8.357)	0.869

For all model options, estimates of current and equilibrium yield were derived for the stock based on the fishing mortality rate that corresponds to the interim target biomass level (Table 26). Equilibrium yields at the interim target biomass level are estimated to be about 550–700 t per annum. $F_{SB40\%}$ yields at 2018–19 biomass levels are comparable to the yields at 40% B_0. Current $F_{SB40\%}$ yields are higher than the level of current catch (428 t).

Table 26: Estimates of yield (t) at $F_{SB40\%}$ at the 2018–19 biomass levels and at 40% B_0, for the base model and the model sensitivities. The values represent the median and the 95% confidence interval from the MCMCs.

Model option	$F_{SB40\%}$	
	Yield at 40% B_0	Yield at current biomass
Base	701 (488–834)	692 (285–1044)
NatMort sensitivity	642 (475–747)	549 (2–819)
Recruit sensitivity	660 (455–783)	632 (110–946)
SigmaR sensitivity	486 (322–568)	616 (1–964)
Steepness sensitivity	700 (526–855)	670 (0–1032)

Projections

Projections were conducted for the two model options that either estimated the magnitude of the 2017 year class (Base model) or assumed 2017 recruitment to be at the average level derived from the SRR (Recruit sensitivity). Stock projections were conducted for the 6-year period following the terminal year of the model (i.e., 2019–2024). Projections assumed future recruitments were resampled from the lognormal distribution around the geometric mean. Annual catches in 2019 were assumed to be equivalent to 2018. Catches in the subsequent years were held constant at the same level, comprised a commercial catch equivalent to the TACC of 250 t, an allowance for additional mortality of 25 t, and a recreational catch of 153 t, representing a total catch of 428 t. There was no explicit allowance for customary catch.

Table 27: Probability of the spawning biomass being above default biomass limits and the interim target level in 2024 from model projections for the base case and recruitment (Recruit) sensitivity that assumed average recruitment for the 2017 year class from the time series of recruitment deviates estimated by the model.

Model option	*Pr(SB 2024 > X% SB_0)*		
	10%	20%	40%
Base	0.986	0.981	0.910
Recruit sensitivity	0.973	0.950	0.508

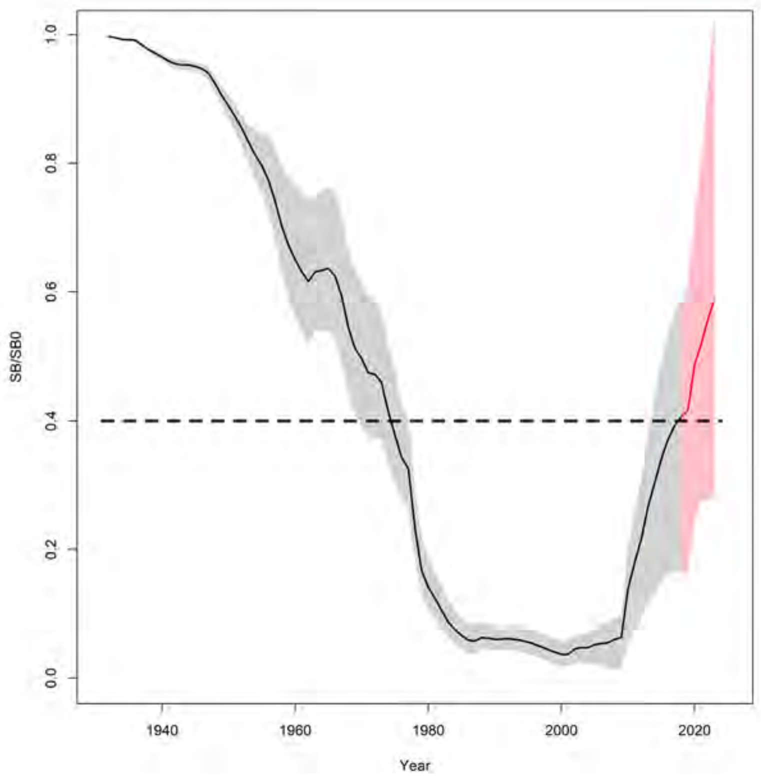


Figure 24a: Annual trend in spawning biomass relative to the 40% *SB0* interim target biomass level for the base model, including the estimation of recruitment for the 2017 year class. The line represents the median and the shaded area represents the 95% confidence interval. The projection period (2019–2024) is in red. The dashed line represents the interim target level.

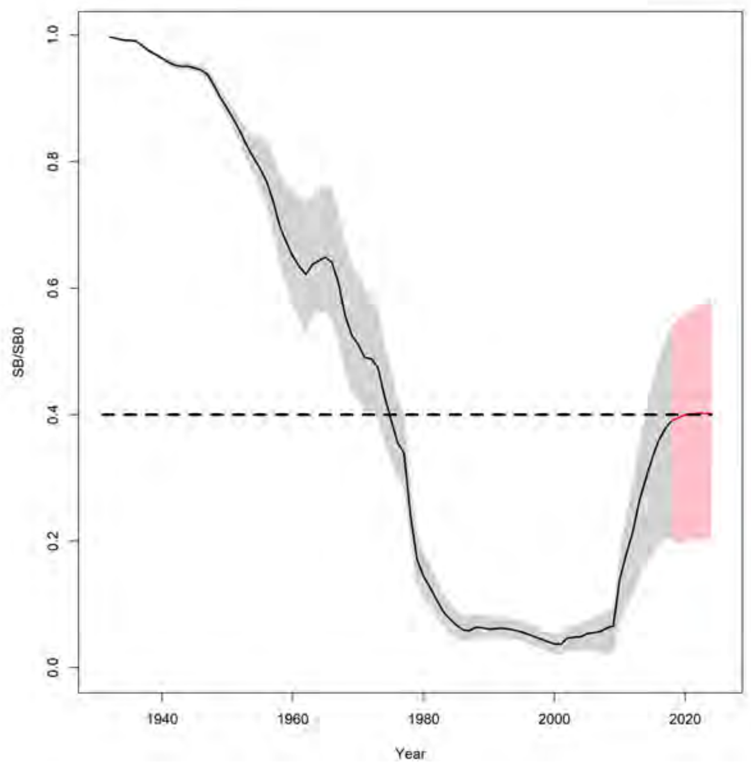


Figure 24b: Annual trend in spawning biomass relative to the 40% *SB0* interim target biomass level for the Recruit2016 model, assuming average recruitment for the 2017 year class. The line represents the median and the shaded area represents the 95% confidence interval. The projection period (2019–2024) is in red. The dashed line represents the interim target level.

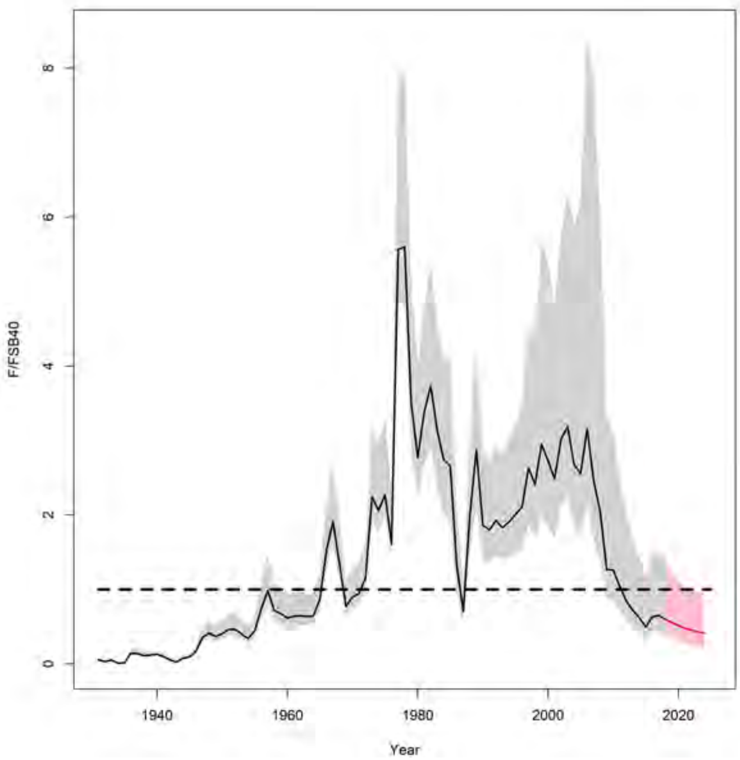


Figure 25: Annual trend in fishing mortality relative to the $F_{SB40\%}$ interim target biomass level for the base model (including estimation of the 2017–18 year class). The line represents the median and the shaded area represents the 95% credible interval. The projection period (2019–2024) is in red. The dashed line represents the interim target level.

The projections are strongly influenced by the continued increase in the biomass of the 2007 and 2010 year classes, resulting in an increase in total biomass during the projection period (Figures 24a, 24b). The projections are also sensitive to the magnitude of the recruitment from the 2017 year class. Model options that incorporate the estimation of the 2017 year class yield projected levels of biomass that are above the target biomass ($SB_{40\%}$ level) in 2024, whereas the model option that assumes average recruitment for the 2017 year class estimated projected biomass at about the target biomass level in 2024 (Table 27).

The two projections are considered to have equal validity on the basis that the magnitude of recent recruitment (2017 year class) is not precisely estimated in the assessment model.

Qualifying comments

The 1987 tag biomass estimate is considered to be an underestimate of the total recruited biomass due to the relatively small proportion of older fish estimated to be in the tagged fish population. However, model testing, either excluding or increasing the tag biomass estimate, has indicated that the assessment is relatively insensitive to the tag biomass estimate, especially with the assumed level of precision (CV 30%) (Langley 2015).

The level of stock depletion in the mid-1980s is strongly determined by the large catches taken during late 1970s and early 1980s. There is an assumed level of unreported catch taken throughout the period based on assumed levels of under-reporting from the SNA 1 and SNA 8 fisheries (i.e., 20% of the reported catch). It is unknown of the scale of unreported catch is appropriate for the SNA 7 fisheries, especially during the period of peak catches.

Recent trends in stock abundance, and the associated estimates of recent recruitments (especially the 2007 year class), are dependent on the large increase in the CPUE indices between 2010–11 and 2011–12. The CPUE indices are assumed to be directly proportional to stock abundance, although the assumption cannot be evaluated explicitly in the absence of other indices of stock abundance. A detailed analysis of fine-scale trawl-based catch and effort data did not reveal any appreciable shift in the spatial operation of this fishery that would result in an increase in the vulnerability of snapper to the trawl fishery. However, the fit to the recent CPUE indices is quite poor, which is reflected in the high CVs for these indices, and the uncertainty associated with the estimates of current stock status.

The time series of trawl survey biomass estimates of recruited (25+ cm FL) snapper from Tasman Bay/Golden Bay (TBGB) reveal a large increase in relative abundance from 2010–11 that is broadly consistent with the trend in stock abundance from the stock assessment model (Figure 26). The age composition of the snapper sampled by the trawl survey in 2016–17 also reveals the presence of the strong 2007 year class and a moderately strong 2010 year class.

The time series of core area trawl survey biomass estimates was not included in the stock assessment because the survey does not sample the shallower areas of Tasman Bay/Golden Bay and catch rates of snapper are variable, resulting in broad confidence intervals associated with the biomass estimates. Recent modifications of the trawl survey design to include the shallower areas of Tasman Bay/Golden Bay are likely to improve the utility of the survey for monitoring of SNA 7.

Comparisons of recent age compositions of snapper from the commercial fisheries and the trawl survey reveal differences in the relative proportion of the 2007 year class. For the most recent trawl survey age composition, the year class was less dominant (relative to the 2010 year class) than predicted by the assessment model. This may be related to spatial (depth) differences in the age structure of the snapper population in the area of operation of the commercial fisheries relative to the deeper core area sampled by the Tasman Bay/Golden Bay trawl survey. Currently, there is insufficient data in the model to adequately resolve these potential differences in selectivity (availability) in the assessment model.

Limited information is available regarding the magnitude of recent recruitment (2014–2019). There is some indication from the sampling of the shallow areas of Tasman Bay/Golden Bay during the 2019 trawl survey of the presence of a strong or above average (2017) year class. However, there is only a single observation of the year class from the trawl survey which is not sufficient to precisely quantify the magnitude of this year class.

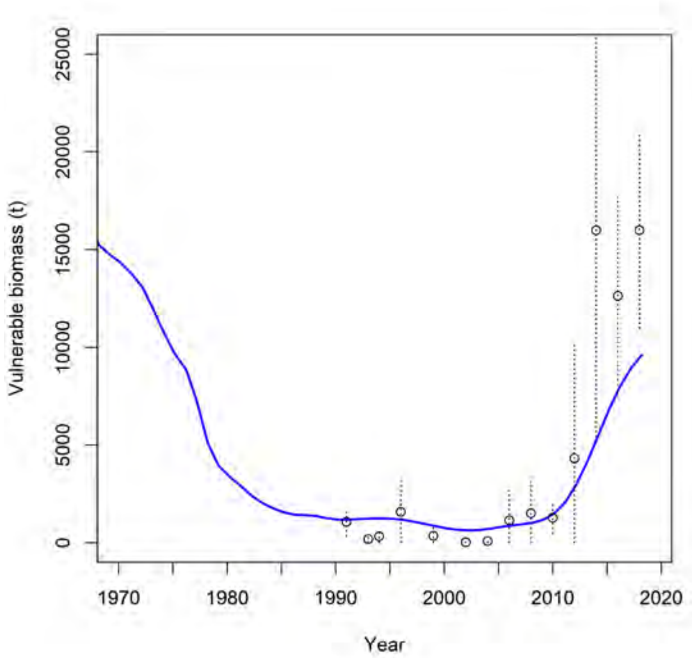


Figure 26: A comparison of the trend in trawl survey vulnerable biomass derived from the SNA 7 stock assessment (blue line) and *Kaharoa* west coast South Island trawl survey biomass estimates snapper from the Tasman Bay/Golden Bay area (points). The biomass indices are not included in the model likelihood.

Future research considerations

Estimates of current (and projected) stock status are relatively uncertain due to the low precision of the recent CPUE indices and, correspondingly, the uncertainty in the estimation of the strength of recent year classes (particularly the 2007–08 and 2017–18 year classes). The RV *Kaharoa* trawl survey was modified in 2017 to encompass the shallower areas of Tasman Bay/Golden Bay and, thereby, improve the monitoring of snapper abundance. The results of the 2017 and 2019 surveys were encouraging and the modified trawl survey design may enable snapper abundance to be monitored more accurately, thus improving future estimates of stock biomass.

Further sampling of the snapper age composition would provide additional information regarding the relative strength of the dominant year classes. Additional age composition data will be available from the sampling of the commercial catch in 2019–20. However, the additional sample will not provide information regarding the magnitude of the 2017–18 year class; these fish will not recruit to the commercial fisheries until the following year (from 2020–21).
The 2017–18 year class was sampled again by the next trawl survey in March–April 2021. The additional age composition data from this survey, in conjunction with the commercial age composition from 2019–20, will improve model estimates of trawl survey selectivity and may enable the time series of trawl survey biomass estimates to be incorporated directly into the stock assessment model. The next stock assessment is also scheduled for 2021. It is recommended that the model structure be refined to address the apparent conflict between a number of the key data sets (CPUE indices and age compositions) by incorporating additional spatial structure in the stratification of the commercial fisheries. This may include partitioning the snapper catch, CPUE, and age composition data by depth strata, reflecting the depth stratification of the trawl survey area (partitioned at 20 m). The analyses will be reliant on the event-based catch and effort data available from the SNA 7 trawl fishery from 2007–08 onwards. The resultant CPUE indices will augment the established time series of CPUE indices (derived from daily aggregate catch and effort data) in the assessment model.

Uncertainty in the estimate of the 2017 year class has highlighted the importance of monitoring recent levels of recruitment. A retrospective analysis of the assessment model may provide some insights into the number of observations of an individual year class (from trawl surveys or catch sampling) required to obtain adequate levels of precision for year-class strength estimates from the model.

In recent years, the recreational fishery has accounted for a significant proportion of the total catch from the fisheries and it is anticipated that recreational catches will remain relatively high in future years. Regular estimates of recreational catch would improve the precision of current estimates of total catch from SNA 7. There should be ongoing sampling of the recreational catch of snapper from boat ramps; such data also need to be analysed in more detail. Boat ramp data may also provide the opportunity to collect additional size composition data from the recreational fishery. There is also a potential to derive age compositions of the recreational catches from otolith samples collected from other sources (commercial catch sampling or trawl survey).

The recreational catches from the period prior to 2005 have been assumed and are highly uncertain. Future modelling should include an evaluation of alternative levels of recreational catch from this period. There is also considerable uncertainty regarding the historical commercial catches from SNA 7, especially during the period of peak catch in the late 1970s and early 1980s. Interviews with participants in the fishery during that period may improve estimates of the extent of under reported catches, including discards. This may result in an adjustment to the current assumption of a 20% overrun in the earlier years.

Further refinements to the assessment modelling should include a consideration of the assumptions related to the selectivity of the bottom trawl fishery, especially during the earlier period of the fishery (prior to 1970). During this period, it is considered likely that the trawl method would have had a lower selectivity for larger (older) snapper than is currently estimated by the assessment model.

The performance of the MCMCs have highlighted issues related to some of the productivity assumptions included in the range of model options investigated. For example, for a subset of the MCMC chains the productivity of the stock was insufficient to support the observed catches taken at low stock levels. Further evaluation of appropriate productivity assumptions related to the stock-recruitment relationship (functional form, steepness, and sigmaR) should be conducted.

Estimates of stock status have been provided principally based on the assumption of long-term, equilibrium conditions. Recruitment in SNA 7 has varied considerably over the history of the fisheries. Recent recruitment is estimated to be at a historically high level suggesting the stock is currently in a phase of higher productivity and that there is a degree of non-stationarity in the assumed nature of the relationship between spawning biomass and recruitment that is likely to violate the assumptions of equilibrium conditions. Further consideration is required to develop stock status indicators that account for variation in the productivity of the SNA 7 stock.

Recruitment variation is undoubtedly linked to variation in the prevailing environmental conditions associated with the spawning period and/or larval phase. Further investigation should be conducted to identify correlations between snapper recruitment estimates and key environmental variables to improve our understanding of snapper recruitment dynamics.

6.4 SNA 8 (Auckland West/Central West)

A stock assessment for SNA 8 was conducted in 2020 (Langley 2020b) and updated and finalised in 2021 (Langley in press). The assessment superseded the assessment conducted in 2005 (Davies et al 2013) and incorporated data from the intervening period, including recent trawl survey recruitment indices, commercial age composition data, and trawl CPUE indices.

6.4.1. Stock assessment model

The 2021 stock assessment of SNA 8 was conducted using an age-structured population model implemented in Stock Synthesis. The model incorporated data to the 2020–21 fishing year (2021 model year) including:

- Commercial catches by method, 1931–2021;
- Recreational catches, 1931–2021;
- Tag biomass estimates and population length compositions 1990, 2002;
- Estimates of numbers at age 2, 3, 4, and 5 year from *Kaharoa* inshore trawl surveys;
- Single trawl CPUE indices 1997–2020;
- Pair trawl CPUE indices 1974–1991;
- Single trawl catch age compositions (26 observations) 1975–2019;
- Pair trawl catch age compositions (18 observations) 1975–2006;
- Recreational catch length compositions; and
- Average length-at-age derived from otolith samples.

Commercial catches

Reported commercial catches from 1931–1990 were compiled by Gilbert & Sullivan (1994). These catches include estimates of reported foreign catches for 1968 to 1979 (Gilbert & Sullivan 1994). Annual commercial catches from 1986–87 to 2019–20 fishing years were available from catch reporting under the Quota Management System (Figure 27).
Previous snapper assessments have included an additional component of catch to account for unreported commercial catches (Davies et al 2006). Annual unreported catches were assumed to represent an additional 20% of the reported catch in the period prior to the introduction of the QMS and 10% of the reported catch in the subsequent years.

The commercial catch was dominated by two main fishing methods: single trawl and pair trawl. The pair trawl fishery developed in the mid-1970s and was the dominant method during 1976–1989 accounting for an average of 75% of the annual catch. The proportion of the catch taken by each trawl method during 1989–90 to 2019–20 was determined from the catch and effort data from the fisheries.

The compiled commercial catch history includes estimates of foreign catch; i.e., trawl catches from 1967 to 1977 and longline catch from 1975 to 1977 were included at the reported levels (Davies 1999). However, catch reports from the Japanese longline fleet were not available for 1965–1974 (Davies et al 2006). Following previous assessments (e.g., Davies et al 2006), an additional catch of 2000 t per annum was assumed for the Japanese fleet for that period.

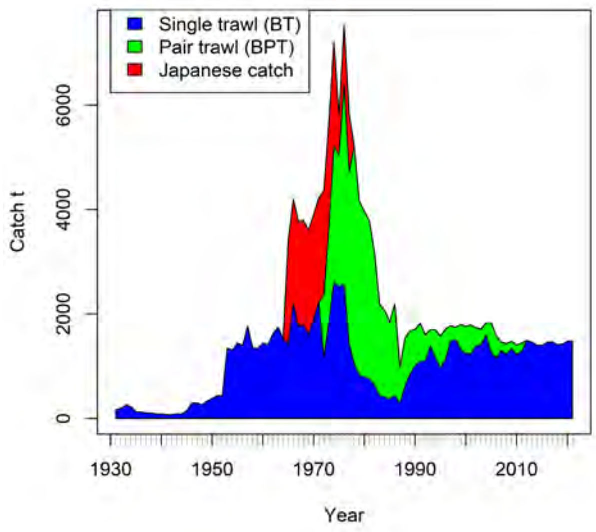


Figure 27: Annual commercial catches included in the base model, assuming unreported Japanese longline catches of 2000 t.

Recreational catches

A time series of recreational catch for 1931–2021 was configured, informed by recreational catch estimates available from 1990 (Figure 28). There is no information available regarding earlier (pre-1990) levels of recreational catch. Previous assessments formulated annual catches for this period based on an assumed initial (1931) level of recreational catch of 60 t and a linear increase in catch over subsequent years to the level of the 1990 recreational catch estimate (239 t). Annual catches were assumed to remain at the same level during 1990–1996.

Recreational catches in 2007, 2012, and 2018 were assumed to be equivalent to the point estimates from the respective recreational surveys, assumed known without error. A preliminary catch history was configured that assumed recreational catches increased linearly between each successive survey. The resultant catch history was incorporated in a preliminary configuration of the assessment model to generate a biomass trajectory that provided estimates of the exploitation rate for the recreational fishery corresponding to each survey estimate. The resultant estimates of exploitation rate were then used to iteratively regenerate the recreational catches in the years between the survey estimates (for 1997 to 2019). Exploitation rates were assumed to change linearly between successive surveys and the interpolated exploitation rate was applied to the annual biomass estimates to determine the recreational catches for the intervening years. The recreational catch in 2019 was derived based on the exploitation rate corresponding to the recreational catch estimate from 2018. This approach allows the recreational catch to vary annually in response to variations in stock abundance (as opposed to linear interpolation of catches between successive surveys). For the base model, recreational catches in 2020 and 2021 were held constant at the 2019 level. An alternative series of recent (2019–2021) recreational catches was derived using the recreational harvest rate from 2018 (*RecF* model).

Length composition data from the SNA 8 recreational fishery reveal that smaller fish are typically caught inside the west coast harbours (Hokianga, Kaipara, Manukau, Raglan, Kawhia) rather than the coastal area outside the harbours. On that basis, the annual recreational catches were partitioned into two fisheries based on these definitions, apportioned based on the recent distribution of catch (approximately 25% within harbours).

Customary Catch

There were no reliable estimates of annual customary catches from SNA 8 available for inclusion in the assessment model, although recent information indicates that the level of customary catch was relatively low (less than 6 t per annum, Table 6b). A component of the customary catch is probably included within the time series of recreational catch estimates and no additional estimate for customary catch was included in the assessment model.

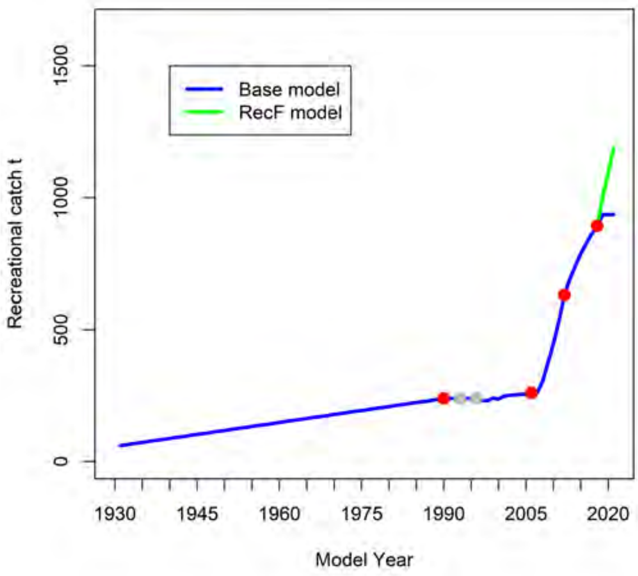


Figure 28: Recreational catch estimates from SNA 8 (red points) used in the derivation of the recreational catch history (blue line). The green line represents an alternative series of recent recreational catches assuming a constant recreational harvest rate from 2018. The grey points are additional recreational catch estimates from the 1993–94 and 1995–96 telephone diary surveys (presented for comparison only).

Tagging biomass

Two estimates of absolute biomass are available from tagging programmes conducted in 1990 and 2002. The current assessment used the equivalent biomass estimates included in a previous assessment; i.e., 1990, 9505 t (CV = 0.18) and 2002, 10 442 t (CV = 0.12) (Davies et al 2013). The biomass estimates were derived to represent all fish in the population 3 years and older, corresponding to fish above 25 cm fork length (FL).

The two tagging programmes also provided estimates of the population length composition for fish above 25 cm FL. The current assessment used the population proportions-at-length included in the previous assessment (Davies et al 2013). These length compositions represented fish aged 3 years and older and, accordingly, were truncated at a lower bound of 25 cm which approximates the lower length range of 3-year old fish.

Trawl survey indices

Trawl surveys of inshore finfish species, including snapper, off the west coast of the North Island were first conducted by RV *Kaharoa* in October–November 1986 and 1987. The spatial extent of these initial surveys was relatively limited and did not encompass the broader distribution of snapper. The survey area was extended for the subsequent series of trawl surveys that were conducted in 1989, 1991, 1994, 1996, and 1999. The *Kaharoa* trawl surveys were reinstated in 2018 and additional surveys were conducted in 2019 and 2020.

Since 1989, all surveys have encompassed a core area (from Ninety Mile Beach to North Taranaki Bight extending to the 100 m depth contour) and applied a similar spatial stratification. The spatial domain of the core area was refined to account for the removal of the Māui dolphin trawl exclusion area which was not sampled by the 2018–2020 trawl surveys.

The core area was applied to derive a comparable time series of survey biomass indices and scaled length compositions. The length compositions were converted to age compositions using an age-length key derived from otoliths collected from the core area of the survey.

The surveys were conducted at the beginning of the fishing year (October–November) and have been assigned to the corresponding model year following the calendar year of the survey. For example, the trawl survey in November 2018 was assigned to the 2019 model year (and denoted the 2018–19 survey).

Correspondingly, the ages of the sampled fish were incremented to the age at 1 January following the survey (e.g., fish aged 1+ at the time of the survey were assigned an age of 2 years).

The five biomass indices from the earlier surveys are substantially lower than the biomass estimates from the three recent surveys, although there is also a considerable difference in the magnitude of these three recent indices (Figure 29). The corresponding age compositions from the surveys reveal that the earlier surveys were dominated by 2- to 5-year old fish. For the recent surveys, the age compositions comprised a higher proportion of fish older than 6 years, particularly for the two most recent surveys (2019–20 and 2020–21).

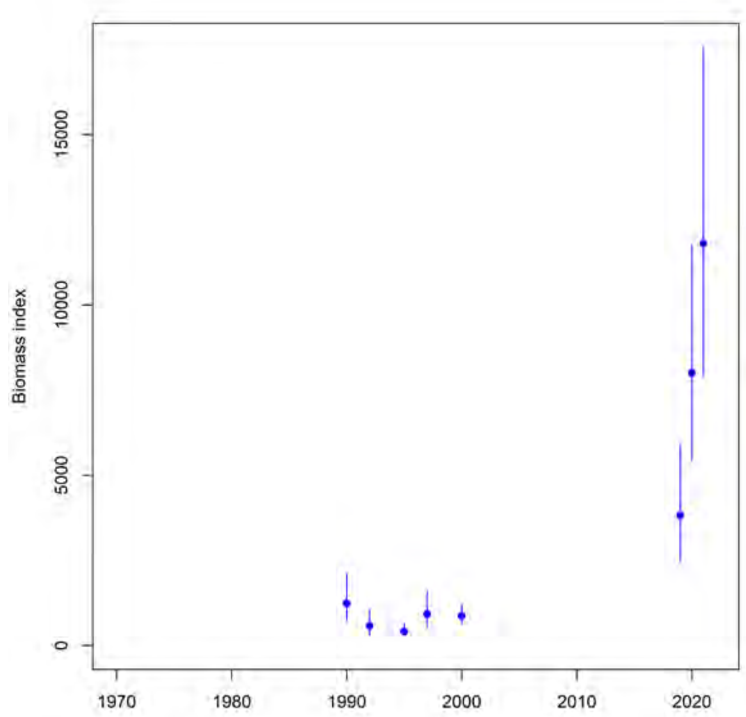


Figure 29: Snapper total biomass indices (and 95% confidence intervals) from the core area of the WCNI trawl survey area.

Most of the large increase in the biomass indices between the 2018–19 and 2019–20 trawl surveys was attributable to an increase in the abundance of fish surveyed in the 8- to 12-year old age range fish. The comparison of successive estimates of the individual year classes indicates that the catchability of these older fish was greater for the 2019–20 survey than for the 2018–19 survey. There is some concern regarding the timing of the 2018–19 trawl survey which was later than the other surveys in the series. The distribution of snapper catches and the gonadal maturation data suggested that the 2018–19 survey may have coincided with the main spawning period. Consequently, a significant proportion of the adult biomass may have been concentrated in areas not adequately sampled by the survey, in particular the shallower areas in the vicinity of harbour entrances.

Similarly, there was a considerable increase in the snapper biomass indices between the 2019–20 and 2020–21 trawl surveys (Figure 29), including an increase in the abundance of older fish (> 10 years). Most of the increase in biomass was in the 50–100 m depth range in the vicinity of Kaipara Harbour and Manukau Harbour. This may indicate an expansion of the main distribution of mature snapper, from the shallower areas not fully sampled by the current trawl survey, thereby increasing the overall availability of snapper to the trawl survey.

The survey age compositions were partitioned to derive estimates of numbers of fish in each age class. Survey estimates of 1-year old fish (0+) are relatively imprecise compared with estimates of numbers of fish in the older age classes. There are a limited number of year classes for which successive estimates of relative abundance (numbers of fish) are available from across a range of age classes from successive surveys. However, estimates of the numbers of 1-year old fish are generally substantially lower than subsequent estimates of the same year class at older ages and the individual estimates are poorly correlated. This indicates that the survey estimates of 1-year old fish probably do not provide a reliable index of the relative abundance of an individual year class. Probably because a large proportion resides in shallow water and harbours, which are not surveyed.

In contrast, there is a reasonable correspondence between successive trawl survey estimates of the number of fish in a specific year class over the 2- to 5-year age classes (Figure 30). For example, the estimates of abundance of the 2016 year class from the three successive trawl surveys (at ages 3, 4, and 5 years) indicated that the year class was one of the strongest indices from the respective series. This suggests that the trawl surveys are consistently sampling fish within those age classes.

Commercial age compositions

There is a considerable time series of age compositions available from the single trawl (26 years) and pair trawl fisheries (18 years), including samples from the mid-late 1970s. Those samples are characterised by a high proportion of fish in the oldest, aggregated age group (20+ 'plus group'). Fish older than 20 years represented a trivial proportion of the sampled catch from 1990 onwards. The more recent age compositions tended to be dominated by relatively strong year classes that are evident in successive samples.

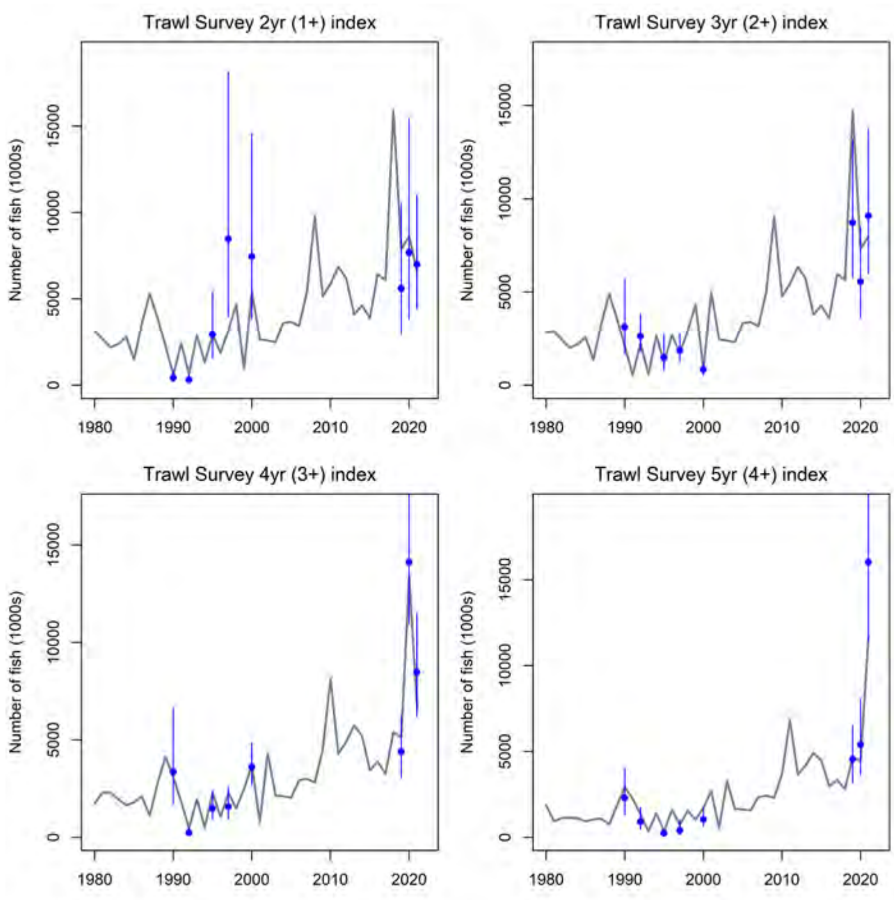


Figure 30: The four sets of age-specific trawl survey abundance indices (blue points and associated 95% confidence intervals) and the model fit to each set of indices (grey lines).

CPUE indices

Vignaux (1993) derived CPUE indices for the pair trawl fishery for 1974–1991 and the CPUE indices have been incorporated in the stock assessments of SNA 8 conducted since Gilbert & Sullivan (1994). The CPUE indices decline considerably during 1974–1986 and then recover somewhat over the subsequent years (Figure 31). The CPUE indices have an associated CV of 0.13–0.30 (Vignaux 1993) and the most recent assessment (Davies et al 2013) assumed an additional process error of 0.20.

A standardised CPUE analysis of the SNA 8 single trawl fishery catch and effort data was updated, including data from 1996–97 to 2019–20 (following Langley 2017). The data set comprised individual trawl records (fishing event-based data) from trawls targeting snapper, trevally, and red gurnard during January–April. The annual CPUE indices were relatively constant during 1996–97 to 2003–04. The indices increased over the subsequent years, initially increasing by approximately 70% during 2003–04 to 2007–08, and then increasing considerably during 2007–08 to 2014–15 (Figure 31). The indices remained at the higher level during 2015–16 to 2018–19 but were considerably lower in 2019–20. In recent years, there have been a limited number of vessels operating in the inshore trawl fishery and the operation of the vessels has changed in response to the increase in the abundance of snapper (increased avoidance). The standardised CPUE analysis has not adequately accounted for the change in fishing operation, particularly in the most recent year, as indicated by a divergence in the CPUE trends from the two main vessels in the fishery.

The recent trawl CPUE indices have an associated CV of 0.12–0.18. From the results of preliminary modelling, the CPUE indices were assigned a process error of 0.1.

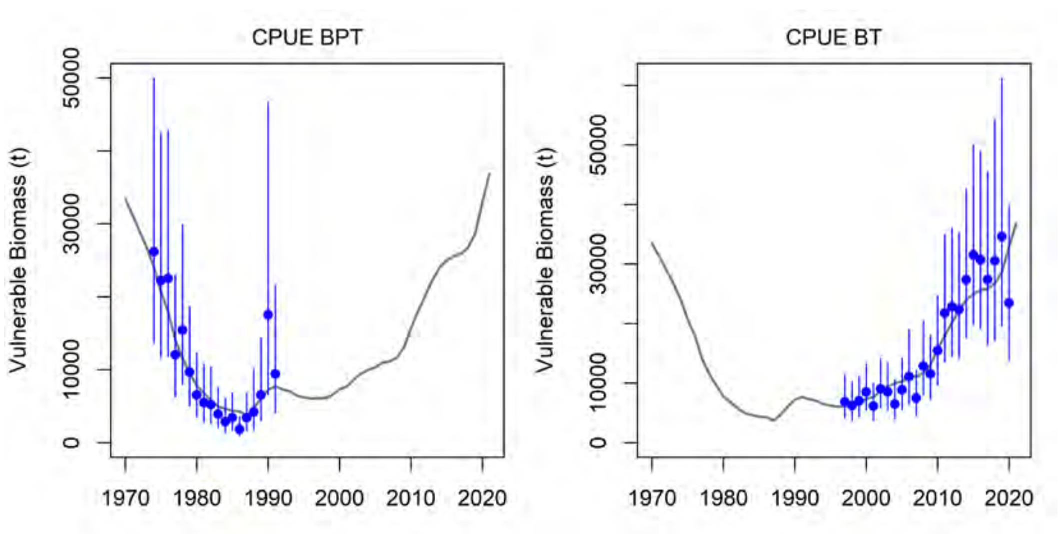


Figure 31: BPT CPUE indices (left) and recent BT CPUE indices (right). The grey line represents the model fit to the indices.

Model structure

The assessment model included the entire SNA 8 catch history (from 1932) and assumed that the initial population age structure was in an equilibrium, unexploited state. The population structure included 30 age classes (both sexes combined), the oldest age class representing an aggregated ‘plus’ group (30 years and older). The model data period extended to the 2021 year (2020–21 fishing year).

The key biological parameters for the SNA 8 stock assessment are presented in Table 28. Natural mortality (M) was specified as a constant value of 0.075 based on the analysis of Hilborn & Starr (given in Langley 2020).

There is no evidence of sexual dimorphism in snapper growth and the growth parameters have been determined for both sexes combined. There is a large data set of age-length observations from snapper sampled from the mid-1970s to recent years. These data indicate the growth of snapper has varied over time characterised by three periods: slower growth rates of fish sampled during the 1970s, higher growth rates during the 1980s, 1990s, and early 2000s, and slower growth rates since the mid-2000s. Separate growth parameters (k and $Linf$) of the von Bertalanffy function were estimated for these three time blocks (1931–1979, 1980–2005, and 2006–2021) during the preliminary modelling phase. The model was informed by the time series of age-length data aggregated as annual mean length-at-age observations. The resultant growth parameters were fixed in the final set of model options (and the mean length-at-age observations were not included in the input data sets). The estimated growth parameters were very similar for the early and recent periods, and the growth parameters for the intervening period were comparable with the published growth parameters derived from the same period.

The parameterisation of growth in Stock Synthesis constrains annual growth increments to be greater than or equal to zero. Thus, the decline in growth rates between 2005 and 2006 resulted in a transition in the growth of individual cohorts with the length of the older cohorts remaining constant for several years.

Maturity was assumed to be age-specific with all fish reaching sexual maturity at age 3 years. The age of maturity was constant for the entire model period.

Table 28: Biological parameters and priors for the interim base case model.

Component	Parameters	Value, Priors	
Biology	*M*	0.075	Fixed
	VB Growth	*Len1* = 13.1 cm	Fixed
	1931–1979	*k* = 0.146, *Linf* = 54.5 cm	Fixed
	1980–2005	*k* = 0.112, *Linf* = 69.6 cm	Fixed
	2006–2021	*k* = 0.150, *Linf* = 54.4 cm	Fixed
	CV length-at-age	0.08	Fixed
	Length-wt	*a* = 4.467e-5, *b* = 2.793	Fixed
	Maturity	0.0 ≤2 yr, 1.0 ≥3 yr	Fixed
Recruitment	LnR_0		Estimated (1)
	B-H SRR steepness *h*	0.95	Fixed
	SigmaR σR	0.6	Fixed
	Recruitment deviates	Lognormal deviates (1960–2019)	Estimated (60)

The model was structured with an annual time step comprising two seasons (October–January and February–September). The seasonal structure partitions the main spawning period and commercial catch (season 1). Spawning is assumed to occur instantaneously at the start of the year and recruitment is a function of the spawning biomass at the start of the year. A Beverton-Holt spawning stock-recruitment relationship was assumed with a fixed value of steepness (h). Recruitment deviates (1960–2019) from the SRR were estimated assuming a standard deviation of the natural logarithm of recruitment (σ_R) of 0.6.

Initially, a value of steepness of 0.85 was assumed for the SRR, equivalent to the default value of steepness used in the SNA 1 stock assessment. However, an evaluation of initial model options revealed that a significant proportion of MCMCs samples were crashing the population during the 2000s due to very low recruitments resulting from the combination of very low spawning biomass and the value of steepness assumed for the SRR. Subsequent model options specified a higher value of steepness of 0.95.

The model was configured to encompass three commercial fisheries: single trawl (BT), pair trawl (BPT), and Japanese longline. In addition, there were two recreational fisheries (inside and outside harbours). Age composition data are available from the single trawl fishery (23 observations) and the pair trawl fishery (18 observations). For all age compositions there was assumed to be no error associated with the age determination.

A comparison between the age compositions from the single and pair trawl fisheries revealed no appreciable difference in the age structure of the catch from the two methods. A common age-specific selectivity function was assumed for the two fisheries, and the associated sets of CPUE indices parameterised using a flexible, double normal selectivity function enabling the estimation of the age of peak selectivity, the widths of the ascending and descending limbs, and the selectivity of the terminal (oldest) age class.

There are no data from the Japanese longline fishery and the level of catch was assumed. The selectivity function for the fishery was defined to approximate the selectivity of a generalised snapper longline fishery with a knife-edge selectivity at age 5 years and full selection of the older age classes.

The two recreational fisheries are characterised by differences in length composition. The length composition data were included in a preliminary model option and the selectivity of each fishery was estimated using a length-based, double normal selectivity function. The resultant estimate of selectivity for the harbour fishery was tightly constrained around a mode of 28–32 cm, whereas the recreational fishery outside the harbours was estimated to have a broader selectivity for larger fish. The selectivity parameters were fixed in the final model options and the recreational fishery length frequency observations were excluded from the estimation procedure.

The tagging biomass estimates and associated population length observations were derived for all fish aged 3 years and older (Davies et al 2006. Accordingly, an age-specific, knife-edged selectivity function was assumed with an associated catchability of 1.0.

Initially, the time series of *Kaharoa* trawl survey biomass indices and associated age compositions were included in preliminary modelling and the selectivity of the survey was estimated using an age-specific double normal selectivity function. However, there was a persistent lack of fit to the two recent (2019–20 and 2020–21) trawl survey biomass indices related to a difference in the catchability of older fish between recent surveys (see Trawl Survey Biomass Indices - above).

For the final model options, the trawl survey data were reconfigured to determine estimates of the relative abundance of the individual age classes which appear to be consistently sampled by the trawl survey; i.e., fish aged 2 (1+), 3 (2+), 4 (3+), and 5 (4+) years. Thus, four separate sets of indices were derived from the trawl survey data, expressed as the number of fish at age from each survey (with an associated coefficient of variation). The indices were incorporated in the model with a corresponding age-specific selectivity and separate catchability coefficients. The abundance indices and age compositions used in the model are summarised in Table 29. Estimated parameters and structural assumptions are summarised in Table 30.

Fishing mortality was modelled using a hybrid method that calculates the harvest rate using Pope's approximation and then converts it to an approximation of the corresponding fishery specific F. The timing of the fisheries and CPUE indices within the year was specified so that annual catches were taken instantaneously halfway through the first season (October–January). This is generally consistent with the period of the main commercial catch.

The main data inputs were assigned relative weightings based on the approach of Francis (2011). The two sets of trawl CPUE indices (BPT and BT) were assumed to have a lognormal distribution with observation error specified as the standard error of the individual CPUE indices. Based on initial model fits the indices were assigned an additional process error of 0.1 for the BT CPUE indices and 0.2 for the BPT CPUE indices. The tagging biomass indices and age-specific trawl survey indices were assigned the native coefficient of variation from each index with no additional process error. For the two sets of fisheries age compositions, the individual age compositions were each assigned an Effective Sample Size approximating the value derived from Method TA1.8 of Francis (2011).

Model uncertainty was determined using Markov chain Monte Carlo (MCMC) implemented using the Metropolis-Hastings algorithm. For each model option, 1000 MCMC samples were drawn at 1000 intervals from a chain of 1.1 million following an initial burn-in of 100 000. The performance of the MCMC sample was evaluated using a range of diagnostics.

Stock status was determined relative to the equilibrium, unexploited spawning (mature) biomass of female fish (SB_0). Current biomass was defined as the biomass in the 2021 model year (2020–21 fishing year) ($SB_{CURRENT}$ or SB_{2020}).

Following the Harvest Strategy Standard (HSS), current biomass was assessed relative to the default soft limit of 20% SB_0 and hard limit of 10% SB_0 (Ministry of Fisheries 2008). The HSS includes a default target biomass level of 40% SB_0 for stocks with low productivity where an operational ('real world') SB_{MSY} has not been fully evaluated. The Inshore Fisheries Assessment Working Group accepted 40% SB_0 as an appropriate SB_{MSY} proxy for SNA 8. Current stock biomass is reported relative to the default target biomass level ($SB_{40\%}$) and current levels of fishing mortality are reported relative to the level of fishing mortality that result in $SB_{40\%}$ under equilibrium conditions (i.e., $F_{SB40\%}$). The reference level of age specific fishing mortality is determined from the composite age-specific fishing mortality from the last year of the model data period (2020–21). Estimates of equilibrium yield are determined from the level of fishing mortality that produces the target biomass level ($F_{SB40\%}$).

Table 29: Summary of input data sets for the Base Case assessment model. The relative weighting includes the Effective Sample Size (ESS) of age/size composition data and the coefficient of variation (CV) associated with the abundance data.

Data set	Model years	Nobs	Error structure	Observation error/ESS	Process error
			Lognormal		
Tag biomass	1990, 2002	2	Lognormal	0.18, 0.12	–
BT CPUE indices	1997–2020	23	Lognormal	0.12–0.18	0.1
BPT CPUE indices	1974–1991	18	Lognormal	0.12–0.30	0.2
Trawl survey age 2yr	1990, 1992, 1995, 1997, 2000, 2019, 2020, 2021	7	Lognormal	0.26–0.48	–
Trawl survey age 3yr	1990, 1992, 1995, 1997, 2000, 2019, 2020, 2021	7	Lognormal	0.16–0.38	–
Trawl survey age 4yr	1990, 1992, 1995, 1997, 2000, 2019, 2020, 2021	7	Lognormal	0.12–0.38	–
Trawl survey age 5yr	1990, 1992, 1995, 1997, 2000, 2019, 2020, 2021	7	Lognormal	0.18–0.45	–
BT age comp	1975, 1976, 1990–2010, 2013, 2016, 2019	26	Multinomial	ESS 20	
BPT age comp	1975, 1976, 1978–1980, 1986, 1987, 1989–1992, 2000–2006	18	Multinomial	ESS 10	
Tag length comp	1990, 2002	2	Multinomial	ESS 10	

Table 30: Estimated parameters and structural assumptions for the interim base model.

Parameter	Number of parameters	Parameterisation, priors, constraints
LnR_0	1	Uniform, uninformative
Rec devs (1960–2019)	60	SigmaR 0.6
Selectivity BPT and BT commercial	4	Double normal
Selectivity JP	–	Knife edged 5 yr
Selectivity trawl survey age indices	–	Fixed, age specific (4)
Catchability trawl survey age indices	4	Uniform, uninformative
Selectivity tag	–	Knife edged 3 yr
Selectivity Recreational (2)	–	Fixed
CPUE *q*	2	Uniform, uninformative

Results

The model provided a coherent fit to all the main datasets. The trend in stock biomass is consistent with the previous stock assessments (Davies et al 2013, Langley 2020); i.e., the stock is estimated to have been heavily depleted during the 1960s and 1970s, reaching a nadir in 1987 at about 6% of the virgin biomass level. The spawning biomass increased slightly in the late 1980s, following the recruitment of the strong 1985 and 1986 year classes, and then remained at about 9% of the virgin biomass level throughout the 1990s. The more recent data sets, specifically the recent CPUE indices and age compositions, provided a coherent signal that stock abundance has increased considerably from 2009, primarily due to an increase in recruitment from the mid-2000s.

Annual recruitment remained relatively constant during the 1960s and 1970s (Figure 32), although recruitment was generally lower during the 1980s and 1990s when spawning biomass was at the lowest level (below 10% SB_0). However, relatively large recruitments were estimated during the mid-2000s when the stock was still at a relatively low level (10–20% SB_0). Recruitment was well above average during 2005–2018, with exceptionally high recruitments estimated for 2006 and 2016–2018. The estimates of recent recruitment are informed by the age-specific trawl survey indices.

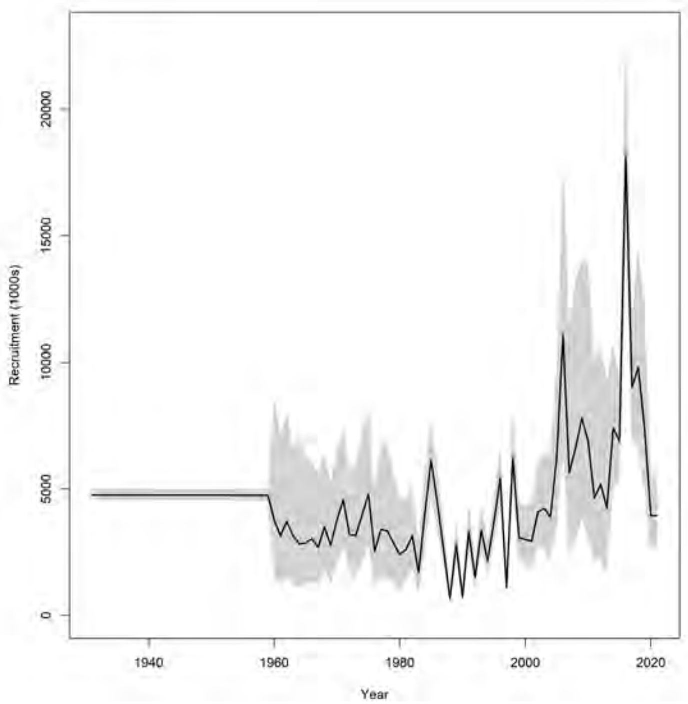


Figure 32: Annual estimates of recruitment (numbers of fish, thousands) from the Base Case model (MCMCs). The black line represents the median of the MCMC estimates and the shaded error represents the 95% confidence interval.

Current (2021 = 2020–21 fishing year) stock status was determined relative to equilibrium, unexploited spawning biomass. Spawning biomass has increased considerably over the last 10 years and current biomass was estimated to exceed the default target (40% SB_0) biomass level, and the probability of the stock being below the hard (10% SB_0) and soft (20% SB_0) limits is negligible (Table 31). There has been a corresponding decline in fishing mortality over the last 10 years and current (2021) fishing mortality is estimated to be below the rate that equates to the target biomass level (under equilibrium conditions i.e., $F_{SB40\%}$).

Sensitivities

A number of key assumptions of the model were investigated as (single change) sensitivities to the Base Case model (Table 31). The historical level of Japanese catch is unknown and in previous assessments (Davies et al, 2006, 2013, Langley 2020), the base level of catch (2000 t) was bracketed by alternative catch levels of 1000 t (*JPcatch1000*) and 3000 t (*JPcatch3000*). The resulting estimates of stock status was insensitive to the level of Japanese catch and the two sensitivities were not repeated for the current assessment.

The influence of key stock productivity parameters were also investigated, specifically a lower value of natural mortality of 0.06 (*NatMort06*), a higher variability (sigmaR 0.8) in the deviations of recruitment deviations (*SigmaR08*), and a lower value of steepness (0.85) of the SRR (*Steep085*). For the *Steep085* sensitivity, a significant proportion of MCMC chains resulted in the stock crashing at low levels of stock biomass due to the lower value of steepness of the SRR. On that basis, the *Steep085* was not included in the final set of model sensitivities.

The lower natural mortality option (*NatMort06*) estimated lower levels of current biomass (relative to virgin spawning biomass) compared with the Base Case, although the level of biomass approaches the default target level and there was a very low probability of the stock being below the hard and soft limits, while current fishing mortality rates were above the reference level. The *SigmaR08* model provided very similar estimates of current stock status to the Base Case and is not included in the final suite of sensitivities.

The influence of key data sets was also investigated. The trawl CPUE indices from the last five years (2016–2020) were excluded due to concerns regarding the reliability of the indices (*CPUEex5yr*). The selectivity of the commercial fisheries was alternatively configured to fully select the older age classes (*BTlogistic*) The alternative series of recreational catches from 2019–2021 derived from a constant recreational harvest rate (*RecF*) was also included. These model sensitivities yield estimates of current stock status that are very similar to the Base Case.

Table 31: Estimates of current (2021 = FY 2020–21) and virgin spawning biomass (t) (median and the 95% confidence interval from the MCMCs) and probabilities of current biomass being above specified levels and probability of fishing mortality being below the level of fishing mortality associated with the interim target biomass level. The potential yield in 2021 was derived by applying the $F_{SB40\%}$ fishing mortality rate to the current (2021) biomass.

Model option	SB_0	SB_{2021}	SB_{2021}/SB_0	Pr(SB_{2021} > X% SB_0)		
				40%	20%	10%
Base	99 319 (95 129–104 419)	53 689 (37 876–68 059)	0.541 (0.39–0.663)	0.967	1.000	1.000
NatMort06	111 315 (106 790–116 147)	47 244 (29 475–60 641)	0.423 (0.267–0.53)	0.664	0.990	0.998
BTlogistic	93 724 (90 592–96 961)	46 153 (25 223–58218)	0.493 (0.275–0.61)	0.845	0.991	1.000
CPUEex5yr	99 063 (94 668–103 793)	52 097 (34 866–67 410)	0.528 (0.358–0.658)	0.942	0.999	1.000
RecF	99 497 (94 786–104 014)	5 656 (35 840–67 824)	0.54 (0.36–0.661)	0.959	0.998	1.000

	$F_{SB40\%}$	$F_{2021}/F_{SB40\%}$	Pr(F_{2021} < $F_{SB40\%}$)	Yield 2021
Base	0.054 (0.053–0.056)	0.81 (0.643–1.136)	0.916	3 951 (2 977–4 881)
NatMort06	0.043 (0.041–0.045)	1.167 (0.909–1.843)	0.121	3 046 (2 112–3 714)
BTlogistic	0.058 (0.057–0.059)	0.882 (0.705–1.557)	0.761	3 367 (2 039–4 144)
CPUEex5yr	0.054 (0.052–0.056)	0.831 (0.647–1.226)	0.873	3 876 (2 818–4 813)
RecF	0.054 (0.053–0.056)	0.901 (0.721–1.336)	0.787	3 922 (2 871–4 793)

Projections

Five-year stock projections (to the 2025–26 fishing year) were conducted using the Base Case model assuming annual catches equivalent to the 2019–2020 catch; i.e., a commercial catch of 1346 t (approximating the current TACC of 1300 t) and an allowance of 10% for unreported catches (total 1481 t). Annual recreational catches were either assumed to be constant at 935 t (the 2019 catch level, representing a total annual catch of 2416 t) or were projected forward based on the recreational fishery mortality rate from the terminal year of the *RecF* model (2021). An additional 5-year projection was conducted assuming total annual catches in the projection period at the level equivalent to the current (2021) potential yield at $F_{SB40\%}$ (3951 t, commercial and recreational catch combined).

Annual recruitment deviates for the 5-year projection period were resampled from the long-term average level with the standard deviation equivalent in sigmaR (0.6). The average level of estimated recruitment in the recent (10 year) period was considerably higher (~65% higher) than the long-term average level of recruitment.

The projections indicate that the stock biomass will continue to increase during the 5-year projection period due, in part, to the contribution of the exceptionally large 2016 year class. At current levels of catch, the biomass at the end of the period (2026) is projected to be 21% higher than current (2020–21) biomass (SB_{2026}/SB_0 = 0.653, C.I. 0.49–0.77) (Table 32). The higher catch scenario (3951 t) results in a smaller (8%) increase in biomass during the projection period.

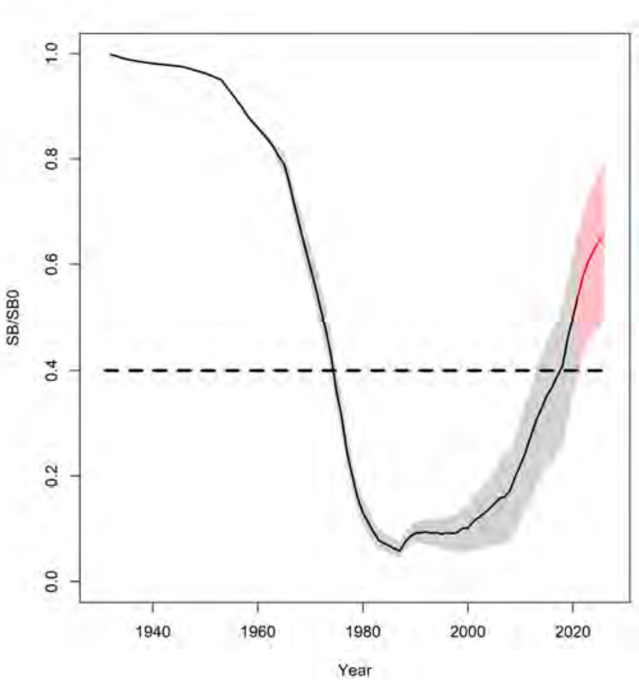


Figure 33: Annual spawning biomass relative to virgin biomass (equilibrium, unexploited) estimated from the Base Case model (black) and the five-year projection (red) assuming annual catches equivalent to the 2021 catch. The solid line represents the median of the MCMCs and the shaded area represents the 95% confidence interval. The horizontal dashed line represents the default target biomass level.

Table 32: Projected spawning biomass relative to virgin biomass (and 95% confidence interval) and the probability of the spawning biomass being above default biomass limits and interim target level in 2026 (fishing year 2025–26) for the base case at the current level of catch and the potential yield corresponding to $F_{SB40\%}$. The *RecF* model assumes current commercial catch and a constant harvest rate for the recreational fishery.

Model	Catch (t)	SB_{2026}/SB_0	SB_{2026}/SB_{2021}	Pr ($SB_{2026} > X\%SB0$)		
				10%	20%	40%
Base	2 416 (1 481+935)	0.653 (0.493–0.789)	1.207 (1.119–1.349)	1.00	1.00	1.00
RecF	1 481 + Rec (Rec ~ 1250)	0.635 (0.478–0.759)	1.175 (1.090–1.340)	1.00	1.00	1.00
Base	3 951 ($F_{SB40\%}$)	0.587 (0.421–0.723)	1.081 (0.998–1.188)	1.00	1.00	0.98

Qualifying comments

For the current assessment, recent trends in stock abundance are strongly informed by the recent CPUE indices from the trawl fishery. The overall trend in these indices is generally consistent with other recent observations from the fisheries. However, it is apparent that the operation of the commercial fisheries has changed considerably in response to the increase in the abundance of snapper over the last decade. These changes are unlikely to have been fully accounted for in the derivation of the standardised CPUE indices.

Since 1989–90, the area north of Cape Egmont has accounted for 90–95% of the SNA 8 commercial catch. Most observational data included in the model are also derived from the northern area of the fisheries including the CPUE indices, trawl survey indices, and the commercial age composition data. Consequently, the dynamics of the assessment model will be strongly influenced by the data from the northern area of the fisheries.

Prior to the mid-1980s, the southern area of the fisheries accounted for approximately 30% of the commercial catch. The 2002 tagging programme estimated that 21% of the SNA 8 biomass resided in the southern area (Gilbert et al 2005) and while most movements of tagged fish were relatively limited, there were northward movements of tagged fish from the South Taranaki Bight and reciprocal movements of fish from the areas north of Cape Egmont.

Similar patterns in the age structure of snapper from South Taranaki Bight and northern areas of the SNA 8 fisheries were apparent from commercial catch-at-age data (Walsh et al 2006). However, the results of the recent *Kaharoa* trawl surveys have identified some differences in the age structure of the snapper population between the two areas, including differences in the relative strength of individual year classes. This may indicate some degree of spatial structure in the SNA 8 population and possible linkages between the southern area of SNA 8 and the SNA 7 (Tasman Bay/Golden Bay) stock.

Estimates of stock status have been provided principally based on the assumption of long-term, equilibrium conditions. Productivity of the SNA 8 stock appears to have varied considerably over the history of the fisheries, with variable levels of recruitment and variation in growth rates (that appear to be related to stock abundance). Recent recruitment is estimated to be at an historically high level suggesting the stock is currently in a phase of higher productivity and that there is a degree of non-stationarity in the assumed nature of the relationship between spawning biomass and recruitment that may violate the assumptions of equilibrium conditions. Further consideration is required to develop stock status indicators that account for variation in the productivity of the SNA 8 stock.

The higher potential yields estimated for the stock are attributable to the higher recruitment estimated for the recent period (10 years). These recruitments have the potential to support higher catches over the short term (5 years), although future catch levels would need to be determined based on ongoing monitoring and assessment.

Future research considerations

Abundance indices

Trawl surveys: The variability in the catchability of adult snapper in the recent west coast North Island (WCNI) trawl surveys has limited the utility of the trawl surveys to monitor the overall magnitude of the increase in the abundance of snapper. The limitations of the trawl survey are partly attributable to variability in the timing of the survey relative to the main spawning period and the restriction from sampling within the Māui dolphin trawl exclusion zone. Further, the distribution of snapper appears to have expanded (into deeper water) as the abundance of snapper has increased over recent years. A longer time series of trawl surveys may enable a more thorough evaluation of the factors influencing the variability in catchability of adults (> 5 y) and, thereby, increase the utility of the trawl surveys to monitor stock abundance. In the interim, subsequent trawl surveys would continue to provide additional estimates of the abundance of recent year classes (surveyed as 2- to 5-year old fish). A current project to review the utility of the WCNI trawl survey series will further investigate the potential for including adult biomass indices in the stock assessment modelling framework.

CPUE indices: The trawl CPUE indices represent an important index of abundance within the current assessment model. However, there have been considerable recent changes in the operation of the inshore trawl fishery to minimise snapper catches. These changes in fishing operation are not fully accounted for in the standardised CPUE analysis and, consequently, the CPUE indices are likely to under-estimate the extent of the increase in snapper abundance, especially in recent (3–5) years. This limits the utility of the CPUE indices to monitor current and future trends in stock abundance.

Changes in fishing behaviour: A project to document past and ongoing changes in gear and fishing behaviour should also be undertaken to help interpret CPUE data. This should be considered as two phases: (i) developing ongoing relationships with fishers, and (ii) working together to ensure relevant information is identified and provided. (This is generic across snapper and other fisheries.)

Given the breakdown of the bottom trawl CPUE series in recent years, and difficulties encountered with including the estimates of adult biomass from the trawl survey in the stock assessment, a review of future monitoring of SNA8 biomass is recommended.

Other methods for developing abundance indices: Such a review should also consider other potential methods for monitoring abundance such as another traditional mark-recapture experiment or a genetics-based estimate of stock size.

Stock structure and biological parameters

Stock structure: Age compositions from recent inshore trawl surveys should be examined to further investigate stock relationships between SNA 8 and SNA 7 and the spatial structure of the snapper population within sub areas of SNA 8.

Biological parameters: The current assumption that maturity is knife-edged at 3 years needs to be reviewed. Trawl survey data should be analysed to test this assumption and to determine whether it is preferable to represent the age of maturity as an ogive. Estimates of several other biological parameters also rely on old analyses and should also be revisited and revised if necessary. In particular, estimates of growth by eras should be evaluated.

Catch and age

Catch sampling: The current assessment highlights the utility of regular (currently triennial) sampling of the age composition of the commercial catch, particularly to provide information regarding the relative strength of recruited year classes. The current assessment estimates an exceptionally strong 2016 year class based on observations of the year class from the three recent trawl surveys (at ages 3, 4, and 5 years). This year class is likely to have recruited to the commercial fisheries over the last few years and age composition data from the fisheries will refine model estimates of the relative strength of the year class. The next catch sampling programme for the SNA 8 is scheduled for 2021–22. A review of the frequency, seasonal coverage, and gear types included (e.g., add PRB - Precision Seafood Harvesting Bottom Trawl) of future sampling should be conducted following an evaluation of the efficacy of the trawl survey sampling of the snapper population.

Age composition data: Age composition data from the 1970s are being regenerated following a re-ageing of the older (> 20 year) fish in the samples. This will improve the utility of the age composition data particularly in the estimation of recruitment variation in the period prior to 1960. The revised age composition data should be included in the next iteration of the SNA 8 stock assessment.

Recreational fisheries

The recent increase in the catch from the recreational fishery highlights the importance of this component of the fishery, which currently accounts for approximately 40% of the total catch. Consequently, it is important to routinely monitor the level of recreational catch to determine total removals from the stock. The next national panel survey to estimate recreational catch is scheduled for 2022–23, depending on budgets and priorities. Indices of recreational fishing activity have also been developed from web cam observations at key boat ramps within SNA 8. These observations should be evaluated in conjunction with the overall recreational harvest survey data. There is potential for the web cam indices to provide more regular monitoring of recreational fishing activity and catch.

Consideration should also be given to including a sensitivity for recreational catches prior to the 1970s.

Other

Model assumptions: A simulation approach to evaluate current model assumptions is currently underway and outputs should be used to inform the next assessment. This project is focusing on the potential biases associated with key structural assumptions of the assessment, particularly those related to the spatial structure of the snapper population within SNA 8, non-stationarity in recruitment, and the potential for variation in growth rates to be related to stock abundance (i.e., density dependence).

Environmental considerations: Recruitment variation is undoubtedly linked to variation in the prevailing environmental conditions associated with the spawning period and/or larval phase. Further investigation should be conducted to identify correlations between snapper recruitment estimates and key environmental variables to improve understanding of snapper recruitment dynamics. Consideration should be given to examining SNA 7 and SNA 8 together with a view to understanding the drivers of productivity changes.

Density-dependent processes: Projections indicate a continued increase in population biomass at current catch levels. The potential for density-dependent processes to curb such large increases should be considered and possibly modelled.

Other sources of fishing-related mortality: The default assumption is that Other Sources of Fishing Related Mortality) added 20% to catches prior to the introduction of snapper into the QMS in 1986 and 10% thereafter. The basis for this assumption should be revisited, particularly for the latter period. In particular, it is important to identify whether there are any regulations or changes in fishing behaviour that could have resulted in step changes.

Commercial trawl selectivities: Prior to about 1980 when the fleet of bottom trawl vessels was upgraded to more powerful vessels, the ability of this fleet to catch large snapper is likely to have been considerably lower than it currently is. A sensitivity investigating a reduced selectivity for single bottom trawl pre-1980 by moving the right-hand limb of the selectivity curve down to reduce the vulnerability of the largest fish should be considered for the next assessment update. (One such run was conducted post-Plenary and resulted in a small increase in SB_0 and a small decrease in the current stock status. However, the differences were not sufficient to alter current conclusions about the relative magnitude of the increase in stock size.)

7. 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 the greatest exchange between the Bay of Plenty and Hauraki Gulf.

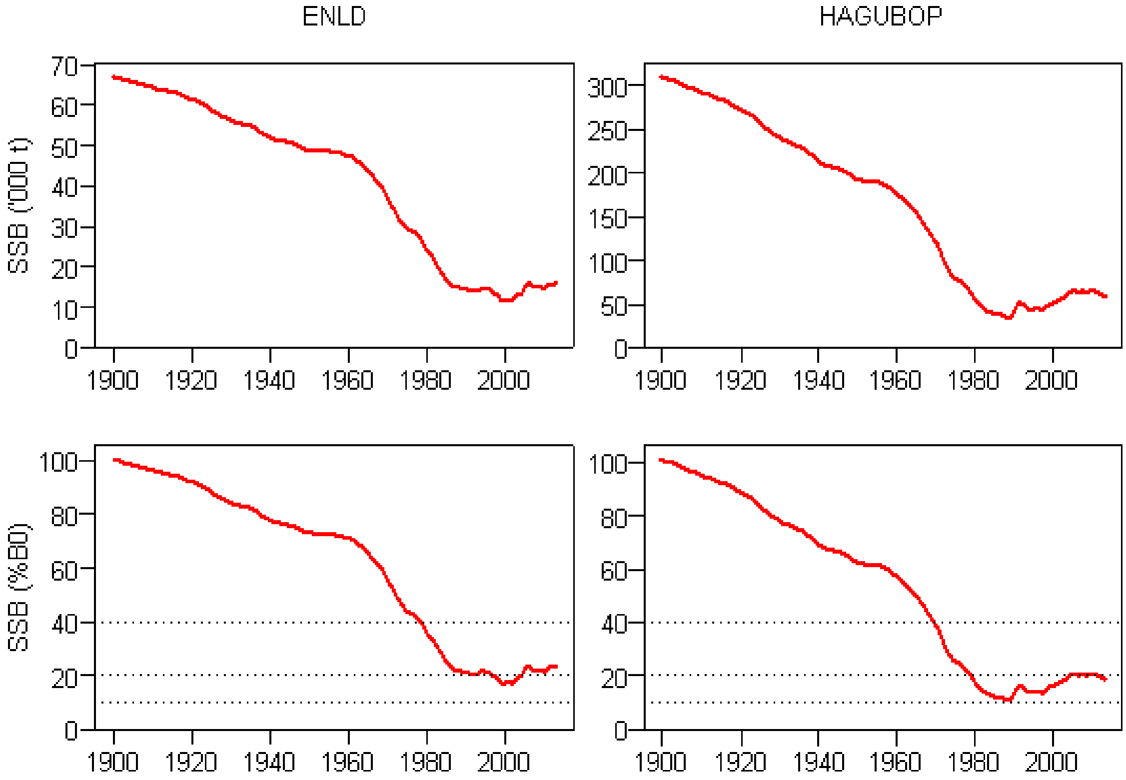
- **SNA 1**

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.

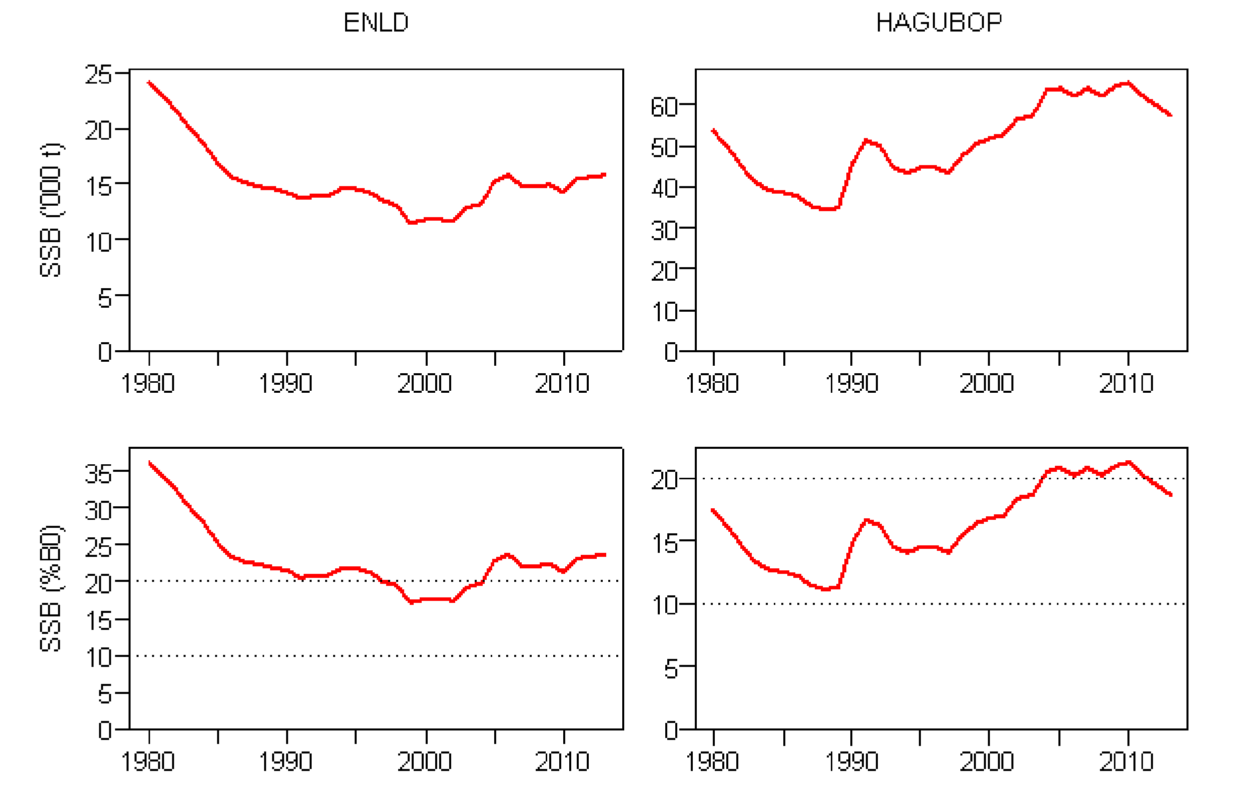
Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	Base case models (M = 0.075, h = 0.85) for East Northland and the Hauraki Gulf and Bay of Plenty to 2012–13
Reference Points	Interim target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $U_{40\%B0}$
Status in relation to Target	<u>East Northland</u> 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

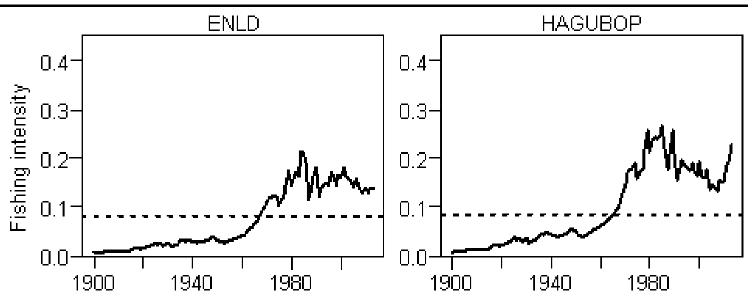
Historical Stock Status Trajectory and Current Status



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)).

Fisheries 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 Intensity 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	An update of the longline CPUE indices was conducted in 2016 extending the time series to include 2012–13 to 2014–15. The most recent indices were broadly comparable to the indices from 2007–08 to 2011–12, i.e., fluctuating without trend
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 *SSB*s 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 – Full Quantitative Stock Assessment.	
Assessment Method	Spatially-disaggregated, 3-stock, age-structured, single-sex model undertaken in CASAL	
Assessment Dates	Latest assessment: 2013	Next assessment: 2021
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) - Data from tagging in 1994 (all areas)	1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
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	- Stock structure and degree of exchange between BoP and HG - Conflict between catch-at-age and tagging data - Relationship between standardised longline CPUE and abundance, because the methodology may not account for perceived changes in fishing behaviour - 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, whereas others were concerned that alternative assumptions could affect outcomes about stock status.

Fisheries 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 very high risk in the Seabird Risk Assessment.[1]

- **SNA 2**

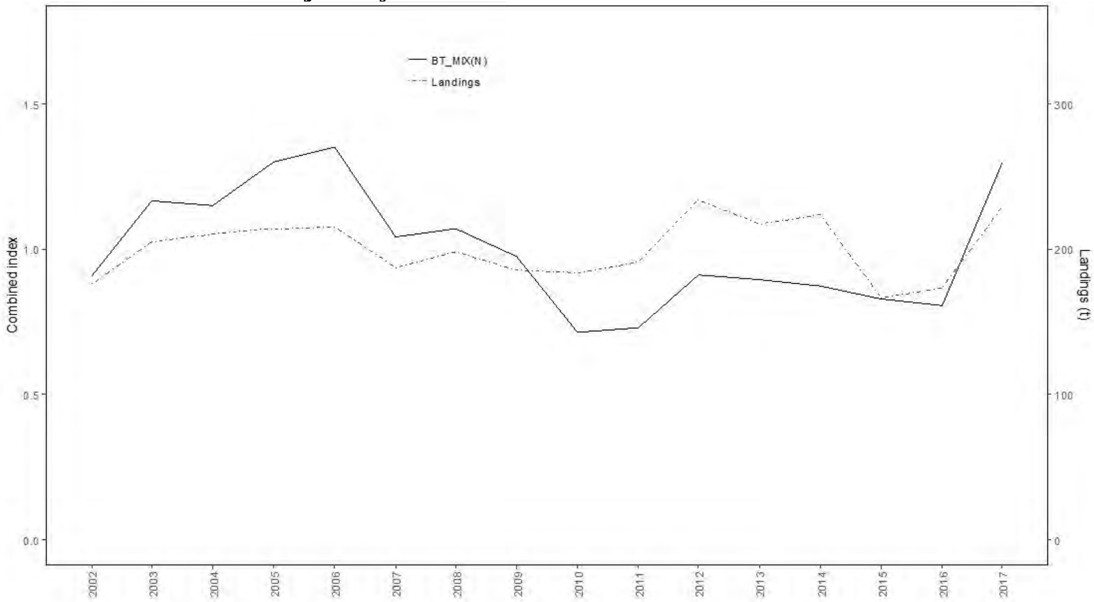
SNA 2 is assumed to occur in two sub-stocks. The northern sub-stock occurs between the southern tip of the Mahia Peninsula and Cape Runaway and is likely to be associated with the SNA 1 Bay of Plenty stock. The southern sub-stock occurs within Hawke Bay and may be peripheral to the northern stock rather than entirely discrete. The majority of the SNA 2 catch is taken from the northern sub-stock, and this is assumed to be the primary stock in SNA 2.

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Standardised combined CPUE (Weibull + binomial) model based on SNA, TRE, GUR, and TAR single trawl vessel-day data for both the northern and southern sub stocks of SNA 2.
Reference Points	<u>Northern Stock</u> Target: B_{MSY}-compatible proxy based on CPUE: not determined Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: F_{MSY} <u>Southern Stock</u> Target: B_{MSY}-compatible proxy based on CPUE: not determined Soft Limit: 50% of target

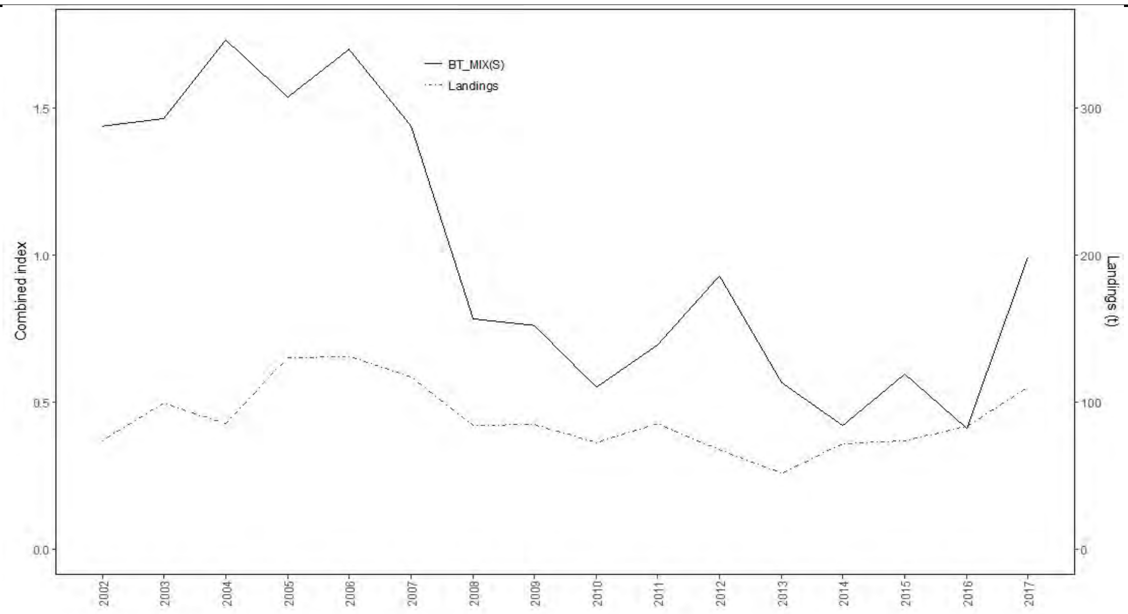
[1] The risk was defined as the ratio of the estimated annual number of fatalities of birds due to bycatch in fisheries to the Potential Biological Removal (PBR), which is an estimate of the number of seabirds that may be killed without causing the population to decline below half the carrying capacity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

	Hard Limit: 25% of target Overfishing threshold: F_{MSY}
Status in relation to Target	Northern Stock: Unknown Southern Stock: Unknown
Status in relation to Limits	Northern Stock Soft: Unknown Hard: Unknown Southern Stock Soft: Unknown Hard: Unknown
Status in relation to Overfishing	Northern Stock: Unknown Southern Stock: Unknown

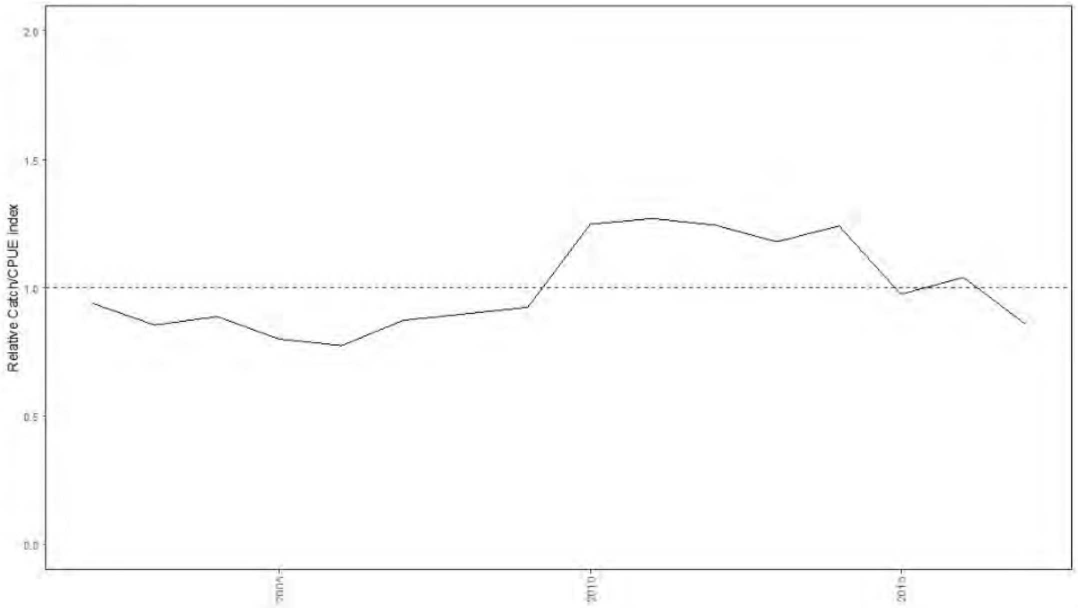
Historical Stock Status Trajectory and Current Status



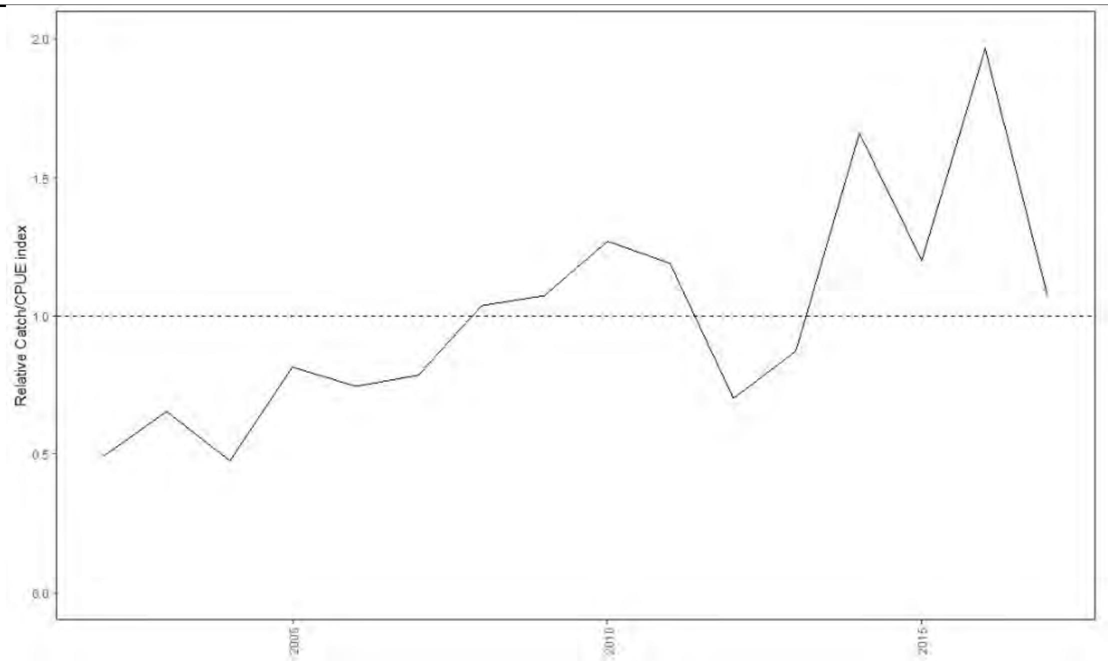
Standardised combined catch per unit effort (CPUE) indices for SNA 2 from bottom trawling targeting gurnard, snapper, tarakihi, and trevally (BT_MIX(north)) that combines all form types at a daily aggregation (Schofield et al 2018b). In the occurrence of positive catch model, a binomial distribution was assumed, and in the magnitude of positive catch model a Weibull error distribution was assumed. Horizontal lines are the target and the soft limits.



Standardised combined catch per unit effort (CPUE) indices for SNA 2 from bottom trawling targeting gurnard, snapper, tarakihi, and trevally (BT_MIX(south)) that combines all form types at a daily aggregation (Schofield et al 2018b). In the occurrence of positive catch model, a binomial distribution was assumed, and in the magnitude of positive catch model a Weibull error distribution was assumed. Horizontal lines are the target and the soft limits.



Annual relative exploitation rate (catch/CPUE) for snapper in the northern sub-stock of SNA 2.



Annual relative exploitation rate (catch/CPUE) for snapper in the southern sub-stock of SNA 2.

Fisheries and Stock Trends	
Recent Trend in Biomass or Proxy	In both the northern and southern sub-stocks CPUE indices were relatively stable between 2002 and 2006 then declined between 2006 and 2009 in the southern sub-stock and to 2010 in the northern sub-stock. Both sub-stocks were relatively stable between 2010 and 2016, with the southern sub-stock showing more inter-annual variation. Abundance in both sub-stocks increased in 2017.
Recent Trend in Fishing Mortality or Proxy	In the northern stock, exploitation rate remained around the series average, decreasing from above average to below average in the period from 2014 to 2017. In the southern stock the rate had an upward trend from 2002 to 2016 but decreased to just above the series average in 2017.
Other Abundance Indices	Tow based CPUE series for the period 2008 to 2017 closely resemble the mixed form type analysis for corresponding periods in both stocks.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Northern Stock Soft: Unknown Hard: Unknown Southern Stock Soft: Unknown Hard: Unknown
Probability of Current Catch or TACC causing overfishing to continue or to commence	Northern Stock: Unknown Southern Stock: Unknown

Assessment Methodology	
Assessment Type	Level 2 – Partial Quantitative Stock Assessment

Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2018	Next assessment: 2022
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Standardised single trawl CPUE index of abundance	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Full quantitative stock assessment replaced with partial quantitative assessment based on standardised CPUE - Two stocks assumed instead of one	
Major Sources of Uncertainty	- Relationships between the two SNA 2 sub-stocks, and with the Bay of Plenty sub-stock (SNA 1). - The current CPUE analysis is truncated to 2002 to 2016 due to concerns about data quality prior to this period. - Regression partitioning was used to subdivide Statistical Area 013 catch from the CELR data between sub-stocks.	

Qualifying Comments
-

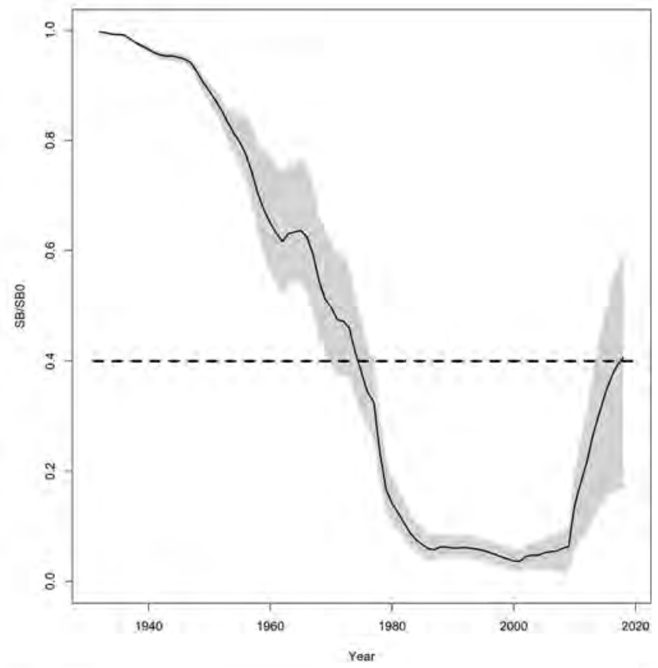
Fisheries Interactions
Snapper is a bycatch of the main inshore fisheries within SNA 2, principally the red gurnard and tarakihi bottom trawl fisheries. The operation of these fisheries is constrained by the SNA 2 TACC.

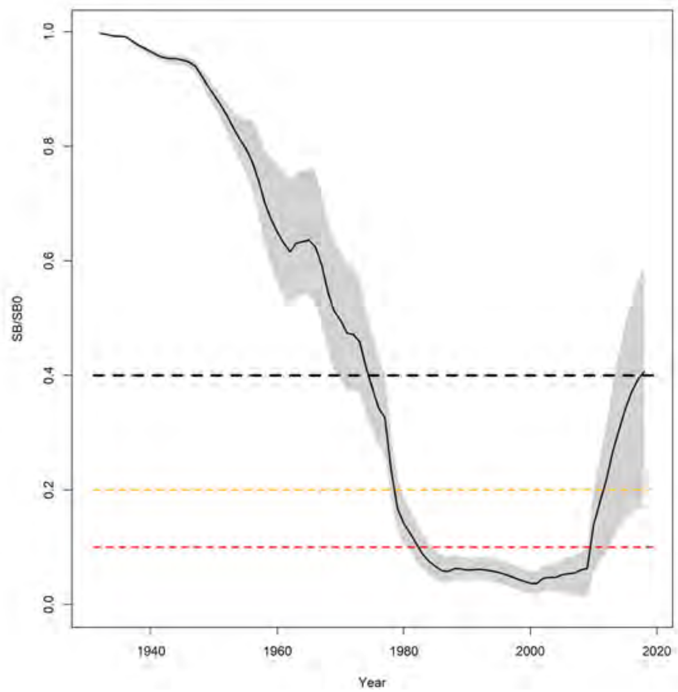
- **SNA 7**

The assessment is for the Tasman Bay, Golden Bay, and west coast South Island stock unit of SNA 7. The Marlborough Sounds is considered to support a separate stock of snapper within SNA 7.

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Base case model and sensitivities
Reference Points	Target: Interim target 40% SB_0 Soft Limit: 20% SB_0 Hard Limit: 10% SB_0 Interim overfishing threshold: $F_{SB40\%}$
Status in relation to Target	$B_{2018–19}$ was estimated to be 41% B_0; About as Likely as Not (40–60%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	F was estimated to be 0.60 $F_{SB40\%}$; overfishing is Very Unlikely (< 10%) to be occurring

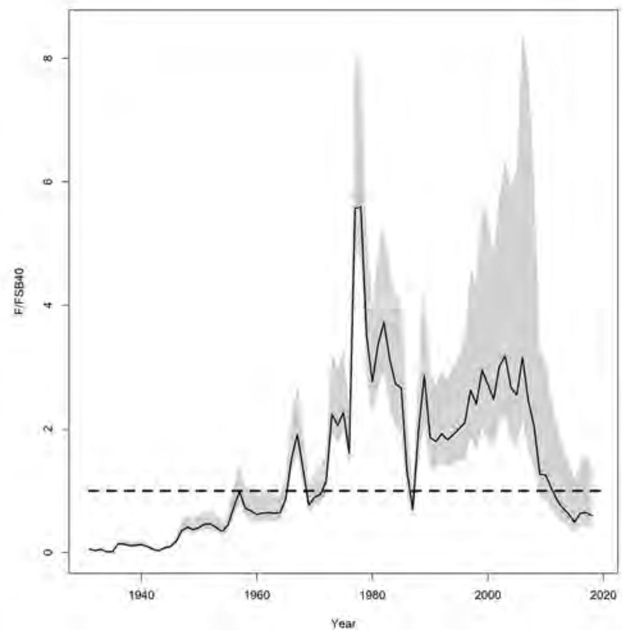
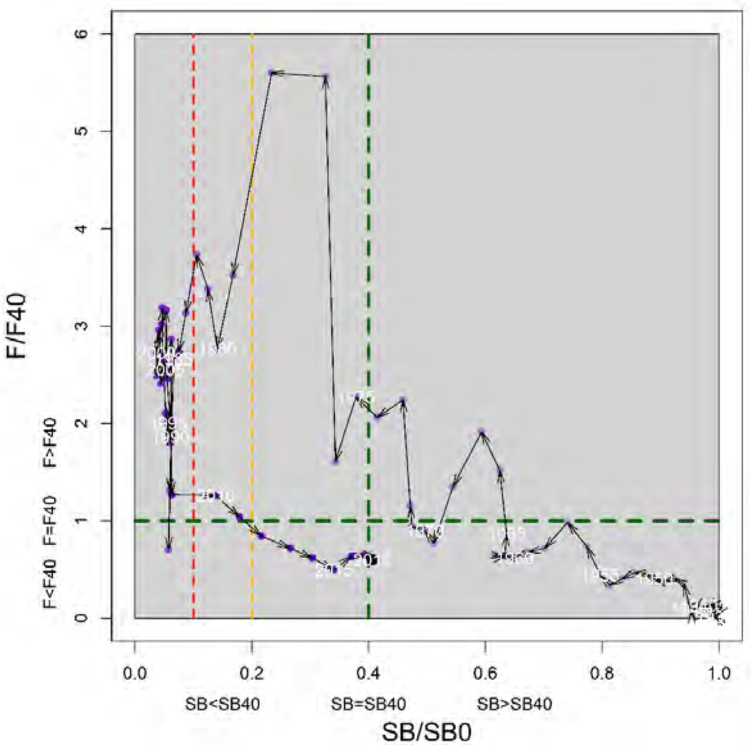
Historical Stock Status Trajectory and Current Status





Annual trend in spawning biomass relative to the 40% SB_0 interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% credible interval. The black dashed line represents the interim target level. The red and orange dashed lines represent the hard and soft limits, respectively.

Fisheries and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass was at an historical low level in the early 2000s and has increased rapidly since 2009 due to the recent recruitment of one or two large year classes.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality has declined steadily since 2006.

	 **Annual trend in fishing mortality relative to the $F_{SB40\%}$ interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% credible interval. The dashed line represents the interim target level.**  **Annual spawning biomass and fishing mortality compared to the $SB_{40\%}$ interim target biomass level and corresponding fishing mortality reference for the updated base model (median values from MCMCs). The green dashed lines represent the biomass and fishing mortality target levels. The red and orange dashed lines represent the hard and soft biomass limits, respectively.**
Other Abundance Indices	The West Coast South Island trawl survey also shows an increase in abundance from 2010 to 2019.
Trends in Other Relevant Indicators or Variables	The increase in recreational catch estimates from 2005 onwards suggests that abundance has increased.

Projections and Prognosis	
Stock Projections or Prognosis	Two projections are provided based on alternative assumptions regarding recent recruitment: either including the model estimate of the 2017/18 year class or assuming average recruitment for 2017/18. Biomass is projected to increase to a level well above the target level if the 2017/18 year class is estimated. Otherwise, if average recruitment is assumed, the biomass is projected to remain at about the target biomass level over the next five years. The two options for the projections are considered to have equal validity.
Probability of Current Catch or TAC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TAC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 – Full Quantitative Stock Assessment	
Assessment Method	Age-structured Stock Synthesis model with MCMC estimation	
Assessment Dates	Latest assessment: 2020	Next assessment: 2021
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Commercial catch history (1983 onwards) - Commercial catch history (pre-1983) Tagging biomass estimate - CPUE indices - Historical commercial age frequency - Recent commercial age frequency - Recreational catch history (2005 onwards) - Recreational catch history (preceding period) -Trawl survey age compositions (2016, 2018) -Trawl survey length compositions (2008–2016)	1 – High Quality 2 – Medium or Mixed Quality: catches are considered to be less reliable. 2 – Medium or Mixed Quality: whether the older ages are indexed by the tagging study is uncertain 1 – High Quality 2 – Medium or Mixed Quality: needs to be better characterised by method of capture 1 – High Quality 1 – High quality 2 – Medium or Mixed Quality: historical levels of recreational catch are assumed. 1 – High Quality 1– High Quality
Data not used (rank)	Kaharoa trawl survey biomass indices (core area) Commercial size grade data	3 – Low Quality: survey not designed to provide abundance index for SNA 7 2 – Medium or Mixed Quality: quality of the grading is unknown and did not contribute to model results.
Changes to Model Structure and Assumptions	-	

Major Sources of Uncertainty	- Strength of recent recruitment (2017 year class) - Historical commercial catches - Historical and projected levels of recreational catch.

Qualifying Comments
The estimate of the magnitude of the 2017 year class is solely based on a single trawl survey observation. There have only been two surveys that included the shallower areas of TBGB and, hence, there is not an adequate time series of surveys to monitor the relative abundance of juvenile snapper and precisely estimate recent recruitment.

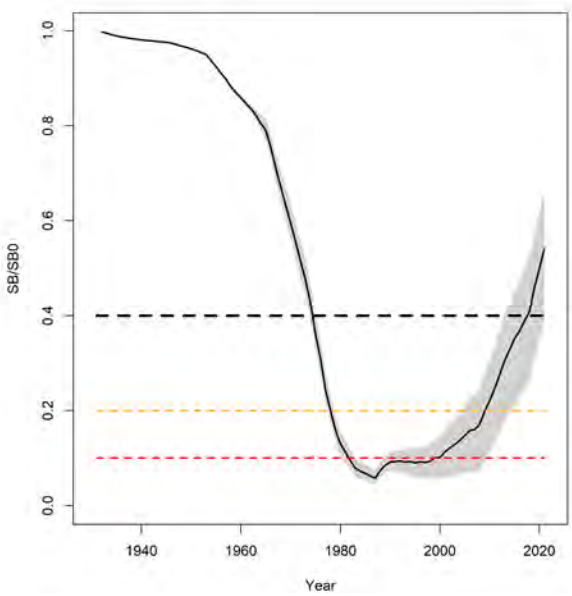
Fisheries Interactions
Snapper target fisheries have a bycatch of flatfish, red cod, gurnard, tarakihi, and small amounts of barracouta and blue warehou. Snapper is taken as a bycatch of the inshore trawl fisheries operating within FMA 7, particularly within Tasman Bay and Golden Bay. Since 2013/14, most (> 80%) of the snapper catch has been taken as a bycatch of those fisheries.

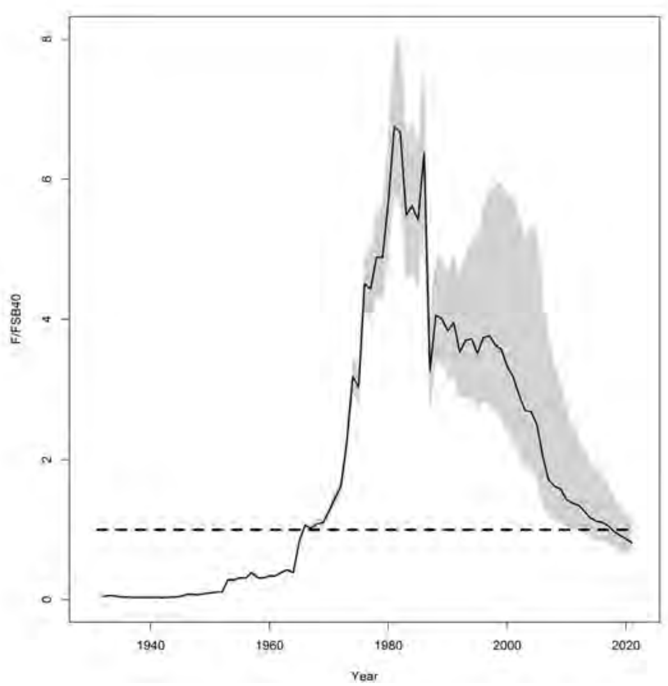
- **SNA 8**

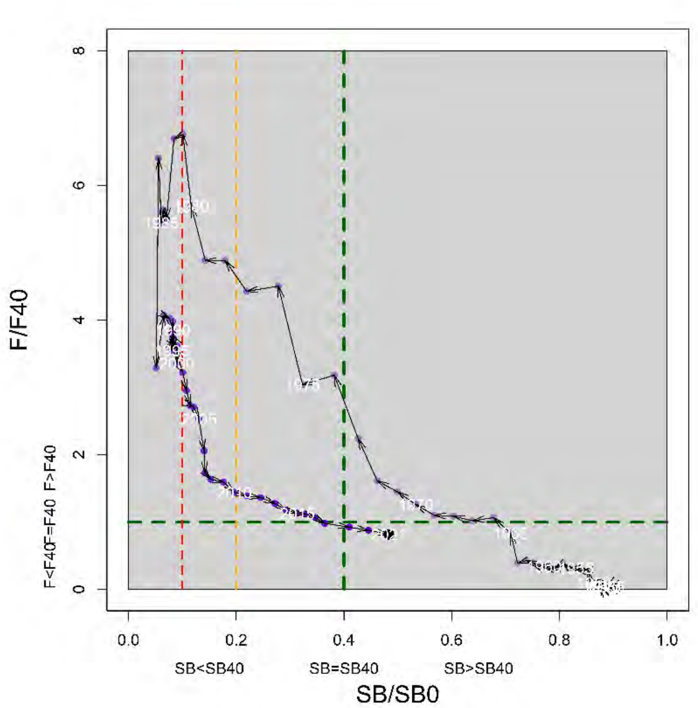
Stock Structure Assumptions

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

Stock Status	
Year of Most Recent Assessment	2021
Assessment Runs Presented	Base Case model
Reference Points	Interim Target: 40% B_0 (HSS default) Soft Limit: 20% B_0 (HSS default) Hard Limit: 10% B_0 (HSS default) Overfishing threshold: $F_{SB40\%}$
Status in relation to Target	$B_{2020–21}$ was estimated to be 54% B_0; Likely (> 60 %) to be at or above the target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Exceptionally Unlikely (< 1%) to be below
Status in relation to Overfishing	$F_{2020–21}$ was estimated to be 81% $F_{SB40\%}$. Overfishing is Unlikely (< 40%) to be occurring.

Historical Stock Status Trajectory and Current Status

Annual trend in spawning biomass relative to the 40% *SB0* interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% credible interval. The dashed line represents the interim target level. The red and orange dashed lines represent the hard and soft biomass limits, respectively.

Fisheries and Stock Trends	
Recent Trend in Biomass or Proxy	Spawning biomass was estimated to have increased gradually during the 2000s followed by a more rapid increase in biomass from 2009 (in response to the recruitment of the strong 2006 and 2016 year classes).
Recent Trend in Fishing Mortality or Proxy	Fishing mortality is estimated to have declined by around 75% since 2000.  **Annual fishing mortality compared to the *SB40%* interim target fishing mortality level (dashed line) for the interim base case model (median values from MCMCs).**



Annual spawning biomass and fishing mortality compared to the *$SB_{40\%}$* interim target biomass level and corresponding fishing mortality reference for the interim base case model (median values from MCMCs). The green dashed lines represent the biomass and fishing mortality target levels. The red and orange dashed lines represent the hard and soft biomass limits, respectively.

Other Abundance Indices	The increase in the trawl survey adult (> 6 y) biomass indices between 1989–1999 and 2018–2020 corroborates the recent increase in biomass.
Trends in Other Relevant Indicators or Variables	Estimates of recreational catch have increased 3-fold since 2006. The increase in catch is likely to be related to an increase in stock abundance.

Projections and Prognosis	
Stock Projections or Prognosis	Abundance is Very Likely (> 90%) to increase over the next five years at current levels of catch (2,416 t compared to a TAC of 1785 t and a TACC of 1300 t) and Likely (> 60%) to increase at higher levels of catch (corresponding to $F_{SB40\%}$ in 2021 = 3951 t).
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Level 1 – Full Quantitative Stock Assessment	
Assessment Method	Age-structured Bayesian stock assessment implemented with Stock Synthesis software and uncertainty estimated by MCMC	
Assessment Dates	Latest assessment: 2021	Next assessment: 2024
Overall assessment quality rank	1 – High Quality	
Main data inputs	- Proportions at age data from the commercial fisheries - Estimates of biological parameters (e.g., growth, age-	1 – High Quality

	at-maturity and length/ weight), including temporal variation in growth - Standardised single trawl CPUE index of abundance - Estimates of recreational harvest (recent levels) - Estimates of recreational harvest (pre-1990) - Commercial catch (from 1983 onwards) - Commercial catch (prior to 1983) - Two tag-based biomass estimates - Trawl survey age specific indices	1 – High Quality 1 – High Quality (less reliable CPUE indices for the last 2-3 years) 1 – High Quality 2 – Medium or Mixed Quality: level of catch is assumed 1 – High Quality 2 – Medium or Mixed Quality: less reliable reporting of catches prior to 1983 1 – High Quality (second estimate) 1 – High Quality
Data not used (rank)	- Trawl survey total biomass indices	2 – Medium or Mixed Quality: variable catchability of older age classes for the three most recent trawl surveys
Changes to Model Structure and Assumptions	Relative to the 2005 assessment: - parameterising fisheries selectivities as age-specific functions - BH SRR with an assumed value of steepness and recruitment deviates estimated (from 1960) - Natural mortality fixed rather than estimated - revised recreational catch history incorporating recent recreational catch estimates (2006/07, 2011/12, and 2017/18) - partitioning of the recreational catch by fisheries areas - incorporating additional age specific indices (2, 3, 4, and 5 year old fish) from the trawl survey - parameterisation of time varying growth - updated single trawl CPUE time series for 1997–2020	

Major Sources of Uncertainty	- There have been considerable changes in the operation of the trawl fisheries during the assessment period related to the extent of targeting/avoidance of snapper. The CPUE analysis has endeavoured to account for some of these changes; however, the CPUE indices are considered to under-estimate the increase in abundance during the more recent years. - The precision of the estimates of the recent (2014 onwards) year class strengths from the trawl survey have yet to be fully supported by sufficient additional observations from the commercial catch-at-age. - The shift in the overall level of recruitment is likely to be related to environmental conditions. Non-stationarity of the relationship between spawning biomass and recruitment is not represented by SRR and the assumed value of steepness.

Qualifying Comments
The stock structure relationship between the northern and southern areas of SNA 8 is unclear. The current assessment is primarily based on data from the northern area of the fisheries and the population dynamics may differ in the southern area. It was recognised that if the increases in abundance represented a regime shift, or a significant change in productivity levels, with an associated increase in B_0, then the use of historical levels of relative abundance to establish a soft limit may not be appropriate.

Fisheries Interactions
The primary species caught in association with snapper in bottom trawl fisheries are trevally, red gurnard, John dory, and tarakihi. Since 2010–11, most (> 80%) of commercial catch of snapper has been taken as a bycatch of trawls targeting trevally and red gurnard.

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