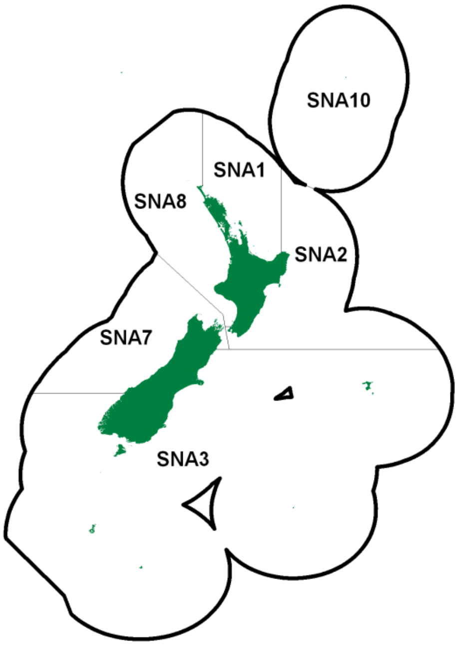
SNAPPER (SNA 8)

(*Chrysophrys auratus*)
Tamure, Kouarea



1. FISHERIES SUMMARY

1.1 Commercial fisheries

Table 1 and Table 2 provide a summary by fishing year of the reported commercial catches, TACCs, and TACs for SNA 8. Landings and TACC are plotted in Figure 1.

Table 1: Reported landings (t) of snapper from SNA 8 from 1931 to 1990.

Year	SNA 8	Year	SNA 8
1931–32	140	1961	1 178
1932–33	159	1962	1 352
1933–34	213	1963	1 456
1934–35	190	1964	1 276
1935–36	108	1965	1 182
1936–37	103	1966	1 831
1937–38	85	1967	1 477
1938–39	89	1968	1 491
1939–40	71	1969	1 344
1940–41	76	1970	1 588
1941–42	62	1971	1 852
1942–43	57	1972	1 961
1943–44	75	1973	3 038
1944	69	1974	4 340
1945	124	1975	4 217
1946	244	1976	5 326
1947	251	1977	3 941
1948	215	1978	4 340
1949	277	1979	3 464
1950	318	1980	3 309
1951	364	1981	3 153
1952	361	1982	2 636
1953	1 124	1983	1 814
1954	1 093	1984	1 536
1955	1 202	1985	1 866
1956	1 163	1986	959
1957	1 472	1987	1 072
1958	1 128	1988	1 565
1959	1 114	1989	1 571
1960	1 202	1990	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 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.
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 from SNA 8 from 1983–84 to present and gazetted and actual TACCs (t) for 1986–87 to present. QMS data from 1986–present.

Fishstock	SNA 8	
FMAs	8, 9	
	Landings	TACC
1983–84†	1 725	–
1984–85†	1 546	–
1985–86†	1 828	–
1986–87	893	1 331
1987–88	1 401	1 383
1988–89	1 527	1 508
1989–90	1 551	1 594
1990–91	1 659	1 594
1991–92	1 459	1 594
1992–93	1 543	1 500
1993–94	1 542	1 500
1994–95	1 436	1 500
1995–96	1 558	1 500
1996–97	1 613	1 500
1997–98	1 589	1 500
1998–99	1 636	1 500
1999–00	1 604	1 500
2000–01	1 631	1 500
2001–02	1 577	1 500
2002–03	1 558	1 500
2003–04	1 667	1 500
2004–05	1 663	1 500
2005–06	1 434	1 300
2006–07	1 327	1 300
2007–08	1 304	1 300
2008–09	1 345	1 300
2009–10	1 280	1 300
2010–11	1 313	1 300
2011–12	1 360	1 300
2012–13	1 331	1 300
2013–14	1 275	1 300
2014–15	1 272	1 300
2015–16	1 328	1 300
2016–17	1 334	1 300
2017–18	1 288	1 300
2018–19	1 293	1 300
2019–20	1 347	1 300
2020–21	1 295	1 300
2021–22	1 720	1 600

† FSU data. SNA 8 = Statistical Areas 037, 039–048. § Includes landings from unknown areas before 1986–87.

From 1 October 2005 the TACC for SNA 8 was reduced to 1300 t within a TAC of 1785 t to ensure a faster rebuild of the stock (Table 3). All commercial fisheries have a minimum legal size (MLS) for snapper of 25 cm.

Table 3: TACs, TACCs, and allowances (t) for SNA 8 from 1 October 2022.

Fishstock	TAC	TACC	Customary allowance	Recreational allowance	Other mortality
SNA 8	3 065	1 600	100	1 205	160

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 8
1967		3092	30	NA
1968		19 721	562	309
1969		25 997	1 289	929
1970		31 789	676	543
1971		42 212	522	403
1972		49 133	1 444	1 217
1973		45 601	616	466
1974		52 275	472	363
1975		55 288	922	735
1976		133 400	970	676
1977		214 900	856	708
Year	**(b) Longline**		**Total Snapper**	**SNA 8**
1975			1 510	749
1976			2 057	1 127
1977			2 208	1 104

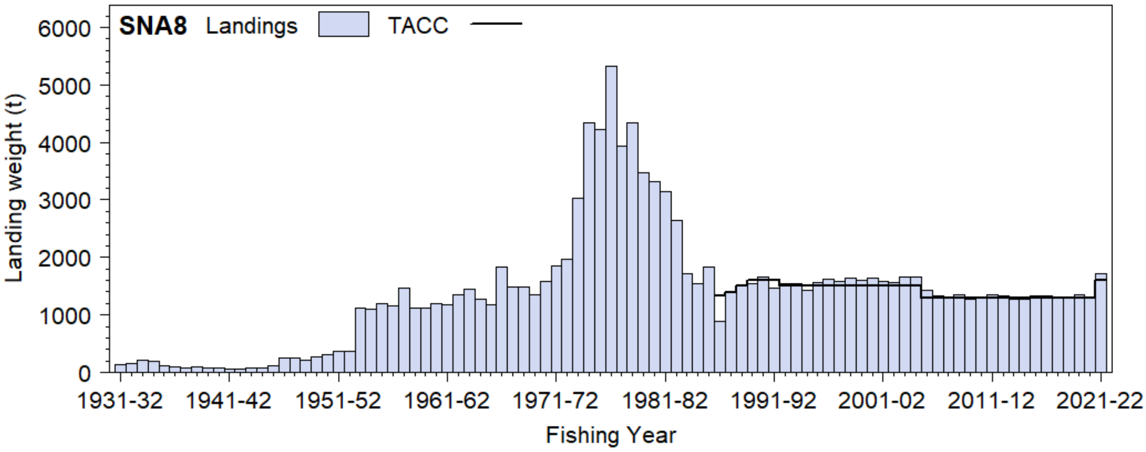


Figure 1: Total reported landings and TACC for the SNA 8.

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 allowance within the SNA 8 TAC is 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 SNA 8.

Stock	MLS	Bag limit	Introduced
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

A background to the estimation on recreational harvest of snapper is provided in the Introduction – Snapper chapter. Recreational harvest estimates for SNA 8 are provided in Table 6.

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.

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.

Stock	Year	Method	Number of fish (thousands)	Mean weight (g)	Total weight (t)	CV
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**

[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).

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 7). 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 7 may be underestimated.

Table 7: 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 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

For further information on snapper biology refer to the Introduction – Snapper chapter. A summary of published estimates of biological parameters for SNA 8 is presented in Table 8.

Table 8: 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 = $a(\text{length})^b$ (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 8 (1990s)	0.16	-0.11	66.7	Gilbert & Sullivan (1994)
4. Age at recruitment (years)				
SNA 8	3			Gilbert & Sullivan (1994)

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 8 have shown considerable movements of fish between South Taranaki Bight and the area north of Cape Egmont. However, recent *Kaharoa* WCNI 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.

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 was relatively low during that period.

Location-based snapper catch data from the trawl fisheries in SNA 7 and southern SNA8 has revealed an overlap of the distribution of snapper catches in western approaches to Cook Strait between Durville Island and Kapiti Island, particularly since 2014/15. Snapper age compositions are available from recent (2018-2020) *Kaharoa* trawl surveys of the South Taranaki Bight and the Tasman Bay/Golden Bay area of the WCSI trawl survey. There are strong differences in the relative strength of individual year classes from the 2019 South Taranaki Bight age composition compared to the 2018 and 2020 surveys, while the 2019 STB age composition was very similar to the age structures from the 2019 Tasman Bay/Golden Bay trawl survey and the commercial fishery in the TBGB area. These observations indicate a degree of mixing of the snapper populations between SNA 7 and the STB area (SNA8), although the extent of mixing may vary between years, potentially related to variation in the timing of the main spawning period in each area.

4. STOCK ASSESSMENT

An assessment for SNA 8 was conducted in 2020 and finalised in 2021.

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 2021). 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.

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 2).

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.

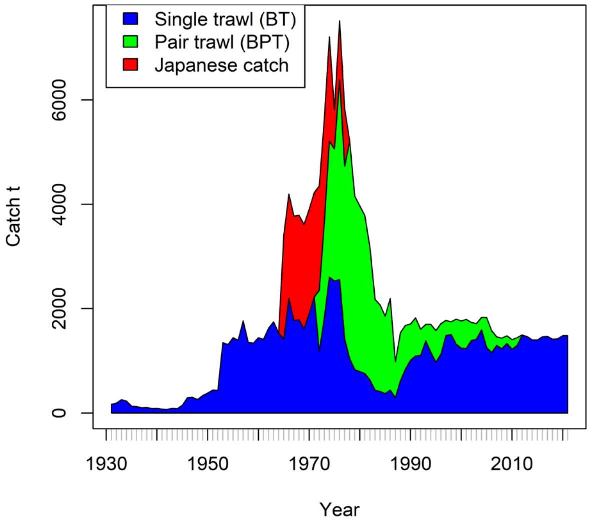


Figure 2: Annual commercial catches included in the base model, assuming unreported Japanese longline catches of 2000 t.

Recreational catches

A time series of recreational catch for 1931–2021 was configured, informed by recreational catch estimates available from 1990 (Figure 3). 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 7). 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.

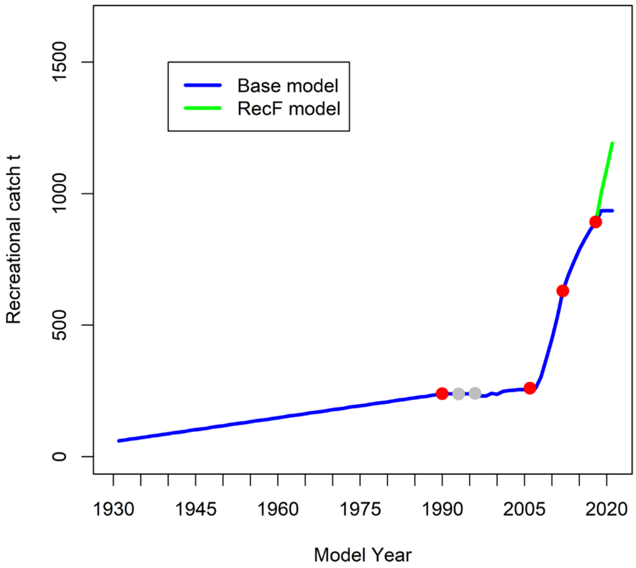


Figure 3: Recreational catch estimates from SNA 8 (red points) used in the derivation of the recreational catch history (blue line). The green line represents an alternative series of recent recreational catches assuming a constant recreational harvest rate from 2018. The grey points are additional recreational 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 4). 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).

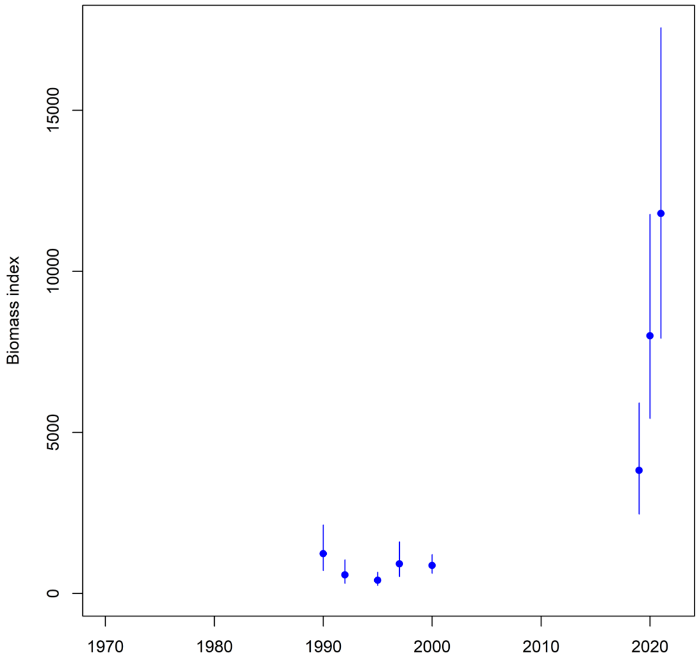


Figure 4: Snapper total biomass indices (and 95% confidence intervals) from the core area of the WCNI trawl survey area.

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 4), 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 5). 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.

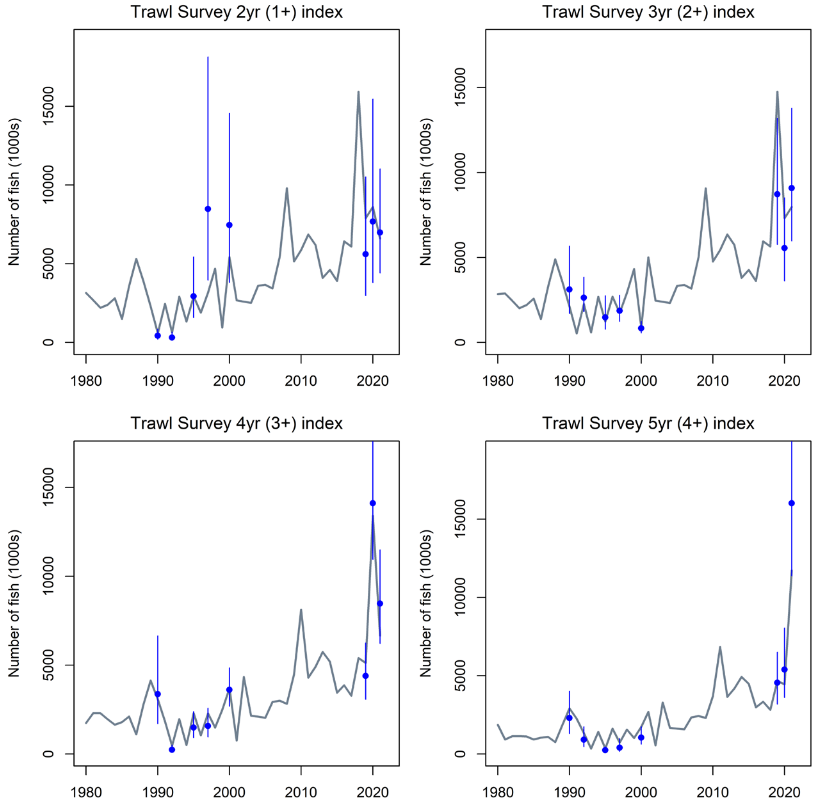


Figure 5: The four sets of age-specific trawl survey abundance indices (blue points and associated 95% confidence intervals) and the model fit to each set of indices (grey lines).

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 6). 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 6). 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.

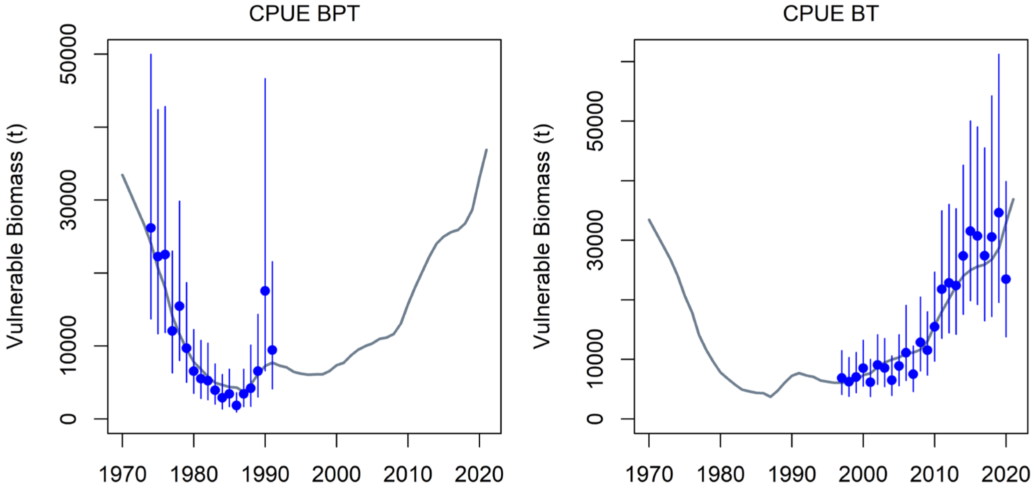


Figure 6: BPT CPUE indices (left) and recent BT CPUE indices (right). The grey line represents the model fit to the indices.

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 9. 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 9: 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 10. Estimated parameters and structural assumptions are summarised in Table 11.

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 10: 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 11: 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 7), 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.

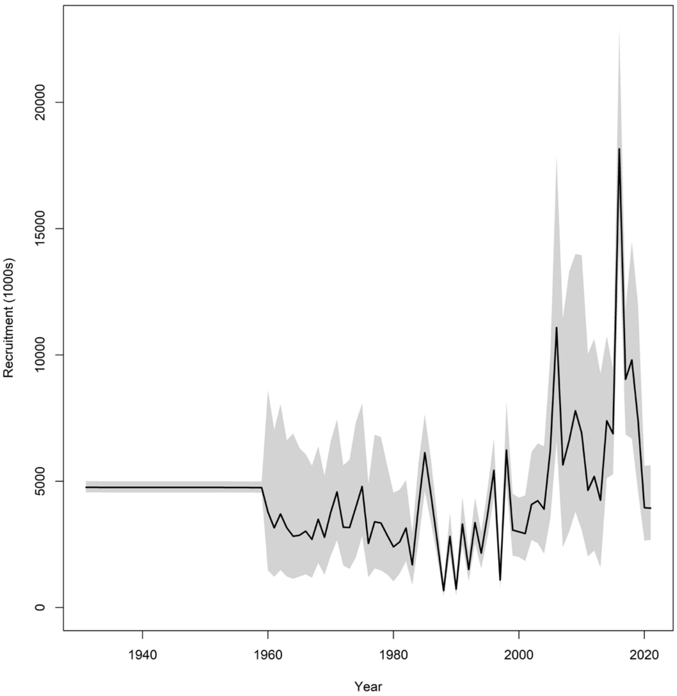


Figure 7: Annual estimates of recruitment (numbers of fish, thousands) from the Base Case model (MCMCs). The black line represents the median of the MCMC estimates and the shaded error represents the 95% confidence interval.

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 12). 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 12: 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) (Figure 8, Table 13). The higher catch scenario (3951 t) results in a smaller (8%) increase in biomass during the projection period.

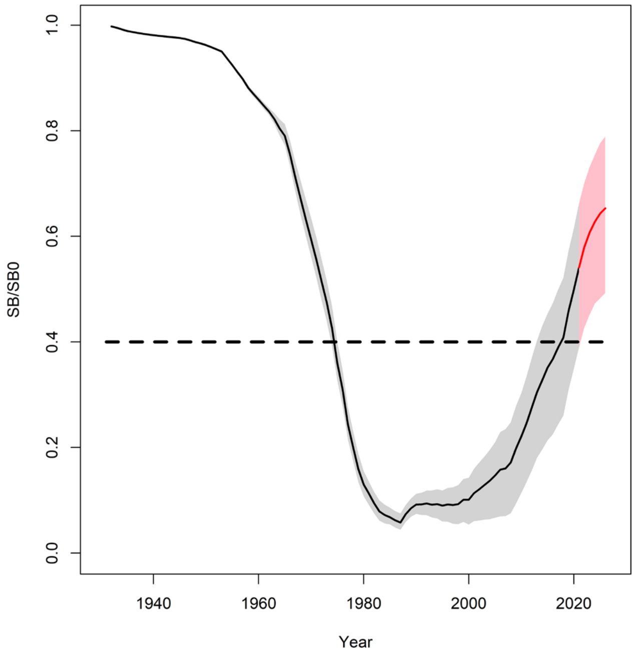


Figure 8: Annual spawning biomass relative to virgin biomass (equilibrium, unexploited) estimated from the Base Case model (black) and the five-year projection (red) assuming annual catches equivalent to the 2021 catch. The solid line represents the median of the MCMCs and the shaded area represents the 95% confidence interval. The horizontal dashed line represents the default target biomass level.

Table 13: 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.)

5. 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.

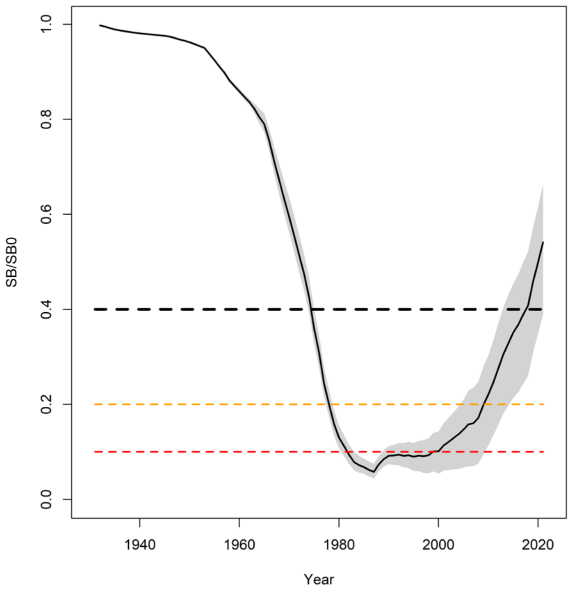
- **SNA 8**

Stock Structure Assumptions

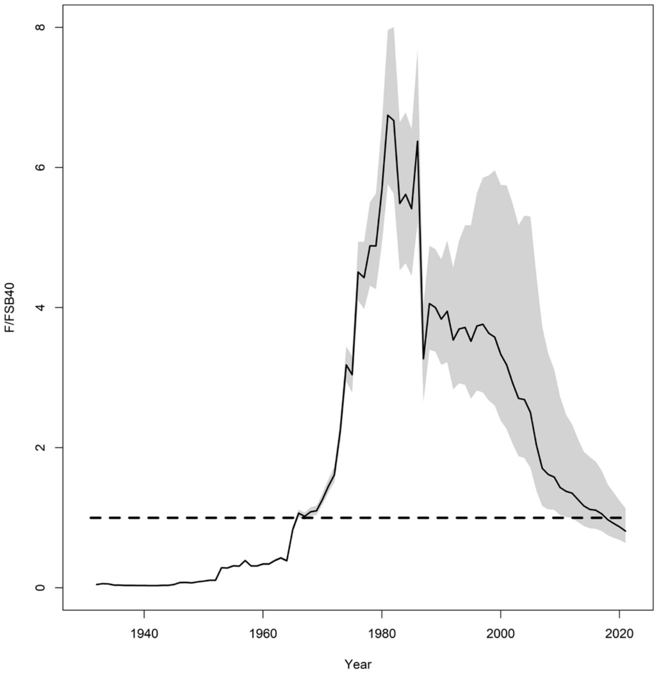
Tagging, genetic, and morphological studies have revealed that snapper off the west coast of the North Island (i.e., SNA 8) are likely to comprise a separate biological unit.

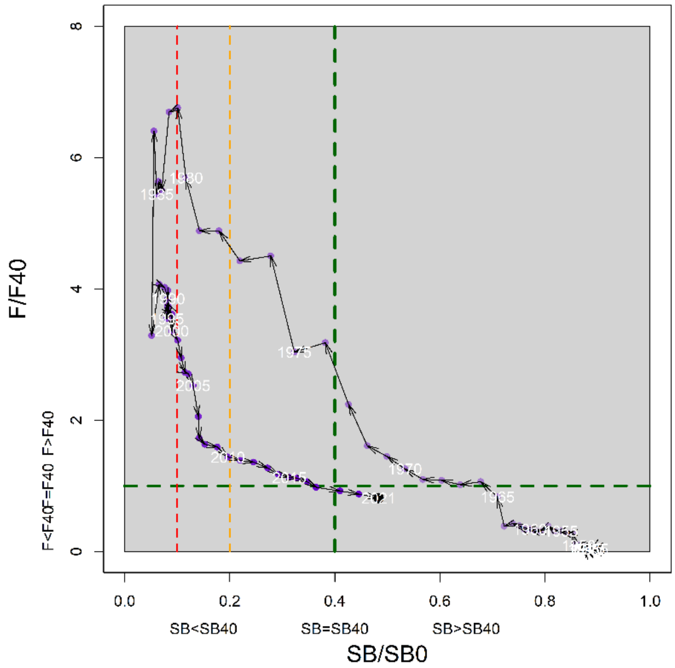
Stock Status	
Year of Most Recent Assessment	2021
Assessment Runs Presented	Base Case model
Reference Points	Interim Target: 40% B_0 (HSS default) Soft Limit: 20% B_0 (HSS default) Hard Limit: 10% B_0 (HSS default) Overfishing threshold: $F_{SB40\%}$
Status in relation to Target	$B_{2020–21}$ was estimated 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% 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 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 $SB_{40\%}$ 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	1 – High Quality
	- Standardised single trawl CPUE index of abundance	1 – High Quality (less reliable CPUE indices for the last 2-3 years)
	- Estimates of recreational harvest (recent levels)	1 – High Quality
	- Estimates of recreational harvest (pre-1990)	2 – Medium or Mixed Quality: level of catch is assumed
	- Commercial catch (from 1983 onwards)	1 – High Quality
	- Commercial catch (prior to 1983)	2 – Medium or Mixed Quality: less reliable reporting of catches prior to 1983
	- Two tag-based biomass estimates	1 – High Quality (second estimate)
	- Trawl survey age specific indices	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.

6. FOR FURTHER INFORMATION

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

Bian, R; McKenzie, J R; Davies, N M (2009) Determination of optimum frequency for SNA 8 snapper market sampling based on retrospective analysis. *New Zealand Fisheries Assessment Report 2009/50*. 15 p.

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 national marine recreational fishing survey: diary results and harvest estimates. Final Research Report for Ministry of Fisheries. (Unpublished report held by Fisheries New Zealand, Wellington.) 93 p.

Boyd, R O; Reilly, J L (2002) 1999/2000 National marine recreational fishing survey: harvest estimates. Final Research Report for Ministry of Fisheries Research Project REC9803. (Unpublished report held by Fisheries New Zealand, Wellington.)

Bradford, E (1998) Harvest estimates from the 1996 national marine fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished document held by NIWA library, Wellington.)

Bull, B; Francis, R I C C; Dunn, A; Gilbert, D J; Bian, R; Fu, D (2012) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.30.2012/03/21. *NIWA Technical Report 135*. 280 p.

Bull, B; Francis, R I C C; Dunn, A; McKenzie, A; Gilbert, D J; Smith, M H (2004) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.06-2004/09/26. *NIWA Technical Report 126*. 261 p.

Davies, N M (1997) Assessment of the west coast snapper (*Pagrus auratus*) stock (SNA 8) for the 1996–97 fishing year. New Zealand Fisheries Assessment Research Document 1997/12. 47 p. (Unpublished document held by NIWA library, Wellington.)

Davies, N M (1999) Assessment of the SNA 1 and 8 stocks for the 1997–98 fishing year. New Zealand Fisheries Assessment Research Document 1999/19. 87 p. (Unpublished document held by NIWA library, Wellington.)

Davies, N M; Gilbert, D J; McKenzie, J R (1999a) Assessment of the SNA 1 and 8 stocks for the 1998–99 fishing year. New Zealand Fisheries Assessment Research Document 1999/28. 82 p. (Unpublished document held by NIWA library, Wellington.)

Davies, N M; McKenzie, J R; Gilbert, D J (1999b) Monte Carlo estimation of bias in Petersen mark-recapture estimates for snapper (*Pagrus auratus*). New Zealand Fisheries Assessment Research Document 1999/20. 52 p. (Unpublished document held by NIWA library, Wellington.)

Davies, N M; McKenzie, J R; Gilbert, D J (2006) Assessment of the SNA 8 stock for the 2003–04 fishing year. *New Zealand Fisheries Assessment Report 2006/9*. 32 p.

Davies, N M; McKenzie, J R; Gilbert, D J (2013) Assessment of the SNA 8 stock for the 2004–05 fishing year. *New Zealand Fisheries Assessment Report 2013/28*. 73 p.

Francis, M P; Paul, L J (2013) New Zealand inshore finfish and shellfish commercial landings, 1931–82. *New Zealand Fisheries Assessment Report 2013/55*. 136 p.

Francis, R I C C (2011) Data weighting in statistical fisheries stock assessment models *Canadian Journal of Fisheries and Aquatic Sciences*. 68: 1124–1138.

Francis, R I C C; McKenzie, J R (2015a) Assessment of the SNA 1 stocks in 2012. *New Zealand Fisheries Assessment Report 2015/75.*

Francis, R I C C; McKenzie, J R (2015b) Assessment of the SNA 1 stocks in 2013. *New Zealand Fisheries Assessment Report 2015/76.*

Froese, R; Pauly, D (2000) FishBase 2000: concepts, design and data sources. ICLARM, Los Banos, Laguna, Philippines. 344 p.

Gilbert, D J; Sullivan, K J (1994) Stock assessment of snapper for the 1992–93 fishing year. New Zealand Fisheries Assessment Research Document 1994/3. 37 p. (Unpublished document held by NIWA library, Wellington.)

Kendrick, T H; Bentley, N (2010) Fishery characterisation and catch-per-unit-effort indices for snapper in SNA 8, 1989–90 to 2007–08. *New Zealand Fisheries Assessment Report 2010/42.*

King, M R (1985) Fish and shellfish landings by domestic fishermen, 1974–82. *Fisheries Research Division Occasional Publication: Data Series 20*. 96 p.

King, M R (1986) Catch statistics for foreign and domestic commercial fishing in New Zealand waters, January–December, 1983. *Fisheries Research Division Occasional Publication: Data series 21*. 140 p.

King, M R; Jones, D M; Fisher, K A; Sanders, B M (1987) Catch statistics for foreign and domestic commercial fishing in New Zealand waters, January – December 1984. *New Zealand Fisheries Data Report No. 30*. 150 p.

Langley, A D (1995b) Trawl survey of snapper and associated species off the west coast of the North Island, October 1994 (KAH9410). *New Zealand Fisheries Data Report No. 65*. 35 p.

Langley, A D (2017) Catch-Per-Unit-Effort indices for snapper in SNA 8. *New Zealand Fisheries Assessment Report 2017/45*. 40 p.

Langley, A D (2020b) Stock assessment of snapper in SNA 8 for 2020. *New Zealand Fisheries Assessment Report 2020/20.* 87 p

Langley, A D (2021) Stock assessment of snapper in SNA 8 for 2021. *New Zealand Fisheries Assessment Report 2021/38.* 86 p

McKenzie, J R; Diggles, B; Tubbs, L; Poortenaar, C; Parkinson, D; Webster, K; Miller, N (2006) An evaluation of a new type of plastic-coated PIT tag for tagging snapper (*Pagrus auratus*). *New Zealand Fisheries Assessment Report 2006/8*. 40 p.

Methot, R D (1990) Synthesis model: an adaptable framework for analysis of diverse stock assessment data. *International North Pacific Fisheries Commission Bulletin 50*: 259–275.

Methot, R D (2005) Technical description of the Stock Synthesis II assessment program. NOAA Technical Memorandum SEDAR 16-AW-04.

Methot, R D (2009) User manual for Stock Synthesis, model version 3.02C.

Methot, R D; Wetzell, C R (2013) Stock Synthesis: A biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research 142*: 86–99.

Millar, R B; Akroyd, J M; Walshe, K A R (2001) Incidental mortality of snapper in SNA 1 and SNA 8. *New Zealand Fisheries Assessment Report 2001/78*. 36 p.

Ministry of Fisheries (2008). Harvest Strategy Standard for New Zealand Fisheries. 25 p. Available online at: https://fs.fish.govt.nz/Doc/16543/harveststrategyfinal.pdf.ashx

Morrison, M A (1998) Trawl survey of snapper and associated species off the west coast of the North Island, November 1996 (KAH9615). *NIWA Technical Report 33*. 48 p.

Morrison, M A; Parkinson, D M (2001) Trawl survey of snapper and associated species off the west coast of the North Island, November 1999 (KAH9915). *NIWA Technical Report 100*. 51 p.

Morrison, M A; Stevenson, M L (2001) Review of west coast North Island trawl survey time series, 1986–96. *NIWA Technical Report 107*. 55 p.

Paul, L J (1977) The commercial fishery for snapper *Chrysophrys (Pagrus) auratus* in the Auckland region, New Zealand, from 1900 to 1971. *Fisheries Research Division Bulletin No 15*. 84 p.

Ritchie, L; Saul, P; O'Sullivan, K. (1975) The wetfish report 1941–1970. *New Zealand Ministry of Agriculture and Fisheries Fisheries Technical Report 137*. 370 p.

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

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

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

Teirney, L D; Kilner, A R; Millar, R B; Bradford, E; Bell, J D (1997) Estimation of recreational harvests from 1991–92 to 1993–94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished document held by NIWA library, Wellington.)

Vignaux, M (1993) Catch per unit of effort (CPUE) analysis of the SNA 8 snapper fishery. New Zealand Fisheries Assessment Research Document 1993/2. 12 p. (Unpublished document held by NIWA library, Wellington.)

Walsh, C; Armiger, H; Bian, R; Buckthought, D; McKenzie, J (2017) Length and age composition of commercial snapper landings in SNA 8, 2015–16. *New Zealand Fisheries Assessment Report 2017/02*. 40 p.

Walsh, C; Davies, N M (2004) Length and age composition of commercial landings in SNA 8, 2003–04. *New Zealand Fisheries Assessment Report 2004/56*. 18 p.

Walsh, C; Davies, N M; Buckthought, D (2006a) Length and age composition of commercial snapper landings in SNA 8, 2005–06. *New Zealand Fisheries Assessment Report 2006/54*. 21 p.

Walsh, C; McKenzie, J; Arminger, H (2006d) Spatial and temporal patterns in snapper length and age composition and movement, west coast North Island, New Zealand. *New Zealand Fisheries Assessment Report 2006/6*. 59 p.

Wright, P; McClary, D; Boyd, R O (2004) 2000/2001 National Marine Recreational Fishing Survey: direct questioning of fishers compared with reported diary data. Final Research Report for Ministry of Fisheries Project REC2000-01: Objective 2. (Unpublished report held by Fisheries New Zealand, Wellington.)

Wynne-Jones, J; Gray, A; Heinemann, A; Hill, L; Walton, L (2019). National Panel Survey of Marine Recreational Fishers 2017–2018. *New Zealand Fisheries Assessment Report 2019/24*. 104 p.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.