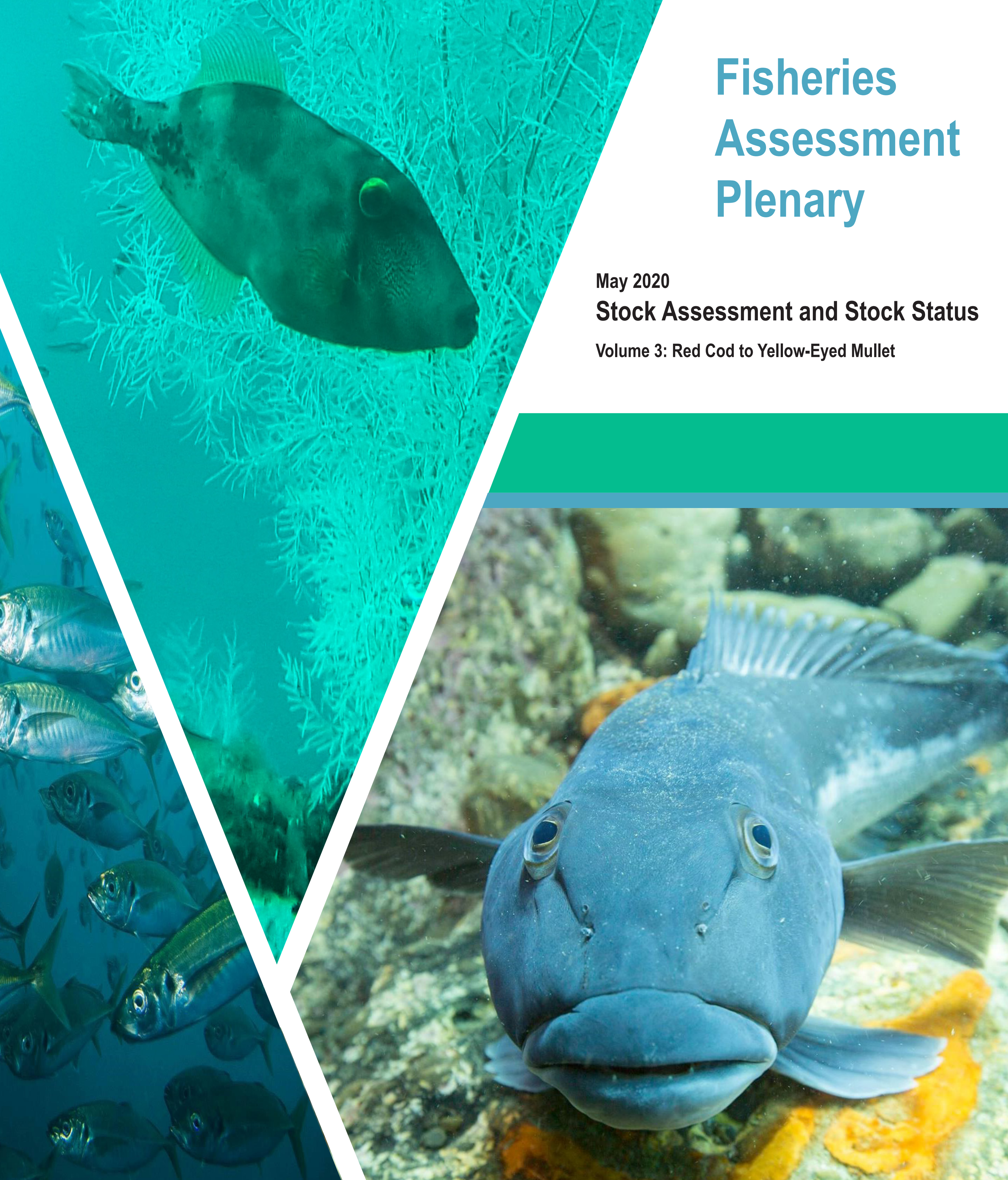

Fisheries Assessment Plenary

May 2020

Stock Assessment and Stock Status

Volume 3: Red Cod to Yellow-Eyed Mullet

Fisheries New Zealand

Tini a Tangaroa

New Zealand Government

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MAY 2020 PLENARY VOLUME CONTENTS

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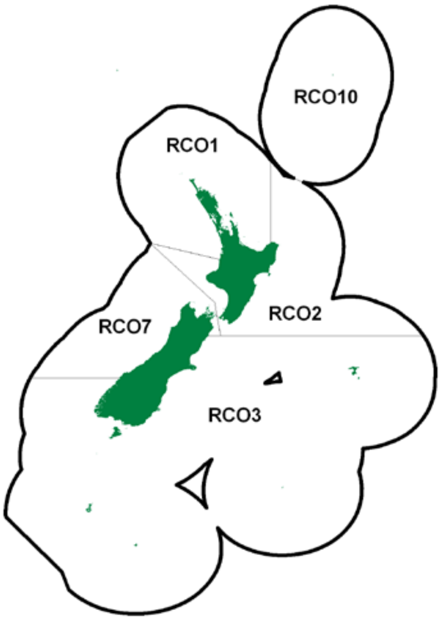
Volume 3: Red Cod to Yellow-eyed Mullet

RED COD (RCO)

(*Pseudophycis bachus*)
Hoka



1. FISHERY SUMMARY

1.1 Commercial fisheries

Red cod are targeted primarily by domestic trawlers in the depth range between 30 and 200 m and are also a bycatch of deepwater fisheries off the southeast and southwest coasts of the South Island. The domestic red cod fishery is seasonal, usually beginning in November and continuing to May or June, with peak catches around January and May. During spring and summer, red cod are caught inshore before the fishery moves into deeper water during winter. RCO entered the QMS in 1986.

Reported annual catches by nation from 1970 to 1986–87 are given in Table 1. Foreign vessel catches declined during the 1980s and were negligible by 1987–88.

Table 1: Reported annual catch (t) of red cod by nation from 1970 to 1986–87.

	New Zealand					Foreign licensed	Combined Total
Year	Domestic	Chartered	Japan	Korea	USSR	Total	
1970*	760	–	995	–	–	995	1 755
1971*	393	–	2 140	–	–	2 140	2 533
1972*	301	–	2 082	–	< 100	2 182	2 483
1973*	736	–	2 747	–	< 100	2 847	3 583
1974*	1 876	–	2 950	–	< 100	3 050	4 926
1975*	721	–	2 131	–	< 100	2 231	2 952
1976*	948	–	4 001	–	600	4 601	5 549
1977*	2 690	–	8 001	1 358	§2 200	11 559	14 249
1978–79*	5 343	124	2 560	151	51	2 762	8 229
1979–80*	5 638	883	537	259	116	912	7 433
1981–82*	3 210	387	474	70	102	646	4 243
1982–83*	4 342	406	764	675	52	1 493	6 241
1983–83†	3 751	390	149	401	3	553	4 694
1983–84†	10 189	1 764	1 364	480	49	1 893	13 846
1984–85†	14 097	2 381	978	829	7	1 814	18 292
1985–86†	9 035	1 014	739	147	5	891	10 940
1986–87‡	2 620	1 089	197	4	59	261	3 969

Note: 1970–1977 = calendar years; 1978–79 to 1982–83 = 1 April–31 March; 1980–1981=no fishing returns processed this year; 1983–1983 = 1 April–30 September; 1983–84 to 1986–87 = 1 October–30 September; * MAF data; † FSU data; ‡ QMS data § mainly ribaldo and red cod.

Reported landings for 1931 to 1982 are given by red cod QMAs 1, 2, 3, and 7 in Table 2. Recent reported landings and TACCs of red cod by Fishstock are shown in Table 3, and Figure 1 depicts historical landings and TACC values for the three main RCO stocks.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	RCO 1	RCO 2	RCO 3	RCO 7	Year	RCO 1	RCO 2	RCO 3	RCO 7
1931–32	0	0	16	6	1957	0	5	189	6
1932–33	0	51	41	67	1958	0	8	84	6
1933–34	0	0	28	21	1959	0	15	95	23
1934–35	0	0	18	0	1960	0	16	165	46
1935–36	0	0	12	0	1961	0	16	184	41
1936–37	0	13	35	14	1962	0	48	193	60
1937–38	0	27	143	32	1963	0	27	248	46
1938–39	0	19	279	27	1964	0	29	377	49
1939–40	5	24	213	19	1965	0	65	339	120
1940–41	0	41	213	50	1966	0	91	500	234
1941–42	0	12	539	61	1967	0	54	1 358	243
1942–43	1	4	728	54	1968	0	13	1 124	87
1943–44	0	3	362	34	1969	0	35	1 645	69
1944	0	2	287	5	1970	0	34	1 536	184
1945	0	5	423	5	1971	0	8	2 453	72
1946	0	13	434	51	1972	1	10	274	19
1947	3	18	322	74	1973	1	44	475	219
1948	9	8	202	17	1974	1	37	6 788	949
1949	0	4	123	19	1975	0	37	4 798	233
1950	0	3	199	13	1976	0	20	10 960	535
1951	0	13	198	23	1977	0	242	12 379	2666
1952	0	11	133	35	1978	4	224	7 069	2296
1953	0	19	205	41	1979	5	76	7 921	1936
1954	0	59	233	48	1980	2	41	3 644	628
1955	0	28	247	37	1981	0	42	2 478	705
1956	0	11	297	18	1982	9	125	5 088	787

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.
3. 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 includes both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 3: Reported landings (t) and TACCs (t) for red cod by Fishstock. Source: QMR/MHR from 1986–present.

Fishstock		RCO 1		RCO 2		RCO 3		RCO 7
FMA (s)		1 & 9		2 & 8		3, 4 & 5		7
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	12	–	197	–	9 357	–	3 051	–
1984–85*	9	–	126	–	14 751	–	1 442	–
1985–86*	6	–	48	–	9 346	–	408	–
1986–87	5	30	46	350	3 300	11 972	619	2 945
1987–88	8	40	81	357	2 880	12 182	1 609	2 982
1988–89	9	40	85	359	7 840	12 362	1 357	3 057
1989–90	8	42	105	362	6 589	13 018	800	3 105
1990–91	12	42	68	364	4 630	12 299	856	3 125
1991–92	26	42	358	364	6 517	12 299	2 222	3 125
1992–93	46	42	441	364	9 635	12 389	4 088	3 125
1993–94	44	42	477	364	7 977	12 389	2 992	3 125
1994–95	63	42	762	364	12 603	12 389	3 570	3 125
1995–96	28	42	584	500	10 983	12 389	3 712	3 125
1996–97	42	42	396	500	10 037	12 389	3 657	3 125
1997–98	22	42	192	500	9 954	12 389	2 595	3 125
1998–99	10	42	282	500	13 919	12 389	2 055	3 125
1999–00	3	42	130	500	4 824	12 389	632	3 125
2000–01	5	42	112	500	2 776	12 389	1 538	3 125
2001–02	6	42	150	500	2 857	12 396	1 410	3 126
2002–03	8	42	144	500	5 107	12 396	1 657	3 126
2003–04	11	42	225	500	7 724	12 396	2 358	3 126
2004–05	21	42	423	500	4 212	12 396	3 052	3 126
2005–06	24	42	372	500	3 223	12 396	3 061	3 126
2006–07	25	42	256	500	1 877	12 396	3 409	3 126
2007–08	12	42	225	500	3 236	4 600	2 984	3 126
2008–09	12	42	212	500	2 542	4 600	2 131	3 126
2009–10	14	42	364	500	2 994	4 600	1 868	3 126
2010–11	19	42	501	500	4 568	4 600	1 603	3 126
2011–12	8	42	549	500	5 386	4 600	1 681	3 126
2012–13	6	42	300	619[1]	5 294	4 944[1]	1 282	3 126
2013–14	6	42	167	500	4 410	5 391[1]	1 272	3 126

Table 3 [Continued]

Fishstock	RCO 1		RCO 2		RCO 3		RCO 7	
FMA (s)	1 & 9		2 & 8		3, 4 & 5		7	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2014–15	7	42	142	500	2 171	4 600[2]	1 482	3 126
2015–16	15	42	419	500	3 837	4 600	1 417	3 126
2016–17	20	42	385	733[2]	4 543	4 600	1 929	3 126
2017–18	21	42	151	500	2 250	4 600	945	3 126
2018–19	8	42	69	500	1 817	4 600	1 014	3 126

[1] Commercial catch allowance increased through application of in-season MP with additional ACE provided under S68 of FA1996
[2] Recommended commercial catch allowance increase to 6289 t consulted but not implemented.

Fishstock	RCO 10		Total NZ	
FMA (s)	10		Total	
	Landings§	TACC	Landings§	TACC
1983–84*	0	–	13 848	-
1984–85*	0	–	18 292	-
1985–86*	0	–	10 940	-
1986–87	0	10	3 970	15 290
1987–88	0	10	4 506	15 571
1988–89	0	10	9 171	15 828
1989–90	0	10	7 502	16 537
1990–91	0	10	5 549	15 840
1991–92	0	10	9 104	15 840
1992–93	0	10	14 203	15 930
1993–94	0	10	11 491	15 930
1994–95	0	10	16 997	15 930
1995–96	0	10	15 350	16 066
1996–97	0	10	14 204	16 066
1997–98	0	10	12 886	16 066
1998–99	0	10	16 273	16 066
1999–00	0	10	5 590	16 066
2000–01	0	10	4 432	16 066
2001–02	0	10	4 427	16 067
2002–03	0	10	6 916	16 067
2003–04	0	10	10 318	16 067
2004–05	0	10	7 708	16 067
2005–06	0	10	6 679	16 067
2006–07	0	10	5 567	16 067
2007–08	0	10	6 457	8 278
2008–09	0	10	4 897	8 278
2009–10	0	10	5 236	8 278
2010–11	0	10	6 691	8 278
2011–12	0	10	7 627	8 278
2012–13	0	10	6 881	8 278
2013–14	0	10	5 855	9 069
2014–15	0	10	3 804	8 278
2015–16	0	10	5 688	8 278
2016–17	0	10	6 876	8 511
2017–18	0	10	3 367	8 278
2018–19	0	10	2 908	8 278

*FSU data.
§ Includes landings from unknown areas before 1986–87.

The bulk of reported landings are taken from RCO 3, in particular the Canterbury Bight and Banks Peninsula areas. The red cod fishery is characterised by large variations in catches between years. Research indicates that this interannual variation in catch is due to varied recruitment causing biomass fluctuations rather than a change in catchability. The RCO 3 TACC was reduced by 63% from 1 October 2007 to 4600 t, with the TAC being set at 4930 t (customary, recreational, and other sources of mortality were allocated 5 t, 95 t, and 230 t respectively). All RCO stocks fisheries have been put on to Schedule 2 of the Fisheries Act 1996. Schedule 2 allows that for certain “highly variable” stocks, the Total Annual Catch (TAC) can be increased within a fishing season. Increased commercial catch is provided for through the creation of additional ‘in-season’ ACE. The base TACC is not changed by this process and the ‘in-season’ TAC reverts to the original level at the end of each season. The RCO 2 TAC was increased under Schedule 2 in 2012–13 and 2016–17 and the RCO 3 TAC was increased in 2012–13 and 2013–14 (see Table 3). The 2016–17 RCO 2 increase was not authorised until late August, too late for the fishery to respond. A recommended RCO 3 commercial catch allowance increase to 6289 t in 2014–15 was not implemented because discussions with commercial operators concluded that the increase was not required for that fishing year and that managemant resources would be better allocated elswhere.

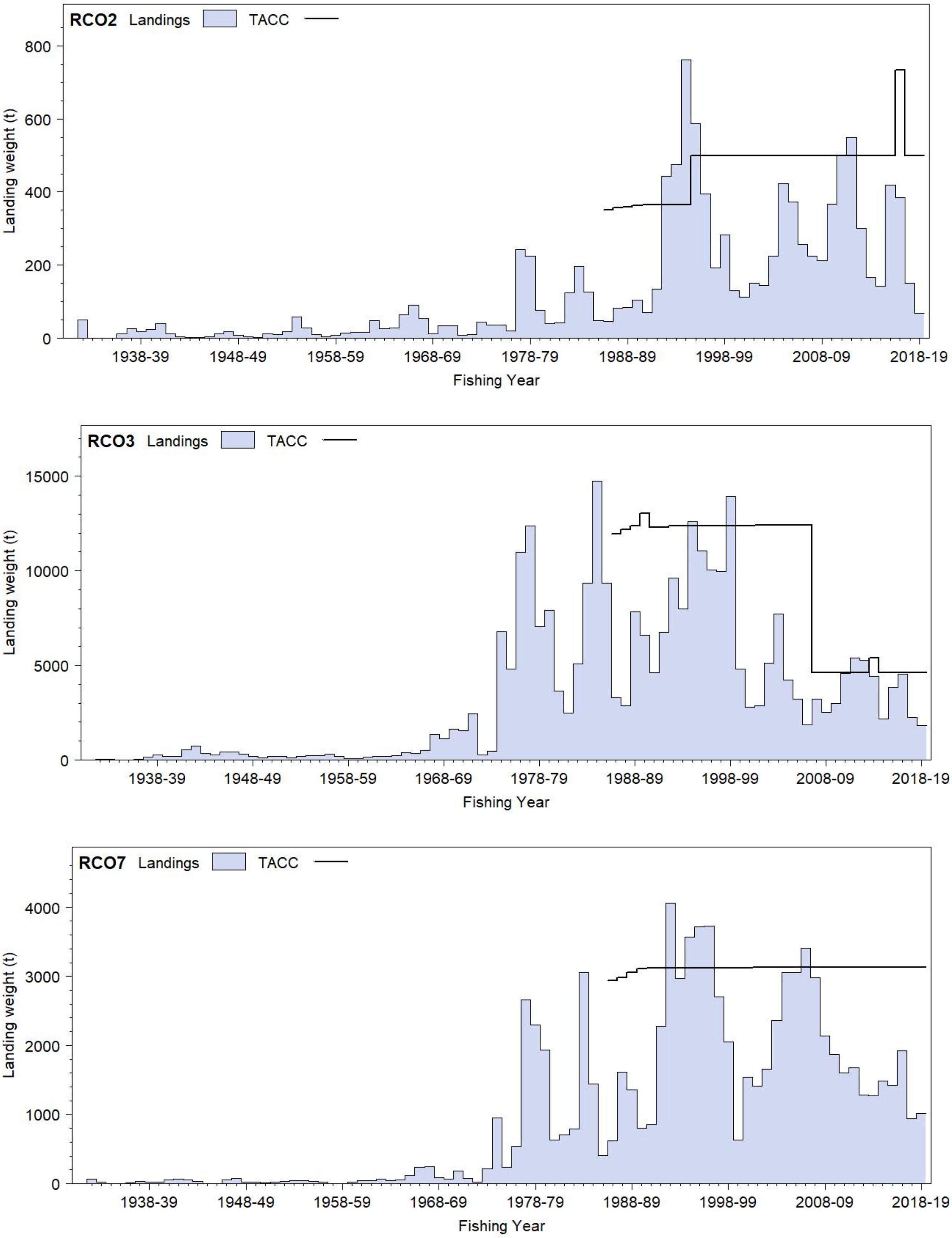


Figure 1: Reported commercial landings and TACC for the three main RCO stocks. Top to bottom: RCO 2 (Central East), RCO 3 (South East Coast), and RCO 7 (Challenger). RCO 2 and RCO 3 show in-season adjustments to the commercial limit.

1.2 Recreational fisheries

Recreational fishers take red cod throughout New Zealand. Estimates of harvest from telephone/diary surveys conducted between 1991 and 2000 are given in Table 4a.

Table 4a: Estimated number and weight of red cod harvested by recreational fishers, by Fishstock and survey. Surveys were carried out in different years in the MAF Fisheries regions: South in 1991–92, Central in 1992–93, North in 1993–94 (Teirney et al 1997) and nationally in 1996 (Bradford 1998) and 1999–00 (Boyd & Reilly 2002). Survey harvest is presented as a range to reflect the uncertainty in the estimates.

Fishstock	Survey	Number	CV %	Estimated harvest range (t)	Estimated point estimate (t)
					1991–92
RCO 3	South	104 000	16	90–120	–
RCO 7	South	1 000	–	0–5	–
					1992–93
RCO 2	Central	151 000	19	105–155	–
RCO 7	Central	1 100	34	5–15	–
					1993–94
RCO 1	North	9000	34	5–15	–
					1996
RCO 1	National	11 000	18	5–15	11
RCO 2	National	88 000	11	80–105	92
RCO 3	National	99 000	10	90–115	103
RCO 7	National	38 000	15	30–50	40
					1999–00
RCO 1	National	21 000	36	5–11	8
RCO 2	National	39 000	25	8–14	11
RCO 3	National	207 000	25	210–349	280
RCO 7	National	23 000	50	5–14	9

The harvest estimates provided by these telephone/diary surveys are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year. 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 (Wynne-Jones et al 2014). The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 4b. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 4b: Recreational harvest estimates for red cod stocks (Wynne-Jones et al 2014, 2019). Mean fish weights were obtained from boat ramp surveys (Hartill & Davey 2015, Davey et al 2019).

Stock	Year	Method	Number of fish	Total weight (t)	CV
RCO 1	2011–12	Panel survey	2 949	3.1	0.32
	2017–18	Panel survey	2 300	2.4	0.34
RCO 2	2011–12	Panel survey	20 637	24.7	0.18
	2017–18	Panel survey	18 441	19.4	0.28
RCO 3	2011–12	Panel survey	8 192	8.9	0.23
	2017–18	Panel survey	6 411	6.8	0.27
RCO 7	2011–12	Panel survey	2 184	2.3	0.46
	2017–18	Panel survey	3 049	3.2	0.31

1.3 Customary non-commercial fisheries
Quantitative estimates of the current level of customary non-commercial catch are not available.

1.4 Illegal catch
Quantitative estimates of the level of illegal catch are not available.

1.5 Other sources of mortality
Processing limits on red cod are sometimes imposed to discourage fishers from landing red cod when the species cannot be processed or when markets are poor. This practice has encouraged dumping. Processing limits are currently less of a problem than in earlier years.

2. BIOLOGY

Red cod are a fast-growing, short-lived species with few fish in the commercial fishery older than six years. Red cod grow to about 25 cm total length (TL) in the first year, followed by annual growth increments of around 15, 10, and 5 cm. Growth of sexes is similar for the first two years, after which females tend to grow faster than males and reach a larger overall length. Sexual maturity ranges from 45 to 55 cm TL with a mean value of 52 cm TL for both sexes at an age of 2–3 years. *M* has been estimated to equal 0.76 for both sexes. In 1995, ageing of red cod was validated using marginal zone analysis.

In the 1989–90 to 1992–93 fishing years, 80% of the landings in RCO 3 were 2^+ and 3^+ fish (50–57 cm TL). The sex ratio of the commercial catch during this period was skewed towards females during November (F:M ratio of 3.4:1) with the ratio tending to even out by May. Schools generally comprise single age cohorts rather than a mix of age classes.

Spawning in red cod varies with latitude, with spawning occurring later at higher latitudes. In the Canterbury Bight, spawning occurs from August to October. No definite spawning grounds have been identified off the southeast coast, but there is some evidence that red cod spawn in deeper water (300–750 m). Running ripe fish were caught on the Puysegur Bank in 600 m during the Southland trawl survey in February 1994. Juvenile red cod are found in offshore waters after the spawning period; however, no nursery grounds are known for this species.

Red cod are seasonally abundant, with schools appearing in the Canterbury Bight and Banks Peninsula area around November. These schools are feeding aggregations and are not found in these waters after about June. Catch data indicate that they move into deeper water after this time. Recruitment is highly variable resulting in large variations in catches between years.

Biological parameters relevant to the stock assessment are shown in Table 5.

Table 5: Estimates of biological parameters for red cod.

Fishstock							Estimate	Source
1. Natural mortality (*M*)								
RCO 3							0.76	Beentjes (1992)
2. Weight = a(length)^b (Weight in g, length in cm fork length).								
		Females				Males		
		a	b			a	b	
RCO 3		0.0074	3.059			0.0145	2.892	Beentjes (1992)
RCO 3 combined sexes		0.009249	3.001					Beentjes (1992)
3. von Bertalanffy growth parameters								
		Females				Males		
	L_∞	k	t_0	L_∞	k	t_0		
RCO 3	76.5	0.41	-0.03	68.5	0.47	0.06		Horn (1995)
RCO 7	79.6	0.49	0.20	68.2	0.53	0.22		Beentjes (2000)

3. STOCKS AND AREAS

The number of red cod stocks is unknown. There is no information about stock structure, recruitment patterns, or other biological characteristics that would indicate stock boundaries.

4. STOCK ASSESSMENT

No recent stock assessments have been carried out on any red cod stocks. Previous assessments were undertaken, however, these are now outdated. Details appear in previous versions of the Plenary report.

Trawl survey biomass estimates are available from four Southland *Tangaroa* surveys, five summer and twelve winter east coast South Island (ECSI) *Kaharoa* surveys, and fourteen west coast South Island (WCSI) autumn *Kaharoa* surveys (Table 6, Figures 2–4).

4.1 Biomass estimates

East coast South Island inshore trawl survey

The ECSI winter surveys from 1991 to 1996 in 30–400 m were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range; but in 2001, the Inshore FAWG recommended that the summer ECSI trawl survey be discontinued because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007 and this time included additional 10–30 m strata in an attempt to index elephant fish and red gurnard which were officially included in the list of target species in 2012. Only the 2007, 2012, 2014, 2016, and 2018 surveys provide full coverage of the 10–30 m depth range. The winter surveys are currently conducted on a biennial cycle.

Red cod core strata biomass from 2007 to 2009 was stable, but was low relative to the period between 1991 and 1996 before a more than six-fold increase in 2012, followed by a decline of the same magnitude in 2014, with a biomass estimate similar to 2014 in 2016 (Table 6, Figure 2) (MacGibbon et al 2019). The biomass in 2018 has declined further and is the second lowest in the time series although the associated CV is high at 83%. The relatively high biomass in 1994 and the low biomass in 2007–09 are consistent with commercial landings in RCO 3, a fishery in which cyclical fluctuating catches are characteristic. The large biomass in 2012 consisted predominantly of 1+ year fish. The proportion of pre-recruit biomass in the core strata varied greatly among surveys, ranging from 7% to 59% and in 2018 it was 9%. The proportion of juvenile biomass (based on the length-at-50% maturity) also varied greatly among surveys from 27% to 80% and in 2018 it was 29% (Figure 4).

The additional red cod biomass captured in the 10–30 m depth range accounted for only 4%, 2%, 4%, and 5% of the biomass in the core plus shallow strata (10–400 m) for 2007, 2012, 2016, and 2018, respectively, but in 2014 it was 44% indicating the sporadic importance of shallow strata for red cod (Table 6, Figure 2) (Beentjes et al 2016). The addition of the 10–30 m depth range had little effect on the shape of the length frequency distributions in 2007, 2012, 2016, and 2018, but in 2014 the largest fish (over 60 cm) were in 10–30 m.

The distribution of red cod hot spots within the ECSI survey area varies, but overall this species is consistently well represented over the entire survey area, most commonly from 30 m to about 300 m, but is also found in waters shallower than 30 m.

West coast South Island inshore trawl survey

Total biomass estimates were fairly stable for the first four WCSI surveys, varying from 2546 t to 3370 t. There was a sharp decline in 2000 to 414 t, but the biomass gradually increased subsequently to 2782 t in 2009. The biomass estimate of 666 t from the 2019 survey is the second lowest in the time series and is part of an overall declining trend since 2009 (Table 6, Figure 3).

Population numbers have declined dramatically from 2011 and the majority of the population is from the west coast strata with little coming from Tasman Bay and Golden Bay (MacGibbon 2019). The numbers of 0+ fish (under 25 cm) in the 2019 survey is the largest seen in the time series. The large numbers of 1+ fish (25–40 cm) seen in a number of years (e.g., 2005–2013) have been absent since 2015 which does not bode well for a recruitment-driven fishery.

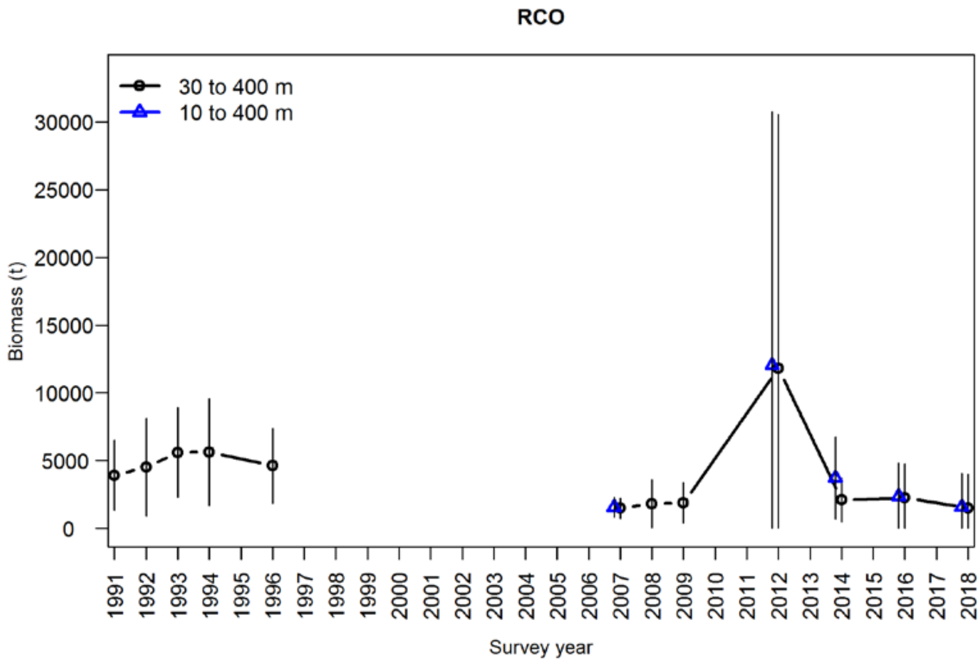


Figure 2: Red cod total biomass for east coast South Island winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m). Error bars are ± two standard deviations.

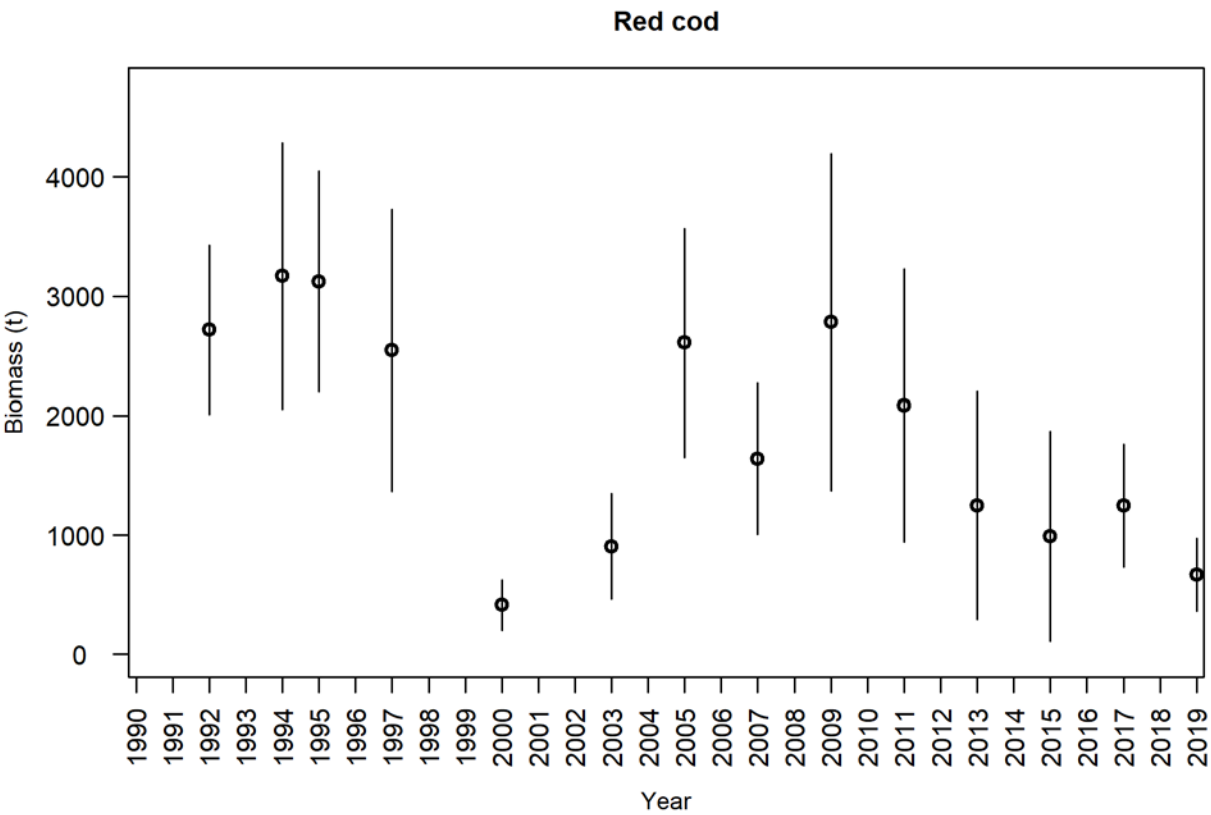


Figure 3: Biomass estimates from the west coast South Island inshore trawl survey. Error bars are ± two standard deviations.

Table 6: Relative biomass indices (t) and coefficients of variation (CV) for red cod for east coast South Island (ECSI) - summer and winter, west coast South Island (WCSI), and Southland survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16, and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (40 cm).

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)
					30–400m		10–400m		30–400m		30–400m
ECSI(winter)	RCO 3										
		1991	KAH9105	3 760	40	–	–	1 823	45	2 054	37
		1992	KAH9205	4 527	40	–	–	2 089	50	2 438	33
		1993	KAH9306	5 601	30	–	–	1 025	51	4 469	27
		1994	KAH9406	5 637	35	–	–	3 338	40	2 299	36
		1996	KAH9606	4 619	30	–	–	590	31	4 029	34
		2007	KAH0705	1 486	25	1 552	24	190	33	1 295	25
		2008	KAH0806	1824	49	–	–	129	36	1 695	50
		2009	KAH0905	1 871	40	–	–	833	50	1 038	41
		2012	KAH1207	11 821	79	12 032	78	7 015	97	4 806	55
		2014	KAH1402	2 096	39	3 714	41	1 038	58	1 057	23
		2016	KAH1605	2 268	54	2 360	52	597	40	1 670	61
		2018	KAH1803	1 500	83	1 584	78	137	60	1 363	86
ECSI(summer)	RCO 3										
		1996–97	KAH9618	10 634	23	–	–	4 101	23	–	–
		1997–98	KAH9704	7 536	23	–	–	4 426	24	–	–
		1998–99	KAH9809	12 823	17	–	–	3 770	15	–	–
		1999–00	KAH9917	6 690	30	–	–	2 728	41	–	–
		2000–01	KAH0014	1 402	82	–	–	1 283	89	–	–
ECNI	RCO 2										
		1993	KAH9304	913	52			197	31		
		1994	KAH9402	1 298	50			547	52		
		1995	KAH9502	469	36			47	34		
WCSI	RCO 7										
		1992	KAH9204	2 719	13	–	–			–	–
		1994	KAH9404	3 169	18	–	–			–	–
		1995	KAH9504	3 123	15	–	–			–	–
		1997	KAH9701	2 546	23	–	–			–	–
		2000	KAH0004	414	26						
		2003	KAH0304	906	24	–	–			–	–
		2005	KAH0503	2610	18	–	–		–	–	–
		2007	KAH0704	1638	19	–	–		–	–	–
		2009	KAH0904	2 782	25	–	–			–	–
		2011	KAH1104	2 055	28						
		2013	KAH1305	1 247	38	–	–				
		2015	KAH1503	988	45						
		2017	KAH1703	1 247	21						
		2019	KAH1902	666	23						
Southland	RCO 3										
		1993	TAN9301	100	68						
		1994	TAN9402	707	68						
		1995	TAN9502	2 554	49			182	66		
		1996	TAN9604	33 390	94			736	99		

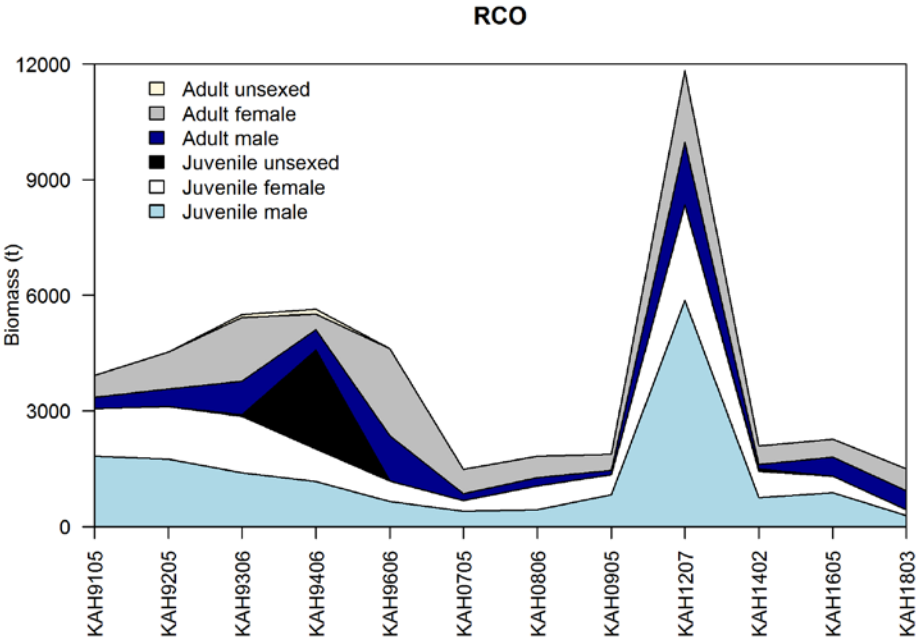


Figure 4: Red cod juvenile and adult biomass for ECSI winter surveys in core strata (30–400 m), where juvenile is below and adult is equal to or above length at which 50% of fish are mature.

4.2 Length frequency distributions

East coast South Island inshore trawl survey

The size distributions of red cod in each of the eleven core strata (30–400 m) ECSI surveys were similar and generally characterised by a 0+ mode (10–20 cm), 1+ mode (30–40 cm), and a less defined right hand tail comprised predominantly of 2+ and 3+ fish (Beentjes et al 2016). The 1996 to 2009 surveys showed poor recruitment of 1+ fish compared with earlier surveys, whereas the 1+ cohort was the largest of all eleven surveys in 2012 and only average in 2014 and 2016. Red cod on the ECSI, sampled during these surveys, were generally smaller than those from Southland, suggesting that this area may be an important nursery ground for juvenile red cod. The addition of the 10–30 m depth range had little effect on the shape of the length frequency distributions in 2007 and 2012, but in 2014 the largest fish were in 10–30 m (Beentjes et al 2016).

West coast South Island inshore trawl survey

The size distributions of red cod from the WCSI surveys are similar to that seen in the ECSI with a 0+ mode (10–20 cm), 1+ mode (25–40 cm), and a less defined right hand tail that comprised predominantly 2+ and 3+ fish. Red cod are often low in numbers or absent from Tasman Bay and Golden Bay strata but when present are typically 1+ fish (25–40 cm). Based on a lack of 0+ fish there appears to be low recruitment since 2000. Although biomass appeared fairly stable from 2005–09 the lack of recruitment appears to have made an impact after 2009 with a general decline in biomass. The 0+ cohort in 2019 appears to be the strongest seen in the time series and may help sustain the fishery in the short term.

RCO 2 and RCO 3 in-season management procedure

Management procedures (MP), used to inform in-season adjustments to the RCO 2 and RCO 3 commercial catch, were developed in 2013 by Bentley & Langley (2013). These MPs were based on a predictive relationship between annual standardised CPUE for RCO 2 (or RCO 3) with the total annual RCO 2 (or RCO 3) landings which effectively estimate an average exploitation rate in either QMA (Figures 5 and 6, left panels). A standardisation model is used to predict the annual CPUE for the active fishing year based on the accumulated data to the month preceding the evaluation month. The parameters from the predictive regression are then applied to the index based on incomplete data from the final year in the standardised model, resulting in a prediction of the full-season commercial catch. The partial year in-season estimate of standardised CPUE is used as a proxy for the final annual index, with the recommended catch defined by the slope of the regression line (Figures 5 and 6) multiplied by the CPUE proxy estimate. The 2013 MP rule stipulated that:

a) only years which were less than 90% of the full-season commercial catch allowance were used in developing the Figure 5 and Figure 6 regressions;
b) the regression would be forced to go through the origin (i.e., estimated without a constant);
c) only the positive catch data would be used in developing the standardised index.

Review of the RCO 2 and RCO 3 MPs

The RCO 2 and RCO 3 MPs were reviewed on a five-year cycle in 2018 (Starr & Kendrick 2019a). The basic structure of each MP was retained, with the predictive model based on the regression of total annual CPUE with the landings in the corresponding year. Total annual CPUE for the fishing year in progress was estimated from the partial year data accumulated to the end of a specified month. However, the components of the MP were individually evaluated with following changes made:

a) all years were included in the predictive regression (Figures 5 and 6), because no bias was detected among the residuals, even those where the catch exceeded 90% of the full-season commercial catch allowance;
b) the regression was estimated with a constant (Figures 5 and 6). This made little difference for the RCO 3 predictive regression (because the constant in that regression is not statistically significant) but the residuals in the RCO 2 regression were badly skewed when the regression was forced through the origin;
c) a binomial presence/absence standardised model was also fitted and then combined with the positive catch standardised model. This was done because the SINSWG has determined that such models are more likely to capture all components of the CPUE trends.

Figures 7 and 8 show the respective operation of the RCO 2 and RCO 3 MPs up to 2017–18 and predicting the 2018–19 fishing year. These rules have moderate predictive capability as was demonstrated by a retrospective analysis which showed that the absolute relative error for CPUE (=100*abs(prediction-annual)/annual) in the predictions averaged from 32% (December) to 16% (April) (months indicate the final month in the predictive year) for RCO 2 and 24% (December) to 13% (April) for RCO 3. The WG recommended that data be accumulated up to the end of January, if possible, because the drop in absolute relative error between those two months was sufficient to justify the delay (from 32% to 28% for RCO 2 and from 24% to 20% for RCO 3).

Operation of the RCO 2 and RCO 3 MPs

The 2013 MP for RCO 2 was operated six times from 2013 up to and including 2018 (Table 7). Even though the RCO 2 MP was reviewed in 2018, the operation of the MP preceded the review and thus used the earlier procedure. Only two of the six evaluations resulted in a recommendation for a commercial catch allowance increase in RCO 2 (Table 7), with the other years coming in near to or less than the current TACC of 500 t. The operation of the revised RCO 2 MP in 2019, using data accumulated up to the end of January, resulted in no increase in the commercial catch allowance (Table 7).

The 2013 MP for RCO 3 was operated six times from 2013 up to and including 2018 (Table 7). Even though the RCO 3 MP was reviewed in 2018, the operation of the MP preceded the review and thus used the earlier procedure. Four of the six evaluations resulted in a recommendation for a commercial catch allowance increase (Table 7), with the other two years coming in at less than the current TACC of 4600 t. The operation of the revised RCO 3 MP in 2019, using data accumulated up to the end of January, resulted in a recommendation for an increase of 712 t in the commercial catch allowance (which was declined by Industry) (Table 7).

Establishing B_{MSY} compatible reference points for RCO 2 and RCO 3

Given the large recruitment driven fluctuations in biomass observed for RCO, a target biomass is not meaningful. In-season adjustments are therefore based on relative fishing mortality, with increases made when this drops below the target value. F_{msy} proxies accepted for RCO 2 and RCO 3 are the relative fishing mortality values calculated by dividing the baseline TACCs by the corresponding CPUE values on the landings: CPUE regressions shown in Figures 5 and 6, respectively.

Table 7: Results of the operation of the RCO 2 and RCO 3 MP by prediction year. NA: not available.

Prediction year	Fishing year	CPUE prediction	CPUE total year[1]	Recommended commercial allowance	Approved commercial allowance[2]	Full-season catch (t)	Date of approval[2]	Reference
RCO 2								
2013*	2012–13	NA[3]	NA[3]	NA[3]	619	300	17 May 2013	–[3]
2014	2013–14	NA[3]	NA[3]	NA[3]	500	167	–	–[3]
2015	2014–15	0.20	0.52	53	500	142	–	Bentley 2015
2016	2015–16	1.90	2.55	527	500	419	–	Bentley 2016a
2017*	2016–17	3.39	2.32	966	733	385	23 Aug 2017	Bentley 2017a
2018	2017–18	1.56	0.75	448	500	151	–	Starr&Bentley 2018a
2019	2018–19	0.75	NA	219	NA	NA	NA	Starr&Kendrick 2019b
RCO 3								
2013*	2012–13	NA[3]	NA[3]	NA[3]	4 944	5 294	15 May 2013	–[3]
2014*	2013–14	NA[3]	NA[3]	NA[3]	5 391	4 410	25 July 2014	–[3]
2015*	2014–15	1.19	0.81	6 289	4 600	2 171	not approved	Bentley 2015
2016	2015–16	0.48	0.71	2 405	4 600	3 837	–	Bentley 2016b
2017	2016–17	0.85	1.15	4 291	4 600	4 543	–	Bentley 2017b
2018[4]	2017–18	1.71	1.11	8 912	4 600	2 250	–	Starr&Bentley 2018b
2019[4]	2018–19	1.01	NA	5 312	NA	NA	NA	Starr&Kendrick 2019c

[1] calculated in the year following.
[2] information supplied by MPI.
[3] supporting documents are contradictory and inconsistent: requires further research.
[4] recommendation for increase declined by Industry.
* MP operation that resulted in a commercial catch allowance increase recommendation.

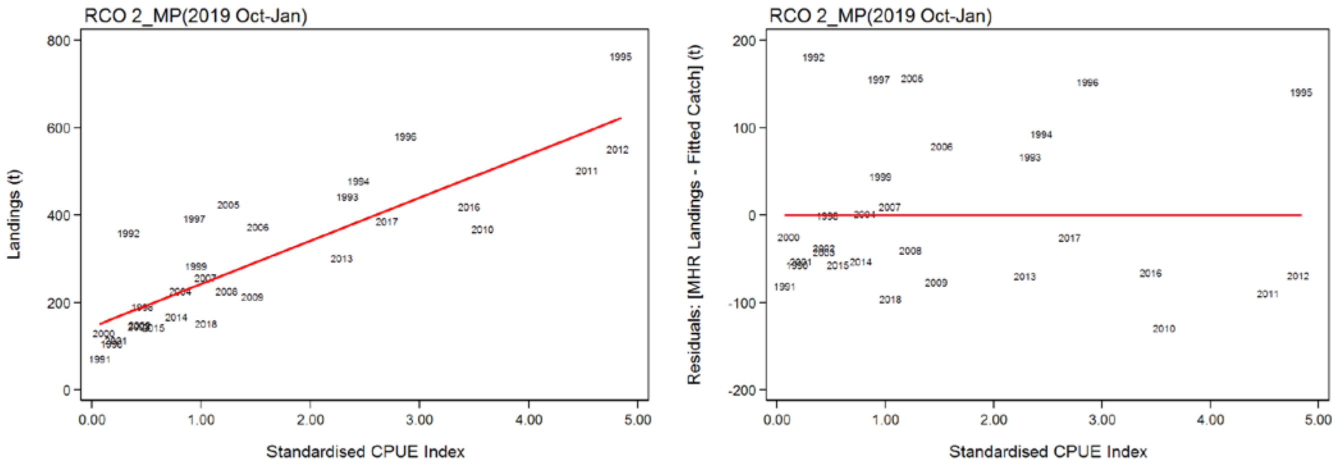


Figure 5: Relationship between annual RCO 2 CPUE and total annual RCO 2 QMR/MHR landings from 1989–90 to 2017–18; [left panel]: regression based on TACC and declared landings for all years; [right panel]: residuals from the left panel regression.

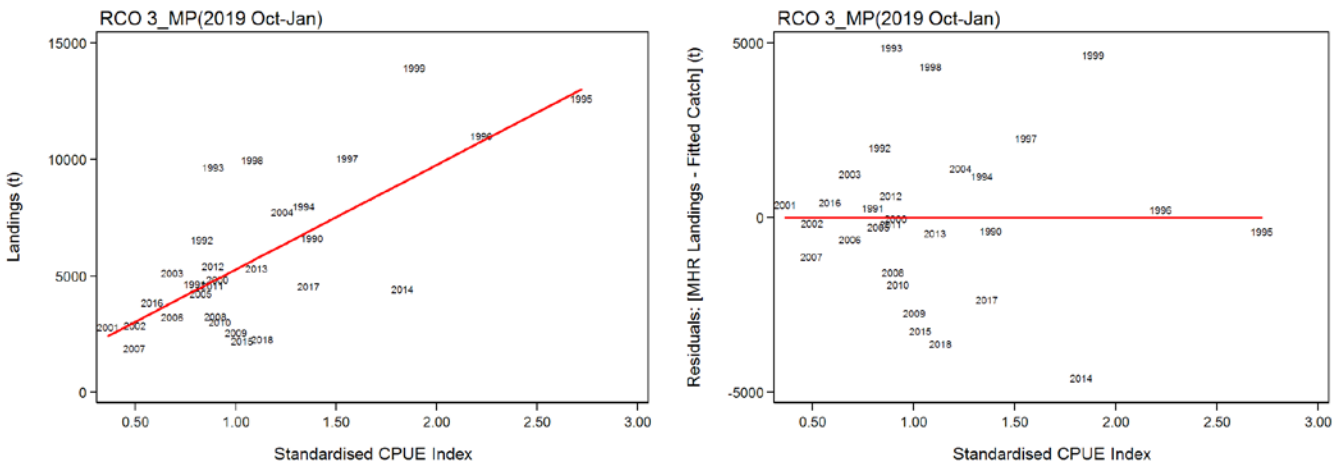


Figure 6: Relationship between annual RCO 3 CPUE and total annual RCO 3 QMR/MHR landings from 1989–90 to 2017–18; [left panel]: regression based on TACC and declared landings for all years; [right panel]: residuals from the left panel regression.

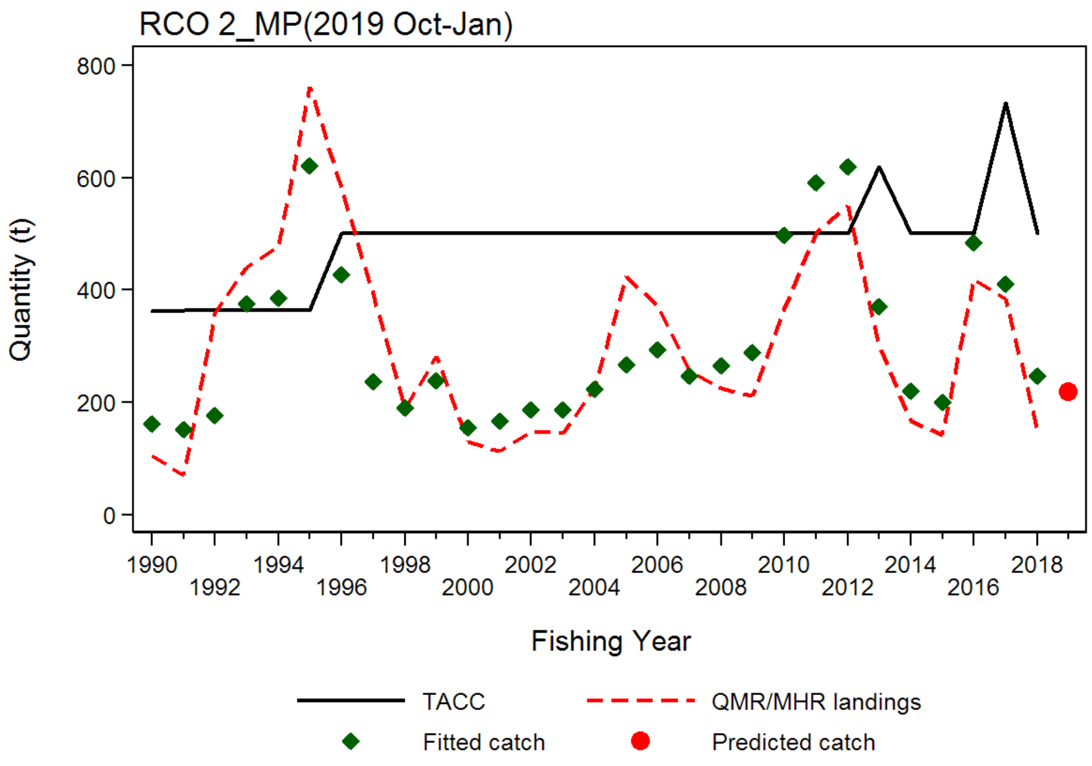


Figure 7: Operation of the 2019 MP for RCO 2, showing the relationship of the fitted catch estimates to the observed MHR/QMR landings and the annual recommended catches for all years to 2017–18 based on the estimated standardised CPUE up to the end of January. The TACC line includes approved additional ACE for the year, if present.

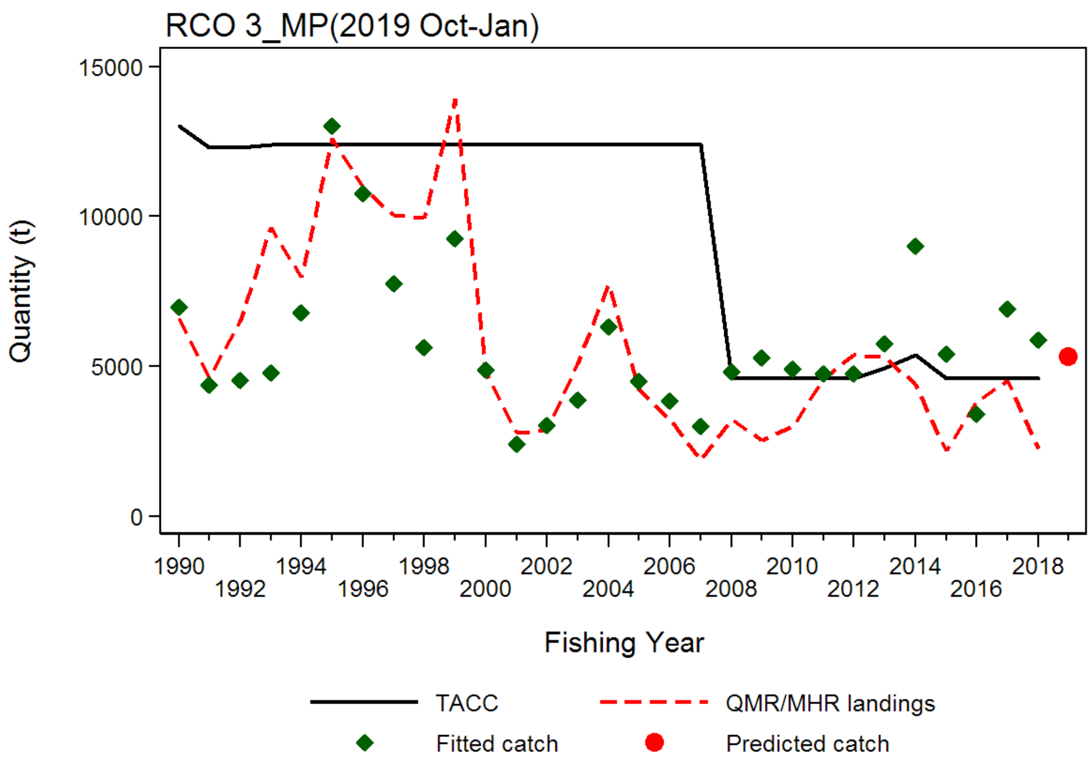


Figure 8: Operation of the 2019 MP for RCO 3, showing the relationship of the fitted catch estimates to the observed MHR/QMR landings and the annual recommended catches for all years to 2017–18 based on the estimated standardised CPUE up to the end of January. The TACC line includes approved additional ACE for the year, if present.

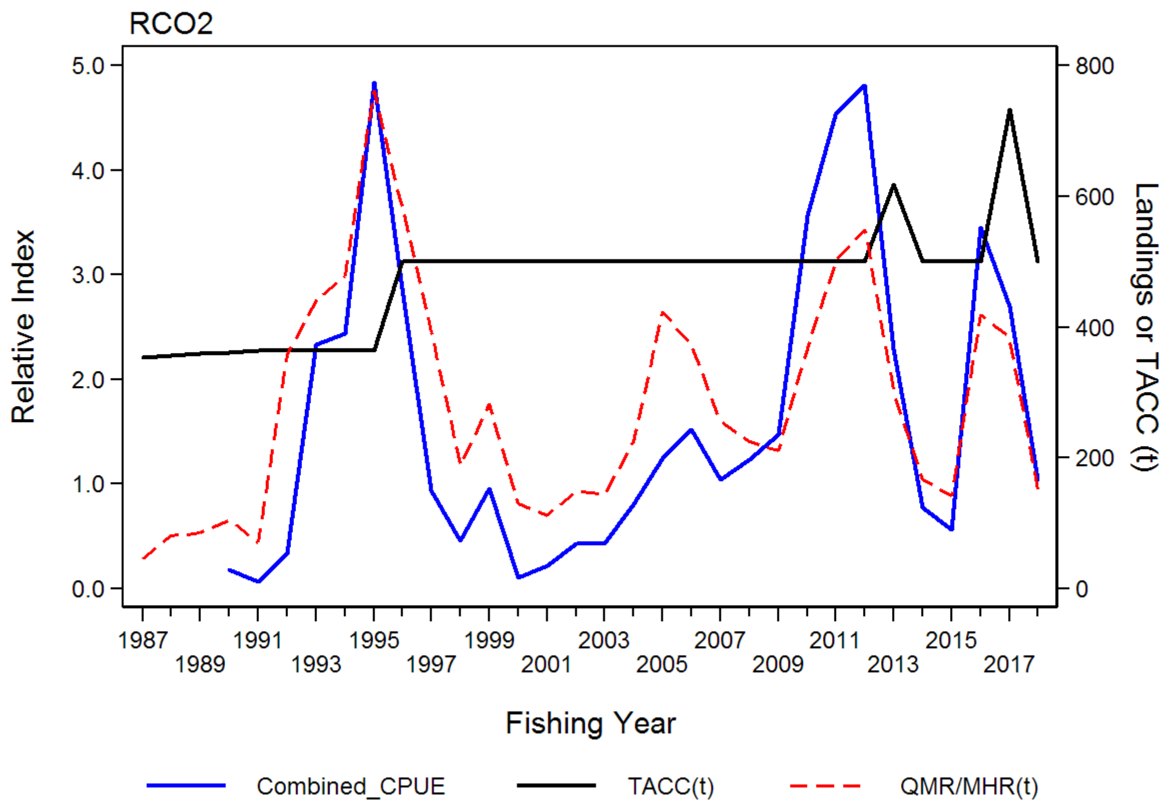
5. STATUS OF THE STOCKS

Yearly fluctuations in red cod catch reflect changes in recruitment. Trawl surveys and catch sampling of red cod have shown that the fishery is based almost exclusively on two and three year old fish and is highly dependent on recruitment success. RCO 2 and 3 are presently managed using in-season adjustments based on a decision rule and associated management procedure.

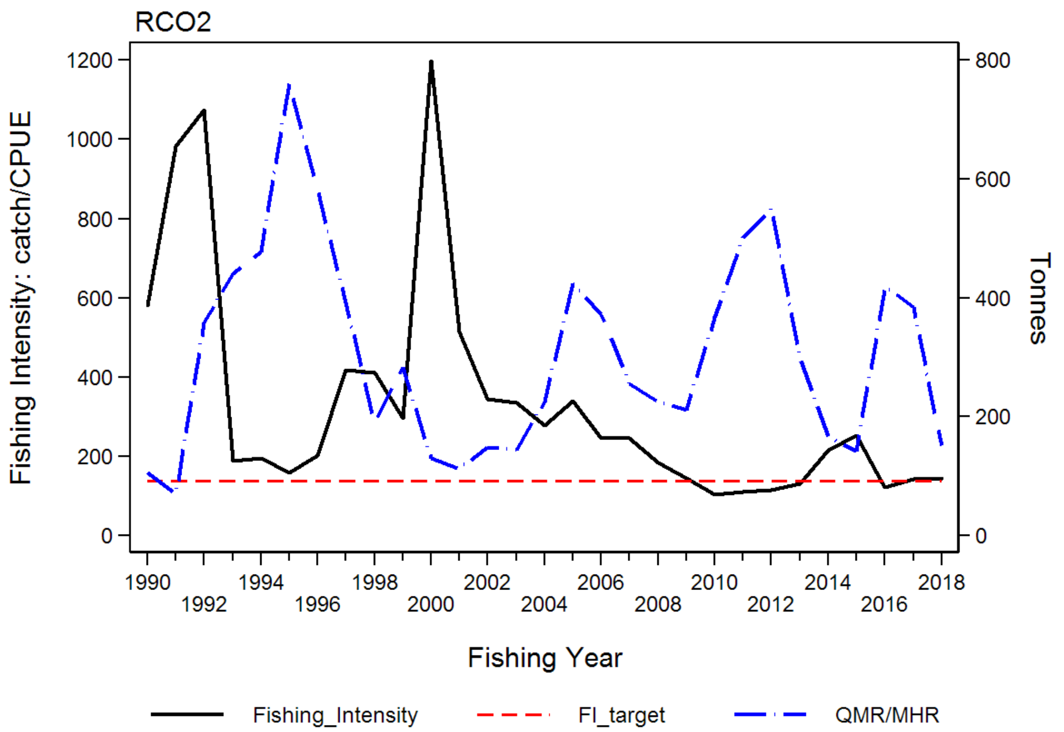
- **RCO 2**

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Standardised CPUE and relative exploitation rate
Reference Points	Target: F_{MSY} proxy Soft Limit: to be determined Hard Limit: to be determined Overfishing threshold: F_{MSY} proxy
Status in relation to Target	About as Likely as Not (40–60%) to be at or below the target
Status in relation to Limits	Soft limit: not determined Hard Limit: not determined
Status in relation to Overfishing	Overfishing is About as Likely as Not (40–60%) to be occurring

Historical Stock Status Trajectory and Current Status



Combined lognormal/binomial CPUE, TACC and total annual QMR/MHR landings for RCO 2. Fishing year designated by second year of the pair.



Fishing intensity (catch/CPUE) and a target fishing intensity calculated by dividing the base RCO 2 TACC by the CPUE associated with that base RCO 2 TACC from the catch/CPUE regression (left panel, Figure 5). Also plotted are the annual RCO 2 QMR/MHR landings.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Large variation in CPUE in the mid-1990s and after 2010, with no apparent trend
Recent Trend in Fishing Mortality or Proxy	Fishing intensity has fluctuated around the target since 2007–08.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	There are only two or three year classes in the fished population and the biomass is expected to fluctuate according to recruitment strength.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%) with the implementation of the in-season adjustment rule

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE series used to operate the RCO 2 in season MP	
Assessment Dates	Latest assessment: 2018	Next assessment: 2023
	MP: latest assessment: 2019	MP: next assessment 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Standardised CPUE series	1 – High Quality
Data not used (rank)	N/A	

Changes to Model Structure and Assumptions	-
Major Sources of Uncertainty	-

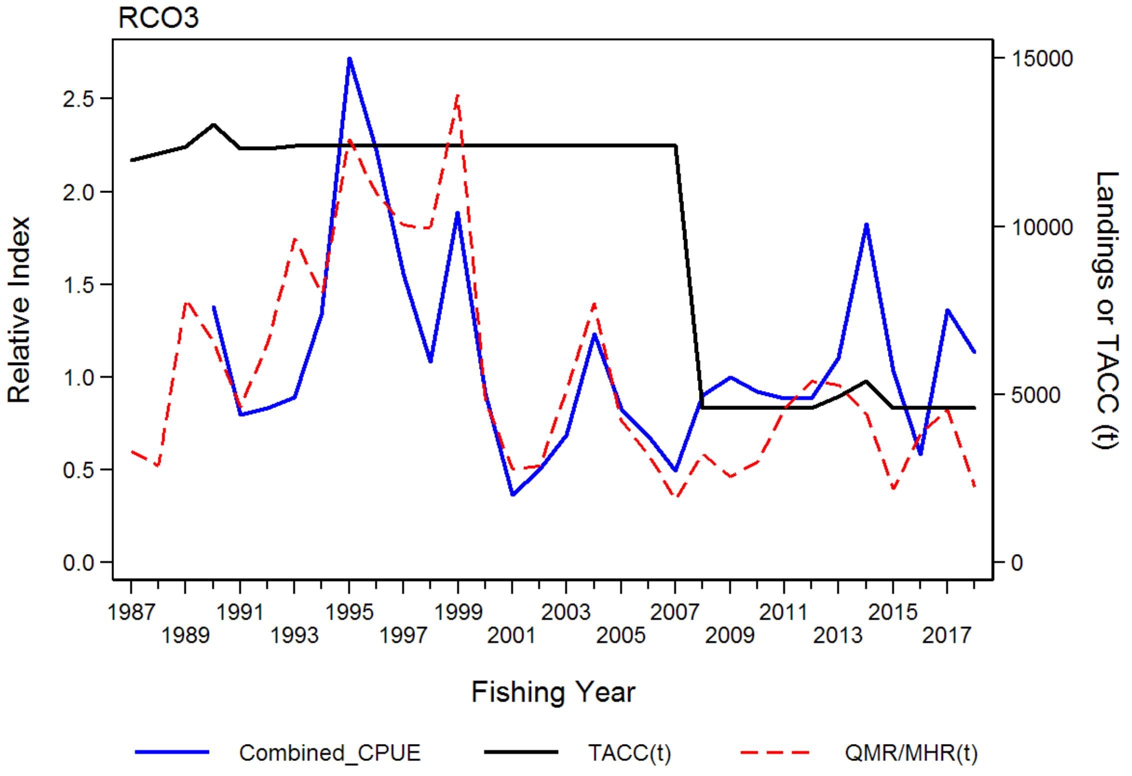
Qualifying Comments
-

Fishery Interactions
Red cod are landed as bycatch in barracouta, flatfish, squid and tarakihi bottom trawl fisheries and ling, school shark, spiny dogfish, rig, tarakihi and moki setnet fisheries. Incidental captures of seabirds occur.

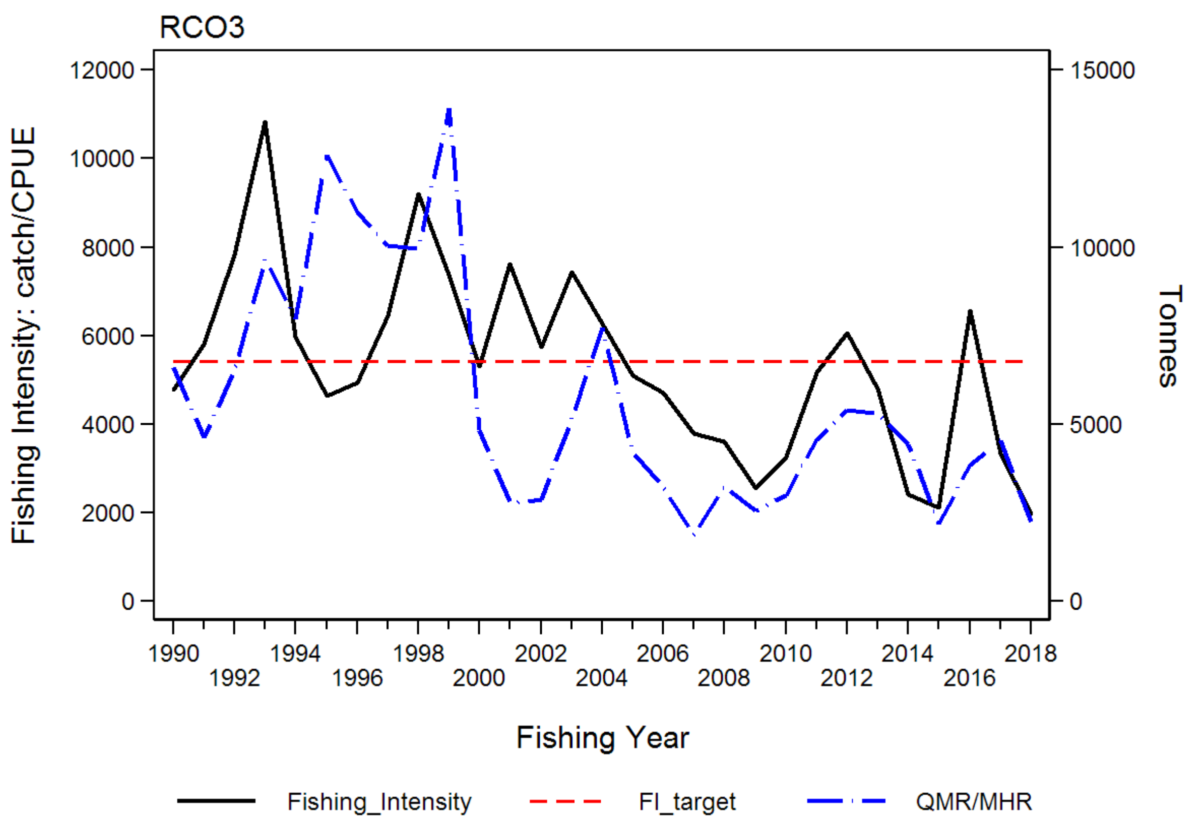
- **RCO 3**

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Standardised CPUE and relative exploitation rate
Reference Points	Target: F_{MSY} proxy Soft Limit: to be determined Hard Limit: to be determined Overfishing threshold: F_{MSY} proxy
Status in relation to Target	Fishing mortality is Likely (> 60%) to be at or below the target
Status in relation to Limits	Soft limit: Not determined Hard Limit: Not determined
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status



Combined lognormal/binomial CPUE, TACC and total annual QMR/MHR landings for RCO 3. Fishing year designated by second year of the pair.



Fishing intensity (catch/CPUE) and a target fishing intensity calculated by dividing the base RCO 3 TACC by the CPUE associated with that base RCO 3 TACC from the catch/CPUE regression (left panel, Figure 6). Also plotted are the annual RCO 3 QMR/MHR landings.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Recent catch and survey biomass are much below the equivalent values from the early to mid-1990s.
Recent Trend in Fishing Mortality or Proxy	Although variable, fishing mortality has been relatively low since 2005, exceeding the target only twice during the period: 2004–05 to 2017–18.
Other Abundance Indices	- Biomass estimates from the ECSI trawl survey
Trends in Other Relevant Indicators or Variables	From 1991 to 1994 large recruitment pulses were seen in the survey catch. Recent surveys (from 2007) have not detected significant recruitment with the possible exception of the 2012 index which had a very high CV.

Projections and Prognosis	
Stock Projections or Prognosis	There are only two or three year classes in the fished population and the biomass is expected to fluctuate according to recruitment strength.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%) with the implementation of the in-season adjustment rule

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Accepted trawl survey biomass index	
Assessment Dates	Latest assessment: 2018	Next assessment: 2023
	MP: latest assessment: 2019	MP: next assessment 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	Standardised CPUE series	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
-

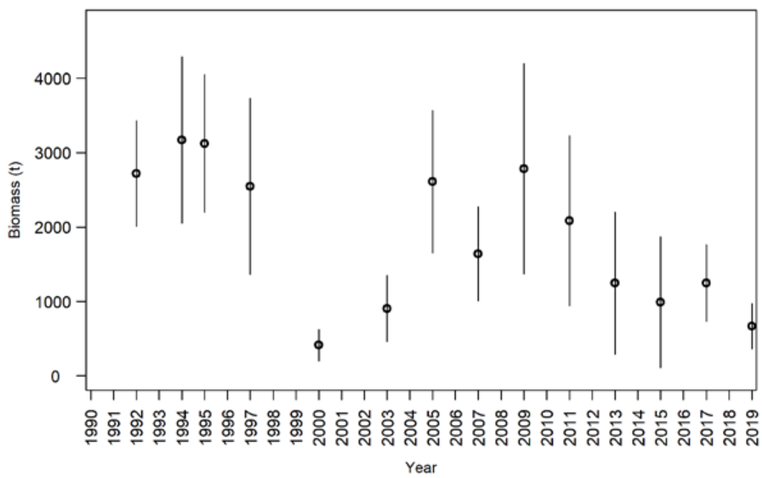
Fishery Interactions
Red cod are landed as bycatch in barracouta, flatfish, squid and tarakihi bottom trawl fisheries and ling, school shark, spiny dogfish, rig, tarakihi and moki setnet fisheries. Incidental captures of seabirds occur.

- **RCO 7**

Stock Structure Assumptions
Stock boundaries are unknown, but for the purpose of this summary RCO 7 is considered to be a single management unit.

Stock Status	
Year of Most Recent Assessment	2019 west coast South Island trawl survey
Reference Points	Target: *MSY*-compatible proxy based on the West Coast South Island trawl survey (to be determined) Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: Not defined
Status in relation to Target	Unknown
Status in relation to Limits	Soft limit: Unknown Hard Limit: Unlikely (< 40%) to be below
Status in relation to Overfishing	Unknown

Historical survey biomass, Catch and TACC Trajectories



Biomass estimates from the west coast South Island inshore trawl survey. Error bars are ± two standard deviations.

Fishery and Stock Trends	
Trend in Biomass or Proxy	The 2019 biomass estimate is the second lowest estimate in the time series. There is an overall declining trend since 2009.
Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	Continued low numbers of 1+ fish, fairly high numbers of 0+ fish (10–20 cm) in 2017.

Projections and Prognosis	
Stock Projections or Prognosis	The continued lack of 1+ fish in 2017 is of concern for a recruitment-driven fishery. Record numbers of 0+ fish seen in the 2019 survey may help sustain the fishery in the short term.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Evaluation of survey biomass trends and length frequencies.	
Assessment Date	Latest assessment: 2015	Next assessment: 2018
Overall assessment quality rank	1 – High Quality. The Southern Inshore Working Group agreed that the West Coast South Island survey was a credible measure of biomass.	
Main data inputs (rank)	West Coast South Island survey biomass length frequency	1 – High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
-

Fishery Interactions
Red cod are primarily taken in conjunction with the following QMS species: stargazer, red gurnard, tarakihi and various other species in the West Coast South Island target bottom trawl fishery. Smooth skates are caught as a bycatch in this fishery, and the biomass index for smooth skates in the west coast trawl survey has declined substantially since 1997. There may be similar concerns for rough skates but the evidence is less conclusive. Incidental captures of seabirds occur.

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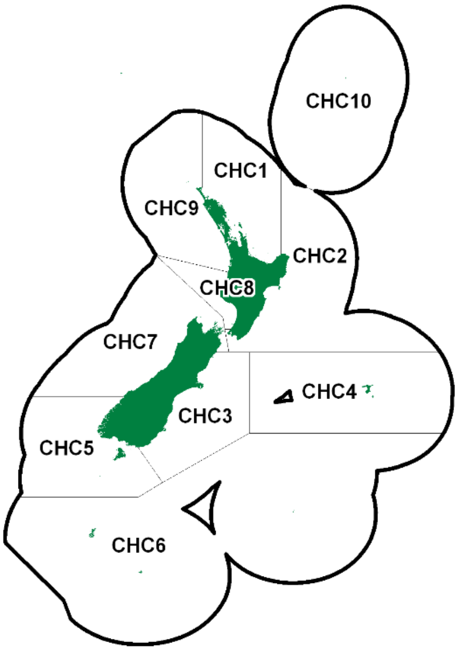
RED CRAB (CHC)

(*Chaceon bicolor*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

The red crab (*Chaceon bicolor*) was introduced into the Quota Management System on 1 April 2004 with a combined TAC and TACC of 48 t. There are no allowances for customary, recreational, or other sources of mortality.

The fishing year is from 1 April to 31 March and commercial catches are measured in greenweight. There were no reported commercial catches of this crab until 2001–02, when landings of about 1.3 t were reported. *C. bicolor*, along with several other deepwater crabs, was the focus of an exploratory fishing (potting) permit during 2000–02. Exploratory fisheries have found crabs in the Bay of Plenty, east of Great Barrier Island, and east of Northland. The other region fished has been the east coast of the North Island south of East Cape, where smaller catches were periodically reported.

CHC 1 landings peaked at 5.87 t and 5.53 t in 2007–08 and 2010–11, respectively. In 2013–14 CHC 1 landings of 1.05 t were recorded. Landings ceased in 2014–15 to 2017–18 and were very low in 2018–19. CHC 2 landings have ranged from nil to 0.42 t annually since the beginning of the fishery in 2001–02. There has been nil or negligible catch from the CHC 3–10 stocks, so only landings for CHC 1 and CHC 2 over time are reported in Table 1. Figure 1 shows the historical landings and TACC for CHC 1.

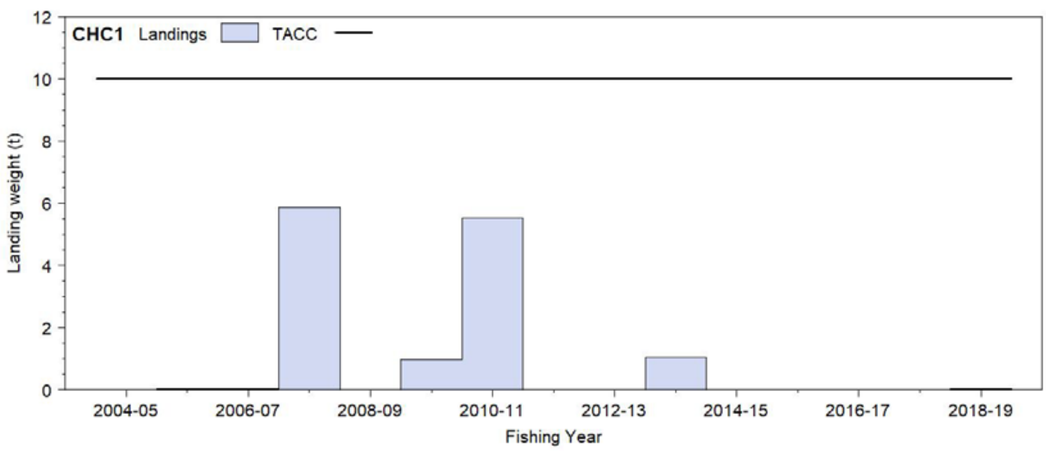


Figure 1: Reported commercial landings and TACC for CHC 1 (Auckland East) from 2004–05 to present.

There are two species of *Chaceon* known from New Zealand waters. *C. yaldwyni* is almost indistinguishable from *C. bicolor*, but is a very rarely caught species from the eastern Chatham Rise (fewer than five specimens have ever been caught).

Table 1: TACCs and reported landings (t) of red crab for CHC 1 and CHC 2 from 2001–02 to present from CELR and CLR data. There has been nil or negligible catch from the CHC3–10 stocks, so these are not tabulated; although CHC 3–9 have TACCs of 4 t.

Fishstock	CHC 1		CHC 2		Total	
	Landings	TACC	Landings	TACC	Landings	
2001–02	1.13	–	0.07	–	1.27	–
2002–03	0.60	–	0	–	0.60	–
2003–04	0	–	0.01	–	0.01	–
2004–05	0	10	0.22	10	0.22	48
2005–06	0.02	10	0	10	0.02	48
2006–07	0.02	10	0	10	0.02	48
2007–08	5.87	10	0.08	10	5.95	48
2008–09	0	10	0.07	10	0.07	48
2009–10	0.99	10	0.07	10	1.06	48
2010–11	5.53	10	0.42	10	5.97	48
2011–12	0	10	0.01	10	0.04	48
2012–13	0	10	0.01	10	0.01	48
2013–14	1.05	10	0.06	10	1.14	48
2014–15	0	10	0.11	10	0.11	48
2015–16	0	10	0.06	10	0.06	48
2016–17	0	10	0.06	10	0.06	48
2017–18	0	10	0	10	0.01	48
2018–19	<1	10	<1	10	0.04	48

*In 2001–02 77.5 kg were reportedly landed, but the FMA was not recorded. This amount is included in the total landings for that year.

1.2 Recreational fisheries
There are no known records of recreational use of this crab.

1.3 Customary non-commercial fisheries
There are no known records of customary use of this crab.

1.4 Illegal catch
There is no known illegal catch of this crab.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality, although very small quantities of this crab is sometimes taken as a bycatch of fisheries such as orange roughy.

2. BIOLOGY

C. bicolor is a very large, purple and tan to yellowy tan coloured crab that reaches at least 192 mm carapace width. It is found on and north of the Chatham Rise, and particularly along the east coast north of Hawke Bay to North Cape. It has been found on both hard and soft substrates, but is considered to be a burrowing crab, living in soft sediments. It has been recorded from depths between 800 m and 1100 m around New Zealand, and between 275 m and 1620 m elsewhere in the Pacific.

C. bicolor was previously referred to as *C.* (sometimes *Geryon*) *quinquedens* and belongs to the family Geryonidae which has an almost worldwide distribution. There is no information on its reproduction, age, growth, or natural mortality in New Zealand waters, which may or may not be similar to the same or similar *Chaceon* species elsewhere.

Geryonid crabs such as *C. bicolor* tend to show partial sex segregation, females being in shallower water than males. Small crabs are usually found in deeper water than the adults, as a result of juvenile settlement in deep water. There can be both seasonal and ontogenetic movements between depth zones. Females carry a single clutch of eggs during the winter, which hatch the following summer. Clutch size increases with female size, and egg numbers are of the order of 100 000 to 400 000. The eggs are small (0.5–0.6 mm diameter), suggesting a relatively long larval life, probably resulting in widespread dispersal. Off Western Australia, however, *C. bicolor* females may be ovigerous at any time of the year.

One study off Western Australia found that the lengths at 50% maturity were 90.5 mm and 94 mm carapace length for females and males respectively.

Pot catches usually yield a very biased sex ratio favouring males, which may be due to the fact that ovigerous females remain buried in the substrate during incubation.

3. STOCKS AND AREAS

For management purposes, stock boundaries are based on FMAs. There is currently no biological or fishery information that could be used to identify biological stock boundaries.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any red crab fishstock.

4.2 Biomass estimates

There are no biomass estimates for any red crab fishstock.

4.3 Yield estimates and projections

There are no estimates of *MCY* for any red crab fishstock.

There are no estimates of *CAY* for any red crab fishstock.

5. STATUS OF THE STOCKS

There are no estimates of reference or current biomass for any red crab fishstock.

6. FOR FURTHER INFORMATION

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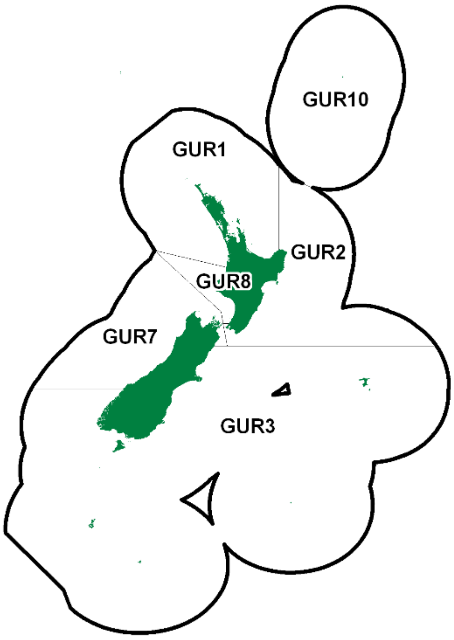
RED GURNARD (GUR)

(*Chelidonichthys kumu*)
Kumukumu



1. FISHERY SUMMARY

1.1 Commercial fisheries

Red gurnard are a major bycatch of inshore trawl fisheries in most areas of New Zealand, including fisheries for red cod in the southern regions and flatfish off the west coast of the South Island (WCSI) and in Tasman Bay. They are also directly targeted in some areas e.g., GUR 2. Some minor target fisheries for red gurnard are known in Pegasus Bay, off Mahia, and off the west coast South Island. Red gurnard is also a minor bycatch in the jack mackerel trawl fishery in the South Taranaki Bight. Up to 15% of the total red gurnard catch is taken by bottom longline and set net.

Red gurnard was introduced into the Quota Management System (QMS) in 1986. The 1986 TACCs were based on 1984 landings for Southland and 1983 landings for other regions. TACCs for all red gurnard Fishstocks were gradually increased from 1986 to 1990, with the total TACC increasing from 4230 t to 4762 t. TACCs for GUR 1, GUR 2, and GUR 8 have remained unchanged since. The TACCs for GUR 3 and 7 were further increased by 76 t (14%) and 137 t (20%) respectively for the 1991–92 fishing year under the Adaptive Management Programme (AMP), to 600 t in GUR 3 and to 815 t in GUR 7. The GUR 7 TACC was reduced to 678 t, in 1997–98. All AMP programmes ended on 30 September 2009. For the 2009–10 fishing season, the TACC in GUR 7 was increased to 715 t, including an allocation of 10 t for customary, 20 t for recreational use, and 14 t allocation for other sources of mortality. The GUR 7 TACC was further increased to 785 t in October 2012, 845 t in October 2015, 975 t in October 2017, and to 1073 t in October 2019 along with increased allowances. The TACC for GUR 3 was increased by 300 t (50%) to 900 t for the 1996–97 fishing year under the AMP, but was decreased to 800 t in 2002–03. For the 2009–10 fishing season, the TACC for GUR 3 was increased from 800 t to 900 t, with allocations of 3 t, 5 t, and 45 t for customary, recreational, and other sources of mortality respectively. The GUR 3 TACC was increased to 1100 t in October 2012, 1220 t in October 2015, and to 1320 t in October 2018. This TACC is given in Table 1 along with all current allowances, TACCs, and TACs.

Reported landings since 1931 are shown in Tables 2 and 3, and a historical record of landings and TACC values for the five main GUR stocks is depicted in Figure 1.

RED GURNARD (GUR)

Table 1: Current TACs, TACCs, and allowances (t) for red gurnard by Fishstock as of October 2019.

Fishstock	TAC	TACC	Customary allowance	Recreational allowance	Other mortality
GUR 1		2 288			
GUR 2		725			
GUR 3	1 593	1 320	3	6	264
GUR 7	1 176	1 073	15	38	50
GUR 8		543			
GUR 10		10			

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	GUR 1	GUR 2	GUR 3	GUR 7	Year	GUR 1	GUR 2	GUR 3	GUR 7
1931–32	67	0	1	16	1957	494	402	737	409
1932–33	42	0	0	13	1958	430	394	745	400
1933–34	67	84	1	20	1959	460	320	806	212
1934–35	50	179	0	2	1960	489	417	1 008	421
1935–36	75	147	18	2	1961	559	419	1 180	419
1936–37	114	215	37	25	1962	505	592	1 244	322
1937–38	205	193	83	21	1963	576	562	1 364	367
1938–39	109	118	151	31	1964	977	814	1 708	397
1939–40	121	149	147	25	1965	1 020	668	1 459	400
1940–41	124	222	215	38	1966	1 157	754	1 178	436
1941–42	107	200	267	38	1967	1 051	836	745	522
1942–43	124	332	287	58	1968	1 137	583	510	368
1943–44	128	244	294	53	1969	1 345	632	487	256
1944	238	292	291	60	1970	1 493	823	841	381
1945	360	338	222	94	1971	1 225	570	940	379
1946	426	387	290	119	1972	770	347	662	333
1947	376	297	243	162	1973	1 278	406	1 393	491
1948	385	243	267	226	1974	881	299	1 083	586
1949	371	264	316	323	1975	691	199	655	365
1950	306	186	486	332	1976	1 055	217	960	545
1951	221	231	750	202	1977	1 288	381	975	579
1952	394	378	658	211	1978	1 571	519	1 106	487
1953	490	494	614	334	1979	1 936	382	690	349
1954	496	462	660	382	1980	1 845	438	672	253
1955	495	283	652	490	1981	2 349	603	438	318
1956	434	312	782	435	1982	2 084	454	379	368

Year	GUR 8	Year	GUR 8
1931–32	0	1957	46
1932–33	0	1958	51
1933–34	0	1959	44
1934–35	0	1960	27
1935–36	0	1961	27
1936–37	1	1962	14
1937–38	0	1963	8
1938–39	2	1964	16
1939–40	1	1965	34
1940–41	1	1966	27
1941–42	0	1967	45
1942–43	0	1968	52
1943–44	0	1969	33
1944	0	1970	53
1945	3	1971	37
1946	4	1972	15
1947	10	1973	21
1948	9	1974	41
1949	13	1975	28
1950	13	1976	52
1951	10	1977	45
1952	5	1978	26
1953	3	1979	18
1954	7	1980	34
1955	25	1981	16
1956	29	1982	34

Notes:

1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.
3. 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 includes both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 3: Reported landings (t) of red gurnard by Fishstock from 1983–84 to the present and actual TACCs (t) from 1986–87 to the present. The QMS data are from 1986 to the present.

Fishstock	GUR 1		GUR 2		GUR 3		GUR 7	
QMA (s)	1 & 9		2		3, 4, 5 & 6		7	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	2 099	–	782	–	366	–	468	–
1984–85*	1 531	–	665	–	272	–	332	–
1985–86*	1 760	–	495	–	272	–	239	–
1986–87	1 021	2 010	592	610	210	480	421	610
1987–88	1 139	2 081	596	657	386	486	806	629
1988–89	1 039	2 198	536	698	528	489	479	669
1989–90	916	2 283	451	720	694	501	511	678
1990–91	1 123	2 284	490	723	661	524	442	678
1991–92	1 294	2 284	663	723	539	600	704	815
1992–93	1 629	2 284	618	725	484	601	761	815
1993–94	1 153	2 284	635	725	711	601	469	815
1994–95	1 054	2 287	559	725	685	601	455	815
1995–96	1 163	2 287	567	725	633	601	382	815
1996–97	1 055	2 287	503	725	641	900	378	815
1997–98	1 015	2 287	482	725	477	900	309	678
1998–99	927	2 287	469	725	395	900	323	678
1999–00	944	2 287	521	725	411	900	331	678
2000–01	1 294	2 287	623	725	569	900	571	678
2001–02	1 109	2 287	619	725	717	900	686	681
2002–03	1 256	2 287	552	725	888	800	793	681
2003–04	1 225	2 287	512	725	725	800	717	681
2004–05	1 354	2 287	708	725	854	800	688	681
2005–06	1 113	2 287	542	725	957	800	604	681
2006–07	1 180	2 287	575	725	1 004	800	714	681
2007–08	1 198	2 287	517	725	842	800	563	681
2008–09	1 060	2 287	621	725	939	800	595	681
2009–10	1 075	2 287	853	725	1 018	900	603	715
2010–11	1 046	2 288	587	725	929	900	545	715
2011–12	981	2 288	558	725	915	900	684	715
2012–13	1 103	2 288	603	725	1 168	1 100	763	785
2013–14	1 005	2 288	555	725	1 223	1 100	837	785
2014–15	1 020	2 288	695	725	1 150	1 100	852	785
2015–16	860	2 288	748	725	1 348	1 220	852	845
2016–17	856	2 288	669	725	1 279	1 220	905	845
2017–18	785	2 288	560	725	1 419	1 220	882	975
2018–19	710	2 288	587	725	1 467	1 320	998	975

Fishstock	GUR 8		GUR 10			
QMA (s)	8		10			Total
	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	251	–	0	–	3 966	–
1984–85*	247	–	0	–	3 047	–
1985–86*	163	–	0	–	2 929	–
1986–87	159	510	0	10	2 403	4 230
1987–88	194	518	0	10	3 121	4 381
1988–89	167	532	0	10	2 749	4 596
1989–90	173	538	0	10	2 745	4 730
1990–91	150	543	0	10	2 866	4 762
1991–92	189	543	0	10	3 390	4 975
1992–93	208	543	0	10	3 700	4 978
1993–94	174	543	0	10	3 142	4 978
1994–95	217	543	0	10	2 969	4 982
1995–96	182	543	0	10	2 927	4 982
1996–97	219	543	0	10	2 796	5 281
1997–98	249	543	0	10	2 532	5 143
1998–99	170	543	0	10	2 284	5 143
1999–00	222	543	0	10	2 429	5 143
2000–01	291	543	0	10	3 348	5 143
2001–02	302	543	0	10	3 429	5 143
2002–03	342	543	0	10	3 831	4 993
2003–04	329	543	0	10	3 508	4 993
2004–05	370	543	0	10	3 974	4 993
2005–06	373	543	0	10	3 589	4 993
2006–07	349	543	0	10	3 822	4 993
2007–08	223	543	0	10	3 344	4 993
2008–09	274	543	0	10	3 489	4 993
2009–10	239	543	0	10	3 789	5 181
2010–11	182	543	0	10	3 289	5 181
2011–12	213	543	0	10	3 351	5 181
2012–13	170	543	0	10	3 807	5 451
2013–14	151	543	0	10	3 769	5 451
2014–15	193	543	0	10	3 910	5 451
2015–16	145	543	0	10	3 953	5 631
2016–17	145	543	0	10	3 854	5 631
2017–18	209	543	0	10	3 855	5 761
2018–19	267	543	0	10	4 029	5 761

*FSU data.

RED GURNARD (GUR)

Annual landings of GUR 1 were relatively stable from 1986–87 to 2014–15, generally ranging between 920 t and 1300 t; substantially lower than the 2288 t TACC. In recent years catches have declined slightly, with 710 t landed in 2018–19. About 60% of the GUR 1 total is taken from FMA 1, as a bycatch of a number of fisheries including inshore trawl fisheries for snapper, John dory, and tarakihi. The remaining 40% is taken from FMA 9, mainly as a bycatch of the snapper and trevally inshore trawl fisheries.

GUR 2 landings have fluctuated within the range of 451–853 t since 1991–92, typically well below the TACC. In addition to the target fishery, red gurnard are taken as a bycatch of the tarakihi, trevally and snapper inshore trawl fisheries.

GUR 3 landings regularly exceeded the TACC between 1988–89 and 1995–96 and this stock has been consistently over-caught since 2004–05.

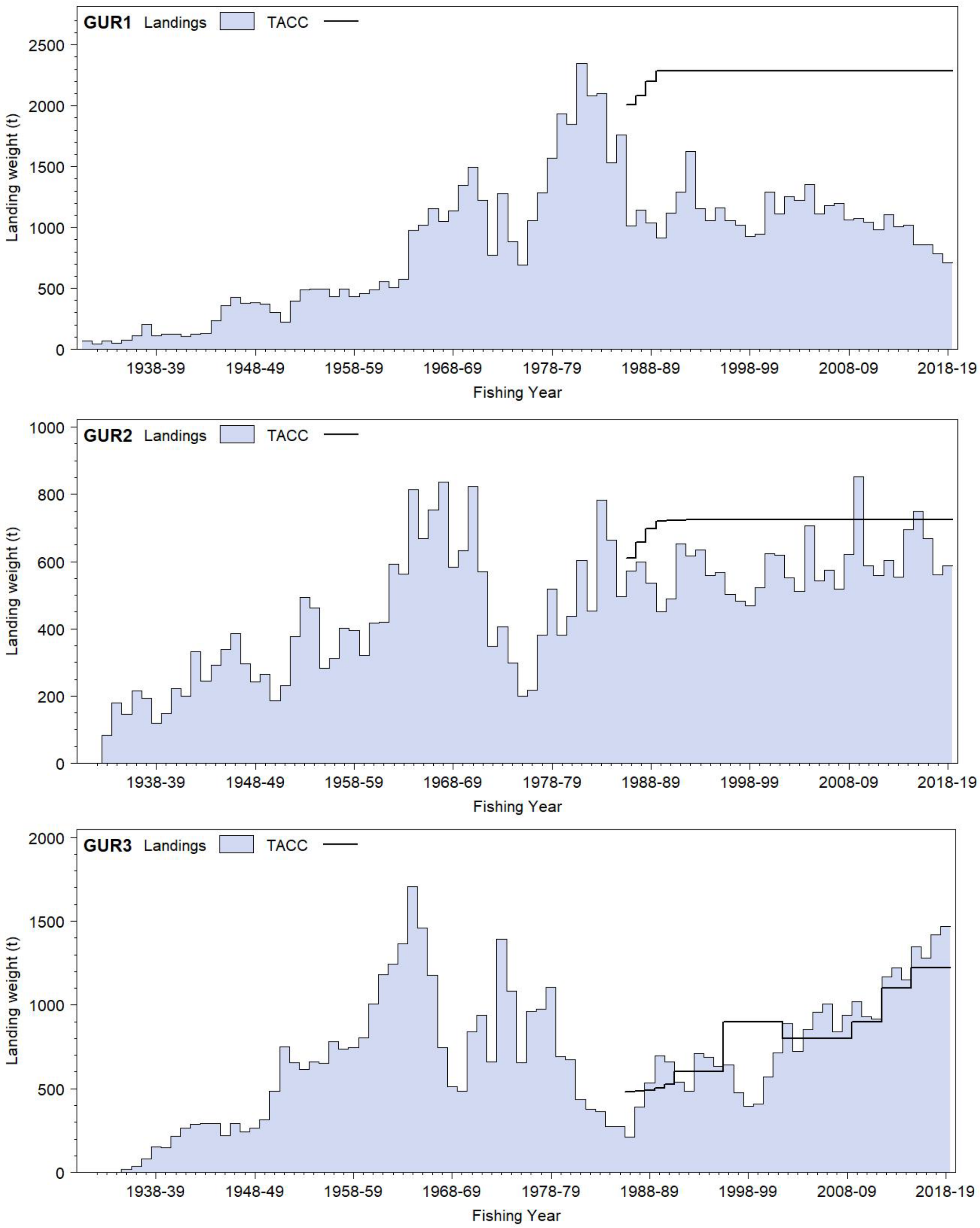
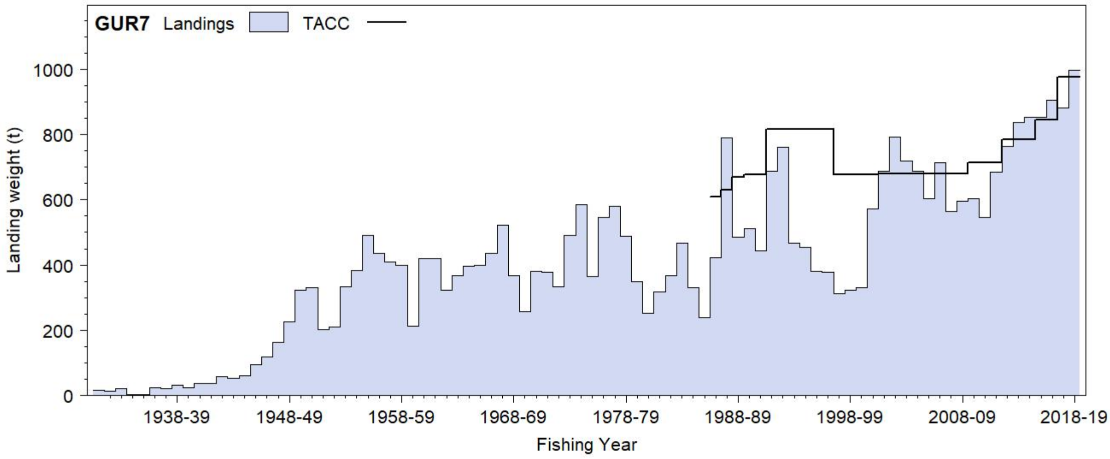


Figure 1: Reported commercial landings and TACCs for the five main GUR stocks. From top to bottom: GUR 1 (Auckland East), GUR 2 (Central East) and GUR 3 (South East Coast). [Continued on next page]



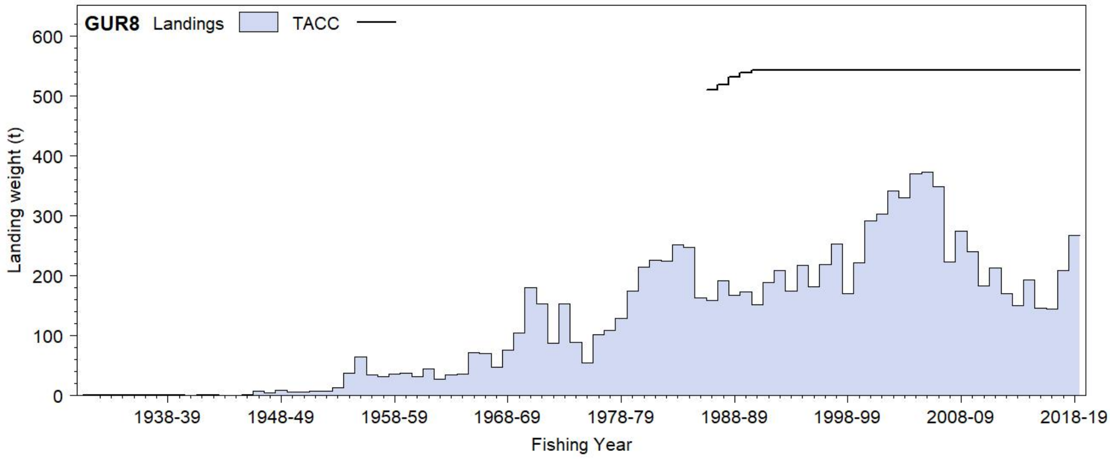


Figure 1 [Continued]: Reported commercial landings and TACCs for the five main GUR stocks. From top to bottom: GUR 7 (Challenger) and GUR 8 (Central Egmont).

GUR 7 landings declined steadily from 761 t in 1992–93, to 309 t in 1997–98, but then increased to 793 t by 2002–03. Landings then generally declined to 2010–11, before increasing to a peak of 998 t in 2018–19.

Landings in GUR 8 have remained well below the TACC since 1986–87, averaging 225 t.

1.2 Recreational fisheries

Red gurnard is, by virtue of its wide distribution in harbours and shallow coastal waters, an important recreational species. It is often taken by fishers targeting snapper and tarakihi, particularly around the North Island. The allowances within the TAC for each Fishstock are shown in Table 1, but have currently only been set for GUR 3 and GUR 7.

1.2.1 Management controls

The main methods used to manage recreational harvests of red gurnard are minimum legal size limits (MLS), method restrictions, and daily bag limits. Fishers can take up to 20 GUR as part of their combined daily bag limit and the MLS is 25 cm.

1.2.2 Estimates of recreational harvest

Recreational catch estimates are given in Table 4. 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.

RED GURNARD (GUR)

The first estimates of recreational harvest for red gurnard were calculated using an offsite approach: the offsite regional telephone and diary survey approach. 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).

The harvest estimates provided by these telephone diary surveys are no longer considered reliable for various reasons. With the early telephone/diary method, fishers were recruited to fill in diaries by way of a telephone survey that also estimates the proportion of the population that is eligible (likely to fish). A "soft refusal" bias in the eligibility proportion arises if interviewees who do not wish to co-operate falsely state that they never fish. The proportion of eligible fishers in the population (and, hence, the harvest) is thereby under-estimated. Pilot studies for the 2000 telephone/diary survey suggested that this effect could occur when recreational fishing was established as the subject of the interview at the outset. Another equally serious cause of bias in telephone/diary surveys was that diarists who did not immediately record their day's catch after a trip sometimes overstated their catch or the number of trips made. There is some indirect evidence that this may have occurred in all the telephone/diary surveys (Wright et al 2004).

Table 4: Recreational harvest estimates for red gurnard stocks. The telephone/diary surveys and earlier aerial-access surveys ran from December to November but are denoted by the January calendar year. The surveys since 2010 have run through the October to September fishing year but are denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey harvest estimates, Hartill & Davey 2015 and Davey et al 2019).

Stock	Year	Method	Number of fish	Total weight (t)	CV
GUR 1	1996	Telephone/diary	262 000	108	0.07
	2000	Telephone/diary	465000	223	0.16
FMA 1 only	2005	Aerial–access	–	127	0.14
FMA 1 only	2012	Aerial–access	–	24	0.09
FMA 1 only	2012	Panel survey	120 500	49	0.16
	2012	Panel survey	241 957	103	0.15
FMA 1 only	2018	Aerial–access	–	31	0.11
FMA 1 only	2018	Panel survey	85 000	36	0.14
	2018	Panel survey	168 798	86	0.15
GUR 2	1996	Telephone/diary	38 000	16	0.18
	2000	Telephone/diary	209 000	127	0.37
	2012	Panel survey	66 661	38	0.20
	2018	Panel survey	71 702	39	0.28
GUR 3	1996	Telephone/diary	1 000	–	–
	2000	Telephone/diary	11 000	5	0.70
	2012	Panel survey	4 605	2	0.62
	2018	Panel survey	3 486	2	0.39
GUR 7	1996	Telephone/diary	26 000	12	0.15
	2000	Telephone/diary	36 000	11	0.23
	2012	Panel survey	23 653	12	0.24
	2018	Panel survey	60 759	38	0.18
GUR 8	1996	Telephone/diary	67 000	28	0.15
	2000	Telephone/diary	99 000	40	0.36
	2012	Panel survey	93 656	47	0.23
	2018	Panel survey	55 314	31	0.19

The recreational harvest estimates provided by the 2000 and 2001 telephone diary surveys are thought to be implausibly high for many species, 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 and optimised to estimate snapper harvests in the Hauraki Gulf in 2003–04. It was then extended to survey the wider SNA 1 fishery in 2004–05 and to provide estimates for other species, including red gurnard (FMA 1 only for GUR). 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 development and implementation of a national panel survey for the 2011–12 fishing year (Wynne-Jones et al 2014) and repeated for the 2017–18 fishing year (Wynne-Jones et al 2019). The panel survey used face-to-face interviews of a random sample of New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information collected in standardised phone interviews.

1.3 Customary non-commercial fisheries

Red gurnard is an important species for customary non-commercial fishing interests, by virtue of its wide distribution in shallow coastal waters. However, no quantitative estimates of customary non-commercial catch are currently available.

1.4 Illegal catch

No quantitative information is available.

1.5 Other sources of mortality

No quantitative information is available**.**

2. BIOLOGY

Gurnard growth rate varies with location, and females grow faster and are usually larger at age than males. Maximum age (A_{MAX}) is about 16 years and maximum size is 55+ cm. Red gurnard reach sexual maturity at an age of 2–3 years and a fork length (FL) of about 23 cm, after which the growth rate slows. An analysis of the age and growth of red gurnard in FMA 7 revealed that young fish 1–4 years old tend to be most common in Tasman Bay and Golden Bay. Three to six year old fish are found on the inshore areas off the west coast South Island and the older fish are predominantly found further offshore (Lyon & Horn 2011).

Biological parameters relevant to the stock assessment are shown in Table 5.

Table 5: Estimates of biological parameters for red gurnard.

Fishstock						**Estimate**	**Source**
1. Natural mortality (M)							
				Female		Males	
GUR 1W & 1E				0.30		0.35	Stevenson (2000)
GUR 3				0.29		0.35	Sutton (1997)
GUR 7				0.31		0.31	Sutton (1997)
2. Weight = a(length)^b (Weight in g, length in cm fork length).							
				Both Sexes			
				a		b	
GUR 1				0.00998		2.99	Elder (1976)
GUR 1W & 1 E				0.026		2.775	Stevenson (2000)
GUR 2				0.0053		3.19	Stevenson (2000)
3. von Bertalanffy growth parameters							
	Females			Males			
	L_∞	k	t_0	L_∞	k	t_0	
GUR 1	36.4	0.641	0.189	28.8	0.569	-0.552	Elder (1976)
GUR 1W	45.3	0.25	-0.88	36.5	0.45	-0.30	Stevenson (2000)
GUR 1E	44.5	0.28	-0.76	35.2	0.49	-0.24	Stevenson (2000)
GUR 3	48.2	0.44	0.1	42.2	0.49	-0.26	Sutton (1997)
GUR 7	45.7	0.40	-0.36	40.3	0.37	-0.96	Sutton (1997)

M was estimated using the equation $M = \log_e 100$/maximum age, where maximum age is the age to which 1% of the population survives in an unexploited stock. Samples from the ECSI suggested an A_{MAX} of about 16 years for males and 13 years for females, giving estimates for M of 0.29 and 0.35 respectively. Samples from the WCSI indicate an A_{MAX} of about 15 years for both sexes, giving an estimate of 0.31 for M. These samples were not from virgin populations, so M may be overestimated.

Red gurnard have a long spawning period which extends through spring and summer with a peak in early summer. In the Hauraki Gulf, ripe adults can be found throughout the year. Spawning grounds appear to be widespread, although perhaps localised over the inner and central shelf. Egg and larval development takes place in surface waters, and there is a period of at least eight days before feeding starts. Small juveniles (under 15 cm FL) are often caught in shallow harbours, but rarely in commercial trawls.

3. STOCKS AND AREAS

There are no data that would alter the current stock boundaries. No information is available on stock separation of red gurnard. For GUR 3 the Working Group noted that spatial information from the CPUE analyses indicated that separate stocks or sub-stocks may exist between the east and south coasts of the South Island.

4. STOCK ASSESSMENT

4.1 Biomass estimates

Relative abundance indices have been obtained from trawl surveys of the Bay of Plenty, west coast North Island, and Hauraki Gulf within the GUR 1 Fishstock; west coast South Island and Tasman Bay/Golden Bay combined (GUR 7); and east coast South Island (GUR 3) (Table 6). The west coast South Island (WCSI) and east coast South Island (ECSI) surveys are the only ongoing surveys, currently conducted on a biennial basis.

ECSI

The ECSI winter surveys from 1991 to 1996 in 30–400 m were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range, but these were discontinued after the fifth in the annual time series because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007 and this time included additional 10–30 m strata in an attempt to index elephant fish and red gurnard which were officially included in the list of target species in 2012. Only the 2007, 2012, 2014, 2016, and 2018 surveys provide full coverage of the 10–30 m depth range.

In the 1990s, red gurnard biomass averaged 422 t in the core strata, increasing more than three-fold to 1453 t in 2007. From 2007 to 2014 biomass had an upward trend followed by a substantial decline in 2016 when biomass more than halved (Table 6, Figure 2). The biomass increased again in 2018 to 2043 t, the second highest estimate in the time series. Biomass for the four core plus shallow strata followed the same general trend as that for the core strata. The proportion of pre-recruit biomass in the core strata varied greatly among surveys, but was generally low, 2–20%, and in 2018 it was 15%. In some years the proportion of pre-recruit biomass in the core plus shallow strata was greater than that of the core strata alone, indicating that younger fish were more common in shallow water. The proportion of juvenile biomass (based on the length-at-50% maturity) within the core strata was close to zero for all surveys (MacGibbon et al 2019).

Table 6: Relative biomass indices (t) and coefficients of variation (CV) for red gurnard for research trawl survey areas around the North Island and South Island*. Biomass estimates for ECSI in 1991 were adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16, and 17). The sum of pre-recruit and recruited biomass values does not always match the total biomass for the earlier surveys because at several stations length frequency data were not collected, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (30 cm). [Continued on next page]

Region	Fishstock	Year	Trip number	Total biomass estimate	CV (%)	Total biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
Bay of Plenty	GUR 1	1983	KAH8303	380	23	–	–	–	–	–	–	–	–	–	–
		1985	KAH8506	57	17	–	–	–	–	–	–	–	–	–	–
		1987	KAH8711	410	28	–	–	–	–	–	–	–	–	–	–
		1990	KAH9004	432	12	–	–	–	–	–	–	–	–	–	–
		1992	KAH9202	290	9	–	–	–	–	–	–	–	–	–	–
		1996	KAH9601	332	14	–	–	–	–	–	–	–	–	–	–
		1999	KAH9902	364	14	–	–	–	–	–	–	–	–	–	–
North Island west coast	GUR 9	1986	KAH8612	1 763	16	–	–	–	–	–	–	–	–	–	–
		1987	KAH8715	2 022	24	–	–	–	–	–	–	–	–	–	–
		1989	KAH8918	1 013	12	–	–	–	–	–	–	–	–	–	–
		1991	KAH9111	1 846	23	–	–	–	–	–	–	–	–	–	–
		1994	KAH9410	2 498	30	–	–	–	–	–	–	–	–	–	–
		1996	KAH9615	1 820	14	–	–	–	–	–	–	–	–	–	–
North Island west coast	GUR 8	1989	KAH8918	628	15	–	–	–	–	–	–	–	–	–	–
		1991	KAH9111	817	9	–	–	–	–	–	–	–	–	–	–
		1994	KAH9410	685	22	–	–	–	–	–	–	–	–	–	–
		1996	KAH9615	370	37	–	–	–	–	–	–	–	–	–	–
		1999	KAH9915	2 099#	13	–	–	–	–	–	–	–	–	–	–
Hauraki Gulf	GUR 1	1984	KAH8421	595	15	–	–	–	–	–	–	–	–	–	–
		1985	KAH8517	49	44	–	–	–	–	–	–	–	–	–	–
		1986	KAH8613	426	36	–	–	–	–	–	–	–	–	–	–
		1987	KAH8716	255	15	–	–	–	–	–	–	–	–	–	–
		1988	KAH8810	749	19	–	–	–	–	–	–	–	–	–	–
		1989	KAH8917	105	29	–	–	–	–	–	–	–	–	–	–
		1990	KAH9016	141	16	–	–	–	–	–	–	–	–	–	–
		1992	KAH9212	330	9	–	–	–	–	–	–	–	–	–	–
		1993	KAH9311	177	17	–	–	–	–	–	–	–	–	–	–
		1994	KAH9411	247	19	–	–	–	–	–	–	–	–	–	–
		1997	KAH9720	242	14	–	–	–	–	–	–	–	–	–	–
		2000	KAH0012	24	46	–	–	–	–	–	–	–	–	–	–

*Assuming areal availability, vertical availability and vulnerability equal 1.0. Biomass is only estimated outside 10 m depth. Note: because trawl survey biomass estimates are indices, comparisons between different seasons (e.g., summer and winter ECSI) are not strictly valid.
FMAs 8 and 9 combined.

Table 6 [Continued]: Relative biomass indices (t) and coefficients of variation (CV) for red gurnard around the North Island and South Island*. Biomass estimates for ECSI in 1991 were adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16, and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (30 cm). Biomass estimates from current surveys with extreme catchability are denoted with a #.

Region	Fishstock	Year	Trip number	Total biomass estimate	CV (%)	Total biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
		1992	KAH9204	572	15	–	–	–	–	–	–	–	–	454.0	15.4
WCSI	GUR 7	1994	KAH9404	559	15	–	–	–	–	–	–	–	–	478.3	16.0
		1995	KAH9504	584	19	–	–	–	–	–	–	–	–	501.6	21.7
		1997	KAH9704	471	13	–	–	–	–	–	–	–	–	309.8	14.5
		2000	KAH0004	625	15	–	–	–	–	–	–	–	–	444.0	14.9
		2003	KAH0304	#270	20	–	–	–	–	–	–	–	–	253.7	20.9
		2005	KAH0503	442	17	–	–	–	–	–	–	–	–	374.7	16.2
		2007	KAH0704	553	17	–	–	–	–	–	–	–	–	431.6	17.9
		2009	KAH0904	651	18	–	–	–	–	–	–	–	–	400.4	19.1
		2011	KAH1104	1 070	17	–	–	–	–	–	–	–	–	798.6	18.6
		2013	KAH1305	754	12	–	–	–	–	–	–	–	–	546.5	13.4
		2015	KAH1503	1 774	16	–	–	–	–	–	–	–	–	1 335.2	18.6
		2017	KAH1703	1 708	12	–	–	–	–	–	–	–	–	1 352.0	12.0
		2019	KAH1902	1 642	16	–	–	–	–	–	–	–	–	1 079.0	16.0
North Island east coast	GUR 2	1993	KAH9304	439	44	–	–	–	–	–	–	–	–	–	–
		1994	KAH9402	871	16	–	–	–	–	–	–	–	–	–	–
		1995	KAH9502	178	26	–	–	–	–	–	–	–	–	–	–
		1996	KAH9602	708	29	–	–	–	–	–	–	–	–	–	–
ECSI (winter)	GUR 3			30–400 m		10–400 m		30–400 m		10–400 m		30–400 m		10–400 m	
		1991	KAH9105	763	33	–	–	NA	NA	–	–	NA	NA	–	–
		1992	KAH9205	142	30	–	–	21	58	–	–	121	30	–	–
		1993	KAH9306	576	31	–	–	26	45	–	–	551	31	–	–
		1994	KAH9406	123	34	–	–	2	42	–	–	121	34	–	–
		1996	KAH9606	505	27	–	–	8	44	–	–	496	26	–	–
		2007	KAH0705	1 453	35	2 048	27	298	40	494	32	1 155	35	1 554	27
		2008	KAH0806	1 309	34	–	–	100	59	–	–	1 210	33	–	–
		2009	KAH0905	1 725	30	–	–	62	34	–	–	1 663	30	–	–
		2012	KAH1207	1 680	28	3 515	17	193	40	742	31	1 487	27	2 773	16
		2014	KAH1402	2 063	25	3 215	17	409	45	585	32	1 654	23	2 630	16
		2016	KAH1605	941	30	2 420	15	63	41	306	19	877	30	2 114	15
		2018	KAH1803	2043	19	3 831	17	308	24	610	21	1735	20	3221	18
ECSI (summer)	GUR 3	1996–97	KAH9618	765	13	–		–	–	–	–	–	–	–	–
		1997–98	KAH9704	317	16	–		–	–		–	–	–	–	–
		1998–99	KAH9809	493	13	–	–	–	–	–	–	–	–	–	–
		1999–00	KAH9917	202	20	–	–	–	–	–	–	–	–	–	–
		2000–01	KAH0014	146	34	–	–	–	–	–	–	–	–	–	–

*Assuming areal availability, vertical availability and vulnerability equal 1.0. Biomass is only estimated outside 10 m. Note: because trawl survey biomass estimates are indices, comparisons between different seasons (e.g., summer and winter ECSI) are not strictly valid.

The additional red gurnard biomass captured in the 10–30 m depth range accounted for 29%, 52%, 36%, 61%, and 47% of the biomass in the core plus shallow strata (10–400 m) for 2007, 2012, 2014, 2016, and 2018 respectively, indicating the importance of shallow strata for red gurnard biomass. These observations indicate that the core strata survey (30–400 m) may not be shallow enough to provide an index for sub-mature gurnard.

The addition of the 10–30 m depth range had no significant effect on the length frequency distributions in 2007 and 2014, but in 2012 and 2016 there was a strong 1+ cohort in 10–30 m, which was poorly represented in the core strata (MacGibbon et al 2019). In 2018 the distributions in the 10–30 m and the core strata were similar. Based on the five surveys that included the 10–30 m strata, there are generally more pre-recruit fish in the shallow strata, suggesting that the core plus shallow strata (10 to 400 m) survey is probably indexing red gurnard abundance, including juveniles. The distribution of red gurnard hot spots varies, but overall this species is consistently well represented over the entire survey area from 10 m to 100 m, but is most abundant in the shallow 10 m to 30 m strata. They are almost absent deeper than 100 m.

WCSI

There has been a steady increase in red gurnard biomass since the mid-2000s and the last three points were the highest in the series (Figure 3). Sixty-six percent of the total biomass in 2017 was recruited fish (30 cm and over). A significant proportion of the biomass has always occurred in the Tasman Bay and Golden Bay region, although for the last four surveys a higher proportion was found off the west coast South Island. The trend in pre-recruit biomass for the entire survey area has largely followed that of the recruited (> 30 cm) fish; however, in 2019 recruited biomass dropped compared with 2017 and pre-recruited biomass increased (Figure 4).

Scaled length frequencies are similar between surveys. Larger numbers of smaller fish are found in Tasman Bay and Golden Bay which is thought to be a nursery area, and larger number of large fish are found off the west coast, although a wide size range occurs in both areas (see figure 5i from MacGibbon 2019).

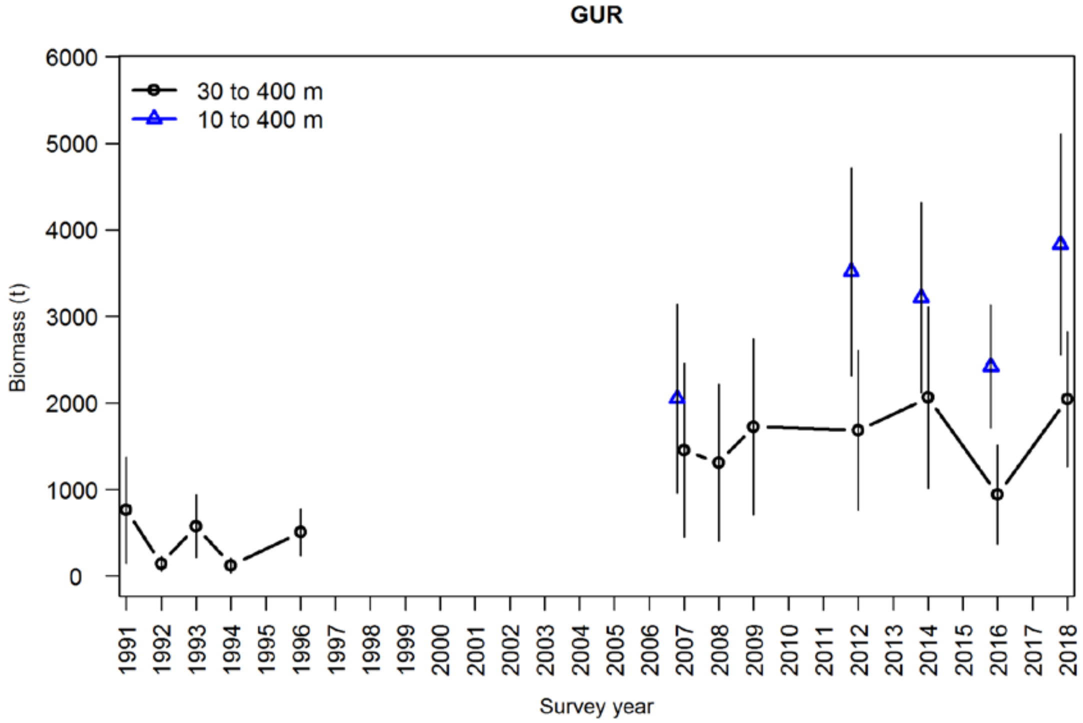


Figure 2: Red gurnard total biomass for all ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m) in 2007, 2012, 2014, 2016, and 2018. Error bars are ± two standard deviations.

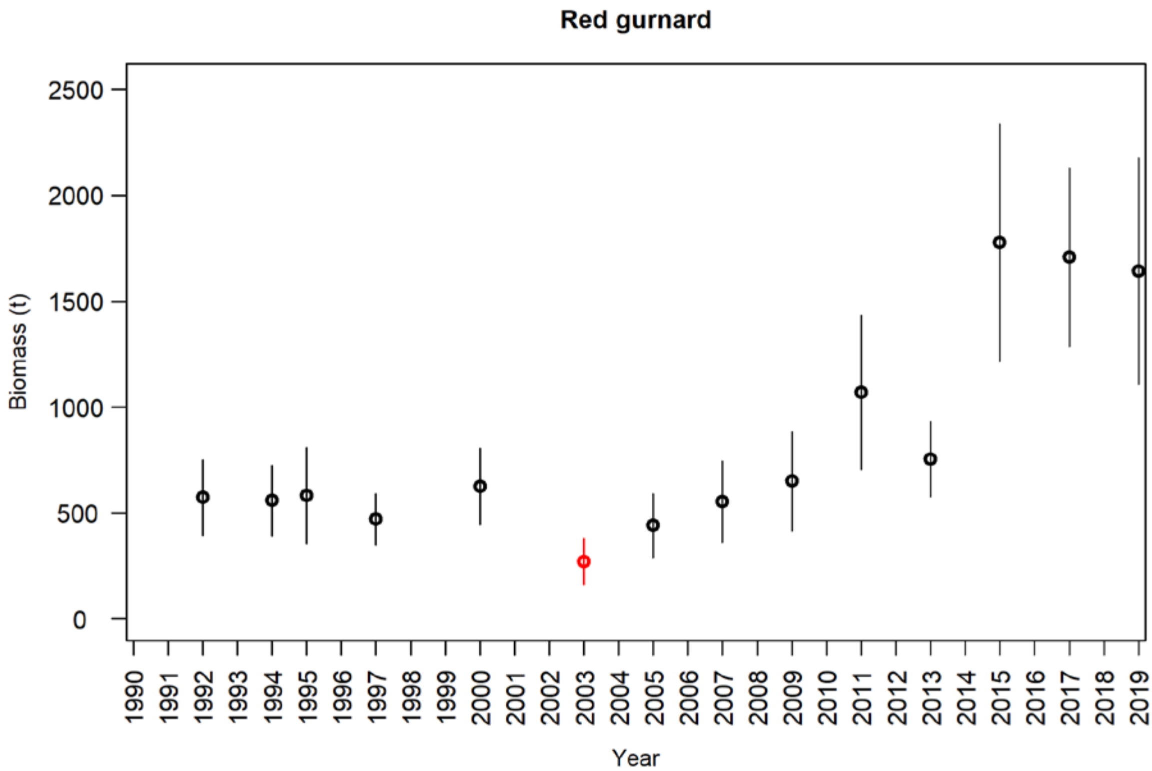


Figure 3: Red gurnard biomass trends from the West Coast South Island inshore trawl survey time series. Error bars are ± two standard deviations. The red symbol denotes biomass estimated from a survey conducted when catchability was extremely low.

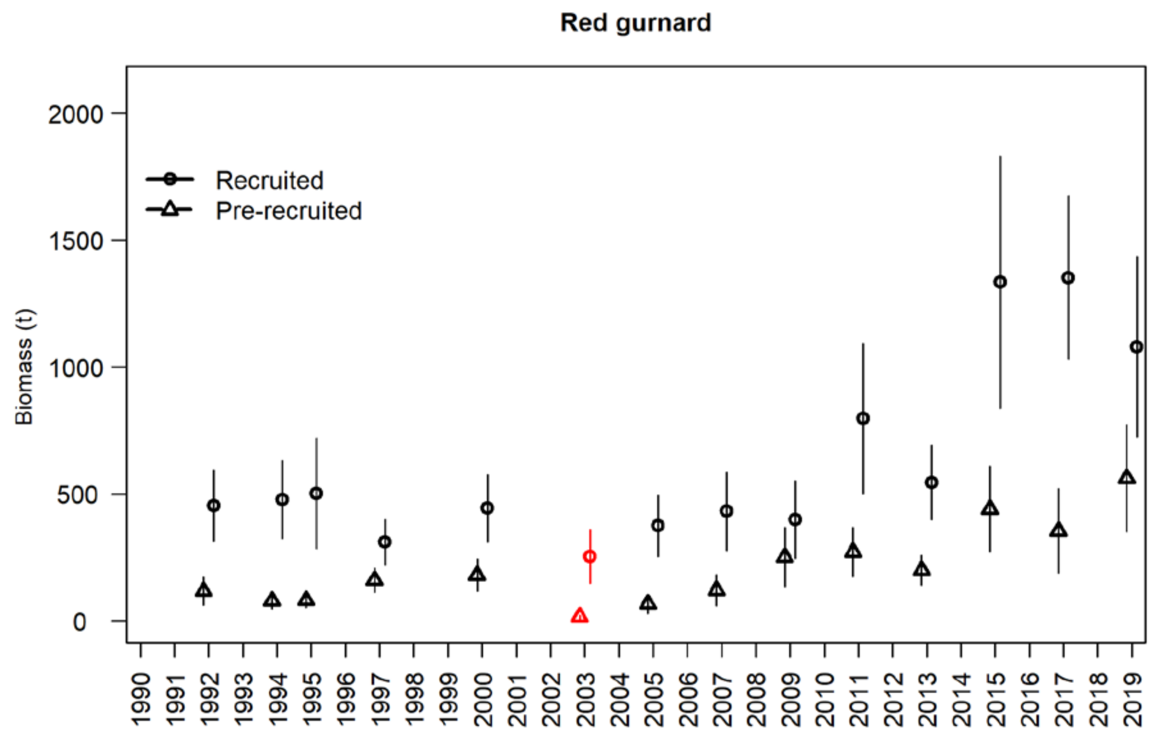


Figure 4: Red gurnard pre-recruit (< 30 cm) and recruited biomass trends from the West Coast South Island inshore trawl survey time series. Error bars are ± two standard deviations. The red symbols denote biomass estimated from a survey conducted when catchability was extremely low.

4.2 CPUE Analyses

GUR 1

In 2017, Kendrick & Bentley (in prep. a) updated CPUE analyses for GUR 1W (west coast, Figure 5), GUR 1E (east Northland and Hauraki Gulf, Figure 6), and GUR 1BP (Bay of Plenty, Figure 7).

The analyses were based on catch and effort data for individual tows reported on TCEPR and TCER forms because adequate time series are available in the northern inshore trawl fisheries from 1995–96. Based on catch and effort data from single bottom trawls targeting gurnard, snapper, trevally, tarakihi, or John dory, two GLM models were produced for each subarea: one based on the magnitude of positive catch (gamma error distribution), and the other a binomial model of the probability of capture (based on the proportion of tows capturing GUR). The two models were then combined to produce a single series for each sub-area, and the Working Group accepted the combined models as indices of abundance. The data used to generate the GLM models were restricted to core fleets of vessels having had at least three trips in each of three years.

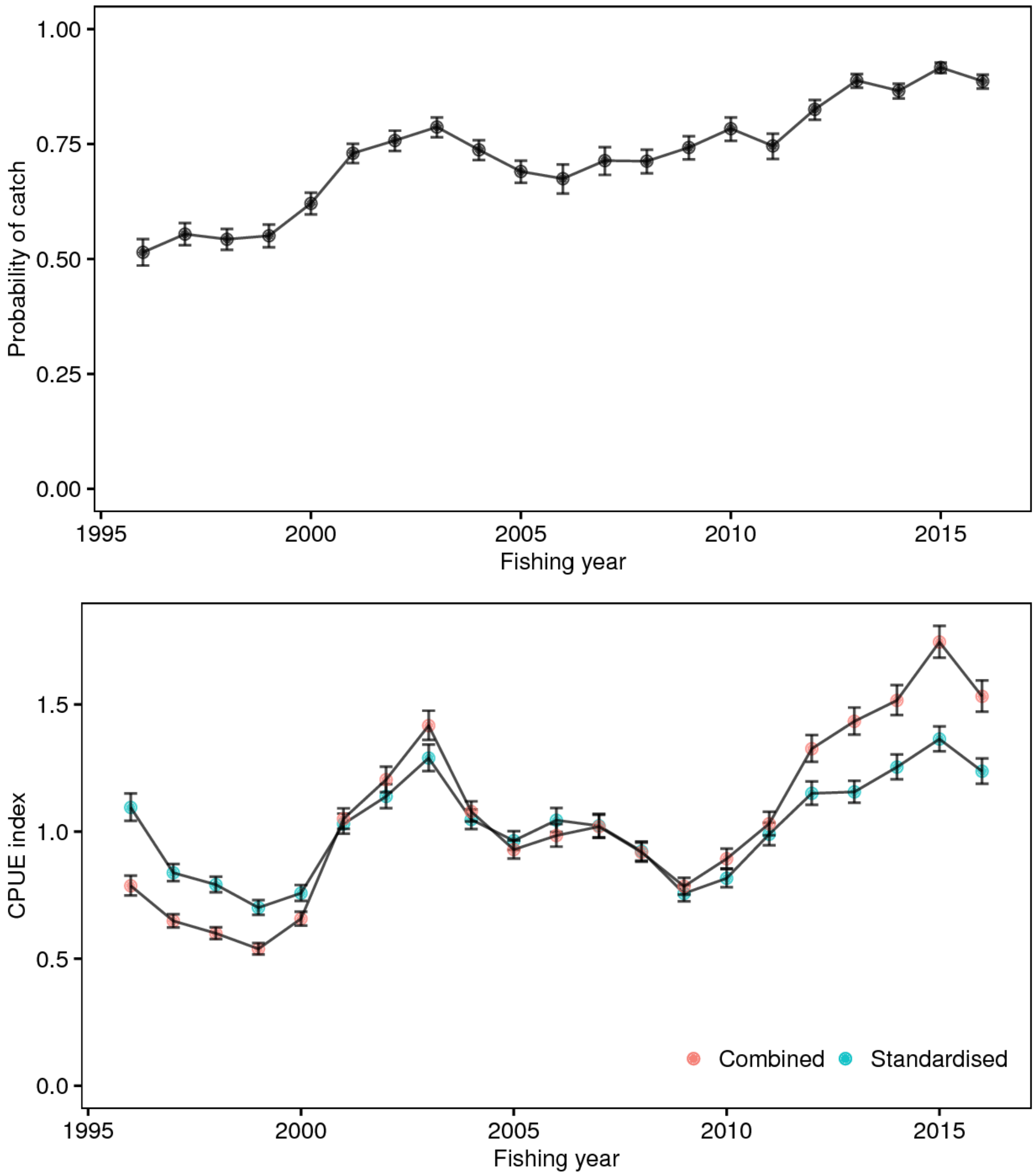


Figure 5: Standardised probability of catch (binomial model), positive CPUE indices (gamma model), and combined model for GUR 1W using bottom trawl tow data from TCEPR/ TCER forms (Kendrick & Bentley in prep a). Error bars are 95% confidence intervals.

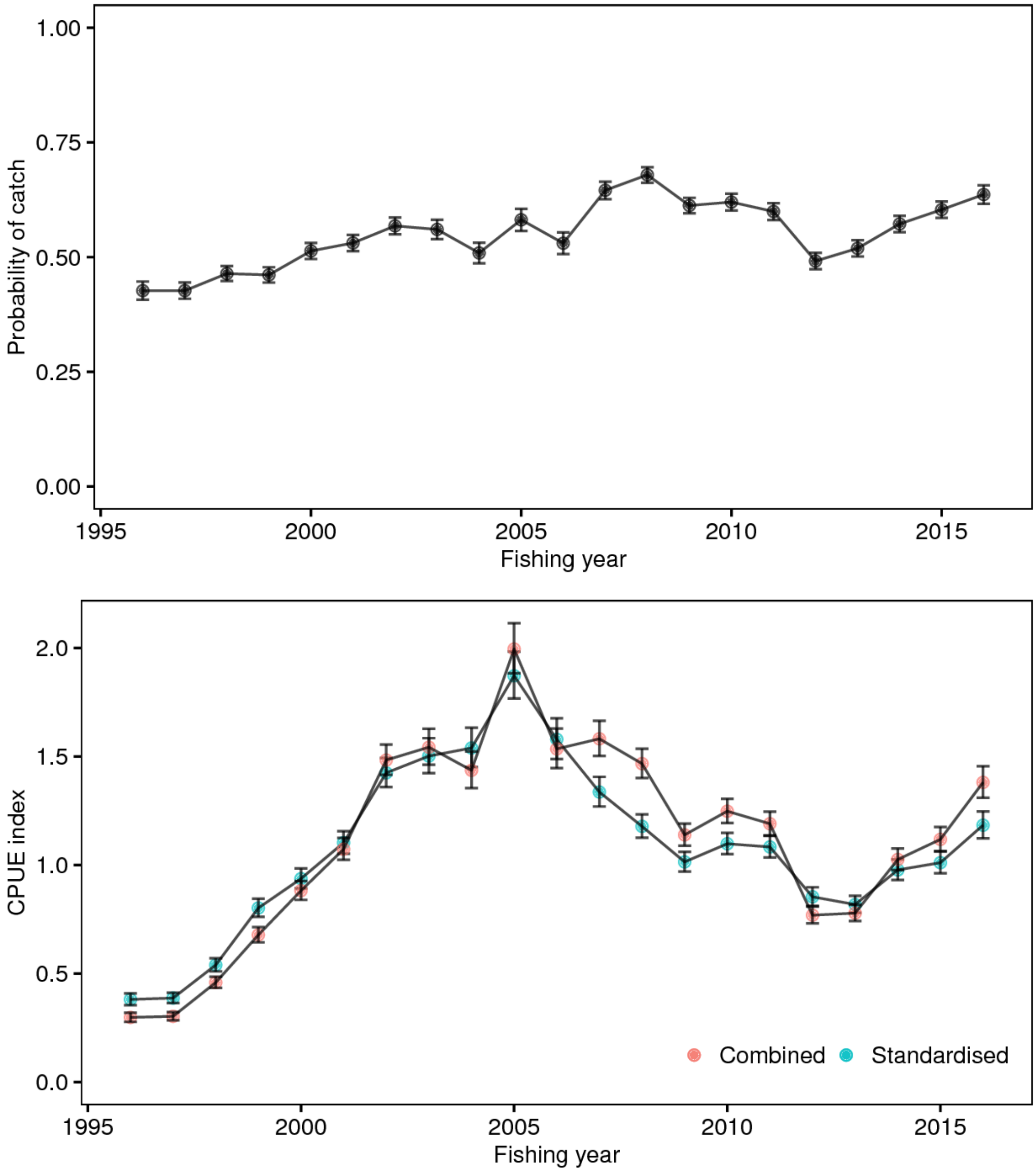


Figure 6: Standardised probability of catch (binomial model), positive catch CPUE indices (gamma model), and combined model for GUR 1E using bottom trawl tow data from TCEPR/ TCER forms (Kendrick & Bentley in prep a). Error bars are 95% confidence intervals.

All three series show strong cyclical fluctuations with a recovery from low levels between 1995 and 1999 to a peak in the early 2000s, followed by a subsequent decline to low levels again between 2009 and 2013. In all three regions there have been subsequent increases and all combined series have a value near, or above, the long-term average in 2016. Despite overall similarities, the series differ somewhat with respect to the magnitude of the fluctuations and the specific years for the nadir and the peak.

The Working Group accepted the tow-based combined series for ongoing monitoring of each substock. The trends for these series are consistent with previous analyses for corresponding periods (Kendrick & Bentley in prep a).

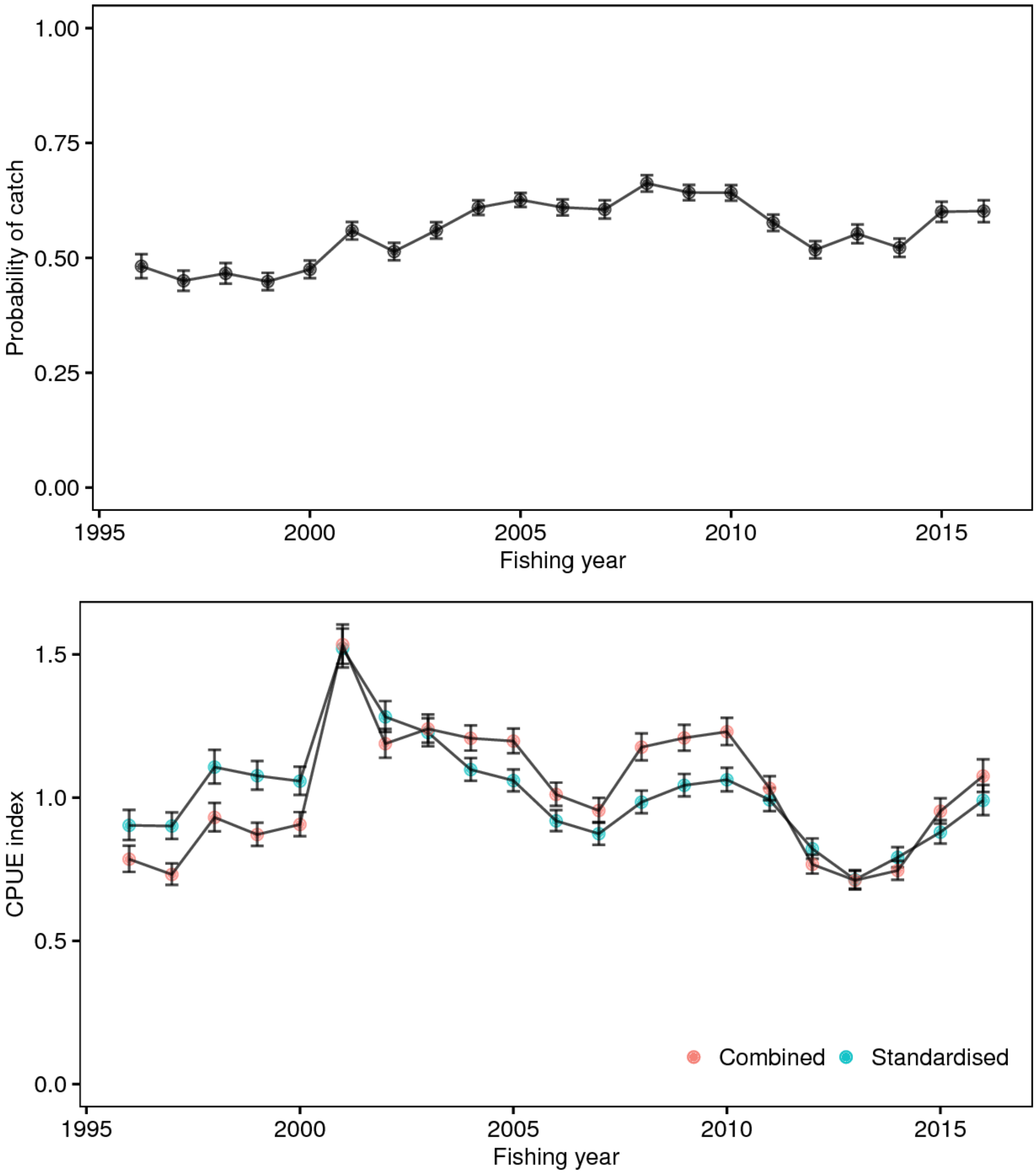


Figure 7: Standardised probability of catch (binomial model), positive catch CPUE indices (gamma model), and combined model for GUR 1BP using bottom trawl tow data from TCEPR/ TCER forms (Kendrick & Bentley in prep a). Error bars are 95% confidence intervals.

Establishing B_{MSY} compatible reference points for GUR 1

In 2013, the Working Group accepted mean standardised bottom trawl CPUE for the period 1995–96 to 2011–12 as B_{MSY}-compatible proxies for each of the GUR 1 sub-stocks. All three series were based on combined positive catch and probability of capture models derived from event scale fishing events (i.e., tow). GUR abundance tends to fluctuate in cycles, according to recruitment, and the period was chosen because it included at least one cycle of abundance and high catch. The Working Group accepted the default Harvest Strategy Standard definitions that the Soft and Hard Limits would be one half and one quarter the target for each sub-stock, respectively.

GUR 2

GUR 2 is monitored using standardised CPUE from the bottom trawl fishery targeting gurnard, snapper, or trevally.

In 2017, Schofield et al (2018a) updated CPUE analyses for GUR 2. Landings were allocated to daily aggregated effort using methods described by Langley (2014) to improve the consistency of the data collected from the different statutory reporting forms (CELR and TCER). A core fleet of vessels that had completed at least five trips per year in at least seven years was modelled using a Weibull distribution. A shorter time series based on TCEPR and TCER format data available since 2007–08, and analysed at tow by tow resolution, closely resembled the mixed-form series for the years in common.

The NINSWG noted that almost of the records in the aggregated data had catches of gurnard and that a binomial index was flat. As a result, the positive catch index was retained as the key monitoring series.

The indices were updated in 2018 and 2019, and in 2020 a new fisheries characterisation was also carried out. This indicated that the fishery had been stable in the intervening period, and the accepted indices were updated with the addition of data from the ERS – Trawl reporting regime which was introduced for deepwater vessels from 2017–18, and for all other fisheries during 2019.

In the longer CPUE series using aggregated data (i.e., PseudoCELR series) there are indications of cyclical variations in abundance with a 4- to 5-year period (Figure 8). There was an overall decreasing trend in CPUE from 1990 to 2007, after which CPUE stabilised and then increased to 2016, before decreasing to 2017 followed by a recent slight increase. As before, the series using tow level data showed a similar pattern to the longer, daily aggregated, index for years after 2007–08 (Figure 8).

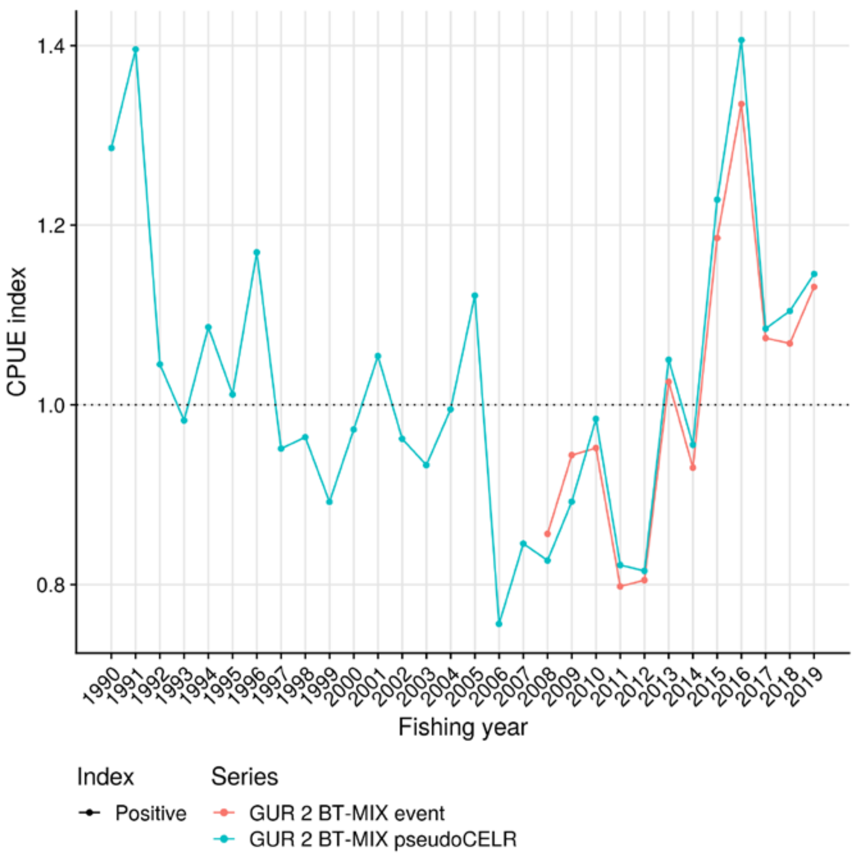


Figure 8: Comparison of standardised catch per unit effort (CPUE) indices for GUR 2 from bottom trawling targeting gurnard, snapper, and trevally (BT-MIX pseudoCELR; Weibull) combined over all form types, and more recently from data based on TCEPR/ TCER (tow) format data only (BT-MIX event; gamma). The series are scaled relative to the geometric mean of the years they have in common.

Chapman-Robson estimates of total mortality (Z) for GUR 2, based on the age composition of bottom trawl landings in 2009–10, were 0.518 (SE = 0.0159, CV=3.1%) and 0.632 (0.0196, 3.1), depending on whether the age at full recruitment was 2 or 3 years (Parker & Fu 2012). Assuming an instantaneous rate of natural mortality of 0.307, fishing mortality was estimated to be 0.189 or 0.303.

Although it was not possible to produce reliable estimates of spawner biomass per recruit based targets of F (due to unreliable estimates of growth rate and size at maturity), estimates of F from this study were either lower or approximately equal to the estimate of natural mortality (depending on the age at full recruitment assumed). Assuming that the fishery is sampling the age structure of the population, and given that catches and standardised CPUE have been reasonably constant over the last decade, these results suggest that GUR 2 was not over-exploited in 2010, and that the stock is likely to be at or above B_{MSY}.

Establishing B_{MSY} compatible reference points

In 2014, the NINSWG adopted mean CPUE from the (BT(MIX)) model for the period 1990–91 to 2009–10 as a B_{MSY}-compatible proxy for GUR 2. In 2020 the reference period was extended from 1991 to 2018, on the grounds that the new period included two peaks in abundance. The Working Group adopted the default Harvest Strategy Standard definitions for the Soft and Hard Limits of one half and one quarter the target, respectively.

GUR 3

In 2012, the Working Group accepted two standardised CPUE series for GUR 3 with both series based on the bycatch of red gurnard in bottom trawl fisheries defined by different target species combinations from fishing within the inshore statistical areas of GUR 3 (018, 020, 022, 024, 026, 025, and 030). The BT(MIX) index included fishing effort targeting red cod, giant stargazer, barracouta, tarakihi, and red gurnard, and the BT(FLA) index comprised flatfish target trawls only (Starr & Kendrick 2013).

In 2014, the two CPUE analyses were updated with data from 1989–90 to 2012–13 (Langley 2014). The analysis also included several refinements to improve the comparability between the data collected from two statutory reporting forms (CELR and TCER) which collect data at different levels of detail (daily and by tow), including the approach used to apportion red gurnard landed catches from individual fishing trips to the associated fishing effort records and the daily aggregation of fishing effort. These refinements in data processing resulted in no appreciable change in the resulting CPUE indices for the corresponding period. The 2014 CPUE analyses used the equivalent model formulations to the previous analyses (dependent and explanatory variables and Weibull error structure following Starr & Kendrick 2013).

The two sets of indices were updated in 2015 to include data from 2013–14. The time-series of CPUE indices from the two fisheries are very similar. The indices were at a relatively low level in 1997–98 to 1999–2000 and increased steadily to a peak during 2007–08 to 2010–11 (Figure 9). Both sets of indices were lower than the peak level in 2011–12 to 2013–14, although the indices remained well above the longer term average level from the entire time series (Figure 9).

The longer term trends in the CPUE indices are similar to the increase in estimates of recruited biomass (defined as fish at least 30 cm TL) from the time series of winter ECSI inshore trawl surveys (Figure 9), although the magnitude of the overall increase in the trawl survey biomass is greater than the overall increase in the CPUE indices. Since 2007, the trawl survey biomass estimates have increased and there is no indication of the recent reduction in the CPUE indices from 2011–12 to 2013–14.

The accepted CPUE indices were updated in 2018 (Schofield et al 2018b) to include data to 30 September 2017. However, the Working Group concluded that a full update of CPUE indices, including a binomial component, was required.

Establishing B_{MSY} compatible reference points

In 2012, BT(MIX+FLA), the mean of the BT(MIX) and BT(FLA) series in each year, was accepted by the Working Group as the series for monitoring GUR 3. These fisheries cover different aspects of gurnard distribution, both by depth and spatially, but still have very similar trajectories, providing some confidence that these series are likely to be tracking abundance. The mean from 1997–98 to 1999–00 of BT(MIX+FLA) was selected as the Soft Limit because it was a well-defined low point in the series, along with the observations that both catch and CPUE increased simultaneously from that point. The Working Group accepted the default Harvest Strategy Standard definitions that the target "B_{MSY}-compatible proxy" for GUR 3 would be twice the Soft Limit and the Hard Limit was one-half the Soft Limit.

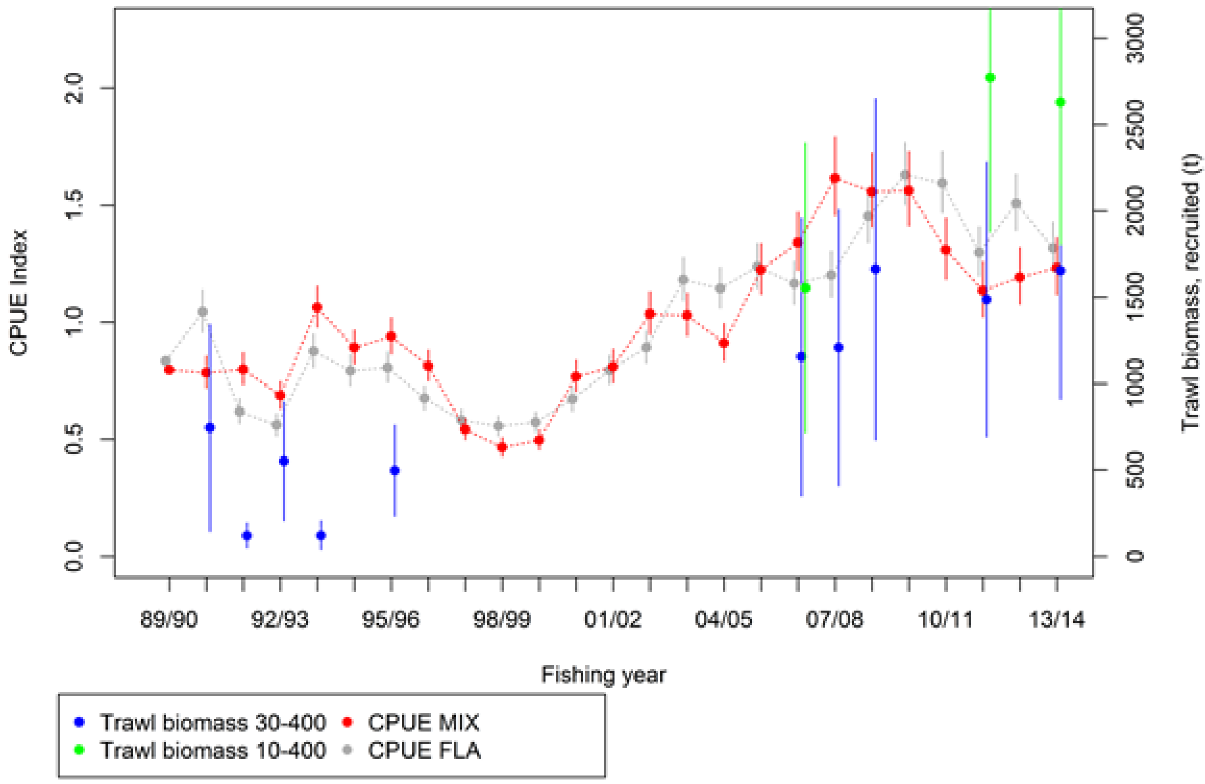


Figure 9: Standardised CPUE indices for two east coast South Island bottom trawl fisheries (BT(MIX) and BT(FLA)) compared with trawl survey estimates of recruited (≥ 30 cm TL) biomass for red gurnard from the winter ECSI inshore trawl survey for two survey depth strata (30–400 m and 10–400 m). Error bars show ±95% confidence intervals.

GUR 7

In both 2014 and 2017, only two standardised CPUE analyses based on the catch of gurnard in bottom trawl fisheries operating off the west coast of the South Island for monitoring GUR 7 were accepted. These fisheries are defined as follows:

- WCSI(FLA): bottom trawl effort targeted at flatfish (or any of the species that make up this complex) in Statistical Areas 033, 034, 035, or 036;
- WCSI(MIX): bottom trawl effort targeted at red gurnard, red cod, tarakihi, barracouta, giant stargazer, or blue warehou in Statistical Areas 033, 034, 035, or 036;

The data for these analyses were prepared using the "daily effort" procedure documented by Langley (2014). The Plenary agreed in 2017 to use the combined model (lognormal model of positive catches and binomial model of probability of capture) using the delta-lognormal method (Vignaux 1994) for stock evaluations. This was done because the Inshore Working Groups have adopted the standard of combining positive catch and fishing success models when there is a trend in the proportion zero catch. In addition, simulation work has indicated that calculating a combined index may reduce bias when reporting small catch amounts (Langley 2015).

These fishery definitions build on the work of Kendrick et al (2011) and Langley (2014), which defined four fisheries for monitoring GUR 7, two on the WCSI and two in western Cook Strait/Tasman Bay-Golden Bay, some with slightly different target species definitions than indicated above. These four GUR 7 BT fisheries were reviewed in 2014, comparing the CPUE series with the red gurnard biomass indices obtained from the West Coast South Island trawl survey (Table 6). The Plenary rejected the two series based on catch-effort data from Tasman Bay-Golden Bay, partly because those series did not match the biomass survey indices very well, and because there was a marked shift in the spatial distribution of fishing effort in the western Cook Strait fishery, with a reduction in the proportion of fishing effort within the areas of higher red gurnard catch rates and a shift towards trawling in deeper waters (Langley 2014). On the other hand, the two sets of CPUE indices from the west coast South Island fisheries showed similar cyclical trends with relatively high CPUE indices during 1990–91 to 1991–92 and 2001–02 to 2003–04 and also relatively low CPUE indices in 1993–94 to 1999–2000 and 2006–07 to 2010–11 (Figure 10). These CPUE indices have since steadily increased from 2009–10 to a high level in 2015–16.

A composite series (WCSI(MIX+FLA)), which averaged the WCSI(MIX) and WCSI(FLA) series in each year, was accepted in 2014 by the Plenary as the best CPUE series for monitoring GUR 7.

The biomass estimates of recruited (≥ 30 cm TL) red gurnard from the WCSI trawl survey do not show the same strong abundance signal in the early to mid-2000s as do the CPUE indices. However, with the omission of the 2003 survey on the basis of an apparently large (negative) change in catchability (see Appendix 6, Stevenson & MacGibbon 2015), the trends are not incompatible. Also, recent survey biomass estimates in 2015, 2017, and 2019 are consistent with the high levels of CPUE observed in the two WCSI BT series (Figure 10).

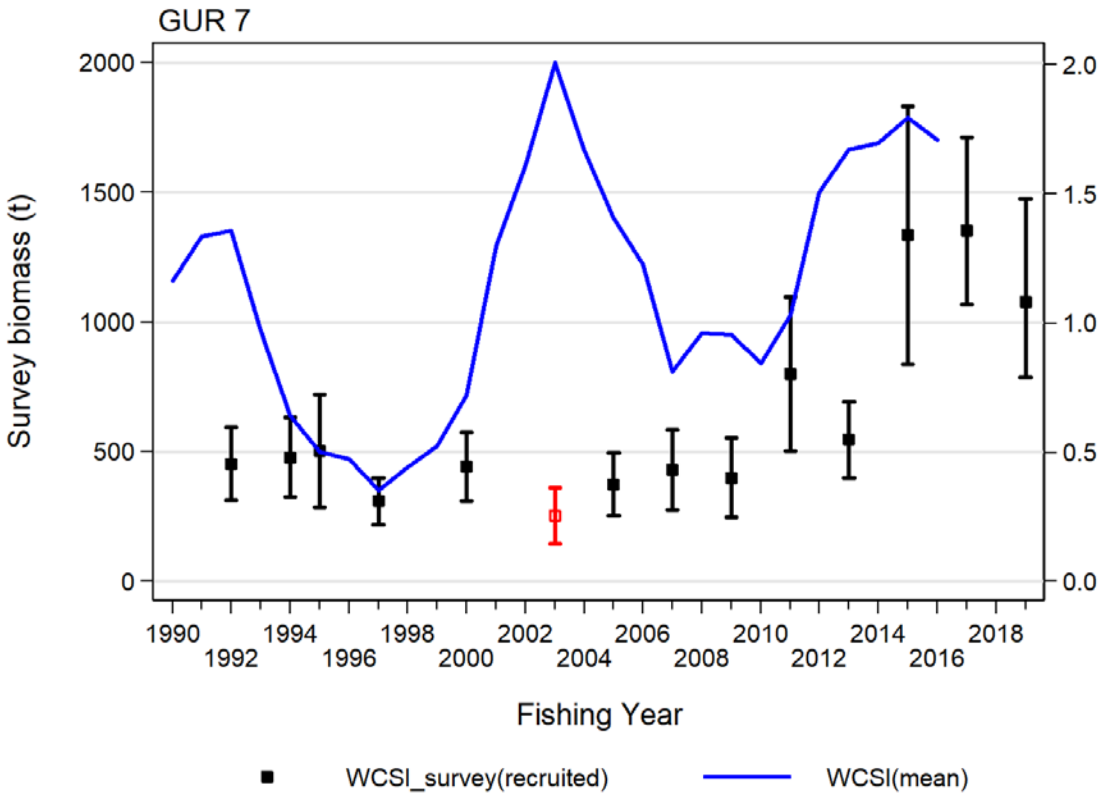


Figure 10: Comparison of the combined (mean) indices from two independent CPUE series for GUR 7 from the inshore WCSI bottom trawl fisheries (Statistical Areas 033, 034, 035, and 036); a) WCSI(FLA): target FLA; b) WCSI(MIX): target, GUR, BAR, TAR, WAR, STA, RCO. Trawl survey biomass estimates of recruited (≥ 30 cm TL) red gurnard from the WCSI inshore trawl survey are also presented with the excluded 2003 survey estimate plotted in red with a hollow marker. The vertical bars represent the associated 95% confidence intervals.

Establishing B_{MSY} compatible reference points

The Plenary reviewed the WCSI trawl survey biomass estimates in 2017 and concluded that there was no need to separate the Tasman Bay-Golden Bay strata from the WCSI strata, given the strong similarity in the biomass signals from the two survey components in 9 of the 11 survey years. Consequently, it was agreed that the recruited biomass from the total survey should be used as the main tool for monitoring GUR 7.

The Plenary concluded that the trawl survey time series is a better index of trends in abundance than the CPUE time series, primarily because it is more consistent through time and is not affected by changes in fishing behaviour. The mean of the WCSI trawl survey series from 1992–2013, but excluding 2003 because of a large negative change in catchability, was chosen as a "B_{MSY} compatible proxy" for GUR 7 on the basis that this was a period of relative stability in the series. The Plenary then adopted the default Harvest Strategy Standard definitions that the Soft and Hard Limits would be one half and one quarter the target, respectively.

The averaged WCSI(MIX+FLA) series was retained for corroboration purposes only, with no associated reference points being derived from it.

4.3 Other factors

Red gurnard is a major bycatch of target fisheries for several different species, such as snapper and flatfish. The target species may differ between areas and seasons. The recorded landings are influenced directly by changes in the fishing patterns of fisheries for these target species and indirectly by the abundance of these target species. Some target fishing for gurnard also occurs.

4.4 Future research considerations

- Investigate the potential benefits of undertaking a full stock assessment for GUR 7, which would entail conducting more ageing of otoliths.
- Further investigation of the relationship between pre-recruits and subsequent recruitment may be useful.

5. STATUS OF THE STOCKS

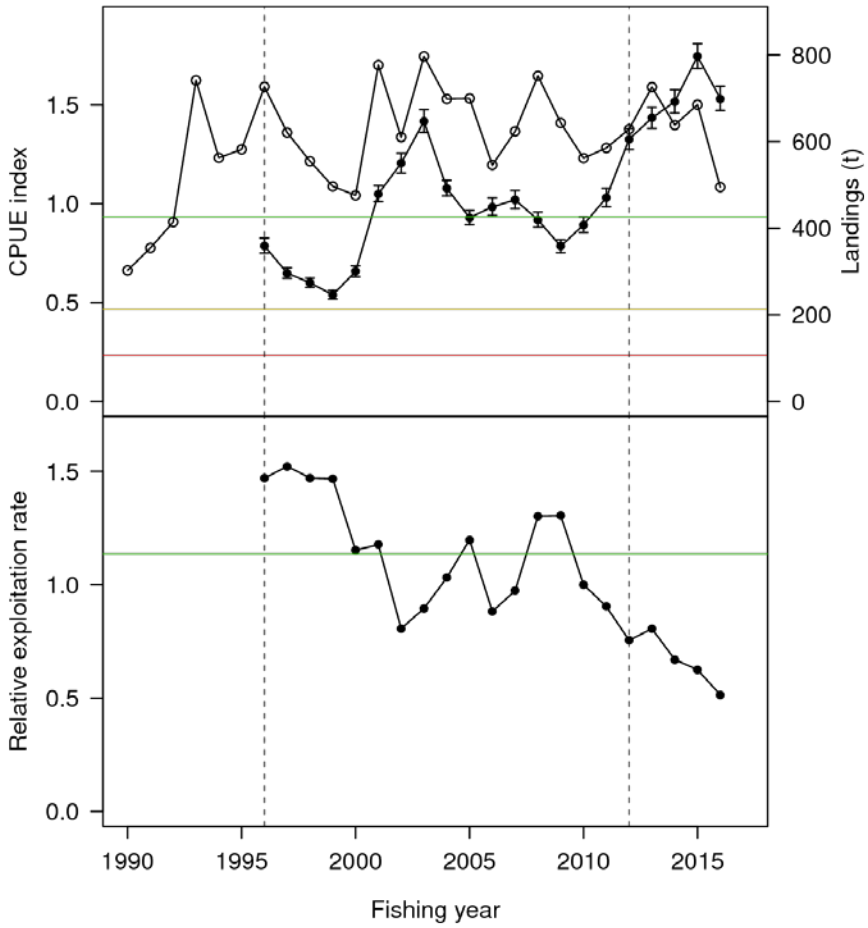
Stock Structure Assumptions

For the purpose of this summary GUR 1 is considered to be a single stock with three sub-stocks.

- **GUR 1W**

Stock Status	
Year of Most Recent Assessment	2017
Assessment Runs Presented	Standardised CPUE
Reference Points	Target: B_{MSY}-compatible proxy based on the mean CPUE from 1995–96 to 2011–12 of the bottom trawl GUR 1 west (tow) series Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: F_{MSY} compatible proxy based on the mean relative exploitation rate for the period: 1995–96 to 2011–12
Status in relation to Target	Very Likely (> 90%) 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	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Top panel: landings (open circles) and standardised CPUE (combined model using tow by tow data from 1995–96, ±2 s.e.). The green, yellow and red horizontal lines represent the target, soft and hard limits, respectively. Bottom panel: annual relative exploitation rate (landings divided by standardised CPUE and normalised to a geometric mean of one) for red gurnard in the GUR 1 west coast sub-stock. The horizontal green line represents the average relative exploitation rate during the period used to define the reference points (depicted by vertical dotted lines).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The CPUE index cycles over a 4–10 year period consistent with the dynamics of a short lived species with variable recruitment. CPUE suggests that stock size has fluctuated around the long-term average since 1995–96, recovering from lows in 1998–99 and 2008–09. The CPUE has increased since 2008–09 and in 2015–16 was well above the long-term mean.
Recent Trend in Fishing Intensity or Proxy	Relative exploitation rate has declined since 1995–96.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Without information on recruitment, it is not possible to predict how the stock is going to respond in the next few years.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	<u>Current Catch</u> Soft Limit: Unlikely (< 40%) Hard Limit: Unlikely (< 40%) <u>TACC</u>

	Unknown for both the Soft and Hard Limits
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%) if the catch remains at current levels Unknown if the catch were to increase to the level of the TACC

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from bottom trawl	
Assessment Dates	Latest assessment: 2017	Next assessment: 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	The accepted CPUE index is now a tow based index, rather than trip-stratum based.	
Major Sources of Uncertainty	-	

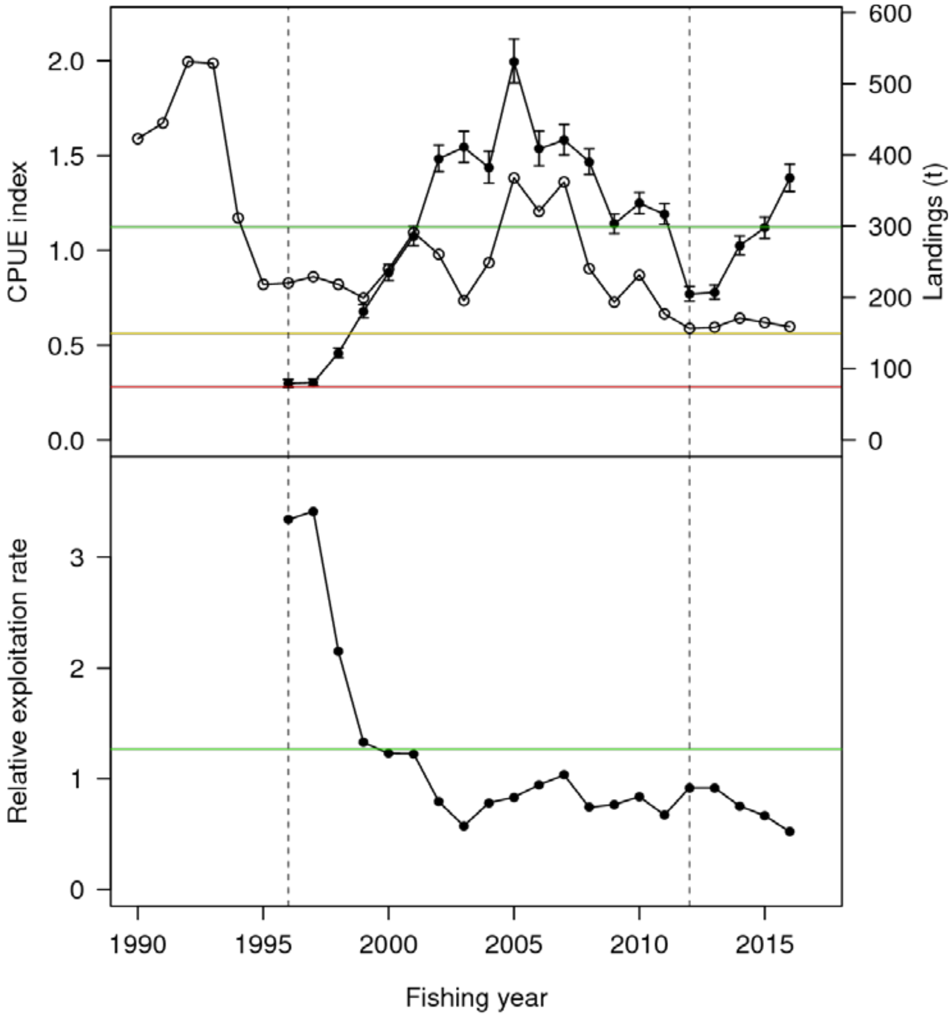
Qualifying Comments
As the red gurnard fishery in FMAs 1 and 9 has a long history, it is difficult to infer stock status from recent abundance trends. The abundance of all three sub-stocks appears to be cyclical, probably in response to recruitment variation. This makes it difficult to predict future trends without recruitment information. Given that the catch levels observed from 1986–87 to 2015–16 has been relatively consistent and that red gurnard are mainly taken as bycatch, current catch levels are unlikely to compromise the long-term viability of this stock. As the TACC is substantially higher than the current catch, it is not possible to evaluate potential impacts if catches increased to the level of the TACC.

Fishery Interactions
Red gurnard is taken on the west coast by bottom trawl targeted at snapper and trevally. A Danish seine summer fishery for Red gurnard and John dory also occurs on the west coast. Interactions with other species are currently being characterised.

- **GUR 1E**

Stock Status	
Year of Most Recent Assessment	2017
Assessment Runs Presented	Standardised CPUE
Reference Points	Target: B_{MSY}-compatible proxy based on the mean CPUE from 1995–96 to 2011–12 for the bottom trawl GUR 1 East (tow) series Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: F_{MSY} compatible proxy based on the mean relative exploitation rate for the period: 1995–96 to 2011–12
Status in relation to Target	About as Likely as Not (40–60%) to be at or above the target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status



Top panel: landings (open circles) and standardised CPUE (combined model using tow by tow data from 1995–96, ±2 s.e.). The green, yellow and red horizontal lines represent the target, soft and hard limits, respectively. Bottom panel: annual relative exploitation rate (landings divided by standardised CPUE and normalised to a geometric mean of one) for red gurnard in the GUR 1 east coast sub-stock. The horizontal green line represents the average relative exploitation rate during the period used to define the reference points (depicted by vertical dotted lines).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The CPUE index fluctuates in a way that is consistent with the dynamics of a short lived species with variable recruitment, although the period is longer than that for other gurnard stocks. An increase from the lowest levels in 1995–96 was sustained over eight consecutive years, peaked in 2004–05. The CPUE index declined to slightly below the target in 2011–12 and has subsequently risen to above it in 2015–16
Recent Trend in Fishing Intensity or Proxy	Relative exploitation rate declined from 1995–96 to 2002–03 and has then fluctuated without trend below the long-term average.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Without information on recruitment, it is not possible to predict how the stock is going to respond in the next few years.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown if the catch remains at current levels Unknown if catch were to increase to the level of the TACC

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from bottom trawl	
Assessment Dates	Latest assessment: 2017	Next assessment: 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	The accepted CPUE index is now a tow based index, rather than trip-stratum based.	
Major Sources of Uncertainty	-	

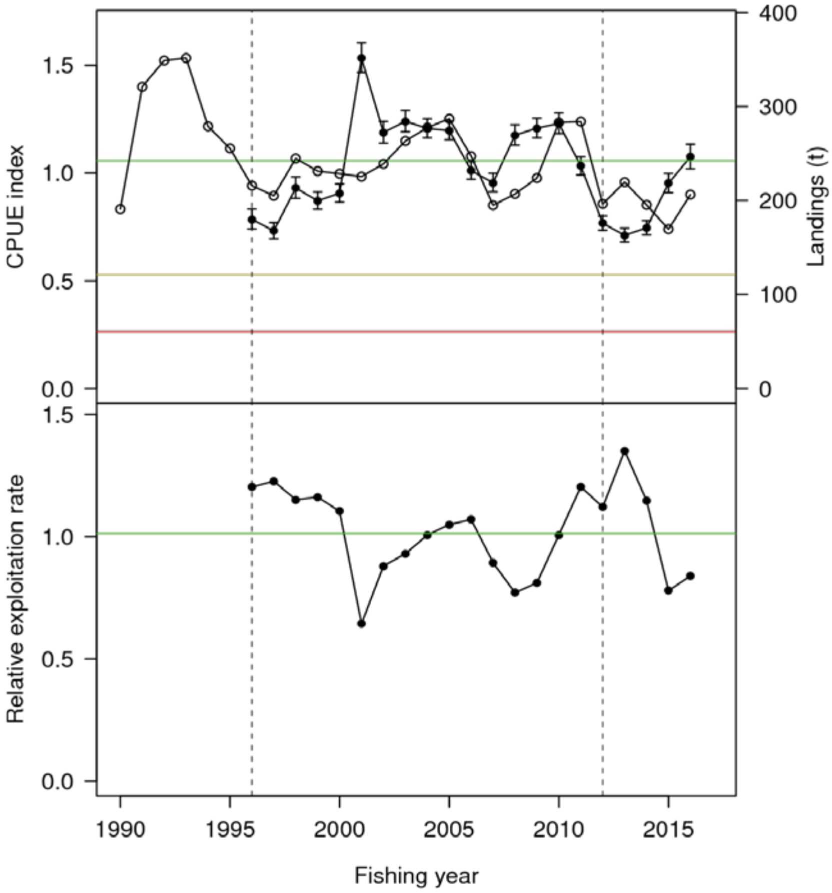
Qualifying Comments
As the red gurnard fishery in FMAs 1 and 9 has a long history, it is difficult to infer stock status from recent abundance trends. The abundance of all three sub-stocks appears to be cyclical, probably in response to recruitment variation. This makes it difficult to predict future trends without recruitment information. Given that the catch levels observed from 1986–87 to 2015–16 has been relatively consistent and that red gurnard are mainly taken as bycatch, current catch levels are unlikely to compromise the long-term viability of this stock. As the TACC is substantially higher than the current catch, it is not possible to evaluate potential impacts if catches increased to the level of the TACC.

Fishery Interactions
Red gurnard is taken as a bycatch on the east coast mainly by bottom longline targeted at snapper, with the balance taken almost equally by bottom trawl and Danish seine targeting snapper and John dory. Interactions with other species are currently being characterised.

- **GUR 1 Bay of Plenty**

Stock Status	
Year of Most Recent Assessment	2017
Assessment Runs Presented	Standardised CPUE
Reference Points	Target: B_{MSY}-compatible proxy based on the mean CPUE from 1995–96 to 2011–12 for the bottom trawl GUR 1 BoP (tow) series Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: F_{MSY} compatible proxy based on the mean relative exploitation rate for the period: 1995–96 to 2011–12
Status in relation to Target	About as Likely as Not (40–60%) to be at or above the Target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status



Top panel: landings (open circles) and standardised CPUE (combined model using tow by tow data from 1995–96, ±2 s.e.). The green, yellow and red horizontal lines represent the target, soft and hard limits, respectively. Bottom panel: annual relative exploitation rate (landings divided by standardised CPUE and normalised to a geometric mean of one) for red gurnard in the Bay of Plenty. The horizontal green line represents the average relative exploitation rate during the period used to define the reference points (depicted by vertical dotted lines).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The CPUE index fluctuates in a way that is consistent with the dynamics of a short lived species with variable recruitment. There was an increase from low levels in 1996–97 to a peak in 2000–01, and a subsequent decline to similarly low levels in 2002-03. The index has since increased and is currently near the target.
Recent Trend in Fishing Intensity or Proxy	Relative exploitation rate has fluctuated without trend around the long-term mean since 1995–96.
Other Abundance Indices	The GUR 1 BoP (stratum) series is slightly longer than the GUR 1 BoP (tow) series, but has a similar trend for the overlapping period.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Without information on recruitment, it is not possible to predict how the stock is going to respond in the next few years.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown if the catch remains at current levels Unknown if the catch were to increase to the level of the TACC

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE based on positive catches from bottom trawl	
Assessment Dates	Latest assessment: 2017	Next assessment: 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	The accepted CPUE index is now a tow based index, rather than trip-stratum based.	
Major Sources of Uncertainty	-	

Qualifying Comments
As the red gurnard fishery in FMAs 1 and 9 has a long history, it is difficult to infer stock status from recent abundance trends. The abundance of all three sub-stocks appears to be cyclical, probably in response to recruitment variation. This makes it difficult to predict future trends without recruitment information. Given that the catch levels observed from 1986–87 to 2015–16 has been relatively consistent and that red gurnard are mainly taken as bycatch, current catch levels are unlikely to compromise the long-term viability of this stock. As the TACC is substantially higher than the current catch, it is not possible to evaluate potential impacts if catches increased to the level of the TACC.

Fishery Interactions
Red gurnard is taken as a bycatch in the Bay of Plenty mainly by bottom longline targeted at snapper, with the balance taken almost equally by bottom trawl and Danish seine targeting snapper and John dory. Interactions with other species are currently being characterised.

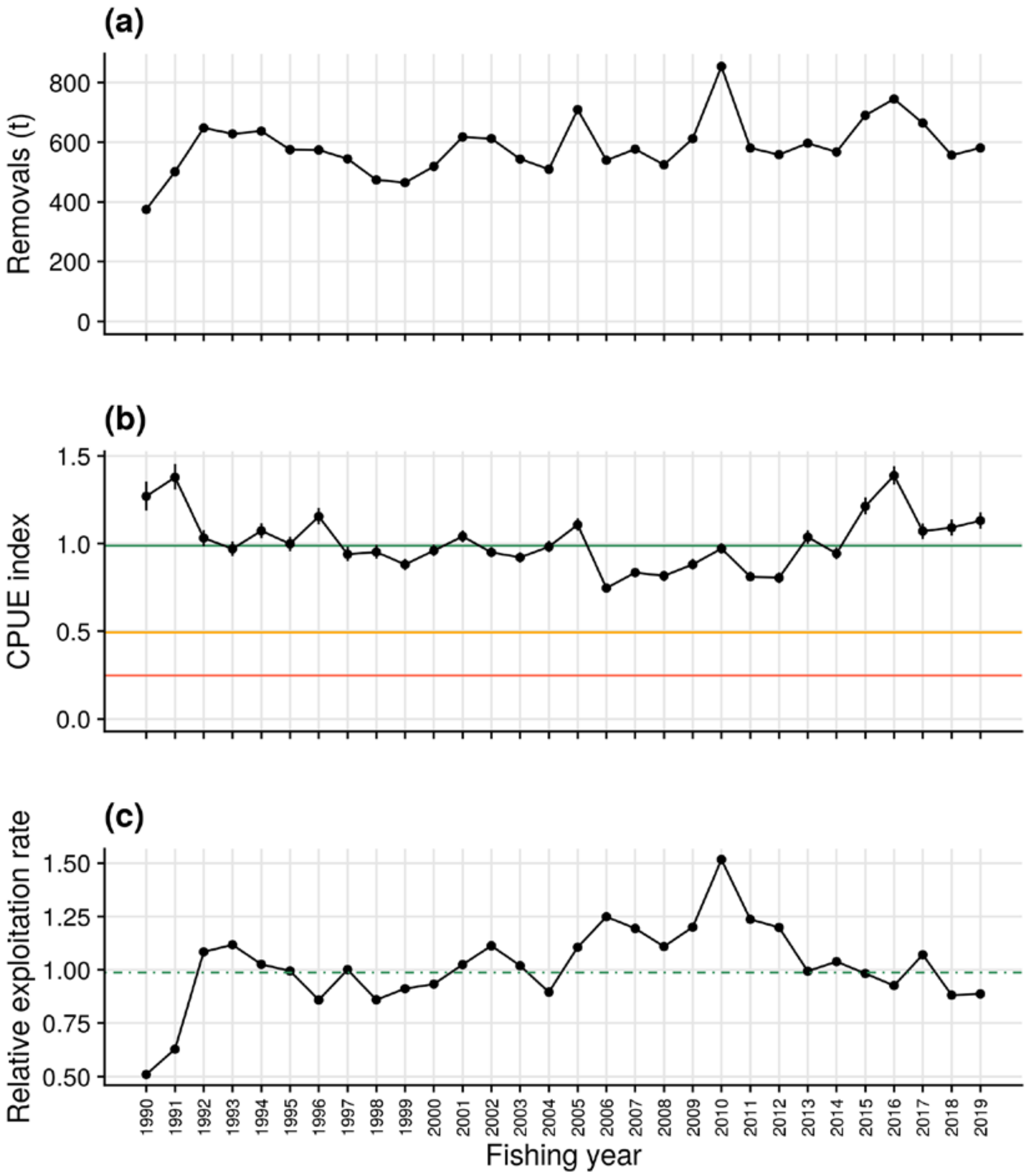
- **GUR 2**

Stock Structure Assumptions

For the purpose of this summary GUR 2 is considered to be a single stock.

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Standardised CPUE for BT.MIX
Reference Points	Target: B_{MSY}-compatible proxy based on the mean CPUE (BT(MIX)) for period 1990–91 to 2017–18 Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: F_{MSY} compatible proxy based on the mean relative exploitation rate for the period 1990–91 to 2017–18
Status in relation to Target	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	Overfishing is About as Likely as Not (40–60%) to be occurring

Historical Stock Status Trajectory and Current Status



(a) annual removals for GUR 2; (b) the standardised catch per unit effort (CPUE) index, relative to the agreed reference points, for GUR 2 from bottom trawling targeting gurnard, snapper and trevally (BT-MIX) and combining data from all form types at a daily aggregation; (c) annual relative exploitation rate (catch/CPUE) gurnard in GUR 2.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE indices generally trended downwards between 1990 and 2007, then flattened to 2012, with a strong increase to 2016. Standardised CPUE decreased to just above the target in 2016–17 and showed a slight increase to 2018–19.
Recent Trend in Fishing Intensity or Proxy	Relative exploitation rate increased gradually from 1989–90 to 2009–10, dropped to around the long-term average in 2013–14, and has been below the long-term average since 2017–18.
Other Abundance Indices	Tow based analysis of 2007–08 to 2018–19 data closely resembles the mixed form type analysis.
Trends in Other Relevant Indicators or Variables	Catch curve analysis indicated that fishing mortality was at or below M in 2010 (depending on the age at full recruitment).

Projections and Prognosis	
Stock Projections or Prognosis	Without information on recruitment, it is not possible to predict how the stock is going to respond in the next few years.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%) Unknown if the catch were to increase to the level of the TACC
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%) for current catch Unknown if the catch were to increase to the level of the TACC

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2020	Next assessment: 2021
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	BT-Mix CPUE series	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Most of the GUR2 commercial catch is made in Hawke Bay, and the index of abundance is naturally weighted to abundance of GUR in this area.

Fishery Interactions
Red gurnard is taken in FMA 2 by the bottom trawl fishery targeting gurnard and tarakihi.

- **GUR 3**

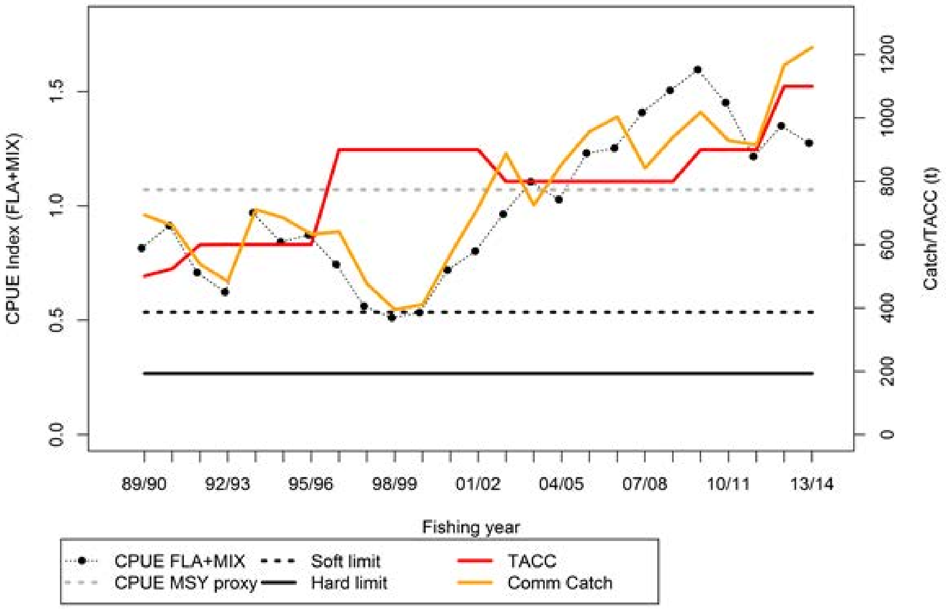
Stock Structure Assumptions

No information is available on the stock separation of red gurnard. The Fishstock GUR 3 is treated in this summary as a unit stock.

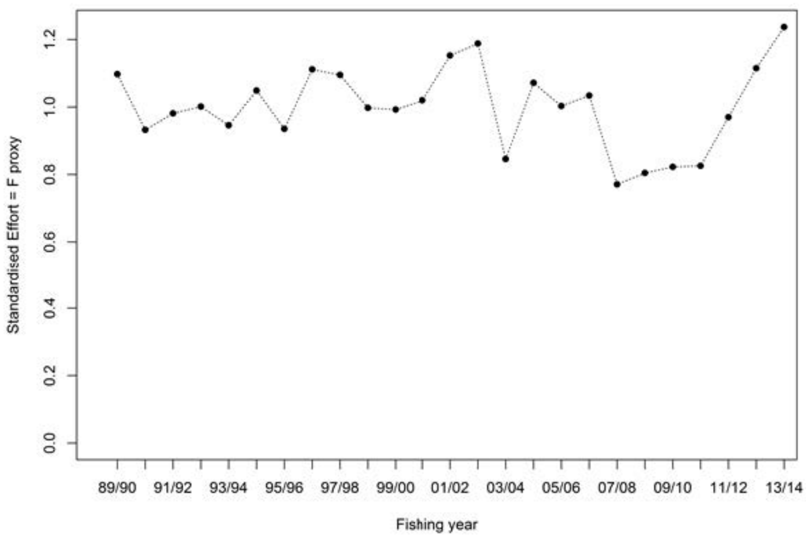
Stock Status	
Year of Most Recent Assessment	2015
Assessment runs presented	The CPUE series BT(MIX+FLA), which is the mean of two standardised bottom trawl CPUE series: one based on bottom trawls targeting mixed species (RCO, STA, BAR, TAR, GUR) and the other based on flatfish targeting.
Reference Points	Target: B_{MSY}-compatible proxy based on CPUE is twice the soft limit Soft Limit: Mean from 1997–98 to 1999–00 of BT(MIX+FLA) series, as defined in Starr & Kendrick (2013) Hard Limit: 50% of soft limit Overfishing threshold: F_{MSY}
Status in relation to Target	Likely (> 60%) to be 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	About as Likely as Not (40–60%) to be overfishing

Historical Stock Status Trajectory and Current Status

East coast South Island winter trawl survey, CPUE, Catch and TACC Trajectories



Comparison of east coast South Island winter trawl survey recruited biomass and CPUE indices (average FLA and MIX) and the trajectories of catch and TACCs from 1989–90 to 2013–14. The horizontal grey line represents the MSY proxy relative to the CPUE series. The black dotted and solid lines represent the soft and hard limits, respectively.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Two bottom trawl CPUE series (one targeted at flatfish and the other at RCO, STA, BAR, TAR, GUR), which are considered to be an index of stock abundance, increased steadily from the late 1990s to 2009–10, and then declined, remaining above the target level.
Recent Trend in Fishing Intensity or Proxy	 **Fishing mortality proxy is Standardised Fishing Effort = Total catch/CPUE (normalised). Fishing mortality proxy increased sharply from 2010–11 to 2013–14 to above the series mean in 2011–12 and 2013–14.**
Other Abundance Indices	ECSI winter survey (30–400 m) shows a substantial increase since the early 1990s, declining in 2016, but increasing again in 2018. The expanded survey (10–400 m) shows a marked increase from 2007–2014, but declining in 2016 and then increasing in 2018 (n = 5).
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Quantitative stock projections are unavailable.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%) Current abundance is at historically high levels and is unlikely to decline below limits in 3–5 years.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	GUR is mostly taken as a bycatch (about 10% targeted). The correspondence between relative abundance and catch suggests a constant exploitation rate. The current catch is therefore Unlikely (< 40%) to cause overfishing.

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Agreed standardised CPUE series and trawl survey biomass indices	
Assessment Dates	Latest assessment: 2015	Next assessment: 2021
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	-Trawl survey biomass indices and associated length frequencies - Catch and effort data	1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	Prior to 2007 the ECSI trawl survey did not cover the entire depth range for red gurnard. A variable proportion of the population in the previously unsurveyed 10–30 m depth range suggests that survey catchability varies between years in the core survey area (30–400 m).	

Qualifying Comments
Red gurnard are relatively short-lived and reasonably productive. They exhibit cyclic fluctuations and were at low levels in the mid-1990s. Stock size has increased substantially since then and commercial fishers indicate that they find it difficult to stay within the TACC despite the low level of targeting on this species. Two independent CPUE series and the winter trawl survey corroborate that stock size for GUR 3 has increased since the late 1990s. There are potentially sufficient data to undertake a quantitative stock assessment for GUR 3. This would allow the estimation of B_{MSY} and other reference points.

Fishery Interactions
Red gurnard in GUR 3 are taken almost entirely by bottom trawl in fisheries targeted at red cod, barracouta and flatfish. Some gurnard are also taken in the target tarakihi and stargazer bottom trawl fisheries. The level of targeting on this species is low, averaging less than 10% of the total landed catch since 1989–90. Interactions with other species are currently being characterised.

- **GUR 7**

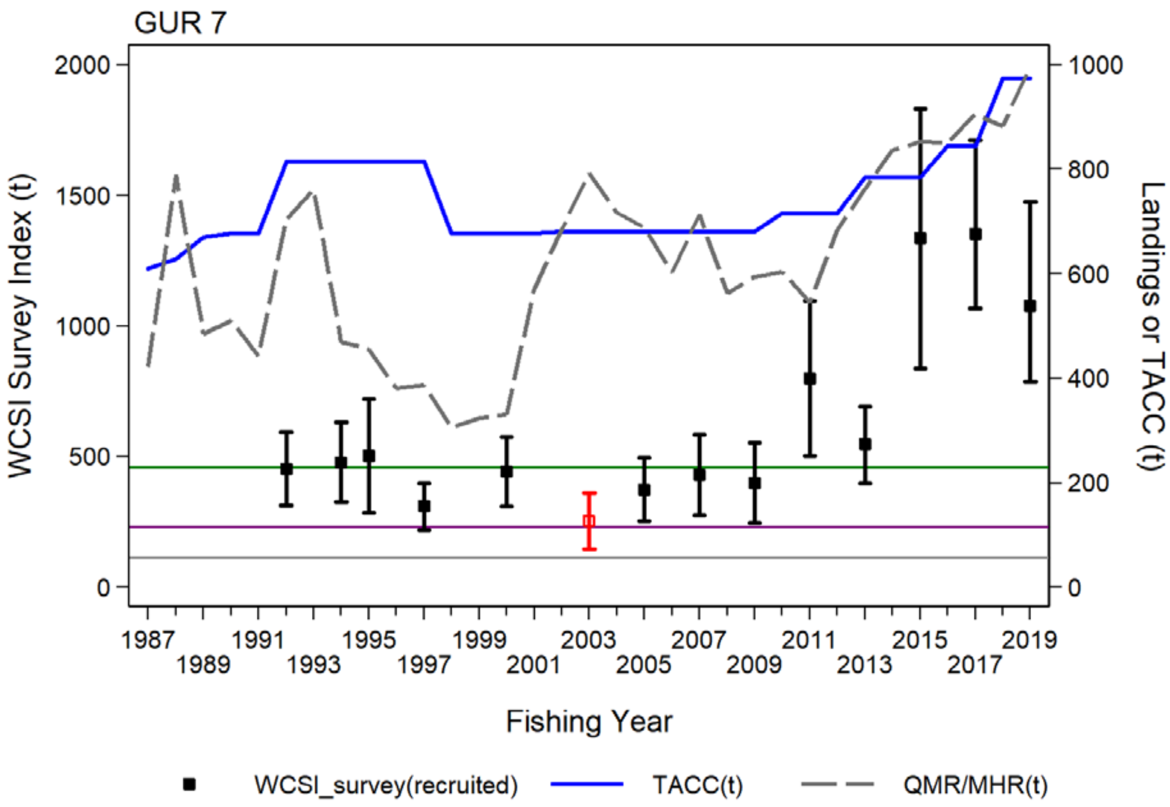
Stock Structure Assumptions

Stock boundaries are unknown, but for the purpose of this summary, GUR 7 is considered to be a single management unit.

Advice for GUR 7 is based on the biomass series for the recruited portion of the total WCSI trawl survey.

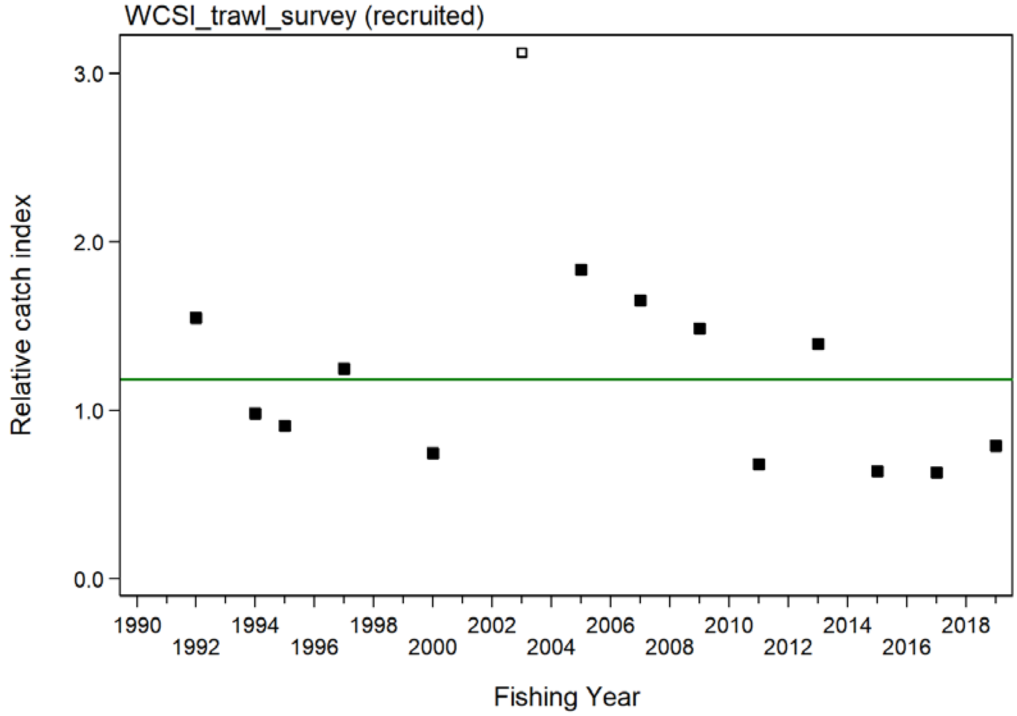
Stock Status	
Year of Most Recent Assessment	2019
Assessment runs presented	West Coast South Island trawl survey
Reference Points	Target: B_{MSY}-compatible proxy based on the mean WCSI trawl survey indices from 1992 to 2013, but excluding the 2003 index Soft Limit: 50% target Hard Limit: 25% target Overfishing threshold: F_{MSY} compatible proxy based on the WCSI trawl survey mean relative exploitation rate from 1992 to 2013, excluding the 2003 index
Status in relation to Target	Very Likely (> 90%) 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	Overfishing is Unlikely (< 40%) to be occurring

Historical Abundance and Catch Trajectories

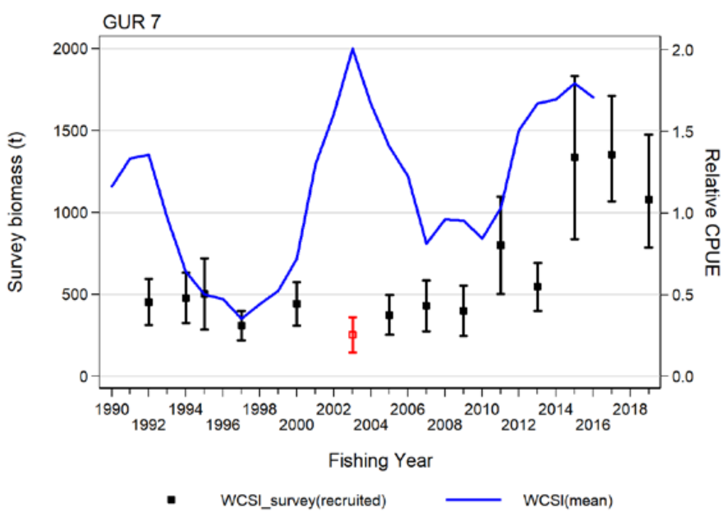


Comparison of the GUR WCSI trawl survey indices with the QMR/MHR landings and TACC for GUR 7. The agreed B_{MSY} proxy (geometric average: 1992–2013 (excluding 2003) WCSI survey biomass estimates=460 t) is shown as a green line; the calculated Soft Limit (=0.5xB_{MSY} proxy) is shown as a purple line; the calculated Hard Limit (=0.25xB_{MSY} proxy) is shown as a grey line. The excluded 2003 survey is shown in red with a hollow marker.

Fishing Intensity Trajectories



Relative fishing pressure for GUR 7 based on the ratio of QMR/MHR landings relative to the WCSI trawl survey (recruited). Horizontal green line is the geometric mean fishing pressure from 1992 to 2013, excluding 2003. Fishing pressure for the excluded 2003 survey is shown as a hollow marker.

Fishery and Stock Trends	
Recent trend in Biomass or Proxy	The west coast South Island trawl survey relative biomass indices from 2015 and 2017 were by far the highest of the entire time series. While the 2019 index dropped relative to the 2017 index, it still remains well above the B_{MSY} proxy target.
Recent trend in Fishing Intensity or Proxy	Unlikely (< 40%) that overfishing is occurring as biomass has increased considerably since 2009–10 while there has been only a moderate increase in annual catches.
Other Abundance Indices	WCSI CPUE indices increased from 2009–10 to 2015–16.  **Mean WCSI-BT(FLA+MIX) CPUE series compared with WCSI(recruited) trawl survey. Excluded 2003 survey index shown in red with hollow marker.**
Trends in Other Relevant Indicators or Variables	Estimates of pre-recruit fish from the West Coast South Island inshore trawl survey indicate that recruitment has been increasing since about 2005 and is currently well above average.

Projections and Prognosis	
Stock Projections or Prognosis	Quantitative stock projections are unavailable. However, above average recruitment is likely to ensure continuing high biomass at current catch levels, at least in the short term.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%) Current abundance is at historically high levels and is unlikely to decline below limits in 3–5 years
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	West Coast South Island trawl survey biomass - Survey length frequency - Standardised CPUE indices	
Assessment Dates	Latest assessment: 2019	Next assessment: 2021 (trawl survey)
Overall assessment quality rank	1 – High Quality	
Main data inputs	- Survey biomass and length frequencies - CPUE indices	1 – High Quality 1 – High Quality

Changes to Model Structure and Assumptions	- Tasman and Golden Bay survey data combined into the WCSI survey series - WCSI trawl survey series given precedence over the CPUE series for monitoring abundance - Use of the WCSI survey only to derive reference points CPUE used to provide corroboration
Major Sources of Uncertainty	- Choice of the period used to derive reference points

Qualifying Comments
Red gurnard are a survey target of the west coast South Island trawl survey and the Plenary regards the series as a reliable index of abundance. Trends in CPUE indices are broadly consistent with trends in trawl survey biomass, particularly since the late 2000s, corroborating the recent increase.

Fishery Interactions
Red gurnard are primarily taken in conjunction with the following QMS species: flatfish, barracouta, stargazer, red cod, tarakihi and other species in the West Coast South Island target bottom trawl fishery. Interactions with other species are currently being characterised.

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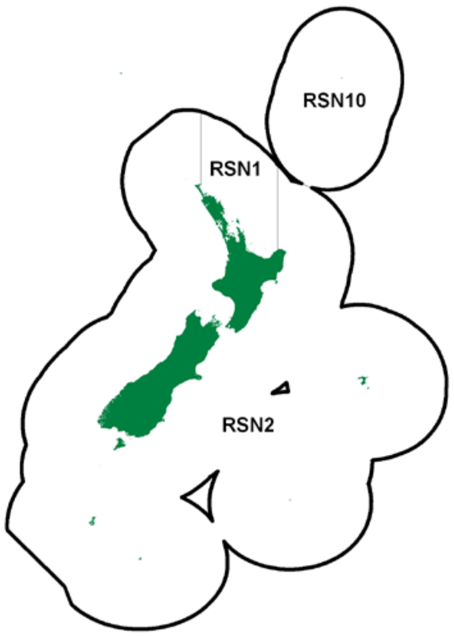
RED SNAPPER (RSN)

(Centroberyx affinis)
Kaorea



1. FISHERY SUMMARY

Red snapper was introduced into the Quota Management System on 1 October 2004 with the TACs, TACCs and allowances as shown in Table 1. These have not changed.

Table 1: Recreational and customary non-commercial allowances, TACCs and TACs of red snapper.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other sources of mortality	TACC	TAC
RSN 1	13	2	1	124	140
RSN 2	2	1	1	21	25
RSN 10	1	1	1	1	4
Total	16	4	3	146	169

1.1 Commercial fisheries

Small commercial catches of red snapper in New Zealand have almost certainly been made for decades, but would have been included among “assorted minor species” in reported landings. Historical estimated and recent reported red snapper landings and TACCs are shown in Tables 2, 3 and 4, while Figure 1 shows the historical and recent landings and TACC values for the main red snapper stocks.

Reported total annual landings increased to a peak of 212 t in 1996–97, and declined to an average of 50 t since the fishing year 2003-04. From 1989-90 to 2012-13 an average of 80% of total landings originated from RSN 1. Since 2013-14 landings in RSN 2 have increased, exceeding the TACCs in 2013-14, 2014-15, 2016-17, and 2017-18; in 2017-18 and 2018-19 similar amounts of landings were recorded in RSN 1 and RSN 2. RSN 10 landings have always been negligible, with no landing recorded at all since the late 1990s.

Red snapper is mostly taken as a bycatch of 1) the longline fishery for snapper off east Northland, 2) the trawl fisheries for tarakihi off east and west Northland, and 3) the setnet fishery for snapper and trevally in the Bay of Plenty.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	RSN 1	RSN 2	Year	RSN 1	RSN 2
1931–32	0	0	1957	0	0
1932–33	0	0	1958	0	0
1933–34	0	0	1959	0	0
1934–35	0	0	1960	0	0
1935–36	0	0	1961	0	0
1936–37	0	0	1962	0	0
1937–38	0	0	1963	0	0
1938–39	0	0	1964	0	0
1939–40	0	0	1965	0	0
1940–41	0	0	1966	0	0
1941–42	0	0	1967	0	0
1942–43	0	0	1968	0	0
1943–44	0	0	1969	0	0
1944	0	0	1970	0	0
1945	0	0	1971	0	0
1946	0	0	1972	0	0
1947	0	0	1973	0	0
1948	0	1	1974	0	1
1949	0	1	1975	0	0
1950	0	13	1976	0	4
1951	0	47	1977	0	7
1952	0	57	1978	0	4
1953	0	35	1979	0	1
1954	0	23	1980	0	9
1955	0	18	1981	0	3
1956	0	18	1982	0	3

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. 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 includes both foreign and domestic landings.

Table 3: Reported landings (t) by commercial fishers of red snapper by FMA from 1989–90 to 2003–04. Data are derived from the landing section of CELRs and CLRs.

	FMA 1	FMA 2	FMA 3	FMA 4	FMA 7	FMA 8	FMA 9	FMA 10	Unknown	Total
1989–90	67.9	3	3.1	0	1.8	0.9	0	0	0.0	76.7
1990–91	107.3	1.2	2.8	0	0.6	0.7	0	0	0.0	112.7
1991–92	89.1	0.7	1.1	0	0	1.6	0	0.6	0.0	93.2
1992–93	98.2	2.1	0.4	0	0	0.6	0	0	0.3	101.6
1993–94	78.2	2.6	0.3	0.1	0.4	0.4	0.2	0	0.0	82.4
1994–95	78.2	1.8	0.3	0	0.2	0.6	0.5	0	1.0	82.6
1995–96	126.7	2.1	0.8	0.2	1.2	0.2	1	0	1.3	133.4
1996–97	186.4	17.4	0.9	0	1	0.3	2.9	0.2	2.8	211.8
1997–98	159.1	3.4	0.3	0	0.2	0.7	3.6	0	0.8	168.2
1998–99	134.4	1.5	0.4	0.1	0.3	1	4.7	0	0.4	142.8
1999–00	108.1	1.3	0.8	0	0.1	21.3	25.4	0	0.7	157.7
2000–01	140.0	1.1	2.3	0.8	0	0.8	51.5	0	0.0	196.5
2001–02	109.7	1.5	2.2	0.1	0	0.4	12.3	0	0.6	126.7
2002–03	117.5	2.2	0.3	0	0	0.6	37.5	0	14.2	172.5
2003–04	40.9	1.8	0.2	0	0.3	1.3	6.7	0	0	51.3

1.2 Recreational fisheries

None of the telephone-diary surveys of recreational fishers in 1994, 1996, and 2000 nor the National Panel Survey conducted over the 2011–12 fishing and 2017–18 years (Wynne-Jones et al 2014, 2019) provided estimates of the recreational catch of red snapper. However, recreational fishers periodically catch this species while line fishing on deep reefs in Northland, the outer Hauraki Gulf, and Bay of Plenty.

1.3 Customary Fisheries

There is no quantitative information available to allow the estimation of the amount of red snapper taken by customary non-commercial fishers.

Table 4: Reported domestic landings (t) of red snapper Fishstock and TACCs from 2004–05 to 2018–19.

	RSN 1 FMA 1		RSN 2 FMA 2–9		RSN 10 FMA 10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2004–05	43	124	11	21	0	1	54	146
2005–06	41	124	8	21	0	1	49	146
2006–07	44	124	10	21	0	1	53	146
2007–08	70	124	17	21	0	1	87	146
2008–09	30	124	12	21	0	1	42	146
2009–10	22	124	9	21	0	1	31	146
2010–11	27	124	8	21	0	1	35	146
2011–12	23	124	5	21	0	1	27	146
2012–13	38	124	7	21	0	1	45	146
2013–14	38	124	25	21	0	1	63	146
2014–15	33	124	25	21	0	1	58	146
2015–16	26	124	18	21	0	1	44	146
2016–17	43	124	23	21	0	1	66	146
2017–18	23	124	24	21	0	1	46	146
2018–19	22	124	16	21	0	1	38	146

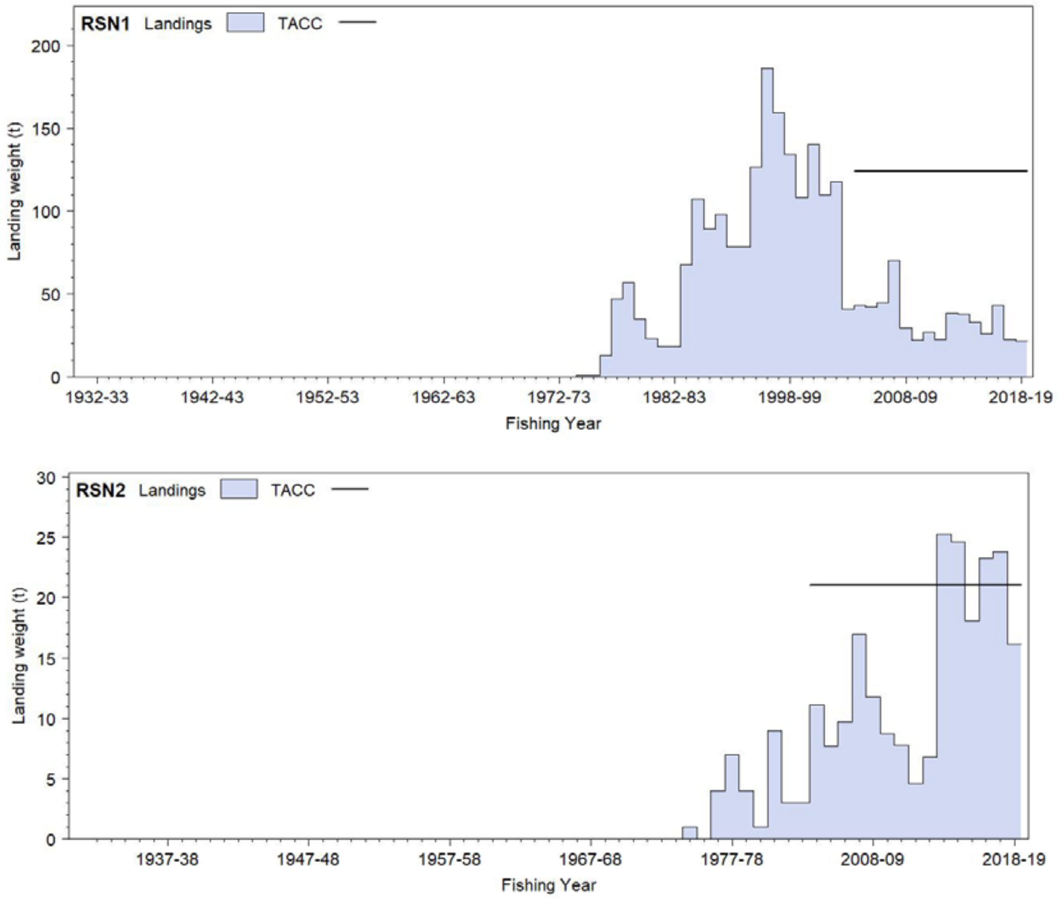


Figure 1: Reported commercial landings and TACC for the main RSN stock, RSN 1 (Auckland) and RSN 2 (Central East).

2. BIOLOGY

The red snapper (*Centroberyx affinis*) is present throughout New Zealand coastal waters, but is generally rare south of East Cape and Cape Egmont. In southeastern Australia (known as redfish) it occurs from Brisbane to Melbourne, and off northern Tasmania.

Red snapper occur in association with deep coastal reefs, in particular caves and overhangs, as well as in open water, to depths of about 400 m. Their relative abundance within this depth range is unknown. The southeastern Australian target fishery operates at depths of 100–250 m (Rowling 1994).

There have been no formal ageing studies of New Zealand red snapper, but Leachman et al (1978) reported a maximum ring count of 80, based on examination of a few broken and burned otoliths. These rings were not, however, validated. Work in Australia, based on tagging and thin otolith sections suggest unvalidated ages of at least 35 (Rowling 1994) and 40 years (Smith & Robertson 1992). Radiocarbon analysis supported an age of at least 37 years (Kalish 1995).

Red snapper attain 55 cm in New Zealand but average 30–40 cm. Nothing is known of their reproductive biology.

3. STOCKS AND AREAS

There has been no research to determine if there are separate biological stocks of red snapper.

4. STOCK ASSESSMENT

There has been no scientific stock assessment of the biomass that can support the Maximum Sustainable Yield (*MSY*) for red snapper.

5. STATUS OF THE STOCK

The reference or current biomass is not known for any red snapper stock. It is not known if the recent catch levels are sustainable. The status of RSN 1, 2 and 10 relative to B_{MSY} is unknown. TACCs and reported landings by Fishstock, for the 2017–18 fishing year, have been summarised in Table 5.

Table 5: Summary of TACCs (t) and reported landings (t) of red snapper for the 2018–19 fishing year.

Fishstock		FMA	2018–19 Actual TACC	2018–19 Reported landings
RSN 1	Auckland (East)	1	124	22
RSN 2	Auckland (West), South east, Southland, Sub-Antarctic, Central, Challenger	2,3,4,5,6, 7,8&9	21	16
RSN 10	Kermadec	10	1	0
Total			146	38

6. FOR FURTHER INFORMATION

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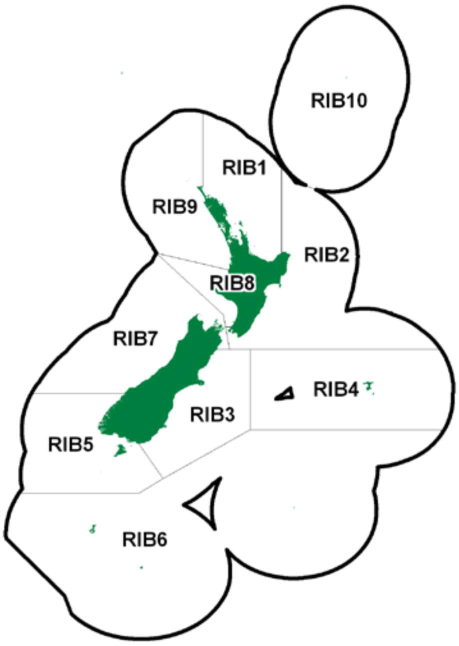
RIBALDO (RIB)

(*Mora moro*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

In New Zealand ribaldo is caught mainly on bottom longlines and as a bycatch of trawling. About 4 500 t catch was reported in 1977 by Japanese and Korean longline vessels target fishing for ling on the Chatham Rise and east coast of the South Island in the 1970s. Since 1982–83, overall reported catch has been mainly from the Chatham Rise, east coast South Island, and the Challenger Plateau (QMAs 3, 4 and 7). RIB 3 landings have fluctuated since entering the QMS, with landings reaching 348 t in 2010-11, dropping to 104 t in 2013-14, and increasing to 358 t in 2018-19. RIB 4 landings peaked at just under 850 t in 1996-97, and have fluctuated between 137 t and 492 t since. RIB 7 landings increased from 1994-95 until reaching a maximum at 456 t in 2008-09. Landings subsequently fluctuated between 177 t in 2011-12, 434 t in 2014-15, and just 151 t in 2018-2019. The reasons for these changes in catch levels are not well understood as ribaldo is mainly taken as bycatch. Levels of discarding and unreported catch are likely to have changed with the introduction of ribaldo into the QMS. Ribaldo are caught throughout the New Zealand Exclusive Economic Zone by a variety of fishing methods in different target fisheries but mainly as bycatch in bottom trawls targeting hoki (*Macruronus novaezelandiae*), hake (*Merluccius australis*) and ling (*Genypterus blacodes*) and bottom longlines for ling.

There is no seasonality of catch other than on the west coast South Island where catch is related to target fishing of hoki and hake during the winter spawning season. Catches by Japanese and Korean longliners in the mid 1970s are shown in Table 1. Landings from 1982–83 onwards are shown in Table 2, while Figure 1 shows the landings and TACC values for the main RIB stocks since the introduction of the QMS.

Table 1: Japanese and Korean longline catch (t) of ribaldo ("deep-sea cod[1]") from New Zealand waters, probably mostly Chatham Rise and east coast South island, by calendar year from 1975 to 1977.

Year	1975	1976	1977
Japan	2 417	4 920	4 283
Korea	-	-	286

1. Reported as "cods" but considered to be mainly ribaldo. The Korean fleet began fishing in April 1977.

Ribaldo was introduced into the QMS from 1 October 1998, no customary, recreational or other mortality allowances have been set. Historical catch limits up to the most recent fishing year are shown in Table 2. TACCs were increased from 1 October 2006 in RIB 6 to 231 t and in RIB 7 to 330 t. In these stocks landings were above the TACC for a number of years and the TACCs were increased to the average of the previous seven years plus an additional 10%. Current levels of reported landings are below TACCs in most areas, but catches exceeded the TACCs by over a third for RIB 4 in 2013-14, and RIB 7 in 2014-15.

Table 2: Reported landings (t) of ribaldo by QMA for fishing years 1983–84 to 2018–19 and TACCs (t). QMA 10 has no landings and a TACC of 0. Total includes catches from outside the NZ EEZ. [Continued next page]

	RIB 1		RIB 2		RIB 3		RIB 4		RIB 5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1982–83	0		8		15		33		111	
1983–84	0		3		24		21		68	
1984–85	0		4		17		61		21	
1985–86	1		1		26		13		35	
1986–87	4		1		44		20		41	
1987–88	19		4		65		31		56	
1988–89	1		2		33		41		6	
1989–90	8		9		23		28		6	
1990–91	15		15		177		119		34	
1991–92	95		40		160		169		73	
1992–93	131		54		217		228		67	
1993–94	87		70		217		186		23	
1994–95	116		136		437		303		68	
1995–96	121		168		286		253		26	
1996–97	114		188		365		843		64	
1997–98	78		122		141		375		80	
1998–99	24	121	55	176	161	394	290	357	71	52
1999–00	22	121	89	176	264	394	347	357	80	52
2000–01	5	121	107	176	269	394	306	357	78	52
2001–02	7	121	53	176	198	394	370	357	62	52
2002–03	12	121	98	176	211	394	183	357	50	52
2003–04	12	121	120	176	175	394	299	357	50	52
2004–05	28	121	127	176	156	394	379	357	44	52
2005–06	49	121	137	176	126	394	202	357	47	52
2006–07	39	121	125	176	149	394	312	357	49	52
2007–08	53	121	135	176	134	394	173	357	43	52
2008–09	45	121	74	176	216	394	216	357	31	52
2009–10	28	121	63	176	213	394	162	357	27	52
2010–11	42	121	67	176	348	394	137	357	30	52
2011–12	29	121	27	176	174	394	304	357	32	52
2012–13	16	121	74	176	182	394	234	357	35	52
2013–14	29	121	80	176	104	394	492	357	41	52
2014–15	35	121	154	176	122	394	341	357	47	52
2015–16	49	121	125	176	163	394	330	357	43	52
2016–17	43	121	160	176	139	394	212	357	46	52
2017–18	36	121	155	176	182	394	182	357	36	52
2018-19	39	121	69	176	358	394	199	357	36	52

	RIB 6		RIB 7		RIB 8		RIB 9		Total	
	Landing	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1982–83	0		58		0		0		225	
1983–84	1		25		0		0		142	
1984–85	13		18		0		0		134	
1985–86	2		37		0		0		115	
1986–87	10		6		0		0		126	
1987–88	12		68		0		0		255	
1988–89	6		69		1		10		169	
1989–90	13		21		0		0		108	
1990–91	106		55		0		0		521	
1991–92	98		40		0		0		675	
1992–93	96		106		0		0		899	
1993–94	92		42		1		0		718	
1994–95	122		39		2		6		1 231	
1995–96	109		62		0		0		1 025	
1996–97	158		77		1		0		1 824	
1997–98	262		110		1		1		1 214	
1998–99	223	124	243	55	1	1	0	2	1 081	1 282
1999–00	237	124	300	55	< 1	1	< 1	2	1 359	1 282
2000–01	191	124	275	55	< 1	1	< 1	2	1 242	1 282
2001–02	322	124	254	55	0	1	< 1	2	1 311	1 282
2002–03	172	124	338	55	< 1	1	1	2	1 209	1 282
2003–04	205	124	364	55	< 1	1	2	2	1 302	1 282
2004–05	105	124	307	55	< 1	1	2	2	1 240	1 282
2005–06	62	124	336	55	0	1	4	2	1 018	1 282
2006–07	61	231	404	330	0	1	9	2	1 162	1 664
2007–08	80	231	356	330	< 1	1	14	2	992	1 664
2008–09	63	231	456	330	< 1	1	10	2	1 111	1 664
2009–10	104	231	137	330	< 1	1	21	2	755	1 664

Table 2: [Continued]

	RIB 6		RIB 7		RIB 8		RIB 9		Total	
	Landing	TACC	Landings	TACC	Landings	Landings	TACC	Landings	TACC	Landings
2010–11	67	231	198	330	3	1	20	2	913	1 664
2011–12	76	231	177	330	3	1	12	21	835	1 683
2012–13	66	231	180	330	2	1	10	21	799	1 683
2013–14	133	231	291	330	2	1	22	21	1 194	1 683
2014–15	83	231	434	330	1	1	13	21	1 231	1 683
2015–16	67	231	322	330	<1	1	28	21	1 127	1 683
2016–17	92	231	245	330	1	1	15	21	953	1 683
2017–18	182	231	290	330	<1	1	14	21	1 094	1 683
2018-19	113	231	151	330	<1	1	7	21	1 020	1 683

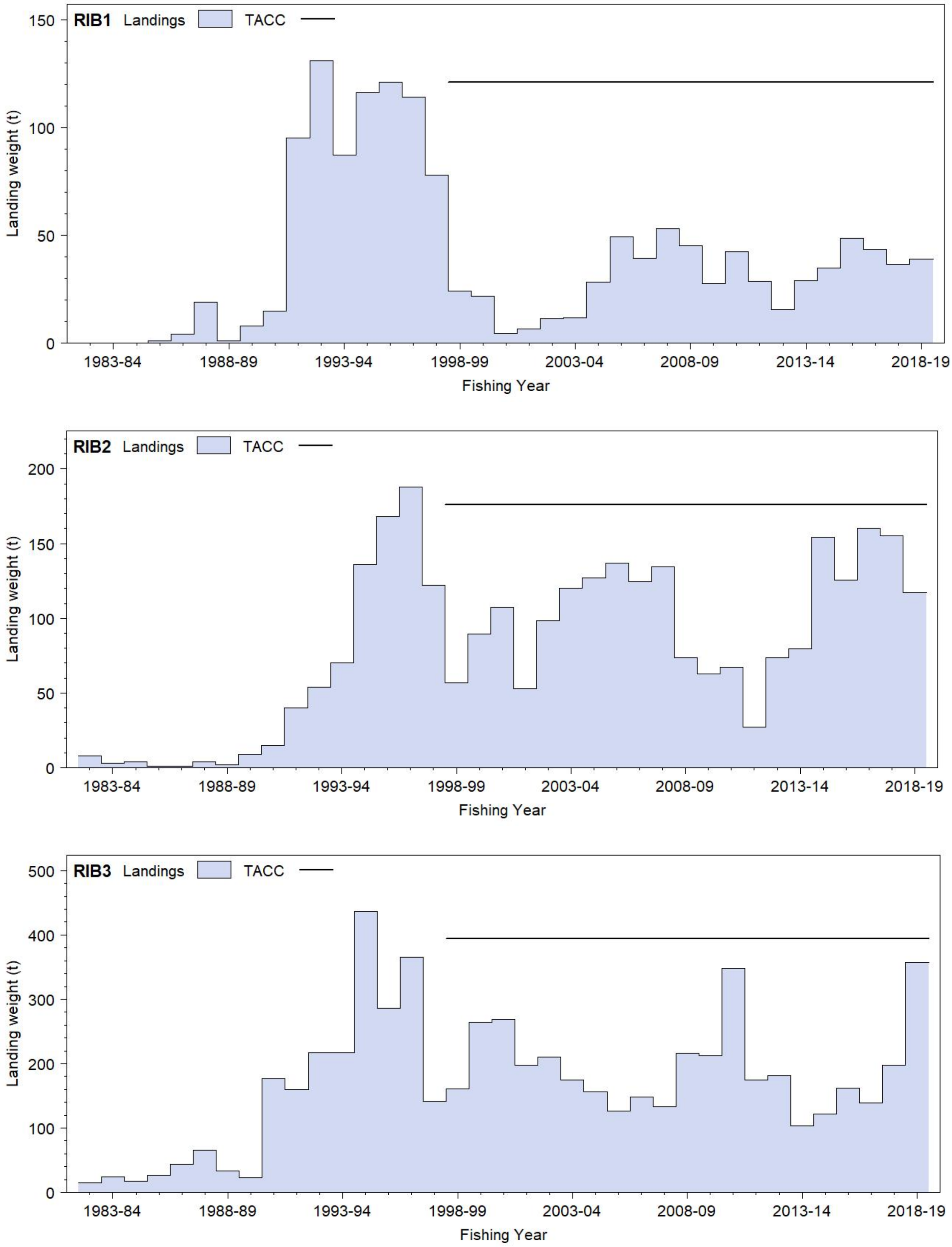
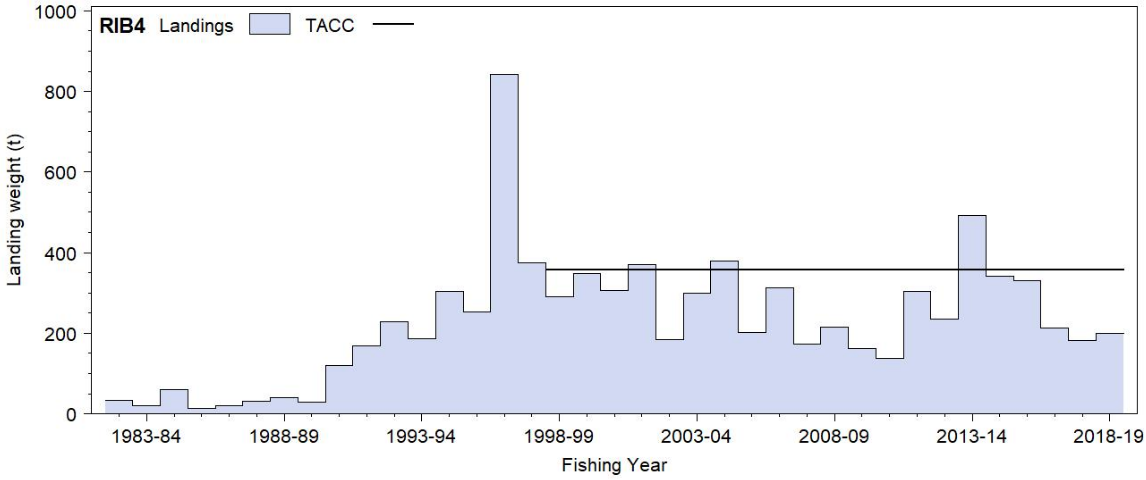
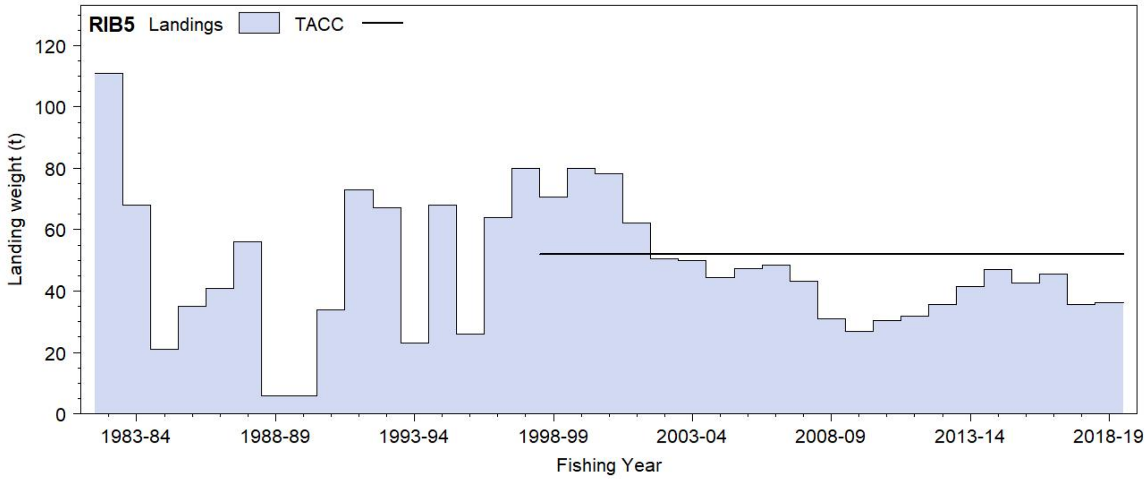


Figure 1: Reported commercial landings and TACC for the seven main RIB stocks. From top to bottom: RIB 1 (Auckland East), RIB 2 (Central East), RIB 3 (South East Coast). [Continued on next page]





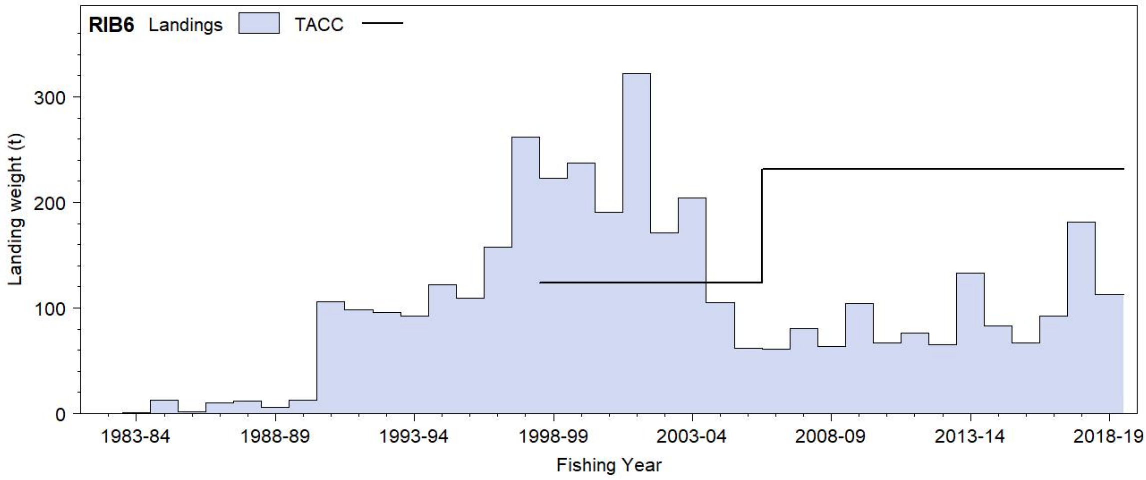


Figure 1: [Continued] Reported commercial landings and TACC for the seven main RIB stocks. From top to bottom: RIB 4 (South East Chatham Rise), RIB 5 (Southland), RIB 6 (Sub-Antarctic). [Continued on next page].

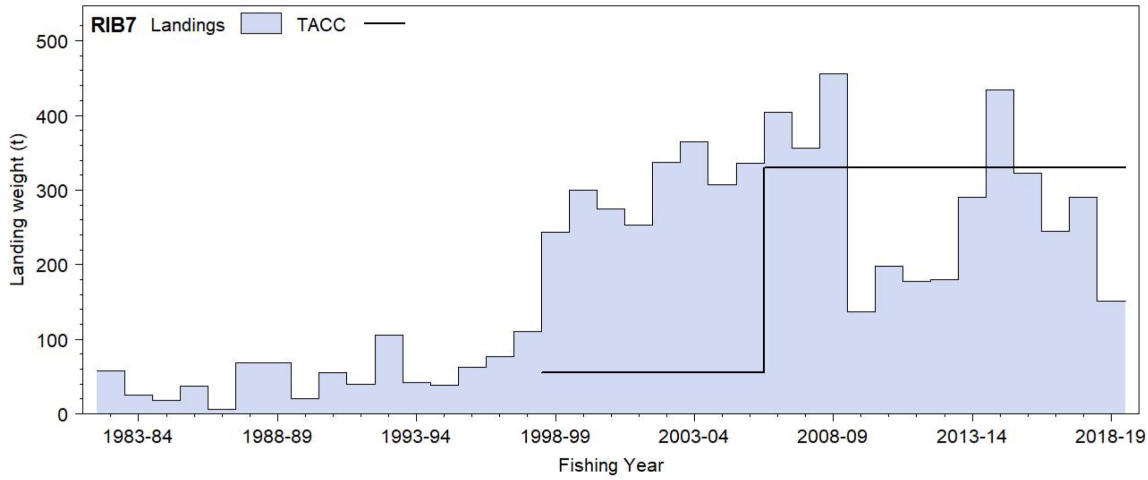


Figure 1 [Continued]: Reported commercial landings and TACC for the seven main RIB stocks. RIB 7 (Challenger).

In RIB 1, ribaldo are taken as bycatch primarily in the ling and to a lesser extent bluenose bottom longline fisheries. There is also some direct targeting of ribaldo by bottom longline. In RIB 2, ribaldo are taken as bycatch primarily in the ling and bluenose bottom longline fisheries and to a lesser extent the hoki and orange roughy bottom trawl fisheries. There is also some direct targeting of ribaldo by bottom longline. In RIB 9 very small amounts of ribaldo are taken as bycatch in orange roughy, cardinal and alfonsino target trawl fisheries and in the ling bottom longline fishery. In all areas, a variety of other fishing methods and target fisheries also report catching ribaldo but only in negligible amounts. Fisheries interactions are described in Section 5.

1.2 Recreational fisheries
Recreational catches are likely to be negligible given the depth and location of ribaldo.

1.3 Customary non-commercial fisheries
Customary catches are likely to be negligible given the depth and location of ribaldo.

1.4 Illegal catch
Estimates of illegal catch are not available. Given the low value of ribaldo illegal catch is likely to be negligible.

1.5 Other sources of mortality
There is no quantitative information on the level of other sources of mortality.

2. BIOLOGY

Ribaldo is known from the North Atlantic Ocean from Iceland to West Africa, the western Mediterranean Sea, the Indian Ocean south of Madagascar and the Pacific Ocean from Australia, New Zealand and Chile. In New Zealand it is widespread and has been caught by research trawl at depths from 200 to 1300 m. It appears to be most common at 500–1000 m. The relatively high catch by bottom longline suggests that it favours rough bottom habitats.

Ribaldo reach maximum fork lengths (FL) of about 75 cm and 65 cm for females and males respectively. Most research trawls have caught fish ranging from 30 to 70 cm FL. The 50% length at sexual maturity has been estimated at 45 cm total length for New Zealand ribaldo (O’Driscoll et al 2003). Analysis of data on female gonad development, collected by the Ministry of Fisheries Observer Programme, indicated a winter/early spring spawning season. Fish do not appear to form large spawning aggregations. Locations at which spawning fish have been observed are the upper North Island (extending outside the EEZ), north-east and west Chatham Rise, the area between the Snares and Auckland Islands shelves, and the west coast of the South Island. Early life history is largely unknown but a few individuals less than 10 cm FL were captured in plankton nets in the upper 200 m of the water column over bottom depths of about 1000 m at the south west end of Chatham Rise. The distribution of juveniles under 28 cm is similar to that of observed spawning females. Juveniles up to 35 cm have been observed in all fished areas of the EEZ except for the Bounty Islands.

Ageing by zone counts of otoliths has been validated using radiometric techniques (Sutton et al 2010) using ribaldo caught on Chatham Rise trawl surveys by *Tangaroa* from 2001 to 2005. Maximum observed ages were 37 and 39 years for females and males respectively. Von Bertalanffy growth parameters are presented in Table 3, estimates of natural mortality (*M*) are presented in Table 4 and length-weight parameters in Table 5.

Ribaldo are caught in low numbers both in research trawl surveys and in observed commercial fisheries making tracking of cohorts by length frequencies difficult. Analyses of trawl survey and observer data has shown that the biomass of females is usually greater than that of males on the Chatham Rise although sex ratios by number are about 1:1. In the Sub-Antarctic and west coast South Island the biomass and numbers of females are significantly greater than males, often over 10:1. Sex ratios elsewhere in the EEZ are less clear.

Table 3: Von Bertalanffy growth parameter values for ribaldo. Source: Sutton et al 2010.

Von Bertalanffy growth parameters	K	t_0	L_∞
RIB 3 & 4 females	0.135	0.221	67.526
RIB 3 & 4 males	0.072	-5.246	61.444
RIB 3 & 4 combined sexes	0.14	-0.287	60.47

Table 4: Estimates of natural mortality (*M*). Source: Sutton et al 2010.

	Females	Males
Natural mortality (*M*)	0.106	0.112

Table 5: Length-weight parameter values for ribaldo.

Fishstock					Estimate	Source
Weight = a(length)^b (Weight in g, length in cm total length)						
		Females			Males	
		a	b	a	b	
RIB 3 & 4		0.0037	3.27	0.0053	3.18	Sutton et al (2010)
RIB 5 & 6	-	-	-	-		
					Sexes combined	
				a	b	
RIB 3 & 4				0.004289	3.237753	Sutton et al (2010)
RIB 5 & 6				0.0039	3.15	Bagley et al (unpublished data)

3. STOCKS AND AREAS

It is not known whether different regional stocks of ribaldo occur in New Zealand waters but it is possible that there are separate stocks based on natural bathymetric boundaries. The Working Group had previously agreed on five fishstocks based on the four main fishing areas plus the Kermadec area, i.e., the east coast of the North Island (QMAs 1 and 2), Chatham Rise and east coast South Island (QMAs 3 and 4), Southland and Sub-Antarctic (QMAs 5 and 6), the west coast of New Zealand (QMAs 7, 8 and 9) and QMA 10. Reviews of all available information in 2010 and 2014 indicated that the main fishing areas are still as found previously. The reviews also indicated spawning activity in all areas, except RIB 8 and RIB 10 (for which there is no information). This is not inconsistent with the management of the fishery by the current 10 FMAs. Highly skewed sex ratios in the Sub-Antarctic and west coast South Island have unknown implications for stock structure.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

The Middle Depths Working Group agreed in February 2011 that relative biomass estimates of ribaldo from middle depth trawl surveys on the Chatham Rise and the Sub-Antarctic were suitable for monitoring major changes in ribaldo abundance for RIB 3 & 4 and RIB 5 & 6 respectively. The west coast South Island trawl survey on *Tangaroa* may provide an index of abundance but with just three years of data points (2000, 2012, 2013) there was insufficient data with which to draw any conclusions. It is not certain that standardised CPUE indices from the hoki bottom trawl fisheries in RIB 3 & 4, and in RIB 5 & 6 track abundance. Standardised CPUE indices for these two areas are flat and indices from the corresponding trawl surveys are also flat, making it difficult to validate CPUE. CPUE indices from the spawning hoki and hake target fisheries in RIB 7 show a possible steady decline but with just three data points in the corresponding trawl survey and a lack of any other information it is not possible to validate the indices. There are no stock monitoring indices available for RIB 1, 2, 8 or 9.

4.2 Biomass estimates

Estimates of biomass are given in Table 6.

4.3 Yield estimates and projections

MCY cannot be estimated.

CAY cannot be estimated.

4.5 Other yield estimates and stock assessment results

No information is available.

Table 6: Biomass indices (t) and coefficients of variation (CV) of ribaldo from *Tangaroa* trawl surveys (Assumptions: areal availability, vertical availability and vulnerability = 1). NB: estimates are for the core strata only for the respective time series. [Continued on next page]

Chatham Rise	Vessel	Trip code	Date	Biomass (t)	%CV
	Tangaroa	TAN9106	Dec 91–Feb 92	417	12.2
		TAN9212	Dec 92–Feb 93	336	17.2
		TAN9401	Jan 94	602	10.8
		TAN9501	Jan–Feb 95	406	19.7
		TAN9601	Dec 95–Jan 96	470	18.2
		TAN9701	Jan 97	333	21.3
		TAN9801	Jan 98	510	14.3
		TAN9901	Jan 99	395	18
		TAN0001	Dec 99–Jan 00	387	20.8
		TAN0101	Dec 00–Jan 01	762	18.3
		TAN0201	Dec 01–Jan 02	417	13.2
		TAN0301	Dec 02–Jan 03	455	18.1
		TAN0401	Dec 03–Jan 04	535	15.6
		TAN0501	Dec 04–Jan 05	491	14.2
		TAN0601	Dec 05–Jan 06	313	16.9
		TAN0701	Dec 06–Jan 07	380	15
		TAN0801	Dec 07–Jan 08	479	14.3
		TAN0901	Dec 08–Jan 09	463	12.7
		TAN1001	Jan 10	416	19.9
		TAN1101	Jan 11	396	16.7
		TAN1201	Jan 12	469	14.6
		TAN1301	Jan 13	428	15.7
		TAN1401	Jan 14	477	18
Sub-Antarctic	*Tangaroa*	TAN9105	Nov–Dec 91	1 035	11.2
		TAN9211	Nov–Dec 92	389	18.6
		TAN9310	Nov–Dec 93	996	12.8
		TAN0012	Nov–Dec 00	873	14
		TAN0118	Nov–Dec 01	1 017	17.2
		TAN0219	Nov–Dec 02	656	17.5
		TAN0317	Nov–Dec 03	653	18.9
		TAN0414	Nov–Dec 04	951	16.5

Table 6 [Continued]

Sub-Antarctic	Vessel	Trip code	Date	Biomass (t)	%CV
	Tangaroa	TAN0515	Nov–Dec 05	721	14.6
		TAN0714	Nov–Dec 07	1 062	13.5
		TAN0617	Nov–Dec 06	780	16.4
		TAN0813	Nov–Dec 08	658	18
		TAN0911	Nov–Dec 09	1 056	13.4
		TAN1117	Nov–Dec 11	1 017	17.2
		TAN1215	Nov–Dec 12	787	16.7
		TAN1412	Nov–Dec 14		
		TAN9204	Apr–May 92	768	17.1
		TAN9304	May–Jun 93	1 162	15.1
		TAN9605	Mar–Apr 96	989	16.7
		TAN9805	Apr–May 98	837	14.2

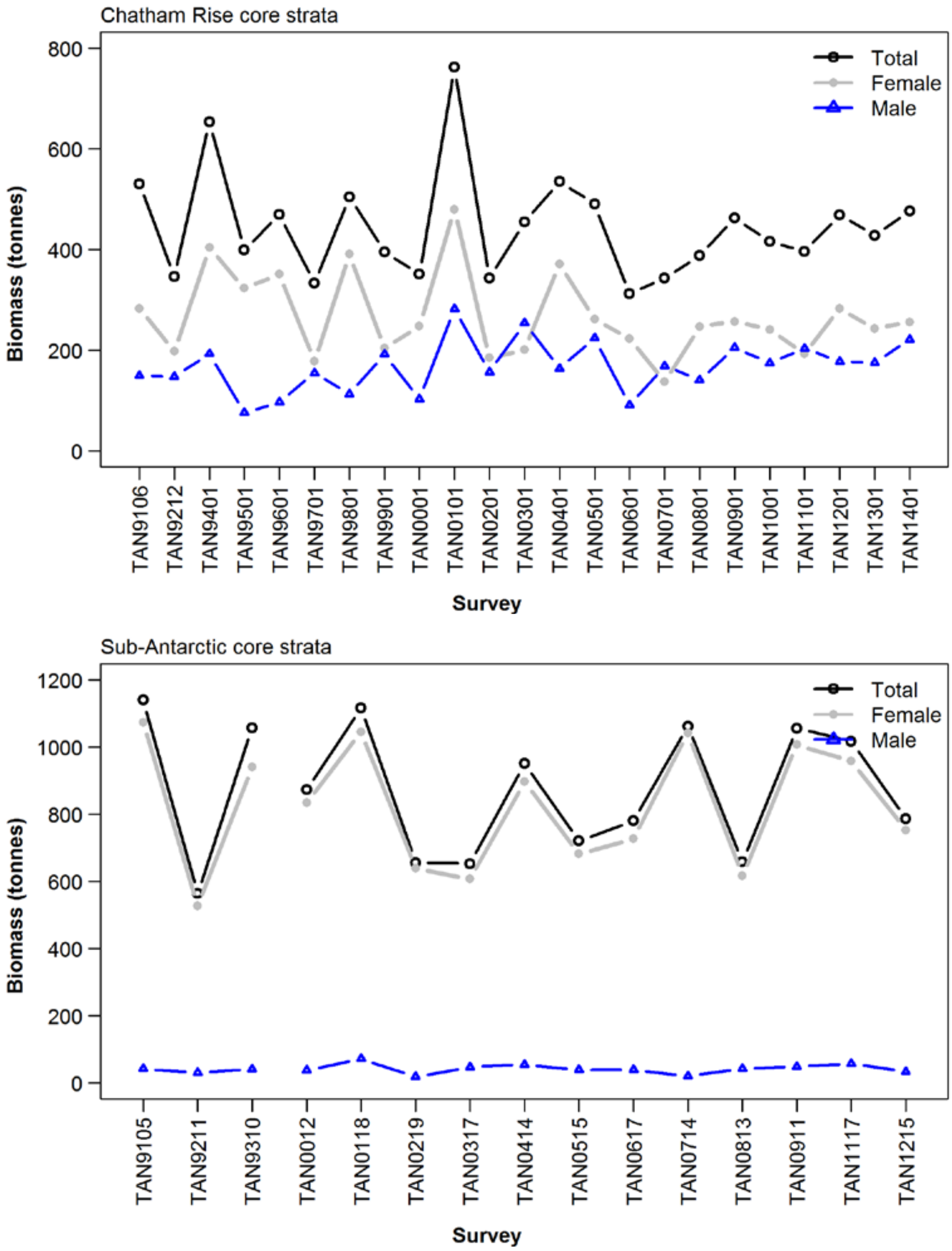


Figure 2: Doorspread biomass estimates of ribaldo by sex from the Chatham Rise 1991 to 2014 (upper) and Sub-Antarctic 1991 to 1993 and 2000 to 2012 (lower), from *Tangaroa* trawl surveys.

5. STATUS OF THE STOCKS

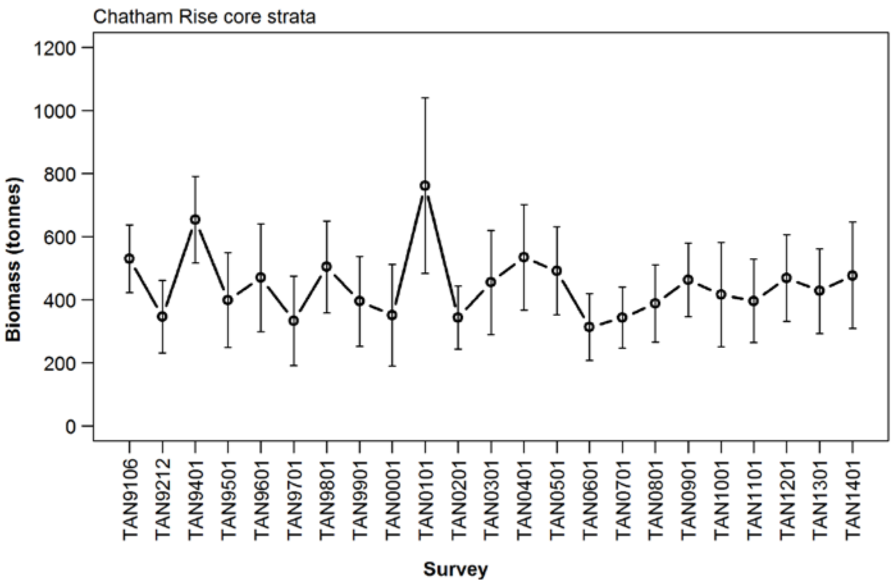
- **RIB 1, 2, 7, 8 and 9**

There are no accepted stock monitoring indices available for RIB 1, 2, 7, 8 or 9.

- **RIB 3 & 4**

Stock Status	
Year of Most Recent Assessment	2014
Reference Points	Target: Not established but 40% B_0 assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	Unknown
Status in relation to Limits	Unlikely (< 40%) to be below soft limit Unlikely (< 40%) to be below hard limit
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Doorspread biomass estimates of ribaldo (error bars are ± two standard deviations) from the Chatham Rise, from *Tangaroa* surveys from 1991 to 2014.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The relative biomass index of ribaldo from summer middle depth trawl surveys of the Chatham Rise is relatively flat. Precision is generally good in this time series (< 20%). Although numbers of individual ribaldo caught are low the Working Group considered this index to be suitable to monitor major trends in this stock.
Recent Trend in Fishing Mortality or Proxy	-
Other Abundance Indices	-
Trends in Other Relevant Indicators of Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Stock size is Likely (> 60%) to remain near current levels under recent catches, that were well below the current TACC before 2013–14

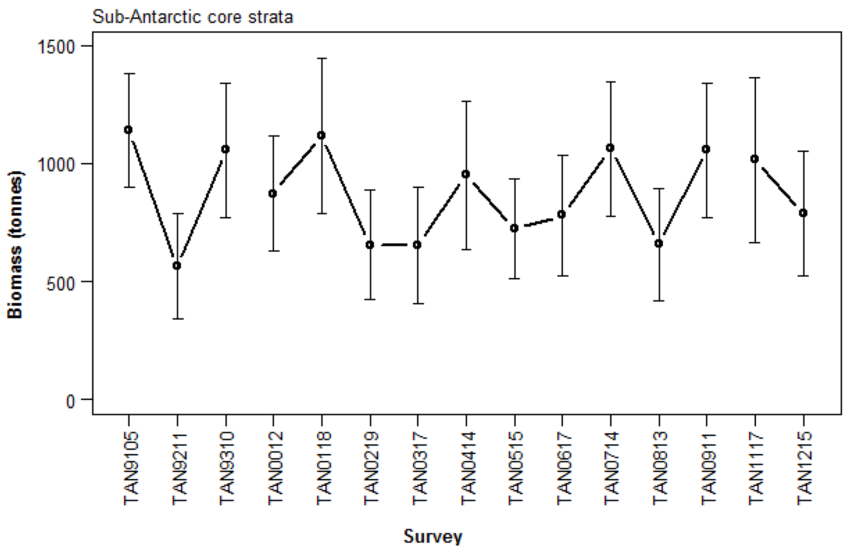
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft limit: Unlikely (< 40%) for recent catches Hard limit: Unlikely (< 40%) for recent catches
Probability of Current Catch or TACC causing Overfishing to continue or commence	Unknown as catches increased in 2013–14

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Evaluation of agreed trawl survey indices thought to index RIB 3 & 4 abundance	
Assessment Dates	Latest assessment: 2014	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	Data collected on trawl surveys	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Low numbers of individuals caught on trawl surveys.	
Qualifying Comments		
-		
Fishery Interactions		
In RIB 3 & 4, ribaldo are taken as bycatch primarily in the ling and hoki bottom trawl fisheries and ling bottom longline fishery. Interactions with other species are currently being characterised.		

- **RIB 5 & 6**

Stock Status	
Year of Most Recent Assessment	2014
Reference Points	Target: Not established but 40% B_0 assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	Unknown
Status in relation to Limits	Unlikely (< 40%) to be below Unlikely (< 40%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Doorspread biomass estimates of ribaldo (error bars are ± two standard deviations) from the Sub-Antarctic, from *Tangaroa* surveys from 1991 to 1993, and 2000 to 2012.

Fishery and Stock Trends		
Recent Trend in Biomass or Proxy	Relative biomass estimates of ribaldo from summer middle depth surveys of the Sub-Antarctic show a relatively flat index. CVs are consistently low in this time series (< 20%). Although numbers of individual ribaldo caught are low the Working Group considered this index to be suitable to monitor major trends in this stock.	
Recent Trend in Fishing Mortality or Proxy	Unknown	
Other Abundance Indices	-	
Trends in Other Relevant Variables of Indicators	-	
Projections and Prognosis		
Stock Projections or Prognosis	Stock size is Likely (> 60%) to remain near current levels under current catches and TACCs	
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft limit: Unlikely (< 40%) Hard limit: Unlikely (< 40%)	
Probability of Current Catch or TACC causing Overfishing to continue or commence	Unknown	
Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial quantitative stock assessment	
Assessment Method	Evaluation of agreed trawl survey indices thought to index RIB 5 & 6 abundance	
Assessment Dates	Latest assessment: 2014	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Data collected on trawl surveys	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	Low numbers of individuals caught on trawl surveys; and unknown implications of highly skewed sex ratios (females usually make up > 90% of biomass) for stock structure. Observer data also shows skewed sex ratios favouring females.	

Qualifying Comments
-

Fishery Interactions
In RIB 5 & 6, ribaldo are mainly caught as bycatch in hoki and ling bottom trawl fisheries and ling bottom longline fisheries. Interactions with other species are currently being characterised.

TACCs and reported landings for the 2017–18 fishing year are summarised in Table 7.

Table 7: Summary of TACCs (t) and reported landings (t) of ribaldo for the most recent fishing year.

Fishstock		QMA	2018–19 Actual TACC	2018–19 Estimated Landings
RIB 1	Auckland (East)	1	121	39
RIB 2	Central (East)	2	176	69
RIB 3	South-east (Coast)	3	394	358
RIB 4	South-east (Chatham)	4	357	199
RIB 5	Southland	5	52	36
RIB 6	Sub-Antarctic	6	231	113
RIB 7	Challenger	7	330	151
RIB 8	Central (West)	8	1	<1
RIB 9	Auckland (West)	9	21	7
RIB 10	Kermadec	10	0	0
Total			1 683	1 020

6. FOR FURTHER INFORMATION

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McMillan, P J; Hart, A C (1998) Summary of biology and commercial landings, and a stock assessment of ribaldo *Mora moro* (Risso, 1810), in New Zealand waters. New Zealand Fisheries Assessment Research Document 1998/9. 16 p. (Unpublished report held in NIWA library, Wellington.)

O'Driscoll, R L; Booth, J D; Bagley, N W; Anderson, O F; Griggs, L H; Stevenson, M L; Francis, M P (2003) Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand deepwater fish, pelagic fish, and invertebrates. *NIWA Technical Report 119*. 377 p.

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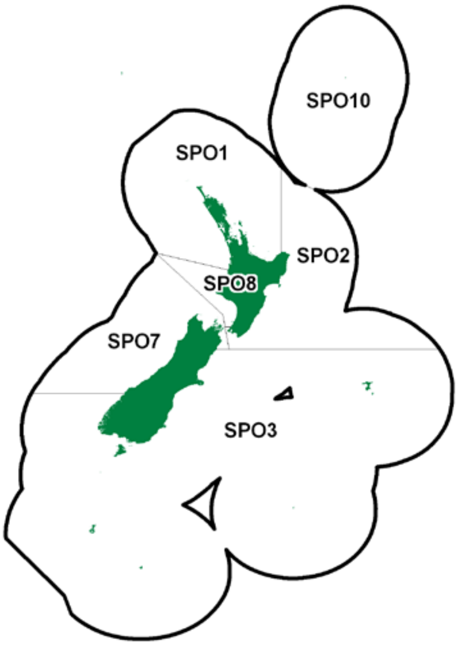
RIG (SPO)

(Mustelus lenticulatus)
Pioke, Makoo



1. FISHERIES SUMMARY

Rig was introduced into the Quota Management System on 1 October 1986. Table 1 gives the TACs, TACCs, and allowances that were applicable to the 2018–19 fishing year.

Table 1: TACs (t), TACCs (t), and allowances (t) for rig in 2019–20.

Fishstock	Recreational allowance	Customary non-commercial allowance	Other sources of mortality	TACC	TAC
SPO 1	25	20	15	692	752
SPO 2	10	5	7	108	130
SPO 3	60	20	30	600	710
SPO 7	33	15	27	298	373
SPO 8	–	–	–	310	401
SPO 10	–	–	–	10	10
Total	128	60	64	1 966	2 309

1.1 Commercial fisheries

Rig are caught in coastal waters throughout New Zealand. Most of the set net catch is taken in water less than 50 m deep during spring and summer, when rig aggregate inshore. Before the introduction of the QMS in 1986, 80% of the commercial catch was taken by bottom set net and most of the remainder by trawl. Total reported landings of rig increased rapidly during the 1970s and averaged about 3200 t per year during the late 1970s and early 1980s (Table 2, Table 3). Since then, a larger proportion has been taken by trawlers as bycatch. The most important bottom set net fisheries are at Ninety Mile Beach, Kaipara Harbour, Manukau Harbour, South Taranaki Bight–Tasman Bay/Golden Bay, Canterbury Bight, Kaikoura, and Hauraki Gulf.

Following the introduction of rig into the QMS in 1986, landings declined to less than half those of the previous decade in response to TACCs which were set at levels that were lower than previous catches. The total TACCs were subsequently increased to a maximum of 2098 t from 1994–95 to 1996–97, allowing landings to rise to 1888 t in 1996–97. Total landings subsequently declined steadily to a minimum of 1186 t during the fishing year 2008–09, before increasing to an annual average of just under 1400 t in more recent years (fishing years 2010–11 to 2018–19, Table 4).

Table 2: Reported total New Zealand landings (t) of rig for the calendar years 1965 to 1985. Sources: MAF and FSU data.

Year	Landing	Year	Landing	Year	Landing	Year	Landing	Year	Landing
1965	723	1970	930	1975	1 841	1980	3 000	1985	3 222
1966	850	1971	1 120	1976	2 610	1981	3 006		
1967	737	1972	1 011	1977	3 281	1982	3 425		
1968	677	1973	–	1978	3 300	1983	3 826		
1969	690	1974	2 040	1979	2 701	1984	3 562		

TACCs for all Fishstocks except SPO 10 were increased by 20% for the 1991–92 fishing year under the Adaptive Management Programme (AMP). Another TACC increase (from 454 t to 600 t) was implemented in SPO 3 for the 2000–01 fishing year. The TACCs for SPO 1, SPO 2, and SPO 8 reverted to the pre-AMP levels in the 1997–98 fishing year, when these Fishstocks were removed from the AMP in July 1997. All AMP programmes ended on 30 September 2009. The TACC for SPO 2 was increased from 72 t to 86 t from 1 October 2004 under the low knowledge bycatch framework (Table 4). In 2011–12 the SPO 2 TACC was further increased to 108 t. The SPO 7 TACC was raised to 246 t for 1 October 2015 based on increased abundance. The TACC for SPO 7 was decreased to 221 t on 1 October 2006, as a result of a stock assessment based on a declining CPUE. SPO was introduced into Schedule 6 on 1 May 2012, which means that rig that are alive and likely to survive can be released (but must be reported as Destination “X”). Figure 1 shows the historical landings and TACC values for the main SPO stocks.

In October 1992, the conversion factors for headed and gutted, and dressed, rig were both reduced from 2.00 to 1.75. They were each further reduced to 1.55 in 2000–01. Landings and TACCs prior to 2000–01 have not been adjusted for the changes in the conversion factor in the accompanying tables.

The Banks Peninsula Marine Mammal Sanctuary was established in 1988 by the Department of Conservation under the Marine Mammal Protection Act 1978, for the purpose of protecting Hector’s dolphins. The sanctuary extends 4 nautical miles from the coast from Sumner Head in the north to the Rakaia River mouth in the south. Before 1 October 2008, no set nets were allowed within the sanctuary from 1 November to the end of February. For the remainder of the year, set nets were allowed, but could only be set from an hour after sunrise to an hour before sunset, be no more than 30 metres long, with only one net per boat which was required to remain tied to the net while it was set.

Voluntary set net closures were implemented by the SEFMC from 1 October 2000 to protect nursery grounds for rig and elephant fish and to reduce interactions between commercial set nets and Hector’s dolphins in shallow waters. The closed area extended from the southernmost end of the Banks Peninsula Marine Mammal Sanctuary to the northern bank of the mouth of the Waitaki River. This area was closed for the entire year for a distance of 1 nautical mile offshore and for 4 nautical miles offshore for the period 1 October to 31 January.

From 1 October 2008, a suite of regulations intended to protect Māui and Hector’s dolphins was implemented for all of New Zealand by the Minister of Fisheries.

For SPO 1, there have been three changes to the management regulations affecting set net fisheries which target school shark off the west coast of the North Island. The first was a closure to set net fishing from Maunganui Bluff to Pariokariwa Point for a distance of 4 nautical miles on 1 October 2003. This closure was extended by the Minister to 7 nautical miles on 1 October 2008. An appeal was made by affected fishers who were granted interim relief by the High Court, allowing set net fishing beyond 4 nautical miles during daylight hours between 1 October and 24 December during three consecutive years: 2008–2010. The west coast North Island set net closure to 7 nautical miles offshore was extended around Cape Egmont to Hawera in 2012, with fishing allowed between 2 and 7 nautical miles if an Observer was on board the vessel.

For SPO 3, commercial and recreational set netting was banned in most areas from 1 October 2008 to 4 nautical miles offshore from the east coast of the South Island, extending from Cape Jackson in the Marlborough Sounds to Slope Point in the Catlins. Some exceptions were allowed, including an exemption for commercial and recreational set netting to only one nautical mile offshore around the Kaikoura Canyon, and permitting set netting in most harbours, estuaries, river mouths, lagoons, and inlets except for the Avon-Heathcote Estuary, Lyttelton Harbour, Akaroa Harbour, and Timaru

Harbour. In addition, trawl gear within 2 nautical miles of shore was restricted to flatfish nets with defined low headline heights. Commercial and recreational set netting was banned in most areas to 4 nautical miles offshore, extending from Slope Point in the Catlins to Sandhill Point east of Fiordland and in Te Waewae Bay. An exemption permitted set netting in harbours, estuaries, and inlets. In addition, trawl gear within 2 nautical miles of shore was restricted to flatfish nets with defined low headline heights.

For SPO 7, both commercial and recreational set netting were banned to 2 nautical miles offshore from the South Island west coast, with the recreational closure effective for the entire year and the commercial closure restricted to the period 1 December to the end of February. The closed area extends from Awarua Point north of Fiordland to the tip of Cape Farewell at the top of the South Island. Both sides of Farewell Spit were voluntarily closed to set nets, beginning in October 2006, to protect large females in a known pupping area. The net effect of these set net area closures was to greatly reduce the importance of the SPO 7 set net fishery, particularly off the west coast. Fifty-six percent of the average 2000–01 to 2002–03 annual set net catch came from the combined west coast statistical areas, and 36% came from Tasman Bay/Golden Bay. The equivalent percentages from 2015–16 to 2017–18 are 3% for the west coast areas and 96% from Tasman Bay/Golden Bay. Over the same period, the overall set net catch has declined from 64% of the catch to 31%, with the balance taken up by bottom trawl and (in the most recent three years) Danish seine nets.

Table 3: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	SPO 1	SPO 2	SPO 3	SPO 7	SPO 8	Year	SPO 1	SPO 2	SPO 3	SPO 7	SPO 8
1931–32	28	0	0	0	0	1957	115	69	60	108	28
1932–33	30	0	0	0	0	1958	106	73	87	119	34
1933–34	29	0	0	0	0	1959	136	76	98	105	30
1934–35	33	0	0	0	0	1960	118	77	141	153	26
1935–36	31	0	0	0	0	1961	118	98	160	158	27
1936–37	73	0	8	0	0	1962	126	100	269	124	40
1937–38	56	1	5	0	0	1963	142	81	193	126	27
1938–39	32	1	70	0	0	1964	157	78	243	132	24
1939–40	10	1	12	0	0	1965	145	90	360	98	30
1940–41	13	1	54	1	0	1966	171	118	386	141	38
1941–42	18	0	32	0	0	1967	129	108	266	200	33
1942–43	49	1	33	1	0	1968	147	89	236	173	31
1943–44	42	6	44	5	1	1969	145	83	299	141	21
1944	60	10	14	7	4	1970	167	97	436	192	38
1945	56	5	24	10	8	1971	183	95	603	203	37
1946	71	12	8	19	9	1972	139	69	629	138	36
1947	73	27	28	45	7	1973	189	105	775	133	54
1948	51	26	51	43	7	1974	417	134	1118	249	126
1949	57	33	60	49	9	1975	390	146	896	255	157
1950	87	48	62	73	17	1976	629	230	906	610	233
1951	94	46	101	68	22	1977	723	307	1327	541	382
1952	115	41	132	63	21	1978	701	330	1225	638	404
1953	117	56	95	45	20	1979	614	232	1138	349	368
1954	103	68	40	58	39	1980	499	252	2667	470	387
1955	93	49	42	84	47	1981	618	188	1443	413	343
1956	106	54	38	77	29	1982	840	210	1255	629	399

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.
3. 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. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 4: Reported landings (t) of rig by Fishstock from 1985–86 to 2018–19 and actual TACCs (t) from 1986–87 to 2018–19. QMS data from 1986–present. [Continued on next page]

Fishstock	SPO 1		SPO 2		SPO 3		SPO 7		SPO 8	
FMA (s)	1 & 9		2		3,4,5, & 6		7		8	
	Landing	TACC	Landing	TACC	Landing	TACC	Landing	TACC	Landing	TACC
1985–86*	845	–	96	–	921	–	367	–	465	–
1986–87	366	540	55	60	312	330	233	240	125	240
1987–88	525	614	66	68	355	347	262	269	187	261
1988–89	687	653	68	70	307	352	239	284	212	295
1989–90	689	687	61	70	292	359	266	291	206	310
1990–91	656	688	63	71	284	364	268	294	196	310
1991–92	878	825	105	85	352	430	290	350	145	370
1992–93	719	825	90	86	278	432	324	350	239	370

Fishstock	SPO 1		SPO 2		SPO 3		SPO 7		SPO 8	
FMA (s)	1 & 9		2		3,4,5, & 6		7		8	
	Landing	**TACC**	**Landing**	**TACC**	**Landing**	**TACC**	**Landing**	**TACC**	**Landing**	**TACC**
1993–94	631	829	96	86	327	452	310	350	255	370
1994–95	666	829	88	86	402	454	341	350	273	370
1995–96	603	829	107	86	408	454	400	350	330	370
1996–97	681	829	99	86	434	454	397	350	277	370
1997–98	621	692	85	72	442	454	325	350	287	310
1998–99	553	692	86	72	426	454	336	350	235	310
1999–00	608	692	86	72	427	454	330	350	219	310
2000–01	554	692	81	72	458	600	338	350	174	310
2001–02	436	692	86	72	391	600	282	350	216	310
2002–03	477	692	86	72	417	600	264	350	209	310
2003–04	481	692	81	72	354	600	293	350	203	310
2004–05	429	692	108	86	366	600	266	350	208	310
2005–06	345	692	110	86	389	600	288	350	163	310
2006–07	400	692	101	86	423	600	265	221	176	310
2007–08	297	692	104	86	472	600	231	221	220	310
2008–09	297	692	106	86	328	600	233	221	222	310
2009–10	302	692	114	86	371	600	229	221	246	310
2010–11	311	692	106	86	395	600	229	221	220	310
2011–12	328	692	119	108	433	600	227	221	198	310
2012–13	369	692	106	108	463	600	226	221	120	310
2013–14	349	692	125	108	489	600	230	221	192	310
2014–15	324	692	117	108	556	600	235	221	181	310
2015–16	316	692	106	108	557	600	248	246	180	310
2016–17	318	692	101	108	543	600	258	246	197	310
2017–18	317	692	89	108	648	600	247	246	159	310
2018–19	238	692	105	108	615	600	265	246	142	310

	SPO 10			
FMA (s)	10		Total	
	Landings	**TACC**	**Landings§**	**TACC**
1985–86*	0	–	2 906	–
1986–87	0	10	1 091	1 420
1987–88	0	10	1 395	1 569
1988–89	0	10	1 513	1 664
1989–90	0	10	1 514	1 727
1990–91	0	10	1 467	1 737
1991–92	0	10	1 770	2 070
1992–93	< 1	10	1 650	2 072
1993–94	0	10	1 619	2 097
1994–95	0	10	1 769	2 098
1995–96	0	10	1 848	2 098
1996–97	0	10	1 888	2 098
1997–98	0	10	1 760	1 888
1998–99	0	10	1 635	1 888
1999–00	0	10	1 670	1 888
2000–01	0	10	1 607	2 034
2001–02	0	10	1 411	2 034
2002–03	0	10	1 453	2 034
2003–04	0	10	1 412	2 034
2004–05	0	10	1 377	2 048
2005–06	0	10	1 295	2 048
2006–07	0	10	1 365	1 919
2007–08	0	10	1 324	1 919
2008–09	0	10	1 186	1 919
2009–10	0	10	1 262	1 919
2010–11	0	10	1 260	1 919
2011–12	0	10	1 305	1 941
2012–13	0	10	1 283	1 941
2013–14	0	10	1 386	1 941
2014–15	0	10	1 413	1 941
2015–16	0	10	1 406	1 966
2016–17	0	10	1 417	1 966
2017–18	0	10	1 459	1 966
2018–19	0	10	1 364	1 966

*FSU data.
§Includes landings from unknown areas before

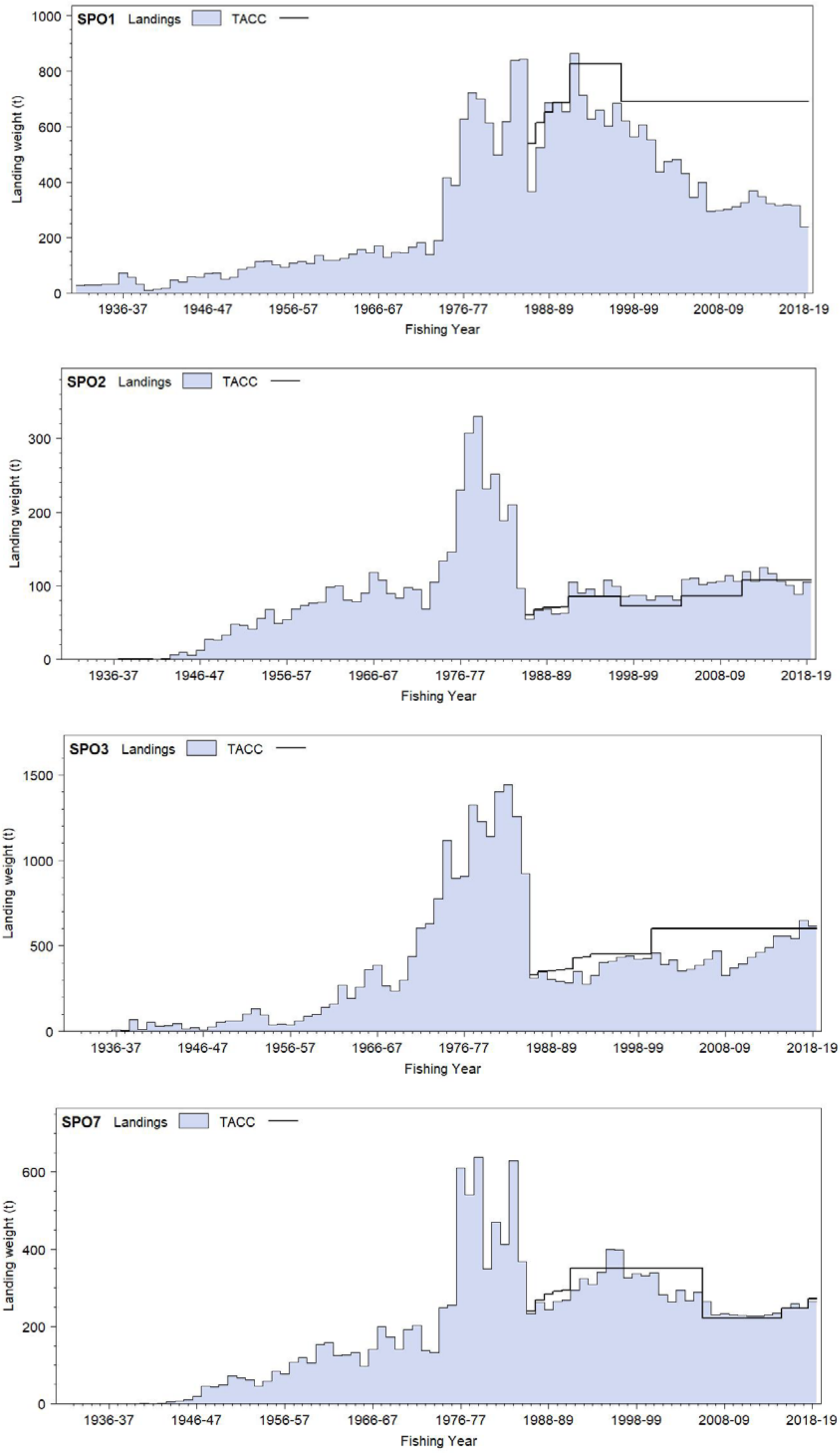


Figure 1: Historical landings and TACCs for the five main SPO stocks. From top to bottom: SPO 1 (Auckland East) and SPO 2 (Central East), SPO 3 (South East Coast), SPO 7 (Challenger). [Continued on next page.]

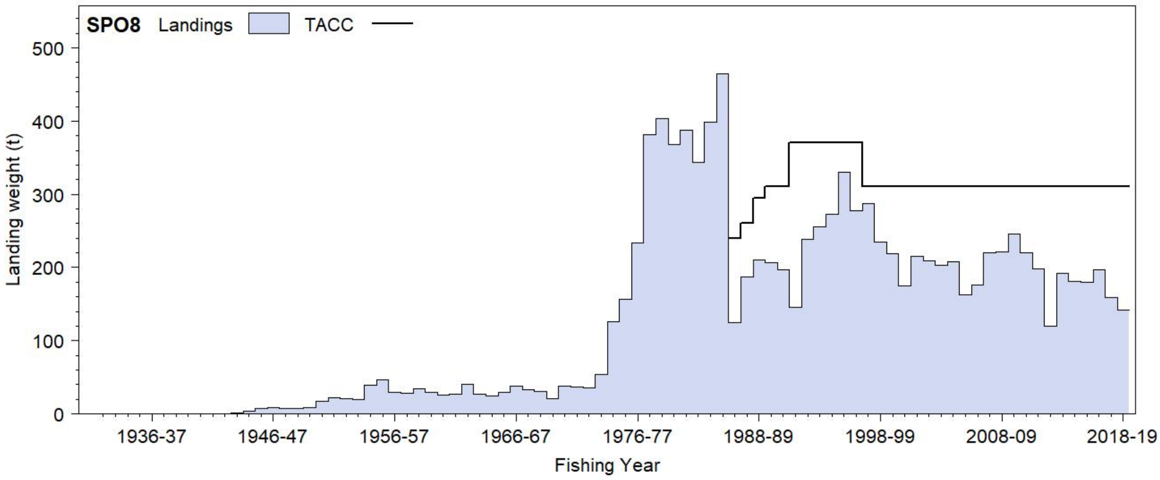


Figure 1 [Continued]: Historical landings and TACCs for the five main SPO stocks. SPO 8 (Central Egmont).

1.2 Recreational fisheries

Rig are the most commonly recreationally caught shark in New Zealand (Wynne-Jones et al 2014). Rig are caught by recreational fishers throughout New Zealand. They are predominantly taken on rod and reel (75.2%) with some taken on longline (16.6%) and less in set net (7.2%). The rod and reel catch is taken predominantly from land (57.5%) and trailer boat (29.6%), highlighting the importance of this species to land-based fishers.

1.2.1 Management Controls

The main method used to manage recreational harvests of rig is daily bag limits. Spatial and method restrictions also apply. Fishers can take up to 20 rig as part of their combined daily bag limit in the Auckland and Kermadec, Central, and Challenger Fishery Management Areas. Fishers can take up to 5 rig as part of their combined daily bag limit in the Fiordland and South-East Fishery Management Areas. Fishers can take up to 3 rig as part of their combined daily bag limit in the Kaikoura Fishery Management Area. Spatial closures for set netting and minimum mesh sizes for rig are also in place in all areas. There is currently no bag limit in place for the Southland Fishery Management Area.

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 for rig were calculated using an offsite approach, the offsite regional telephone and diary survey approach. 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). The harvest estimates provided by these telephone diary surveys (Table 5) are no longer considered reliable.

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 development and implementation of a national panel survey for the 2011–12 fishing year (Wynne-Jones et al 2014). The panel survey used face-to-face interviews of a random sample of New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information collected in standardised phone interviews. Estimated catches in numbers of fish were converted to weights using mean weights estimated from boat ramp surveys (Hartill & Davey 2015). The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019, Davey et al 2019).

Recreational catch estimates from the two national panel surveys are given in Table 5. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 5: Recreational harvest estimates for rig stocks. Early surveys were carried out in different years in the regions: South in 1991–92, Central in 1992–93, and North in 1993–94. Early survey harvests are presented as a range to reflect the considerable uncertainty in the estimates. The telephone/diary surveys ran from December to November but are denoted by the January calendar year. National panel surveys ran throughout the October to September fishing year but are denoted by the January calendar year.

Stock	Year	Method	Number of fish	Total weight (t)	CV
SPO 1	1994	Telephone/diary	11 000	5–25	–
	1996	Telephone/diary	28 000	35	0.31
	2000	Telephone/diary	13 000	17	0.30
	2012	Panel survey	7 780	8.5	0.25
	2018	Panel survey	3 830	6.1	0.34
SPO 2	1993	Telephone/diary	5 000	5–15	–
	1996	Telephone/diary	4 000	–	–
	2000	Telephone/diary	16 000	21	0.58
	2012	Panel survey	7 172	7.8	0.26
	2018	Panel survey	3 044	4.8	0.32
SPO 3	1992	Telephone/diary	12 000	15–30	0.22
	1996	Telephone/diary	12 000	15	0.20
	2000	Telephone/diary	43 000	57	0.32
	2012	Panel survey	8 142	8.9	0.24
	2018	Panel survey	9 372	14.9	0.26
SPO 7	1993	Telephone/diary	8 000	10–25	0.39
	1996	Telephone/diary	19 000	24	0.20
	2000	Telephone/diary	33 000	33	0.38
	2012	Panel survey	19 126	20.9	0.25
	2018	Panel survey	11 688	18.6	0.27
SPO 8	1993	Telephone/diary	18 000	20–60	0.43
	1994	Telephone/diary	1 000	0–5	–
	1996	Telephone/diary	7 000	–	–
	2000	Telephone/diary	7 000	9	0.48
	2012	Panel survey	5 499	6.0	0.45
	2018	Panel survey	7 435	11.8	0.41

1.3 Customary non-commercial fisheries

Maori fishers traditionally caught large numbers of "dogfish" during the last century and early this century. Rig was probably an important species, although spiny dogfish and school shark were also taken. The historical practice of having regular annual fishing expeditions, during which thousands of dogfish were sun-dried on wooden frames, is no longer prevalent. However, rig are still caught in small quantities by customary non-commercial fishers in parts of the North Island, especially the harbours of the Auckland region. Quantitative information on the current level of customary non-commercial take is not available.

1.4 Illegal Catch

Quantitative information on the level of illegal catch is not available.

1.5 Other sources of mortality

Unknown quantities of juvenile rig are caught by set nets placed in harbours and shallow bays. Quantitative information on the level of other sources of mortality is not available.

2. BIOLOGY

Rig are born at a total length (TL) of 25–30 cm. Off the South Island male and female rig attain maturity at 5–6 y (about 85 cm) and 7–8 y (about 100 cm), respectively (Francis & Ó Maolagáin 2000). Rig in the Hauraki Gulf mature earlier – 4 y for males and 5 y for females – and at smaller sizes (Francis & Francis 1992 a & b). Longevity is not known because few large fish have been aged. However, a male rig that was mature at tagging was recaptured after nearly 14 years of liberty, suggesting a longevity of 20 years or longer. Females reach an average maximum length of 151 cm and males 126 cm TL.

Rig give birth to young during spring and summer, following a 10–11 month gestation. Most females begin a new pregnancy immediately after parturition, and therefore breed annually. The number of young produced increases exponentially with the length of the mother, and ranges from 2 to 37 (mean about 11). Young are generally born in shallow coastal waters, especially in harbours and estuaries, around the North Island and South Island. They grow rapidly during their first summer and then disappear as water temperatures drop in autumn when they presumably move into deeper water.

Rig make extensive coastal migrations, with one tagged female moving at least 1160 km. Over half of the tagged rig that were recaptured had moved over 50 km, and over half of the females had moved more than 200 km. Females travel further than males, and mature females travel further than immature females. Biological parameters relevant to stock assessment are shown in Table 6.

Table 6: Estimates of biological parameters for rig.

Fishstock					**Estimate**	**Source**
1. Natural mortality (*M*)						
All					0.2–0.3	Francis & Francis (1992a)
2. Weight = a(length)^b (Weight in g, length in cm total length).						
	Females			Males		
	a	b		a	b	
SPO 3	3.67×10^{-7}	3.54		1.46×10^{-6}	3.22	Francis (1979)
SPO 7&8	9.86×10^{-7}	3.32		$3.85 \times 10^{-}$	3.01	Blackwell (unpubl. data)
3. von Bertalanffy growth parameters						
			Both Sexes			
			L	k	t_o	
SPO 3 &7			147.2	0.119	-2.35	Francis & Ó Maolagáin (2000)

3. STOCKS AND AREAS

Information relevant to determining rig stock structure in New Zealand was reviewed in 2009 (Smith 2009, Blackwell & Francis 2010, Francis 2010). These reviews concluded that the existing QMAs are a suitable size for rig management, although the boundaries between biological stocks are poorly defined, especially in the Cook Strait region. Insufficient tagging had occurred in SPO 1 to determine whether division of that stock into separate 1E and 1W stocks is warranted. Genetic, biological, fishery, and tagging data were all considered, but the evidence available for the existence and geographical distribution of biological stocks is poor. Some differences were found in CPUE trends at a small spatial scale but stock separation at the indicated spatial scales seems unlikely, and the CPUE differences may have resulted from processes acting below the stock level, such as localised exploitation of different sexes or different size classes of sharks. Genetic and morphological evidence indicate that a separate undescribed species of *Mustelus* occurs at the Kermadec Islands, but it is not known if rig occur there.

The most useful source of information was a tagging programme undertaken mainly in 1982–84 (Francis 1988a). However, most tag releases were made around the South Island, so little information was available for North Island rig. Male rig rarely moved outside the release QMA, even after more than five years at liberty. Female rig were more mobile than male rig, with about 30% of recaptures reported beyond the release QMA boundaries within 2–5 years of release. The proportion reported beyond the release QMA increased steadily with time. However, few females moved more than one

QMA away from the release point. Because males move shorter distances than females, a conservative management approach is to set rig QMAs at a size appropriate for male stock ranges.

4. STOCK ASSESSMENT

Estimates of fishery parameters and abundance

New Zealand rig stock status has been assessed based on standardised CPUE analyses of the set net and bottom trawl fisheries in SPO 3 and SPO 7 since the early 2000s. A comprehensive CPUE analysis of the SPO 1 set net and bottom trawl fisheries was done in 2011 by Kendrick & Bentley (2012). Starr & Kendrick (2015) did an EEZ-wide CPUE analysis of all five rig QMAs in 2013. This extensive analysis was repeated in 2016 (Starr & Kendrick 2017) and again in 2019 (Starr & Kendrick in prep.).

All CPUE analyses presented here are based on commercial catch and effort data reported by fishers using compulsory statutory forms. These forms have changed over the period covered by these analyses, most notably in 2006–07 for set net and 2007–08 for trawl, when the form changed from a daily report to an "event" report, where an event is defined as a net set or a tow made. To derive continuous series of relative abundance, the catch and effort data collected with the new event-based forms needed to be converted into the equivalent daily form to create a series that spanned the change in form type. However, in the old system a fisher only needed to report the estimated catch of the top 5 species (by weight) in a day, whereas the equivalent reporting on the event-based forms is the top 8 species for the event.

It is furthermore necessary to base the rig CPUE analysis on landed rather than estimated weight, because this species is processed at sea and many fishers report the estimated catch as processed weight instead of green [whole] weight. This is achieved by allocating the trip landings proportionately to each fishing day, based on the reported estimated catch, so the explanatory information associated with each day can be incorporated into the CPUE analysis. For trips when rig are landed and sold at the end of a trip, but there is no estimated rig catch information for the trip, the procedure defaults to using the effort to make the allocation. When this happens, it means that the CPUE for the trip is directly proportional to the effort expended, not where rig are caught. This is not usually a problem when only a small proportion (less than 10%) of the trips fall into this category, but can introduce bias when 50–80% of trips have no estimated catches, as occurs for rig caught in bottom trawl fisheries. Because of this problem, the 2016 Plenary agreed to use data amalgamated to the level of a complete trip for all rig bottom trawl CPUE analyses. The auxiliary information on location of capture and intended target species was retained by assigning each trip with the value of the most frequent statistical area occupied and the most common target species.

The set net CPUE data were prepared by amalgamating the effort data and other associated information (month, year, target species, vessel, statistical area) to represent a day of fishing. The procedure assigns the most frequent statistical area and target species for that day of fishing to the trip/date record. All estimated catches for the day were summed and the five species with the greatest catch were assigned to the date. Landings were then assigned to each daily record in one of two ways: 1) by allocating the landings for the trip proportionately to the estimated catch for each day of fishing; or 2) calculating a "vessel correction factor" (*vcf*) for each vessel in a year (Kendrick & Bentley 2012). This factor is then applied to all estimated catches for that vessel in that year. Only *vcf* values in a specified range (0.75 to 2.0) were used, dropping all remaining vessels. This latter procedure is required in SPO 1 because fishers in that QMA tend to hold back their catch rather than deliver it to a Licensed Fish Receiver, thus breaking the link between the top part of the form which holds the effort, location of catch, and the catch estimate and the bottom part of the form which holds the actual catch information.

The set net and bottom trawl CPUE analyses were conducted in a similar manner and included: a) identification of core vessels which participated consistently in the fishery for a reasonably long period so that the analysis could be confined to these vessels; b) a stepwise selection of explanatory variables, with each step selecting the variable with the greatest remaining explanatory power, after forcing fishing year (the abundance variable) as the first variable. The available explanatory variables included fishing year (forced), month, vessel, statistical area, target species, duration of fishing, and length of net set (for the set net analysis) or number of tows (for the bottom trawl analysis). The landing information had been corrected for changes in conversion factors that have occurred over the history of the dataset as well as to eliminate trips with unreasonably large landings (Starr & Kendrick 2016). Three standardised analyses were conducted for all bottom trawl fisheries: a) a lognormal non-zero catch model; b) a binomial presence/absence catch model; and c) a delta-lognormal model that combines the two series, using the method of Vignaux (1994). Both Inshore Working Groups have agreed to use combined models which integrate the signal from the tows with positive catch with the signal from presence/absence models based on the same data. These methods are preferred for use as the basis for monitoring species that are taken by bottom trawl, especially those for species taken predominantly as bycatch. Simulation work has shown that the use of the combined series accounts for reporting trends as well as trends in the incidence of capture (Langley 2015). Only standardised models based on positive catch records were used for the set net catch/effort data. This is because zero catch records are relatively rare (less than 5% in most instances and only rarely >10%). Experience has shown that models which combine positive and zero catch information are nearly indistinguishable from the positive catch model when the zero catch records are less than 10% of the total records.

SPO 1

Standardised CPUE indices were calculated for five SPO 1 setnet fisheries by modelling (GLM) non-zero catches by core vessels targeting rig and other shark species when this species was reviewed in 2016. Two coastal bottom trawl fisheries targeting a range of species were analysed by combining a non-zero catch series with a binomial presence/absence series. The SPO 1 set net analyses were complicated by the fact that up to 50% of the set net landings were accumulated ashore using intermediate destination codes for subsequent landing to a Licensed Fish Receiver, thus breaking the link between effort and landing within a trip. Estimated catches are unreliable in rig fisheries because many fishers report the processed weight rather than the equivalent green weight. This problem was solved by applying a “vessel correction factor” (*vcf*), calculated for each vessel and year, to correct the estimated catch observations (see above).

SPO 1E

In 2016, three CPUE analyses for SPO 1E were presented to the Working Group: a) a target shark (NSD, SPO, SHK, SPD) set net fishery operating in the Firth of Thames (Area 007) [SN(007)]; b) a target shark set net fishery operating in the remaining SPO 1E Statistical Areas (002 to 006 and 008 to 010) [SN(coast)]; and c) a mixed target species (SNA, TRE, GUR, JDO, BAR, TAR) bottom trawl fishery operating in all SPO 1E Statistical Areas (002 to 010) [BT(coast)].

The Southern Inshore Working Group (SINSWG) and Plenary gave the SN(007) series a research rating of ‘2’ because, although this fishery targets mature female rig and the diagnostics were considered credible, it provides an index of abundance for only a portion of the total area. The Plenary gave the BT(coast) and SN(coast) series research ratings of ‘3’ because annual catches were unacceptably low and, in the case of the set net index, the fishing locations were widely dispersed and occupied sporadically. The latter two series were not updated in 2019 (Starr & Kendrick 2019) because of their low research rating. The SN(007) analysis was updated, showing a relatively strong upturn since the 2016 analysis (Figure 2).

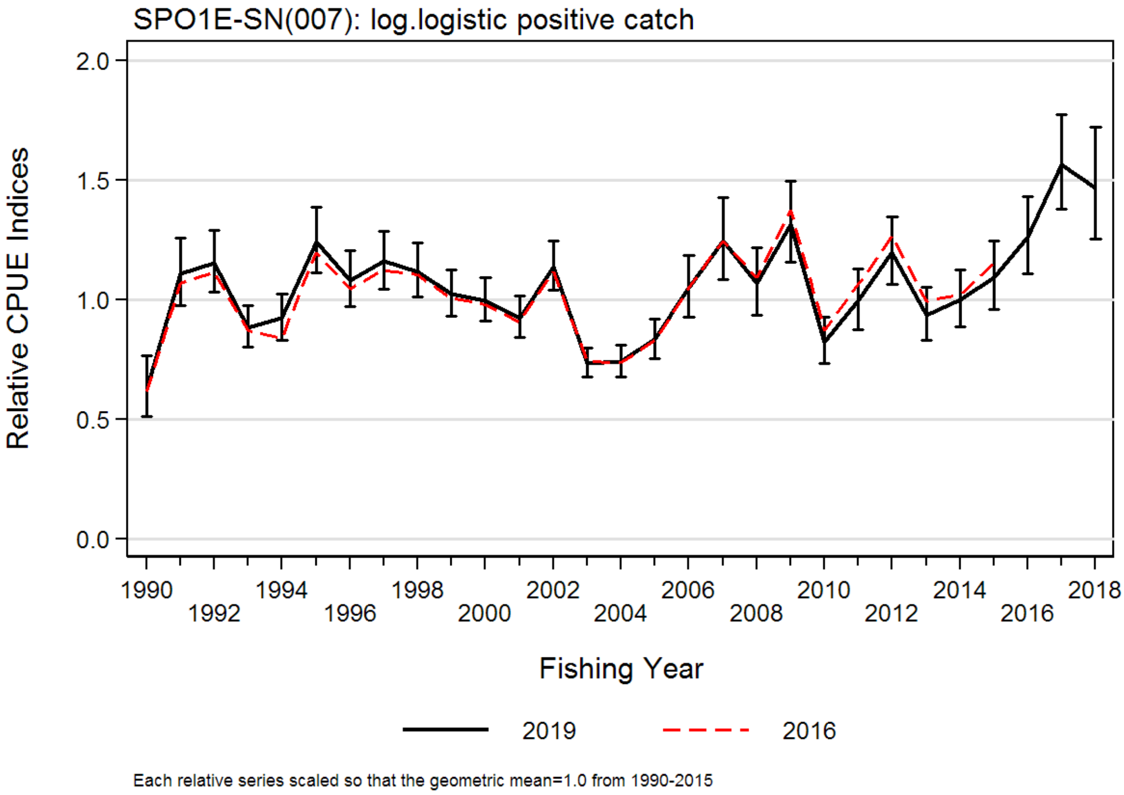


Figure 2: Standardised CPUE for SPO 1E in the target shark set net in the Firth of Thames (Statistical Area 007) [SN(007)]. Error bars show 95% confidence interval on the prediction.

SPO 1W

In 2016, four CPUE analyses for SPO 1W were presented to the Working Group: a) a target shark (NSD, SPO, SHK, SPD) set net fishery operating in Manukau Harbour (Statistical Area 043) [SN(043)]; b) a target shark set net fishery operating in Kaipara Harbour (Statistical Area 044) [SN(044)]; c) a target shark set net fishery operating in all the remaining SPO 1W Statistical Areas (042, 045–048) plus the most northerly SPO 8 Statistical Area (041) [SN(41–47)]; and d) a mixed target species (SNA, TRE, GUR, JDO, BAR, TAR) bottom trawl fishery operating in all SPO 1W Statistical Areas (042, 045–048) [BT(coast)] outside the harbours plus the most northerly SPO 8 Statistical Area (041).

The 2016 Plenary assigned the BT index a quality ranking of ‘1’, but noted that although the analysis was credible the method of capture does not representatively sample large female rig. The two harbour-based set net indices were given a ranking of ‘2’ (medium or mixed quality) because they are probably indexing localised abundance. The Plenary rejected the coastal set net index as an index of abundance on account of the considerable impact the dolphin closures have had on this fishery.

The coastal set net index series was not updated in 2019 (Starr & Kendrick 2019) because of its rejection in 2016. The other three series were updated in 2019. The coastal BT series has shown a slow increasing trend since the mid-2000s, although the 2016–17 and 2017–18 indices appear to have dropped relative to 2015–16. The SN(043 Manukau Harbour) series shows a strong decline in the early portion of the series whereas the SN(044 Kaipara Harbour) series shows no trend throughout the 1990s. Both set net indices show a slowly declining trend since the late 1990s, although there is a suggestion that the Kaipara Harbour series may be showing an increase from 2013–14 (Figure 3).

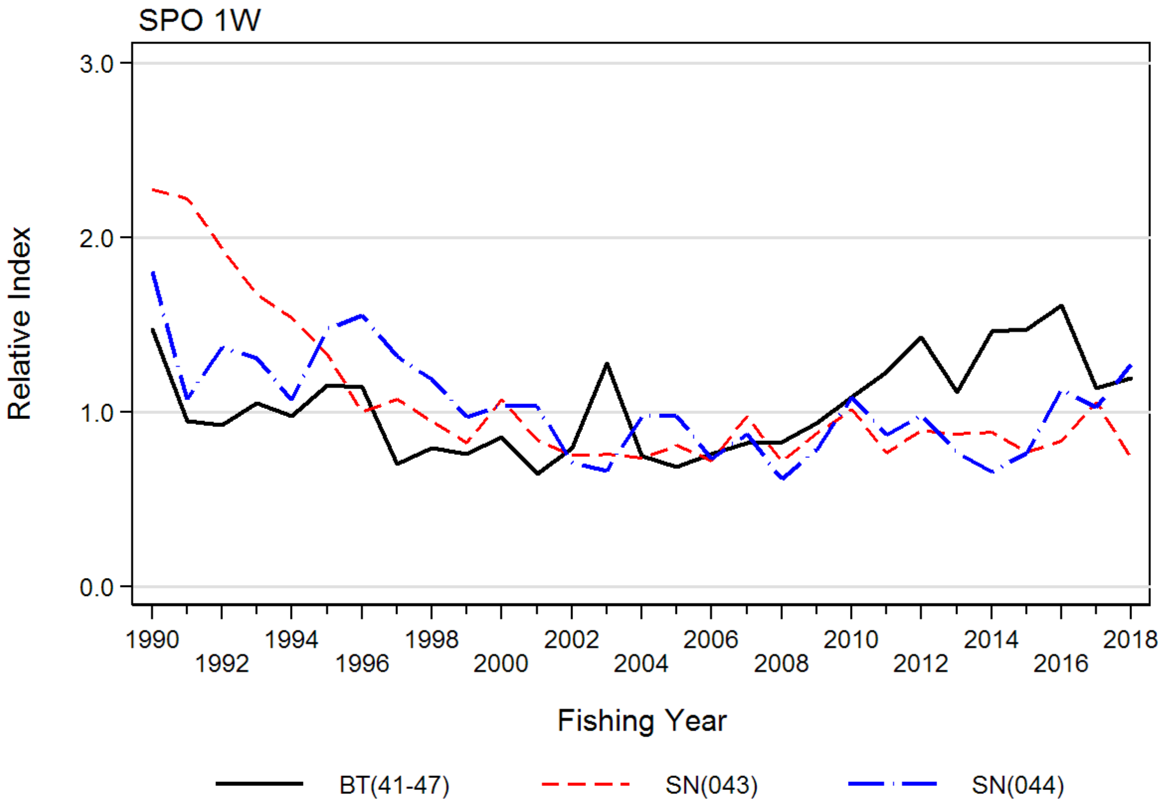


Figure 3: Comparison of standardised CPUE for SPO 1W in three fisheries: a) target shark set net in Manukau Harbour (Area 043) [SN(043)]; b) target shark set net in Kaipara Harbour (Area 044) [SN(044)]; c) coastal bottom trawl north of Cape Egmont [BT(41-47)].

SPO 2

As done for the 2016 review, a trip-based bottom trawl series was used to index SPO 2 relative abundance from 1989–90 to 2017–18 (Starr & Kendrick 2019). As before, the corresponding set net analysis was not repeated due to the small amount of available data. The SPO 2 landing data, regardless of the method of capture, did not exhibit the behaviour observed in SPO 1 of landing to temporary holding receptacles. Only one SPO 2 (BT) analysis was conducted in 2019; this analysis defined the data set by selecting trips which fished exclusively in the Statistical Areas 011–015 and targeted flatfish, gurnard, or tarakihi.

The trip-based combined SPO 2 series constructed from bottom trawl data shows a gradually increasing trend from 1989–90 to 2002–03, after which the series drops to a nadir in 2009–10 (Figure 4). This is followed by an increasing trend, culminating in 2016–17, the highest level in the series and more than double the 2009–10 index. The 2017–18 index dropped 16% relative to the 2016–17 index but is still more than 50% greater than the series geometric mean. The Plenary gave the BT(trip) series an overall assessment quality rank of ‘1’ but noted that, though the analysis was credible, the method of capture does not representatively sample large female rig.

Establishing B_{MSY} compatible reference points

The Plenary agreed to use a Proxy for B_{MSY} based on the average CPUE during 2005–2015, a period of relatively stable CPUE and catches.

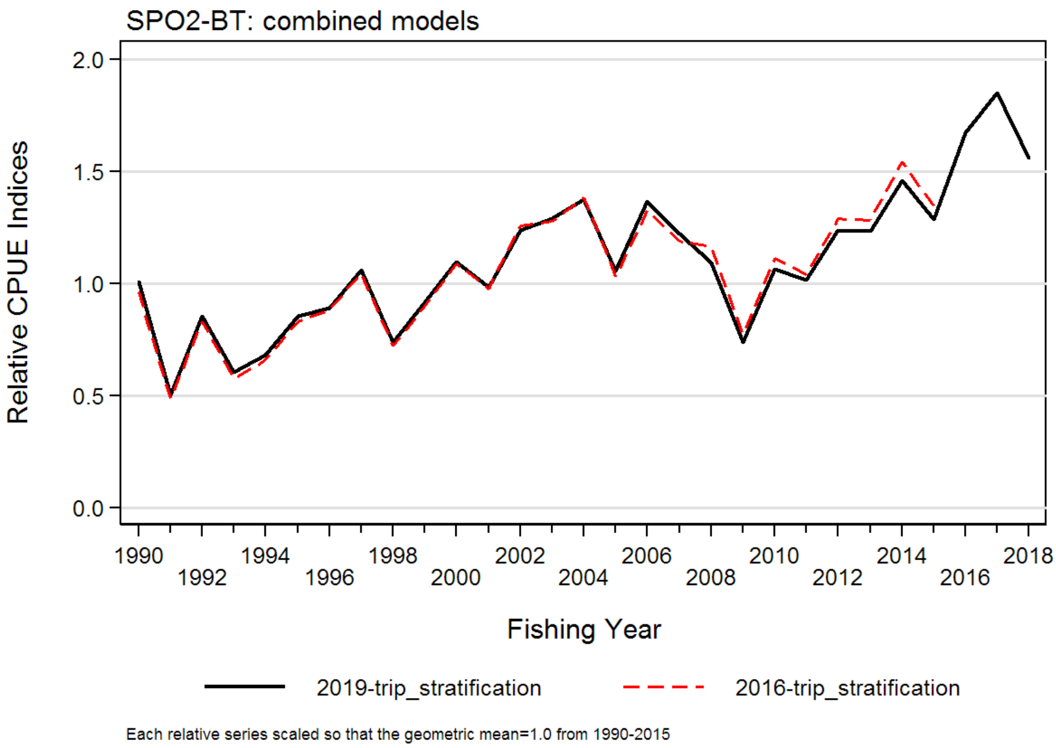


Figure 4: Standardised combined delta-lognormal CPUE series for SPO 2 bottom trawl based on trips which landed rig from Statistical Areas 011 to 015 and targeted flatfish, red gurnard, or tarakihi up to 2017–18. Also plotted is the equivalent series from the 2016 SPO 2 review.

SPO 3

Rig in SPO 3 are mostly landed in the shark set net and bottom trawl fisheries directed at a range of species, with additional small amounts landed by Danish seine vessels. Two CPUE standardisations were accepted by the Working Group in 2016, one based on a shark target set net fishery (SN[SHK]) and the other based on a mixed target species (flatfish, barracouta, red cod, tarakihi, stargazer, elephant fish, and red gurnard) bottom trawl fishery (BT[All]). Two bottom trawl series had previously been constructed from the bottom trawl data, separating the target flatfish data from the target species that are taken at deeper depths. However, the switch to a trip-based analysis showed that the two SPO 3 bottom trawl fisheries (FLA and MIX) had very similar CPUE trends for rig. The SINSWG agreed that it would be advisable to perform a single analysis on the full suite of bottom trawl target species, amalgamated at the level of a trip. The final two fisheries (set net and trawl) will have different selectivities, harvesting a different size range of rig, with the set net fishery taking larger fish and the trawl fishery taking juveniles and sub-adults.

The SPO 3 landing data, regardless of the method of capture, did not exhibit the behaviour observed in SPO 1 of landing to temporary holding receptacles.

The 2019 review (Starr & Kendrick 2019) repeated the BT(All) and SN(SHK) analyses. The trawl series shows an increasing trend (1989–90 to 2017–18), whereas the SN(SHK) series fluctuates without trend (Figure 5). The point estimates for rig from the East Coast South Island (ECSI) winter trawl survey core strata largely follow the pattern of the BT(All) series, except for the 1991, 2008, and 2018 observations which show large deviations from the BT(All) series. The 2016 Plenary assigned all three indices of abundance (SN(SHK), BT(ALL), and ECSI Trawl Survey) a quality ranking of ‘1’, but noted that the method of capture used for the BT(All) analysis and the ECSI trawl survey does not representatively sample mature rig. The 2019 review undertook an event based (tow-by-tow) standardised analysis to test whether amalgamating the data to the level of a complete trip was introducing bias. Figure 5 shows that the two series agree well in the overlapping years.

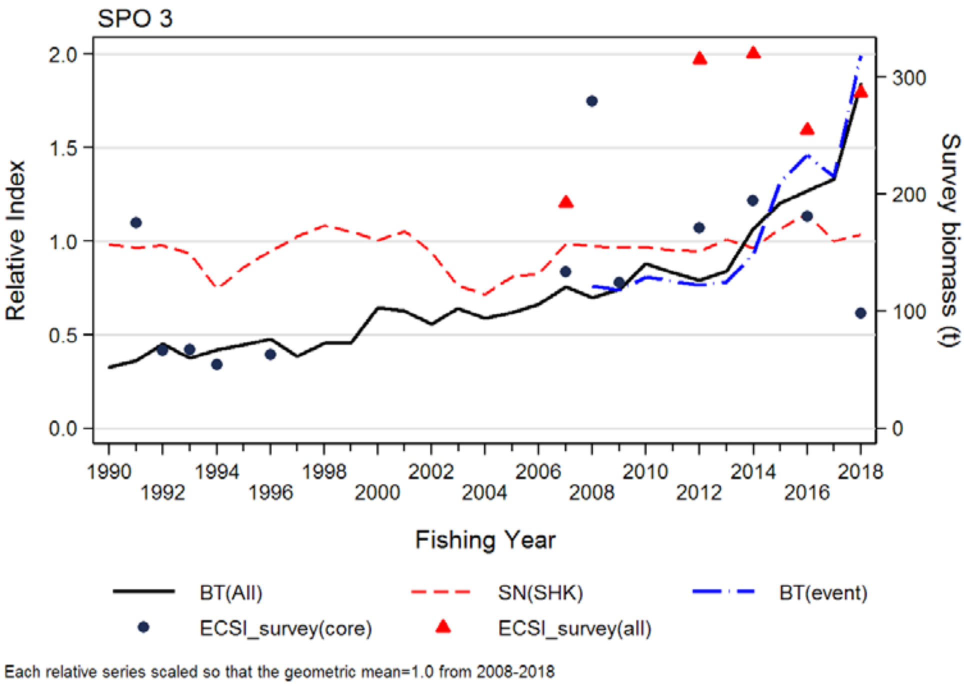


Figure 5: Comparison of the standardised indices from the three CPUE series for SPO 3: a) BT(All): trip-based mixed target species (including flatfish) bottom trawl fishery; b) SN(SHK): target shark species setnet fishery; c) BT(event): tow-by-tow mixed target species bottom trawl data; also shown are 12 index values collected for rig from the East Coast South Island winter trawl survey core strata and combined core and shallow strata ('all').

Biomass estimates: ECSI

Rig biomass estimates in the East Coast South Island winter trawl survey core strata (30–400 m) are generally higher in recent years compared with the 1990s (Figure 6, Table 7). The additional biomass captured in the 10–30 m depth range accounts for 30%, 46%, 39%, 29%, and 66% of the biomass in the core plus shallow strata (10–400 m) for 2007, 2012, 2014, 2016, and 2018 respectively, indicating that it is necessary to monitor the shallower strata as well as the core area for this species. This observation is particularly important for 2018: the 2018 SPO estimate in the core strata dropped nearly 50% relative to the 2016 estimate (Figure 5), whereas the total 2018 estimate, which includes the shallow strata, was greater than the equivalent 2016 estimate (Figure 6, Table 7). The core strata (30–400 m) of the ECSI winter trawl survey are not fully representative of the rig population because there is a large and variable proportion of the rig biomass inside the 30 m depth contour.

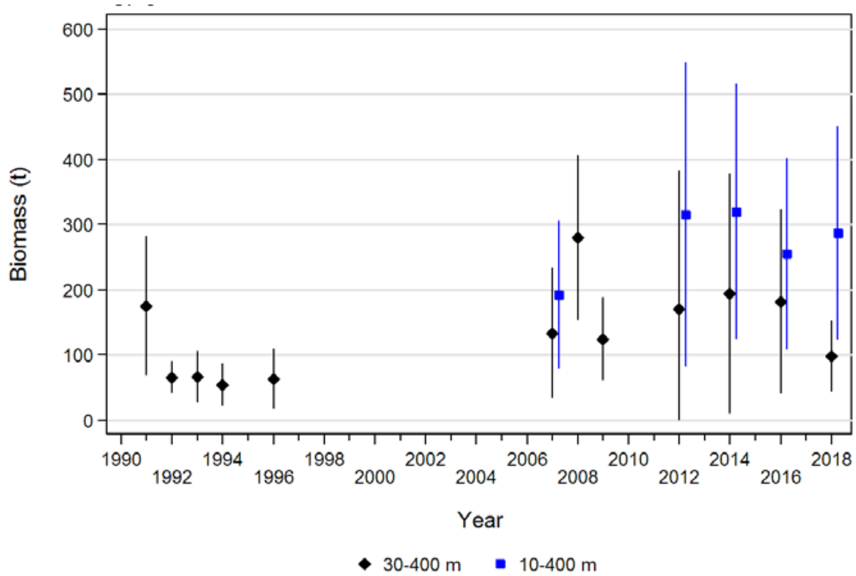


Figure 6: Rig total biomass and 95% confidence intervals for all ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m) in 2007, 2012, 2014, 2016, and 2018.

Table 7: Relative biomass indices (t) and coefficients of variation (CV) for rig for the East Coast South Island (ECSI) winter survey area*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16, and 17). – , not measured; NA, not applicable.

Region	Fishstock	Year	Trip number	Total biomass estimate	CV (%)	Total biomass estimate	CV (%)
				30–400m		10–400m	
ECSI (winter)	SPO 3						
		1991	KAH9105	175	30	–	–
		1992	KAH9205	66	18	–	–
		1993	KAH9306	67	30	–	–
		1994	KAH9406	54	29	–	–
		1996	KAH9608	63	37	–	–
		2007	KAH0705	134	37	192	30
		2008	KAH0806	280	23	–	–
		2009	KAH0905	125	26	–	–
		2012	KAH1207	171	62	315	37
		2014	KAH1402	194	48	320	21
		2016	KAH1605	181	39	255	29
		2018	KAH1803	98	28	287	29

Length frequency distributions: ECSI

The length frequency distributions for the East Coast South Island winter trawl survey often have modes centred round 40 cm and 60 cm, most pronounced in the shallow 10–30 m depth range. These two modes correspond to pre-recruit rig of ages 1+ and 2+. Rig tend to be larger overall in the 30–100 m depth range. The survey appears to be monitoring pre-recruited cohorts (1+ and 2+) reasonably well, but probably not the full extent of the recruited size distribution, because the proportion of rig over 1 m long in the survey catch is low. Plots of time series length frequency distributions are spiky because of the low numbers caught, but the size range is reasonably consistent among surveys. The addition of the 10–30 m depth range has changed the shape of the length frequency distribution, by increasing the proportion of fish under 70 cm in the survey catch. Figure 7 demonstrates that catches from the shallow (10–30 m) strata included a higher proportion of smaller rig than those in the core (30–400 m) strata. High numbers of rig under 70 cm in both core and inshore strata in the 2012, 2014, and 2016 surveys are indicative of strong recruitment in recent years (Starr & Kendrick in prep.).

By combining length distributions across years to overcome small sample sizes, Figure 8 shows there are substantial differences in the mean length distributions between the ECSI trawl survey, the SPO 3 BT fishery, and the SPO 3 SN fishery.

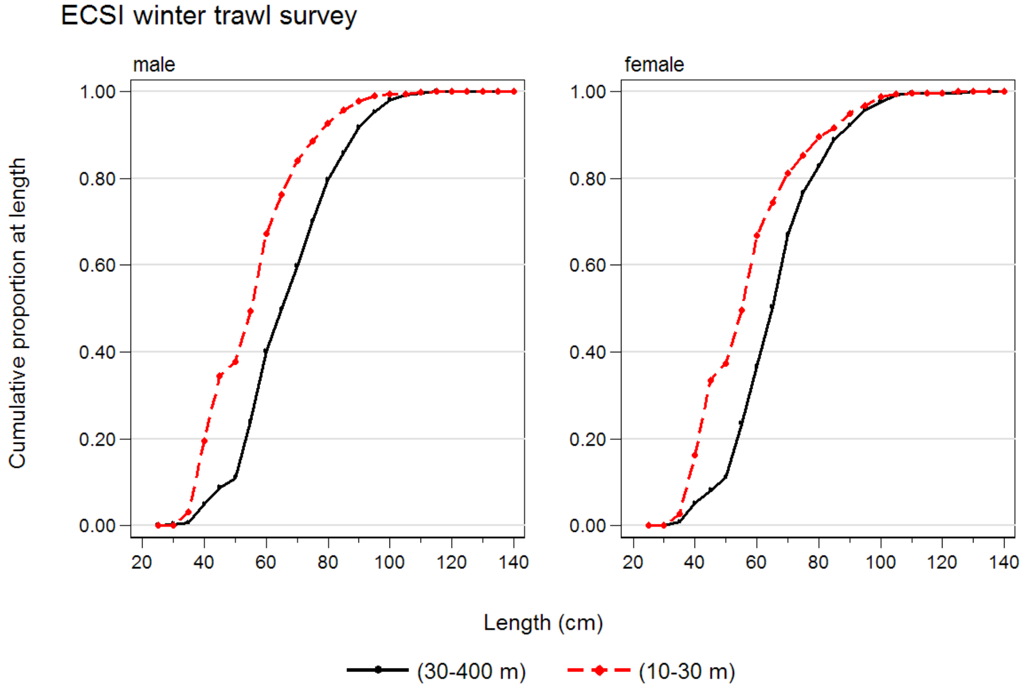


Figure 7: Empirical cumulative frequency plots for male and female rig comparing the combined length frequencies for the core (30–400 m) and shallow (10–30 m) strata across the five years (2007, 2012–2018) with valid surveys in the shallow (10–30 m) strata.

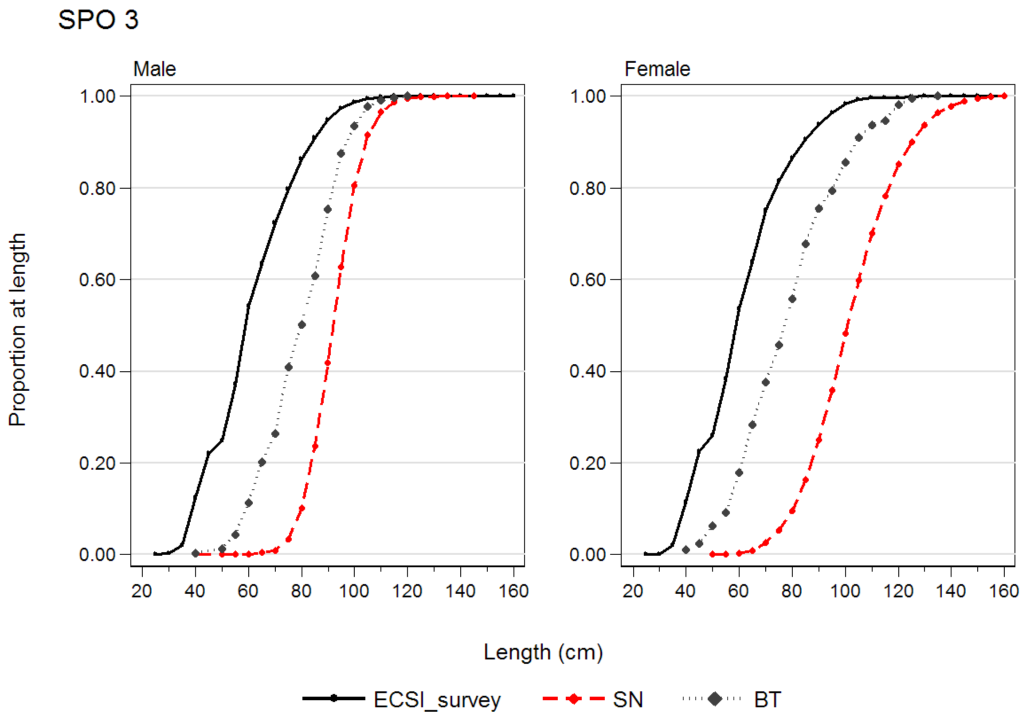


Figure 8: Empirical cumulative frequency plots for male and female rig comparing the combined length frequencies for the total (10–400 m) ECSI trawl survey, the SPO 3 SN observer data and the SPO 3 BT observer data. The ECSI trawl survey data include 2007, 2012–2018; the SPO 3 SN observer data include 2008, 2010, 2014–2018; the SPO 3 BT observer data include 2010, 2012–2014.

Establishing B_{MSY} compatible reference points

The above conclusion that core strata (30–400 m) of the ECSI winter trawl survey are not fully representative of the rig population renders the previously selected B_{MSY} proxy target reference point invalid because it was based on the core strata. The SINSWG agreed to revise the definition of the *Bmsy* proxy target reference point to be the average of the five survey years which adequately covered the 10–30 m strata (2007, 2012, 2014, 2016, and 2018). The rationale for choosing this period was that abundance was stable and catches were relatively high, indicating high surplus production. The Soft Limit will be one-half of the *Bmsy* proxy and the Hard Limit will be one-quarter of the *Bmsy* proxy.

SPO 7

CPUE analyses standardising set net and bottom trawl catches for core vessels were undertaken in 2016 to assess relative abundance of rig in SPO 7. Two of these analyses were updates of analyses previously accepted by the Working Group: 1) set net fishery in Statistical Area 038 targeting rig, spiny dogfish, and school shark [SN(038)]; and 2) bottom trawl fishery in Statistical Areas 016–018, 032–037, 038, 039, and 040 targeting flatfish, red cod, rig, barracouta, tarakihi, red gurnard, snapper, blue warehou, and trevally [BT(ALL)]. An analysis of the set net fishery in Statistical Areas 032–037 was rejected by the SINSWG in 2015 (after being accepted in the 2006–2013 analyses) because of lack of sufficient data to create a reliable index. This lack is attributed to the movement of ACE to other SPO 7 fisheries and the management regulations imposed to protect Hector's dolphins. Examination of the distribution of set net effort off the west coast of the South Island showed that there had been a substantial decline in the number of vessels operating in these statistical areas since 2005–06, with less than 2% of the set net fishery catches originating from statistical areas other than 038 during 2015–16 to 2017–18. In 2016, an alternate set net fishery analysis was trialed (SN[STB]), covering the statistical areas of the South Taranaki Bight (037, 039, and 040). This was done after examining the fine scale spatial distribution of catches in these three statistical areas, showing that most of the catch came from the coastal section of South Taranaki Bight. This analysis also showed there was catch in Statistical Area 037 on the line separating Statistical Areas 037 and 038 (between D'Urville Island and Farewell Spit) which may belong more logically to the Statistcal Areas 038 analysis. However, spatial data at this level of detail are not available before October 2007 from the earlier daily forms. The SN(STB) series was rejected by the 2016 Plenary (quality ranking of '3') on account of the impact the dolphin closures have had on this fishery.

The SPO 7 landing data, regardless of the method of capture, did not exhibit the behaviour of landing to temporary holding receptacles observed in SPO 1.

The 2019 review (Starr & Kendrick 2019) repeated the BT(All) and SN(038) analyses. The SN(038) index, which was assigned a quality ranking of '1', showed a continuous declining trend from the beginning of the series to a low in the mid-2000s, approximately coincident with the lowering of the SPO 7 TACC. This low point was followed by an increasing trend to a peak in 2010–11, after which the series has varied about the series mean, with the 2016–17 index 14% above the mean and the 2017–18 index 9% below the mean (Figure 8).

The BT(ALL) series (also with a quality ranking of '1') shows an increasing trend since the mid-2000s, with low points observed in both 2004–05 and 2006–07, but has since more than doubled to reach the highest point in the series in 2016–17, followed by a 10% drop in 2017–18. The Plenary noted that the BT(All) index does not adequately sample large female rig. The 2019 review also implemented an event-based (tow-by-tow) standardised analysis to test whether amalgamating the data to the level of a complete trip was introducing bias. Figure 9 shows that two series agree well in the overlapping years.

Although large rig are not effectively targeted with bottom trawl gear, the WCSI trawl survey is believed to provide reliable indices of the relative biomass of males and younger females in SPO 7. Relative biomass declined by more than 50% between 1995 and 2005, and subsequently increased to a stable level from 2007 to 2013. It then increased sharply in 2015, with total biomass remaining high in the 2017 survey, but dropped relative to the 2015 index (Figure 10, Table 8).

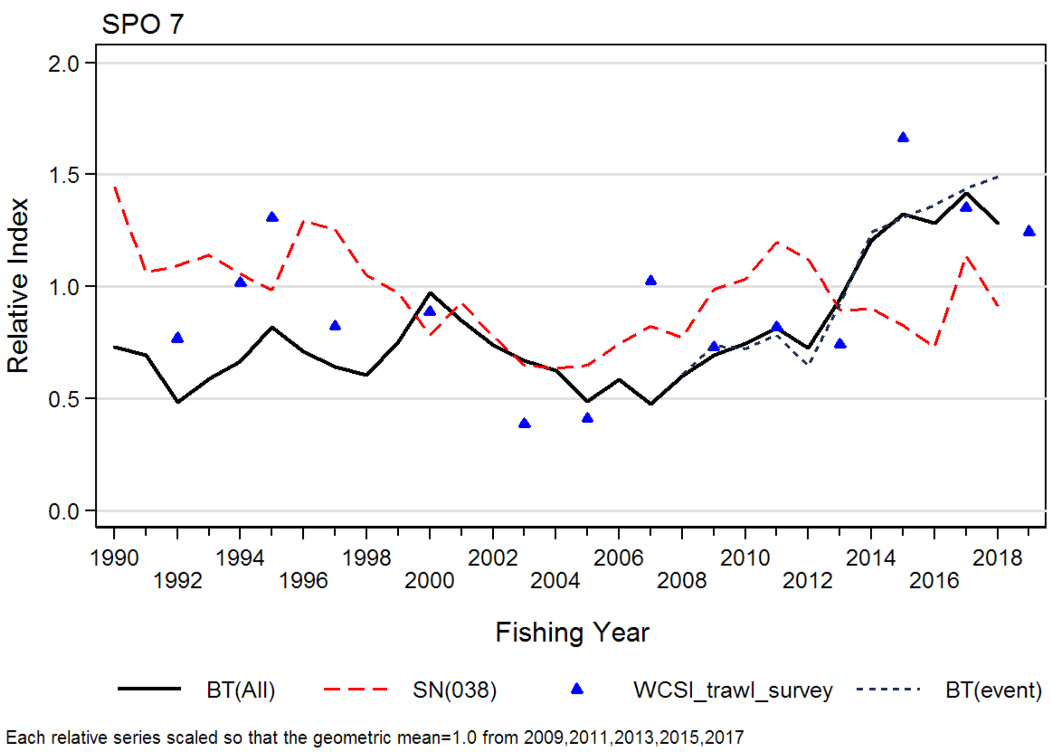


Figure 9: Comparison of three SPO 7 standardised CPUE series: a) bottom trawl fishery (mix of targets in all SPO 7) [BT(ALL)]; b) shark target set net fishery in Tasman Bay/Golden Bay [SN(038)]; c) BT(event): tow-by-tow mixed target species bottom trawl data. Also shown are rig index values from the West Coast South Island (WCSI) trawl survey: 1992–2019. The 2019 survey index is preliminary.

Table 8: Relative biomass indices (t) and coefficients of variation (CV) for rig for the west coast South Island (WCSI) trawl survey.

Survey	Fishstock	Year	Trip number	Total biomass (t)	CV (%)
WCSI	SPO 7				
		1992	KAH9204	288	14
		1994	KAH9404	380	10
		1995	KAH9504	490	11
		1997	KAH9701	308	18
		2000	KAH0004	333	18
		2003	KAH0304	144	22
		2005	KAH0503	153	19
		2007	KAH0704	383	33
		2009	KAH0904	274	26
		2011	KAH1104	307	18
		2013	KAH1305	278	20
		2015	KAH1503	622	27
		2017	KAH1703	506	33
		2019	KAH1902	467	14

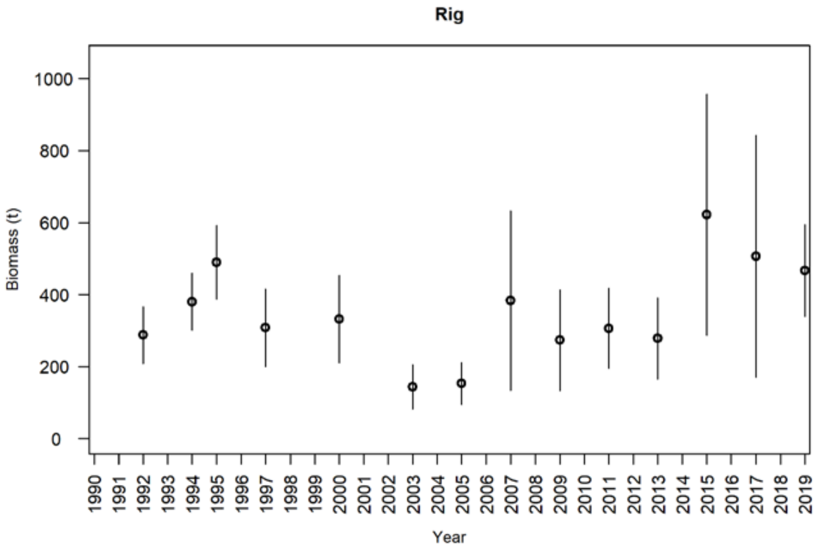


Figure 10: Plots of biomass estimates (t) for rig from the West Coast South Island trawl survey by year. Error bars are ± two standard deviations.

<u>West Coast South Island inshore trawl survey</u>

Although not optimised for rig, the West Coast South Island inshore trawl survey still provides useful abundance indices (Table 8, Figure 10). Stevenson & Hanchet (2000) reported that the survey is likely to provide a reasonable index of abundance for juveniles and pre-recruits less than 90 cm (Stevenson 2007). The depth range of the core survey (20–400 m) is suitable for rig but the lack of larger female rig in the length frequency distribution from the trawl survey suggests they may not be well sampled as noted by Stevenson & Hanchet (2000), but that pre-recruit and adult males are well sampled.

Total biomass has been relatively steady over time but has increased in recent years with the last three surveys having three of the four highest estimates in the time series.

Length frequency distributions of rig show that distinct modes can be present in some years particularly for 0+ fish under 40 cm (e.g. 2007, 2011, 2013, and 2019) (Figure 11). Several distinct year classes are visible in some years (e.g., 2011). The distributions show that 0+ fish are relatively common in Tasman Bay and Golden Bay (e.g., 2007, 2009, 2017) but these fish are in some years present in strong numbers off the west coast as well (e.g., 2011, 2019).

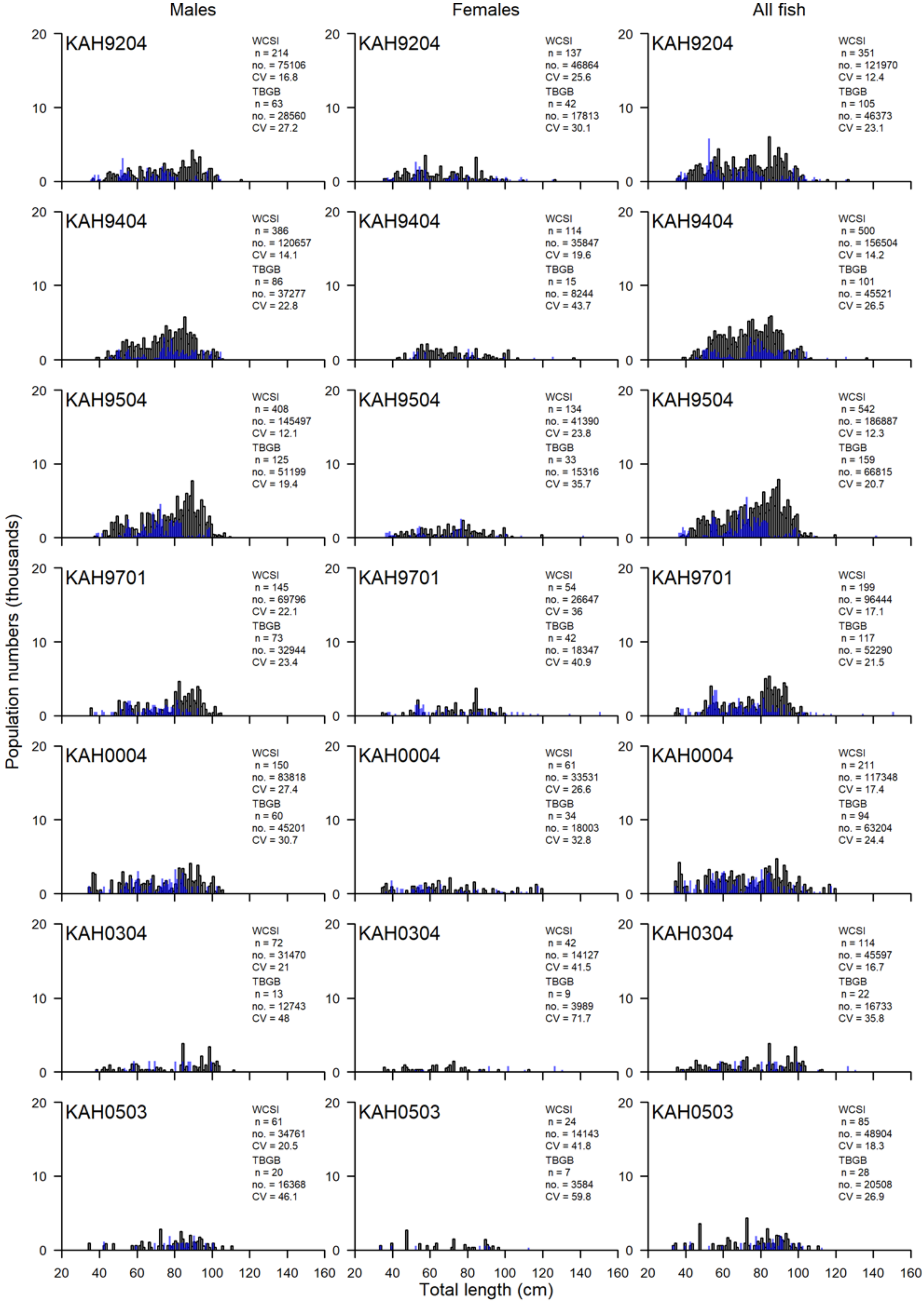


Figure 11: Scaled population length frequencies for rig from the West Coast South Island inshore trawl survey time series core strata (20–400 m). Blue bars represent strata from Tasman Bay and Golden Bay, black bars represent the west coast of the South Island strata.

RIG (SPO)

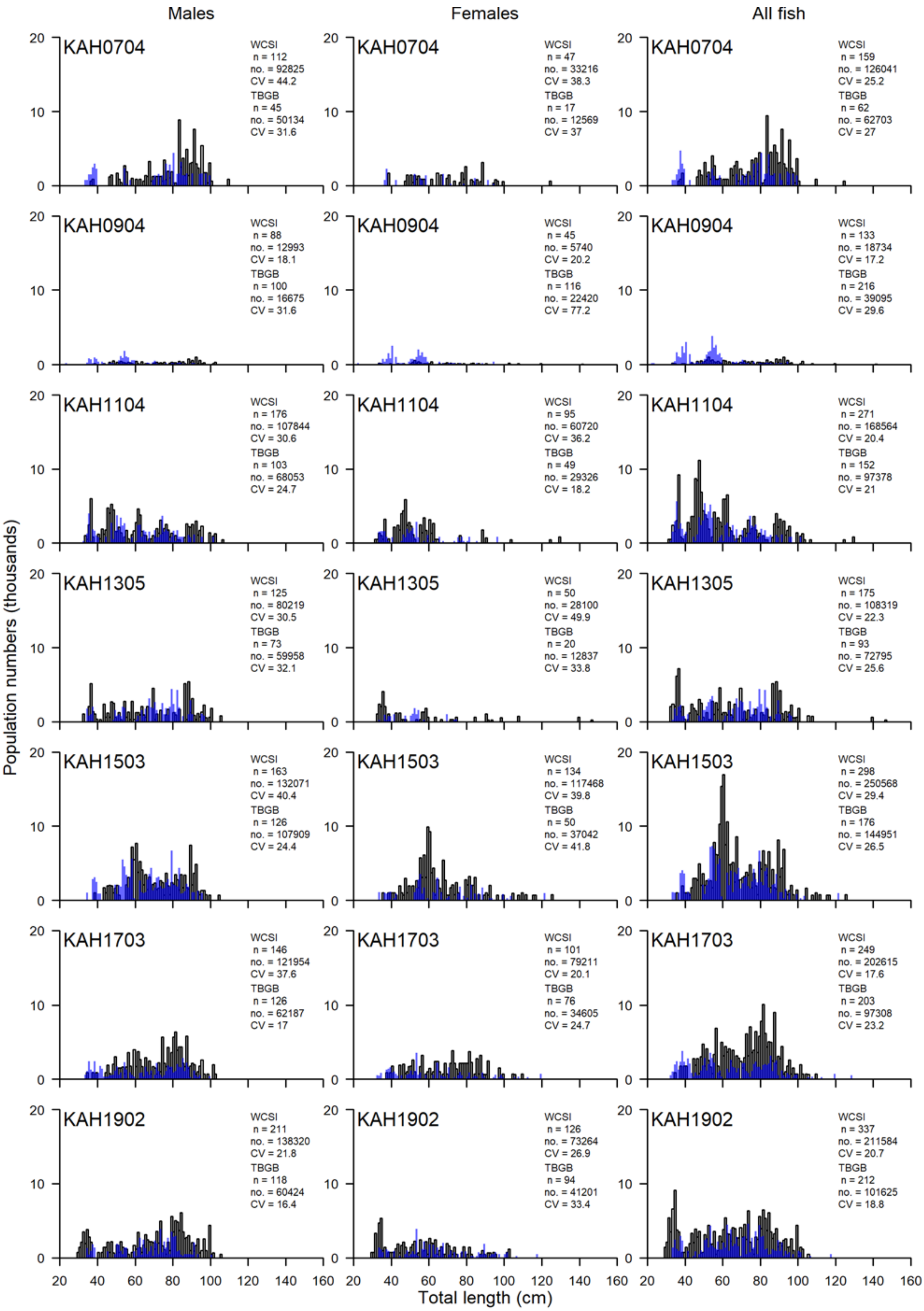


Figure 11 [Continued]

By combining length distributions across years to overcome small sample sizes, Figure 12 shows there are differences in the mean length distributions between the WCSI trawl survey and the SPO 7&8 BT fishery, with the latter being larger than the former. Unfortunately, SN was only sampled in one year in SPO 7&8 by observers and the resulting length distribution seems small compared with unpublished length frequency data available from the SPO 7 Adaptive Management Programme for the same fishery (Starr et al. 2010).

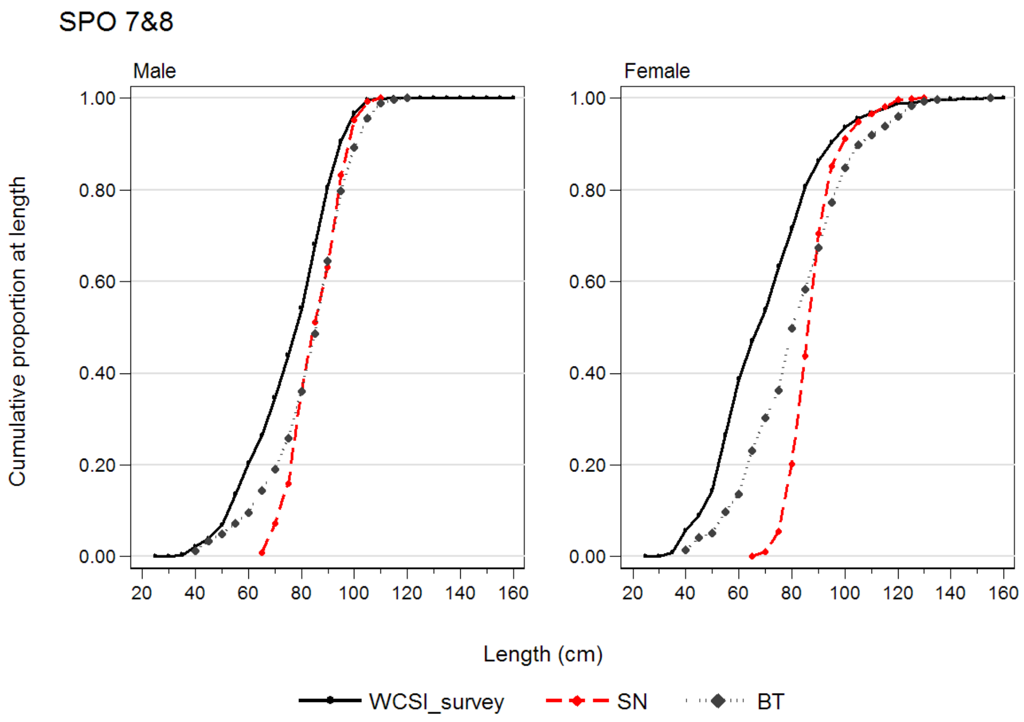


Figure 12: Empirical cumulative frequency plots for male and female rig comparing the combined length frequencies for the WCSI trawl survey, the SPO 7&8 SN observer data and the SPO 7&8 BT observer data. The WCSI trawl survey data include 2007, 2009, 2011, 2013, 2015, and 2017; the SPO 7&8 SN observer data only include a single year of sampling in 2008 from Area 038; the SPO 7&8 BT observer data include 2010, 2011 and 2012.

Establishing B_{MSY} compatible reference points

The Working Group agreed to use the two lowest survey biomass values (2003 and 2005: see Table 8) as a proxy for the SPO 7 Soft Limit. This definition establishes the B_{MSY} proxy target reference point as twice the average 2003–2005 biomass level and the Hard Limit as one-half the average 2003–2005 biomass level. These are based on the definitions from the default Harvest Strategy Standard where the Soft and Hard Limits are one-half and one-quarter the target, respectively.

SPO 8

SPO 8 landings are primarily from a set net fishery that operates along the coast from Kapiti to beyond New Plymouth. The SPO 8 bottom trawl fishery operates further offshore in the North and South Taranaki bights and takes rig as a bycatch in fisheries targeted at tarakihi, snapper, and red gurnard. Recent average set net landings in SPO 8 have been between 150 and 200 t per year, whereas bottom trawl landings average between 10 and 30 t per year. The SPO 8 landing data, regardless of the method of capture, did not exhibit the behaviour of landing to temporary holding receptacles.

The CPUE analyses previously completed for SPO 8 have been discontinued by agreement of the SINSWG. The SPO 8 BT analysis consisted of four Statistical Areas (037, 039, 040, and 041), three of which were also used in the SPO 7_BT(All) analysis. Examination of the spatial distributions of the Statistical Area 041 set net and bottom trawl catches indicated that rig catches in this area merge seamlessly with the equivalent catches in Statistical Area 042, immediately to the north of Statistical Area 041. As a result, it was decided that Statistical Area 041 should be amalgamated with the

SPO 1W coastal bottom fishery, adding much needed data to these analyses. A new fishery to monitor the South Taranaki Bight was constructed from the remaining statistical areas that were included in the discontinued SPO 8_SN fishery, but this analysis was not accepted by the 2016 Plenary because of the disappearance of the set net fishery in all statistical areas other than Statistical Area 038 (Tasman Bay/Golden Bay).

4.2 Other factors

Stock mixing occurs in the South Taranaki Bight to the Cook Strait and South Westland regions, and probably elsewhere. Some regional fisheries therefore exploit more than one stock. This means that biological stock boundaries do not necessarily coincide with QMA boundaries. Consequently, management by quota within Fishstocks may be sub-optimal for individual stocks.

The use of small mesh commercials set nets (125 mm) in the Auckland FMA probably results in a large proportion of the rig catch being immature fish. Elsewhere, the minimum size is 150 mm.

There have been several changes to the rig conversion factors over the period that SPO has been managed within the QMS. The trend has been towards lower conversion factors. Although researchers correct catches for these changes when undertaking CPUE analyses, this has not been done for total landings reported in this Working Group Report. These changes reduce the relative effect of catches in recent years compared with early years, e.g., if actual catch had been constant it would appear to be declining.

5. STATUS OF THE STOCKS

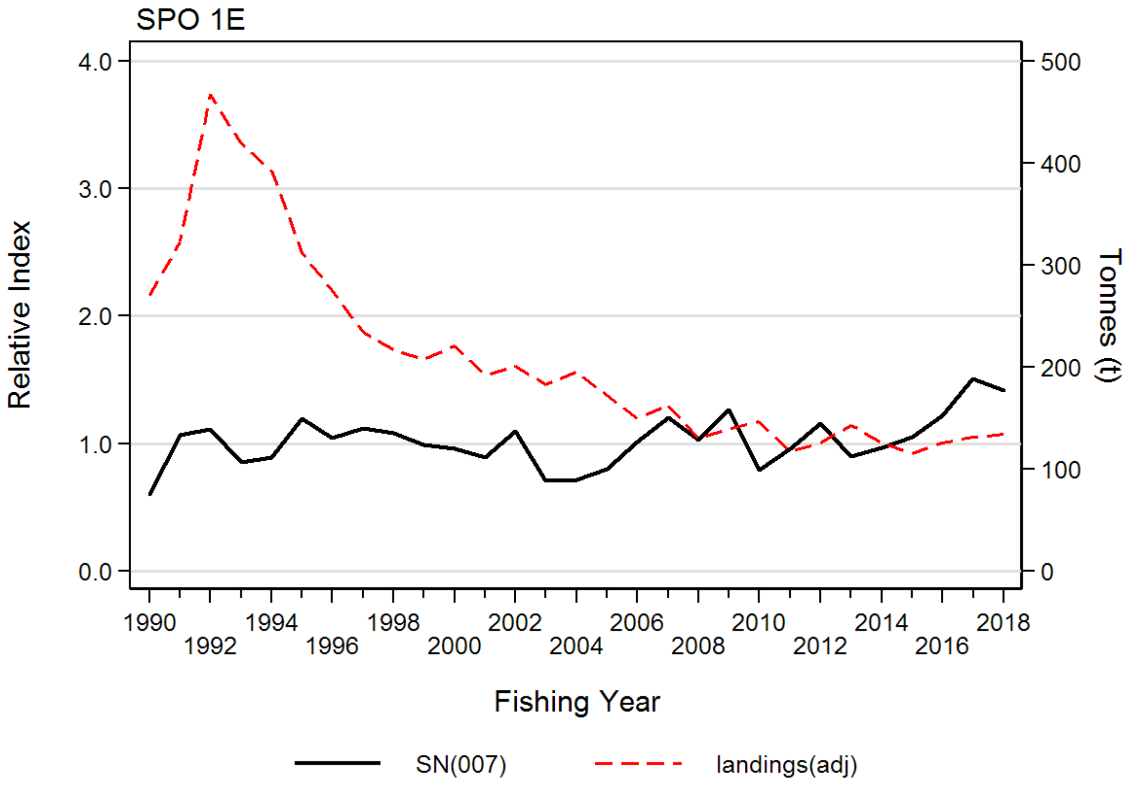
A review of stock structure in 2009 concluded that the existing QMAs were suitable for rig management, although the boundaries between biological stocks were poorly defined, especially in the Cook Strait region (Francis 2010).

- **SPO 1**

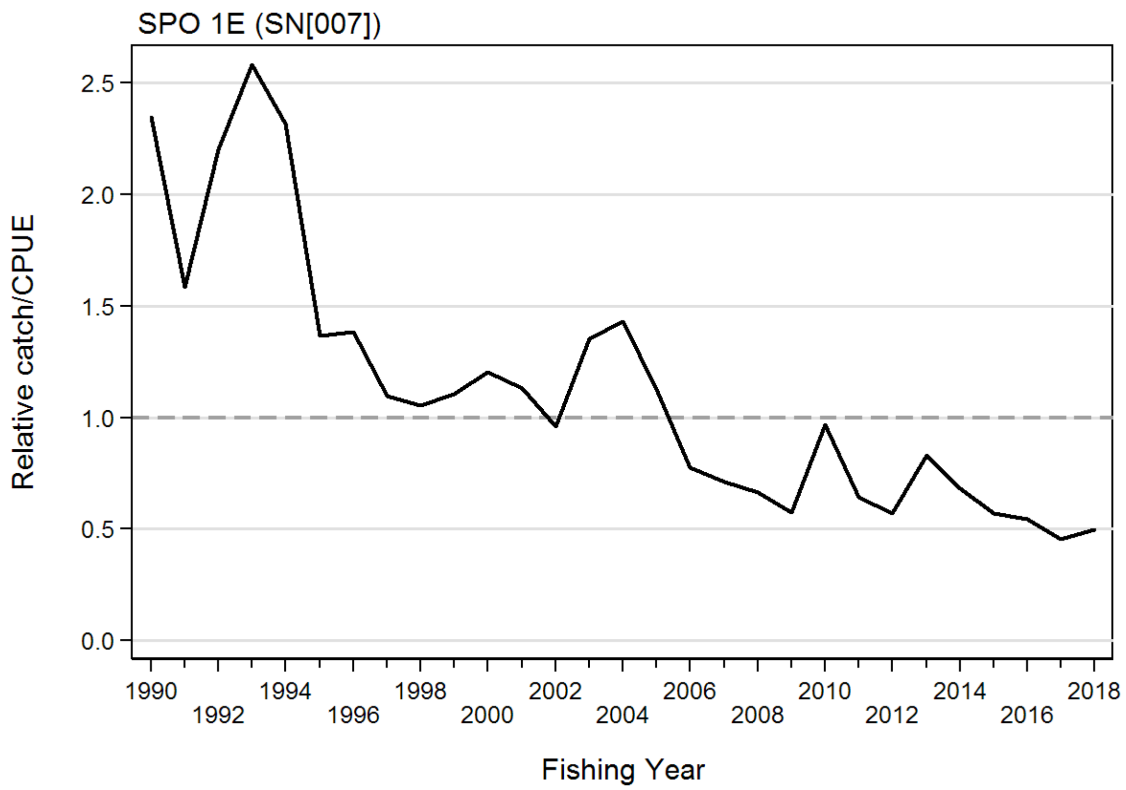
Stock Structure Assumption
For the purposes of this summary SPO 1E is defined as the sum of Statistical Areas 002 to 010 and is treated as a discrete stock. SPO 1W is defined as the sum of Statistical Areas 041 to 048 and is treated as a discrete stock. It is not known if the rig stocks on the west and east coasts of the North Island are separate.

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	Standardised CPUE index: SPO 1E: SN(007) SPO 1W: BT(41-47), SN(043), SN(044)
Reference Points	Target (1E and W): 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	1E and 1W: Unknown
Status in relation to Limits	1E and 1W Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	1E and 1W: Unknown

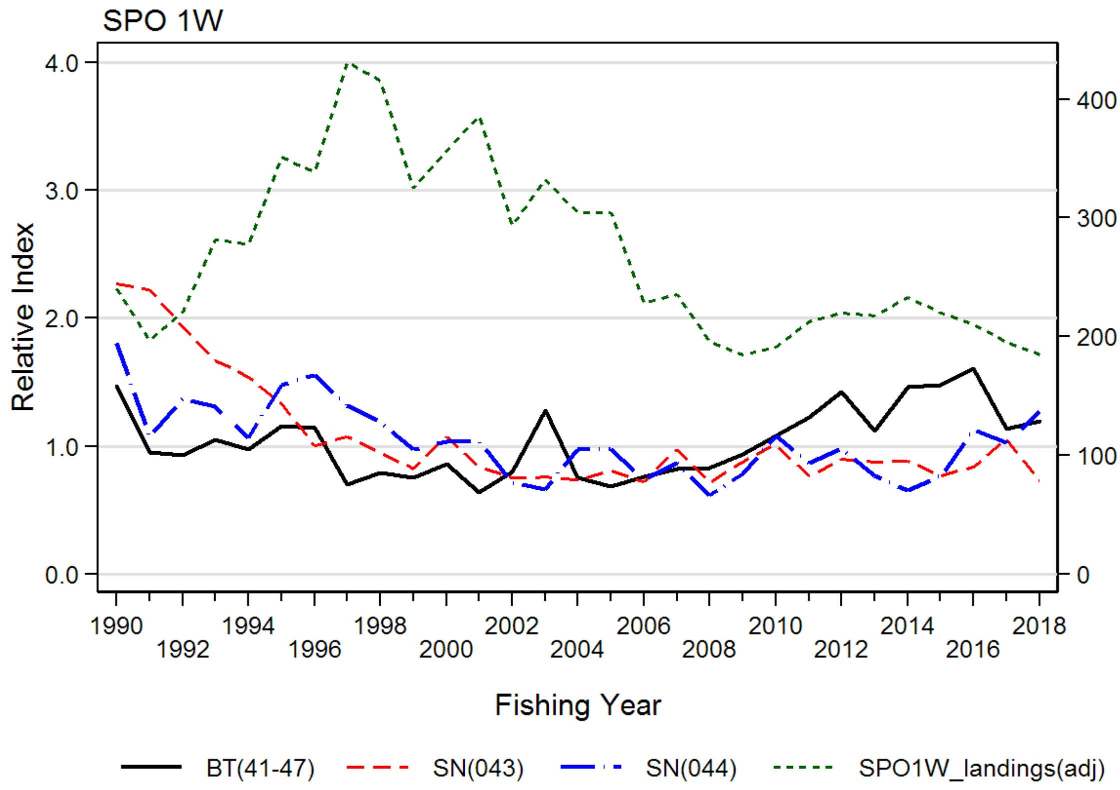
Historical Stock Status Trajectory and Current Status



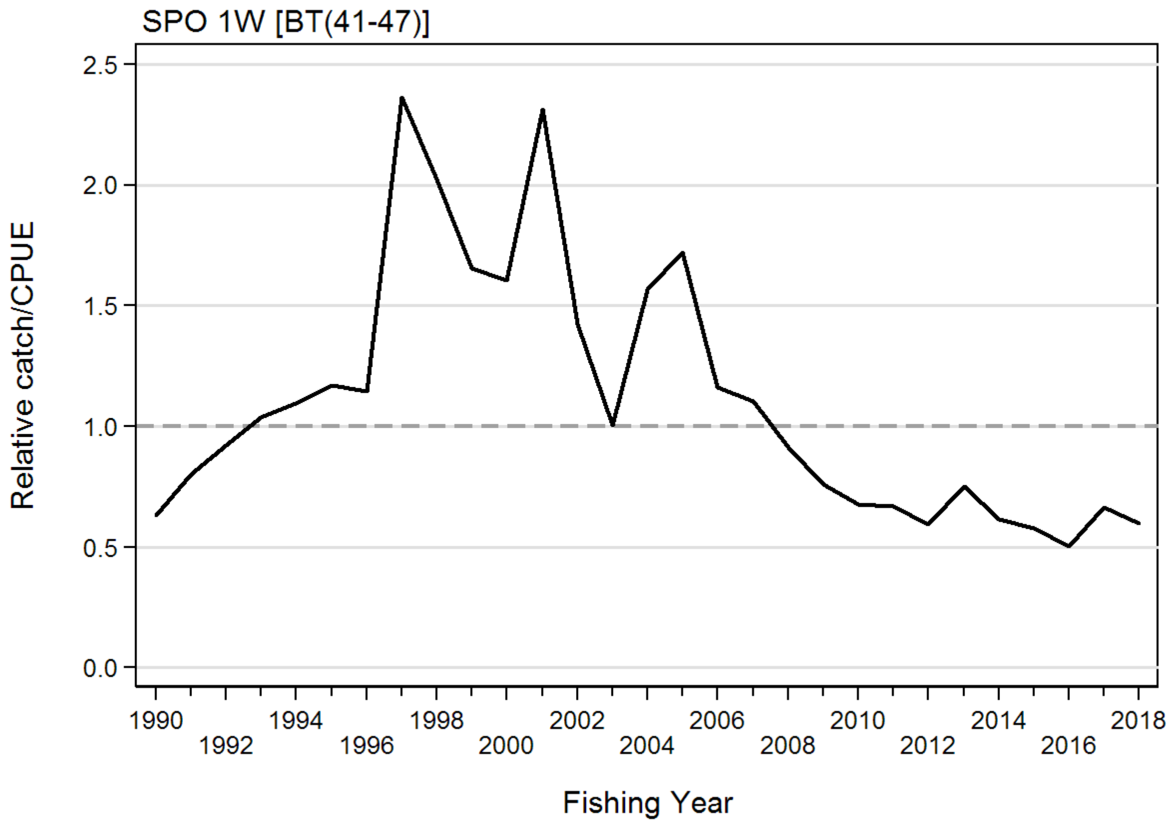
Accepted CPUE indices for SN(007) with the adjusted QMR/MHR landings for SPO 1E. Adjustments were made to ensure that all values in every year are based on a common conversion factor.



Relative fishing pressure for SPO 1E based on the ratio of QMR/MHR (adj) landings relative to the SN(007) CPUE series. Each series has been normalised so that its geometric mean=1.0 for all common years.



Comparison of three accepted CPUE indices [SN(043), SN(044), BT(41-47)] with the adjusted QMR/MHR landings for SPO 1W. Adjustments were made to ensure that all values in every year are based on a common conversion factor.



Relative fishing pressure for SPO 1W based on the ratio of QMR/MHR (adj) landings relative to the BT(41-47) CPUE series.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	1E: Adult biomass (as indexed by the set net fishery in Statistical Area 007) has fluctuated without trend since 1990. 1W: The coastal BT series is relatively flat from 1990 to the late 2000s, but showed a strong upturn around 2008, which peaked in 2015 and has since dropped; the SN(043 Manukau harbour) series shows a strong decline in the early portion of the series while the SN(044 Kaipara harbour) series showed a modest decline through the 1990s. Both set net indices have been relatively stable, fluctuating below the series mean since the early 2000s.
Recent Trend in Fishing Intensity or Proxy	1E: Fishing intensity (as indexed by the set net fishery in area 007) appears to have been declining since the mid-1990s. 1W: The coastal BT series indicates that fishing intensity increased to relatively high levels from the late 1990s to the early 2000s and has been declining to relatively low levels since
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown (Catch) Hard Limit: Unknown (Catch) Since current catches are well below the TACC, it is Unknown if the TACC will cause the stock to decline.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Fishery characterisation and standardised CPUE analysis	
Assessment Dates	Latest assessment: 2019	Next assessment: 2022
Overall assessment quality rank	1E: 2 – Medium or mixed quality: decline in catch should have resulted in an increase in CPUE 1W: 1 – High Quality	
Main data inputs (rank)	1E: Set net CPUE series: target shark in Area 007 (Firth of Thames)	2 – Medium or mixed quality: series only indexes a small proportion of area 1E
	1W: Bottom trawl CPUE series: mixed target species (Areas 042, 045–048)	1 – High Quality
	Setnet CPUE series: target shark in Area 043 (Manukau Harbour)	2 – Medium or Mixed Quality: series only indexes a small proportion of area 1W
	Setnet CPUE series: target shark in Area 044 (Kaipara Harbour)	2 – Medium or Mixed Quality: series only indexes a small proportion of area 1W

Data not used (rank)	1E: Bottom trawl CPUE series: mixed target species (Areas 002–010) Setnet CPUE series: target shark (Areas 002–006 and 008–010) 1W: Setnet CPUE series: shark target species (Areas 041–047)	3 – Low Quality: few data 3 – Low Quality: few data 3 – Low Quality: regulatory changes appear to have had significant impact
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Contradictory trends in the bottom trawl and setnet CPUE indices - Lack of historical information relating to stock abundance during the 1970s–1980s when the stock was believed to have been heavily fished means that the current relative stock status is difficult to determine - BT CPUE series may not index large mature females	

Qualifying Comments
The accepted BT(coast) CPUE series (SPO 1E) and BT(41-47) (SPO 1W) do not sample large mature females in the rig population.

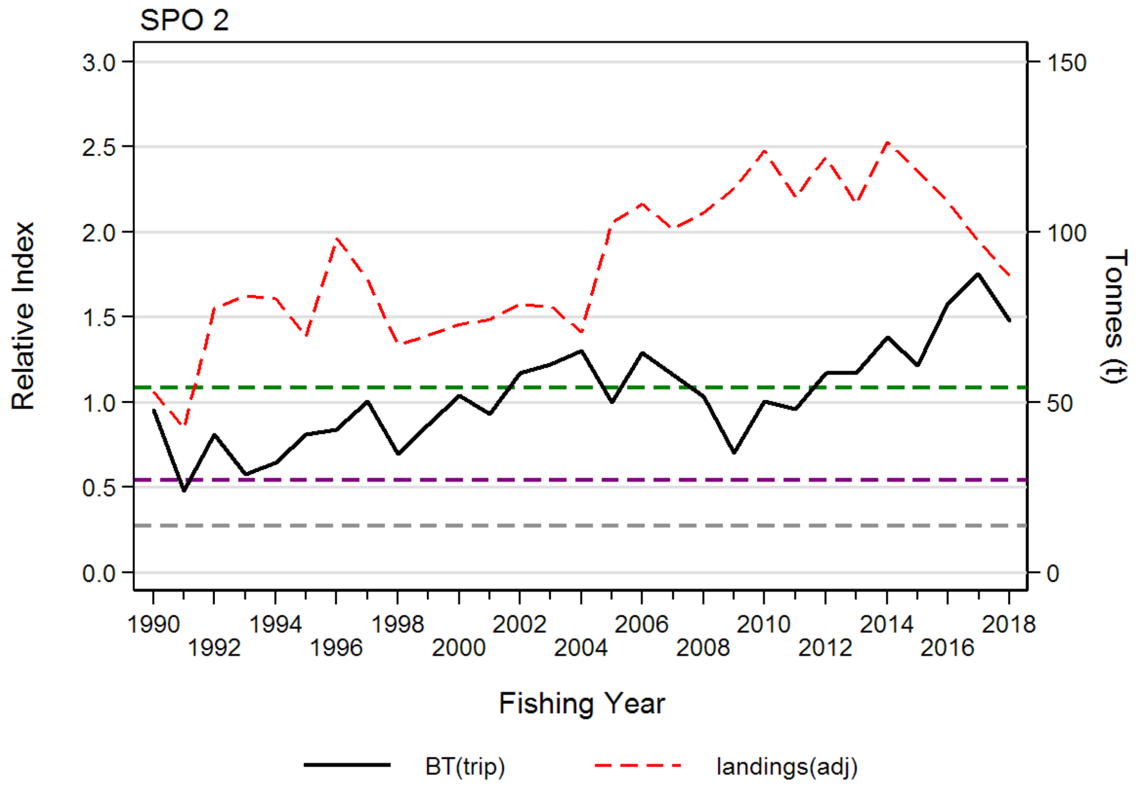
Fishery Interactions
Rig are taken as a bycatch in bottom trawl fisheries targeted mainly at snapper, tarakihi, gurnard, John dory, barracouta, trevally (SPO 1E) while the setnet fisheries are almost exclusively targeted at rig in both SPO 1E and SPO 1W. Interactions with other species are currently being characterised.

- **SPO 2**

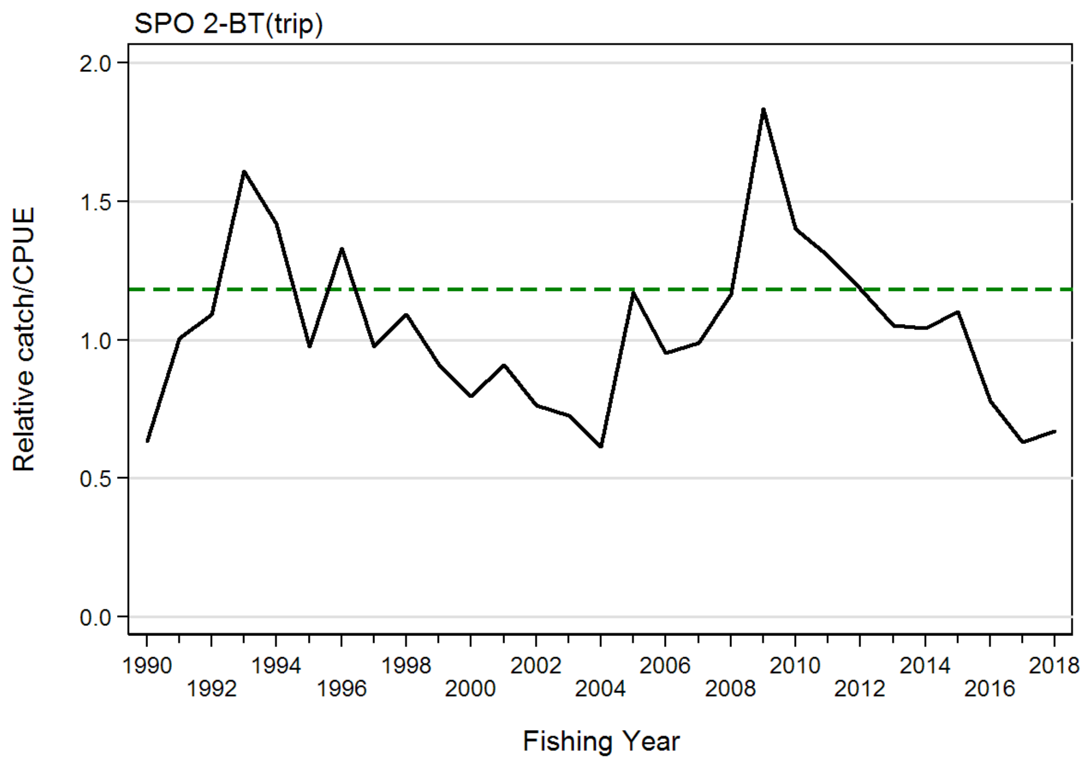
Stock Structure Assumption
For the purposes of this summary SPO 2 is defined as the sum of Statistical Areas 011 to 015 and is treated as a discrete stock.

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	Standardised CPUE: BT(stat area)
Reference Points	Target: Proxy for B_{MSY} based on the average CPUE during the period 2005–2015, a period of relatively stable CPUE and catches Soft Limit: 50% of the target Hard Limit: 50% of the soft limit Overfishing threshold: F_{MSY}; assumed to be the average fishing intensity over the period 2005–2015
Status in relation to Target	Likely (> 60%) to be at or above the target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below the soft limit Hard Limit: Very Unlikely (< 10%) to be below the hard limit
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status



Comparison of the accepted CPUE index[BT] with the adjusted QMR/MHR landings for SPO 2. Adjustments were made to ensure that all values in every year are based on a common conversion factor. The agreed B_{MSY} proxy (average: 2005–2015) target is shown as a green line, the Soft Limit is shown as a purple line, and the Hard Limit is shown as a grey line.



Relative fishing pressure for SPO 2 based on the ratio of QMR/MHR (adj) landings relative to the [BT] CPUE series. This series has been normalised so that its geometric mean=1.0.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has increased strongly since 2009.
Recent Trend in Fishing Intensity or Proxy	Relative fishing intensity increased from 1990 to 1993, declined to 2004, increased to 2009 and has since declined to below the series average in 2017 and 2018.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Current catches are Unlikely (< 40%) to cause the stock to decline
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Current catches are Unlikely (< 40%) to cause the stock to decline below the soft or hard limits
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (<40%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Fishery characterisation and standardised CPUE analysis	
Assessment Dates	Latest assessment: 2019	Next assessment: 2022
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	Bottom trawl CPUE series: trip-based analysis	1 – High Quality
Data not used (rank)	The set net CPUE analysis up to 2009–10	3 – Low Quality: This series was not updated in 2016 (not ranked in 2011) as there were insufficient data to produce a reliable index of abundance
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty	- Lack of historical information relating to stock abundance during the 1970s–1980s when the stock was believed to have been heavily fished means that the current relative stock status is difficult to determine - BT CPUE series may not index large mature fish	

Qualifying Comments
The accepted BT(statarea) CPUE series does not adequately sample large mature fish in the rig population; the Working Group agreed that the setnet series was not credible due to lack of data, poor vessel overlap, and the fact that the set net fishery targets a mixed group of species, including blue moki and blue warehou.

Fishery Interactions
Rig are taken as a bycatch in bottom trawl fisheries targeted mainly at flatfish, tarakihi and gurnard while the setnet fisheries target rig, school shark, flatfish, blue warehou and blue moki. Interactions with other species are currently being characterised.

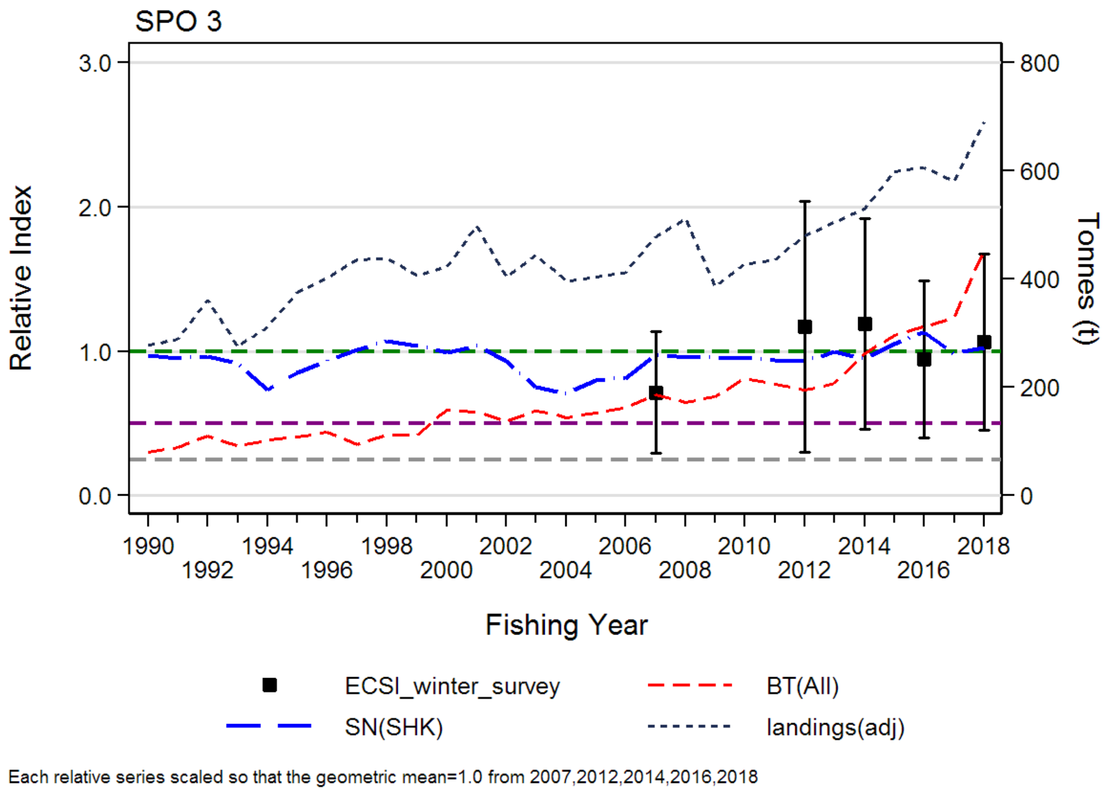
- **SPO 3**

Stock Structure Assumption

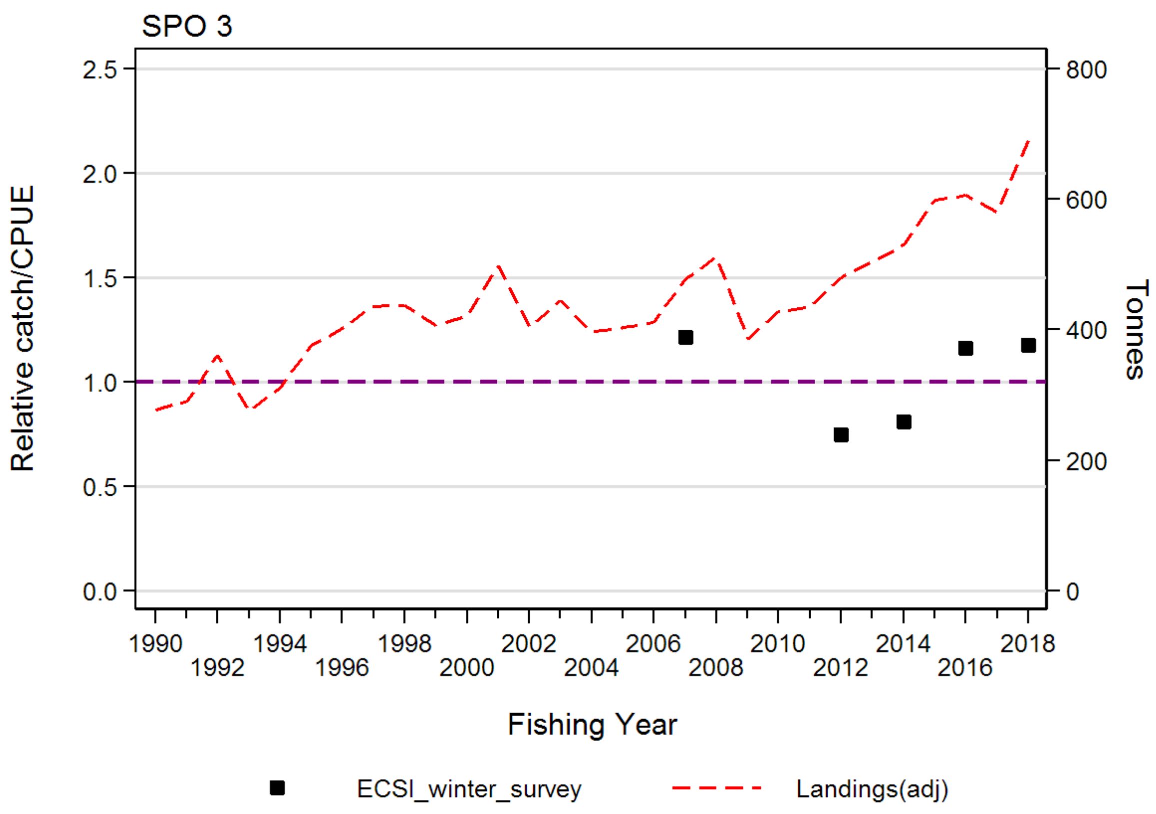
For the purposes of this summary SPO 3 is defined as the sum of Statistical Areas 018 to 032 and areas 049 to 052 and is treated as a discrete stock.

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	ECSI trawl survey and two standardised CPUE indices: SN(SHK) and BT(All)
Reference Points	Target: Proxy for B_{MSY} based on average ECSI trawl survey (all strata) indices for the period 2007 - 2018 Soft Limit: Half the Bmsy proxy Hard Limit: 25% of the Bmsy proxy Overfishing threshold: F_{MSY}; assumed to be the average fishing intensity for the 2007-2018 survey indices
Status in relation to Target	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 the soft limit Hard Limit:Very Unlikely (< 10%) to be below the hard limit
Status in relation to Overfishing	Overfishing is About as Likely as Not (40–60%) to be occurring

Historical Stock Status Trajectory and Current Status



Comparison of the East Coast South Island (ECSI) trawl survey (all strata) with two accepted CPUE indices [BT(All) and SN(SHK)] and with the adjusted QMR/MHR landings for SPO 3. Adjustments were made to ensure that all values in every year are based on a common conversion factor. The agreed B_{MSY} proxy (average: 2007, 2012, 2014, 2016, 2018 ECSI survey biomass estimates) is shown as a green line, and the calculated Soft Limit (= 0.5 x B_{MSY} proxy) is shown as a purple line and the calculated Hard Limit (=0.25 x B_{MSY} proxy) is shown as a grey line.



Relative fishing pressure for SPO 3 based on the ratio of QMR/MHR (adj) landings relative to the ECSI trawl survey which has been normalised so that its geometric mean=1.0.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Core strata biomass estimates from survey years 2012 to 2016 of the ECSI winter trawl survey series suggest that biomass has increased relative to the 1990s. However, the low 2018 core strata biomass estimate contradicts this conclusion unless notice is taken of the considerable and variable biomass of rig in the shallow (10–30 m) strata.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has fluctuated around the overfishing threshold.
Other Abundance Indices	There has been a strong increasing trend in the bottom trawl CPUE series dating from the late 2000s, but the set net CPUE series has been relatively flat.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Catches exceeded the TACC in 2018 for the first time in this QMA. It is Unknown if catches at this level or the TACC will cause the stock to decline.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Current catches and the TACC are Unlikely (< 40%) to cause the stock to decline below the soft or hard limits.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%)

Assessment Methodology and Evaluation			
Assessment Type	Level 2 - Partial Quantitative Stock Assessment		
Assessment Method	Fishery characterisation, trawl survey biomass and standardised CPUE analysis		
Assessment Dates	Latest assessment: 2019	Next assessment: 2022	
Overall assessment quality rank	1 – High Quality		
Main data inputs (rank)	- East coast South Island winter trawl survey - Bottom trawl CPUE series: mixed target species - Setnet CPUE series: target shark		1 – High quality 1 – High Quality 1 – High Quality
Data not used (rank)	N/A		
Changes to Model Structure and Assumptions	-		
Major Sources of Uncertainty	- The increasing trend in the trawl survey (core strata) and bottom trawl CPUE since 1990 is not corroborated by the setnet CPUE series, which has remained relatively flat. - Lack of historical information relating to stock abundance during the 1970s–1980s when the stock was believed to have been heavily fished means that stock status relative to early levels of abundance is difficult to determine - In some years the ECSI trawl survey indices have high CVs - ECSI trawl survey and bottom trawl CPUE do not adequately sample large mature females		

Qualifying Comments
The accepted ECSI trawl survey and the BT(All) CPUE series do not representatively sample large mature female rig. The core strata (30–400 m) of the ECSI winter trawl survey are not fully representative of the rig population because there is a large proportion of rig biomass inside the 30 m depth contour.

Fishery Interactions
A 4 nautical mile setnet closure has been in place since October 2008 for the entire area to reduce the bycatch of Hector's dolphins. Rig are largely targeted by setnet but they are also caught as bycatch in target fisheries for school shark, flatfish, red cod, spiny dogfish and elephant fish in setnet, bottom trawl and bottom longline fisheries. Interactions with other species are currently being characterised.

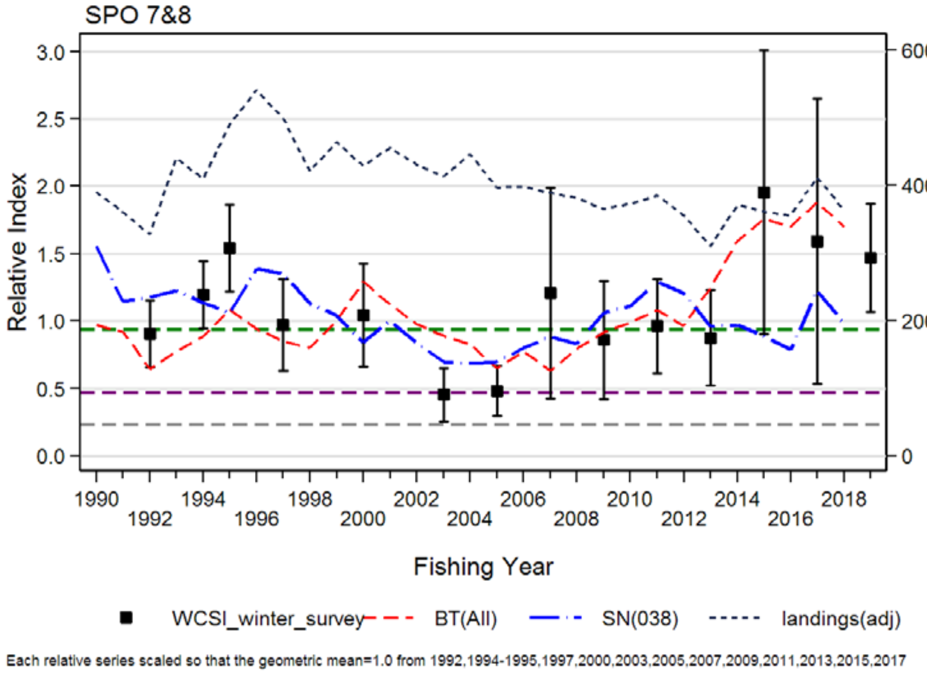
- **SPO 7**

Stock Structure Assumption

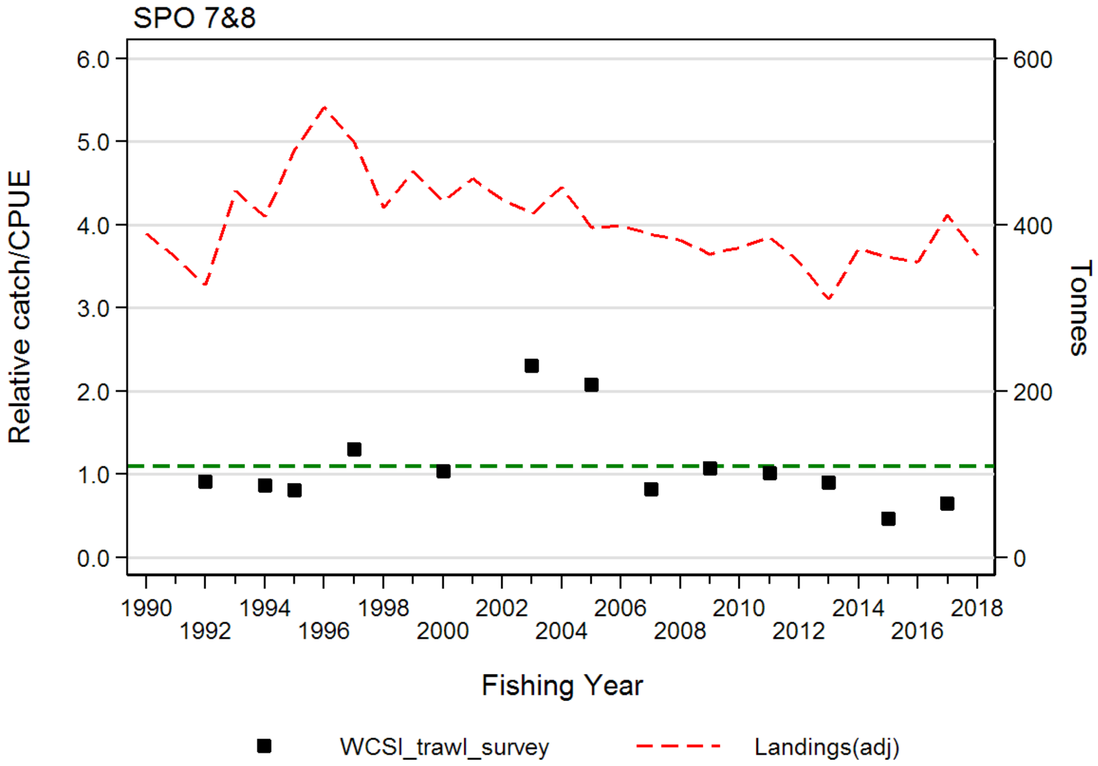
For the purposes of this summary SPO 7 is defined as the sum of Statistical Areas 016, 017, 033 to 040 and is treated as a discrete stock.

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	WCSI trawl survey series and two standardised CPUE series: BT (All) and SN (038)
Reference Points	Target: Proxy for B_{MSY} based on twice the soft limit Soft Limit: Mean WCSI trawl survey biomass estimates for 2003 and 2005 (148.6 t) Hard Limit: 50% of soft limit Overfishing threshold: F_{MSY}
Status in relation to Target	Likely (> 40%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below the soft limit Hard Limit: Very Unlikely (< 10%) to be below the hard limit
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status



Comparison of the West Coast South Island (WCSI) trawl survey and two accepted CPUE indices BT(All) and SN(038) with the adjusted QMR/MHR landings for SPO 7. Adjustments were made to ensure that all values in every year are based on a common conversion factor. The agreed Soft Limit (average: 2003 and 2005 WCSI survey biomass estimates=0.49) is shown as a purple line, and the calculated B_{MSY} proxy (=2×Soft Limit) is shown as a green line and the calculated Hard Limit (=0.5×Soft Limit) is shown as a grey line. The 2019 survey index is preliminary.



Relative fishing pressure for SPO 7 based on the ratio of QMR/MHR (adj) landings relative to the WCSI trawl survey which has been normalised so that its geometric mean=1.0. Target fishing pressure (1.10) is one-half of the fishing pressure associated with the 2003 and 2005 trawl survey indices.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Relative biomass from the WCSI trawl survey was stable, at around the target level, from 2007 to 2013, but increased sharply in 2015 and has remained near that level in 2017. The SPO 7_BT(All) CPUE series shows an increasing trend in recent years from a low point in 2004–05. The SPO 7_SN(038) series has flattened out around the series mean after showing an increase from 2006–07.
Recent Trend in Fishing Intensity or Proxy	Relative fishing intensity has been declining since the early 2000s and is currently below the overfishing threshold.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Size composition data from the WCSI trawl survey catches suggest strong recruitment in recent years.

Projections and Prognosis	
Stock Projections or Prognosis	Unlikely (< 40%) to decline at current catches or the TACC.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	WCSI trawl survey series and two standardised CPUE abundance indices	
Assessment Dates	Latest assessment: 2019	Next assessment: 2022
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	2016: - West Coast South Island trawl survey index - Setnet CPUE series: target shark in Area 038 - Bottom trawl CPUE series: mixed target species (all statistical areas)	 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	- SN(STB) CPUE series	3 – Low Quality: affected by dolphin management regulations
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- The increasing trend in the bottom trawl CPUE and WCSI trawl survey series is not corroborated by set net CPUE series - Lack of historical information relating to stock abundance during the 1970s–1980s when the stock was believed to have been heavily fished means that stock status relative to early levels of abundance is difficult to determine - WCSI trawl survey and bottom trawl CPUE do not adequately sample large mature females	

Qualifying Comments
The WCSI trawl survey and the accepted BT(All) CPUE series do not representatively sample large mature female rig, but they cover most of SPO 7; while the set net index (which does provide an index of mature rig abundance) provides an index of abundance for SPO 7 in Statistical Area 038.

Fishery Interactions
SPO 7 is caught in a targeted set net fishery, which also targets school shark and spiny dogfish, and in a bottom trawl fishery targeting flatfish, barracouta, red cod and tarakihi. The set net fishery has historically been focused in Statistical Area 038 (Tasman and Golden Bays). Interactions with other species are currently being characterised.

6. FOR FURTHER INFORMATION

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Blackwell, R G; Manning, M J; Gilbert, D G; Baird, S J (2006) Standardized CPUE analysis of the target rig (*Mustelus lenticulatus*) setnet fishery in northern New Zealand (SPO 1 and 8). *New Zealand Fisheries Assessment Report 2006/32*. 56 p.

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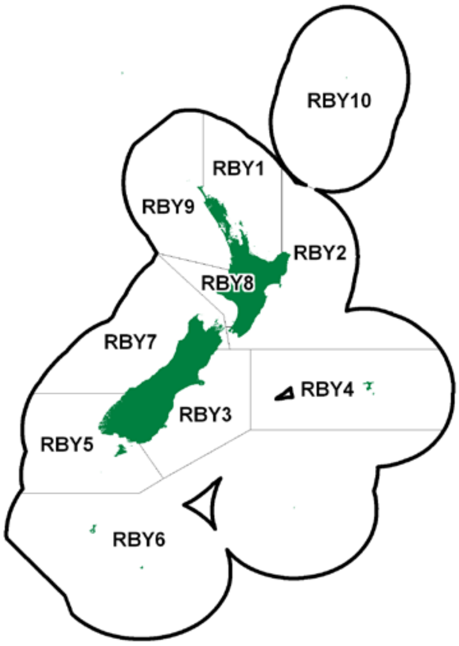
RUBYFISH (RBY)

(*Plagiogeneion rubiginosum*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

Rubyfish catches were first reported in 1982–83. In 1990–91, 245 t were landed (Table 1), mainly as bycatch in the trawl fisheries for alfonsino, gemfish, barracouta, hoki, and jack mackerel. Landings doubled in the following year, and from 1992–93 to 1994–95 landings were about 600 t, taken mainly as bycatch of gemfish in the Bay of Plenty and from target midwater trawling in Statistical Areas 012 and 013 (RBY 2). In 1995–96, landings increased to 735 t, before decreasing to 247 t by 1998–99. Since then landings have fluctuated between about 200 t and 750 t (Table 2). Landing records for 2017–18 and 2018–19 are amongst the lowest in the time series, averaging about 212 t.

The main rubyfish grounds (target species and alfonsino bycatch) are the banks or "hills" off the east coast of the North Island in RBY 2, and the Bay of Plenty (RBY 1). Although landings from RBY 1 increased from the mid-2000s, in most years landings have been greater in RBY 2 (which accounted for 70% of total landings during the 1990s), other than 2011–12 when RBY 1 accounted for 83% of landings. The level of direct targeting on rubyfish has increased over the history of the fishery, and most target catch is now taken from underwater features around East Cape and the Bay of Plenty.

Rubyfish are also taken as a bycatch of tarakihi tows (between 50 and 300 m bottom depth) from around all coasts of the North Island, Chatham Islands, and the upper part of the South Island. Bycatch of rubyfish in the hoki fishery is also widely distributed in deeper waters (200 to 450 m), including the Chatham Rise and the southeast coast of the South Island. Rubyfish have also been reported as an intermittent bycatch with barracouta, jack mackerel, bluenose, black cardinalfish, orange roughy, silver warehou, trevally, and scampi. Commercial concentrations of rubyfish probably also exist in areas that have not been fished in appropriate depths, especially in the northern half of New Zealand.

Rubyfish was introduced into the QMS on 1 October 1998. Initially allowances were not made for non-commercial catch. The historical landings and TACC values for the two main RBY stocks are shown in Figure 1.

In the 2002–03 fishing year, the TACC for RBY 1 was increased under the Adaptive Management Programme (AMP) to 300 t. At the same time a customary allowance of 1 t, a recreational allowance of 2 t, and an allowance of 15 t for fishing-related mortality took the TAC to 318 t. All AMP programmes ended on 30 September 2009. The RBY 1 TACC remains unchanged at 300 t, and with the exception of the fishing year 2009–10 landings have remained below the TACC (Table 2). In RBY 2 the TACC has remained unchanged at 433 t since 1998, with landings only slightly exceeding the TACC in 2008–09 and 2010–11.

The RBY 3 TACC was increased from 3 t to 30 t for the fishing year 2015–16 (when the TACC was met), but landings have been 3 t or less since 2016–17. RBY 4, 7, and 8 stocks landings were above the TACCs for a number of years, so the TACCs were increased to the average of the previous 7 years plus an additional 10% from the 1 October 2006; the TACCs for RBY 4, 7, and 8 were increased to 6, 33, and 5 t respectively. Landings continued to exceed the TACCs after 2006–07, resulting in a further TACC increase to 18 t for RBY 4 from 1 October 2010. An allowance of 1 t was allocated to RBY 4 at the same time, bringing the TAC to 19 t. A TACC of 19 t has been allocated to RBY 9 since the 2000–01 fishing year, but landings have fluctuated between <1 t and 2 t since 2007.

Table 1: Reported landings (t) of rubyfish by QMA and fishing year, 1983–84 to 1997–98. The data in this table has been updated from that published in previous Plenary Reports by using the data through 1996–97 in table 35 on p. 270 of the "Review of Sustainability Measures and Other Management Controls for the 1999–00 Fishing Year - Final Advice Paper" dated 6 August 1998.

	QMA 1	QMA 2	QMA 3	QMA 4	QMA 5	QMA 6	QMA 7	QMA 8	QMA 9	QMA 10	Other	Total
1990–91	66	159	5	3	0	0	9	0	3	0		245
1991–92	147	390	0	0	0	0	20	1	6	0		564
1992–93	90	491	0	0	0	0	31	0	0	0		612
1993–94	116	379	3	0	0	0	72	0	5	0		575
1994–95	43	500	3	12	0	0	13	0	10	0		581
1995–96	106	595	2	0	0	0	9	0	23	0		735
1996–97	128	297	2	1	< 1	0	14	< 1	21	< 1	1	463
1997–98	50	308	< 1	1	0	0	6	< 1	13	< 1	< 1	380

† QMS data.

Table 2: Reported landings (t) of rubyfish by Fishstock and TACCs from 1998–99 to 2018–19.

Fishstock	RBY 1		RBY 2		RBY 3		RBY 4		RBY 5	
FMA	1		2		3		4		5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1998–99	55	104	180	433	< 1	2	< 1	2	0	0
1999–00	138	104	321	433	6	2	< 1	2	0	0
2000–01	39	109	433	433	< 1	3	2	3	0	0
2001–02	36	109	414	433	1	3	8	3	1	0
2002–03	21	300	233	433	< 1	3	11	3	1	0
2003–04	19	300	343	433	< 1	3	2	3	< 1	0
2004–05	109	300	217	433	< 1	3	10	3	1	0
2005–06	135	300	303	433	< 1	3	33	3	0	0
2006–07	293	300	198	433	4	3	37	6	0	0
2007–08	120	300	427	433	< 1	3	11	6	< 1	0
2008–09	192	300	467	433	< 1	3	19	6	0	0
2009–10	351	300	309	433	2	3	11	6	< 1	0
2010–11	297	300	435	433	< 1	3	9	18	< 1	0
2011–12	278	300	73	433	< 1	3	4	18	< 1	0
2012–13	95	300	331	433	2	3	21	18	< 1	0
2013–14	223	300	349	433	<1	3	15	18	<1	0
2014–15	132	300	270	433	14	3	22	18	<1	0
2015–16	145	300	286	433	30	30	19	18	<1	0
2016–17	180	300	213	433	<1	30	13	18	0	0
2017–18	71	300	104	433	<1	30	17	18	1	0
2018–19	47	300	141	433	3	30	16	18	<1	0

Fishstock	RBY 6		RBY 7		RBY 8		RBY 9		RBY 10	
FMA	6		7		8		9		10	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1998–99	0	0	4	27	< 1	0	7	9	< 1	0
1999–00	0	0	13	27	< 1	0	15	9	0	0
2000–01	< 1	0	7	27	0	1	16	19	0	0
2001–02	0	0	35	27	< 1	1	3	19	0	0
2002–03	< 1	0	32	27	2	1	2	19	0	0
2003–04	< 1	0	9	27	8	1	1	19	0	0
2004–05	< 1	0	99	27	< 1	1	3	19	0	0

Table 2 [continued]:

Fishstock	RBY 6		RBY 7		RBY 8		RBY 9		RBY 10	
FMA		6		7		8		9		10
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2005–06	< 1	0	8	27	8	1	20	19	0	0
2006–07	0	0	13	33	< 1	5	1	19	0	0
2007–08	< 1	0	4	33	1	6	1	19	0	0
2008–09	< 1	0	14	33	< 1	6	2	19	0	0
2009–10	0	0	4	33	< 1	6	< 1	19	0	0
2010–11	0	0	5	33	< 1	6	< 1	19	0	0
2011–12	0	0	18	33	< 1	6	<1	19	0	0
2012–13	< 1	0	2	33	< 1	6	1	19	0	0
2013–14	0	0	48	33	<1	6	<1	19	0	0
2014–15	<1	0	4	33	<1	6	1	19	0	0
2015–16	0	0	3	33	<1	6	1	19	0	0
2016–17	0	0	9	33	<1	6	<1	19	0	0
2017–18	0	0	5	33	<1	6	1	19	0	0
2018–19	<1	0	16	33	<1	6	2	19	0	0

	Total	
	Landings	TACC
1998–99	247	577
1999–00	493	577
2000–01	358	595
2001–02	498	595
2002–03	302	595
2003–04	382	595
2004–05	439	595
2005–06	507	786
2006–07	546	849
2007–08	564	800
2008–09	694	800
2009–10	677	800
2010–11	747	812
2011–12	374	812
2012–13	452	812
2013–14	635	812
2014–15	444	812
2015–16	482	839
2016–17	415	839
2017–18	198	839
2018–19	225	839

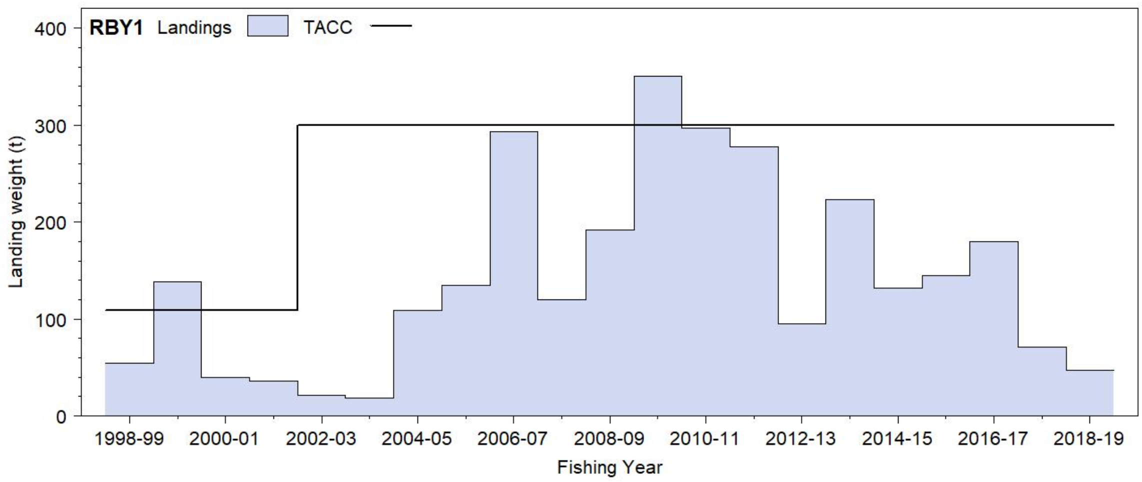


Figure 1: Reported commercial landings and TACC for the two main RBY stocks. RBY 1 (Auckland East) and RBY 2 (Central East). Note that these figures do not show data prior to entry into the QMS [Continued next page]

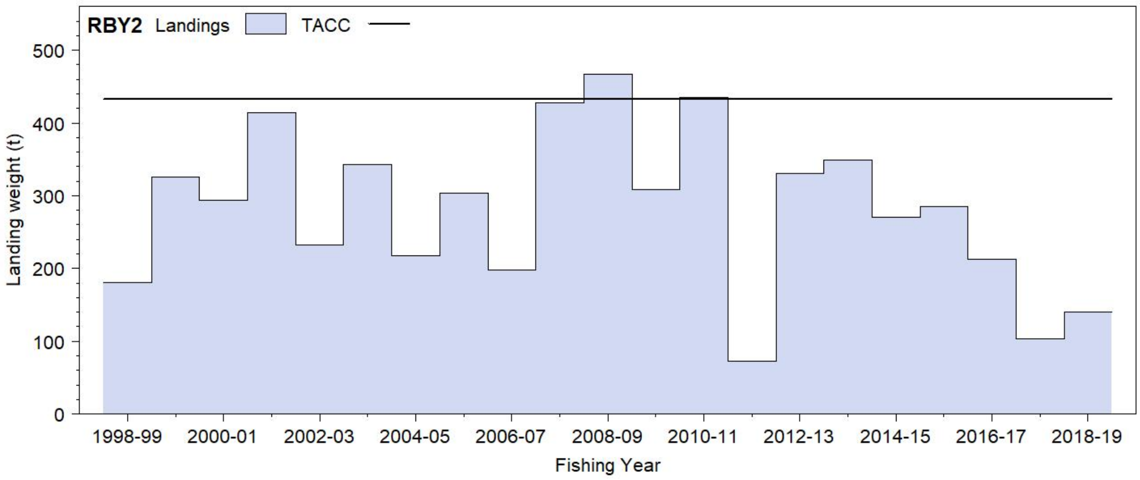


Figure 1 [Continued]: Reported commercial landings and TACC for the two main RBY stocks. RBY 1 (Auckland East) and RBY 2 (Central East). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries
There is no reported recreational catch.

1.3 Customary non-commercial fisheries
There is no quantitative information on the current level of customary non-commercial take.

1.4 Illegal catch
There is no quantitative information on the level of illegal catch.

1.5 Other sources of mortality
There is no quantitative information on the level of other sources of mortality.

2. BIOLOGY

Rubyfish are recorded from southern Australia, South Africa, and from banks in the southern Indian and south-east Atlantic oceans. They occur in the subtropical water around northern and central New Zealand, but are absent from the southern Chatham Rise and Campbell Plateau. Rubyfish occur at depths ranging from 50 m to at least 800 m. Most commercial catch is taken between 200 m and 400 m.

Rubyfish have been recorded up to 58 cm in length. Small catches of rubyfish in research tows have been of similar-sized fish, suggesting schooling by size.

Ageing research based on simple counts of otolith structures indicate that rubyfish are a slow-growing and long-lived species (Paul et al 2000). Paul et al (2003) and Horn et al (2012) used radiocarbon dating techniques on otoliths from 10 rubyfish to determine that the oldest fish in the sample were born prior to the beginning of the period of atmospheric testing and therefore were at least 45 years old. The ages they determined using an age-length-key derived from a catch sampling programme showed that although rubyfish could live to 100+ years, the commercial catch was dominated by young fish (8–15 years).

Horn et al (2012) analysed stable isotopes (oxygen and carbon) from rubyfish otoliths. They showed changes in mean depth with age, with rubyfish near the surface as juveniles, moving deeper with age, and adult rubyfish appearing to reside in 600–1000 m, with some apparent depth through the vertical water column (or possibly changes in geographic location) migrations within this range. They hypothesised that most rubyfish caught commercially are late juveniles and early adults in a transitional phase between early life in near surface semi-pelagic water and adult life in deeper water inaccessible to fishing. However, the suggestion by Bentley et al (2013) that rubyfish populations on distinct topographic features have been serially depleted is supportive of an alternative hypothesis that the exploited fish are part of a transient population which move up sporadically from deeper water to these features for an unknown length of time, probably to feed, thereby becoming vulnerable to fishing operations.

There is little information on rubyfish spawning cycles or areas. Sparse observer records of female gonad stages suggest a November to February spawning season, but that is based on the percentage of fish that are mature. Actual observations of reproductive stage four and five fish during those months are rare, suggesting that they are largely unavailable to the commercial fishery.

Observations on gut contents show that rubyfish feed on midwater crustaceans, salps, and myctophid fishes. Stable oxygen isotope chemistry of samples taken from the core to the outer edge of the otoliths of large fish indicate that juvenile rubyfish feed on significantly lower trophic levels than the adults, but that their metabolic rates declines between age 5 and 10, and trophic level increases as they descend through the water column to depths of about 600 m (Horn et al 2012).

Horn et al (2012) further refined the growth estimates using a four parameter model fitted to the length-age data for ages 8 years and older, while constraining t_0 to be 0.5 (to remove the influence of the younger aged fish). The resulting unweighted length-at-age data were fitted using the von Bertalanffy growth model:

$$L_t = L\infty\,[1 - \exp(-K \times (t - t_0))]^P$$

Note that when P = 1 the growth model becomes the often-used three-parameter von Bertalanffy equation.

Biological parameter estimates are given in Table 3.

Table 3: Estimates of biological parameters for rubyfish.

Fishstock	Estimate				Source
1. Natural mortality (*M*)					
All	*M* = 0.03 – 0.1				Paul et al (2000, 2003)
2. Weight = a (length)^b (Weight in g, length in cm fork length)					
				Both sexes	
	a	b			
RBY 2	0.0255	2.9282			NIWA (unpub. data)
3. von Bertalanffy growth parameters					
				Both sexes	
	L_∞	*K*	t_0	*P*	
RBY 2	48.68	0.045	-16.53		Paul et al (2003)
	47.7	0.031	-0.5(constrained)	0.216	Horn et al (2012)

3. STOCKS AND AREAS

It is not known whether different regional stocks of rubyfish occur in New Zealand waters.

Although landings are reported by Fishstocks which align with the standard QMAs, for stock assessment purposes it may be more appropriate to consider Fishstocks RBY 1 and RBY 9 as one (northern) unit, Fishstock RBY 2 (the main fishery) as an eastern unit, Fishstocks RBY 3–5 as a minor southern unit, and Fishstocks RBY 7 and RBY 8 as a western unit.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

A biomass index derived from a standardised CPUE (log linear, kg/day) analysis of the target trawl fishery represented by 10 main vessels (Blackwell 2000) was calculated for RBY 2. However, the results were highly uncertain, mainly due to the limited amount of data available, and were not accepted by the Inshore Working Group.

Since 2000–01, most of the rubyfish catch has come from target trawling and since 2008–09, most has come from a single vessel. Furthermore, the target fishery is focused on, and has shifted effort between, relatively few underwater features. This provides the potential for aggregate catch per unit effort to mask localised depletion. For these reasons, QMA wide CPUE standardisations have not been attempted in recent analyses. Summaries of catch, effort, and unstandardised CPUE from the target midwater trawl fishery for eight separate groups of underwater features in RBY 1 and RBY 2 suggest serial depletion both between, and within, groups of features. Initially high catch rates at the southernmost features that were the earliest focus of targeting, declined sharply after only a few years of fishing, and both effort and catch subsequently shifted northward. There is evidence of ongoing “test” fishing on southern features, but catches and catch rates have remained low. In the more recently developed fisheries further north at East Cape and in the Bay of Plenty, catch rates appear to have been maintained by shifts in effort within each group prompted by the discovery of new features within them (Bentley et al 2013).

4.2 Biomass estimates
No information is available.

4.3 Estimation of Maximum Constant Yield (*MCY*)
MCY cannot be determined.

4.4 Estimation of Current Annual Yield (*CAY*)
CAY cannot be determined.

4.5 Other yield estimates and stock assessment results
No information is available.

4.6 Other factors
A substantial catch of rubyfish has been taken in conjunction with alfonsino by the trawl fishery off the North Island east coast. Future quotas and catch restraints imposed on rubyfish could, in turn, constrain the alfonsino fishery. Rubyfish is taken in smaller, irregular quantities in other target trawl fisheries and these fisheries could also be affected by future rubyfish management policy.

Catch sampling has occurred in RBY 2 for four years 1998–99 to 2000–01, and 2006–07 and 2007–08 though data for the recent years are of little value. It is likely that the age composition of RBY varies across features and as the exact location of the samples is not known it is unclear whether the samples have come from the areas that have been consistently fished over time. The earlier catch sampling data show that the fishery is comprised of a large number of age classes with a reasonable proportion of the catch coming from fish of greater than 50 years old (Horn & Sutton 2009).

5. ANALYSIS OF ADAPTIVE MANAGEMENT PROGRAMMES (AMP)

The Ministry of Fisheries revised the AMP framework in December 2000. The AMP framework is intended to apply to all proposals for a TAC or TACC increase, with the exception of fisheries for which there is a robust stock assessment. In March 2002, the first meeting of the new Adaptive Management Programme Working Group was held. Two changes to the AMP were adopted:

- a new checklist was implemented with more attention being made to the environmental impacts of any new proposal;
- the annual review process was replaced with an annual review of the monitoring requirements only. Full analysis of information is required a minimum of twice during the five year AMP.

RBY 1
The TACC for RBY 1 was increased from 109 t to 300 t under the Adaptive Management Programme (AMP) in October 2002.

Full-term Review of RBY 1 AMP in 2007
In 2007 the AMP FAWG reviewed the performance of the AMP (Starr et al 2007). The WG noted:

Fishery characterisation

- Fish are landed as green weight, so there are no conversion factor issues.
- Historical landings have been primarily taken as a bycatch of the bottom trawl fishery targeted at gemfish in the Bay of Plenty. These landings have nearly disappeared as a result of the decline in that fishery.
- The main target fishery has been a midwater trawl fishery associated with features in the Bay of Plenty which operated in 2004–05 and 2005–06.
- It was noted that there may be some merit in considering management options like feature limits in this fishery.

CPUE analysis

- There are insufficient data to use for a standardised analysis so four unstandardised analyses were presented, three from bycatch trawl fisheries for gemfish, tarakihi, and hoki, and one from a bycatch bottom longline fishery directed at hapuku and bluenose. No series was constructed from the target rubyfish fishery because there were sufficient data in only three years. The CPUE trends in the four bycatch fisheries showed variable trends which appeared to reflect effort trends in the respective fisheries rather than RBY biomass trends.

Logbook programme

- There are no logbook data in the database, except 1 trip and 4 tows. There is a problem in obtaining samples because it is difficult to sample the fish, because they are directly dumped into sea water tanks on the ship.
- Recommend a shed sampling programme, or a similar approach to obtain biological data, but the programme will endeavour to collect data that will allow the fish to be linked to a tow.

Environmental effects

- Catch has never exceeded the TACC over the term of the AMP. The target gemfish fishery, the primary bycatch fishery for this species, has diminished considerably in recent years.
- No code of practice in RBY fishery.

Conclusion

- If the AMP continues, there is a need to improve the collection of information. There is a need for more biological data, such as otoliths and lengths from every large landing of this species.
- There is also a need for improved fine-scale catch and effort information for smaller areas.
- The Working Group indicated that a catch curve analysis approach is likely to be the most effective way to monitor this Fishstock.

6. STATUS OF THE STOCKS

RBY 1

In 2002, RBY 1 was included in the AMP on the basis that the stock had been lightly fished and it seemed likely that the stock was above B_{MSY}. There has been an increase in targeted midwater trawling in RBY 1 and in the 2011–12 fishing most of the national catch was taken in this QMA. It is not known whether the level of recent commercial catches in this QMA is sustainable. The status of RBY 1 relative to B_{MSY} is unknown.

RBY 2

Catch sampling between 1998–99 and 2000–01 indicated that the fishery was then comprised of a large number of age classes with a reasonable proportion of the catch coming from fish of greater than 50 years old. Although relatively high catches were made prior to this period there was no obvious truncation of the age distribution to indicate high and unsustainable levels of fishing mortality. However, catch rates have since declined and there is evidence of serial depletion of underwater features. The catch age structure has not been adequately sampled since then.

Historically, most of the RBY catch came from RBY 2 but have since declined due to reductions in both gemfish and rubyfish targeted midwater trawling effort in the QMA. It is not known whether the level of recent commercial catches in this QMA is sustainable. The status of RBY 2 relative to B_{MSY} is unknown.

Other areas

For most other areas it is not known if recent catches are sustainable. Commercial concentrations of rubyfish probably also exist in areas that have not been fished. The status of other RBY stocks relative to B_{MSY} is unknown.

TACCs and reported landings are summarised in Table 4.

Table 4: Summary of TACCs (t) and reported landings (t) of rubyfish for the most recent fishing year.

Fishstock		FMA	2018–19 Actual TACC	2018–19 Reported Landings
RBY 1	Auckland (East)	1	300	47
RBY 2	Central (East)	2	433	140
RBY 3	South-east (Coast)	3	30	3
RBY 4	South-east (Chatham)	4	18	16
RBY 5	Southland	5	0	<1
RBY 6	Sub-Antarctic	6	0	0
RBY 7	Challenger	7	33	15
RBY 8	Central (West)	8	6	<1
RBY 9	Auckland (West)	9	19	2
RBY 10	Kermadec	10	0	0
Total			839	225

7. FOR FURTHER INFORMATION

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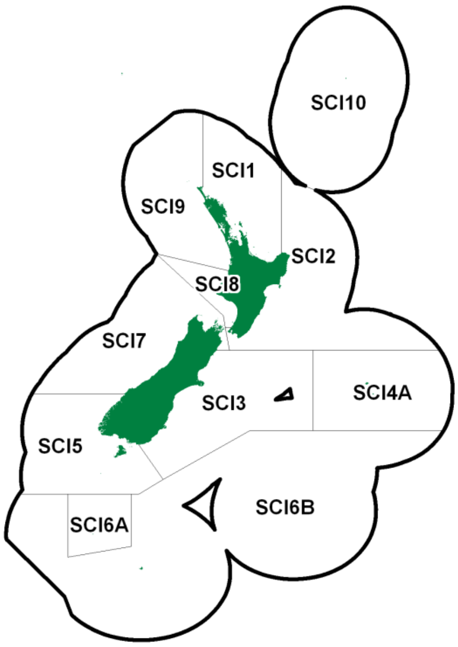
SCAMPI (SCI)

(*Metanephrops challengeri*)



1. FISHERY SUMMARY

Scampi were introduced into the QMS on 1 October 2004. At this time, management areas for scampi on the Chatham Rise (SCI 3 and 4) and in the Sub-Antarctic (SCI 6A and 6B) were substantially modified. Current TACs and TACCs by Fishstock are shown in Table 1.

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for scampi.

		Allowances			
Fishstock	TAC	Customary	Recreational	Other*	TACC
SCI 1	126	0	0	6	120
SCI 2	161	0	0	8	153
SCI 3	428	0	0	20	408
SCI 4A	126	0	0	6	120
SCI 5	42	0	0	2	40
SCI 6A	321	0	0	15	306
SCI 6B	53	0	0	3	50
SCI 7	79	0	0	4	75
SCI 8	5	0	0	0	5
SCI 9	37	0	0	2	35
SCI 10	0	0	0	0	0

1.1 Commercial fisheries

Target trawl fisheries for scampi developed first in the late 1980s and, until the 1999–00 fishing year, there were restrictions on the vessels that could be used in each stock. Between October 1991 and September 2002, catches were restrained using a mixture of competitive and individually allocated catch limits but, between October 2001 and September 2004, all scampi fisheries were managed using competitive catch limits – i.e., there were no individual allocations (Figure 1).

Estimated landings and TACCs are given by scampi QMA for 1986–87 to 2018–19 in Table 2.

Table 2: Estimated commercial landings (t) from the 1986–87 to present (based on management areas in force since introduction to the QMS in October 2004) and catch limits (t) by Fishstock (from CLR and TCEPR forms and data reported electronically, Fisheries New Zealand landings and catch effort databases, early years may be incomplete). No limits before 1991–92 fishing year, (†) catch limits allocated individually until the end of 2000–01. *Note that management areas SCI 3, 4A, 6A, and 6B changed in October 2004, and the catch limits applied to the old areas are not relevant to the landings, which have been reallocated to the revised areas on a prorata basis in relation to the TCEPR data, which has previously been found to match landings well.

Fishing	SCI 1		SCI 2		SCI 3		SCI 4A		SCI 5	
year	Landings	Limit (†) /TACC	Landings	Limit (†) /TACC	Landings	Limit (†) /TACC	Landings	Limit(†) /TACC	Landings	Limit (†) /TACC
1986–87	5	–	0	–	0	–	0	–	0	–
1987–88	15	–	5	–	0	–	0	–	0	–
1988–89	60	–	17	–	0	–	0	–	0	–
1989–90	104	–	138	–	0	–	0	–	0	–
1990–91	179	–	295	–	0	–	32	–	0	–
1991–92	132	120	221	246	153	–	78	–	0	60
1992–93	114	120	210	246	296	–	11	–	2	60
1993–94	115	120	244	246	324	–	0	–	1	60
1994–95	114	120	226	246	292	–	0	–	0	60
1995–96	117	120	230	246	306	–	0	–	0	60
1996–97	117	120	213	246	304	–	0	–	2	60
1997–98	107	120	224	246	296	–	0	–	0	60
1998–99	110	120	233	246	292	–	28	–	30	60
1999–00	124	120	193	246	322	–	23	–	9	40
2000–01	120	120	146	246	333	–	0	–	7	40
2001–02	124	120	247	246	304	–	30	–	< 1	40
2002–03	121	120	134	246	264	–	79	–	7	40
2003–04	120	120	64	246	277	–	41	–	5	40
2004–05	114	120	71	200	335	340	101	120	1	40
2005–06	109	120	77	200	319	340	79	120	< 1	40
2006–07	110	120	80	200	307	340	39	120	< 1	40
2007–08	102	120	61	200	209	340	8	120	< 1	40
2008–09	86	120	52	200	190	340	1	120	< 1	40
2009–10	111	120	125	200	302	340	< 1	120	< 1	40
2010–11	114	120	128	100	256	340	43	120	< 1	40
2011–12	114	120	99	100	278	340	41	120	< 1	40
2012–13	126	120	96	100	300	340	55	120	<1	40
2013–14	107	120	125	133	319	340	107	120	<1	40
2014–15	117	120	143	133	374	340	131	120	<1	40
2015–16	118	120	134	153	336	340	114	120	<1	40
2016–17	129	120	150	153	344	340	129	120	<1	40
2017–18	120	120	152	153	337	340	111	120	<1	40
2018–19	119	120	157	153	413	408	122	120	<1	40

	SCI 6A		SCI 6B		SCI 7		SCI 8		SCI 9	
	Landings	Limit (†) /TACC	Landings	Limit (†) /TACC	Landings	Limit (†) /TACC	Landings	Limit (†) /TACC	Landings	Limit (†) /TACC
1986–87	0	–	0	–	0	–	0	–	0	–
1987–88	0	–	0	–	0	–	0	–	0	–
1988–89	0	–	0	–	0	–	0	–	0	–
1989–90	0	–	0	–	0	–	0	–	0	–
1990–91	2	–	0	–	0	–	0	–	0	–
1991–92	325	–	0	–	0	75	0	60	0	60
1992–93	279	–	0	–	2	75	0	60	2	60
1993–94	303	–	0	–	0	75	0	60	1	60
1994–95	239	–	0	–	2	75	0	60	0	60
1995–96	270	–	0	–	1	75	0	60	0	60
1996–97	275	–	0	–	0	75	0	60	0	60
1997–98	279	–	0	–	0	75	0	60	0	60
1998–99	325	–	< 1	–	1	75	0	60	< 1	60
1999–00	328	–	0	–	1	75	0	5	0	35
2000–01	264	–	0	–	< 1	75	0	5	0	35
2001–02	272	–	0	–	< 1	75	0	5	0	35
2002–03	255	–	0	–	< 1	75	0	5	0	35
2003–04	311	–	0	–	1	75	0	5	0	35
2004–05	295	306	0	50	1	75	0	5	0	35
2005–06	286	306	0	50	1	75	0	5	0	35
2006–07	302	306	0	50	< 1	75	0	5	0	35
2007–08	287	306	0	50	1	75	0	5	0	35
2008–09	264	306	< 1	50	1	75	0	5	0	35
2009–10	144	306	0	50	2	75	0	5	0	35
2010–11	198	306	< 1	50	4	75	0	5	0	35
2011–12	166	306	< 1	50	6	75	0	5	< 1	35

Table 2 [Continued]

	SCI 6A		SCI 6B		SCI 7		SCI 8		SCI 9	
	Landings	**Limit (†) /TACC**	**Landings**	**Limit (†) /TACC**	**Landings**	**Limit (†) /TACC**	**Landings**	**Limit (†) /TACC**	**Landings**	**Limit (†) /TACC**
2012–13	146	306	0	50	7	75	0	5	<1	35
2013–14	107	306	<1	50	4	75	0	5	<1	35
2014–15	102	306	<1	50	9	75	0	5	<1	35
2015–16	263	306	<1	50	9	75	0	5	<1	35
2016–17	300	306	<1	50	3	75	0	5	<1	35
2017–18	295	306	<1	50	4	75	0	5	<1	35
2018–19	262	306	0	50	1	75	0	5	<1	35

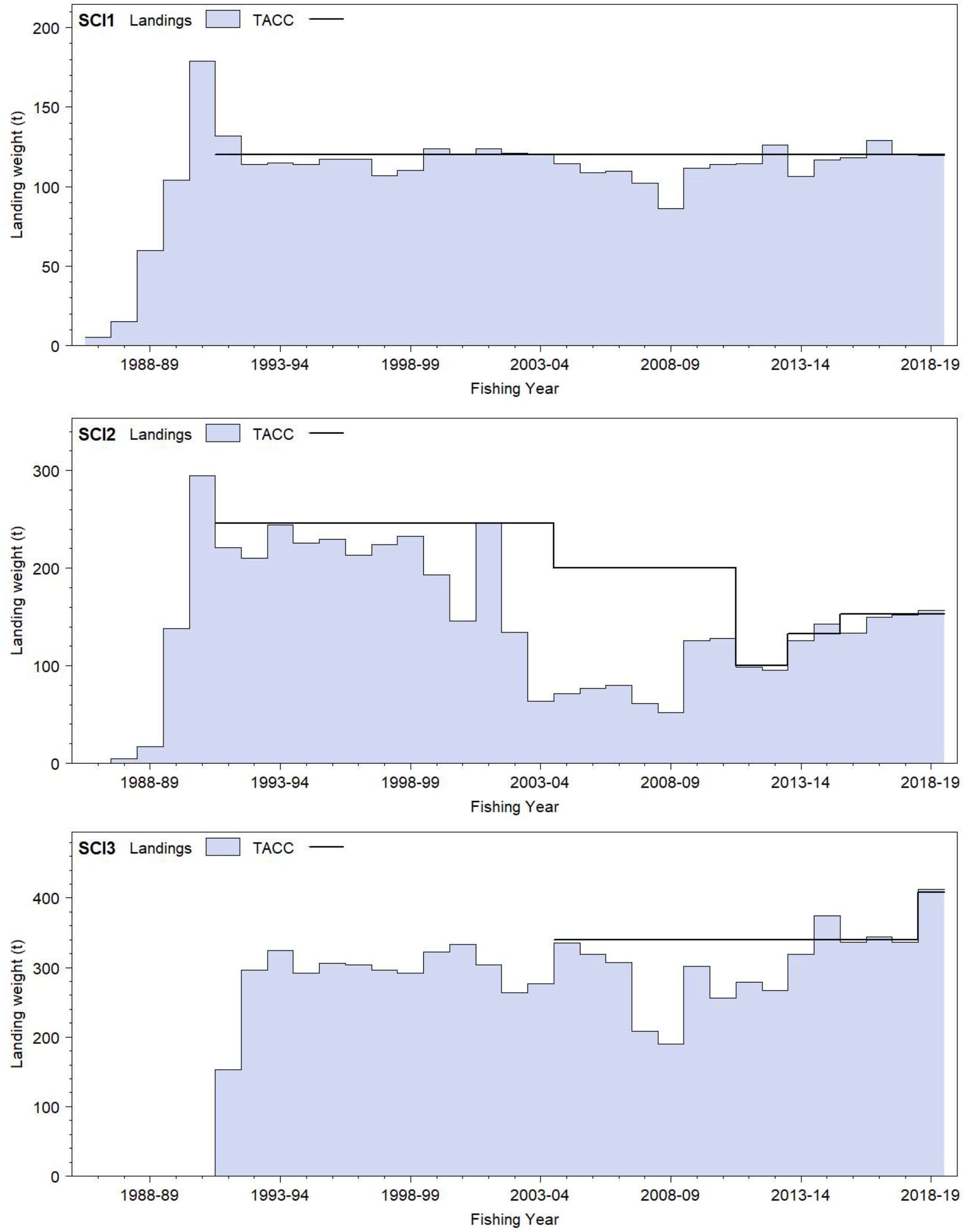


Figure 1: Reported commercial landings and TACCs (or catch limits prior to 2004–05) for the five main SCI stocks from fishing years 1986–87 to present. SCI 1 Bay of Plenty, SCI 2 Wairarapa coast and SCI 3 Chatham Rise. **[Continued on next page]**

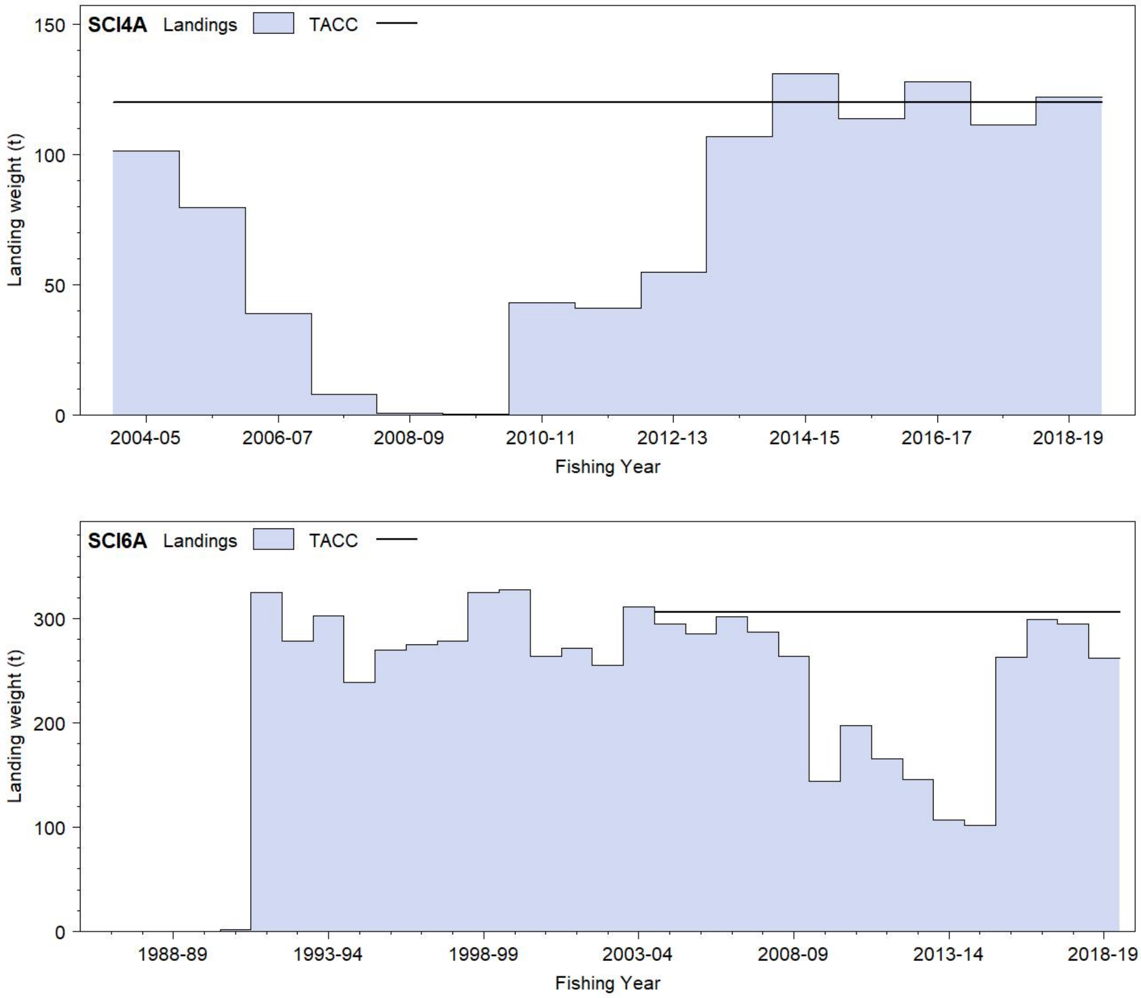


Figure 1: [Continued] Reported commercial landings and TACCs (or catch limits prior to 2004–05) for the five main SCI stocks from fishing years 1986–87 to present: SCI 4A Chatham Islands, and SCI 6A Auckland Islands.

Fishing has been conducted by 20–40 m vessels using light bottom trawl gear but over the last ten years, all vessels are less than 32 m long. All vessels use multiple rigs of two or three nets of very low headline height. The main fisheries are in waters 300–500 m deep in SCI 1 (Bay of Plenty), SCI 2 (Hawke Bay, Wairarapa Coast), SCI 3 (Mernoo Bank), SCI 4A (western Chatham Rise and Chatham Islands), and SCI 6A (Sub-Antarctic). Some fishing has been reported on the Challenger Plateau outside the EEZ. Minimal fishing for scampi has taken place in SCI 5, 6B, 7, 8, and 9.

1.2 Recreational fisheries
There is no recreational fishery for scampi.

1.3 Maori customary fisheries
There is no customary fishery for scampi.

1.4 Illegal catch
There is no quantitative information on the level of illegal catch. It is assumed to be zero.

1.5 Other sources of mortality
Other sources of fishing related mortality in scampi could include incidental effects of trawl gear on the animals and their habitat.

2. BIOLOGY

Scampi are widely distributed around the New Zealand coast, principally in depths between 200 and 500 m on the continental slope. Like other species of *Metanephrops* and *Nephrops*, *M. challengeri* builds a burrow in the sediment and may spend a considerable proportion of time within this burrow. From trawl catch rates, it appears that there are daily and seasonal cycles of emergence from burrows onto the sediment surface. Catch rates are typically higher during the hours of daylight than night, and patterns vary seasonally between sexes and areas, dependent on the moult cycle.

Scampi moult several times per year in early life and probably about once a year after sexual maturity (at least in females). Early work suggested that female *M. challengeri* achieve sexual maturity at about 40 mm orbital carapace length (OCL) in the Bay of Plenty and on the Chatham Rise, about 36 mm OCL off the Wairarapa coast, and about 56 mm OCL around the Auckland Islands (approximately age 3 to 4 years). Examination of ovary maturity on more recent trawl surveys suggest that 50% of females were mature at 30 mm OCL in SCI 1 and 2, and at about 38 mm in SCI 6A. The peak of moulting and spawning activity seems to occur in spring or early summer. Larval development of *M. challengeri* is probably very short and may be less than three days in the wild. The abbreviated larval phase may, in part, explain the low fecundity of *M. challengeri* compared with *N. norvegicus* (that of the former being about 10–20% that of the latter).

Relatively little is known of the growth rate of any of the *Metanephrops* species in the wild. Males grow to a larger size than females. Tagging of *M. challengeri* to determine growth rates was undertaken in the Bay of Plenty in 1995, and the bulk of recaptures were made late in 1996. About 1% of tagged animals were recaptured, similar to the average return rate of similar tagging studies for scampi and prawns in the UK and Australia. Many more females than males were recaptured, and small males were almost entirely absent from the recapture sample. The reasons for this are not understood, but may relate to the timing of moulting in relation to the study and tag retention. Scampi captured and tagged at night were much more likely to be recaptured than those exposed to sunlight. Estimates from this work of growth rate and mortality for females are given in Table 3. The data for males were insufficient for analysis, although the average annual increment with size appeared to be greater than in females.

Table 3: Estimates of biological parameters.

Population		**Estimate**	**Source**
1. Weight = a(orbital carapace length)^b (weight in g, OCL in mm)			
All males: SCI 1	a = 0.000373	b = 3.145	Cryer & Stotter (1997)
Ovigerous females: SCI 1	a = 0.003821	b = 2.533	Cryer & Stotter (1997)
Other females: SCI 1	a = 0.000443	b = 3.092	Cryer & Stotter (1997)
All females: SCI 1	a = 0.000461	b = 3.083	Cryer & Stotter (1997)
2. von Bertalanffy growth parameters			
	***K* (yr^{-1})**	**L_∞ (OCL, mm)**	
Females: SCI 1 (tag)	0.11–0.14	48.0–49.0	Cryer & Stotter (1999)
Females: SCI 2 (aquarium)	0.31	48.8	Cryer & Oliver (2001)
Males: SCI 2 (aquarium)	0.32	51.2	Cryer & Oliver (2001)
3. Natural mortality (*M*)			
Females: SCI 1		*M* = 0.20–0.25	Cryer & Stotter (1999)

Estimates of *M* are based on the relationship between growth rate and natural mortality and are subject to considerable uncertainty. Analytical assessment models have been examined for *M*=0.2 and *M*=0.3.

Scampi from SCI 2 were successfully reared in aquariums for over 12 months in 1999–2000. Results from these growth trials suggested a Brody coefficient of about 0.3 for both sexes, compared with less than 0.15 from the tagging trial. Extrapolating the length-based results to age-based curves suggests that scampi are about 3–4 years old at 30 mm carapace length and may live for 15 years. There are many uncertainties with captive reared animals, however, and these estimates should not be regarded as definitive. In particular, the rearing temperature was 12 ºC compared with about 10 ºC in the wild (in SCI 1 and 2), and the effects of captivity are largely unknown.

The maximum age of New Zealand scampi is not known, although analysis of tag return data and aquarium trials suggest that this species may be quite long lived. *Metanephrops* spp in Australian waters may grow rather slowly and take up to 6 years to recruit to the commercial fishery (Rainer 1992), consistent with estimates of growth in *M. challengeri* (Table 3). *N. norvegicus* populations in some northern European populations achieve a maximum age of 15–20 years (Bell et al 2006), consistent with the estimates of natural mortality, *M*, for *M. challengeri*.

A tagging project has been conducted in SCI 6A, with five release events (March 2007, 2008, 2009, 2013, and 2016). Most recaptures occur within a year of release. Tagging work has also more recently been conducted in SCI 1, 2, and 3, although recapture rates have been low. Tag recaptures are fitted within assessment models to estimate growth.

3. STOCKS AND AREAS

Stock structure of scampi in New Zealand waters is not well known. Preliminary electrophoretic analyses suggest that scampi in SCI 6A are genetically distinct from those in other areas, and there is substantial heterogeneity in samples from SCI 1, 2, and 4A. Studies using newer mitochondrial DNA and microsatellite approaches are underway and are likely to be more sensitive to differences between stocks. The abbreviated larval phase of this species may lead to low rates of gene mixing. Differences among some scampi populations in average size, size at maturity, the timing of diel and seasonal cycles of catchability, catch to bycatch ratios, and CPUE trends also suggest that treatment as separate management units is appropriate.

A review of stock boundaries between SCI 3 and SCI 4A and between SCI 6A and SCI 6B was conducted in 2000, prior to introduction of scampi into the Quota Management System. Following the recommendation of this review, the boundaries were changed on 1 October 2004, to reflect the distribution of scampi stocks and fisheries more appropriately.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

Tables and accompanying text in this section have been updated for the 2020 Fishery Assessment Plenary where possible. A more detailed summary from an issue-by-issue perspective is available in the 2018 Aquatic Environment & Biodiversity Annual Review (Fisheries New Zealand 2019, https://www.mpi.govt.nz/dmsdocument/34854-aquatic-environment-and-biodiversity-annual-review-aebar-2018-a-summary-of-environmental-interactions-between-the-seafood-sector-and-the-aquatic-environment and Fisheries New Zealand 2020).

4.1 Role in the ecosystem

Scampi are thought to prey mainly on invertebrates (Meynier et al 2008) or carrion. A 3-year diet study on the Chatham Rise showed that scampi was the first, third, and fourth most important item (by IRI, Index of Relative Importance) in the diet of smooth skate, ling, and sea perch respectively (Dunn et al 2009). Scampi build and maintain burrows in the sediment and this bioturbation is thought to influence oxygen and nutrient fluxes across the sediment-water boundary, especially when scampi density is high (e.g., Hughes & Atkinson 1997, who studied *Nephrops norvegicus* at densities of 1–3 m^{-2}). Observed densities from photographic surveys in New Zealand have been 0.02–0.1 m^{-2} (Tuck 2010), similar to densities of *N. norvegicus* in comparable depths.

4.2 Bycatch (fish and invertebrates)

In the 2002–03 to 2015–16 fishing years, total annual bycatch was estimated to range from 2400–5600 t compared with total landed scampi catches of 550–893 t, and scampi accounted for 19% of the total estimated catch by weight from all observed tows (Anderson & Edwards 2018). Nearly 500 bycatch species or species groups were identified by observers, and the main bycatch species were javelin fish (18%), rattails (12%), and sea perch (10%), which were mostly discarded (Figure 2). Smaller catches of hoki (5%), ling (4%), dark ghost shark (3%) were also recorded. Invertebrate species made up a much smaller fraction of the bycatch overall (about 7%), with crustaceans (3%), echinoderms (2%), and squid (0.9%) being the main invertebrate bycatch species groups.

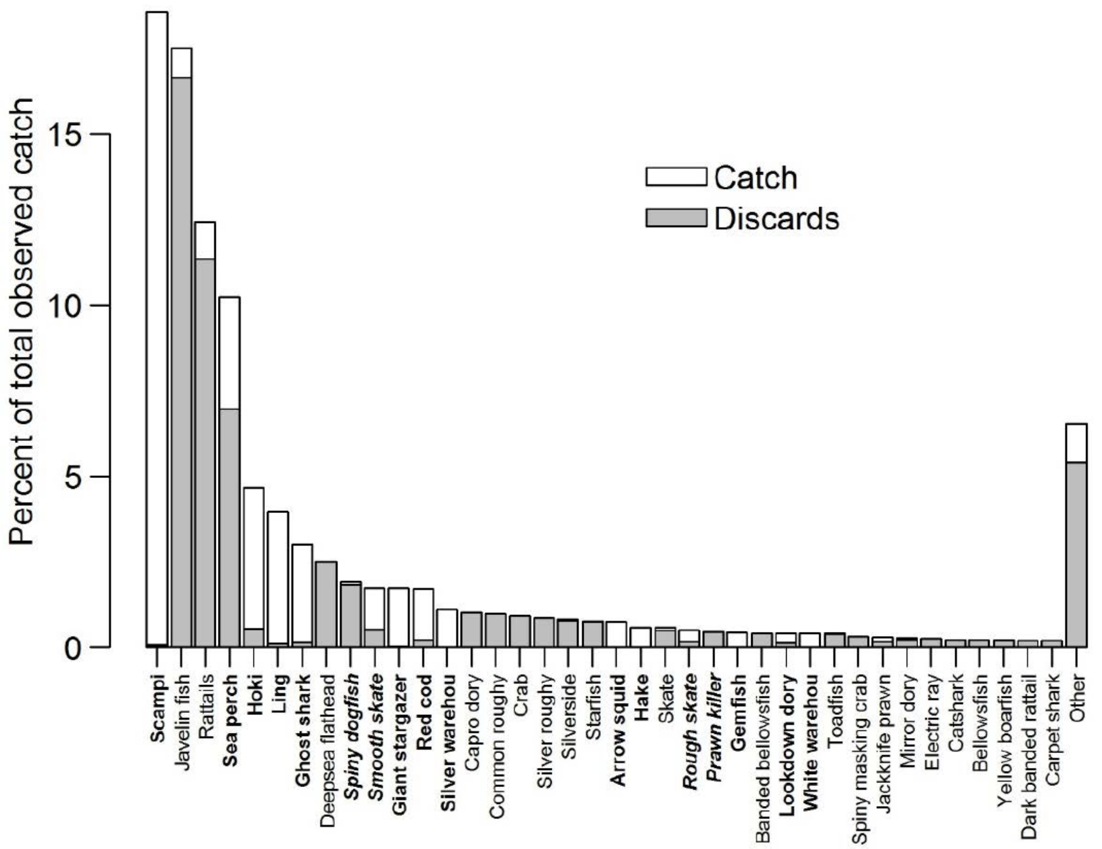


Figure 2: Percentage of the total catch contributed by the main bycatch species (those representing 0.02% or more of the total catch) in the observed portion of the target scampi trawl fishery for fishing years 2002–03 to 2015–16, and the percentage discarded. The Other category is the sum of all bycatch species representing less than 0.02% of the total catch (Anderson & Edwards 2018).

Total annual discard estimates from 2002–03 to 2015–16 showed no trend over time, ranging from a low of 940 t in 2003–04 to 4 070 t in the following year (Anderson & Edwards 2018). Non-QMS species were the main group discarded, often at a magnitude of two to three times that of QMS species discards. Annual estimated discards of scampi were generally low but exceeded 10 t in two years (2002–03 and 2009–10). The species discarded in the greatest amounts were those caught in the greatest amounts, javelin fish (95%), rattails (91%), and sea perch (68%). From 2002–03 to 2015–16, the overall discard fraction value was 3.6 kg, with little trend over time. Discards ranged from 1.2–4.9 kg of discarded fish for every 1 kilogram of scampi caught.

4.3 Incidental catch (seabirds, mammals, 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 but not brought onboard the vessel, Middleton & Abraham 2007). Risk assessments results, which also include estimation of cryptic mortality, are also presented here when relevant.

Marine mammal interactions

Scampi trawlers occasionally catch marine mammals, including New Zealand sea lions and New Zealand fur seals (which were classified as “Nationally Critical” and “Not Threatened”, respectively, under the New Zealand Threat Classification System in 2010, Baker et al 2016).

In the 2017–18 fishing year there were two observed captures of New Zealand sea lions in scampi trawl fisheries (Table 4). Sea lions captured in previous years were all taken close to the Auckland Islands in SCI 6A (Thompson et al 2011).

In the 2017–18 fishing year there were no observed captures of New Zealand fur seals in scampi trawl fisheries, with 12.5% observer coverage (Table 5). Since 2002–03, only about 0.7% of the estimated total captures of New Zealand fur seals in all commercial fisheries have been taken in scampi fisheries; these have been on the western Chatham Rise and close to the Auckland Islands.

Rates of capture for both sea lions and fur seals have been low and have fluctuated without obvious trend.

Table 4: Number of tows by fishing year and observed New Zealand sea lion captures in Auckland Islands scampi trawl fisheries (SCI 6A), 2002–03 to 2017–18. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described by Abraham et al (2016) and available via https://data.dragonfly.co.nz/psc. Data for 2002–03 to 2014–15 are based on data version 2017V01.

Fishing				Observed		Estimated	
year	Tows	No. obs	% obs	Captures	Rate	Captures	95% c.i.
2002–03	5 130	512	10.0	0	0.0	7	2–15
2003–04	3 753	412	11.0	3	0.7	10	5–18
2004–05	4 648	143	3.1	0	0.0	8	2–16
2005–06	4 867	331	6.8	1	0.3	8	3–16
2006–07	5 135	389	7.6	1	0.3	8	3–16
2007–08	4 804	524	10.9	0	0.0	8	2–15
2008–09	3 975	396	10.0	1	0.3	10	3–18
2009–10	4 248	348	8.2	0	0.0	5	1–11
2010–11	4 447	536	12.1	0	0.0	7	2–15
2011–12	4 509	459	10.2	0	0.0	7	2–14
2012–13	4 565	270	5.9	0	0.0	6	1–12
2013–14	4 421	254	5.7	0	0.0	5	1–11
2014–15	4 423	342	7.7	0	0.0	3	0–8
2015–16	5 210	144	2.8	0	0.0		
2016–17	4 707	447	9.5	0	0.0		
2017–18	4 345	545	12.5	2	0.4		

Table 5: Number of tows by fishing year and observed and model-estimated total New Zealand fur seal captures in scampi trawl fisheries, 2002–03 to 2017–18. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described by Abraham et al (2016) and available via https://data.dragonfly.co.nz/psc. Data for 2002–03 to 2015–16 are based on data version 2017v01.

Fishing				Observed		Estimated	
year	Tows	No. obs	% obs	Captures	Rate	Captures	95% c.i.
2002–03	5 130	512	10.0	2	0.4	7	2–21
2003–04	3 753	412	11.0	1	0.2	5	1–15
2004–05	4 648	143	3.1	0	0.0	20	1–84
2005–06	4 867	331	6.8	0	0.0	7	0–25
2006–07	5 135	389	7.6	0	0.0	7	0–24
2007–08	4 804	524	10.9	1	0.2	10	1–31
2008–09	3 975	396	10.0	1	0.3	5	1–17
2009–10	4 248	348	8.2	1	0.3	6	1–22
2010–11	4 447	536	12.1	0	0.0	4	0–16
2011–12	4 509	459	10.2	1	0.2	6	1–22
2012–13	4 565	270	5.9	0	0.0	5	0–17
2013–14	4 421	254	5.7	0	0.0	4	0–17
2014–15	4 423	342	7.7	1	0.3	7	1–23
2015–16	5 210	144	2.8	0	0.0	4	0–16
2016–17	4 707	447	9.5	1	0.2		
2017–18	4 345	545	12.5	0	0.0		

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Seabird interactions

Observed seabird capture rates in scampi fisheries ranged from about 1 to 20 per 100 tows between 1998–99 and 2008–09 (Baird 2001, 2004a, 2004b, 2004c, 2005b, Thompson & Abraham 2009, Abraham et al. 2009, Abraham & Thompson 2011, Abraham et al 2013, Abraham et al 2016, Abraham & Richard 2017, 2018) and have continued to fluctuated without obvious trend. In the 2017–18 fishing year there were 19 observed captures of birds in scampi trawl fisheries, with 130 (95% c.i.: 99–165) estimated captures, with the estimates made using a consistent modelling framework (Abraham et al 2016, Abraham & Richard 2017, 2018; Table 6). There were 11 observed captures in the 2016–17, with estimates of total captures of 127 (95% c.i.: 95–163, Table 6). The estimates are based on relatively low observer coverage and include all bird species and should, therefore, be interpreted with caution. The average capture rate in scampi trawl fisheries over the last sixteen years (all areas combined) is about 4 birds per 100 tows, a moderate rate relative to trawl fisheries for squid (13.79 birds per 100 tows) and hoki (2.32 birds per 100 tows) over the same years.

Table 6: Number of tows by fishing year and observed and model-estimated total New Zealand seabird captures in scampi trawl fisheries, 2002–03 to 2017–18. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described by Abraham et al (2016) and Abraham & Richard (2017, 2018) and available via https://data.dragonfly.co.nz/psc. Data for 2002–03 to 2017–18 are based on data version 2019v01.

Fishing			Observed			Estimated	
year	Tows	No. obs	% obs	Captures	Rate	Captures	95% c.i.
2002–03	5 130	512	10.0	7	1.4	141	103-186
2003–04	3 753	412	11.0	7	1.7	106	78-141
2004–05	4 652	143	3.1	9	6.3	144	110-185
2005–06	4 867	331	6.8	11	3.3	148	113-190
2006–07	5 135	389	7.6	24	6.2	155	120-193
2007–08	4 804	524	10.9	11	2.1	127	95-164
2008–09	3 975	396	10.0	19	4.8	135	103-171
2009–10	4 248	348	8.2	5	1.4	112	82-148
2010–11	4 447	536	12.1	109	20.3	241	205-284
2011–12	4 509	459	10.2	10	2.2	127	95-164
2012–13	4 565	270	5.9	6	2.2	135	100-175
2013–14	4 421	254	5.7	6	2.4	130	96-170
2014–15	4 423	342	7.7	7	2.0	122	91-160
2015–16	5 210	144	2.8	3	2.1	152	114-195
2016–17	4 707	447	9.5	11	2.5	127	95-163
201718	4 345	545	12.5	19	3.5	130	99-165

Observed seabird captures in the SCI target trawl fishery since 2002–03 have been dominated by four species: Salvin's and white-capped albatrosses make up 44% and 28% of the albatrosses captured respectively; white-chinned petrel, flesh-footed shearwaters, and common diving petrel make up 29%, 23%, and 19% of other birds respectively, and the total and fishery risk ratios are presented in Table 7. Most of the captures occur near the Auckland Islands (39%), in the Bay of Plenty (36%), or on the Chatham Rise (21%). These numbers should be regarded as only a general guide on the distribution of captures because observer coverage is not uniform across areas and may not be representative.

Table 7: Risk ratio of seabirds predicted by the level two risk assessment for the SCI target trawl fishery and all fisheries included in the level two risk assessment, 2006–07 to 2016–17, showing seabird species with a risk ratio of at least 0.001 of PST. The risk ratio is an estimate of aggregate potential fatalities (inclusive of cryptic mortality) across trawl and longline fisheries relative to the Population Sustainability Threshold, PST (from Richard et al 2017 and Richard et al 2020, where full details of the risk assessment approach can be found). The DOC threat classifications are shown (Robertson et al 2017 at http://www.doc.govt.nz/documents/science-and-technical/nztcs19entire.pdf). [Continued on next page]

		Risk ratio			
Species name	PST (mean)	SCI target trawl*	Total	Risk category	DOC Threat Classification
Salvin's albatross	3 460	0.077	0.65	High	Threatened: Nationally Critical
Flesh-footed shearwater	1 450	0.033	0.49	High	Threatened: Nationally Vulnerable
Northern Buller's albatross	1 640	0.030	0.26	Medium	At Risk: Naturally Uncommon
Black petrel	447	0.011	1.23	Very high	Threatened: Nationally Vulnerable

Table 7 [Continued]

Species Names	PST (Mean)	Risk Ratio: SCI Target Trawl*	Risk Ratio: Total	Risk Category	DOC Threat Classification
Northern giant petrel	337	0.008	0.15	Medium	At Risk: Naturally Uncommon
New Zealand white-capped albatross	10 800	0.008	0.29	Medium	At Risk: Declining
Southern Buller's albatross	1 360	0.007	0.37	High	At Risk: Naturally Uncommon
White-chinned petrel	25 800	0.006	0.07	Low	At Risk: Declining
Chatham Island albatross	428	0.003	0.28	High	At Risk: Naturally Uncommon
Campbell black-browed albatross	2 000	0.003	0.05	Low	At Risk: Naturally Uncommon

* SCI target trawl from Richard et al 2017.

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 in numerous studies for trawl fisheries targeting deepwater species (Baird et al 2011, Black et al 2013, Black & Tilney 2015, Black & Tilney 2017, Baird & Wood 2018, and Baird & Mules 2019, 2020b) and species in waters shallower than 250 m (Baird et al 2015, Baird & Mules 2020a). The most recent assessment of the deepwater trawl footprint was for the period 1989–90 to 2017–18 (Baird & Mules 2020b).

Bottom trawl effort for scampi peaked in 2001–02 at over 6500 tows (roughly 10% of all TCEPR bottom trawls in that year) but has typically been 4000–5000 tows per year since 1989–90 (Baird & Wood 2018). Most scampi effort is reported on TCEPR forms (Baird et al 2011, Black et al 2013). Tows are located in Benthic-optimised Marine Environment Classification (BOMEC, Leathwick et al 2012) classes F, G (upper slope), H, J, and L (mid-slope) (Baird & Wood 2012), and 95% were between 300 and 500 m depth (Baird et al 2011).

During 1989–90 to 2015–16, about 117 850 scampi bottom trawls were reported on TCEPRs (Baird & Wood 2018). The total footprint generated from these tows was estimated at about 22 537 km^2. This footprint represented coverage of 0.5% of the seabed of the combined EEZ and the Territorial Sea areas; 1.6% of the ‘fishable area’, that is, the seabed area open to trawling, in depths of less than 1600 m. For the 2016–17 fishing year, 4705 scampi bottom tows had an estimated footprint of 3715 km^2 which represented coverage of 0.1% of the EEZ and Territorial Sea and 0.3% of the fishable area (Baird & Mules 2019). There was no change in the percentage cover in 2017–18 (Baird & Mules 2020b).

The overall trawl footprint for scampi (1989–90 to 2015–16) covered < 1.0% of seabed in depths less than 200 m, 10% in 200–400 m, and 3% of 400–600 m seafloor (Baird & Wood 2018). The scampi footprint contacted < 0.1%, 2–3%, and 1% of those depth ranges, respectively, in 2016–17 and 2017–18 (Baird & Mules 2019, 2020b). The BOMEC areas with the highest proportion of area covered by the scampi footprint were classes H (Chatham Rise) and L (deeper waters off the Stewart-Snares shelf and around the main sub-Antarctic islands). In 2016–17, the scampi footprint covered ≤ 0.01% of each BOMEC class (Baird & Mules 2019). In 2017–18, an increase in the spatial extent of the footprint resulted in the coverage of 1.6% of class H and 1.0% of class L (Baird & Mules 2020b).

Bottom trawling for scampi, like trawling for other species, is likely to have effects on benthic community structure and function (e.g., Cryer et al 2002 for a specific analysis and Rice 2006 for an international review) 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 (Fisheries New Zealand 2020).

4.5 Other considerations

None considered by the Aquatic Environment Working Group.

5. STOCK ASSESSMENT

In 2011 the Shellfish Fishery Assessment Working Group (SFWG) accepted the stock assessments for SCI 1 and SCI 2, undertaken using a length-based population model. A length-based assessment was also accepted for SCI 3 in 2015, and for SCI 6A in 2017. No stock assessment has been undertaken for SCI 4A, but a stock characterisation and CPUE standardisation were completed in 2019. Section 5.2 summarises the stock assessments that have to date been accepted by Fisheries New Zealand Working Groups.

Attempts have been made to index scampi abundance using CPUE and trawl survey indices and, more recently, photographic surveys of visible scampi and scampi burrows. There is some level of agreement between the relative trends shown, and all three indices are included in the length-based assessment model.

5.1 Estimates of fishery parameters and abundance

Standardised CPUE indices are calculated for each stock every three years, as part of the stock assessment process. Annual unstandardised CPUE indices for each area (total catch divided by total effort in hours of trawling) are updated annually, using the data from all vessels that fished (Figure 3). The SFWG has raised concerns in the past that potential variability in catchability between years mean that standardised CPUE may not provide a reliable index of abundance, although consistent changes shown by different types of indices for the same area provide more confidence in the data. The standardised indices for areas SCI 3, 4A, 6A, and 6B have been recalculated over the time series in light of the alterations of some stock boundaries, following the review mentioned in Section 3. All discussions below relate to standardised CPUE.

In SCI 1, CPUE increased in the early 1990s, and then declined between 1995–96 and 2001–02, showed a slight increase in 2002–03 and 2003–04, but generally remained stable until 2016–17, with an increase since then. In SCI 2, CPUE increased in 1994–95, then declined steadily to 2001–02, remained at quite a low level until 2007–08, increased until 2013–14 (with CPUE comparable with that recorded in the mid–1990s), declining slightly after this to levels comparable with the late 1990s, remaining stable after 2015–16 with a slight increase in 2018–19. In SCI 3, CPUE rose steadily through the early 1990s, fluctuated around a slowly declining trend in the late 1990s and early 2000s, showed a steeper decline to 2007–08, increased to 2010–11, and then remained stable until increasing in 2016–17 to a level that has been maintained to 2018–19. In SCI 4A, CPUE observations were intermittent between 1991–92 and 2002–03, showing a dramatic increase over this period. Since 2002–03 CPUE has been far lower, but since 2010–11 data show an increase, with a steep increase since 2016–17. In SCI 6A, after an initial decline in the early 1990s, CPUE has fluctuated around a gradually declining trend. With the revision of the stock boundaries, data are only available for one year for SCI 6B, and are therefore not presented. For both SCI 5 and SCI 7, observations have been intermittent, and consistently low.

A time series of trawl surveys designed to measure relative biomass of scampi in SCI 1 and 2 ran between January 1993 and January 1995 (Table 8). Research trawling for other purposes has been conducted in both SCI 1 and SCI 2 in several other years, and catch rates from appropriate hauls within these studies have been plotted alongside the dedicated trawl survey data in Figure 4 and Figure 5. In SCI 1 the additional trawling was conducted in support of a tagging programme (in 1995 and 1996), which was conducted by a commercial vessel in the peak area of the fishery, whereas work to assess trawl selectivity (1996) and in support of photographic surveys (since 1998) may have been more representative of the overall area. This later index has remained relatively stable through the series. In SCI 2 the additional trawling was conducted in support of a growth investigation using length frequency data (1999 and 2000) and in support of photographic surveys (since 2003). All the work was carried out by the same research vessel, but whereas the work in support of photographic surveys was carried out over the whole area, the work related to the growth investigation was concentrated in a small area in the south of the SCI 2 area. Only the additional trawl survey work in support of photographic surveys has been included in Table 8, because the other studies did not have comparable spatial coverage. The trawl survey index shows an increase from the low levels in the mid-2000s to 2015, and a slight decrease by 2018. The trends observed are similar to the trends in commercial CPUE (Figure 3) for both stocks.

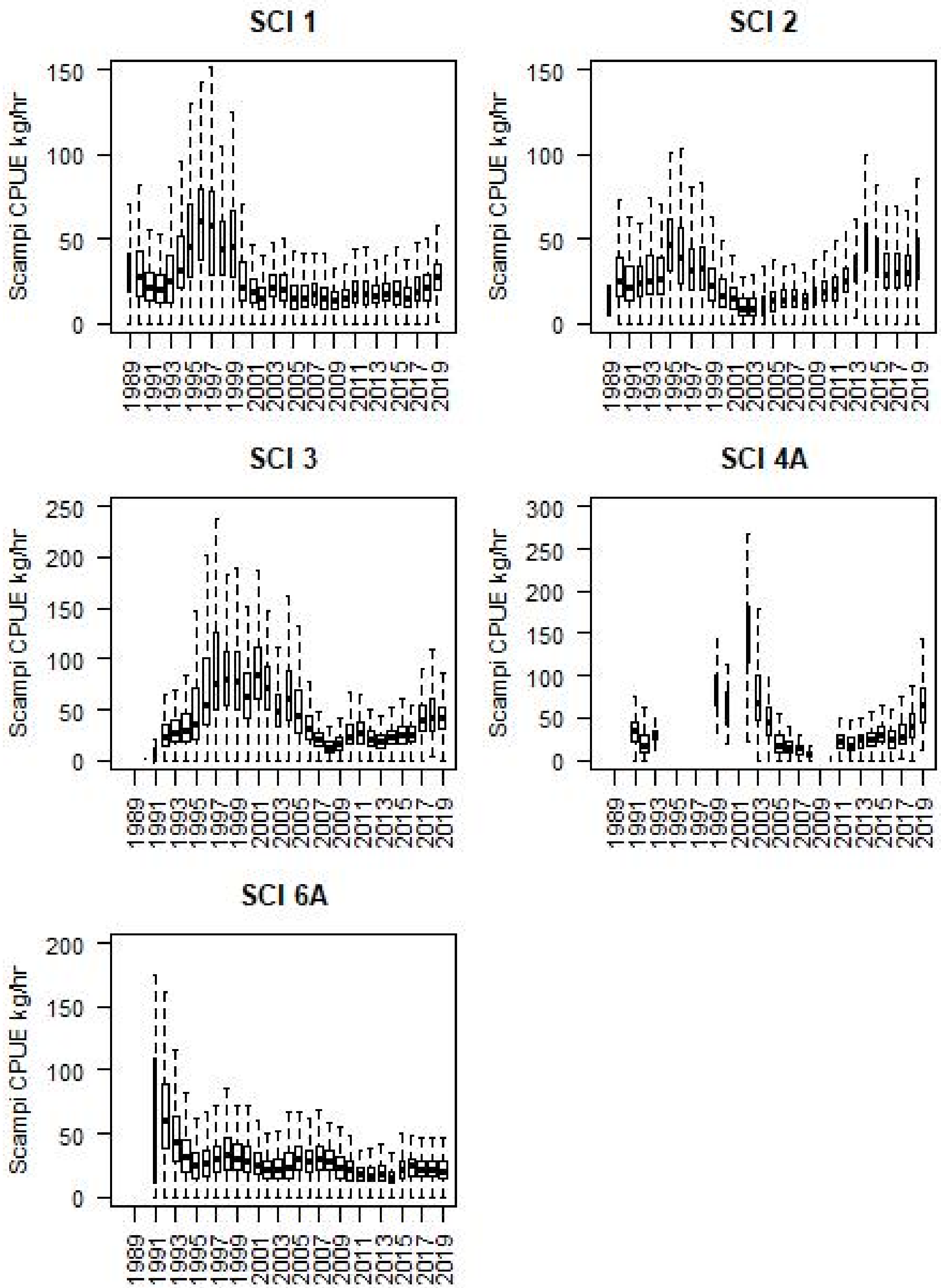


Figure 3: Box plots (with outliers removed) of individual observations of unstandardised catch rate for scampi (tow catch (kilogram) divided by tow effort (hours)) with tows of zero scampi catch excluded, by fishing year for main stocks. Box widths proportional to square root of the number of observations. Note different scales between plots. Horizontal bars within boxes represent distribution median. Upper and lower limits of boxes represent upper and lower quartiles. Whisker extends to largest (or smallest) observation which is less than or equal (greater than or equal) to the upper quartile plus 1.5 times the interquartile range (lower quartile less 1.5 times the interquartile range). Outliers (removed from this plot) are values outside the whiskers. Box width proportional to square root of number of observations.

Surveys have been conducted in SCI 3 in 2001 (two surveys, pre- and post- fishery), 2009, 2010, 2013, and 2016. The trawl component of the surveys did not suggest any difference between the pre and post fishery periods in 2001, but the photographic survey observed more scampi burrows after the fishery. Trawl, photographic, and CPUE data indicate a significant decline in scampi abundance between 2001 and 2009, but an increase in more recent years (Figure 6).

Table 8: Trawl survey indices of biomass (t) for scampi in survey strata within SCIs 1, 2, 3, and 6A. CVs of estimates in parentheses.

Year	SCI 1	SCI 2	SCI 3	SCI 6A	Comments
1993	217.3 (0.12)	238.2 (0.12)			Dedicated trawl survey
1994	288.2 (0.19)	170.0 (0.16)			Dedicated trawl survey
1995	391.6 (0.18)	216.2 (0.18)			Dedicated trawl survey
1996					
1997					
1998	174.0 (0.17)				Trawling in support of photo survey
1999					
2000	181.3 (*)				Trawling in support of photo survey
2001	179.5 (0.27)		272.5 (0.24) (strata 902–3)		Trawling in support of photo survey SCI 3 pre-season survey
2002	130.6 (0.24)				Trawling in support of photo survey
2003		28.0 (*)			Trawling in support of photo survey
2004		46.9 (0.20)			Trawling in support of photo survey
2005		50.8 (0.35)			Trawling in support of photo survey
2006		22.9 (0.19)			Trawling in support of photo survey
2007				1073.5 (0.18)	Trawling in support of photo survey
2008	211.9 (*)			1229.1 (0.18)	Trawling in support of photo survey
2009			40.2 (0.37) (strata 902–3) 418.1 (0.26)	821.6 (0.09)	Trawling in support of photo survey
2010			49.0 (0.11) (strata 902–3) 596.1 (0.04)		Trawling in support of photo survey
2011					
2012	150.0 (0.25)	164.2 (0.28)			Trawling in support of photo survey
2013			126.5 (0.27) (strata 902–3) 551.3 (0.12)	1258.0 (0.06)	Trawling in support of photo survey
2014					
2015	118.5 (0.17)	224.5 (0.19)			Trawling in support of photo survey
2016			139.6 (0.14) (strata 902–3) 913.1 (0.12)	593.3 (0.09)†	Trawling in support of photo survey
2017					
2018	188.6 (0.21)	183.3 (0.29)			Trawling in support of photo survey
2019				710.9 (0.12)†	Trawling in support of photo survey

* Where no CV is provided, one stratum had only one valid station. Strata included: SCI 1 – 302,303, 402, 403; SCI 2 – 701, 702, 703, 801, 802, 803; SCI 3 – 902, 903, 904; SCI 6A (main area) – 350 m, 400 m, 450 m, 500 m. SCI 3 survey in 2009 and 2010 split into area surveyed in 2001, and new area (strata 902A–C & 903A).
† 2016 and 2019 survey in SCI 6A conducted with a different vessel from previous surveys in this area.

There have been no targeted scampi surveys of SCI 4A, but the Chatham Rise *Tangaroa* survey has conducted standardised trawl sampling in the region since 1992. Although the trawl gear used on this survey is not designed to catch scampi, it provides the only fishery-independent abundance index for this stock. Survey catch rates follow a very similar pattern to unstandardised CPUE indices (Figure 7), increasing rapidly from the early 1990s to the early 2000s, declining to 2008, and then increasing more steadily since this time.

Surveys have been conducted in SCI 6A in 2007–2009, 2013, 2016, and 2019 (although with a different vessel after 2013). The trawl component of the photo surveys suggests that the biomass has fluctuated in recent years, although modelling indicated that the fishing power of the vessel used since 2016 was substantially less than that of the vessel used in earlier years. The photographic survey (burrows) suggested a considerable decline in abundance between 2007 and 2008, an increase in 2009 back towards the 2007 level, followed by a decline to lower levels of abundance in 2013 and 2016, but an increase in 2019. Over the longer term, the CPUE data indicate fluctuations around a gradually declining trend (Figure 8).

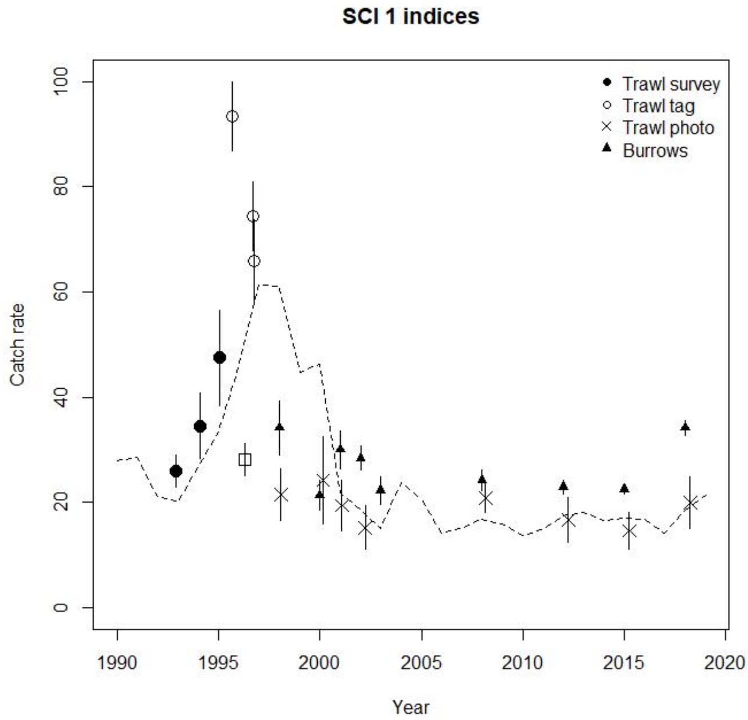


Figure 4: Mean catch rates and relative abundance (± one standard error) of research trawling and photo survey counts in the core area of SCI 1. Symbols represent different aims of survey work (● – trawl survey, ○ – tagging work, □ – trawl selectivity, ×- trawling within photo survey, ▲-scaled photo survey abundance). Dotted line represents median of annual unstandardised CPUE for SCI 1 from Figure 3.

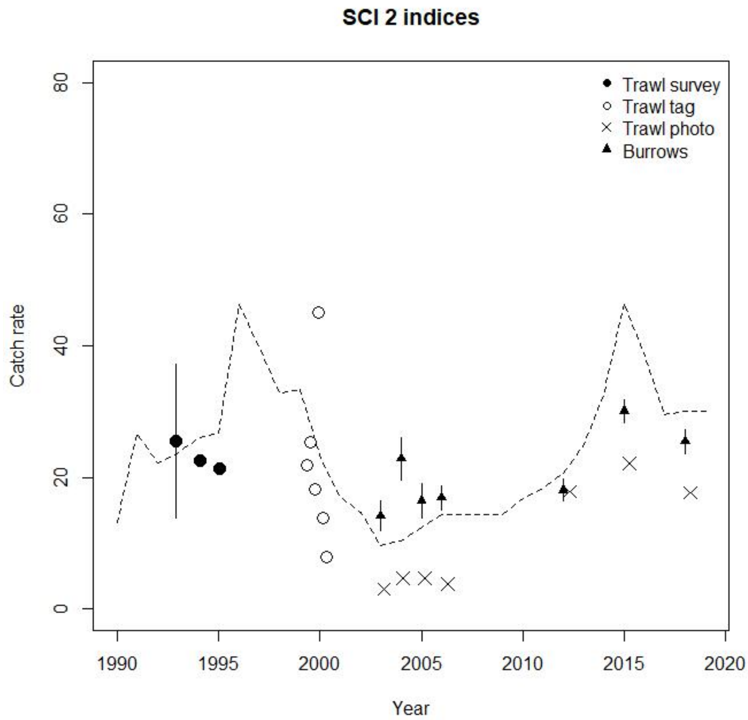


Figure 5: Mean catch rates and relative abundance (± one standard error) of research trawling and photo survey counts in the core area of SCI 2. Symbols represent different aims of survey work (● – trawl survey, ○ – tagging work, ×- trawling within photo survey, ▲-scaled photo survey abundance). Dotted line represents median of annual unstandardised CPUE for SCI 2 from Figure 3.

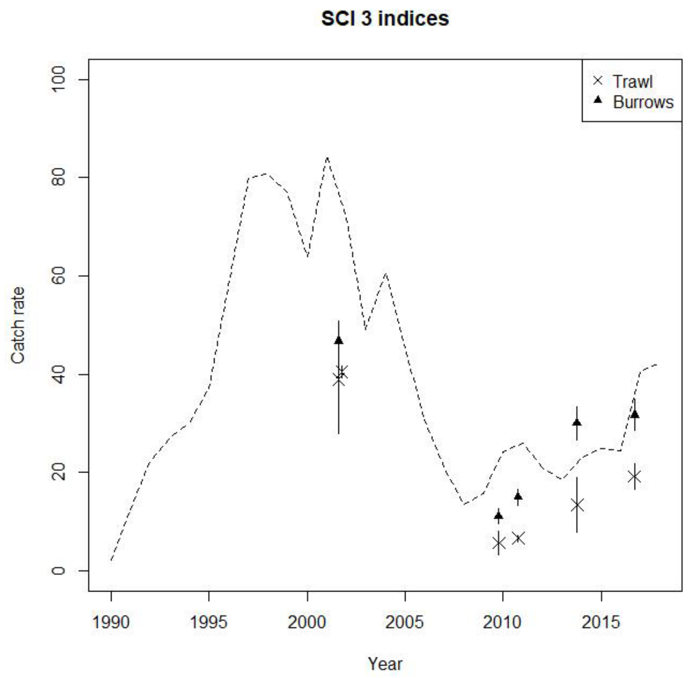


Figure 6: Mean catch rates and relative abundance (± one standard error) of research trawling and photo survey counts in the core area of SCI 3. Symbols represent different aims of survey work (×- trawling within photo survey, ▲-scaled photo survey abundance). Dotted line represents median of annual unstandardised CPUE for SCI 3 from Figure 3.

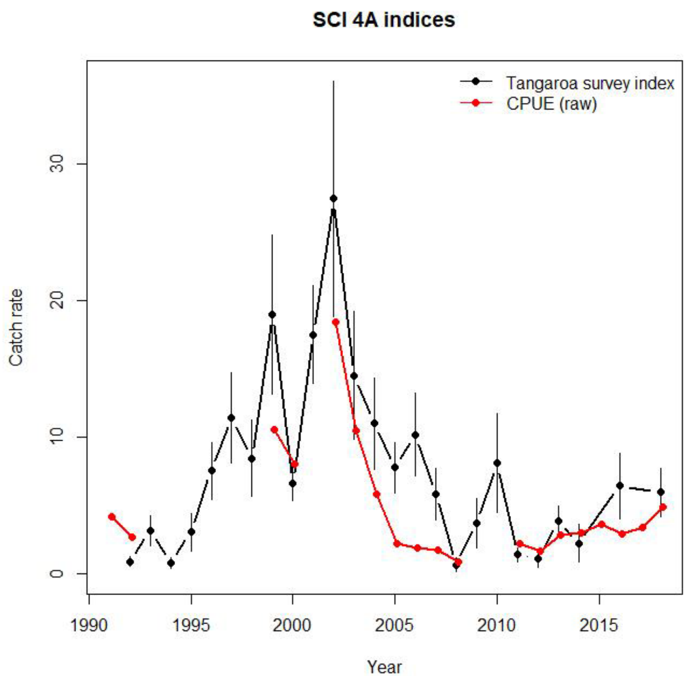


Figure 7: Mean catch rate (± one standard error) of Chatham Rise *Tangaroa* research trawling and unstandardised CPUE in the core area of SCI 4A. The CPUE index has been scaled to the geometric mean of the survey catch rates.

Photographic surveying (usually by video) has been used extensively to estimate the abundance of the European scampi *Nephrops norvegicus*. In New Zealand, development of photographic techniques, including surveys, has been underway since 1998. To date, nine surveys have been undertaken in SCI 1 (between Cuvier Island and White Island at a depth of 300–500 m), seven surveys have been undertaken in SCI 2 (Mahia Peninsula to Castlepoint at 200–500 m depth), five surveys have been undertaken in SCI 3 (north eastern Mernoo Bank only at 200–600 m depth), and six surveys in SCI 6A (to the east of the Auckland Islands at 350–550 m depth). The association between scampi and burrows in SCI 6A appears to be different to other areas examined.

Three indices are calculated from photographic surveys: the density of visible scampi (all visible animals, either observed within a burrow entrance (doorkeepers) or emerged from a burrow, walking free on the seabed); the density of emerged scampi (animals fully emerged from a burrow); and the density of major burrow openings (counts of which are now consistent among experienced readers, and repeatable, following development of a between reader standardisation process). Each of these can be used to estimate indices of abundance or biomass, using estimates of mean individual weight or the size distribution of animals in the surveyed population. The Bayesian length-based assessment model used for SCI 1, SCI 2, and SCI 3 uses the estimated abundance of major burrow openings as an abundance index, but only the emerged scampi index was used in the SCI 6A assessment.

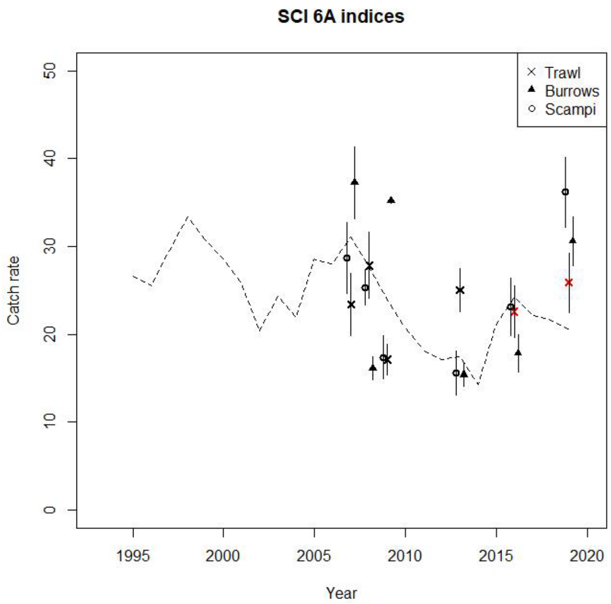


Figure 8: Mean catch rates and relative abundance (± one standard error) of research trawling and photo survey counts in the core area of SCI 6A. Symbols represent different aims of survey work (×- trawling within photo survey, ▲-scaled photo survey abundance). The last two trawl survey indices (denoted by a red ×) used a different vessel, and have been scaled separately from the earlier series. The dotted line represents median of annual unstandardised CPUE for SCI 6A from Figure 3.

Estimates of major burrow opening and visible scampi abundance are provided in Table 9. Acoustic tagging approaches (undertaken during surveys) have been used, in conjunction with burrow and scampi density estimates, to estimate emergence patterns and priors for scampi catchability. A revised approach to estimating priors on the basis of these data, taking greater account of uncertainty in observed burrow and animal density and emergence rates, was adopted in 2016 (Tuck et al 2015).

Length frequency distributions from trawl surveys and from scientific observers do not show a consistent increase in the proportion of small individuals in any SCI stock following the development of significant fisheries for scampi. Analyses of information from trawl survey and scientific observers in SCI 1 and 6A, up to about 1996, suggested that the proportion of small animals in the catch declined markedly in both areas, despite the fact that CPUE declined markedly in SCI 6A and increased markedly in SCI 1. Where large differences in the length frequency distribution of scampi measured by observers have been detected (as in SCI 1 and 6A), detailed analysis has shown that the spatial coverage of observer samples has varied with time, and this may have influenced the nature of the length frequency samples. The length composition of scampi is known to vary with depth and geographical location, and fishers may deliberately target certain size categories.

Some commercial fishers reported that they experienced historically low catch rates in SCI 1 and 2 between 2001 and 2004. They further suggest that this reflects a decrease in abundance of scampi in these areas. Other fishers consider that catch rates do not necessarily reflect changes in abundance because they are influenced by management and fishing practices.

Table 9: Photographic survey estimates of abundance (millions) based on major openings and visible scampi in survey strata within SCIs 1, 2, 3, and 6A. CVs of estimates in parentheses. Major burrow openings are openings on the seabed that are considered to be main entrance of a scampi burrow. Visible scampi represents all scampi seen in photographs (either in a burrow entrance, or walking free on the seabed).

	SCI 1		SCI 2		SCI 3		SCI 6A		Comments
Year	**Major openings**	**Visible scampi**	**Major openings**	**Visible scampi**	**Major openings**	**Visible scampi**	**Major openings**	**Visible scampi**	
1998	154.6 (0.15)	27.9 (0.22)							
1999									
2000	96.8 (0.13)	18.2 (0.18)							
2001	135.9 (0.12)	12.3 (0.26)			224.0 (0.09) (strata 902–3)	48.2 (0.16) (strata 902–3)			
2002	128.7 (0.08)	16.7 (0.21)							
2003	101.0 (0.12)	14.4 (0.21)	93.1 (0.16)	10.0 (0.39)					
2004			150.2 (0.14)	20.6 (0.28)					
2005			108.5 (0.17)	14.6 (0.20)					
2006			111.3 (0.11)	13.3 (0.23)					
2007							305.5 (0.11)	60.4 (0.14)	SCI 6A estimate for main area*
2008	109.8 (0.08)	12.5 (0.13)					132.3 (0.08)	55.4 (0.08)	
2009					54.4 (0.14) (strata 902–3) 285.8 (0.07) (larger survey)	18.4 (0.17) (strata 902–3) 122.6 (0.10) (larger survey)	288.8 (0.10)	36.6 (0.14)	SCI 3, estimates provided for 2001 survey coverage (strata 902–3) and new larger survey
2010					72.0 (0.11) (strata 902–3) 378.0 (0.05) (larger survey)	8.7 (0.22) (strata 902–3) 92.8 (0.11) (larger survey)			SCI 3, estimates provided for 2001 survey coverage (strata 902–3) and new larger survey
2012	104.0 (0.06)	23.9 (0.09)	118.7 (0.09)	32.0 (0.11)					
2013					144.1 (0.11) (strata 902–3) 592.6 (0.06) (larger survey)	20.5 (0.17) (strata 902–3) 130.8 (0.09) (larger survey)	126.5 (0.09)	32.8 (0.16)	
2015	102.2 (0.07)	18.0 (0.14)	197.8 (0.06)	40.0 (0.09)					
2016					152.1 (0.10) (strata 902–3) 747.5 (0.05) (larger survey)	36.7 (0.16) (strata 902–3) 206.9 (0.08) (larger survey)	146.6 (0.12)	48.7 (0.14)	
2018	154.7 (0.05)	45.3 (0.06)	167.2 (0.07)	48.9 (0.29)					
2019							251.1 (0.09)	76.2 (0.11)	

* SCI 6A estimate provided for main area because future surveys may not survey secondary area. SCI 1 estimate provided for strata 302, 303, 402, 403.

5.2 Stock assessment methods

SCI 1 and SCI 2

In 2011 the SFWG accepted the stock assessments for SCI 1 and SCI 2, undertaken using the length-based population model that had been under development for several years (Tuck & Dunn 2012), and updated assessments were accepted in 2013, 2016, and 2019.

A number of model runs were presented, examining sensitivities to *M*, data weighting, and a combined area model (two stock model with no migration, sharing growth and selectivity parameters). For both stocks, the absolute biomass levels and the state of the stock relative to SSB_0 was relatively consistent between models. A base model was agreed upon for each stock (M=0.25 and CPUE process error fixed at 0.15) with sensitivities also presented.

The model's annual cycle is based on the fishing year and is divided into three time-steps (Table 10). The choice of three time steps was based on the current understanding of scampi biology and the sex ratio in catches. Note that model references to "year" refer to the modelled or fishing year and are labelled as the most recent calendar year, i.e., the fishing year 1998–99 is referred to as "1999" throughout.

Table 10: Annual cycle of the population model for SCI 1, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur together within a time step occur after all other processes, with 50% of the natural mortality for that time step occurring before and 50% after the fishing mortality.

Step	Period	Process	Proportion in time step
1	Oct–Jan	Growth (both sexes)	
		Natural mortality	0.33
		Fishing mortality	From TCEPR
2	Feb–Apr	Recruitment	1.0
		Maturation	1.0
		*Growth (males)**	
		Natural mortality	0.25
		Fishing mortality	From TCEPR
3	May–Sep	Natural mortality	0.42
		Fishing mortality	From TCEPR

* the main period of male moulting appears to be from February to April. In the model both sexes are assumed to grow at the start of step 1, and this male growth period (February to April) is ignored.

Investigations into factors affecting scampi catch rates and size distributions (Cryer & Hartill 2000; Tuck 2009) have identified significant depth and regional effects, and regional (strata) and depth stratification were applied in previous models. Preliminary examination of patterns in CPUE indices and other input data suggested that this may not be necessary, and a simplified single area model was developed in 2013. Catches generally occur throughout the year and were divided among the time steps according to the proportion of estimated catches recorded on Trawl Catch, Effort, and Processing Returns (TCEPR). Recreational catch, customary catch, and illegal catch are ignored. The maximum exploitation rate (i.e., the ratio of the maximum catch to biomass in any year) is not known, but was constrained to no more than 0.9 in a time step. Individuals are assumed to recruit to the model at age 1, with the mean expectation of recruitment success predicted by a Beverton-Holt stock-recruitment relationship. Length at recruitment is defined by a normal distribution with mean of 10 mm OCL with a CV of 0.4. Relative year class strengths are encouraged to average 1.0. Growth is estimated in the model, fitting to the tag (Cryer & Stotter 1997, Cryer & Stotter 1999) and aquarium data (Cryer & Oliver 2001) from SCI 1 and SCI 2.

The model uses logistic length-based selectivity curves for commercial fishing, research trawl surveys, and photographic surveys, assumed constant over years but allowed to vary with sex and time step. Although the sex ratio data suggest that the relative catchability of the sexes varies through the year (hence the model time structure adopted), there is no reason to suggest that (assuming equal availability) selectivity-at-size would be different between the sexes. Therefore the selectivity implementation used allowed the L_{50} and a_{95} selectivity parameters to be estimated as single values shared by both sexes in a particular time step, but allowed for different availability between the sexes through estimation of different a_{max} values for each sex. In SCI 1 and SCI 2 selectivity is assumed to be the same in time steps 1 and 3, owing to the relative similarity in sex ratio.

Data inputs included CPUE, trawl and photographic survey indices, and associated length frequency distributions. Informed priors are available for survey catchability estimates based on acoustic tagging of scampi and investigations into burrow emergence patterns. These have been updated since the last assessment based on Working Group discussions.

The assessment reports SSB_0 and $SSB_{CURRENT}$ and used the ratio of current and projected spawning stock biomass ($SSB_{CURRENT}$ and SSB_{2018}) to SSB_0 as preferred indicators. Projections were conducted up to 2024 on the basis of a range of catch scenarios. The probability of exceeding the default Harvest Strategy Standard target and limit reference points are reported.

SCI 3

In 2015 the SFWG accepted a stock assessment for SCI 3, undertaken using the length-based population model, and an updated assessment was accepted in 2018. A number of model runs were presented, examining sensitivities to assumptions about process error on the CPUE indices and *M*. The absolute biomass levels were sensitive to the process error and *M*, but the state of the stock relative to B_0 was consistent between models. A base model was taken with $M = 0.25$ and CPUE process error = 0.2, with sensitivities to these assumptions considered.

The model's annual cycle is slightly adjusted from the fishing year and is divided into two time steps (Table 11). The choice of two time steps was based on the current understanding of scampi biology and the sex ratio in catches. Note that model references to "year" refer to the modelled year and are labelled as the most recent calendar year, i.e., the modelled year 1998–99 is referred to as "1999" throughout.

Table 11: Annual cycle of the population model for SCI 3, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur together within a time step occur after all other processes, with 50% of the natural mortality for that time step occurring before and 50% after the fishing mortality.

Step	Period	Process	Proportion in time step
1	Jul–Dec	Growth (both sexes)	
		Natural mortality	0.5
		Fishing mortality	From TCEPR
2	Jan–Jun	Recruitment	1.0
		Maturation	1.0
		Natural mortality	0.5
		Fishing mortality	From TCEPR

The SCI 3 fishery is focused in three distinct areas on the Chatham Rise (an area to the east of 176º E on the Mernoo Bank – MO; an area to the west of 176º E on the Mernoo Bank – MW; and a separate region to the north east, centred about 177º E – MN), and differences in management between these areas over time have led to different fishing histories. Scampi are not thought to undertake large scale migrations, and so these three areas were considered distinct stocks within the assessment model, sharing some parameters (growth, selectivity, and catchability). The seasonal patterns of catches vary between stocks and over time through the fishery and were divided among the stocks and time steps according to the proportion of estimated catches recorded on Trawl Catch, Effort, and Processing Returns (TCEPR). Recreational catch, customary catch, and illegal catch are ignored. The maximum exploitation rate (i.e., the ratio of the maximum catch to biomass in any year) is not known, but was constrained to no more than 0.9 in a time-step. Individuals are assumed to recruit to the model at age 1, with the mean expectation of recruitment success predicted by a Beverton-Holt stock-recruitment relationship. Length at recruitment is defined by a normal distribution with mean of 10 mm OCL with a CV of 0.4. Relative year class strengths are encouraged to average 1.0. Growth is estimated in the model.

As with the SCI 1 and SCI 2 models, the SCI 3 model uses logistic length-based selectivity curves for commercial fishing, research trawl surveys, and photographic surveys, assumed constant over years and stocks, but allowed to vary with sex and time step. Data inputs for each stock included CPUE, trawl, and photographic survey indices, and associated length frequency distributions.

The assessment reported B_0 and B_{2017} (at both the individual stock and overall FMA level) and used the ratio of current and projected spawning stock biomass (B_{2017} and B_{2020}) to B_0 as preferred indicators. Projections were conducted up to 2020 on the basis of a range of catch scenarios. The probability of exceeding the default Harvest Strategy Standard target and limit reference points are reported.

SCI 4A

In 2019 a CPUE standardisation was conducted for SCI 4A. A targeted scampi fishery started in 1991 and was intermittent through the 1990s and early 2000s, but has been more consistent since 2011. Fishing effort increased from very low levels in 2010 to a peak in 2015 (comparable with previous high levels in this fishery in the early 1990s and mid 2000s), but declines to about half this level by 2018. Scampi have been caught in low numbers across most of the SCI 4A area within the depth range (200–600 m), but the targeted fishery has focused on two distinct patches, one to the north and one to the west of the Chatham Islands (fished between 2005 and 2007). Catch rates appear similar between the two patches, and there are insufficient observer samples to examine length composition by patch. Overall observer coverage has been low (4% of scampi target tows) but varies considerably between years. Scampi length data were not recorded on the earliest *Tangaroa* surveys but have been routinely recorded since 1997. Size at female maturity estimated from the proportion of ovigerous females was comparable with other stocks (L_{50} = 38.2 mm).

SCI 6A

In 2016 the Plenary accepted a stock assessment for SCI 6A, undertaken using the length-based population model, and an updated assessment was accepted in 2019. Preliminary models suggested a discrepancy between photo survey (increasing) and CPUE (decreasing) indices, which led to a reconsideration of the most appropriate index to be used from the photographic survey. The previously used visible scampi index includes both emerged animals and doorkeepers. Doorkeepers may include a high proportion of very small scampi that do not appear in commercial catches (and therefore may provide a useful index of recruitment). Also the length composition of scampi from photographs is unlikely to be representative of these smaller individuals (because they are often not visible enough to measure). An emerged animal index was considered more appropriate to use within the assessment model and was more consistent with the CPUE index. A number of model runs were presented, including a base model (M=0.25; survey q prior mean=0.582, CV=0.21; CPUE, trawl, and photo survey) and examining sensitivities to two alternative prior distributions for survey catchability (mean=0.3 and 0.8), two alternative values of M (0.20 and 0.3), and CPUE only and CPUE excluded models. Estimates of absolute biomass and stock status were sensitive to q priors and exclusion of abundance indices, but less sensitive to M. All models including the CPUE data suggested *SSB* has fluctuated around a gradually declining trend through the history of the fishery, whereas the CPUE excluded model suggests *SSB* declined to around 2000, but has slightly increased since this time. The Deepwater Working Group (DWWG) agreed that the base, low q, low M, and CPUE excluded models represented the range of possibilities of the status of the SCI 6A stock, with the CPUE excluded model considered less likely.

The model’s annual cycle is slightly adjusted from the fishing year and is divided into three time steps (Table 12). The choice of the three time steps was based on the current understanding of scampi biology and the sex ratio in catches. Note that model references to “year” refer to the modelled year, and are labelled as the most recent calendar year, i.e., the modelled year 1998–99 is referred to as “1999” throughout.

Table 12: Annual cycle of the population model for SCI 6A, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur together within a time step occur after all other processes, with 50% of the natural mortality for that time step occurring before and 50% after the fishing mortality.

Step	Period	Process	Proportion in time step
1	Mid Nov–mid Apr	Growth (both sexes)	
		Maturation	1.0
		Natural mortality	0.417
		Fishing mortality	From TCEPR
2	mid Apr–Jun	Recruitment	1.0
		Natural mortality	0.208
		Fishing mortality	From TCEPR
3	Jul–mid Nov	Natural mortality	0.375
		Fishing mortality	From TCEPR

The SCI 6A fishery occurs southeast of the Auckland Islands (between 166˚ E and 168˚ E, and between 50˚15′ S and 51˚15′ S). Scampi are not thought to undertake large scale migrations, and this is considered to be a distinct stock, for which a simplified single area model was developed in 2016. Catches generally occur throughout the year and were divided among the time steps according to the proportion of estimated catches recorded on Trawl Catch, Effort, and Processing Returns (TCEPR). Recreational catch, customary catch, discards, and illegal catch are thought to be zero and are therefore ignored in the model. The maximum exploitation rate (i.e., the ratio of the maximum catch to biomass in any year) is not known, but was constrained to no more than 0.9 in a time-step. Individuals were assumed to recruit to the model at 10 mm, with the mean expectation of recruitment success predicted by a Beverton-Holt stock-recruitment relationship. Length at recruitment was defined by a normal distribution with mean of 10 mm OCL and a CV of 0.4. There was no penalty on year class strength. Growth is estimated in the model from tag recapture data.

The model used logistic length-based selectivity curves for commercial fishing and research trawl surveys, which were assumed to be constant over years but allowed to vary with sex and time step. Although the sex ratio data suggest that the relative catchability of the sexes varies through the year (hence the model time structure adopted), there is no reason to suggest that (assuming equal availability) selectivity-at-size would be different between the sexes. Therefore the selectivity implementation used allowed the L_{50} and a_{95} selectivity parameters to be estimated as single values shared by both sexes in a particular time step, but allowed for different availability between the sexes through estimation of different a_{max} values for each sex. A combined sex double normal selectivity curve was used when fitting photo survey length frequency data for visible scampi.

The assessment reported SSB_0 and $SSB_{CURRENT}$ and used the ratio of current and projected spawning stock biomass ($SSB_{CURRENT}$ out to SSB_{2025}) to SSB_0 as preferred indicators. Projections were conducted up to 2025 for two future catch scenarios. The probability of exceeding the default Harvest Strategy Standard target and limit reference points are reported.

5.3 Stock assessment results

SCI 1 and SCI 2

For SCI 1, model outputs suggest that spawning stock biomass increased to a peak in about 1995, declined to the early 2000s and has remained relatively stable since this time. The *SSB* in SCI 1 in 2018 was estimated to be 72%–76% of SSB_0 (Figure 9, Table 13). Historical changes in biomass in SCI 1 appear to be related to fluctuations in recruitment rather than catches, and likelihood profiles suggest that the priors have more influence than the abundance indices in determining SSB_0. Estimated year class strength seems to be driven largely by the abundance indices with little signal from the length-frequency distributions. Investigations into the sensitivity of excluding the survey indices showed that removing the photo survey increased the estimate of SSB_0, whereas removing the trawl survey had a lesser opposite effect, although stock trajectory and current status ($SSB_{CURRENT}/SSB_0$) was only slightly affected. For SCI 2, model outputs suggest that spawning stock biomass decreased slightly until 1990, increased to a peak in the early 1990s, declined to the early 2000s, increased slightly until about 2008, but increased more rapidly to 2013, and has declined since this time. The *SSB* in SCI 2 in 2018 was estimated to be 73%–78% SSB_0 (Figure 10, Table 14).

Table 13: Results from MCMC runs showing SSB_0, $SSB_{CURRENT}$ and $SSB_{CURRENT}/SSB_0$ estimates for the base model (*M*=0.25, CV=0.15) and sensitivities for SCI 1.

Model	*M*=0.25, CV=0.15	*M*=0.25, CV=0.25	*M*=0.2, CV=0.15	*M*=0.2, CV=0.25
SSB_0	4 620	4 650	4 627	4 777
$SSB_{CURRENT}$	3 498	3 539	3 368	3 521
$SSB_{CURRENT}/SSB_0$	0.76	0.76	0.72	0.74

Table 14: Results from MCMC runs showing SSB_0, $SSB_{CURRENT}$ and $SSB_{CURRENT}/SSB_0$ estimates for the base model (*M*=0.25, CV=0.15) and sensitivities for SCI 2.

Model	*M*=0.25, CV=0.15	*M*=0.25, CV=0.25	*M*=0.2, CV=0.15	*M*=0.2, CV=0.25
SSB_0	3 008	2 914	3 117	2 992
$SSB_{CURRENT}$	2 362	2 269	2 325	2 181
$SSB_{CURRENT}/SSB_0$	0.78	0.78	0.74	0.73

The default management target for scampi of 40% B_0 is below the range of % B_0 estimated for both stocks.

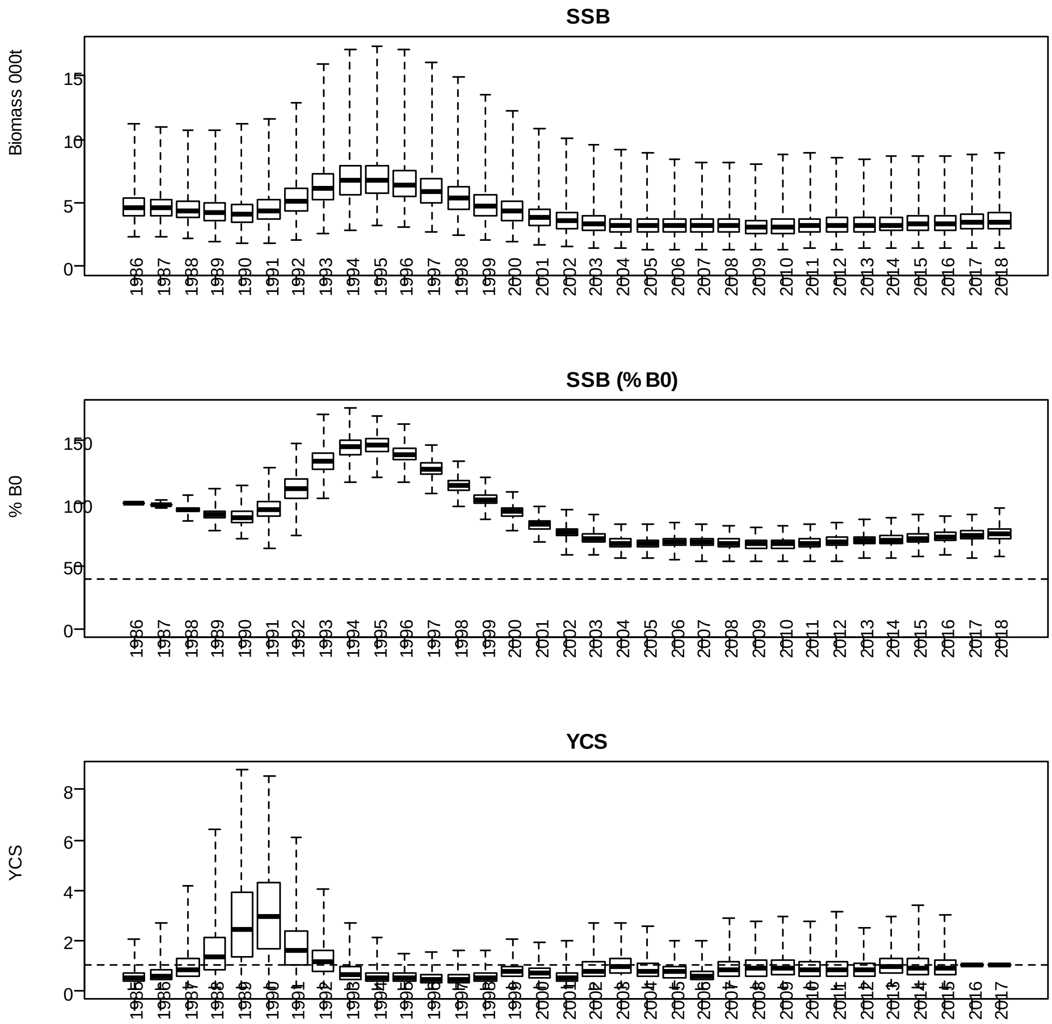


Figure 9: Posterior trajectory from SCI 1 base model (*M*=0.25, CV=0.15) of spawning stock biomass and YCS. Upper plot shows boxplots of *SSB* and the middle plot shows *SSB* as a percentage of B_0. On the middle plot, target reference points are shown as the grey dashed line. Box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.

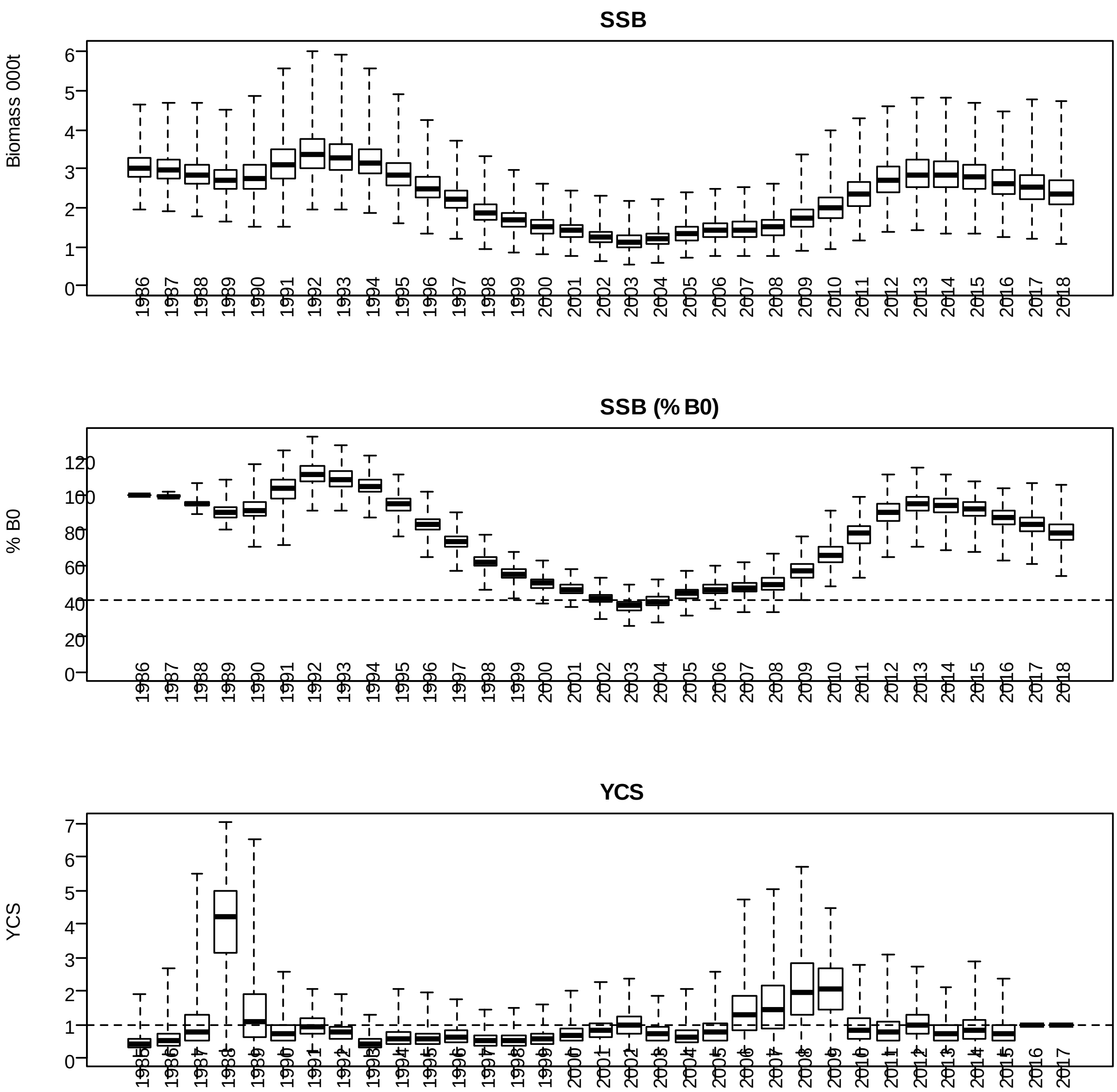


Figure 10: Posterior trajectory from the SCI 2 base model (*M*=0.25, CV=0.15) of spawning stock biomass and YCS. Upper plot shows boxplots of *SSB* and middle plot shows *SSB* as a percentage of B_0. On middle plot, target reference points are shown as the grey dashed line. Box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.

SCI 3

For SCI 3, a base model was taken with *M* = 0.25 and CPUE process error = 0.2, with sensitivities to these assumptions considered. Model outputs suggest that spawning stock biomass (*SSB*) increased to a peak in about 1999, declined to 2010, and then remained more stable, increasing after 2014 (Figure 11). The *SSB* in SCI 3 in 2017 was estimated to be 76% (95% CI 69–83%) of B_0 at the FMA level for the base case, with median estimates ranging between 0.75 to 0.81 for the three sensitivities (Figure 12, Table 15).

The default management target for scampi of 40% B_0 is below the range of % B_0 estimated for the SCI 3 base model, or any of the sensitivities (Figure 12).

Table 15: Results from MCMC runs showing B_0, B_{2017} and B_{2017}/B_0 estimates for the base model and three sensitivities for SCI 3.

Base: *M*=0.25, CV=0.20	MN	MO	MW	SCI 3
SSB_0	6204 (3845–11 349)	4035 (2348–7593)	4905 (2911–9253)	15162 (9086–28 092)
SSB_{2017}	4611 (2451–9305)	3164 (1806–6034)	3783 (2130–7400)	11599 (6420–22 713)
SSB_{2017}/SSB_0	0.74 (0.62–0.86)	0.78 (0.70–0.87)	0.77 (0.68–0.86)	0.76 (0.69–0.83)
P(SSB_{2017} > 40% SSB_0)	1	1	1	1
P(SSB_{2017} < 20% SSB_0)	0	0	0	0
Sensitivity: *M*=0.20, CV=0.20	MN	MO	MW	SCI 3
SSB_0	5625 (3770-9767)	3668 (2275-6650)	4335 (2738-7833)	13643 (8820-24 188)
SSB_{2017}	3946 (2184-7769)	3002 (1804-5538)	3304 (1954-6224)	10248 (6022-19 366)
SSB_{2017}/SSB_0	0.7 (0.57-0.82)	0.82 (0.75-0.89)	0.76 (0.68-0.85)	0.75 (0.67-0.82)
P(SSB_{2017} > 40% SSB_0)	1	1	1	1
P(SSB_{2017} < 20% SSB_0)	0	0	0	0
Sensitivity: *M*=0.20, CV=0.25	MN	MO	MW	SCI 3
SSB_0	5910 (3754–10426)	3728 (2193–6987)	4546 (2722–8316)	14168 (8710–25 614)
SSB_{2017}	4449 (2311–8941)	3127 (1776–5953)	3647 (2031–7097)	11220 (6215–21 827)
SSB_{2017}/SSB_0	0.75 (0.61–0.88)	0.84 (0.77–0.91)	0.80 (0.71–0.89)	0.79 (0.70–0.86)
P(SSB_{2017} > 40% SSB_0)	1	1	1	1
P(SSB_{2017} < 20% SSB_0)	0	0	0	0
Sensitivity: *M*=0.25, CV=0.25	MN	MO	MW	SCI 3
SSB_0	6235 (3810–11 609)	3947 (2265–7553)	4939 (2896–9388)	15118 (9013–28 337)
SSB_{2017}	4961 (2601–10 285)	3228 (1797–6242)	4013 (2211–7991)	12217 (6704–24 213)
SSB_{2017}/SSB_0	0.79 (0.66–0.92)	0.82 (0.73–0.90)	0.81 (0.72–0.92)	0.81 (0.72–0.88)
0.88)P(SSB_{2017} > 40% SSB_0)	1	1	1	1
P(SSB_{2017} < 20% SSB_0)	0	0	0	0

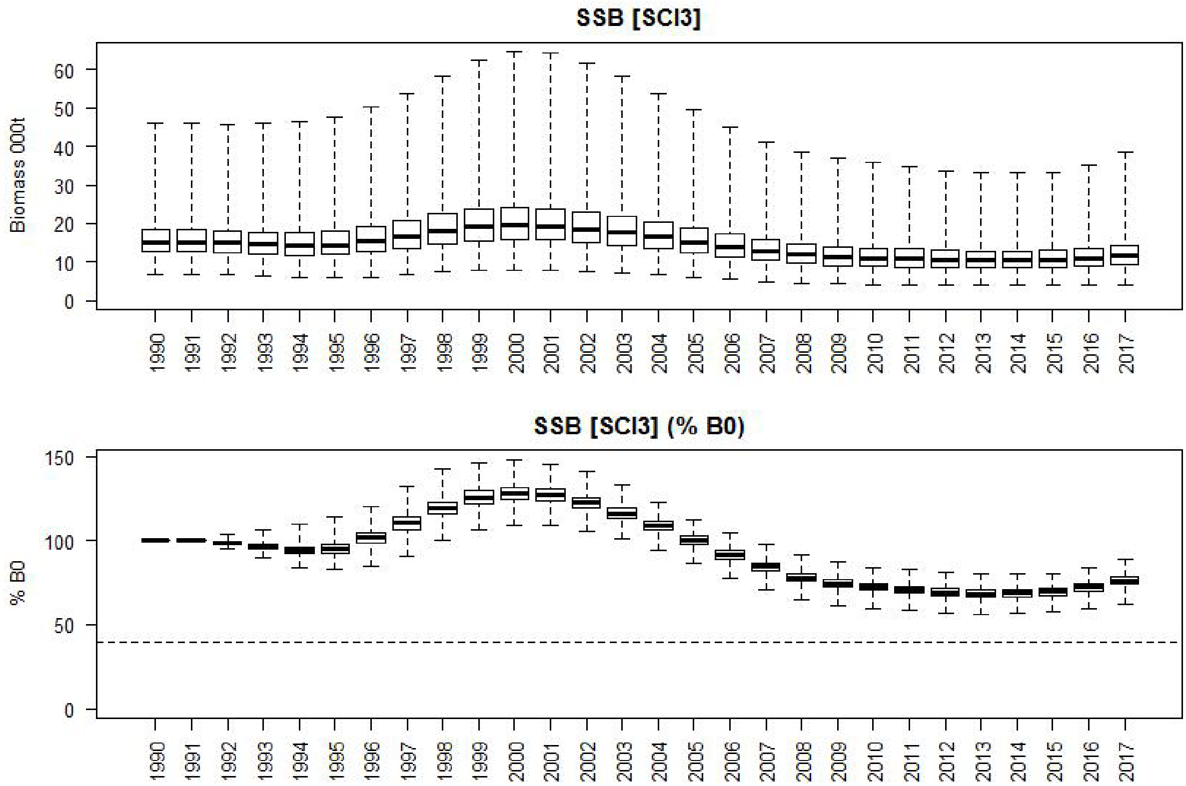


Figure 11: Posterior trajectory from SCI 3 base model (*M*=0.25, CV=0.2) of spawning stock biomass. Upper plot shows boxplots of *SSB*, and the lower plot shows *SSB* as a percentage of B_0. On the lower plot, target reference point is shown as a dashed line. Box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.

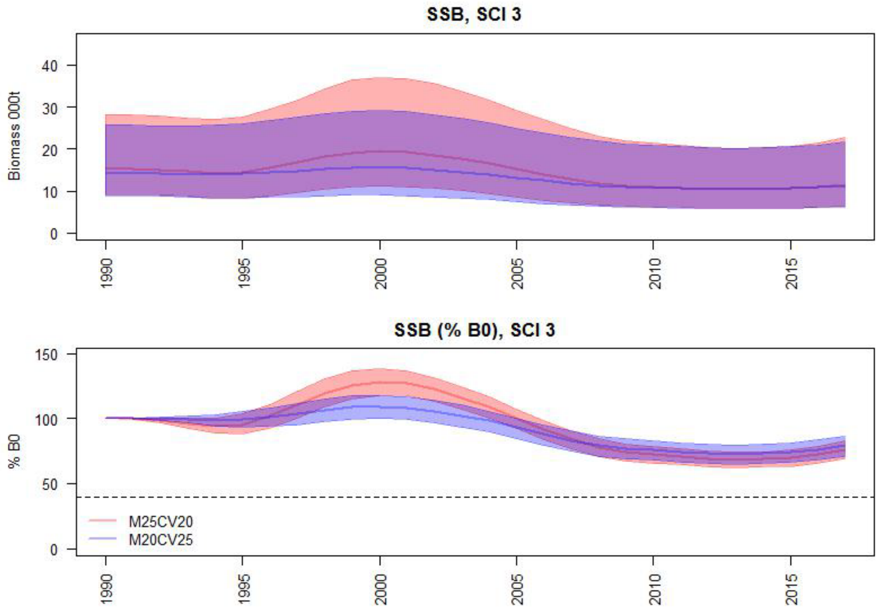


Figure 12: Posterior trajectory of spawning stock biomass from the SCI 3 base model and one of the sensitivities (*M*=0.2, CV=0.25). Upper plot shows boxplots of *SSB*, and the lower plot shows *SSB* as a percentage of B_0. On the bottom plot, the target reference point is shown as a dashed line. 95% CI shown as shaded area around each line.

SCI 4A

Standardised CPUE indices were estimated for the whole SCI 4A region and for the (core) patch to the north, on the basis of TCEPR records from vessels that had been active in the respective areas for at least 5 years. Both indices showed very similar patterns to the unstandardised CPUE data (Figure 3), increasing rapidly from the early 1990s to a peak in 2002, declining rapidly to 2005 and then more slowly to 2008, and then increasing steadily since this time. The standardised CPUE indices (only core area presented) show a very similar pattern to the Chatham Rise *Tangaroa* survey index for scampi (Figure 13).

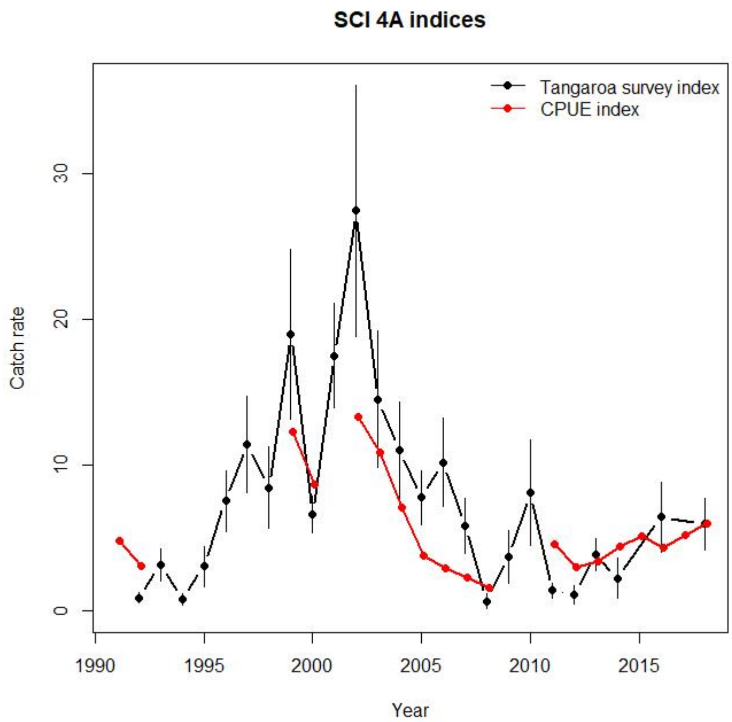


Figure 13: Mean catch rate (± one standard error) of Chatham Rise *Tangaroa* survey index and standardised CPUE in the core area of SCI 4A. The CPUE index has been scaled to the geometric mean of the survey catch rates.

Mean size in observed catches was markedly higher between 2003 and 2005 compared with other years, but length composition data from the Chatham Rise *Tangaroa* trawl survey did not show any patterns over time. The patchiness of observer sampling over time and the trawl gear used on the middle depths survey adds uncertainty about the representativeness of both data sets.

SCI 6A

For SCI 6A, a base model and three sensitivities were presented. Base model outputs suggest that spawning stock biomass (*SSB*) fluctuated around a declining trend between 1991 and 2013, increased slightly after this and has remained stable since 2016. The low *M* and low *q* models indicate very similar stock trends, but with the low *M* model estimating a slightly lower stock status throughout the fishery, and the low *q* model a higher SSB_0 and higher stock status throughout the fishery, and a slightly increasing trend in the most recent years. The model excluding the CPUE data estimated a different trend, with *SSB* declining to the early 2000s, and then showing a slightly increasing trend. The *SSB* in SCI 6A in 2019 was estimated to be 53% of SSB_0 for the base and between 47 and 66% of SSB_0 for the range of sensitivities considered (Figure 14, Table 16). Historical changes in biomass in SCI 6A appear to be related to small fluctuations in recruitment rather than catches, but landings have been lower than the TACC in recent years, coinciding with an increase in recent year class strengths. All four of the models considered produce estimates of current stock status which are above the default management target of 40% B_0.

Table 16: Results from MCMC runs showing B_0, B_{curr} and B_{curr}/B_0 estimates for four alternative models for SCI 6A.

Model	*Base*	*Low q*	*Low M*	*CPUE excluded*
B_0	3 661	5 847	3 906	4 005
B_{2019}	1 950	3 994	1 849	2 623
B_{2019}/B_0	0.53	0.68	0.47	0.66

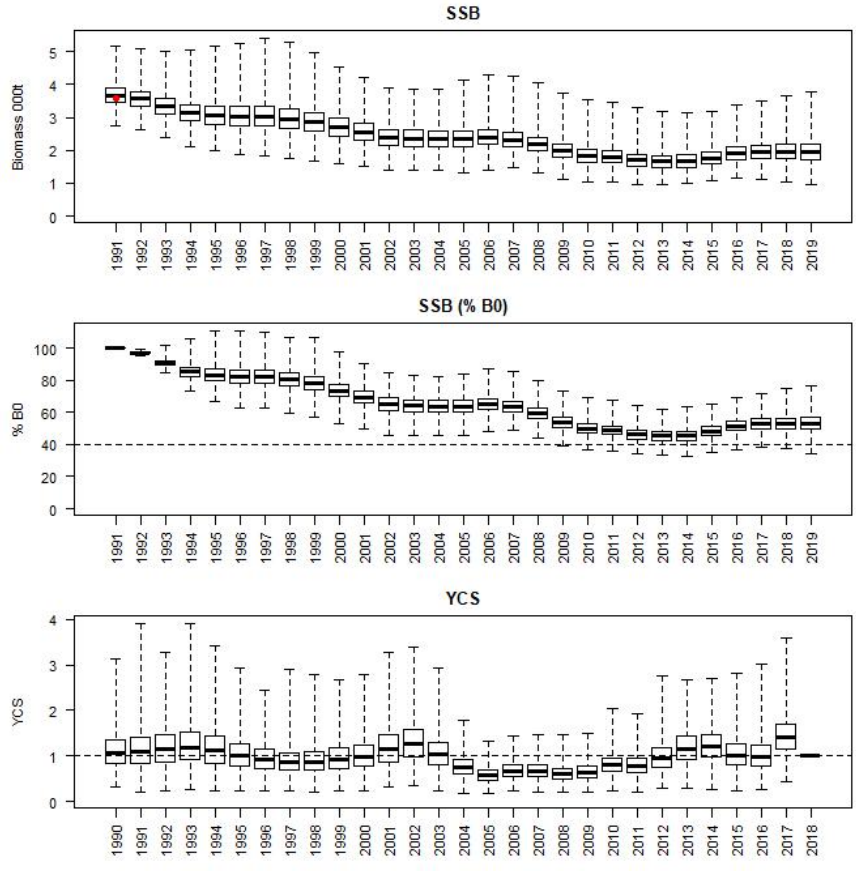


Figure 14: Posterior trajectory from the base SCI 6A model of spawning stock biomass and YCS. Upper plot shows boxplots of *SSB*, while the middle plot shows *SSB* as a percentage of B_0. On the middle plot, target and limit reference points are shown in grey solid and dashed lines. Box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The 2018 year class was not estimated.

5.4 Yield estimates and projections

SCI 1

Projections were examined for the base model with constant annual catch remaining at current levels (status quo; current TACC), or at 10% and 20% higher levels. Future recruitments were resampled from the last 10 estimated years (2006–2015). Median estimates of stock status from the projections are presented in Table 17 and suggest that the stock would remain above 70% SSB_0 by 2024 for any of the future catches considered.

The estimated probability of *SSB* being below either of the limits is zero, and the probability of remaining above the 40% B_0 target remains very high through to 2024 (Table 18).

Table 17: Results from MCMC runs showing SSB_0, SSB_{2019}, and *SSB* projection estimates for future years at varying catch levels for the base model for SCI 1.

	TACC (120 t)		TACC+10% (132 t)		TACC+20% (144 t)	
SSB_0		4 620		4 620		4 620
SSB_{2018}		3 482		3 482		3 482
SSB_{2018}/SSB_0		0.76		0.76		0.76
	Status (proportion of SSB_0)	Status (proportion of SSB_{2018})	Status (proportion of SSB_0)	Status (proportion of SSB_{2018})	Status (proportion of SSB_0)	Status (proportion of SSB_{2018})
SSB_{2019}	0.76	1.01	0.76	1.00	0.76	0.11
SSB_{2020}	0.76	1.01	0.76	1.00	0.75	1.00
SSB_{2021}	0.76	1.01	0.76	1.00	0.75	0.99
SSB_{2022}	0.76	1.01	0.75	0.99	0.74	0.98
SSB_{2023}	0.76	1.01	0.75	0.99	0.74	0.97
SSB_{2024}	0.76	1.01	0.75	0.99	0.74	0.97

Table 18: Results from MCMC runs for the base for SCI 1, showing probabilities of projected spawning stock biomass exceeding the default Harvest Strategy Standard target and limit reference points.

	TACC (120 t)				TACC+10% (132 t)			
	Pr < 10% SSB_0	Pr < 20% SSB_0	Pr > 40% SSB_0	Pr > SSB_{2019}	Pr < 10% SSB_0	Pr < 20% SSB_0	Pr > 40% SSB_0	Pr > SSB_{2019}
2019	0.00	0.00	1.00	0.55	0.00	0.00	1.00	0.53
2020	0.00	0.00	1.00	0.54	0.00	0.00	1.00	0.50
2021	0.00	0.00	1.00	0.52	0.00	0.00	1.00	0.48
2022	0.00	0.00	1.00	0.53	0.00	0.00	1.00	0.46
2023	0.00	0.00	1.00	0.52	0.00	0.00	1.00	0.47
2024	0.00	0.00	1.00	0.53	0.00	0.00	1.00	0.47

	TACC+20% (144 t)			
	Pr < 10% SSB_0	Pr < 20% SSB_0	Pr > 40% SSB_0	Pr > SSB_{2019}
2019	0.00	0.00	1.00	0.52
2020	0.00	0.00	1.00	0.48
2021	0.00	0.00	1.00	0.46
2022	0.00	0.00	1.00	0.44
2023	0.00	0.00	1.00	0.42
2024	0.00	0.00	1.00	0.41

SCI 2

Projections were examined for the base model with constant annual catch remaining at current levels (status quo; current TACC), or at 10% and 20% higher levels. Future recruitments were resampled from the last 10 estimated years (2006–2015). Median estimates of stock status from the projections are presented in Table 19 and suggest that the stock would remain above 70% SSB_0 by 2024 for any of the future catches considered.

The estimated probability of *SSB* being below either of the limits is zero, and the probability of remaining above the 40% B_0 target remains very high through to 2024 (Table 20).

Table 19: Results from MCMC runs showing SSB_0, SSB_{2019}, and SSB projection estimates for future years at varying catch levels for the base model for SCI 2.

	TACC (153 t)		TACC+10% (168 t)		TACC+20% (183 t)	
SSB_0		3 008		3 008		3 008
SSB_{2018}		2 374		2 374		2 374
SSB_{2018}/SSB_0		0.79		0.79		0.79
	Status (proportion of SSB_0)	Status (proportion of SSB_{2018})	Status (proportion of SSB_0)	Status (proportion of SSB_{2018})	Status (proportion of SSB_0)	Status (proportion of SSB_{2018})
SSB_{2019}	0.77	0.98	0.77	0.97	0.77	0.97
SSB_{2020}	0.77	0.98	0.76	0.97	0.76	0.96
SSB_{2021}	0.78	1.00	0.77	0.97	0.76	0.97
SSB_{2022}	0.81	1.02	0.78	0.99	0.77	0.98
SSB_{2023}	0.82	1.04	0.80	1.02	0.78	0.99
SSB_{2024}	0.83	1.06	0.82	1.03	0.80	1.01

Table 20: Results from MCMC runs for the base for SCI 2, showing probabilities of projected spawning stock biomass exceeding the default Harvest Strategy Standard target and limit reference points.

	TACC (153 t)				TACC+10% (168 t)			
	Pr < 10% SSB_0	Pr < 20% SSB_0	Pr > 40% SSB_0	Pr > SSB_{2019}	Pr < 10% SSB_0	Pr < 20% SSB_0	Pr > 40% SSB_0	Pr > SSB_{2019}
2019	0.00	0.00	1.00	0.55	0.00	0.00	1.00	0.53
2020	0.00	0.00	1.00	0.54	0.00	0.00	1.00	0.50
2021	0.00	0.00	1.00	0.52	0.00	0.00	1.00	0.48
2022	0.00	0.00	1.00	0.53	0.00	0.00	1.00	0.46
2023	0.00	0.00	1.00	0.52	0.00	0.00	1.00	0.47
2024	0.00	0.00	1.00	0.53	0.00	0.00	1.00	0.47

	TACC+20% (183 t)			
	Pr < 10% SSB_0	Pr < 20% SSB_0	Pr > 40% SSB_0	Pr > SSB_{2019}
2019	0.00	0.00	1.00	0.52
2020	0.00	0.00	1.00	0.48
2021	0.00	0.00	1.00	0.46
2022	0.00	0.00	1.00	0.44
2023	0.00	0.00	1.00	0.42
2024	0.00	0.00	1.00	0.41

SCI 3

Projections were examined for the base model, with constant annual catch remaining at current levels, approximately the TACC (status quo; average of the last 5 years), or increasing to 10% or 20% above the current TACC. For the 20% increase in TACC, two scenarios were examined, either with catches taken in the same proportion by subarea as current catches, or with the increased allocation (68 tonnes) taken from the MO subarea (which currently has minimal fishing). These two scenarios were considered to encompass the potential extremes of catch patterns. Median estimates of stock status from the projections are presented in Table 21 and suggested that under the current TACC scenario the stock would be around 81% B_0 by 2021. Sensitivities ranged from 80% to 86%.

Table 21: Results from MCMC runs showing B_0, B_{2017}, and B_{2021} estimates at varying catch levels for SCI 3 for the base model.

Catch		MN	MW	MO	SCI 3
340 tonnes (TACC & Status quo)	B_0	6 204	4 905	4 035	15 162
	B_{2017}	4 612	3 862	3 160	11 585
	B_{2017}/B_0	0.74	0.79	0.78	0.76
	B_{2021}/B_0	0.78	0.78	0.84	0.81
	B_{2021}/B_{2017}	1.05	0.99	1.07	1.05
375 tonnes (+10% TACC)	B_{2021}/B_0	0.77	0.78	0.84	0.8
	B_{2021}/B_{2017}	1.04	0.99	1.07	1.05
408 tonnes (+20% TACC)	B_{2021}/B_0	0.76	0.77	0.84	0.79
	B_{2021}/B_{2017}	1.02	0.99	1.07	1.04
408 tonnes (+20% TACC Additional MO)	B_{2021}/B_0	0.78	0.78	0.8	0.79
	B_{2021}/B_{2017}	1.05	0.99	1.02	1.04

On the basis of the outputs for the base model for SCI 3, and the annual catches examined, the probability of *SSB* being below either of the limits is very low, and the probability of remaining above the 40% B_0 target remains very high until 2021 (Table 22).

Table 22: Results from MCMC runs the base model and three sensitivities for SCI 3, showing probabilities of projected spawning stock biomass exceeding the default Harvest Strategy Standard target reference point and being below the limit reference points.

Base: (*M*=0.25, CV=0.20)	340 tonnes (TACC)				375 tonnes (+10% TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	1	1	1	1	0.999	1	1	1
P(B2021> B2017)	0.684	0.465	0.819	0.821	0.630	0.456	0.819	0.781
	408 tonnes (+20% TACC)				408 tonnes (+20% TACC, MO)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	0.999	1	1	1	1	1	1	1
P(B2021> B2017)	0.577	0.445	0.819	0.741	0.684	0.465	0.574	0.741
Sensitivity: (*M*=0.20, CV=0.20)	340 tonnes (TACC)				375 tonnes (+10% TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	0.999	1	1	1	0.998	1	1	1
P(B2021> B2017)	0.703	0.534	0.908	0.884	0.629	0.515	0.908	0.839
	408 tonnes (+20% TACC)				408 tonnes (+20% TACC, MO)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	0.997	1	1	1	0.991	1	1	1
P(B2021> B2017)	0.557	0.500	0.908	0.794	0.703	0.534	0.639	0.793
Sensitivity: (*M*=0.20, CV=0.25)	340 tonnes (TACC)				375 tonnes (+10% TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	1	1	1	1	1	1	1	1
P(B2021> B2017)	0.757	0.585	0.948	0.936	0.696	0.570	0.948	0.913
	408 tonnes (+20% TACC)				408 tonnes (+20% TACC, MO)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	0.999	1	1	1	1	1	1	1
P(B2021> B2017)	0.632	0.556	0.948	0.877	0.757	0.585	0.732	0.877
Sensitivity: (*M*=0.25, CV=0.25)	340 tonnes (TACC)				375 tonnes (+10% TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	1	1	1	1	1	1	1	1
P(B2021> B2017)	0.742	0.500	0.871	0.880	0.688	0.489	0.871	0.851
	408 tonnes (+20% TACC)				408 tonnes (+20% TACC, MO)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	0.999	1	1	1	1	1	1	1
P(B2021> B2017)	0.639	0.478	0.871	0.819	0.742	0.500	0.659	0.819

SCI4A
No yield estimates and projection are available for SCI 4A.

SCI 6A
Projections were examined for the base model with constant annual catch remaining at current levels (status quo; average catch 2016 to 2019), or at the current TACC. Future recruitments were resampled from the last 10 estimated years (2008–2017). Median estimates of stock status from the projections are presented in Table 23 and suggest that under a TACC scenario the stock would remain above 50% SSB_0 by 2025.

The estimated probability of *SSB* being below either of the limits is zero, and the probability of remaining above the 40% B_0 target remains high through to 2025 (Table 24).

Table 23: Results from MCMC runs showing SSB_0, SSB_{2019}, and *SSB* projection estimates for future years at varying catch levels for the base model for SCI 6A.

	Status quo (278 t)		TACC (306 t)	
SSB_0		3 661		3 661
SSB_{2019}		1 950		1 950
SSB_{2019}/SSB_0		0.53		0.53
	Status (proportion of SSB_0)	Status (proportion of SSB_{2019})	Status (proportion of SSB_0)	Status (proportion of SSB_{2019})
SSB_{2020}	0.55	1.03	0.55	1.03
SSB_{2021}	0.56	1.06	0.56	1.04
SSB_{2022}	0.56	1.05	0.55	1.03
SSB_{2023}	0.55	1.04	0.54	1.00
SSB_{2024}	0.54	1.02	0.52	0.98
SSB_{2025}	0.53	1.00	0.51	0.95

Table 24: Results from MCMC runs for the base for SCI 6A, showing probabilities of projected spawning stock biomass exceeding the default Harvest Strategy Standard target and limit reference points.

	Status quo (278 t)				TACC (306 t)			
	Pr < 10% SSB_0	Pr < 20% SSB_0	Pr > 40% SSB_0	Pr > SSB_{2019}	Pr < 10% SSB_0	Pr < 20% SSB_0	Pr > 40% SSB_0	Pr > SSB_{2019}
2020	0.00	0.00	1.00	0.84	0.00	0.00	1.00	0.82
2021	0.00	0.00	0.99	0.76	0.00	0.00	0.99	0.69
2022	0.00	0.00	0.98	0.68	0.00	0.00	0.96	0.60
2023	0.00	0.00	0.95	0.61	0.00	0.00	0.92	0.52
2024	0.00	0.00	0.93	0.55	0.00	0.00	0.88	0.45
2025	0.00	0.00	0.89	0.49	0.00	0.00	0.83	0.39

5.5 Future research considerations

For all stocks

- In the light of continued grade data collection by observers, re-examine spatial and temporal patterns in grade length and sex composition with a view to reconstructing historical length composition data.
- Conduct additional tagging to improve growth estimates.
- Explore evidence for the effects of recent fishing activity on catch rate, through flattening of bioturbation mounds and improved seabed contact (increased catchability) or disturbance of scampi leading to reduced emergence (reduced catchability).
- Recruitment patterns should be examined in more detail by obtaining better information on size composition. This could be accomplished by:
  - re-examining the photo survey data to allocate the animals seen into size ranges and differentiating doorkeepers from emerged animals;
  - investigating the utility of grade data for elucidating recruitment patterns;
  - investigating the potential for developing a juvenile index from ling and sea perch stomach contents.
- Improve the coverage and representativeness of observer data.

For SCI 2

- Investigate whether the decline in SCI 2 in the 1990s is reflected in the monthly CPUE data.

For SCI 3

- Conduct sensitivities on the use of shared *q* between areas for the trawl, CPUE, and photo data, as well as year class strengths.
- Test for the possibility that it is the abundance indices rather than the length-frequency data that are driving differences in year class strength in the three sub-regions: use the same abundance indices in all three models so that the only difference between the three is the length-frequency data. This will determine whether the abundance indices or the length-frequency data is the driving factor in determining year class strength.

For SCI4A

- Consider establishing reference points based on CPUE information.

For SCI 6A

- Explore development of a 2-stock, 2-area model, splitting the fishery by depth to account for differences in length structure and growth

6. STATUS OF THE STOCKS

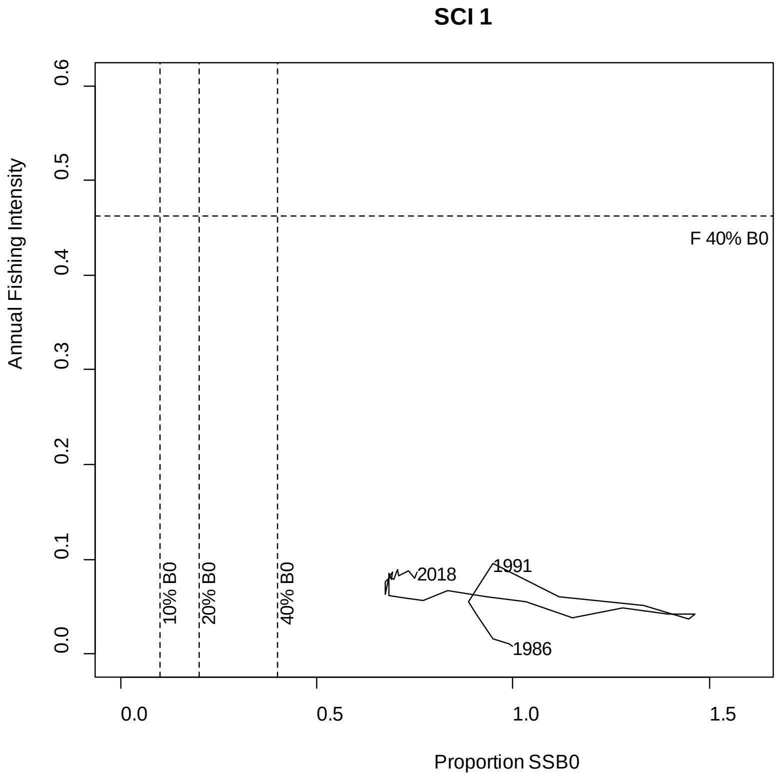
Stock Structure Assumptions

Assessments have been conducted for areas considered to be the core regions of SCI 1, SCI 2, SCI 3, and SCI 6A .

- **SCI 1**

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	Bayesian length based model with *M*=0.25, CPUE process error 0.15
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Very Likely (> 90%) to be at or above target
Status in relation to Limits	Exceptionally Unlikely (< 1%) to be below the soft or hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectories of biomass as a proportion of B_0 and annual equivalent fishing intensity for SCI 1 (*M*=0.25, CV=0.15).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Spawning stock biomass increased to a peak in about 1995, declined to the early 2000s, and has remained relatively stable since this time. 2018 photo survey shows a slight increase in the biomass and the CPUE shows a slight increase too. Trawl survey remains stable between 2018.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has fluctuated without trend since the early 1990s.

Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-
Projections and Prognosis	
Stock Projections or Prognosis	The stock is predicted to remain well above 40% B_0 up to 2024 under TACC and increased catches.
Probability of Current Catch or TACC causing biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Overfishing: Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Length-based Bayesian Model	
Assessment Dates	Latest assessment: 2019	Next assessment: 2022
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Standardised catch and effort data (TCEPR) from MPI	1 – High Quality
	- Length frequency data from MPI observer sampling	2 – Medium or Mixed Quality: data not representative in some years
	- Photographic survey abundance index	1 – High Quality
	- Trawl survey abundance index	1 – High Quality
	- Length frequency data from research sampling	1 – High Quality
	- Length frequency predicted from burrow sizes	2 – Medium or Mixed Quality: estimation of length structure uncertain, and not fitted well in model
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Revised catchability priors developed	
Major Sources of Uncertainty	- Growth, burrow occupancy and catchability - Early CPUE (potential time varying q) - Early (large) YCSs - Absolute biomass determined by the q prior - Calculation of equivalent annual Fs and reference points	

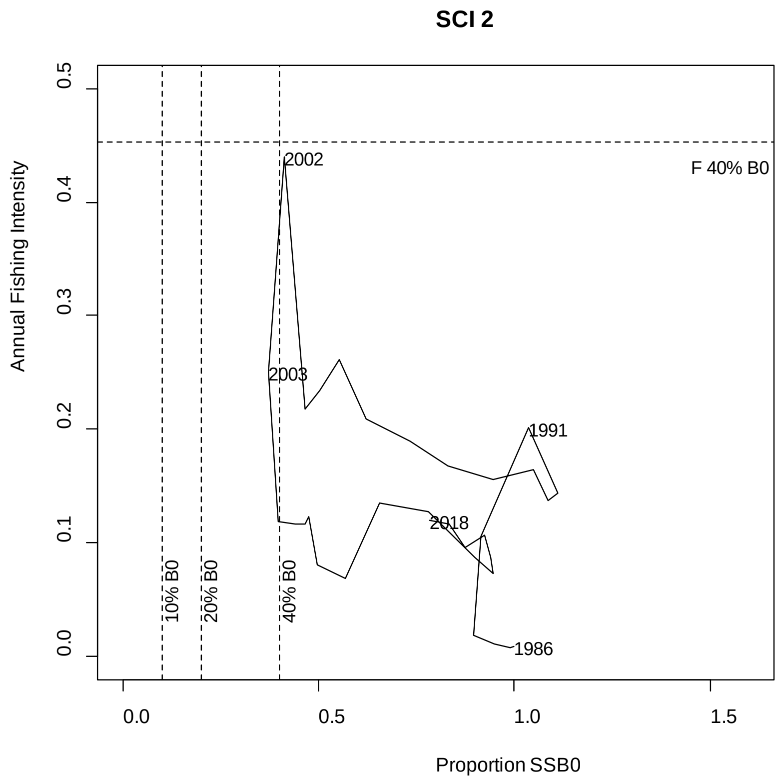
Qualifying Comments
Likelihood profiles suggest priors, rather than abundance indices, are overly important in determining $B_{0,}$ probably due to a lack of contrast in the abundance data. While this reduces the level of confidence in the assessment, there is nothing to indicate that stock status is poor or declining.

Fishery Interactions
Main QMS bycatch species include ling, hoki, sea perch, red cod, silver warehou and giant stargazer. Discards are dominated by rattails, javelinfish, skates and crabs, ling, red cod, hoki, spiny dogfish and sea perch. Interactions with seabirds have been recorded. A wide range of benthic invertebrate species are taken as bycatch.

- **SCI 2**

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	Bayesian length based model with *M*=0.25, CPUE process error 0.15
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Very Likely (> 90%) to be at or above target
Status in relation to Limits	Exceptionally Unlikely (< 1%) to be below the soft or hard limits
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectories of biomass as a proportion of B_0 and annual equivalent fishing intensity for SCI 2 (*M*=0.25, CV=0.15).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass increased during the early 1990s, but declined steadily after this until the early 2000s. Biomass increased steadily between 2008 and 2014, declining slightly since then.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality increased through the 1990s, peaking in 2002, but declined considerable by 2005, and has fluctuated without trend since this time.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The stock is predicted to remain well above 40% B_0 up to 2024 under TACC and increased catches.
Probability of Current Catch or TACC causing biomass to	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)

remain below or to decline below Limits	
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Overfishing: Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Length-based Bayesian Model	
Assessment Dates	Latest assessment: 2019	Next assessment: 2022
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Standardised catch and effort data (TCEPR) from MPI - Length frequency data from MPI observer sampling - Photographic survey abundance index - Trawl survey abundance index - Length frequency data from research sampling - Length frequency predicted from burrow sizes	1 – High Quality 2 – Medium or Mixed Quality: data not representative in some years 1 – High Quality 1 – High Quality 1 – High Quality 2 – Medium or Mixed Quality: estimation of length structure uncertain
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Revised catchability priors developed	
Major Sources of Uncertainty	- Growth, burrow occupancy and catchability - Early CPUE (potential time varying q) - Early and recent (large) YCSs - Absolute biomass determined by the q prior - Calculation of equivalent annual Fs and reference points	

Qualifying Comments
While the abundance indices contribute to determining B_0, catchability priors are also influential. The overall stock trajectory and current stock status appear less sensitive to priors. Stock status is currently declining from a recent peak, but appears to be well above the target level.

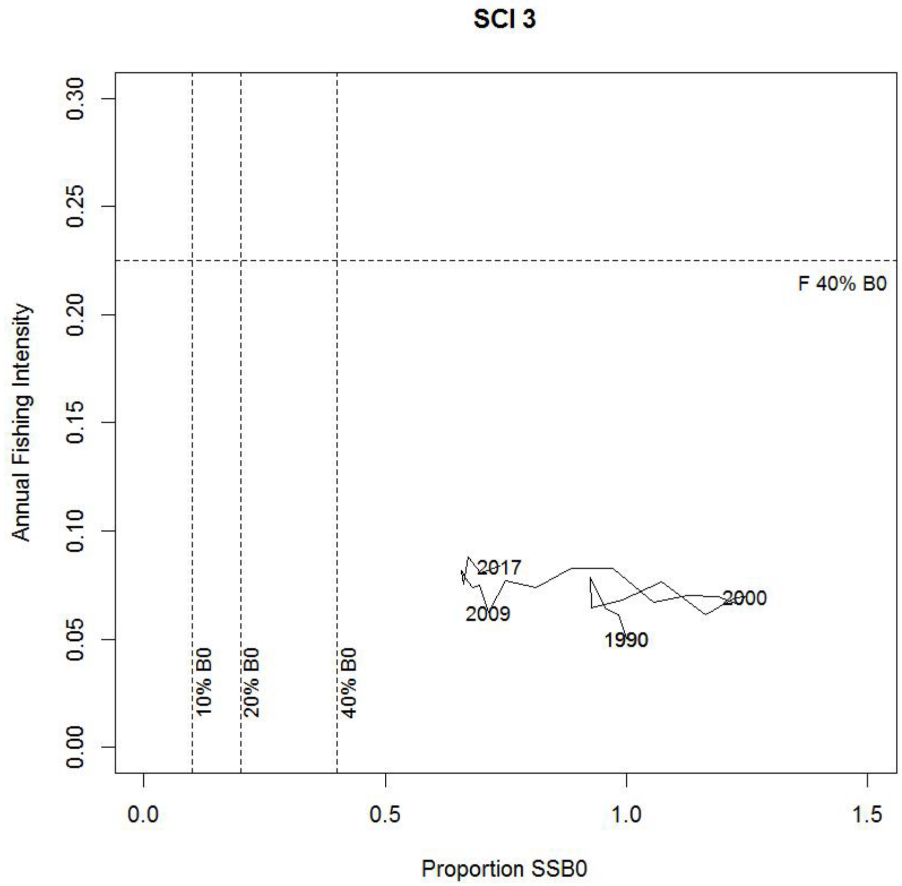
Fishery Interactions
Main QMS bycatch species include ling, hoki, sea perch, red cod, silver warehou and giant stargazer. Discards are dominated by rattails, javelinfish, skates and crabs, ling, red cod, hoki, spiny dogfish and sea perch. In interactions with seabirds have been recorded. A wide range of benthic invertebrate species are taken as bycatch.

- **SCI 3**

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	- Bayesian length based model, base model: *M*=0.25, CPUE CV=0.2
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$

Status in relation to Target	B_{2017} was estimated to be 76% B_0. Very Likely (> 90%) to be at or above the target.
Status in relation to Limits	B_{2017} is Very Unlikely (< 10%) to be below the soft or hard limits (both models)
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectories of biomass as a proportion of B_0 and annual equivalent fishing intensity for SCI 3.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Estimated spawning stock biomass increased to a peak in about 1999, declined to the late 2000s, and has increased in the most recent years.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has been low and without trend throughout the time series
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The stock is predicted to remain above 40% B_0 up to 2021 under current catches (TACC) and increases in TACC of up to 20%.
Probability of Current Catch or TACC 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 TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Length-based Bayesian model	
Assessment Dates	Latest assessment: 2018	Next assessment: 2021
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Standardised catch and effort data (TCEPR) from MPI - Length frequency data from MPI observer sampling - Photographic survey abundance index - Trawl survey abundance index - Length frequency data from research sampling - Length frequency predicted from burrow sizes	1 – High Quality 2 – Medium or Mixed Quality: data not representative in some years 1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Changed YCS strengths parameterisation - Revised priors - Revised model time steps - Separate YCSs (rather than shared) - Shared q's between areas	
Major Sources of Uncertainty	- Growth, burrow occupancy and catchability - Early CPUE (potential time varying q) - Early (large) YCSs - Absolute biomass determined by the q prior - Calculation of equivalent annual Fs and reference points	

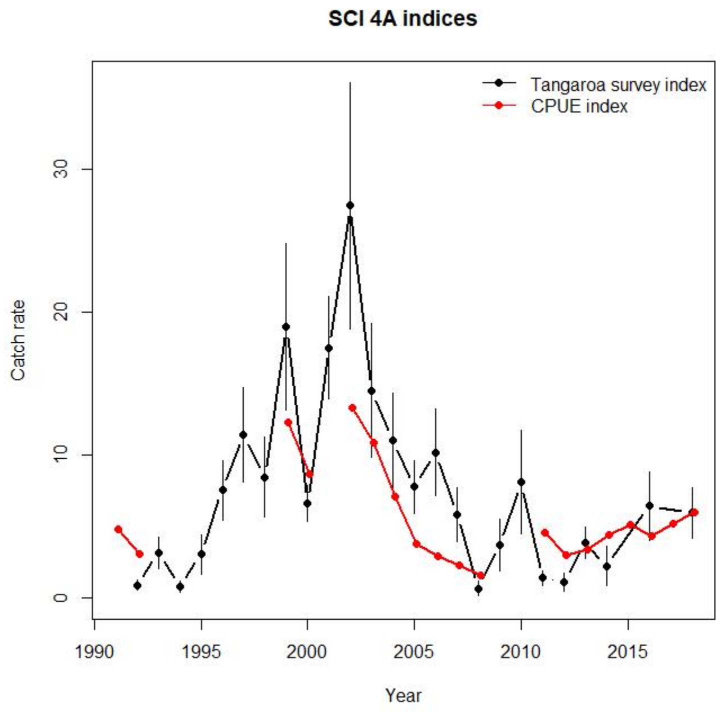
Qualifying Comments
Model scaling is highly dependent on the q priors without much updating by posteriors. Their influence should be investigated further. CPUE is highly influential and may be driving recruitment. This contributes to generating large early YCS(s) that are not fully supported by data.

Fishery Interactions
Main QMS bycatch species include ling, hoki, sea perch, red cod, silver warehou and giant stargazer. Discards are dominated by rattails, javelinfish, skates and crabs, ling, red cod, hoki, spiny dogfish and sea perch. Interactions with seabirds have been recorded. A wide range of benthic invertebrate species are taken as bycatch.

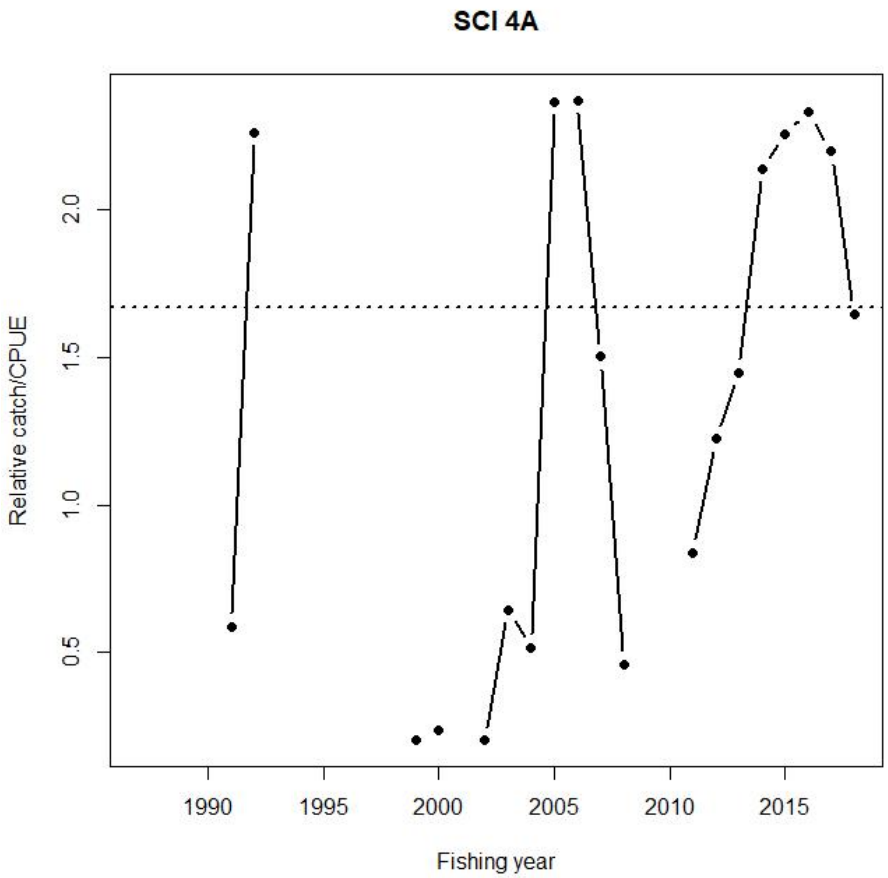
- **SCI 4A**

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	Standardised CPUE
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Trajectories of CPUE and *Tangaroa* trawl survey catch rate for SCI 4A.



Relative fishing pressure for SCI 4A based on the ratio of QMR/MHR landings relative to the SCI 4A CPUE series which has been normalised so that its geometric mean=1.0. Horizontal dotted line is the geometric mean fishing pressure from 20010–11 to 2017–18.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE shows an increasing trend between 2012 and 2018.
Recent Trend in Fishing Intensity or Proxy	Recent relative exploitation rate has been higher than the series mean, but has decreased from a recent peak since 2016.
Other Abundance Indices	The Chatham Rise *Tangaroa* trawl survey index shows a very similar pattern to the standardised CPUE index.
Trends in Other Relevant Indicators or Variables	Fishing effort increased from 2012–2015 but declined to the 2012 level by 2018.

Projections and Prognosis	
Stock Projections or Prognosis	
Probability of Current Catch or TACC causing biomass to remain below or to decline below Limits	
Probability of Current Catch or TACC causing Overfishing to continue or to commence	

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2019	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality. The Shellfish WG agreed the CPUE index was a credible measure of abundance	
Main data inputs	- Standardised catch and effort data (TCEPR) from MPI - Length frequency data from MPI observer sampling - Trawl survey abundance index - Length frequency data from trawl survey abundance index	1 – High Quality 2 – Medium or Mixed Quality: variable representativeness of sampling 1 – High Quality 2 – Medium or Mixed Quality: uncertain representativeness of sampling and small sample sizes
Data not used (rank)		
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty		

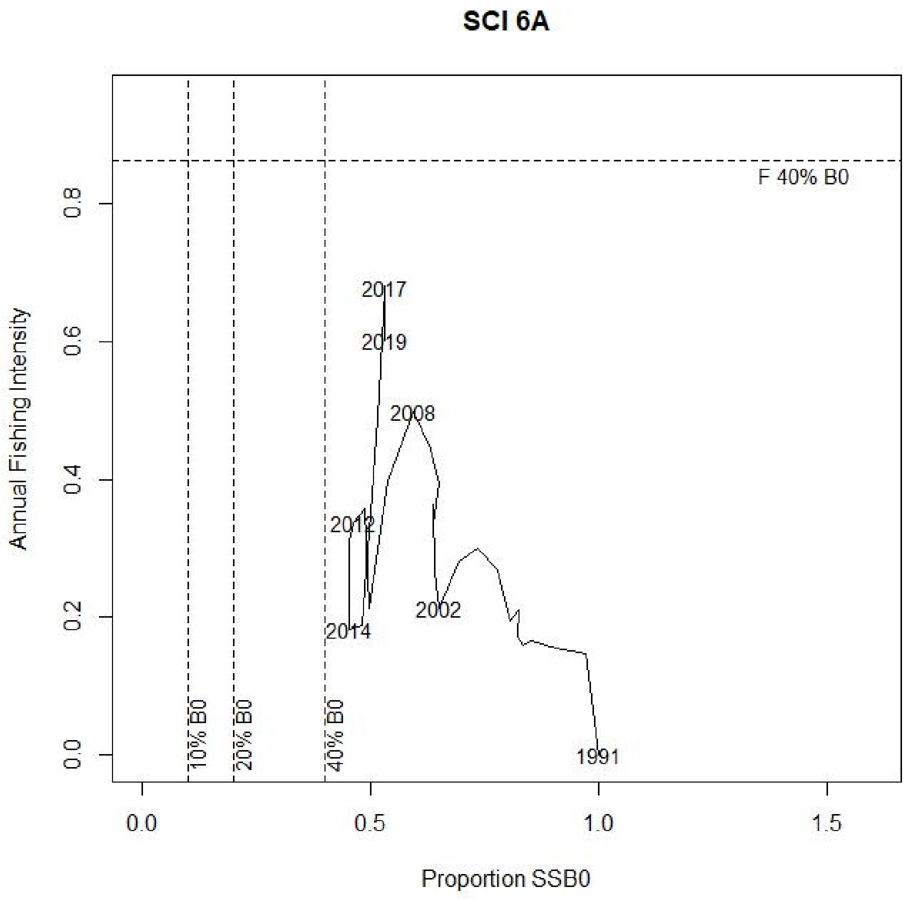
Qualifying Comments
The Chatham Rise *Tangaroa* survey records relatively low catches of scampi, and while it provides the only fishery independent index for scampi in SCI 4A, it was not designed to target this species.

Fishery Interactions
Main QMS bycatch species include ling, hoki, sea perch, red cod, silver warehou and giant stargazer. Discards are dominated by rattails, javelinfish, skates and crabs, ling, red cod, hoki, spiny dogfish and sea perch. Interactions with seabirds and mammals (fur seals and sea lions) have been recorded. A wide range of benthic invertebrate species are taken as bycatch.

- **SCI 6A**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Bayesian length based model with *M*=0.25, informed survey catchability priors, and survey and CPUE abundance indices (base model run)
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Very Likely (> 90%) to be at or above the target
Status in relation to Limits	Exceptionally Unlikely (< 1%) to be below the soft or hard limits
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectories of biomass as a proportion of SSB_0 and annual equivalent fishing intensity for SCI 6A.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Estimated spawning stock biomass has been stable for the last 4 years.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality showed an increasing trend between 2014 and 2019.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-
Projections and Prognosis	

Stock Projections or Prognosis	The stock is predicted to remain above 40% SSB_0 through to 2025 at current levels of catch and the TACC. Projected stock status when catches are at the TACC level is predicted to be about 51% B_0 in 2025.
Probability of Current Catch or TACC causing biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Overfishing Exceptionally Unlikely (< 1%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Length-based Bayesian model	
Assessment Dates	Latest assessment: 2020	Next assessment: 2023
Overall assessment quality rank	1 – High Quality	
Main data inputs	- Standardised catch and effort data (TCEPR) from MPI - Length frequency data from MPI observer sampling - Photographic survey abundance index - Trawl survey abundance index - Length frequency data from trawl survey abundance index - Length frequency data from photos of visible scampi - Growth rates predicted from tag release recapture data	1 – High Quality 2 – Medium or Mixed Quality: variable representativeness of sampling 1 – High Quality 1 – High Quality 1 – High Quality 2 – Medium or Mixed Quality: high level of uncertainty 2 – Medium or Mixed Quality: limited recaptures and within a limited time span
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	Revised prior distributions estimated for survey catchability Model was fitted to emerged abundance index rather than the visible index	
Major Sources of Uncertainty	- Growth, differential selectivity by sex, and sex ratios - Relationship between CPUE and abundance (potential time varying q) -YCS estimation	

Qualifying Comments
Photo surveys in SCI 6A observe a higher number of scampi out of burrows, relative to burrows counted, than has been observed in other areas. This may be related to animal size or sediment characteristics. If emergence is greater, this may imply that scampi in SCI 6A are more vulnerable to trawling than in other areas.

Fishery Interactions
Main QMS bycatch species include ling, hoki, sea perch, red cod, silver warehou and giant stargazer. Discards are dominated by rattails, javelinfish, skates and crabs, ling, red cod, hoki, spiny dogfish and sea perch. Interactions with seabirds and mammals (fur seals and sea lions) have been recorded. A wide range of benthic invertebrate species are taken as bycatch.

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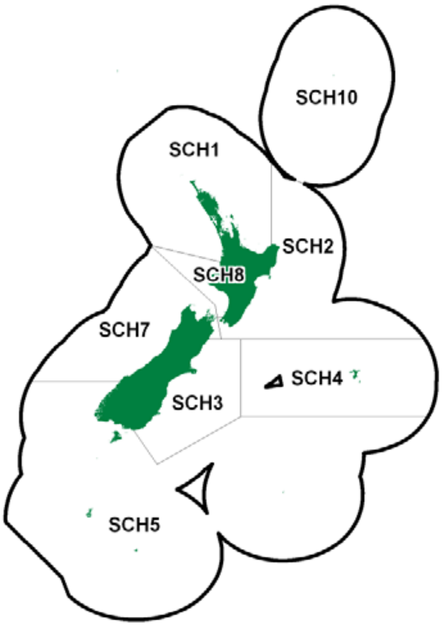
SCHOOL SHARK (SCH)

(*Galeorhinus galeus*)
Tupere, Tope, Makohuarau



1. FISHERY SUMMARY

School shark was introduced into the QMS on 1 October 1986. The recreational, customary, and other mortality allowances as well as TACCs and TACs applicable from the fishing year 2018–19 are shown in Table 1.

Table 1: Recreational and Customary non-commercial allowances, other sources of mortality, TACCs, and TACs for school shark by Fishstock.

Fish Stock	Recreational allowance	Customary Non–Commercial allowance	Other sources of mortality	TACC	TAC
SCH 1	68	102	34	689	893
SCH 2	–	–	–	199	199
SCH 3	48	48	19	387	502
SCH 4	–	–	–	239	239
SCH 5	7	7	37	743	794
SCH 7	58	58	32	641	789
SCH 8	21	21	26	359	427
SCH 10	–	–	–	10	10

1.1 Commercial fisheries

This moderate-sized shark has supported a variety of fisheries around New Zealand from the early 1940s onwards. Landings rose steeply from the late 1970s until 1983 (Table 2), with the intensification of set nets targeting this and other shark species, and a general decline in availability of other, previously more desirable, coastal species. However, because of earlier discarding and under-reporting, this recorded rise in landings did not reflect an equivalent rise in catches. Landings decreased by about 50% from 1986 onwards because quotas were set below previous catch levels when this species was introduced into the QMS (Table 3). From 1987–88 to 1991–92, annual total reported landings were around 2200–2500 t. In 1995–96, total landings increased to above the level of the TACC (3106 t) to 3412 t, exceeding the TACC for the first time. As the TACC was increased, annual total landings remained near the level of the TACC until about to 2012–13, decreasing slightly thereafter with just over 2730 t landed in 2018–19.

TACCs were increased by 5% for SCH 5, and 20% for SCH 3, 7 & 8 under AMP management in October 2004. From 1 October 2007, the TACC for SCH 1 was increased to 689 t, also setting a TAC for the first time at 893 t with 102 t, 68 t, and 34 t allocated to customary, recreational, and other sources of mortality, respectively. In 2004, SCH 3, 5, 7, & 8 were allocated recreational and customary non-commercial allowances of 48 t, 7 t, 58 t, and 21 t, respectively, and other sources of mortality were allocated 19 t, 37 t, 32 t, and 26 t, respectively. All AMP programmes ended on 30 September 2009. School shark were added to the Schedule 6 on the 1 of January 2013; this allows the release of captured school shark that are alive and likely to survive. Table 2 shows total New Zealand historical (pre-1984) SCH landings by calendar year; TACCs and landings by fishing year are provided by Fishstock in Table 3 and Figure 1.

Table 2: Reported domestic landings (t) of school shark from 1948 to 1983.

Year	Landings	Year	Landings	Year	Landings	Year	Landings
1948	75	1957	301	1966	316	1975	518
1949	124	1958	323	1967	376	1976	914
1950	147	1959	304	1968	360	1977	1 231
1951	157	1960	308	1969	390	1978	161
1952	179	1961	362	1970	450	1979	481
1953	142	1962	354	1971	597	1980	1 788
1954	185	1963	380	1972	335	1981	2 716
1955	180	1964	342	1973	400	1982	2 965
1956	164	1965	359	1974	459	1983	3 918

Source: Fisheries New Zealand data.

During the period of high landings in the mid-1980s, set netting was the main fishing method, providing about half the total catch, with lining accounting for one-third of the catch, and trawling the remainder. There were large regional variations. These proportions have shifted somewhat in more recent years, with set net still accounting for just under 50% of the landings, and bottom longline and bottom trawl approximately splitting the remaining 50%. Small amounts of school shark are also caught by the foreign charter tuna longliners fishing offshore in the EEZ to well beyond the shelf edge.

The Banks Peninsula Marine Mammal Sanctuary was established in 1988 by the Department of Conservation under the Marine Mammal Protection Act 1978, for the purpose of protecting Hector’s dolphins. The sanctuary extends 4 nautical miles from the coast from Sumner Head in the north to the Rakaia River mouth in the south. Before 1 October 2008, no set nets were allowed within the sanctuary between 1 November and the end of February. For the remainder of the year, set nets were allowed; but could only be set from an hour after sunrise to an hour before sunset, be no more than 30 metres long, with only one net per boat which was required to remain tied to the net while it was set.

Voluntary set net closures were implemented by the SEFMC from 1 October 2000 to protect nursery grounds for rig and elephantfish and to reduce interactions between commercial set nets and Hector’s dolphins in shallow waters. The closed area extended from the southernmost end of the Banks Peninsula Marine Mammal Sanctuary to the northern bank of the mouth of the Waitaki River. This area was closed permanently for a distance of 1 nautical mile offshore and for 4 nautical miles offshore for the period 1 October to 31 January.

From 1 October 2008, a new suite of regulations intended to protect Mauī and Hector’s dolphins was implemented for all of New Zealand by the Minister of Fisheries.

For SCH 1, set net fishing was closed from Maunganui Bluff to Pariokariwa Point for a distance of 4 nautical miles on 1 October 2003. This closure was extended by the Minister to 7 nautical miles on 1 October 2008. An appeal was made by affected fishers who were granted interim relief by the High Court, allowing set net fishing beyond 4 nautical miles during daylight hours between 1 October and 24 December during three consecutive years: 2008–2010.

For SCH 3, commercial and recreational set netting was banned in most areas from 1 October 2008 to 4 nautical miles offshore of the east coast of the South Island, extending from Cape Jackson in the Marlborough Sounds to Slope Point in the Catlins. Some exceptions were allowed, including an exemption for commercial and recreational set netting to only one nautical mile offshore around the Kaikoura Canyon, and permitting set netting in most harbours, estuaries, river mouths, lagoons, and inlets except for the Avon-Heathcote Estuary, Lyttelton Harbour, Akaroa Harbour, and Timaru Harbour. In addition, trawl gear within 2 nautical miles of shore was restricted to flatfish nets with defined low headline heights.

For SCH 5, commercial and recreational set netting was banned in most areas from 1 October 2008 to 4 nautical miles offshore, extending from Slope Point in the Catlins to Sandhill Point east of Fiordland and in all of Te Waewae Bay. An exemption which permitted set netting in harbours, estuaries, and inlets was allowed. In addition, trawl gear within 2 nautical miles of shore was restricted to flatfish nets with defined low headline heights.

For SCH 7, both commercial and recreational set netting were banned to 2 nautical miles offshore from 1 October 2008, with the recreational closure effective for the entire year and the commercial closure restricted to the period 1 December to the end of February. The closed area extends from Awarua Point north of Fiordland to the tip of Cape Farewell at the top of the South Island. There is no equivalent closure in SCH 8, with the southern limit of the Mauī dolphin closure beginning north of New Plymouth at Pariokariwa Point.

Table 3: Reported landings (t) of school shark by Fishstock from 1931–32 to 2018–19 and actual TACCs (t) from 1986–87 to 2018–19. QMS data from 1986-present. [Continued on next page]

Fishstock	SCH 1		SCH 2		SCH 3		SCH 4		SCH 5	
FMA (s)	1 & 9		2		3		4		5 & 6	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1931–32	0	–	0	–	0	–	0	–	0	–
1932–33	0	–	0	–	0	–	0	–	0	–
1933–34	0	–	0	–	0	–	0	–	0	–
1934–35	0	–	0	–	0	–	0	–	0	–
1935–36	0	–	0	–	0	–	0	–	0	–
1936–37	0	–	0	–	0	–	0	–	0	–
1937–38	0	–	0	–	0	–	0	–	0	–
1938–39	0	–	0	–	0	–	0	–	0	–
1939–40	0	–	0	–	0	–	0	–	0	–
1940–41	0	–	0	–	0	–	0	–	0	–
1941–42	0	–	0	–	0	–	0	–	0	–
1942–43	0	–	0	–	0	–	0	–	0	–
1943–44	0	–	0	–	0	–	0	–	0	–
1944–45	0	–	0	–	0	–	0	–	0	–
1945–46	53	–	2	–	0	–	0	–	0	–
1946–47	73	–	3	–	7	–	0	–	3	–
1947–48	40	–	2	–	0	–	0	–	0	–
1948–49	48	–	3	–	0	–	0	–	0	–
1949–50	92	–	4	–	1	–	0	–	0	–
1950–51	105	–	6	–	1	–	0	–	0	–
1951–52	131	–	5	–	4	–	0	–	0	–
1952–53	144	–	7	–	5	–	0	–	0	–
1953–54	108	–	4	–	10	–	0	–	0	–
1954–55	121	–	10	–	8	–	0	–	0	–
1955–56	124	–	12	–	8	–	0	–	0	–
1956–57	92	–	19	–	5	–	0	–	0	–
1957–58	197	–	28	–	11	–	0	–	0	–
1958–59	211	–	24	–	17	–	0	–	1	–
1959–60	203	–	21	–	18	–	0	–	1	–
1960–61	219	–	19	–	23	–	0	–	1	–
1961–62	268	–	21	–	25	–	1	–	4	–
1962–63	252	–	23	–	29	–	0	–	2	–
1963–64	249	–	42	–	23	–	1	–	3	–
1964–65	186	–	51	–	30	–	1	–	1	–
1965–66	229	–	36	–	37	–	0	–	1	–
1966–67	189	–	31	–	36	–	0	–	1	–
1967–68	211	–	56	–	33	–	0	–	2	–
1968–69	195	–	57	–	41	–	0	–	4	–
1969–70	179	–	46	–	110	–	0	–	7	–
1970–71	157	–	82	–	99	–	0	–	13	–
1971–72	163	–	112	–	109	–	0	–	6	–
1972–73	136	–	59	–	30	–	0	–	3	–
1973–74	103	–	73	–	52	–	0	–	9	–
1974–75	120	–	75	–	98	–	0	–	18	–
1975–76	121	–	64	–	62	–	1	–	29	–
1976–77	389	–	88	–	54	–	0	–	70	–
1977–78	508	–	99	–	68	–	0	–	118	–
1978–79	52	–	28	–	13	–	0	–	6	–
1979–80	197	–	53	–	89	–	0	–	42	–
1980–81	690	–	127	–	295	–	2	–	229	–
1981–82	686	–	199	–	461	–	0	–	497	–
1982–83	598	–	245	–	544	–	1	–	264	–

Table 3 [continued]

Fishstock	SCH 1		SCH 2		SCH 3		SCH 4		SCH 5	
FMA (s)	1 & 9		2		3		4		5 & 6	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	1 087	–	298	–	630	–	8	–	792	–
1984–85*	861	–	237	–	505	–	12	–	995	–
1985–86*	787	–	214	–	370	–	23	–	647	–
1986–87	416	560	123	162	283	270	19	120	382	610
1987–88	528	668	123	199	320	322	22	239	531	694
1988–89	477	668	136	199	220	322	26	239	501	694
1989–90	585	668	156	199	272	322	27	239	460	694
1990–91	554	668	139	199	227	322	20	239	480	694
1991–92	596	668	161	199	255	322	34	239	622	694
1992–93	819	668	202	199	216	322	38	239	594	694
1993–94	657	668	157	199	202	322	41	239	624	694
1994–95	640	668	161	199	238	322	86	239	656	694
1995–96	802	668	214	199	296	322	229	239	714	694
1996–97	791	668	228	199	290	322	179	239	662	694
1997–98	764	668	214	199	270	322	126	239	623	694
1998–99	784	668	275	199	335	322	106	239	714	694
1999–00	820	668	250	199	343	322	97	239	706	694
2000–01	799	668	178	199	364	322	100	239	724	694
2001–02	694	668	208	199	324	322	93	239	676	708
2002–03	689	668	225	199	410	322	130	239	746	708
2003–04	758	668	187	199	323	322	149	239	729	708
2004–05	695	668	201	199	424	387	206	239	743	743
2005–06	634	668	175	199	325	387	183	239	712	743
2006–07	661	668	200	199	376	387	88	239	738	743
2007–08	708	689	227	199	345	387	133	239	781	743
2008–09	713	689	232	199	364	387	145	239	741	743
2009–10	589	689	213	199	426	387	191	239	784	743
2010–11	777	689	187	199	366	387	174	239	701	743
2011–12	689	689	188	199	351	387	201	239	729	743
201213	602	689	200	199	320	387	127	239	748	743
2013–14	659	689	183	199	363	387	126	239	725	743
2014–15	595	689	157	199	362	387	218	239	646	743
2015–16	497	689	152	199	434	387	206	239	623	743
2016–17	530	689	138	199	339	387	238	239	696	743
2017–18	633	689	165	199	357	387	180	239	710	743
2018–19	557	689	168	199	389	387	202	239	608	743

Fishstock	SCH 7		SCH 8		SCH 10		Total	
FMA (s)	7		8		10			
	Landings	TACC	Landings	TACC	Landings	TACC	Landings§	TACC
1931–32	0	–	0	–	–	–	0	–
1932–33	0	–	0	–	–	–	0	–
1933–34	0	–	0	–	–	–	0	–
1934–35	0	–	0	–	–	–	0	–
1935–36	0	–	0	–	–	–	0	–
1936–37	0	–	0	–	–	–	0	–
1937–38	0	–	0	–	–	–	0	–
1938–39	0	–	0	–	–	–	0	–
1939–40	0	–	0	–	–	–	0	–
1940–41	0	–	0	–	–	–	0	–
1941–42	0	–	0	–	–	–	0	–
1942–43	0	–	0	–	–	–	0	–
1943–44	0	–	0	–	–	–	0	–
1944–45	0	–	0	–	–	–	0	–
1945–46	8	–	3	–	–	–	66	–
1946–47	16	–	3	–	–	–	105	–
1947–48	13	–	3	–	–	–	58	–
1948–49	18	–	5	–	–	–	74	–
1949–50	24	–	4	–	–	–	125	–
1950–51	29	–	6	–	–	–	147	–
1951–52	14	–	4	–	–	–	158	–
1952–53	17	–	5	–	–	–	178	–
1953–54	16	–	4	–	–	–	142	–
1954–55	36	–	10	–	–	–	185	–
1955–56	26	–	10	–	–	–	180	–
1956–57	34	–	14	–	–	–	164	–
1957–58	42	–	23	–	–	–	301	–
1958–59	41	–	29	–	–	–	323	–
1959–60	32	–	29	–	–	–	304	–
1960–61	24	–	21	–	–	–	307	–
1961–62	26	-	15	-	-	-	360	-

Table 3 [continued]

Fishstock	SCH 7		SCH 8		SCH 10			**Total**
FMA (s)		**7**		**8**		**10**		
	Landings	**TACC**	**Landings**	**TACC**	**Landings**	**TACC**	**Landings§**	**TACC**
1962–63	21	–	26	–	–	–	353	–
1963–64	29	–	34	–	–	–	381	–
1964–65	31	–	41	–	–	–	341	–
1965–66	26	–	30	–	–	–	359	–
1966–67	25	–	22	–	–	–	304	–
1967–68	51	–	23	–	–	–	376	–
1968–69	35	–	26	–	–	–	358	–
1969–70	28	–	20	–	–	–	390	–
1970–71	69	–	30	–	–	–	450	–
1971–72	159	–	48	–	–	–	597	–
1972–73	77	–	30	–	–	–	335	–
1973–74	75	–	42	–	–	–	354	–
1974–75	144	–	94	–	–	–	549	–
1975–76	153	–	90	–	–	–	520	–
1976–77	220	–	102	–	–	–	923	–
1977–78	280	–	164	–	–	–	1 237	–
1978–79	22	–	44	–	–	–	165	–
1979–80	94	–	44	–	–	–	519	–
1980–81	350	–	106	–	–	–	1 799	–
1981–82	480	–	393	–	–	–	2 716	–
1982–83	947	–	367	–	–	–	2 966	–
1983–84*	1 039	–	694	–	0	–	4 776	–
1984–85*	1 030	–	698	–	0	–	4 501	–
1985–86*	851	–	652	–	0	–	3 717	–
1986–87	454	470	224	310	0	10	1 902	2 513
1987–88	516	534	374	441	0	10	2 413	3 106
1988–89	540	534	419	441	0	10	2 319	3 106
1989–90	516	534	371	441	0	10	2 387	3 106
1990–91	420	534	369	441	0	10	2 209	3 106
1991–92	431	534	409	441	0	10	2 508	3 106
1992–93	482	534	484	441	0	10	2 835	3 106
1993–94	473	534	451	441	0	10	2 605	3 106
1994–95	369	534	417	441	0	10	2 567	3 106
1995–96	636	534	521	441	0	10	3 412	3 106
1995–96	543	534	459	441	0	10	3 152	3 106
1997–98	473	534	446	441	0	10	2 917	3 106
1998–99	682	534	533	441	0	10	3 429	3 106
1999–00	639	534	469	441	0	10	3 324	3 106
2000–01	576	534	453	441	0	10	3 193	3 106
2001–02	501	534	449	441	0	10	2 946	3 120
2002–03	512	534	448	441	0	10	3 161	3 120
2003–04	574	534	405	441	0	10	3 126	3 120
2004–05	546	641	554	529	0	10	3 369	3 416
2005–06	569	641	503	529	0	10	3 100	3 416
2006–07	583	641	534	529	0	10	3 180	3 416
2007–08	606	641	497	529	0	10	3 297	3 436
2008–09	694	641	588	529	0	10	3 478	3 436
2009–10	606	641	460	529	0	10	3 269	3 436
2010–11	677	641	587	529	0	10	3 469	3 436
2011–12	612	641	506	529	0	10	3 276	3 436
2012–13	656	641	512	529	0	10	3 165	3 436
2013–14	620	641	459	529	0	10	3 135	3 436
2014–15	610	641	523	529	0	10	3 110	3 436
2015–16	552	641	458	529	0	10	2 920	3 436
2016–17	559	641	352	529	0	10	2 852	3 436
2017–18	596	641	373	529	0	10	3 014	3 436
2018–19	534	641	277	359	0	10	2 734	3 436

*FSU data. § Includes landings from unknown areas before 1986-87.
Note: Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated because of under-reporting and discarding practices. Data includes both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

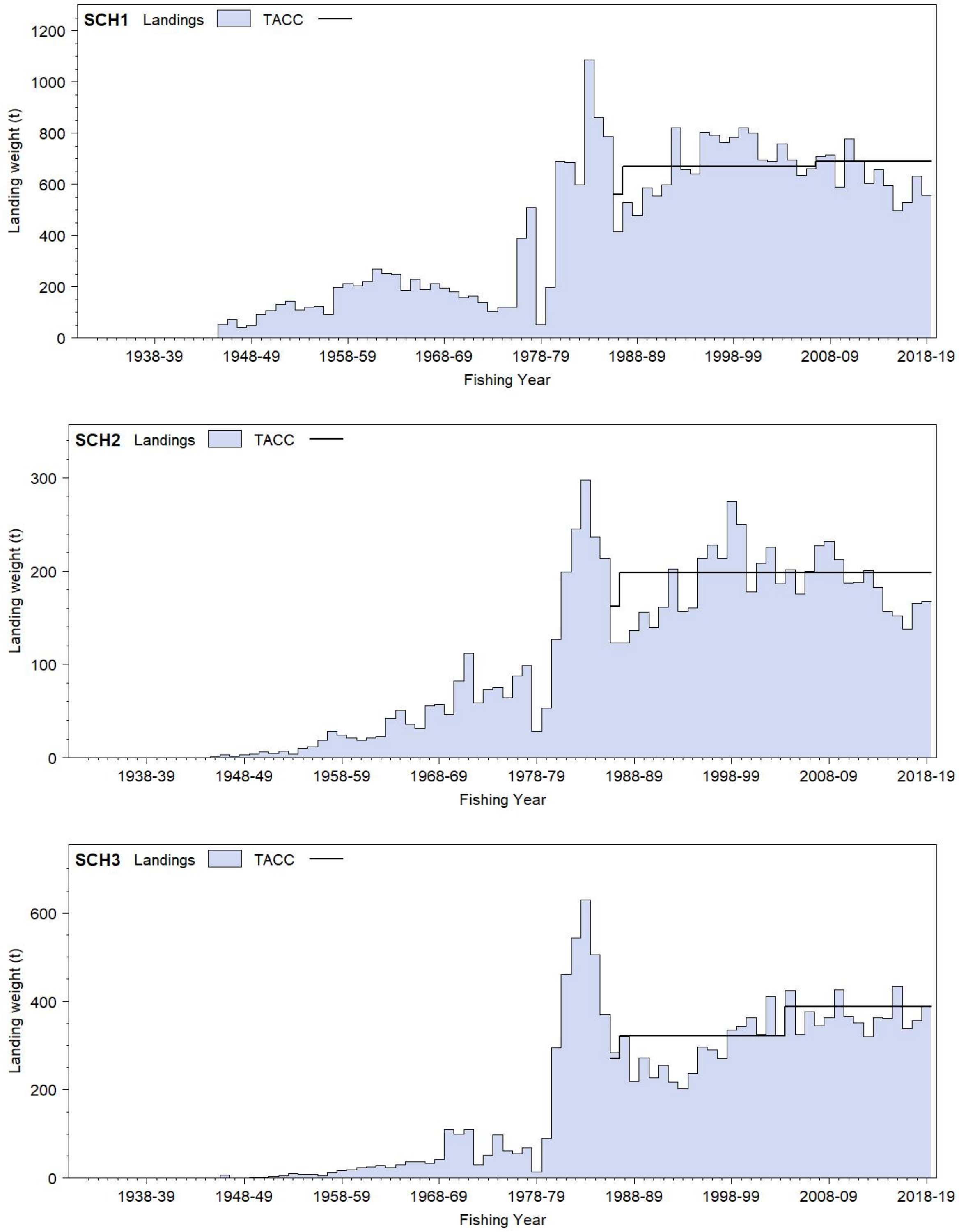
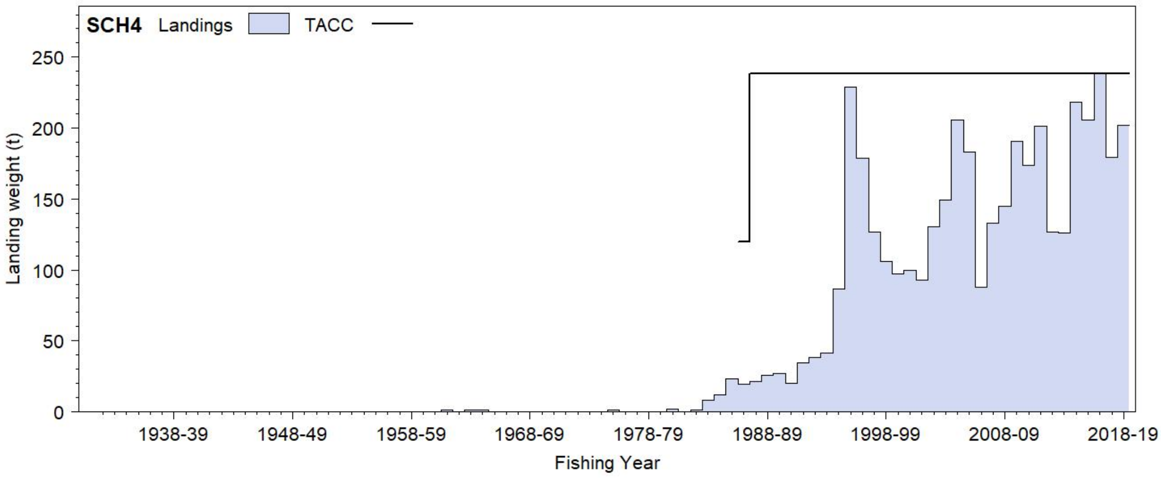
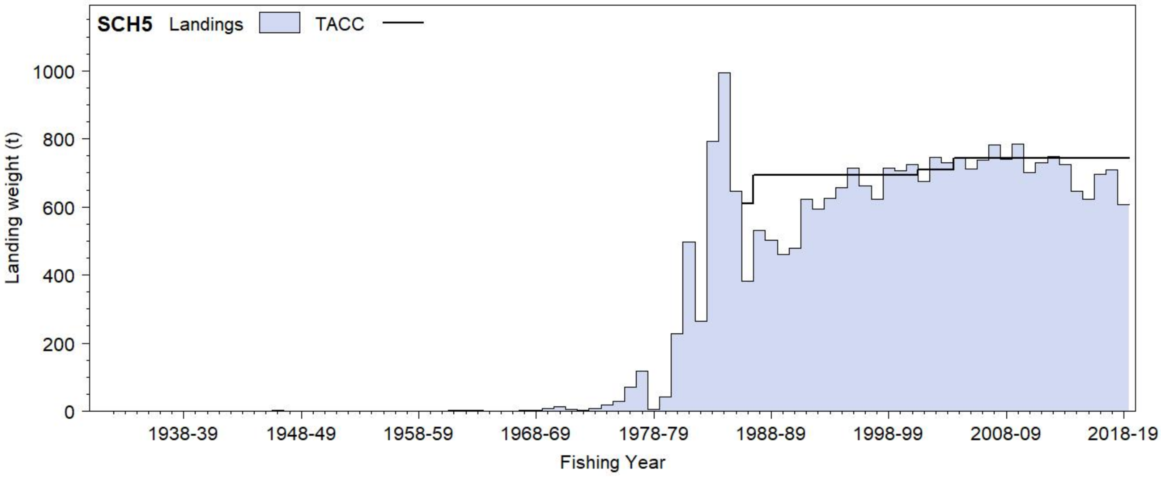


Figure 1: Reported commercial landings and TACC for the seven main SCH stocks. Above: SCH 1 (Auckland East), SCH 2 (Central East), and SCH 3 (South East coast). [Continued on next page]





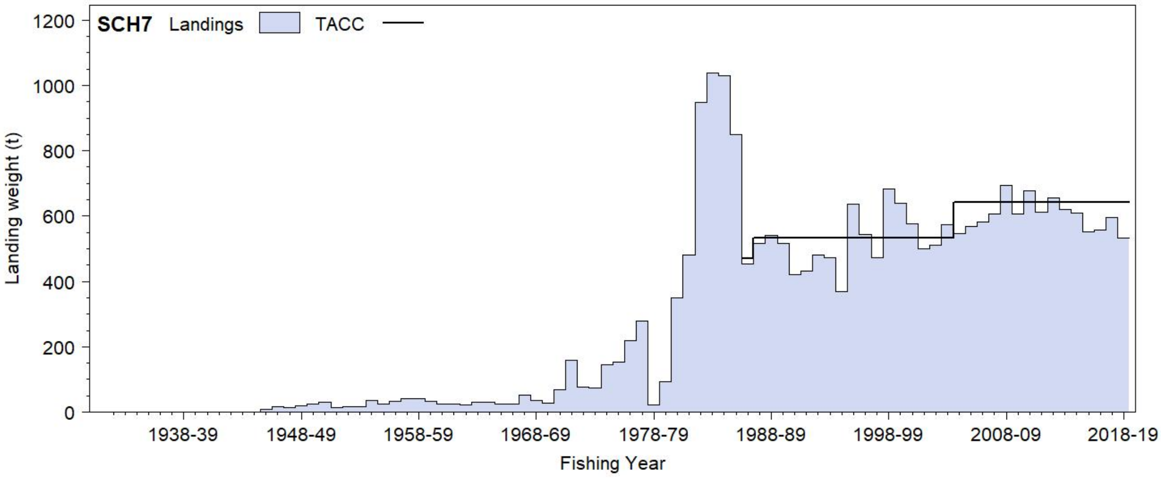


Figure 1 [Continued]: Reported commercial landings and TACC for the seven main SCH stocks. From top to bottom: SCH4 (South East Chatham Rise), SCH 5 (Southland), and SCH 7 (Challenger). [Continued on next page]

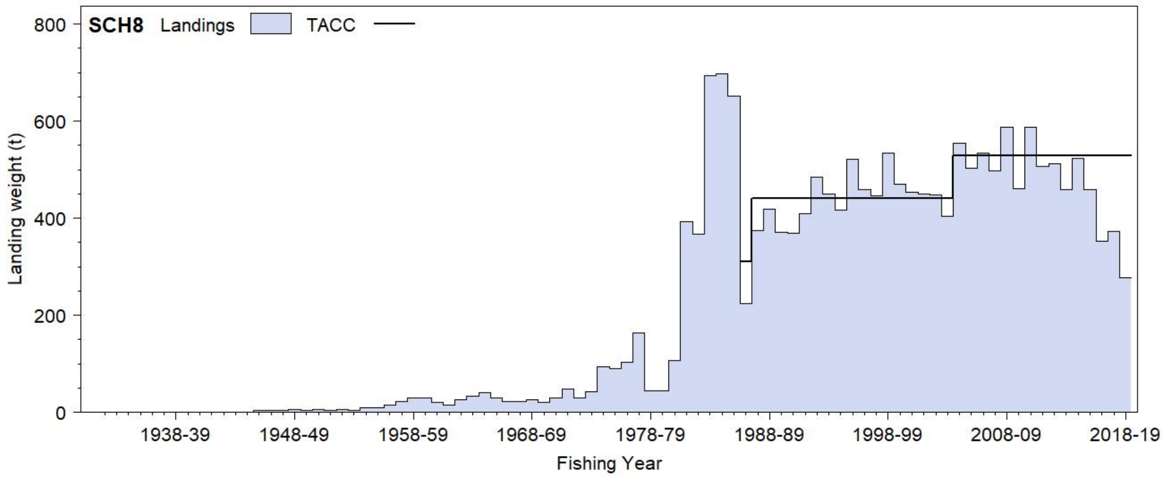


Figure 1[Continued]: Reported commercial landings and TACC for the seven main SCH stocks. SCH8 (Central Egmont).

1.2 Recreational fisheries

Although school shark is a listed gamefish and is regularly caught by recreational fishers, it is not considered to be a particularly desirable target species.

1.2.1 Management controls

The main method used to manage recreational harvests of school shark is daily bag limits. Fishers can take up to 20 school shark as part of their combined daily bag limit in the Auckland and Kermadec, Central, and Challenger Fishery Management Areas. Fishers can take up to 5 school shark as part of their combined daily bag limit in the Southland and South-East Fishery Management Areas.

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 for school shark were calculated using an offsite approach, the offsite regional telephone and diary survey approach. 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 2005). The harvest estimates provided by these telephone/diary surveys (Table 4) are no longer considered reliable.

In response to the cost and scale of the 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 development and implementation of a national panel survey for the 2011–12 fishing year (Wynne-Jones et al 2014). The panel survey used face-to-face interviews of a random sample of New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys (in numbers of fish, no mean weights being available from concurrent boat ramp surveys) are given in Table 4. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 4: Recreational harvest estimates for school shark stocks. The telephone/diary surveys ran from December to November but are denoted by the January calendar year. National panel surveys ran throughout the October to September fishing year but are denoted by the January calendar year.

Stock	Year	Method	Number of fish	Total weight (t)	CV
SCH 1	1996	Telephone/diary	23 000	46	0.17
	2000	Telephone/diary	27 000	66	0.42
	2012	Panel survey	9 788	–	0.24
	2018	Panel survey	1 198	–	0.51
SCH 2	1996	Telephone/diary	5 000	–	–
	2000	Telephone/diary	7 000	18	0.30
	2012	Panel survey	2 739	–	0.54
	2018	Panel survey	1 804	–	0.79
SCH 3	1996	Telephone/diary	3 000	–	–
	2000	Telephone/diary	19 000	48	0.46
	2012	Panel survey	5 381	–	0.37
	2018	Panel survey	627	–	0.43
SCH 5	1996	Telephone/diary	1 000	–	–
	2000	Telephone/diary	3 000	7	0.66
	2012	Panel survey	443	–	0.60
	2018	Panel survey	349	–	1.00
SCH 7	1996	Telephone/diary	8 000	16	0.24
	2000	Telephone/diary	23 000	58	0.56
	2012	Panel survey	10 311	–	0.36
	2018	Panel survey	2 001	–	0.31
SCH 8	1996	Telephone/diary	11 000	21	0.22
	2000	Telephone/diary	3 000	8	0.55
	2012	Panel survey	1 892	–	0.32
	2018	Panel survey	847	–	0.39

1.3 Customary non-commercial fisheries
Māori fishers made extensive use of school shark in pre-European times for food, oil, and skin. There is no quantitative information on the current level of customary non-commercial take.

1.4 Illegal catch
There is no quantifiable information on the level of illegal catch. There is an unknown amount of unreported offshore trawl and pelagic longline catch of school shark, either landed (under another name, or in "mixed") or discarded.

1.5 Other sources of mortality
There is an unknown discarded bycatch of juvenile, mainly first-year, school shark taken in harbour and bay set nets. Quantitative information is not available on the level of other sources of mortality.

2. BIOLOGY

School sharks are distributed across the shelf, generally being inshore in summer and offshore in winter. They extend in smaller numbers near the seafloor down the upper continental slope, to at least 600 m. The capture of school sharks by tuna longliners shows that their distribution extends well offshore, up to 180 nautical miles off the South Island, and 400 nautical miles off northern New Zealand towards the Kermadec Islands. They feed predominantly on small fish and cephalopods (octopus and squid).

Growth rates have not been estimated for New Zealand fish, but in Australia and South America school sharks are slow growing and long-lived (Grant et al 1979, Olsen 1984, Peres & Vooren 1991). They are difficult to age by conventional methods, but up to 45 vertebral rings can be counted. Growth is fastest for the first few years, slows appreciably between 5 and 15 years, and is negligible at older ages, particularly after 20 years. Results from an Australian long-term tag recovery suggest a maximum age of at least 50 years. Age-at-maturity has been estimated at 12–17 years for males and 13–15 years for females (Francis & Mulligan 1998). The size range of commercially caught maturing and adult school shark is 90–170 cm total length (TL), with a broad mode at 110–130 cm TL, which varies with area, season, and depth.

Breeding is not annual; it has generally been assumed to be biennial, but work on a Brazilian stock suggests that females have a 3-year cycle in the South Atlantic (Peres & Vooren 1991). Fecundity (pup number) increases from 5–10 in small females to over 40 in the largest. Mating is believed to occur in deep water, probably in winter. Release of pups occurs during spring and early summer (November–January), apparently earlier in the north of the country than in the south. Nursery grounds include harbours, shallow bays, and sheltered coasts. The pups remain in the shallow nursery grounds during their first one or two years and subsequently disperse across the shelf. The geographic location of the most important pupping and nursery grounds in New Zealand is not known.

Table 5: Estimates of biological parameters for school shark.

Fishstock	**Estimate**		**Source**
1. Weight = a (length)^b (Weight in g, length in cm fork length)			
	Both sexes combined		
	a	b	
SCH 1	0.0003	3.58	McGregor (unpub.)
SCH 3	0.0035	3.08	McGregor (unpub.)
SCH 5	0.0181	2.72	McGregor (unpub.)
SCH 5	0.0068	2.94	Hurst et al (1990)
SCH 7	0.0061	2.94	Blackwell (unpub.)
SCH 8	0.0104	2.84	Blackwell (unpub.)
2. Estimate of *M* for Australia			
	0.1		Grant et al (1979), Olsen (1984)

The combination of late maturity, slow growth, and low fecundity gives a relatively low overall productivity. In Australia, *M* has been estimated as 0.1.

New Zealand tagging studies have shown that school shark may move considerable distances, including trans-Tasman migrations (see below).

Biological parameters relevant to stock assessment are shown in Table 5.

3. STOCKS AND AREAS

Information relevant to determining school shark stock structure in New Zealand was reviewed in 2009 (Smith 2009, Blackwell & Francis 2010, Francis 2010). Primarily based on the tagging evidence, there is probably a single biological stock in the New Zealand EEZ. Genetic, biological, fishery, and tagging data were all considered, but the evidence for the existence of distinct biological stocks is poor. Some differences were found in CPUE trends between QMAs, but stock separation at the QMA level seems unlikely, and the CPUE differences may have resulted from processes acting below the stock level, such as localised exploitation of different sexes or different size classes of sharks. An apparent lack of juvenile school shark nursery areas in SCH 4 and SCH 5 suggests that these Fishstocks are not distinct, but are instead maintained by recruitment from other QMAs.

The most useful source of information was an opportunistic tagging programme undertaken mainly on research trawlers since 1985 (Hurst et al 1999). However most tag releases were made around the South Island so little information is provided for North Island school shark. Female school shark were slightly more mobile than males, with higher proportions of the former moving to non-adjacent QMAs and to Australia. About 30% of school shark recaptures were reported from outside the release QMA within a year of release, and this was maintained in the second year after release. After 2–5 years at liberty about 60% of recaptured school sharks (both sexes) were reported from outside the release QMA. After more than 5 years at liberty, 8% of males and 19% of females were recaptured from Australia. A large proportion of tagged school sharks moved outside the QMA of release within 5 years, and a significant proportion eventually moved to Australia. These trends in apparent movement are consistent across two decades of tagging. The relative importance of various breeding grounds around New Zealand (e.g., aggregations of breeding females in Kaipara Harbour) and whether females return to the area in which they were born are unknown.

The current stock management units are a precautionary measure to spread fishing effort; amalgamation of all QMAs into one QMA for the whole EEZ could create local depletion or sustainability risks for sub-stock components.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

Fishery characterisations and CPUE analyses for SCH 1, SCH 2, SCH 3, SCH 4, SCH 5, SCH 7, and SCH 8 were updated in 2017–18, following a full review in 2014. The 2014 review noted that, in many cases, the fishery definitions were constructs of administrative boundaries and often artificially divided fisheries that should be linked. The result of this review was the creation of revised fishery definitions for monitoring school shark, with boundaries between fisheries drawn in areas where there were gaps in catches, and, as much as possible, the same area definitions were used to define set net and bottom longline fisheries for monitoring purposes. Table 6 lists the definitions of the fisheries selected for monitoring school shark. The fisheries were selected on the basis of fine scale positional data but use general statistical areas to make the definitions in order to apply these definitions to the period before fine scale positional data became available. This approach also assumes that the fine scale positional information from 2007 to the present is representative of the distribution of fishing before that year.

The main difficulty in finalising these definitions was how to deal with Cook Strait, with the decision made to place all Cook Strait catches, even those from the eastern end of Cook Strait, to the central west coast fishery (SCH 7, SCH 8, and lower SCH 1W). Set net (SN) landings from Kaikoura and Pegasus Bay were assigned to the northern east coast fishery and bottom longline (BLL) landings from the western end of the Chatham Rise were assigned to SCH 4.

Table 6: List of fisheries selected to monitor NZ school shark. Core statistical areas are shown as well as any additional statistical areas needed to complete the fishery definition by capture method. There is no recorded fishing for school shark using set net on the Chatham Islands (SCH 4).

Region	Code	Core Statistical Areas	SN	BLL
Far North & SCH 1E	N/1E	043–010	same as core	same as core
SCH 2 & top of SCH 3	2/3N	011–015	add 018, 020	same as core
Chatham Rise (SCH 4)	SCH4	049-051, 401-412	NA	add 019, 020, 021
lower SCH 3 & SCH 5	3S/5	022–033	same as core	same as core
SCH 7, SCH 8 & lower SCH 1W	7/8/1W	034–042,801	add 016, 017	add 016, 017, 018

Characterisation comments by SCH QMA

Statistics reported here refer to the 2013–14 to 2015–16 fishing years.

SCH 1

About 31% of the SCH 1 landings were taken by bottom trawl when targeting tarakihi and snapper, with smaller catches when targeting trevally and red gurnard. The bottom longline SCH 1 fishery, taking about 24% of the total landings, was primarily directed at school shark, with hapuku and snapper being other important targets. The set net fishery, which took about 22% of the landings, was mainly targeted at school shark, with some additional targeting of rig, trevally, red gurnard, and snapper.

SCH 2

SCH 2 were caught primarily in the bottom trawl fishery (37%) targeting tarakihi, hoki, gemfish, and gurnard; and the bottom longline fishery (36%) targeting school shark, ling, hapuku/bass, and bluenose. About 18% of the catch was taken in set net targeting school shark, blue warehou, and blue moki.

SCH 3

SCH 3 was predominantly caught in the set net fishery (59%) targeting school shark and rig, with some targeting of spiny dogfish and tarakihi; and in the bottom trawl fishery (26%) targeting red cod, with some targeting of flatfish, barracouta, and tarakihi. Mixed targeted bottom longline took about 9% of the catch.

SCH 4
SCH 4 was primarily (92%) a bottom longline fishery targeted at bluenose, hapuku/bass, ling, and a few school shark. There was also a small bottom trawl fishery (7% of catches) which targeted a range of species including tarakihi, barracouta, stargazer, hoki, and scampi. The set net fishery has been small (<5%) and cannot be used to monitor the Fishstock.

SCH 5
SCH 5 was almost entirely caught in the school shark targeted set net fishery (87%), with some minor targeting of rig. About 8% was taken by bottom trawl primarily targeting stargazer and squid, and 4% by bottom longline primarily targeting hapuku/bass and ling.

SCH 7
SCH 7 were caught by the set net fishery (14%) targeting school shark, rig, and spiny dogfish; bottom longline (41%) targeting school shark, hapuku/bass, and ling; and bottom trawl (42%) targeting barracouta, tarakihi, flatfish, hoki, red cod, and others.

SCH 8
SCH 8 were caught mainly (59%) by set net targeting school shark and rig; and by bottom longline (30%) targeting school shark and hapuku/bass. About 10% was caught by bottom trawl targeting red gurnard, tarakihi, and trevally.

4.1 Biomass estimates

ECSI
The East Coast South Island (ECSI) winter trawl surveys from 1991 to 1996 in 30–400 m were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range, but these were discontinued after the fifth in the annual time series because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007 and this time included additional 10–30 m strata in an attempt to index elephantfish and red gurnard which were included in the list of target species. Only the 2007, 2012, 2014, and 2016 surveys provide full coverage of the 10–30 m depth range.

Biomass in the core strata (30–400 m) for the ECSI surveys has been variable, but was generally higher in years 2007 onward compared with the 1990s (Figure 2, Table 7). The additional biomass captured in the 10–30 m depth range accounted for only about 3% to 6% of the biomass in the core plus shallow strata (10–400 m) for the 2007, 2012, 2014, and 2016 surveys, and hence the shallow strata (10–30 m) are probably not essential for monitoring school shark biomass

WCSI
The West Coast South Island (WCSI) autumn trawl survey from 1992 to 2017 covers depths of 20–200 m off the west coast of the South Island from Cape Farewell to Karamea; 25–400 m from Karamea to Cape Foulwind; 20–400 m from Cape Foulwind to the Haast River mouth; and the area within Tasman Bay and Golden Bay inside a line drawn between Farewell Spit and Stephens Island.

Biomass in the core strata for the WCSI surveys has been variable, but was relatively low in 2003 (a year when catchability was low for most species (Stevenson & MacGibbon 2018) and relatively high around 1997 and 2011 (Figure 2, Table 7).

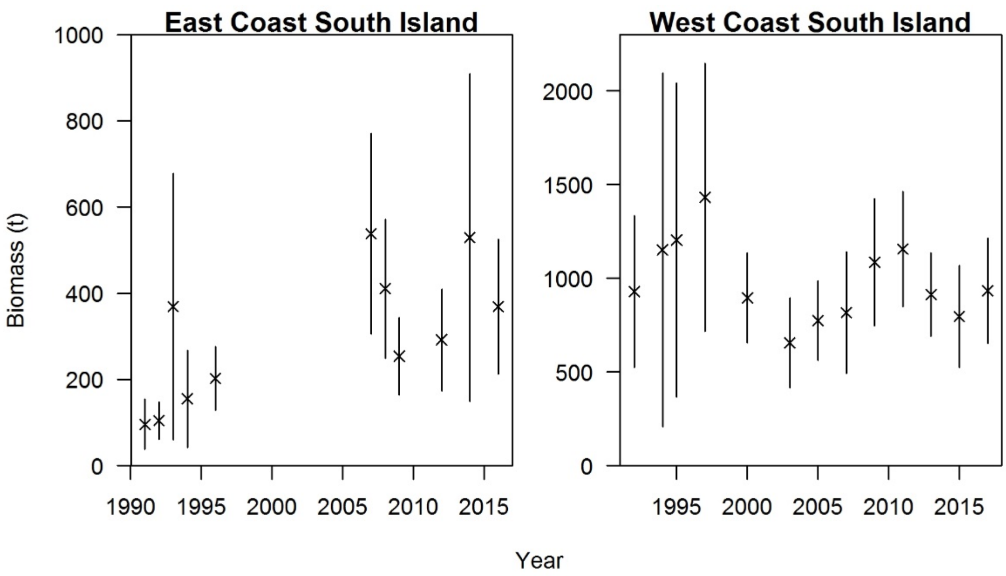


Figure 2: School shark total biomass and 95% confidence intervals for the East Coast South Island (ECSI) winter and West Coast South Island (WCSI) surveys in core strata.

Table 7: Relative total biomass indices (t) and coefficients of variation (CV) for school shark for the east coast South Island (ECSI) winter trawl survey, and west coast South Island (WCSI) autumn trawl survey. ECSI estimates are shown for core, and core plus shallow, strata. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16, and 17). – , not measured; NA, not applicable.

Region	Year	Trip number	Core strata biomass estimate	CV (%)	All strata biomass estimate	CV (%)
				30–400m		10–400m
ECSI (winter)	1991	KAH9105	100	30	–	–
	1992	KAH9205	104	21	–	–
	1993	KAH9306	369	42	–	–
	1994	KAH9406	155	36	–	–
	1996	KAH9608	202	18	–	–
	2007	KAH0705	538	22	552	21
	2008	KAH0806	411	20	–	–
	2009	KAH0905	254	18	–	–
	2012	KAH1207	292	20	310	19
	2014	KAH1402	529	36	547	35
	2016	KAH1605	369	21	379	21
WCSI (autumn)	1992	KAH9204	–	–	933	22
	1994	KAH9404	–	–	1 151	41
	1995	KAH9504	–	–	1 204	35
	1997	KAH9701	–	–	1 432	25
	2000	KAH0004	–	–	896	13
	2003	KAH0304	–	–	655	18
	2005	KAH0503	–	–	774	14
	2007	KAH0704	–	–	816	20
	2009	KAH0904	–	–	1 085	16
	2011	KAH1104	–	–	1 155	13
	2013	KAH1305	–	–	1 135	12
	2015	KAH1503	–	–	795	17
	2017	KAH1703	–	–	933	15

4.2 Length frequency distributions

ECSI

School shark are most common in 30–100 m with a tendency for the youngest cohorts to be in the shallower depth ranges. Three modes around 35, 50, and 60 cm are all pre-recruited school shark and correspond to ages of 0+, 1+, and 2+ (Figure 3). The survey appears to be monitoring pre-recruited cohorts 0+, 1+, 2+ (and possibly a few more older cohorts) reasonably well, but not the recruited school shark size distribution. Plots of time series length frequency distributions are spiky because of the low numbers caught, but the size range is reasonably consistent among surveys.

WCSI

The two modes at 40 and 55 cm are pre-recruited school shark and correspond to ages of 0+ and 1+ (Figure 4). The survey appears to be monitoring pre-recruited cohorts 0+ and 1+ (and possibly a few more older cohorts) reasonably well, but not the recruited school shark size distribution. Plots of time series length frequency distributions are spiky because of the low numbers caught, but the size range is reasonably consistent among surveys.

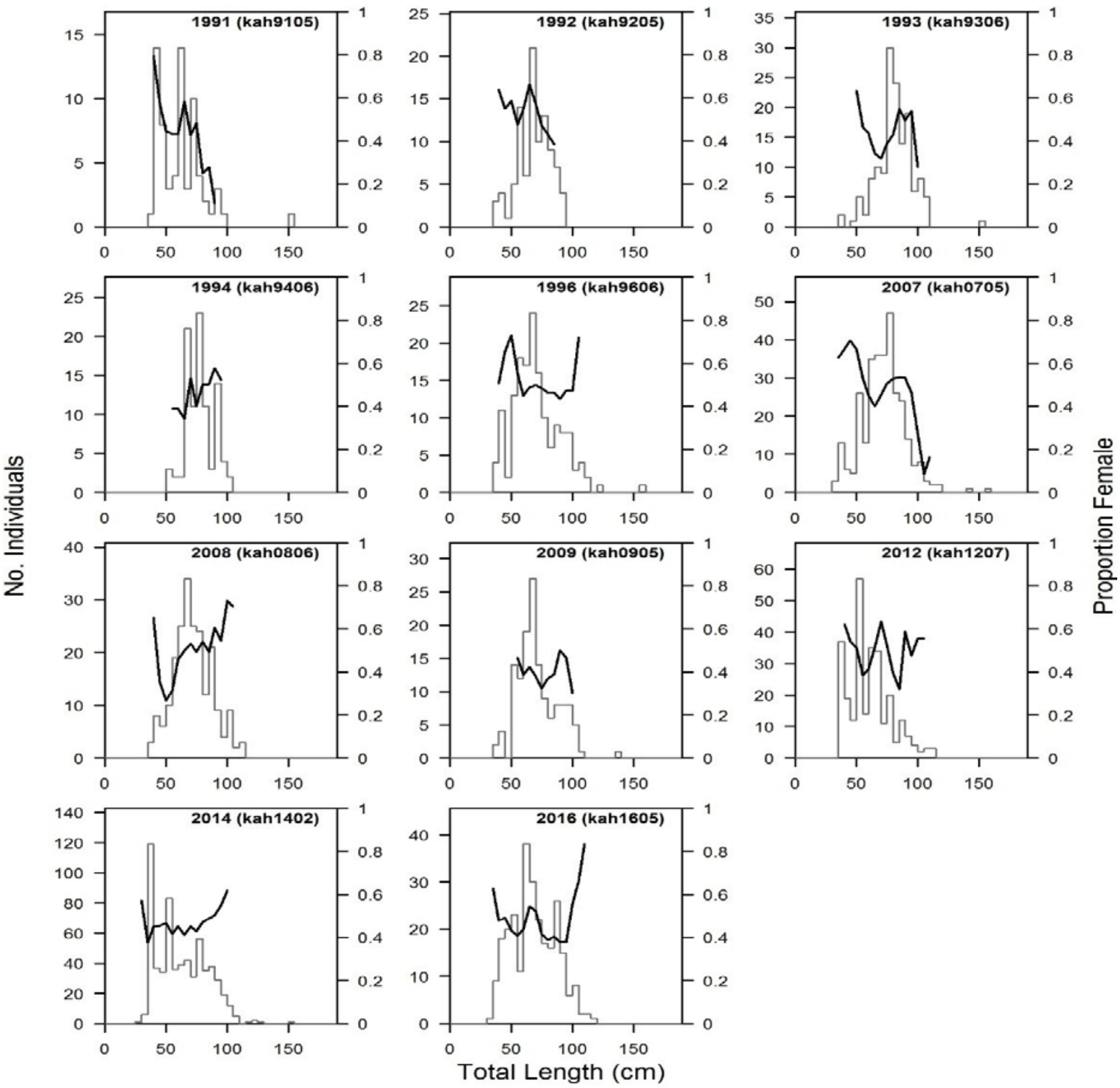


Figure 3: Scaled length frequency distributions for school shark in all strata (10–400 m) for the ECSI winter surveys (histogram), and proportion female (moving average; solid line). The samples include the 10–30 m stratum only in 2007, 2012, 2014, and 2016.

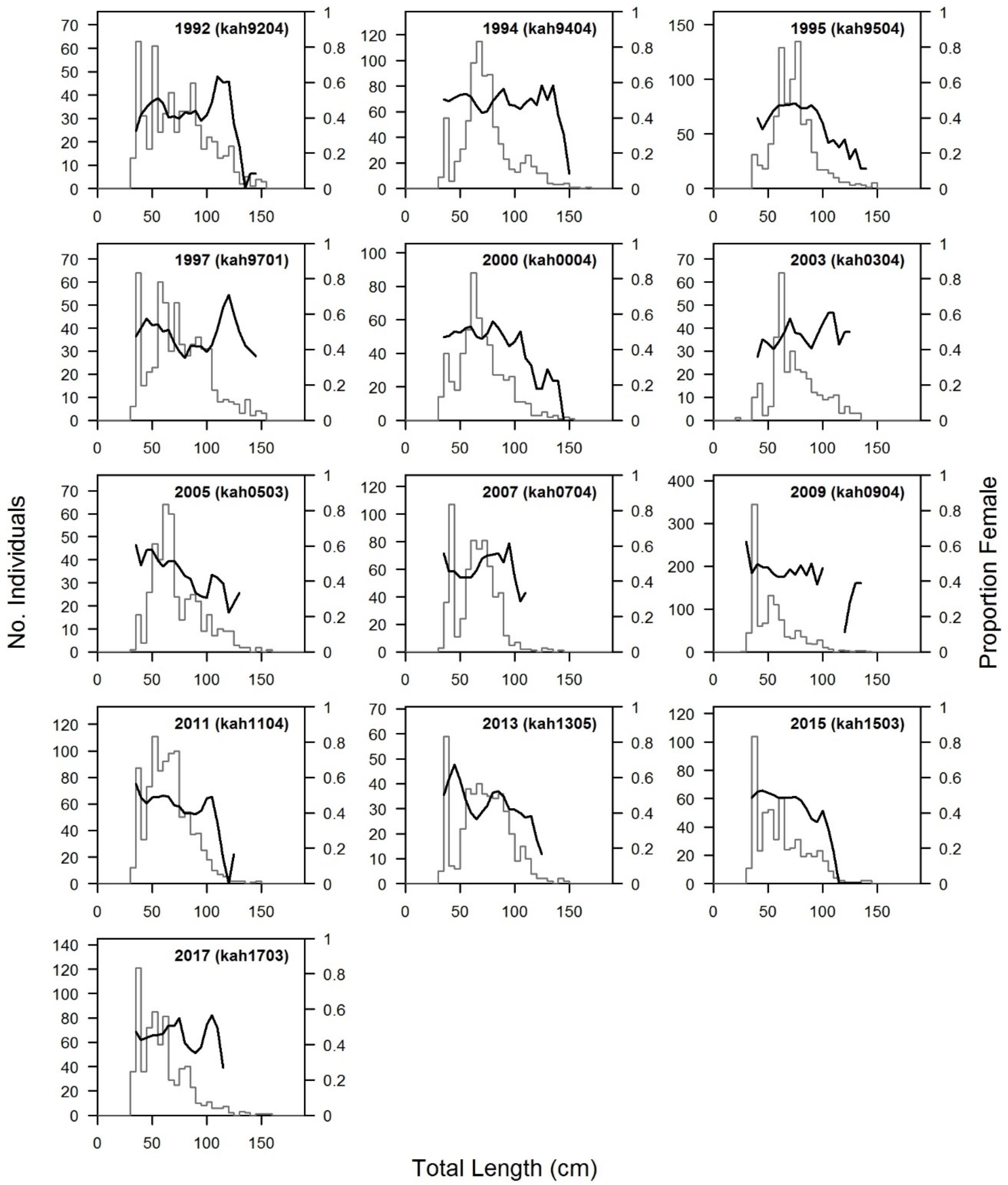


Figure 4: Scaled length frequency distributions for school shark in all strata for the WCSI autumn surveys (histogram), and proportion female (moving average; solid line).

Commercial catch samples

The most comprehensive samples of commercial catch composition from the Observer Programme were available for bottom longline off northern New Zealand (N/1E), and set net and trawl on the southeast of the South Island (3S/5) and west coast (7/8/1W) (Figure 5). Sampling of other gears and other stock monitoring areas has been relatively sparse, or absent. Clear modes of 0+ and 1+ school shark (modes at around 35 cm and 50 cm) were only sampled around northern New Zealand. Fish of >150 cm, which are predominantly female, were found in all areas. For 3S/5 and 7/8/1W, trawls caught a length range comparable to, or wider than, those caught by bottom longline or set net.

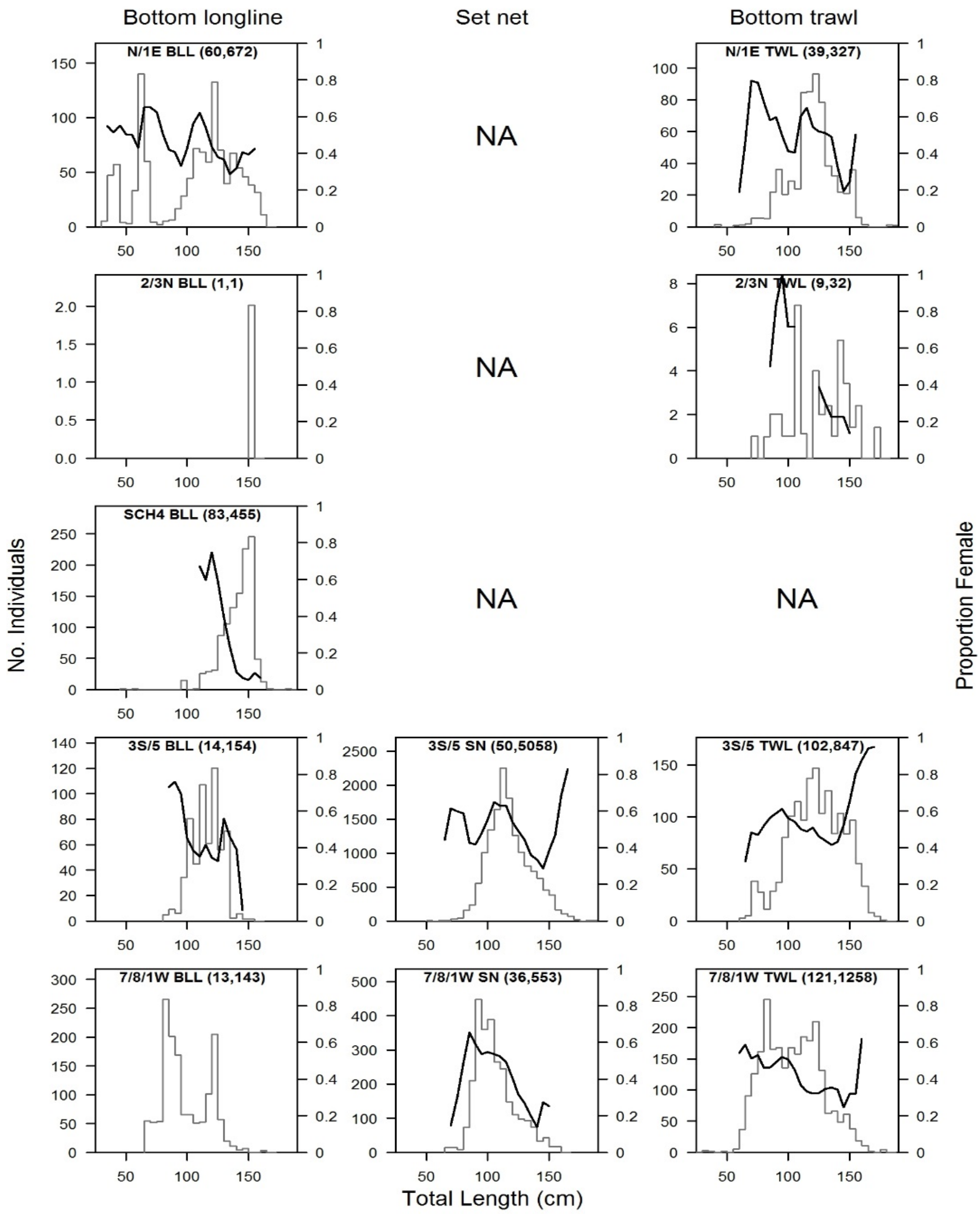


Figure 5: Scaled length frequency distributions (histogram), and proportion female (moving average; solid line) for school shark from all available observer samples of commercial catches taken by bottom longline (BLL), set net (SN), and bottom trawl (TWL), for the five stock monitoring units (see Table 6). Numbers in parentheses show the number of events sampled, and the number of fish (pre-scaling) measured.

A comparison of commercial trawl and research trawl survey catch compositions suggests that recruited fish were caught in greater proportions by the commercial trawl fleet (Figure 6). Catch composition from the Southland offshore research trawl survey (Hurst & Bagley 1994) was similar to that from commercial trawl catches taken from the same area.

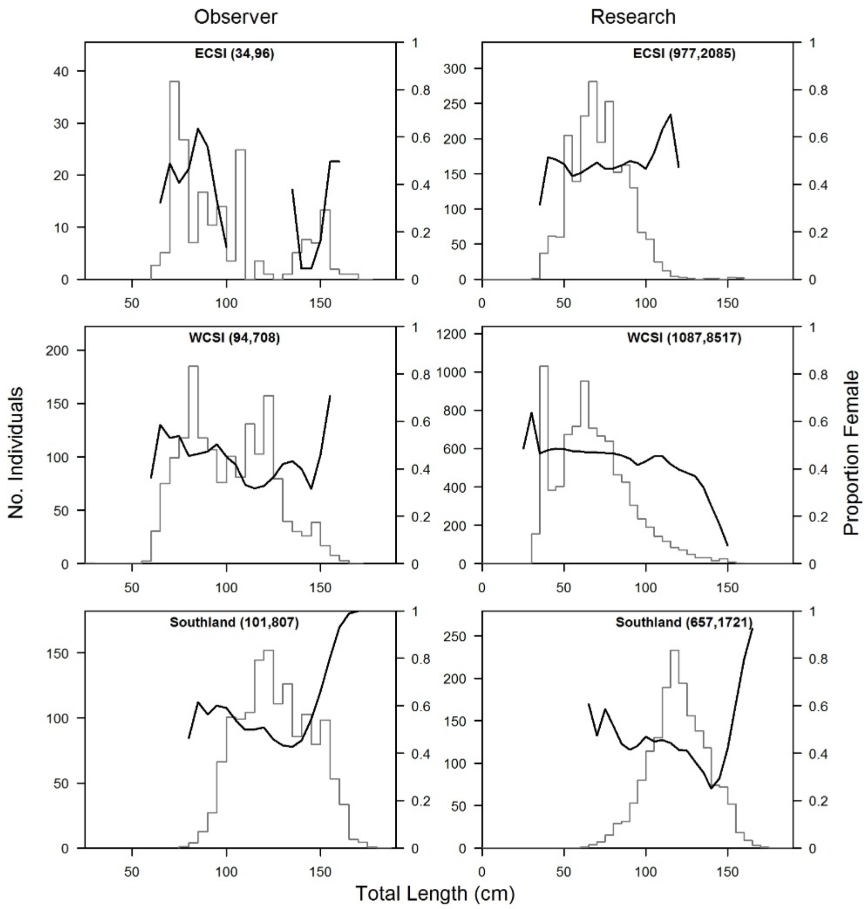


Figure 6: Scaled length frequency distributions (histogram), and proportion female (moving average; solid line) for school shark from all available observer samples of commercial catches taken by bottom trawl, and all research trawl survey samples (ECSI, WCSI, and Southland), for the areas where the two data sets overlap spatially (but for all years and seasons combined). Numbers in parentheses show the number of events sampled, and the number of fish (pre-scaling) measured.

CPUE trends by SCH Region (see Table 6)

School shark is considered to be a New Zealand-wide stock but B_{MSY}-based reference points are not currently able to be established for the stock as a whole.

Far North & SCH 1E

The lognormal set net series shows a shallow increasing trend to 2008–09, followed by variable but flat overall CPUE (Figure 7). The overall trend is mirrored by the combined bottom longline series, although this series indicates a slightly greater overall biomass increase. The lognormal bottom longline series shows a slow decline since the early 2000s, but this is counteracted by a decrease in the number of trips with zero school shark catch.

Establishing interim B_{MSY}-compatible reference points

In 2018, the Plenary accepted both the set net lognormal series, and bottom longline combined series, as valid measures of biomass (noting however that in the future, a combined index should be calculated for set net). Because the trends were similar, a mean of the two series was adopted as the biomass index, and a mean CPUE for the period 2008–09 to 2015–16 was adopted as an interim B_{MSY}-compatible proxy for Far North & SCH 1E. The Plenary considered that the stock was rebuilding slowly from a low level following larger (largely unreported) historical catches prior to the introduction of the QMS. The Plenary adopted the default Harvest Strategy Standard definitions for the Soft and Hard Limits of one half and one quarter the target, respectively.

SCH 2 & top of SCH 3

The bottom longline and set net capture methods provide contradictory trends in this region, with the set net series increasing and both the lognormal and combined-model longline series decreasing (Figure 8). The reason for this contradiction is unknown. It is possible that the relatively small amount of catch and effort data available from this region is partially responsible for this result.

Establishing interim B_{MSY}-compatible reference points

Because of the unexplained contradictory trends in the CPUE series, in 2018 the Plenary rejected CPUE as a biomass index for this region.

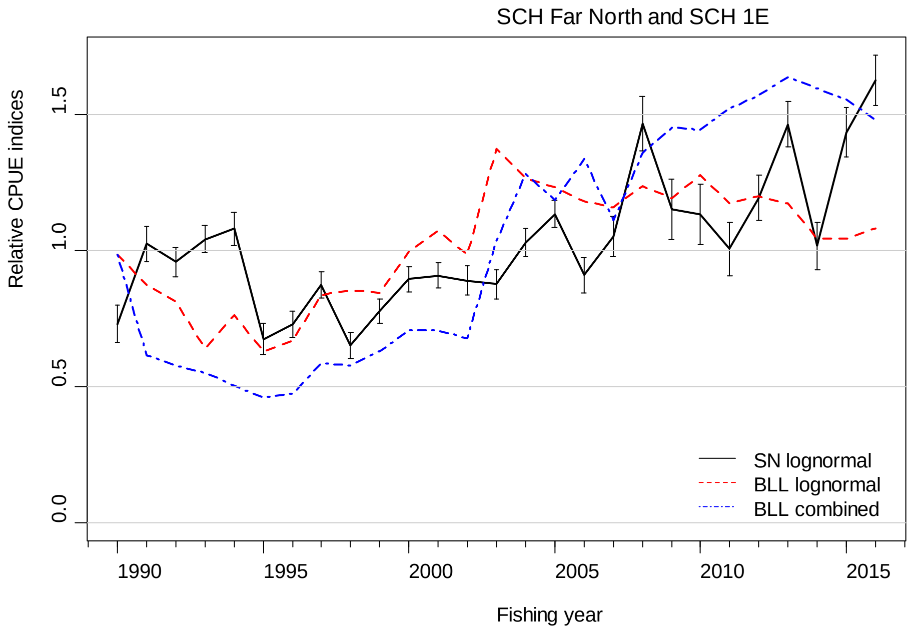


Figure 7: Far North/SCH 1E region (see Table 6): comparison of the lognormal SN series, the lognormal BLL series, and the combined (using the delta-lognormal method) BLL series.

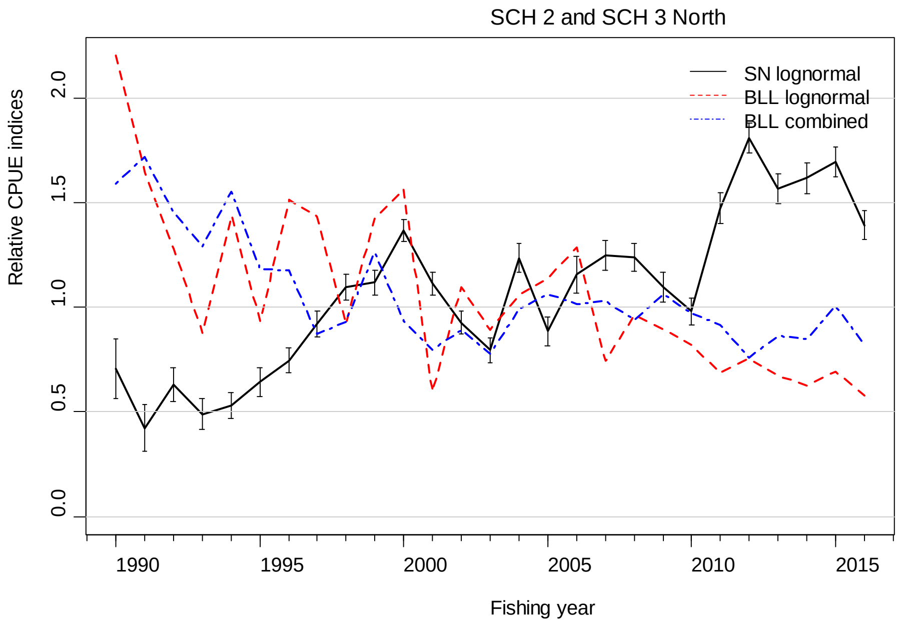


Figure 8: SCH 2 & top of SCH 3 region (see Table 6): comparison of the lognormal SN series, the lognormal BLL series and the combined (using the delta-lognormal method) BLL series.

Chatham Rise (SCH 4)

There is no available set net series to contribute to the monitoring of the Chatham Rise region. A standardised CPUE series was constructed from the recent (since 2003–04) bottom longline catch and effort data (Figure 9). This latter series shows no overall trend over the 13 years. Although earlier data are available, there was a fleet change in 2003–04 and data prior to this period were sparse.

Establishing interim B_{MSY}-compatible reference points

In 2018, the Plenary adopted CPUE from the bottom longline combined model as a biomass index for this region. However, because the CPUE series was relatively short and without trend, no reference period or reference points were adopted.

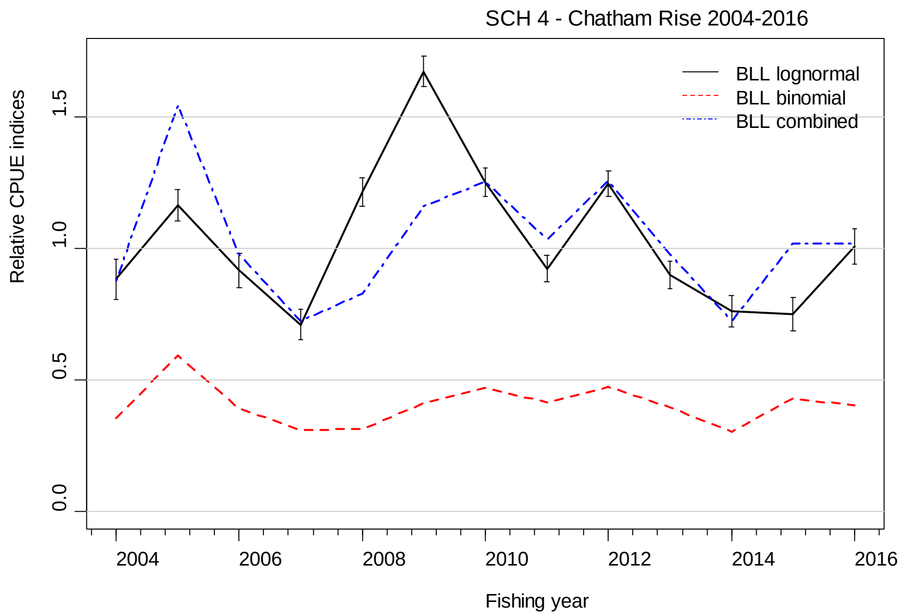


Figure 9: Chatham Rise (SCH 4) region (see Table 6): comparison of the lognormal SN series, the lognormal BLL series, and the combined (using the delta-lognormal method) BLL series.

Lower SCH 3 & SCH 5

The lognormal set net series showed a long and gradual declining trend; the decline in the set net combined index was less, because of a decreasing proportion of trips with zero catch (Figure 10). There was high variability, and therefore no clear trends, in the bottom longline series (Figure 10). The set net fishery is known to target large mature fish, but there is no known nearby spawning or nursery ground (Francis 2010 and section 3 above). The inconclusive bottom longline series is likely to be the result of small amounts of available data, leading to low reliability.

Establishing interim B_{MSY}-compatible reference points

In 2018, the Plenary accepted the set net combined series as a valid measure of relative biomass and rejected the bottom longline series due to the large fluctuations in CPUE which are unlikely to reflect abundance. Mean CPUE for the period 1989–90 to 1998–99 was adopted as an interim B_{MSY}-compatible proxy for Lower SCH 3 & SCH 5. This period was chosen because CPUE was stable, followed by a decline in CPUE as catches increased after 1999. Based on the catch history prior to the reference period, it was assumed the stock was not in a depleted state at the start of the time series of relative abundance. The Plenary adopted the default Harvest Strategy Standard definitions for the Soft and Hard Limits of one half and one quarter the target, respectively.

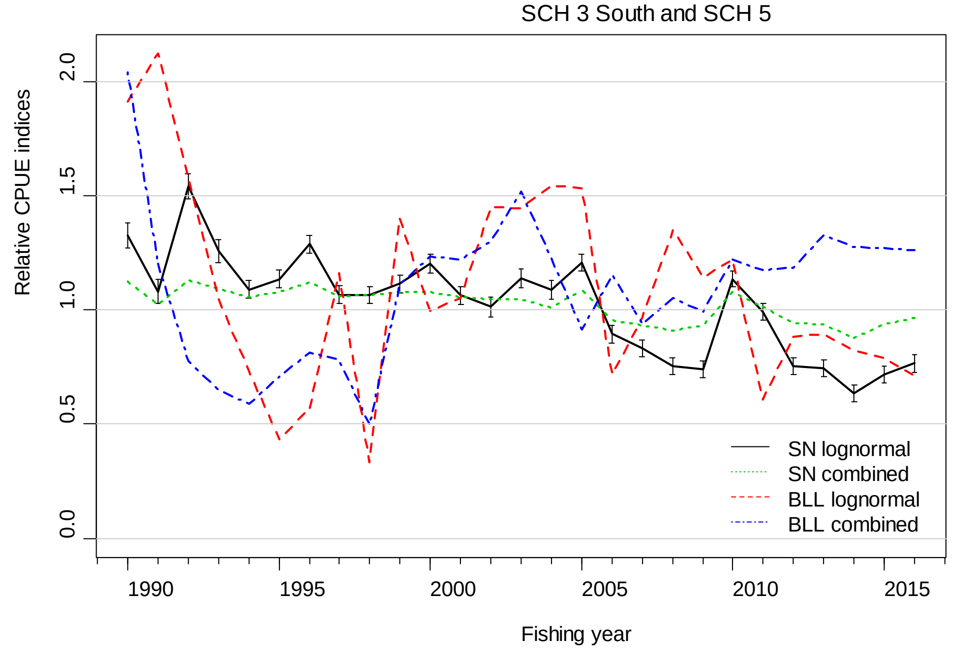


Figure 10: Lower SCH 3 & SCH 5 region (see Table 6): comparison of the lognormal and combined (using the delta-lognormal method) SN series, and the lognormal and combined BLL series.

SCH 7, SCH 8 & lower SCH 1W

The combined set net series shows a gradual biomass increase because of a decrease in the proportion of fishing days with zero catch of school shark (Figure 11). The combined set net trend is consistent with the combined bottom longline series.

Establishing interim B_{MSY}-compatible reference points

In 2018, the Plenary accepted both the set net combined series, and the bottom longline combined series, as valid measures of biomass. Because the trends were similar, a mean of the two series was adopted as the biomass index, and a mean CPUE for the period 2007–08 to 2015–16 was adopted as an interim B_{MSY}-compatible proxy for SCH 7, SCH 8, and lower SCH 1W. This period was chosen because abundance fluctuated without trend, and catch was high and relatively stable. The Plenary adopted the default Harvest Strategy Standard definitions for the Soft and Hard Limits of one half and one quarter the target, respectively.

SCH overview

SCH are mainly caught in set net fisheries targeting sharks (school shark, rig, elephantfish, and spiny dogfish, depending on the region); in bottom trawl fisheries targeting red cod, tarakihi, gurnard, and snapper and others; and in bottom longline fisheries targeting school shark, hapuku/bass, and ling. A large proportion of the school shark catch in the set net and bottom longline fisheries is taken by targeted effort.

There are similarities in the CPUE time series between some regions. For instance, there is broad agreement between the increasing trends seen in the set net fisheries in the Far North and Bay of Plenty (lognormal series, N/1E), the east coast of the North Island (lognormal series, 2/3N), and central west coast of New Zealand (combined series, 7/8/1W) (Figure 12). Only the set net fishery in the lower South Island (3S/5) shows a different trend, which decreases slowly (Figure 10).

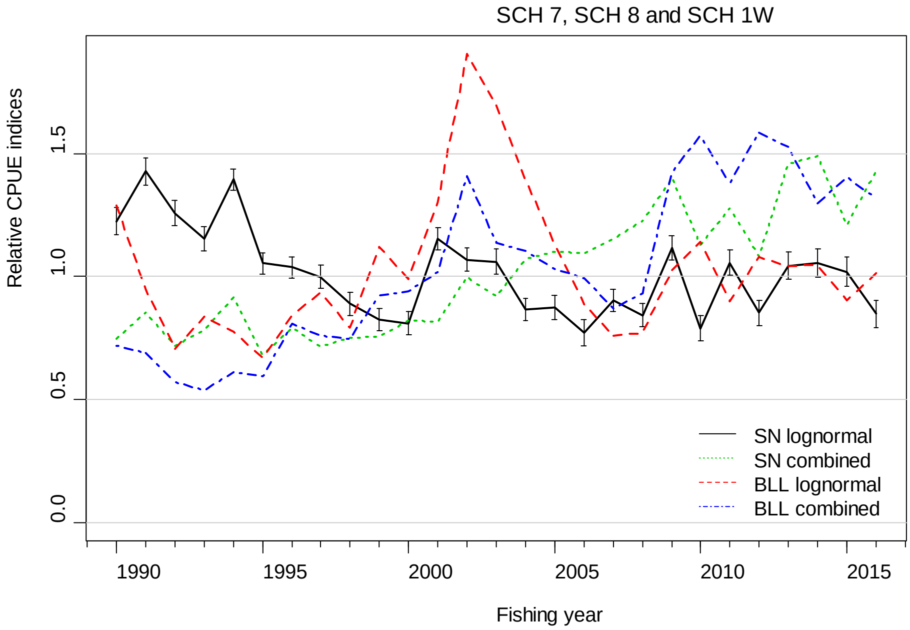


Figure 11: SCH 7, SCH 8 & lower SCH 1W region (see Table 6): comparison of the lognormal and combined (using the delta-lognormal method) SN series, and the lognormal and combined BLL series.

The bottom longline fishery operating in the Far North and Bay of Plenty (N/1E) shows a gradual increase, broadly similar to that seen around the lower South Island (3S/5) and central west coast of New Zealand (7/8/1W) (Figure 13). The decreasing trend in the east coast North Island fishery (2/3N) is not seen in any other bottom longline fishery (Figure 8).

Therefore, six of the nine available CPUE series indicate a gradual CPUE increase, with two indicating a decline, and one (SCH 4 bottom longline) relatively short, and equivocal. In general, it seems that the North and West Coast regions are doing well, showing increasing trends in CPUE. The Southern and East Coast regions have been fluctuating without trend, or gradually declining.

The contradictory trends between set net and bottom longline indices for lower South Island (3S/5) and east coast of North Island (2/3N) are difficult to interpret for a highly mobile species such as this one. The lack of similarity may point to these fisheries tending to operate in different areas and depths, and potentially catching different components of the population.

Recent set net closures have potentially compromised the continuity of set net indices for SCH 1W, 3, 5, and 7.

4.2 Other factors

In Australia, recruitment overfishing occurred to such an extent that the stock was considered seriously threatened and a series of conservative management measures (TAC reductions) were progressively imposed between 1996 and 2007 (Wilson et al 2008). Wilson et al (2008) noted that the stock had been in an overfished state and overfishing was occurring from 1992 to 2004. A 2009 assessment estimated that the stock was at 12% B_0 (Thomson & Punt 2009). An assessment update, in 2012, concluded that the school shark stock remained below 20% B_0, but was recovering (Thomson 2012). A stock recovery has been supported by recent survey work (McAlister et al 2015). The New Zealand stock is known to mix with the Australian stock (Hurst et al 1999).

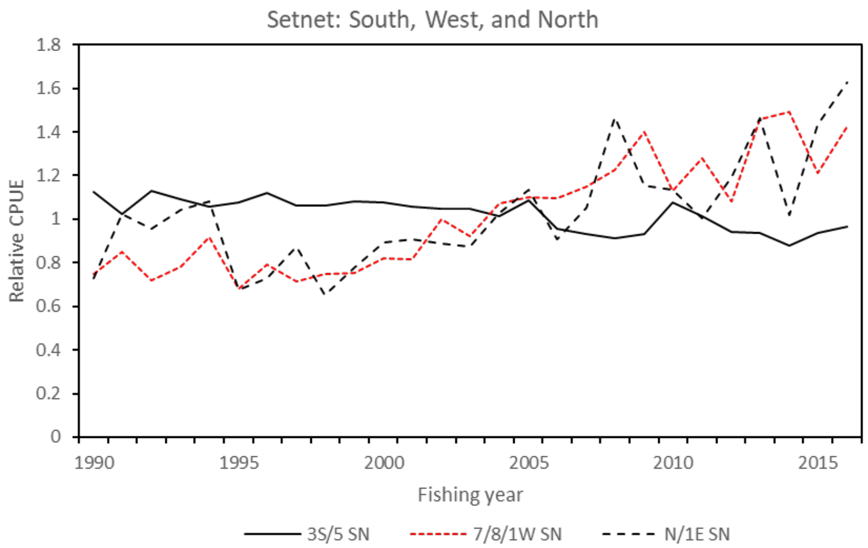


Figure 12: Comparison of lognormal set net series for the north and east sides of New Zealand, and combined set net series for the west side of New Zealand (Regions N/1E, 7/8/1W and 3S/5 – see Table 6).

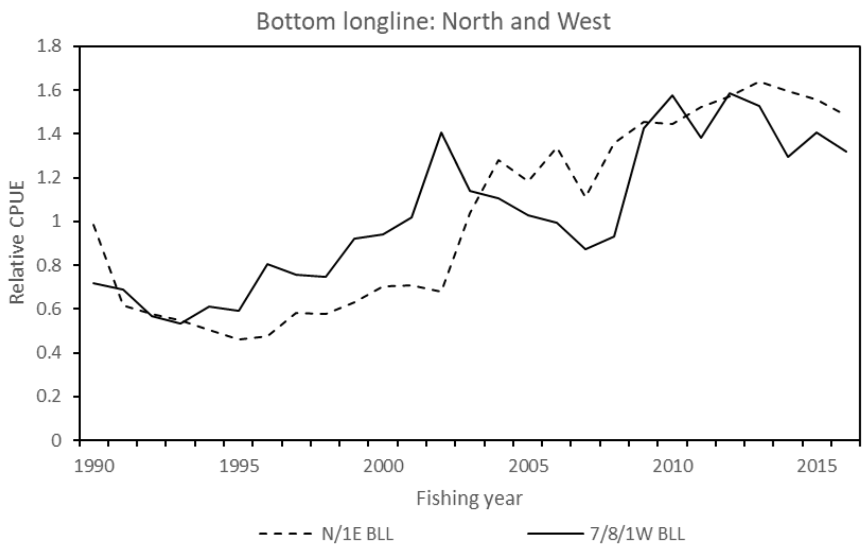


Figure 13: Comparison of combined bottom longline series for Northern, Southern, and Western sides of New Zealand (Regions N/1E and 7/8/1W – see Table 6).

4.3 Future research needs

- Size composition comparisons indicated that the length composition of school shark taken by bottom trawl was similar to those taken using the other two methods, and that observed commercial bottom trawl took similar proportions of large school shark as the other two methods. Comparing catches of different methods between areas suggested that bottom trawl CPUE series should in future be considered for areas where good quantities of trawl catch and effort data are available. Such analyses could be used where data for either of the other two methods are sparse, or to resolve conflicting trends. Bottom trawl CPUE analyses should be validated, where possible, by ensuring that the spatial and temporal distributions of the trawl vessels contributing to the CPUE analysis are similar to the distributions of the observed vessels.
- The feasibility of single New Zealand-wide CPUE index should also be investigated.
- Length data should be collected and examined to determine which components of the population are fished by each gear type:
  - Include the AMP samples.
  - Examine fish length stratification using commercial samples.

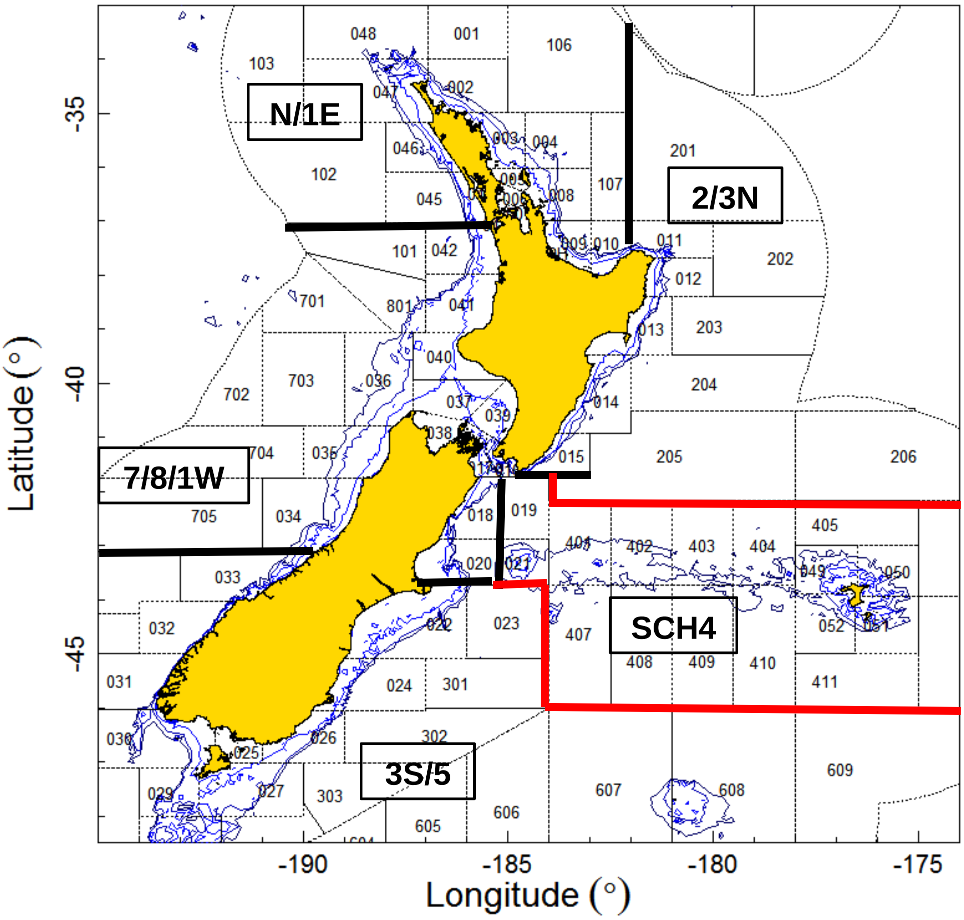
- Given that the current 3S/5 series shows a decline, consider the utility of another Southland *Tangaroa* survey, although not just focused on school shark but also other species.
- Further work on stock structure and movements among stocks should be conducted.
- Prior to the next stock assessment, information on the perceived or potential status of various components of the stock at the time of its introduction to the QMS should be compiled and examined with a view to revisiting reference points.
- Examine the outcome of the Australian close kin analysis, when this become available.

5. STATUS OF THE STOCKS

Stock Structure Assumptions

SCH are known from tagging studies to be highly mobile, moving between the North and South Islands, and as far as Australia. From the tagging evidence, there is probably a single biological SCH stock in the New Zealand EEZ. However, differences in average modal length and CPUE trends between FMAs indicate that movement between areas may be variable, with components of the stock aggregating in different areas. Therefore, the current stock management units are a precautionary measure to spread fishing effort and mortality across components of the stock. Conclusions about the assessment units (see map below) have also been formulated under the assumption that there is some level of persistence in the spatial population structure.

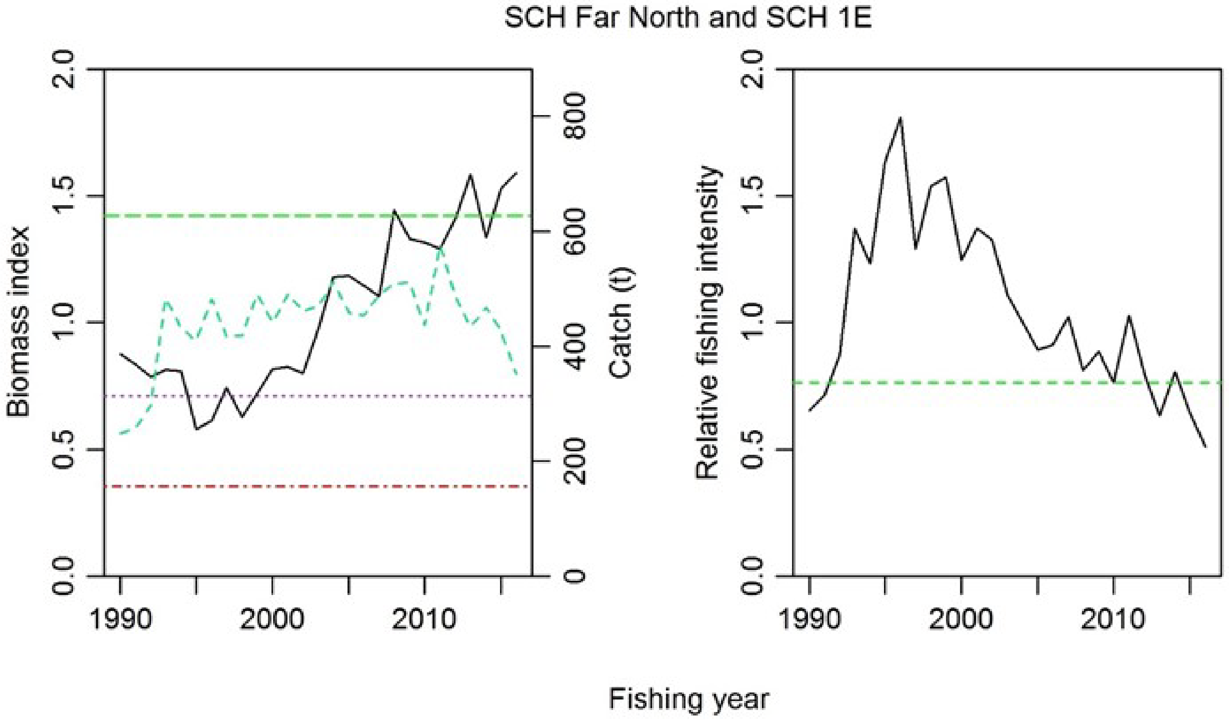
In the 2014 assessment, five proposed New Zealand school shark regions were used, as shown in the map below and described in Table 6. These boundaries follow existing statistical area boundaries so that the regions can be defined before the availability of fine scale positional data. The Cook Strait boundaries differ by method of capture as defined in Table 6. These school shark regions were also used for the 2018 assessment.



- **Far North & SCH 1E (N/1E on the map)**

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Standardised CPUE based on the average of the lognormal set net and combined bottom longline series
Reference Points	Target: Interim B_{MSY}-compatible proxy based on the mean CPUE from 2008–09 to 2015–16 for the average of the lognormal set net and combined bottom longline series Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: Interim F_{MSY}-compatible proxy based on the mean relative exploitation rate for the period: 2008–09 to 2015–16
Status in relation to Target	About as Likely as Not (40–60%) to be at or above B_{MSY}
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	About as Likely as Not (40–60%) to be occurring

Historical Stock Status Trajectory and Current Status



Left panel: Biomass index for school shark in SCH N/1W as the average of the standardised CPUE from the lognormal set net and combined bottom longline series (solid line). Also shown is the trajectory of total landed SCH by all methods from the sub-stock area (dashed line). Horizontal lines represent the target (dashed line), the soft limit (dotted line), and hard limit (dot-dash line). Right panel: Annual relative exploitation rate for school shark in SCH N/1W from the averaged set net and bottom longline CPUE series.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE increased after 1995, and then has fluctuated without trend since 2008–09.
Recent Trend in Intensity or Proxy	Fishing mortality appears to have been declining because CPUE has increased while catches have remained stable or declined.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The stock is Unlikely (< 40%) to decline at current catch
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (<40%) for current catch Hard Limit: Unlikely (< 40%) for current catch
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%) at current catch

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2018	Next assessment: 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Changes to Model Structure and Assumptions	The average of the lognormal setset and combined bottom longline CPUE series was used to index stock status.	

Major Sources of Uncertainty	- The components of the population fished by each gear type - Relationship between stock monitoring areas

Qualifying Comments
The set net lognormal index was accepted, but a combined index should be developed in the next assessment.

Fishery Interactions
Region Far North/SCH 1E catches are primarily taken by bottom trawl while targeting tarakihi and snapper, with smaller catches when targeting trevally and red gurnard. The bottom longline Far North/SCH 1E fishery is primarily directed at school shark, with hapuku, snapper and bluenose being other important targets. The set net fishery is also primarily targeted at school shark, with some targeting of rig, trevally, gurnard and snapper. Interactions with other species are currently being characterised.

- **SCH 2 & top of SCH 3 (Kaikoura and Pegasus Bay); (2/3N on the map)**

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	None
Reference Points	Target: Not established Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: Not established
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	-
Recent Trend in Fishing Intensity or Proxy	-
Other Abundance Indices	-

Trends in Other Relevant Indicators or Variables	Standardised CPUE are available for 1990–2016, with the set net series increasing, and the bottom longline series decreasing.

Projections and Prognosis	
Stock Projections or Prognosis	CPUE trends in this region are contradictory, with the set net series increasing while the bottom longline series has been decreasing. It is not known which series (if any) reflect the true underlying abundance.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unlikely (< 40%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2018	Next assessment: 2020
Overall assessment quality rank	3 – Low Quality: contradictory indices	
Main data inputs (rank)	- Catch and effort data	Unknown
Data not used (rank)		
Changes to Model Structure and Assumptions	None	
Major Sources of Uncertainty	-The components of the population fished by each gear type - Relationship between stock monitoring areas	

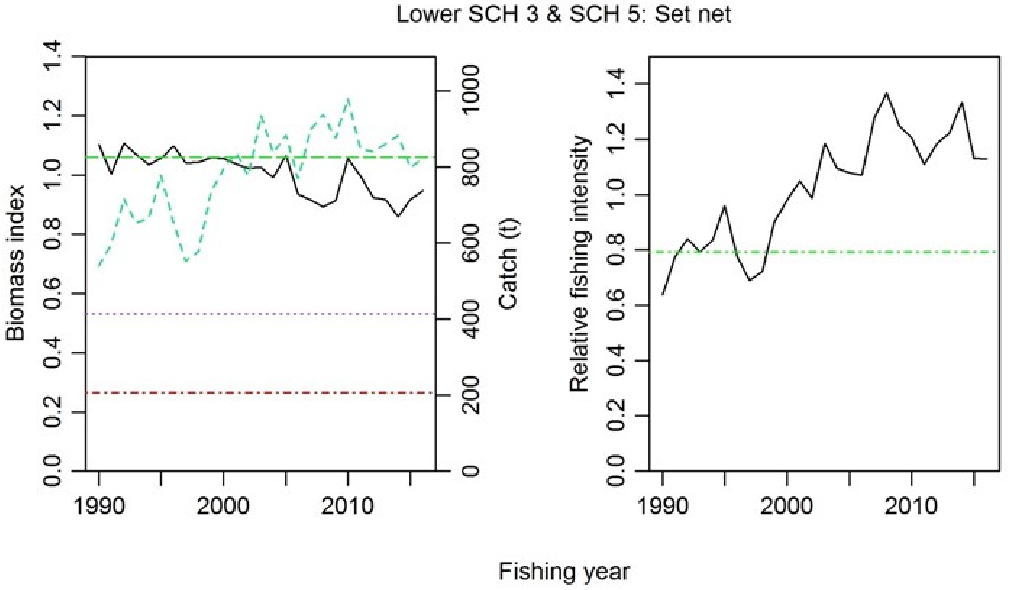
Qualifying Comments
-

Fishery Interactions
Region SCH 2/SCH 3 North catches are caught primarily in the bottom trawl fishery targeting tarakihi, hoki, gemfish and gurnard; and the bottom longline fishery targeting school shark, ling, hapuku/bass and bluenose. About one third of the catch is taken in set net targeting school shark, blue warehou and blue moki. Interactions with other species are currently being characterised.

- **Lower SCH 3 (Canterbury Bight) & SCH 5 (3S/5 on the map)**

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Standardised CPUE based on the combined set net series
Reference Points	Target: Interim B_{MSY}-compatible proxy based on the mean CPUE from 1989-90 to 2015-16 for the set net combined series Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: Interim F_{MSY}-compatible proxy based on the mean relative exploitation rate for the period: 1989–90 to 1998–99
Status in relation to Target	Unlikely (< 40%) to be at or above the target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing is Likely (> 60%) to be occurring

Historical Stock Status Trajectory and Current Status



Left panel: Standardised CPUE for school shark in SCH 3S/5 from combined model of catch rate in set net trips (solid line). Also shown is the trajectory of total landed SCH from the sub-stock area (dashed line). Horizontal lines represent the target (dashed line), the soft limit (dotted line), and hard limit (dot-dash line). Right panel: Annual relative exploitation rate for school shark in SCH 3S/5.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The CPUE was stable from 1989–90 to 1998–99, and then declined.
Recent Trend in Fishing Mortality or Proxy	Fishing mortality has been well above the fishing mortality proxy since 2003.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	- The East Coast South Island trawl survey biomass index has been relatively high since 2007, but it monitors sub-adult fish and does not cover the southern end of the South Island.

Projections and Prognosis	
Stock Projections or Prognosis	The stock is Likely (> 60%) to remain below the target at current catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) for current catch Hard Limit: Very Unlikely (< 10%) for current catch
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Likely (> 60%) for current catch

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2018	Next assessment: 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)		
Changes to Model Structure and Assumptions	Set net combined CPUE index was used to monitor stock status.	
Major Sources of Uncertainty	- Relationship between stock monitoring areas	

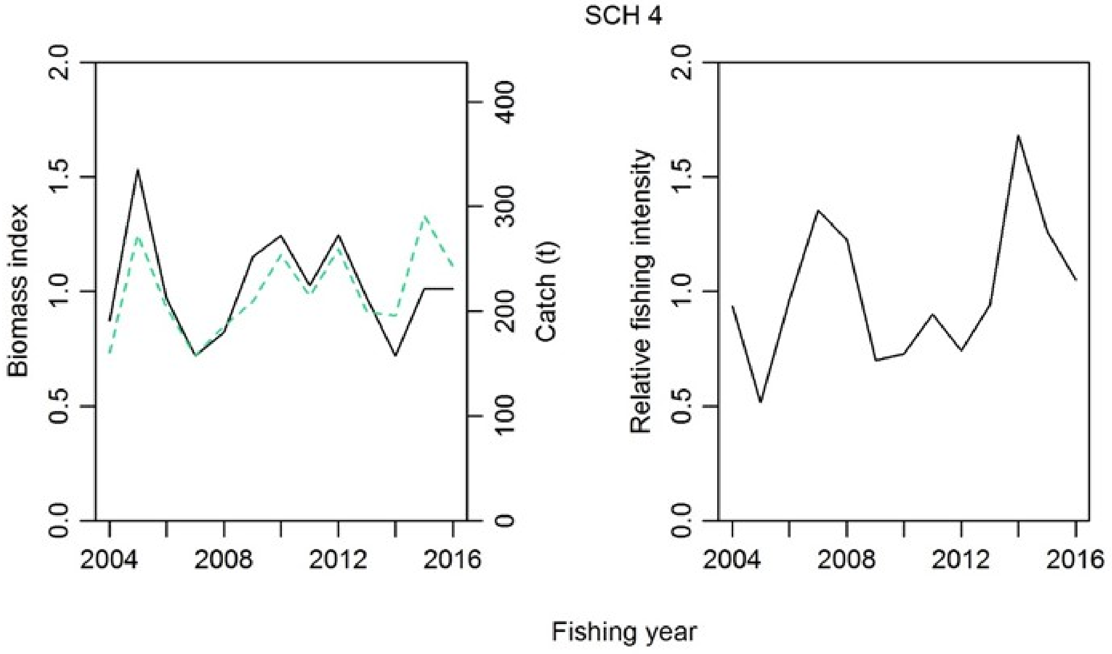
Qualifying Comments
This is the only accepted index exhibiting a declining trend, which made it difficult to choose a reference period to define an interim B_{MSY}-compatible reference point. There is a possibility that the stock may have been in a depleted state at the beginning of the series. This fishery mostly targets large females.

Fishery Interactions
Region SCH 3S/5 is predominantly a set net fishery targeting school shark and small amounts of rig, with other species being very minor; and in the bottom trawl fishery targeting red cod, flatfish, barracouta and stargazer. Mixed targeted bottom longline takes only a small part of the catch. Interactions with other species are currently being characterised.

SCH 4

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Standardised CPUE based on the combined bottom longline series
Reference Points	Target: Not established Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: Not established
Status in relation to Target	-
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Left panel: Standardised CPUE for school shark in SCH 4 from model of catch rate in bottom longline trips (solid line). Also shown is the trajectory of total landed SCH from the sub-stock area (dashed line). Right panel: Annual relative exploitation rate for school shark in SCH 4.

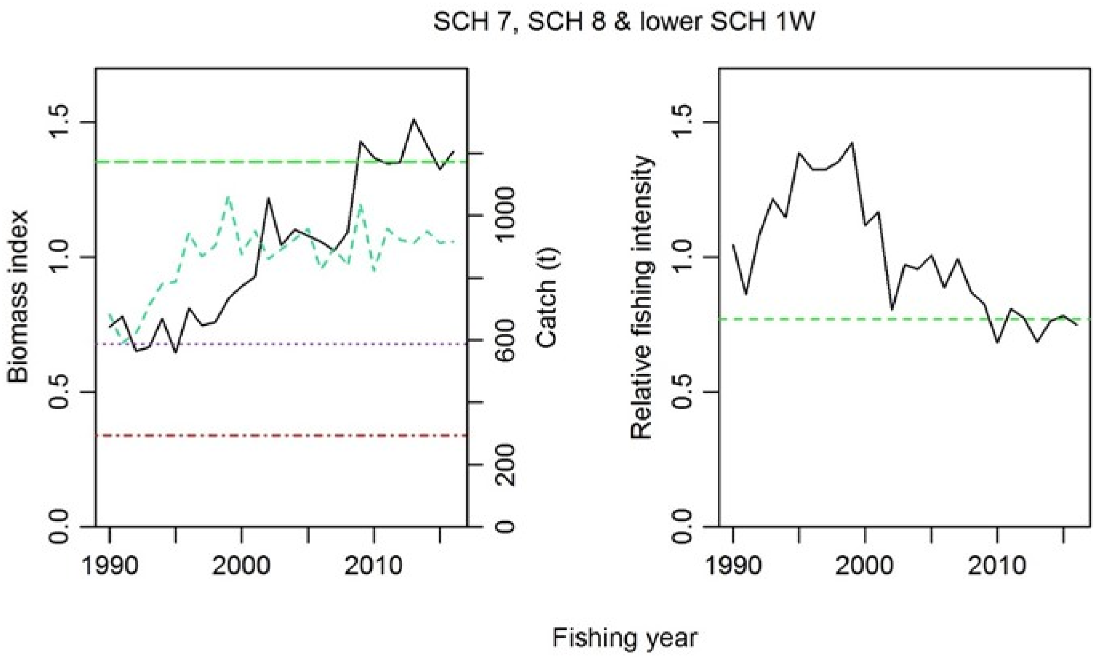
Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The bottom longline CPUE series has fluctuated without trend. The series is short due to a fleet change and sparse data in the earlier period.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has been increasing.
Other Abundance Indices	-
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	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2018	Next assessment: 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)		
Changes to Model Structure and Assumptions	None	
Major Sources of Uncertainty	- Relationship between stock monitoring areas	
Qualifying Comments		
.		

Fishery Interactions
Region SCH 4 (Chatham Rise) catches are caught primarily in the bottom longline fishery targeting school shark, ling, hapuku/bass and bluenose. Interactions with other species are currently being characterised.

- **SCH 7, SCH 8 & lower SCH 1W (7/8/1W on the map)**

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Standardised CPUE based on the combined set net series
Reference Points	Target: Interim B_{MSY}-compatible proxy based on the mean CPUE from 2007–08 to 2015–16 for the average of the bottom longline combined and set net combined series Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: Interim F_{MSY}-compatible proxy based on the mean relative exploitation rate for the period: 2007–08 to 2015–16
Status in relation to Target	About as Likely as Not (40–60%) to be at or above B_{MSY}
Status in relation to Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)
Status in relation to Overfishing	Overfishing is About as Likely as Not to be occurring

Historical Stock Status Trajectory and Current Status	
 **Left panel: Biomass index for school shark in 7/8/1W as the average of the standardised CPUE from the combined set net series and combined bottom longline series (solid line). Also shown is the trajectory of total landed SCH by all methods from the substock area (dashed line). Horizontal lines represent the target (dashed line), the soft limit (dotted line), and hard limit (dot-dash line). Right panel: Annual relative exploitation rate for school shark in 7/8/1W from the combined set net CPUE series.**	
Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE increased after 1999–2000 and has remained high and without trend since 2008–09.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality has been near target levels since 2005–06, because CPUE has been at or above target levels with stable catches.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	The West Coast South Island trawl survey biomass has been variable without overall trend, with no substantive change in catch-at-length.
Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2018	Next assessment: 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)		
Changes to Model Structure and Assumptions	The average of the combined set net and combined longline CPUE series was used to monitor stock status.	
Major Sources of Uncertainty	- Relationship between stock monitoring areas	

Qualifying Comments
-
Fishery Interactions
Region SCH 7/8/1W are caught by set net targeting school shark and rig; bottom longline targeting school shark and hapuku/bass; and bottom trawl targeting barracuda, tarakihi, flatfish, hoki, red cod and others. Interactions with other species are currently being characterised.

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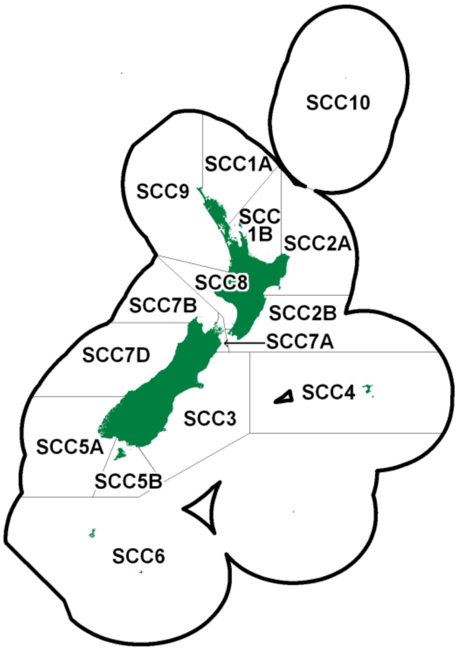
SEA CUCUMBER (SCC)

(*Australostichopus mollis*)



1. FISHERY SUMMARY

Sea cucumbers were introduced into the Quota Management System on 1 April 2004. The fishing year is from 1 April to 31 March. A breakdown of the Total Allowable Catch (TAC) for each Quota Management Area (QMA) is listed in Table 1 and shown in Figure 1. Each TAC is made up of a Total Allowable Commercial Catch (TACC) plus customary and recreational allowances and, in SCC 3, an allowance for mortality associated with fishing. Most TACs have remained unchanged since entering the QMS, but TACs for SCC 3 and SCC 7B were increased in 2018 and the TAC for SCC 7A was increased in 2019.

1.1 Commercial fisheries

More than 100 species of sea cucumber are found in New Zealand waters, but *Australostichopus mollis* is the only species of commercial value, and the only species for which exploratory commercial fishing has taken place. Sea cucumbers are targeted mainly by diving, although some targeted dredging and beam trawling occurs (e.g., in SCC 3), and they are also a common bycatch of bottom trawl and scallop dredge fisheries. Sea cucumber landings of all species are reported as a single code (SCC), although most reported landings are probably *A. mollis*. Sea cucumbers are on Schedule 6 of the Fisheries Act 1996, and as such can be returned to the sea if expected to survive.

Table 1: Recreational and customary non-commercial allowances (t), Total Allowable Commercial Catches (TACC, t), and Total Allowable Catch (TAC, t) as declared for SCC on introduction into the QMS in October 2004. **[Continued on next page]**

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other sources of fishing mortality	TACC	TAC
SCC 1A	3	2	–	2	7
SCC 1B	4	2	–	2	8
SCC 2A	1	1	–	2	4
SCC 2B	4	2	–	5	11
SCC 3	2	1	3	48	54
SCC 4	1	1	–	2	4
SCC 5A	1	1	–	2	4
SCC 5B	1	1	–	2	4
SCC 6	0	0	–	0	0
SCC 7A	2	1	–	15	18
SCC 7B	2	1	–	14	17
SCC 7D	1	1	–	2	4
SCC 8	1	1	–	2	4

Table 1 [Continued]

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other sources of fishing mortality	TACC	TAC
SCC 9	1	1	–	2	4
SCC 10	0	0	–	0	0
TOTAL	24	16	3	100	143

Table 2: TACCs and reported landings (t) of sea cucumber by Fishstock from 1990–91 to 2018–19 from CELR and TCEPR data. Until 2003–04 management areas were the same as FMAs; since then FMAs 1, 2, 5, and 7 were subdivided. These landings are reported in the second and third parts of this table. [Continued on next page]

Fishing	SCC 1		SCC 2		SCC 3		SCC 4	
year	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1998–99	0	–	0	–	0.03	–	0	–
1999–00	0	–	0	–	0.04	–	0.01	–
2000–01	0.04	–	0	–	0.65	–	0	–
2001–02	0.16	–	0.01	–	1.01	–	1.68	–
2002–03	0.39	–	0.37	–	4.62	–	0.92	–
2003–04	0.07	N/A	N/A	N/A	3.79	2	0.12	2
2004–05	N/A	N/A	N/A	N/A	1.14	2	0	2
2005–06	N/A	N/A	N/A	N/A	2.85	2	0	2
2006–07	N/A	N/A	N/A	N/A	2.70	2	0	2
2007–08	N/A	N/A	N/A	N/A	3.67	2	0	2
2008–09	N/A	N/A	N/A	N/A	3.80	2	0	2
2009–10	N/A	N/A	N/A	N/A	0.37	2	0.01	2
2010–11	N/A	N/A	N/A	N/A	0.78	2	0.01	2
2011–12	N/A	N/A	N/A	N/A	3.40	2	0.01	2
2012–13	N/A	N/A	N/A	N/A	8.54	2	0	2
2013–14	N/A	N/A	N/A	N/A	6.77	2	0	2
2014–15	N/A	N/A	N/A	N/A	2.18	2	0	2
2015–16	N/A	N/A	N/A	N/A	7.12	2	0.19	2
2016–17	N/A	N/A	N/A	N/A	1.84	2	0.08	2
2017–18	N/A	N/A	N/A	N/A	0.34	18	0.08	2
2018–19	N/A	N/A	N/A	N/A	18.31	48	0	2

	SCC 1A		SCC 1B		SCC 2A		SCC 2B		SCC 5A	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2003–04	0	2	0	2	0	2	0	5	0	2
2004–05	0	2	1.50	2	0	2	0	5	0.01	2
2005–06	0	2	1.43	2	0	2	0	5	0	2
2006–07	0	2	2.09	2	0	2	0	5	0	2
2007–08	0.12	2	2.18	2	0	2	0	5	0	2
2008–09	0.12	2	0.53	2	0	2	0	5	0	2
2009–10	0.18	2	1.78	2	0	2	0.19	5	0	2
2010–11	0.01	2	1.40	2	0	2	0.05	5	0	2
2011–12	1.47	2	2.01	2	0	2	0.67	5	0.31	2
2012–13	0.36	2	1.68	2	0	2	0.11	5	0	2
2013–14	0	2	1.61	2	0	2	0.19	5	0	2
2014–15	0.67	2	1.84	2	0	2	2.37	5	0.70	2
2015–16	0.09	2	1.78	2	0	2	0.56	5	1.85	2
2016–17	0.04	2	2.00	2	0	2	1.49	5	1.26	2
2017–18	0.29	2	1.98	2	0.14	2	0.87	5	1.79	2
2018–19	0.14	2	1.82	2	0	2	1.00	5	0.37	2

	SCC 5B		SCC 6		SCC 7A		SCC 7B		SCC 7D	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2003–04	0.01	2	0	0	0	5	0	5	0	2
2004–05	0.10	2	5	0	3.19	5	1.01	5	0	2
2005–06	0	2	0.31	0	5.47	5	0.12	5	0	2
2006–07	0	2	0	0	0.17	5	0.04	5	0	2
2007–08	0	2	0	0	8.34	5	0	5	0.02	2
2008–09	0.02	2	0.01	0	4.19	5	0	5	0	2
2009–10	0	2	0	0	4.31	5	1.36	5	0	2
2010–11	0.01	2	0	0	5.09	5	5.46	5	0	2
2011–12	0.37	2	0.04	0	4.77	5	4.70	5	2.15	2
2013–13	0.11	2	0	0	4.97	5	4.27	5	0	2
2013–14	1.81	2	0	0	5.10	5	5.23	5	0	2
2014–15	2.14	2	0	0	4.97	5	5.06	5	0	2
2015–16	1.80	2	0	0	5.45	5	5.03	5	0	2
2016–17	2.00	2	0	0	4.98	5	4.96	5	0	2
2017–18	2.13	2	0	0	5.04	5	5.04	14	0	2
2018–19	0.86	2	0	0	4.92	15	13.44	14	0	2

	SCC 8		SCC 9		Total	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC
1990–91	0	–	0	–	4.653^{+}	–
1991–92	0	–	0	–	3.843^{+}	–
1992–93	0	–	0	–	0.682^{+}	–
1993–94	0	–	0	–	2.5^{+}	–

Table 2 [continued]

Fishstock	SCC 8 Landings	SCC 8 TACC	SCC9 Landings	SCC9 TACC	Total Landings	Total TACC
1994–95	0	–	0	–	2.41+	–
1995–96	0	–	0	–	2.679+	–
1996–97	0	–	0	–	1.415+	–
1997–98	0	–	0.05	–	0.148	–
1998–99	0	–	0	–	0.032	–
1999–00	0	–	0	–	0.052	–
2000–01	0	–	0	–	1.659	–
2001–02	0	–	0	–	8.954	–
2002–03	0	–	0	–	16.847*	–
2003–04	0	–	0	2	21.861	35
2004–05	0	2	0.016	2	12.213	35
2005–06	0	2	0	2	10.183	35
2006–07	0	2	0.01	2	5.012	35
2007–08	0	2	0.001	2	14.315	35
2008–09	0	2	0.07	2	8.73	35
2009–10	0	2	0.03	2	8.22	35
2010–11	0	2	0.14	2	12.95	35
2011–12	0.93	2	0.14	2	20.25	35
2012–13	0.9	2	0.13	2	21.08	35
2013–14	1.11	2	0	2	21.78	35
2014–15	2.04	2	0.16	2	22.16	35
2015–16	1.99	2	0	2	25.95	35
2016–17	2	2	0.14	2	13.83	35
2017–18	2	2	0.06	2	19.76	35
2018–19	2.01	2	0.01	2	40.88	98

*In 2002–03 50 kg were reportedly landed, but the QMA was not recorded. This amount is included in the total landings for that year,
+In 1990–1997, catch was reported, but no QMA was, therefore only the total is shown.

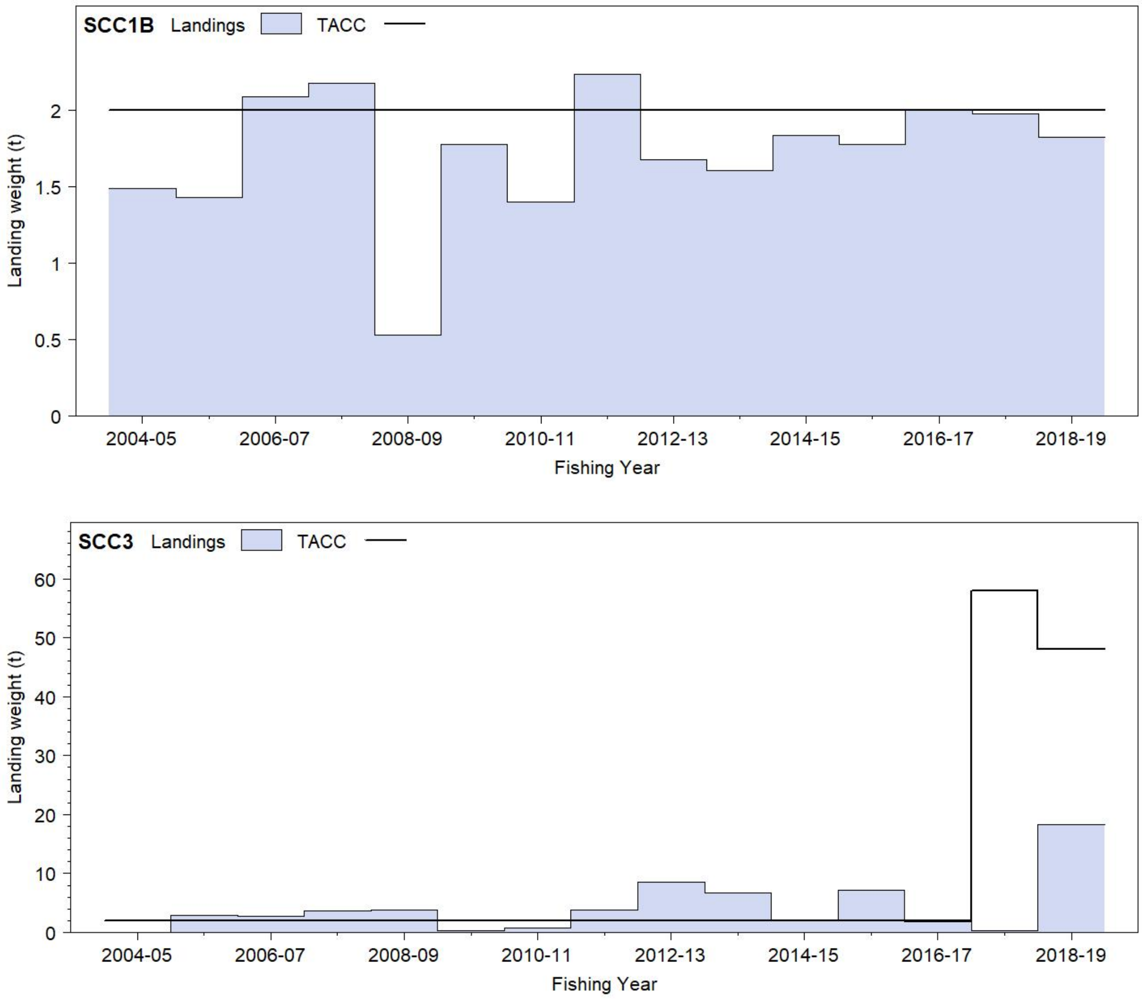


Figure 1: Reported commercial landings and TACC for SCC 1B (Hauraki Gulf, Bay of Plenty), SCC 3 (South East Coast). Note that these figures do not show data prior to entry into the QMS. [Continued next page]

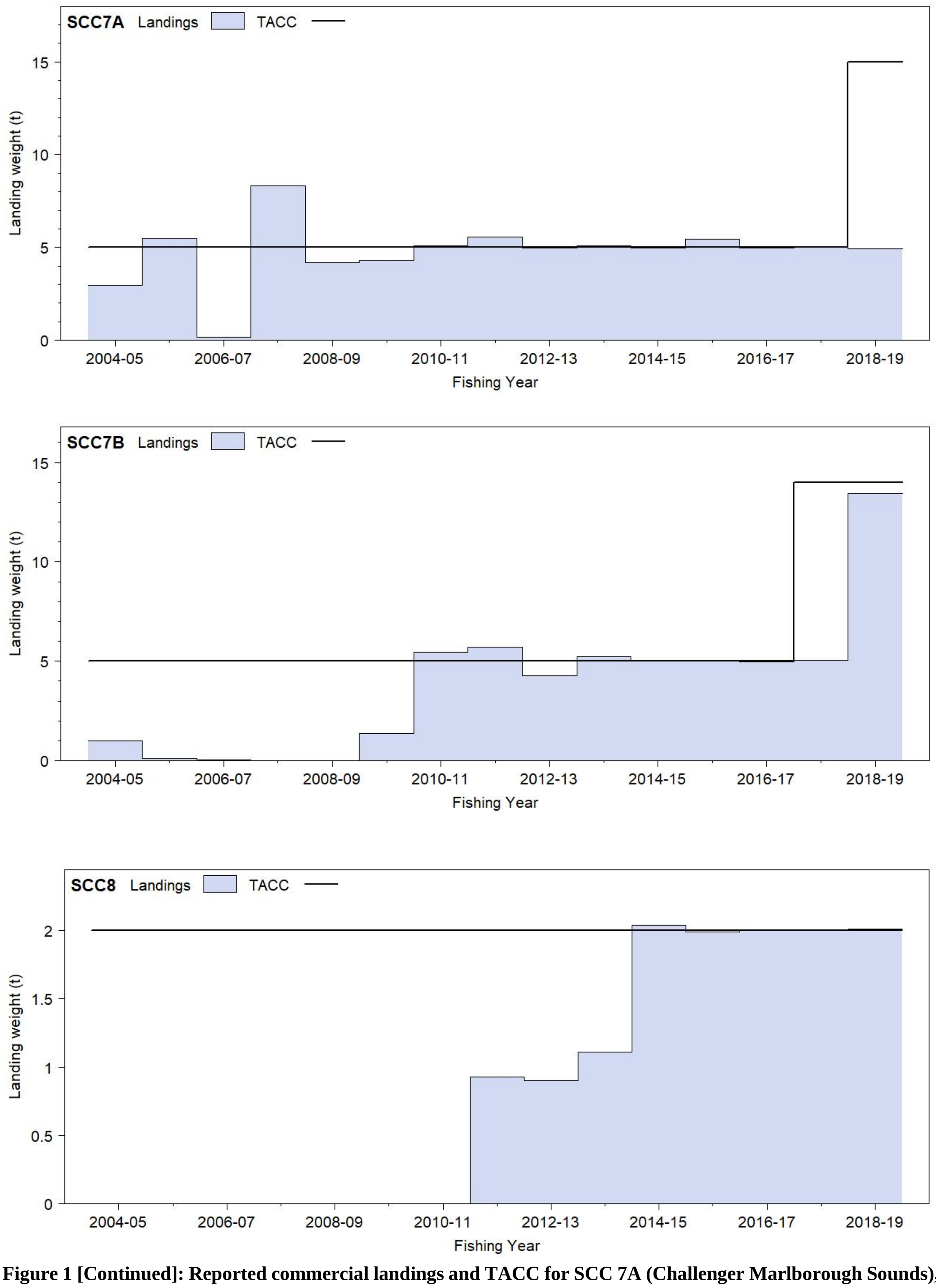


Figure 1 [Continued]: Reported commercial landings and TACC for SCC 7A (Challenger Marlborough Sounds), SCC 7B (Challenger Nelson), and SCC 8 (Central).

Between 1990 and 2001 about 45% of the catch was taken as bycatch in scallop dredging in Tasman Bay and Golden Bay. About 13% was taken as bycatch in bottom trawling around the Auckland Islands, and about 38% was taken by diving. The remainder of the bycatch has been reported from midwater trawls, rock lobster pots, and bottom longlines. Catches were taken by diving from Fisheries Statistical Area 031 (Fiordland) in 1990–91 (when a special permit was being operated), and 1995–96.

Prior to 2000–01 reported total landings never exceeded 5 t, however from 2001–02 to 2018–19 an average of 17 t of sea cucumbers were landed annually. The highest landings in the time series, 41 t, were recorded in 2018–19 (Table 2). Most of these landings came from SCC 3 and SCC 7B. The historical landings and TACC for the main SCC stocks are depicted in Figure 1.

1.2 Recreational fisheries

Recreational fishing surveys indicate that sea cucumbers are not caught by recreational fishers. It is likely that members of the Asian and Pacific Island communities harvest sea cucumber, but their fishing activity is poorly represented in the recreational surveys.

1.3 Customary non-commercial fisheries

There is very limited quantitative information on customary non-commercial use of sea cucumber. In 2010, the harvest of 100 sea cucumbers was permitted in SCC1B and 100 were reported caught.

1.4 Illegal catch

There is qualitative evidence to suggest significant illegal, unreported, unregulated (IUU) activity in this fishery.

1.5 Other sources of mortality

There is no quantitative information on other sources of mortality, although sea cucumbers are often taken as a bycatch in bottom trawl and dredge fisheries.

2. BIOLOGY

Australostichopus mollis is distributed throughout New Zealand waters, as far south as the Snares Islands. It also occurs off the west and south coasts of Australia. It is found in shallow water between 5 m and 40 m in a wide range of habitats from rocky shores to sandy bottoms. It is common off north-east New Zealand, Fiordland, the Marlborough Sounds, and Stewart Island, and displays a preference for sheltered coastlines with complex and diverse habitats. *A. mollis* is less common on exposed coasts, but, if present, tends to be in deeper water.

Sea cucumbers are mobile detritus feeders and form part of the benthic epifaunal community. If disturbed, they can eviscerate their entire gut which can then be regenerated. They tend to be sedentary in suitable habitat, but can move away relatively quickly if stressed.

Little is known about the biology of *A. mollis.* They have an annual reproductive cycle and spawn between November and February. The sexes are separate and develop synchronously. They are broadcast spawners (eggs and sperm are released into the water column) and, following fertilisation, they undergo a 3- to 4-week larval phase before settlement. Populations from sheltered areas such as fiords and sheltered bays may be largely ‘self-seeding’, whereas larvae released on open coasts may disperse more widely.

There is some evidence that recruitment and growth are both patchy and variable. Recruited individuals appear in the adult population at about 10–12 cm (40–60 g) and adults grow to about 18–20 cm (180 g). During an exploratory fishing survey in Fiordland (SCC 5A) in 1989, divers observed small *A. mollis* under rubble, suggesting that pre-recruit sea cucumbers may have different habitat preferences to adults. By contrast, comprehensive surveying in the Mahurangi Harbour (SCC 1B) showed the substratum at sites with high densities of juveniles to be dominated by silt and mud with large shell fragments (over 10 cm) of the horse mussel *Atrina zelandica* (Morrison 2000). The restricted distribution of juveniles at this locality was shown to be unrelated to sediment type and was theorised to be a consequence of localised effects such as predation or larval settlement (Slater & Jeffs 2010). Caging studies comparing growth at different densities underneath and away from a Coromandel mussel farm (SCC 1B) showed that growth ranged from a 15.4% increase in weight over 6 months, at a density of 2.5 per m^2 under a mussel farm, to a 13.9% decrease in weight over 2 months, at a density of 15 per m^2 away from the mussel farm (Slater & Carton 2007). Age at maturity is thought to be about 2 years, and the life span of *A. mollis* is thought to be between 5 and 15 years.

3. STOCKS AND AREAS

The management of sea cucumbers is based on 15 QMAs, which are a combination of existing and sub-divided FMAs. Although there is currently little biological or fishery information which could be used to identify stock boundaries, the QMAs recognise that sea cucumbers are a sedentary shallow water species, and that many sheltered populations may be isolated and vulnerable to localised depletion. Finer scale QMAs, therefore, provide a mechanism whereby stocks can be managed more appropriately. Also, because it is likely that the same group of commercial fishers will be targeting kina and sea cucumbers, and because there are some similarities in their respective habitats, the QMAs for sea cucumber are the same as those for kina.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any sea cucumber fishstock.

4.2 Biomass estimates

There are no biomass estimates for any sea cucumber fishstock overall, although estimates exist for some discrete subareas. For Fiordland, crude biomass estimates of 59, 89, 97, and 134 t for Thompson, Bradshaw, Charles, and Doubtful sounds respectively are reported by Mladenov & Gerring (1991), and Mladenov & Campbell (1998). Their survey did not include the outer coastline, but, extrapolating to all fiords between Puysegur Point and Cascade Point, they estimated a total biomass of 1937 t in the 0 to 20 m depth range.

Dive transect surveys were conducted in Queen Charlotte Sound (SCC 7A) and in the Hauraki Gulf (SCC 1B) in 2014 (Williams et al. 2016). Biomass estimates (for sea cucumbers of commercial size) for the areas sampled in SCC 7A and SCC 1B were 88 t and 115 t split weight[1], respectively. The areas surveyed represented only small percentages of the respective QMAs.

In 2017 a dredge survey of *A. mollis* was conducted in deeper water (60–120 m) off the north Canterbury coast in SCC 3 (Tuck et al. 2017). The total population biomass estimated for the survey area was 3207 t green weight or 1329 t split weight; considering only sea cucumbers with a split weight of 63 g or greater (on the basis of a previously estimated marketable SCC selectivity curve) led to a commercial biomass of 619 t split weight. The survey area was considerably smaller than the QMA.

4.3 Yield estimates and projections

There are no estimates of *MCY* for any sea cucumber fishstock.

There are no estimates of *CAY* for any sea cucumber fishstock.

5. STATUS OF THE STOCKS

There are no estimates of reference or current biomass for any sea cucumber fishstock.

6. FOR FURTHER INFORMATION

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[1] Split weight is an industry processed state where the abdomen is cut to release internal water and gut contents.

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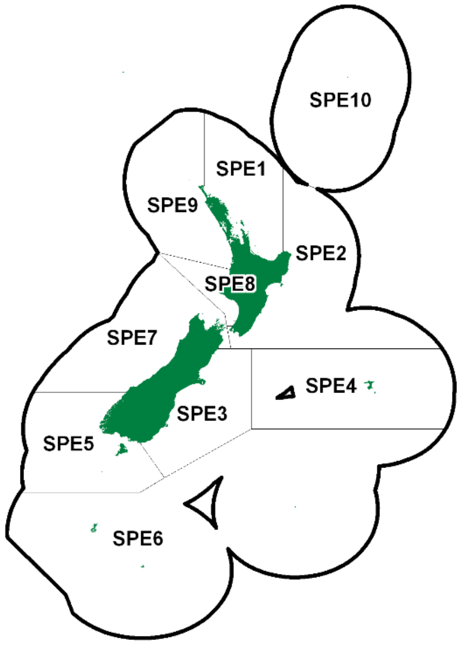
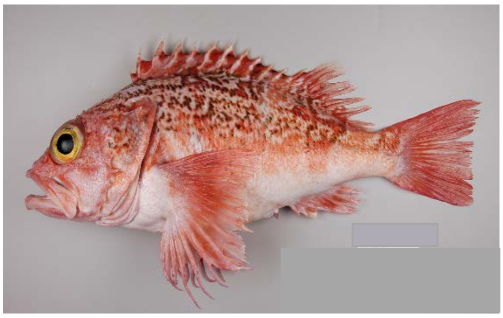
SEA PERCH (SPE)

(*Helicolenus percoides*)
Pohuiakaroa





1. FISHERY SUMMARY

Sea perch was introduced into the QMS from 1 October 1998. Current TACs, TACCs and allowances for non-commercial fishers are displayed in Table 1.

Table 1: Recreational and customary non-commercial allowances and Current TACCs, by Fishstock, for sea perch.

	Recreational	Customary non-	Other sources	TACC	TAC
SPE 1	1	1	3	53	58
SPE 2	9	5	0	79	93
SPE 3	11	11	0	1 000	1 022
SPE 4	0	0	46	910	956
SPE 5	1	1	0	36	38
SPE 6	0	0	0	9	9
SPE 7	8	8	0	82	98
SPE 8	4	2	0	15	21
SPE 9	1	1	0	6	8
SPE 10	0	0	0	0	0

1.1 Commercial fisheries

From 1 October 2000 the TACC for SPE 3 was increased from 738 t to 1 000 t under the Adaptive Management Programme (AMP). The TACC for SPE 4 was increased from 533 t to 910 t from 1 October 2004 under the low knowledge bycatch framework. The TACC for SPE 1 was increased from 18 t to 33 t from 1 October 2006, and to 53 t from October 2013. TACCs in SPE 2, 5 & 6, 7, 8, and 9 have remained unchanged since their introduction in 1998.

In SPE 1 landings were above the TACC for a number of years prior to 2006 and 2013; the TACC was consequently increased to the average of the previous 7 years plus an additional 10%. In SPE 2 landings were above the TACC for a number of years from 1999-00 to 2010-11 but landings have since decreased, averaging about 50 t annually from since 2012. In SPE 3 landings have been well below the TACC since it was increased in 2000. In SPE 7 landings have been above the TACC in most years since the introduction of the TACC, but only 47 t were recorded in 2018-19. The historical landings and TACC values for the four major SPE stocks are depicted in Figure 1.

Very small quantities of sea perch have been landed for local sale for many years, but were largely unreported. Catches have been made by foreign vessels since the 1960s, but were also not recorded (they were most probably included within a “mixed” or “other finfish” category), and most were probably discarded. Despite poor reporting rates, estimated landings are thought to have increased from 400 t in the early 1980s to approximately 1 300 t in recent years (Table 3); an unknown quantity has been discarded over this period.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	SPE 1	SPE 2	SPE 3	SPE 4	Year	SPE 1	SPE 2	SPE 3	SPE 4
1931	0	0	0	0	1957	0	0	1	0
1932	0	0	0	0	1958	0	0	1	0
1933	0	0	0	0	1959	0	0	1	0
1934	0	0	0	0	1960	0	0	1	0
1935	0	0	0	0	1961	0	0	1	0
1936	0	0	0	0	1962	0	0	0	0
1937	0	0	0	0	1963	0	0	0	0
1938	0	0	0	0	1964	0	0	1	0
1939	0	0	0	0	1965	0	0	2	0
1940	0	0	0	0	1966	0	0	1	0
1941	0	0	0	0	1967	0	0	1	0
1942	0	0	0	0	1968	1	0	1	0
1943	0	0	0	0	1969	1	0	3	0
1944	0	0	4	0	1970	1	2	7	0
1945	0	0	2	0	1971	6	0	7	0
1946	0	0	2	0	1972	1	1	2	0
1947	0	0	2	0	1973	0	0	0	0
1948	0	0	1	0	1974	0	0	0	0
1949	0	0	2	0	1975	0	0	0	0
1950	0	0	1	0	1976	0	0	0	0
1951	0	0	5	0	1977	0	0	0	0
1952	0	0	2	0	1978	0	0	2	11
1953	0	0	1	0	1979	0	18	92	248
1954	0	0	0	0	1980	0	1	8	100
1955	0	0	1	0	1981	6	0	70	253
1956	0	0	0	0	1982	22	1	176	164
1931	0	0	0	0	1957	0	0	0	0
1932	0	0	0	0	1958	0	0	0	0
1933	0	0	0	0	1959	0	0	0	0
1934	0	0	0	0	1960	0	0	0	0
1935	0	0	0	0	1961	0	0	0	0
1936	0	0	0	0	1962	0	0	0	0
1937	0	0	0	0	1963	0	0	0	0
1938	0	0	0	0	1964	0	0	0	0
1939	0	0	0	0	1965	0	0	0	0
1940	0	0	0	0	1966	0	0	0	0
1941	0	0	0	0	1967	0	0	0	0
1942	0	0	0	0	1968	0	0	0	0
1943	0	0	0	0	1969	0	1	0	0
1944	29	0	0	0	1970	0	13	0	0
1945	0	0	0	0	1971	0	0	0	0
1946	0	0	0	0	1972	0	0	0	0
1947	0	0	0	0	1973	0	0	0	0
1948	0	0	0	0	1974	0	0	0	0
1949	2	0	0	0	1975	0	0	0	0
1950	2	0	0	0	1976	0	0	0	0
1951	1	0	0	0	1977	0	0	0	0
1952	0	0	0	0	1978	13	11	0	0
1953	0	0	0	0	1979	54	14	1	3
1954	0	0	0	0	1980	40	38	0	0
1955	0	0	0	0	1981	32	15	0	1
1956	0	0	0	0	1982	31	17	1	1

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. 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 includes both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

About 75% of New Zealand’s landed sea perch is taken as a bycatch in trawl fisheries off the east coast of the South Island, including the Chatham Rise. A small catch is made in some central and southern line fisheries, e.g., for groper. Recent reported landings of sea perch by QMAs are shown in Table 3. The most important QMAs in most years are QMA 3 (east coast South Island) and QMA 4 (Chatham Rise).

The catch from SPE 3 is spread throughout the fishing year. There is a variable seasonal distribution between years. A higher proportion of the catch is taken during April, May and September and catches are lower from December to February, and in July. Most of the SPE 3 catch is taken as a bycatch from the red cod (about 30%) and hoki fisheries (15%) and from the sea perch target fishery (21%). The remainder is taken as a bycatch from the target barracouta, flatfish, ling, squid and tarakihi fisheries. Virtually all the

SPE 3 catch is taken by bottom trawling, with a small proportion taken by bottom longline. SPE 3 catch rates are highest between 150–400 m depth.

The trawl fisheries operating in SPE 4 catch sea perch along the northern and southern edge of the Chatham Rise between 200 and 700 m depth. The majority of the SPE 4 catch is taken as a bycatch of the hoki target fishery (about 59%), with the ling and hake fisheries accounting for around 25% and 10% of the total SPE 4 catch, respectively.

Table 3: Reported landings (t) of sea perch by Fishstock and fishing year, 1983–84 to 2018–19. The data in this table have been updated from that published in previous Plenary Reports by using the data up to 1996–97 in table 38 on p. 278 of the "Review of Sustainability Measures and Other Management Controls for the 1998–99 fishing year - Final Advice Paper" dated 6 August 1998. [Continued on next page].

Fishstock		SPE 1		SPE 2		SPE 3		SPE 4		SPE 5 & 6
FMA		1		2		3		4		5 &6
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84	14	-	2	-	150	-	58	-	36	-
1984–85	10	-	2	-	290	-	70	-	26	-
1985–86	14	-	2	-	213	-	218	-	28	-
1986–87	19	-	2	-	507	-	71	-	19	-
1987–88	20	-	1	-	544	-	63	-	18	-
1988–89	14	-	1	-	262*	-	36	-	18	-
1989–90	2	-	6	-	287*	-	177	-	9	-
1990–91	5	-	9	-	559*	-	68	-	33	-
1991–92	12	-	8	-	791*	-	222	-	36	-
1992–93	15	-	15	-	783*	-	317	-	55	-
1993–94	16	-	26	-	690*	-	223	-	28	-
1994–95	25	-	66	-	626*	-	415	-	18	-
1995–96	23	-	50	-	1 047*	-	404	-	62	-
1996–97	19	-	77	-	655*	-	435	-	45	-
1997–98	24	-	54	-	913	-	656	-	29	-
1998–99	21	18	79	79	903	738	872	533	27	45
1999–00	27	18	82	79	862	738	821	533	28	45
2000–01	25	18	81	79	798	738	840	533	19	45
2001–02	41	18	89	79	720	1 000	910	533	22	45
2002–03	19	18	78	79	696	1 000	1 685	533	25	45
2003–04	30	18	80	79	440	1 000	1 287	533	28	45
2004–05	27	18	104	79	372	1 000	894	910	24	45
2005–06	40	18	73	79	436	1 000	502	910	24	45
2006–07	30	33	98	79	519	1 000	591	910	31	45
2007–08	38	33	91	79	422	1 000	568	910	20	45
2008–09	27	33	46	79	328	1 000	338	910	13	45
2009–10	47	33	53	79	428	1 000	345	910	21	45
2010–11	53	33	83	79	644	1 000	572	910	24	45
2011–12	50	33	55	79	349	1 000	555	910	17	45
2012–13	40	33	43	79	495	1 000	492	910	27	45
2013–14	47	53	69	79	500	1 000	332	910	22	45
2014–15	32	53	42	79	734	1 000	475	910	15	45
2015–16	38	53	44	79	774	1 000	436	910	37	45
2016–17	44	53	49	79	589	1 000	424	910	24	45
2017–18	52	53	54	79	625	1 000	490	910	12	36
2018-19	53	53	46	79	555	1 000	432	910	18	36

Fishstock		SPE 7		SPE 8		SPE 9		SPE 10		
FMA		7		8		9		10		Total
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84	16	-	2	-	55	-	0	-	333	-
1984–85	14	-	1	-	2	-	0	-	415	-
1985–86	12	-	2	-	4	-	0	-	493	-
1986–87	11	-	3	-	1	-	0	-	633	-
1987–88	8	-	6	-	0	-	0	-	660	-
1988–89	5	-	2	-	1	-	0	-	339	-
1989–90	14	-	1	-	0	-	0	-	496	-
1990–91	28	-	1	-	0	-	0	-	703	-
1991–92	20	-	2	-	0	-	0	-	1091	-
1992–93	71	-	18	-	0	-	2	-	1276	-
1993–94	52	-	10	-	0	-	0	-	1045	-
1994–95	67	-	7	-	0	-	0	-	1224	-
1995–96	78	-	7	-	1	-	0	-	1672	-
1996–97	64	-	7	-	1	-	< 1	-	1304	-
1997–98	118	-	5	-	7	-	< 1	-	1807	-
1998–99	109	82	< 1	15	2	6	0	0	2014	1 516
1999–00	80	82	2	15	5	6	0	0	1907	1 516
2000–01	80	82	4	15	3	6	0	0	1850	1 778
2001–02	95	82	6	15	3	6	0	0	1886	1 778
2002–03	103	82	4	15	4	6	0	0	2614	1 778
2003–04	95	82	6	15	3	6	0	0	1969	1 778
2004–05	47	82	5	15	2	6	0	0	1475	2 155
2005–06	75	82	5	15	2	6	0	0	1157	2 155
2006–07	67	82	2	15	2	6	0	0	1340	2 170
2007–08	103	82	2	15	2	6	0	0	1246	2 170

Table 3 [Continued[

	SPE 7		SPE 8		SPE 9		SPE 10			Total
		7		8		9		10		
	Landings	**TACC**	**Landings**	**TACC**	**Landings**	**TACC**	**Landings**	**TACC**	**Landings**	**TACC**
2008–09	96	82	2	15	4	6	0	0	854	2 170
2009–10	117	82	4	15	3	6	0	0	1018	2 170
2010–11	124	82	3	15	2	6	0	0	1505	2 170
2011–12	82	82	3	15	3	6	0	0	1115	2 170
2012–13	89	82	4	15	4	6	0	0	1197	2 170
2013–14	100	82	4	15	5	6	0	0	1 077	2 190
2014–15	118	82	4	15	7	6	0	0	1 427	2 190
2015–16	89	82	4	15	7	6	0	0	1 428	2 190
2016–17	90	82	3	15	9	6	0	0	1 232	2 190
2017–18	118	82	4	15	11	6	0	0	1 368	2 190
2018-19	47	82	3	15	8	6	0	0	1 161	2 190

*These numbers may contain erroneous landings data, the situation is currently under investigation and the data will be amended if an error is identified during the course of that investigation.

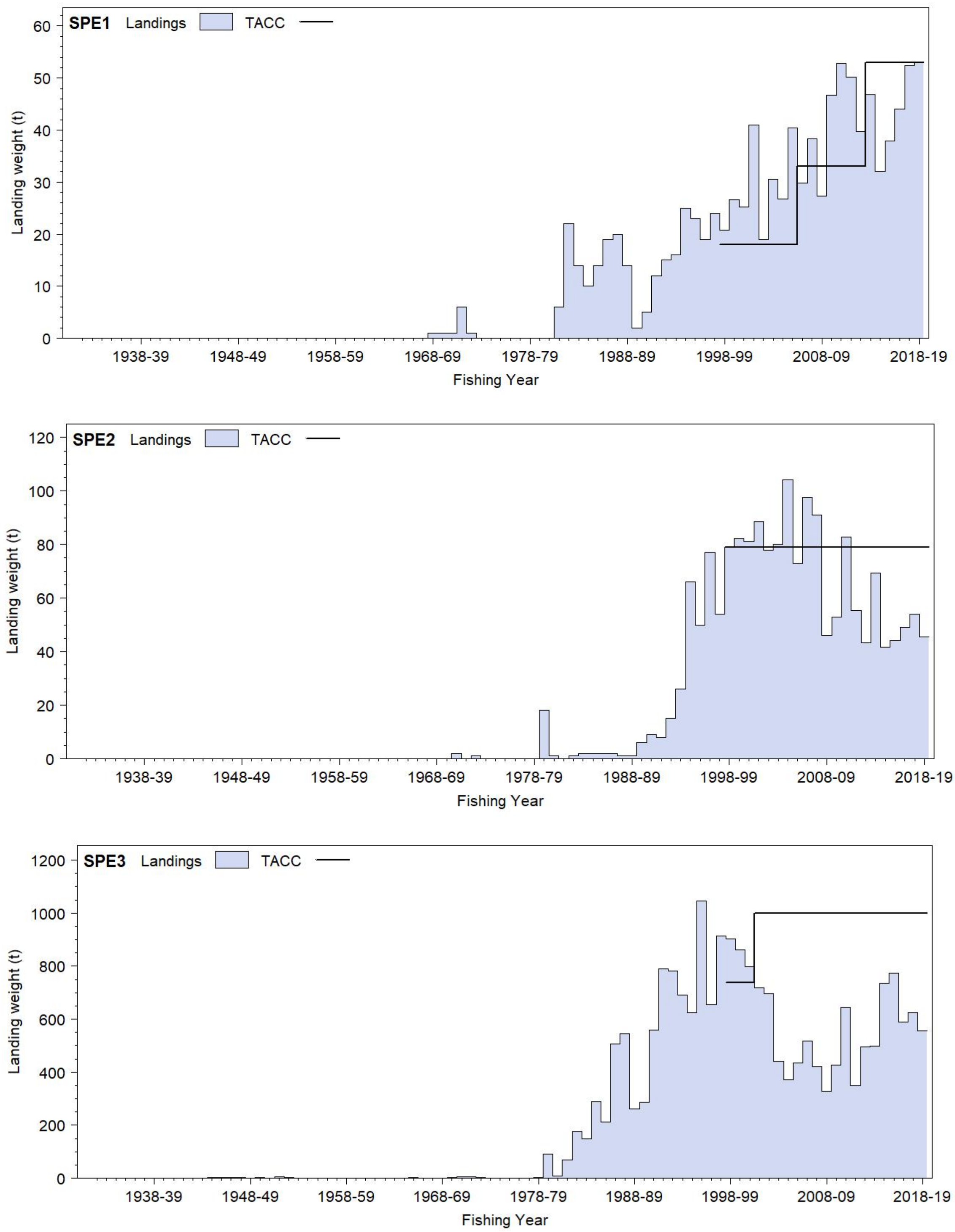


Figure 1: Reported commercial landings and TACC for the four main SPE stocks. SPE 1 (Auckland East), SPE 3 (South East Coast), and SPE 4 (South East Chatham Rise). [Continued on next page].

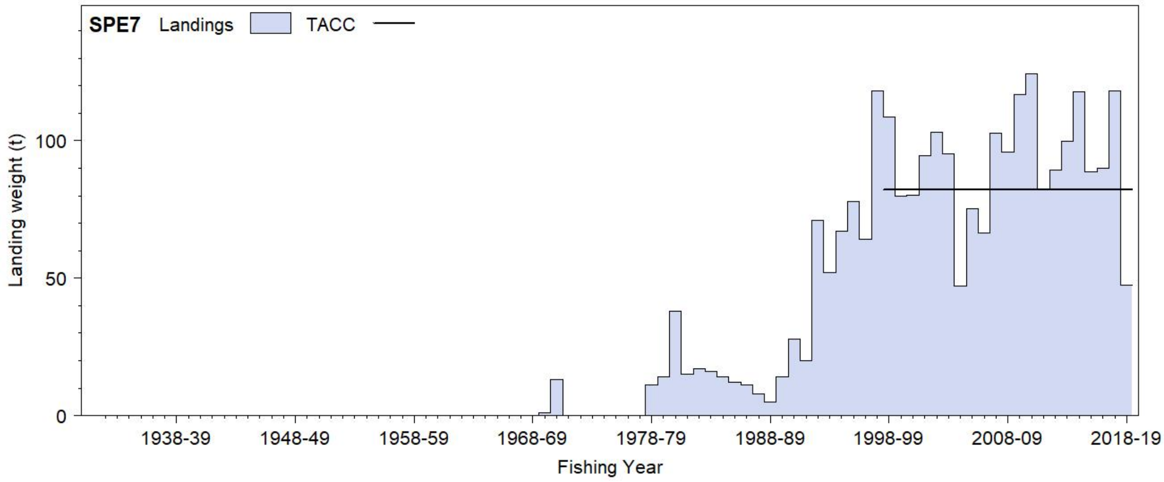


Figure 1: [Continued] Reported commercial landings and TACC for the four main SPE stocks. SPE 7 (Challenger).

1.2 Recreational fisheries

Sea perch are seldom targeted by recreational fishers, but are widely caught in reasonable numbers. Some are used for bait, and many were likely to have been discarded in the past. The quality of sea perch as an eating fish has been increasingly recognised and they are now less likely to be discarded. They are predominantly taken on rod and reel (98.6%) with a small proportion taken by longline (1%). The catch is taken predominantly from boat (93.7%) with a small proportion from land based fishers (3%). The allowances within the TAC for each Fishstock are shown in Table 1.

1.2.1 Management controls

The main method used to manage recreational harvests of sea perch are minimum legal sizes (MLS) and daily bag limits. General spatial and method restrictions also apply. A sea perch MLS for recreational fishers of 26 cm applies only in the Kaikoura Marine Area. Fishers can take up to 20 sea perch as part of their combined daily bag limit in Kaikoura Marine Area. Fishers can take up to 10 sea perch as part of their combined daily bag limit in the Fiordland Marine Area. No bag limit is currently in place in the Auckland, Central, Challenger, South-East, or Southland Fishery Management Areas.

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 for sea perch were calculated using offsite telephone-diary surveys between 1991 and 2000 (Table 4, from Teirney et al 1997, Bradford 1998, Boyd & Reilly 2002). The harvest estimates provided by these telephone-diary surveys are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year. 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 (Wynne-Jones et al 2014). The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 4. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 4: Estimated number and weight of sea perch recreational harvest by Fishstock and survey. Regional surveys were carried out in different years in the MAF Fisheries regions: South in 1991–92, Central in 1992–93, North in 1993–94 (Teirney et al 1997), and national surveys ran in 1996 (Bradford, 1998) and 1999–00 (Boyd & Reilly 2002). National panel surveys ran in 2011–12 and 2017–18 (Wynne-Jones et al 2014, 2019) using mean weights from boat ramp surveys (Hartill & Davey 2015, Davey et al 2019).

Fishstock	Survey	Number	Harvest (t)	CV%
1991–92				
SPE 3	South	110 000		25
SPE 5	South	18 000		35
SPE 7	South	16 000		-
1992–93				
SPE 2	Central	27 000		-
SPE 3	Central	< 500		-
SPE 5	Central	< 500		-
SPE 7	Central	65 000		40
SPE 8	Central	11 000		-
1993–94				
SPE 1 + 9	North	< 500		-
SPE 2	North	< 500		-
SPE 8	North	< 500		-
1996				
SPE 1 + 9	National	2000		37
SPE 2	National	23 000		-
SPE 3	National	28 000		17
SPE 5	National	3000		-
SPE 7	National	20 000		17
SPE 8	National	11 000		-
1999–00				
SPE 2	National	10 000		94
SPE 2	National	16 000		64
SPE 3	National	154 000		38
SPE 5	National	10 000		58
SPE 7	National	63 000		46
SPE 8	National	< 500		101
2011–12				
SPE 1	Panel	1 464	0.7	40
SPE 2	Panel	8 165	4.3	33
SPE 3	Panel	113 955	57.1	25
SPE 5	Panel	4 517	2.1	57
SPE 7	Panel	28 781	12.6	39
SPE 8	Panel	3 699	1.7	48
2017–18				
SPE 1	Panel	478	0.2	87
SPE 2	Panel	3 287	1.6	40
SPE 3	Panel	67 712	40.5	24
SPE 5	Panel	27 993	13.2	89
SPE 7	Panel	13 824	5.4	29
SPE 8	Panel	3 654	1.7	67

1.3 Customary non-commercial fisheries
The customary non-commercial take has not been quantified.

1.4 Illegal catch
There is no quantitative information on illegal fishing activity or catch, and given the low commercial value of sea perch, such activity is unlikely.

1.5 Other sources of mortality
No quantitative estimates are available about the impact of other sources of mortality on sea perch stocks. However, they are commonly caught as bycatch and a moderate quantity, particularly of small fish, is undoubtedly discarded.

2. BIOLOGY

Sea perch are widely distributed around most of New Zealand, but are rare on the Campbell Plateau. They inhabit waters ranging from the shoreline to 1200 m and are most common between 150 and 500 m. Previously it was believed that there were two species of sea perch, *H. percoides* and *H. barathri* in New Zealand waters. However, genetics research determined that there is probably only one species of sea perch in New Zealand waters, *H. percoides* (Smith 1998). Because of confusion between *H. percoides* and *H. barathri* until recent years, there is limited information on sea perch biology. Trawl surveys from about 1990 show sea perch size to vary with depth and locality without an obvious pattern, possibly representing population differences as well as life history characteristics.

Sea perch are viviparous, extruding small larvae in floating jelly-masses during an extended spawning season. Sex ratios observed in trawl survey samples show more males, generally in the ratio 1:0.7 to 1:0.8. Sea perch are opportunistic feeders and prey on a variety of animals on or close to the seafloor.

Growth is relatively slow throughout life. After about age 5 years, males appear to grow faster than females (there is some uncertainty due to small sample sizes). Males mature at 19–25 cm, about 5–7 years, whereas females mature at between 15 and 20 cm, around 5 years (Paul & Francis 2002). Maximum observed ages estimated for sea perch from the east coast South Island and Chatham Rise were 32 and 43 years. The natural mortality estimates derived from these are 0.13 and 0.10 (using the Hoenig method) and 0.07–0.09 (using the Chapman-Robson estimator) (Paul & Francis 2002). Ageing studies have not identified the species involved, but the maximum age of Australian fish listed as *H. percoides* by Withell & Wankowski (1988), is about 40 years. The maximum size for sea perch is about 56 cm.

Biological parameters relevant to stock assessment are shown in Table 5.

Table 5: Estimates of biological parameters for sea perch.

Fishstock						**Estimate**	**Source**
1. Natural mortality (*M*)							
SPE 3						0.10–0.13 (Hoenig method)	Paul & Francis (2002)
SPE 3						0.07–0.09 (Chapman Robson estimator)	Paul & Francis (2002)
2. Weight = a (length)^b (Weight in g, length in cm fork length)							
			Both sexes				
			a			b	
SPE 3			0.007767			3.219132	Schofield & Livingston (1996)
3. von Bertalanffy growth parameters							
	Females			Males			
	K	t_0	L_∞	K	t_0	L_∞	
ECSI 1996	0.128	-0.725	40.7	0.117	-0.64	43.6	Paul & Francis (2002)
ECSI 2000	0.13	-0.895	37.9	0.116	-0.956	42.4	Paul & Francis (2002)

3. STOCKS AND AREAS

There are no data relevant to stock boundaries. However, regional variation in colouration suggests that separate populations could exist.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

Estimates of relative abundance from trawl surveys are presented in Table 6. Annual biomass estimates from the winter and summer east coast South Island and Southland surveys have been variable between years, and were determined with only moderate precision (generally CVs around 30%) (see Figures 4 and 5).

The time series of biomass estimates from the West Coast South Island surveys increased between 1992 and 1995 and declined substantially from 667 t in the subsequent surveys. The 2005 estimate of relative biomass was 150 t (Figure 2). Annual trawl survey biomass estimates from the Chatham Rise have a low associated coefficient of variation (8–15%). The time series of indices is relatively constant between 1992 and 1994, drops significantly in 1995, and recovers in 1996. Biomass estimates increased dramatically from 2 713 t in 1997 to 8 417 t in 2002, but then declined until 2008. (Figure 3). The 2010 estimate was 5 594 t (Table 6).

4.1.1 Biomass estimates

Indices of relative biomass are available from recent *Tangaroa* and *Kaharoa* trawl surveys of the Chatham Rise, East Coast South Island and West Coast South Island (Table 6, and Figures 2–5).

West Coast South Island Trawl Survey

SPE 7 is one of a suite of inshore stocks the WCSI trawl survey is designed to monitor. The depth range for this survey is 30–400 m on the west coast of the South Island and >20 m in Tasman and Golden Bay (MacGibbon & Stevenson, 2013). Biomass estimates increased from 1991 to 1995, declined to well below the series average by 2003, increase to a second peak in 2011, and then dropped substantially in 2013 (Figure 2).

The Chatham Rise Trawl Survey was designed primarily for hoki and covers the depth range 200–400 m. It therefore excludes a small portion of sea perch habitat around the Mernoo Bank in less than 200 m. The survey biomass estimates for sea perch increased three fold from 1997 to 2002, declined to below the series average by 2008 and then increased to 2013 (Figure 3). However, the survey biomass estimates have declined in the last two surveys in 2014 and 2016 (Figure 3). The size composition of sea perch caught by the Chatham rise survey includes a substantial proportion of fish in the 30–45 cm TL range, whereas those caught during the ECSI trawl surveys are mostly under 30 cm TL.

East Coast South Island Trawl Survey

The ECSI winter surveys from 1991 to 1996 (depth range 30–400 m) were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range, but these were discontinued after the fifth in the annual time series because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007, and this time included strata in the 10–30 m depth range, in order to monitor elephantfish and red gurnard which were officially included in the list of target species in 2012. Only the 2007, 2012, 2014, 2016 and 2018 surveys provide full coverage of the 10–30 m depth range.

Sea perch biomass shows no trend over the core strata time series (Table 6, Figure 4) (MacGibbon et al. 2019). The 2018 biomass was a 33% decrease from the time series high in 2016.Pre-recruit biomass has remained a small and reasonably constant component of the total biomass estimate on all surveys (3–8% of total core strata biomass) and in 2018 it was 3%. The juvenile to adult biomass ratio (based on length-at-50% maturity) was relatively constant over the time series at 23–36% juvenile, and in 2018 it was 18% juvenile (Figure 5). There was no sea perch caught in the 10–30 m strata and hence the addition of the shallow strata in 2007 is of no value for monitoring sea perch.

The spatial distribution of sea perch hot spots within the survey area varies, but overall this species is consistently well represented over the entire survey area, most commonly from about 70 to 300 m

The size distributions of sea perch on each of the twelve ECSI winter surveys were similar and generally unimodal with a right hand tail reflecting the large number of age classes (MacGibbon et al. 2019). Sea perch from the ECSI sampled on these surveys were generally smaller than those from the Chatham Rise and Southland surveys (Bagley & Hurst 1996, Livingston et al. 2002). This suggests that this area may be an important nursery ground for juvenile sea perch and/or that sea perch tend to be larger at greater depths and the ECSI survey does not extend to the full depth range of sea perch which are found as deep as 800 m. However, it is thought that there are at least two different species referred to as sea perch around New Zealand; *Helicolenus percoides* and *H. barathri* (Roberts et al. 2015. Bentley et al. (2014) also found notable difference in catch rates at depth with *H. percoides* occurring from 0–250 m in depth with a peak at around 150 m whereas *H. barathri* occur from around 300–1000 m in depth with a peak at around 600 m. Further, Paul & Horn (2009) found difference in growth rates, mortality, and implied year class strengths between ECSI and Chatham Rise sea perch. It is likely that most ‘sea perch’ caught on the ECSI winter time series are *H. percoides* although some *H. barathri* could occur in the deeper range of the 200–400 m strata.

4.2 Yield estimates and projections

No estimate of *MCY* can be made. The method $MCY = cY_{AV}$ (Method 4) requires a longer period of relatively stable, or at least known, catches (in view of a potential longevity of 40 years) than is available.

No estimates of current biomass, fishing mortality, or other information are available which would permit the estimation of *CAY*.

4.4 Other factors

Factors influencing yield estimates (species identification, catch history, biomass estimates, longevity/mortality, and natural fluctuations in population size) are poorly known for sea perch and preclude any reliable yield estimates at present.

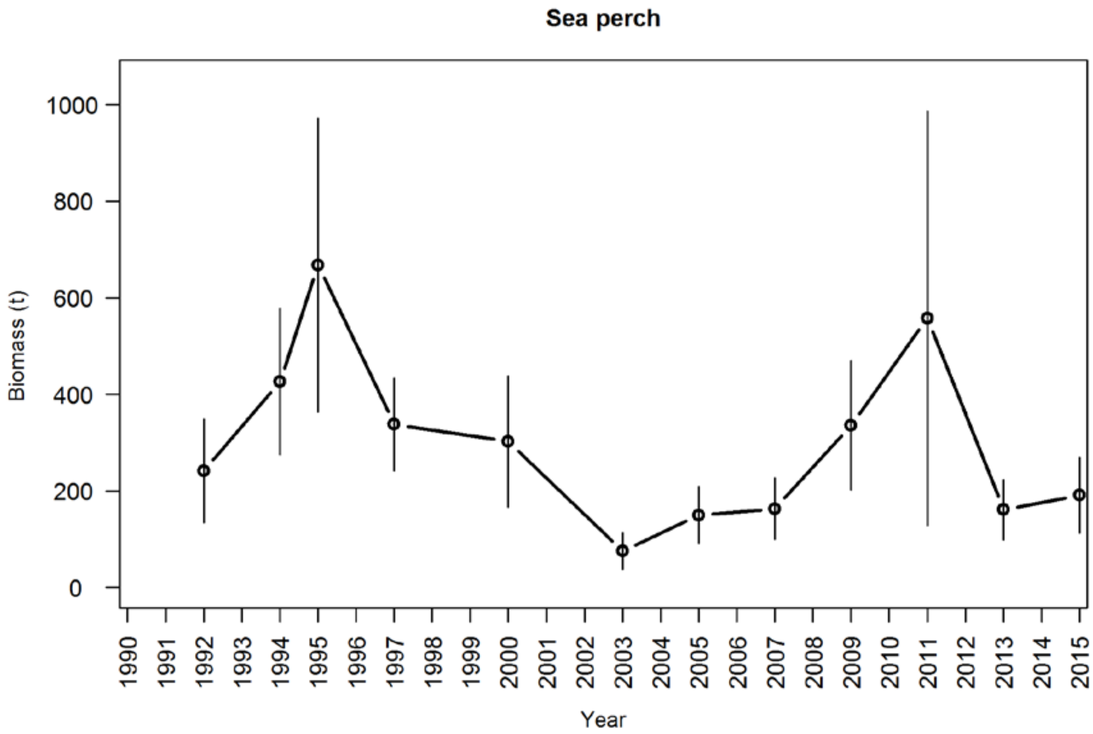


Figure 2: Biomass estimates ±2 standard errors from the West Coast South Island trawl survey.

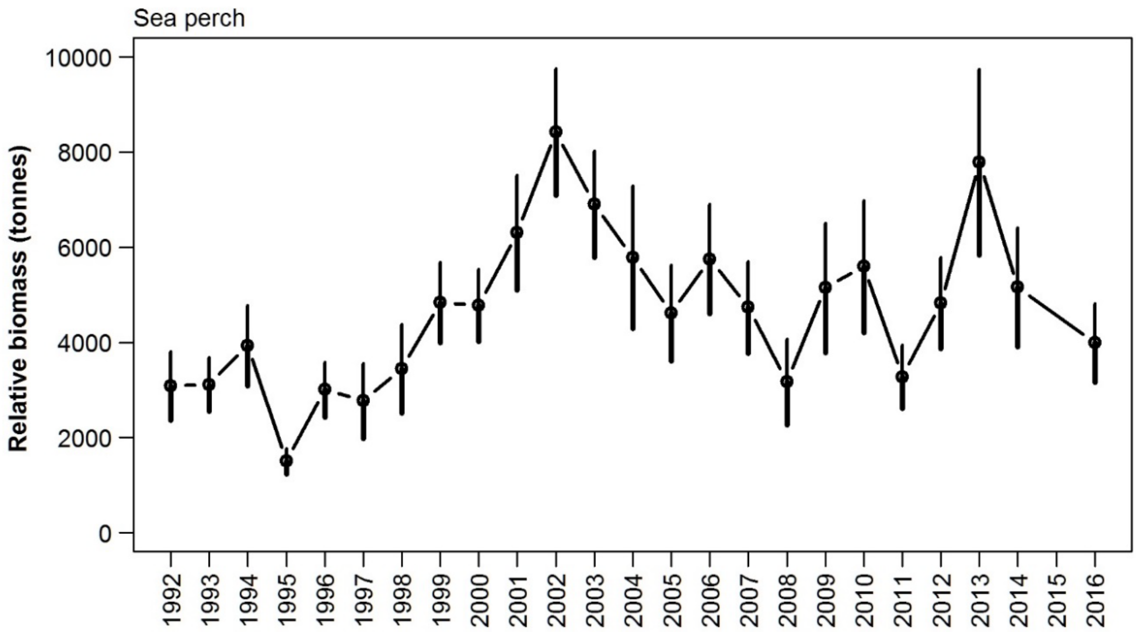


Figure 3: Biomass estimates from the Chatham Rise survey. Error bars are ± 2 standard errors.

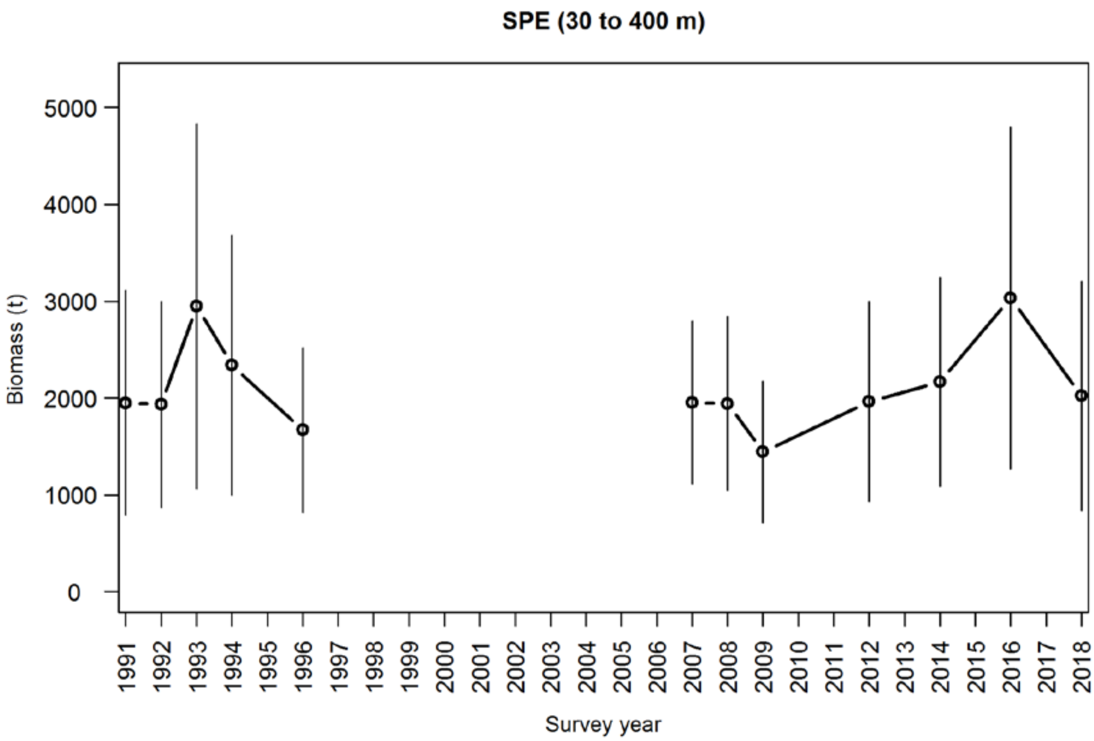


Figure 4: Sea perch total biomass s for ECSI winter surveys in core strata (30–400m). Error bars are ± 2 standard errors.

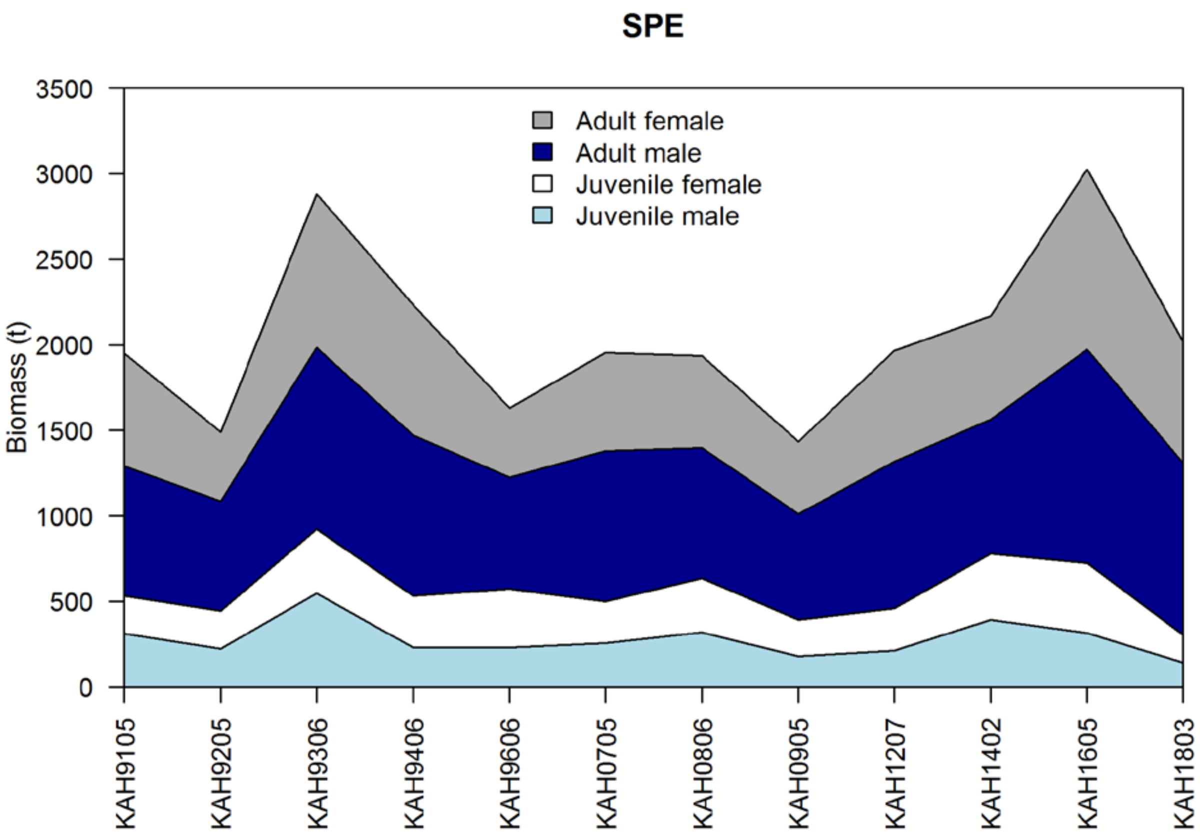


Figure 5: Sea perch juvenile and adult biomass for ECSI winter surveys in core strata (30–400 m), where juvenile is below and adult is equal to or above length at which 50% of fish are mature.

Table 6 Relative biomass indices (t) and coefficients of variation (CV) for sea perch for east coast South Island (ECSI) - summer and winter, west coast South Island (WCSI), the Stewart-Snares Island survey areas, and the Chatham Rise*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16 and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (20 cm). [Continued on next page].

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
ECSI(winter)	SPE 3			30–400 m		10–400m		30–400 m		10–400 m		30–400 m		10–400 m	
		1991	KAH9105	1 716	30	-	-	70	44	-	-	1 483	30	-	-
		1992	KAH9205	1 934	28	-	-	51	28	-	-	1 441	28	-	-
		1993	KAH9306	2 948	32	-	-	178	76	-	-	2 770	30	-	-
		1994	KAH9406	2 342	29	-	-	78	24	-	-	2 264	29	-	-
		1996	KAH9606	1 671	26	-	-	58	45	-	-	1 613	25	-	-
		2007	KAH0705	1 954	22	-	-	74	18	-	-	1 880	22	-	-
		2008	KAH0806	1 944	23	-	-	144	20	-	-	1 800	24	-	-
		2009	KAH0905	1 444	25	-	-	82	18	-	-	1 363	26	-	-
		2012	KAH1207	1 964	26	-	-	66	25	-	-	1 898	27	-	-
		2014	KAH1402	2 168	25	-	-	182	29	-	-	1 986	26	-	-
		2016	KAH1605	3 032	29			109	25			2 923	30		
		2018	KAH1803	2 023	29			64	19			1 959	30		
ECSI(summer)	SPE 3	1996-97	KAH9618	4 041	47	-	-	-	-	-	-	-	-	-	-
		1997-98	KAH9704	1 638	25	-	-	-	-	-	-	-	-	-	-
		1998-99	KAH9809	3 889	41	-	-	-	-	-	-	-	-	-	-
		1999-00	KAH9917	2 203	27	-	-	-	-	-	-	-	-	-	-
		2000-01	KAH0014	1 792	20	-	-	-	-	-	-	-	-	-	-
WCSI	SPE 7	1992	KAH9204	293	24	-	-	-	-	-	-	-	-	-	-
		1994	KAH9404	510	18	-	-	-	-	-	-	-	-	-	-
		1995	KAH9504	667	23	-	-	-	-	-	-	-	-	-	-
		1997	KAH9701	338	14	-	-	-	-	-	-	-	-	-	-
		2000	KAH0004	302	22	-	-	-	-	-	-	-	-	-	-
		2003	KAH0304	76	25	-	-	-	-	-	-	-	-	-	-
		2005	KAH0503	150	20	-	-	-	-	-	-	-	-	-	-
		2007	KAH0704	163	19	-	-	-	-	-	-	-	-	-	-
		2009	KAH0904	336	20	-	-	-	-	-	-	-	-	-	-
		2010	KAH1004	558	39	-	-	-	-	-	-	-	-	-	-
		2013	KAH1305	161	20	-	-	-	-	-	-	-	-	-	-
Stewart-Snares	SPE 5	1993	TAN9301	469	33	-	-	-	-	-	-	-	-	-	-
		1994	TAN9402	443	26	-	-	-	-	-	-	-	-	-	-
		1995	TAN9502	450	27	-	-	-	-	-	-	-	-	-	-
		1996	TAN9604	480	29	-	-	-	-	-	-	-	-	-	-

Table 6 [Continued]: Relative biomass indices (t) and coefficients of variation (CV) for sea perch for east coast South Island (ECSI) - summer and winter, west coast South Island (WCSI), the Stewart-Snares Island survey areas, and the Chatham Rise*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16 and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (20 cm).

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)
Chatham Rise	SPE	1991	TAN9106	3 050	12	-	-	-	-	-	-
		1992	TAN9212	3 110	9	-	-	-	-	-	-
		1994	TAN9401	3 914	11	-	-	-	-	-	-
		1995	TAN9501	1 490	9	-	-	-	-	-	-
		1996	TAN9601	3 006	10	-	-	-	-	-	-
		1997	TAN9701	2 713	14	-	-	-	-	-	-
		1998	TAN9801	3 448	14	-	-	-	-	-	-
		1999	TAN9901	4 842	9	-	-	-	-	-	-
		2000	TAN0001	4 776	8	-	-	-	-	-	-
		2001	TAN0101	6 310	10	-	-	-	-	-	-
		2002	TAN0201	8 417	8	-	-	-	-	-	-
		2003	TAN0301	6 904	8	-	-	-	-	-	-
		2004	TAN0401	5 786	13	-	-	-	-	-	-
		2005	TAN0501	4 615	11	-	-	-	-	-	-
		2006	TAN0601	5 752	10	-	-	-	-	-	-
		2007	TAN0701	4 737	10	-	-	-	-	-	-
		2008	TAN0801	3 081	14	-	-	-	-	-	-
		2009	TAN0901	5 149	13	-	-	-	-	-	-
		2010	TAN1001	5 594	12	-	-	-	-	-	-
		2011	TAN1101	3 278	10	-	-	-	-	-	-
		2012	TAN1201	4 827	10	-	-	-	-	-	-
		2013	TAN1301	7 785	13	-	-	-	-	-	-
		2014	TAN1401	5 158	12						
		2016	TAN1601	3 989	10						

5. STATUS OF THE STOCKS

No estimates of current and reference biomass are available. For all SPE Fishstocks it is not known if recent catch levels are sustainable.

TACCs and reported landings of sea perch in the 2018–19 fishing year are summarised in Table 7.

Table 7: Summary of TACCs (t), and reported landings (t) of sea perch for the most recent fishing year.

Fishstock		QMA	2018–19 Actual TACC	2018–19 Reported Landings
SPE 1	Auckland (East)	1	53	53
SPE 2	Central (East)	2	79	46
SPE 3	South-east (coast)	3	1 000	555
SPE 4	South-east (Chatham)	4	910	432
SPE 5 & 6	Southland and Sub-Antarctic	5	45	18
SPE 7	Challenger	7	82	47
SPE 8	Central (West)	8	15	3
SPE 9	Auckland (West)	9	6	8
SPE 10	Kermadec	10	0	0
Total			2 190	1 161

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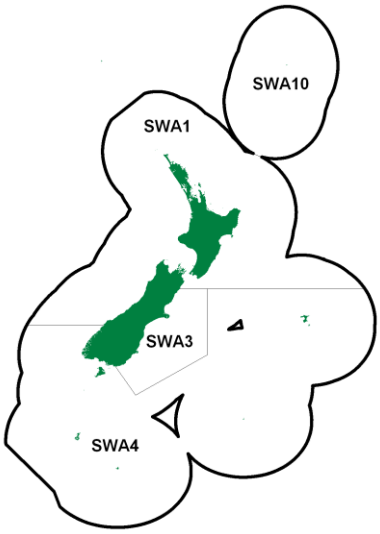
SILVER WAREHOU (SWA)

(*Seriolella punctata*)
Warehou



1. FISHERY SUMMARY

1.1 Commercial fisheries

Silver warehou entered the Quota Management System (QMS) on 1 October 1986. Silver warehou are common around the South Island and on the Chatham Rise in depths of 200–800 m. The majority of the commercial catch is taken from the Chatham Rise, Canterbury Bight, southeast of Stewart Island, and off the west coast of the South Island. Reported landings by nation from 1974 to 1987–88 are shown in Table 1.

Table 1: Reported landings (t) by nation from 1974 to 1987–88. Source: 1974–1978 (Paul 1980); 1978 to 1987–88 (FSU).

Fishing Year	New Zealand				Foreign Licensed			Grand Total
	Domestic	Chartered	Total	Japan	Korea	USSR	Total	
1974*								7 412
1975*								6 869
1976*	estimated as 70% of total warehou landings							13 142
1977*								12 966
1978*								12 581
1978–79**	?	629	629	3 868	122	212	4 203	4 832
1979–80**	?	3 466	3 466	4 431	217	196	4 843	8 309
1980–81**	?	2 397	2 397	1 246	-	13	1 259	3 656
1981–81**	?	2 184	2 184	1 174	186	3	1 363	3 547
1982–83**	?	3 363	3 363	1 162	265	189	1 616	4 979
1983†	?	1 556	1 556	510	98	3	611	2 167
1983–84§#	303	3 249	3 552	418	194	3	615	4 167
1984–85§#	203	4 754	4 957	1 348	387	15	1 749	6 706
1985–86§#	276	5 132	5 408	1 424	217	5	1 646	7 054
1986–87§#	261	4 565	4 826	1 169	29	100	1 299	6 125
1987–88§#	499	7 008	7 507	431	111	39	581	8 088

* Calendar year.
**1 April to 31 March.
†1 April to 30 September.
§1 October to 30 September.
Totals do not match those in Table 2. Data were collected independently and there was known under-reporting to the FSU in 1987–88. This needs to be resolved.

Commercial fishing for silver warehou developed in the late 1960s and early 1970s. Before the establishment of the Exclusive Economic Zone (EEZ), silver warehou, common or blue warehou, and white warehou were all lumped under the category of “warehous”. Estimated total annual catches of silver warehou based on area of capture were about 13 000 t in 1976, 1977, and 1978 (Paul 1980, Livingston 1988; Table 1). Concern about overfishing on the eastern Stewart-Snares shelf led to closure of this area to trawlers between October 1977 and January 1978. Initially, effort shifted to the Chatham Rise and total estimated catch did not change (Ministry of Fisheries 2010). The catches did drop significantly after the establishment of the EEZ, and the reported landings fluctuated between 3000 t and 8000 t from 1978–79 to 1986–87 (Livingston 1988; Table 1 and Table 2).

Some target fishing for silver warehou does still occur, predominantly on the Mernoo Bank and along the Stewart-Snares shelf. Recent reported landings are shown in Table 2, and Figure 1 shows the historical landings and TACC values for the main SWA stocks.

SWA 1

In recent years, most of the silver warehou catch has been taken as a bycatch of the hoki, squid, barracouta and jack mackerel trawl fisheries. Landings from SWA 1 increased substantially after 1985–86 following the development of the west coast South Island hoki fishery. Overruns of the TAC probably partly reflected the hoki fleet fishing in relatively shallow water (northern grounds) in the later part of the season, but could also have reflected changes in abundance.

The TACC in SWA 1 was increased in 1991–92 under the Adaptive Management Programme (AMP). A review of this Fishstock at the completion of 5 years in the AMP concluded that it was not known if the current TACC would be sustainable and an appropriate monitoring programme was not in place. Under the criteria developed for the AMP the Minister therefore removed this Fishstock from the AMP in October 1997 and set the TACC at 2132 t. A new AMP proposal in 2002 resulted in the TACC being increased to 3000 t from 1 October 2002, with 1 t customary and 2 t recreational allowances within a TAC of 3003 t. Landings have not approached the new TACC level in recent years because reductions in the hoki quota have resulted in much less effort on the WCSI in winter; under 550 t were landed annually from 2017–18 and 2018–19.

SWA 3 and 4

In most years from 2000–01 to 2006–07, landings in SWA 3 and SWA 4 were well above the TACCs because fishers landed catches well in excess of ACE holdings and paid deemed values for the overcatch. From 1 October 2007 the deemed values were increased to $1.22 per kg for all SWA stocks and two differential rates were also introduced. The second differential rate applies to all catch over 130% of ACE holding at which point the deemed value rate increased to $3 per kg. The effect of these measures was seen immediately in 2007–08 as fishing without ACE was reduced and catch fell below the TACCs in both SWA 3 and SWA 4. Landings have generally been fluctuating around the TACCs in SWA 3 since then. SWA 4 landings consistently exceeded the TACC during the fishing years 2016–17 to 2018–19.

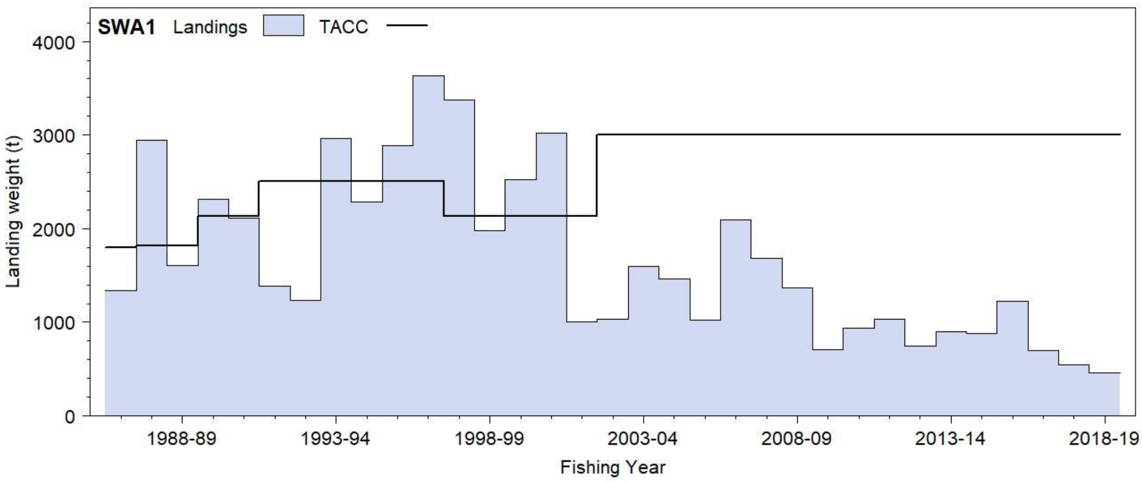
Table 2: Reported landings (t) of silver warehou by Fishstock from 1983–84 to present and TACCs (t) from 1986–87 to present. QMS data from 1986–present. [Continued on next page]

Fishstock	SWA 1		SWA 3		SWA 4		SWA 10			
FMA (s)	1, 2, 7, 8 & 9		3		4, 5 & 6		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	541	–	725	–	1 829	–	0	–	3 095§	–
1984–85*	587	–	1 557	–	4 563	–	0	–	6 707§	–
1985–86*	806	–	2 284	–	3 966	–	0	–	7 056§	–
1986–87	1 337	1 800	1 931	2 600	2 779	3 600	0	10	6 047§	8 010
1987–88	2 947	1 815	3 810	2 601	2 600	3 600	0	10	9 357§	8 026
1988–89	1 605	1 821	1 476	2 640	2 789	3 745	0	10	5 870	8 216
1989–90	2 316	2 128	2 713	3 140	3 596	3 855	0	10	8 625	9 133
1990–91	2 121	2 128	1 889	3 144	3 176	3 855	0	10	7 186	9 137
1991–92	1 388	2 500	2 661	3 144	3 018	3 855	0	10	7 066	9 509
1992–93	1 231	2 504	2 432	3 145	3 137	3 855	0	10	6 800	9 514
1993–94	2 960	2 504	2 724	3 145	2 993	3 855	0	10	8 677	9 514
1994–95	2 281	2 504	2 336	3 280	2 638	4 090	0	10	7 255	9 884
1995–96	2 884	2 504	2 939	3 280	3 581	4 090	0	10	9 404	9 884
1996–97	3 636	2 504	4 063	3 280	5 336	4 090	0	10	13 035	9 884
1997–98	3 380	2 132	3 721	3 280	3 944	4 090	0	10	11 045	9 512
1998–99	1 980	2 132	2 796	3 280	4 021	4 090	0	10	8 797	9 512
1999–00	2 525	2 132	4 129	3 280	4 606	4 090	0	10	11 260	9 512

Table 2 [Continued]

Fishstock	SWA 1		SWA 3		SWA 4		SWA 10			
	1, 2, 7, 8 & 9		3		4, 5 & 6		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2000–01	3 025	2 132	3 664	3 280	4 650	4 090	0	10	11 339	9 512
2001–02	1 004	2 132	2 899	3 280	4 648	4 090	0	10	8 551	9 512
2002–03	1 029	3 000	3 772	3 280	4 746	4 090	0	10	9 547	10 380
2003–04	1 595	3 000	3 606	3 280	5 529	4 090	0	10	10 730	10 380
2004–05	1 467	3 000	3 797	3 280	4 279	4 090	0	10	9 543	10 380
2005–06	1 023	3 000	4 524	3 280	5 591	4 090	0	10	11 138	10 380
2006–07	2 093	3 000	6 059	3 280	6 022	4 090	0	10	14 174	10 380
2007–08	1 679	3 000	2 918	3 280	3 510	4 090	0	10	8 107	10 380
2008–09	1 366	3 000	3 264	3 280	4 213	4 090	0	10	8 843	10 380
2009–10	712	3 000	2 937	3 280	3 429	4 090	0	10	7 078	10 380
2010–11	938	3 000	3 559	3 280	3 507	4 090	0	10	8 004	10 380
2011–12	1 029	3 000	3 318	3 280	2 783	4 090	0	10	7 130	10 380
2012–13	748	3 000	3 788	3 280	4 128	4 090	0	10	8 664	10 380
2013-14	903	3 000	3 201	3 280	3 885	4 090	0	10	7 989	10.380
2014–15	878	3 000	3 820	3 280	4 355	4 090	0	10	9 053	10 380
2015–16	1 225	3 000	2 734	3 280	3 555	4 090	0	10	7 515	10 380
2016–17	696	3 000	3 667	3 280	4 307	4 090	0	10	8 670	10 380
2017–18	543	3 000	3 396	3 280	4 714	4 090	0	10	8 653	10 380
2018–19	463	3 000	3 270	3 280	4 879	4 090	0	10	8 612	10 380

§Totals do not match those in Table 1 because the data were collected independently and there was known under-reporting to the FSU in 1987–88. This needs to be resolved.



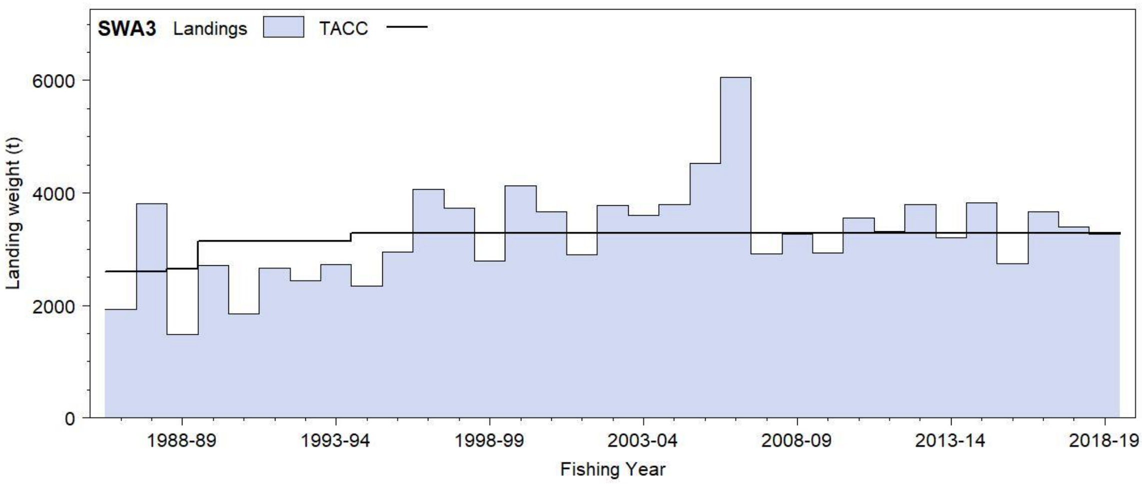


Figure 1: Reported commercial landings and TACCs for the three main SWA stocks. From top to bottom: SWA 1 (Auckland East) and SWA 3 (South East Coast). Note that these figures do not show data prior to entry into the QMS. [Continued on next page]

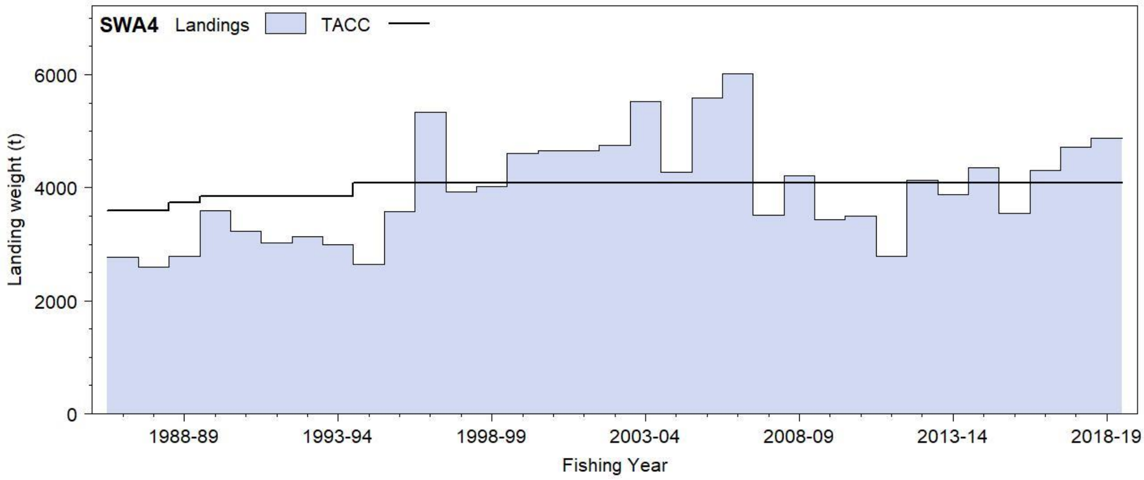


Figure 1 [Continued]: Reported commercial landings and TACCs for the three main SWA stocks. SWA 4 (South East Chatham Rise). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries
There are no current recreational fisheries for silver warehou.

1.3 Customary non-commercial fisheries
Quantitative information on the current level of customary non-commercial take is not available.

1.4 Illegal catch
Silver warehou have been misreported as white and blue warehou in the past. The extent of this practice is unknown and could lead to under-reporting of silver warehou catches.

1.5 Other sources of mortality
Other sources of mortality are unknown.

2. BIOLOGY

Initial growth is rapid and fish reach sexual maturity at around 45 cm fork length in 4 years. Based on a study of ageing methodology and growth parameters (Horn & Sutton 1995), maximum age is considered to be 23 years for females and 19 years for females. An estimate of instantaneous natural mortality (M) was derived by using the equation $M = \log_e 100/A_{MAX}$, where A_{MAX} is the age reached by 1% of the virgin population. From their study, A_{MAX} of 19 years for female silver warehou and 17 years for males produced estimates of M of 0.24 and 0.27, respectively. Horn & Sutton (1995) qualified this result because the samples used in their study were not from virgin populations and the sampling method did not comprehensively sample the whole population. Based on these results M is likely to fall within the range 0.2–0.3.

Horn & Sutton (1995) also calculated von Bertalanffy growth curve parameters from their sample of fish from off the south and southeast coasts of the South Island (Table 3). Other biological parameters relevant to the stock assessment are shown in Table 3. Length weight regressions were calculated from two series of research trawl surveys using *Tangaroa*. One series was conducted on the Chatham Rise in January 1992–97 and the other in Southland during February–March 1993–96.

Silver warehou is a schooling species, aggregating to both feed and spawn. During spring-summer, both adult and juvenile silver warehou migrate to feed along the continental slope off the east and southeast coast of the South Island. Late-stage silver warehou eggs and larvae have been identified in plankton samples, and the early life history of silver warehou appears typical of many teleosts. Juvenile silver warehou inhabit shallow water at depths of 150–200 m and remain apart from sexually mature fish. Few immature fish are consequently taken by trawlers targeting silver warehou. Juveniles have been caught in Tasman Bay, off the east coast of the South Island and around the Chatham

Islands. Once sexually mature, fish move out to deeper water along the shelf edge, such that mature fish dominate catches at depths greater than about 300 m.

Table 3: Estimates of biological parameters of silver warehou.

Fishstock							Estimate	Source
1. Weight = a(length)^b (Weight in g, length in cm, total length).								
							Both sexes	
						a	b	*Tangaroa* Survey:
Chatham Rise						0.00848	3.214	January 1992–97
Southland						0.00473	3.380	February–March 1993–96
2. von Bertalanffy growth parameters								
			Female				Males	
	L_∞	k	t_0	L_∞	k		t_0	
All areas	54.5	0.33	-1.04	51.8	0.41		-0.71	Horn & Sutton (1995)

3. STOCKS AND AREAS

The stock structure is not well known.

Horn et al (2001) suggest four distinct spawning areas: off west coast South Island, southern South Island, eastern North Island, and on the Chatham Rise, with possible sub-areas of spawning within these. For example, Livingston (1988) inferred from voyage reports the time of spawning on the Chatham Islands was later (spring-summer) than that at the Mernoo Bank (winter-spring). The peak timing for spawning appears to be earliest on the WCSI (winter), then proceeding in a southeast direction, at the Mernoo Bank (winter-spring), Stewart-Snares shelf, and around the Chatham Islands (spring-summer). It is uncertain whether the same stock migrates from one area to another, spawning whenever conditions are appropriate, or if there are several separate stocks. The current management areas bear little relation to known spawning areas and silver warehou distribution. Horn et al (2001) investigated growth rates, gonad staging information, and age structure with regard to stock structure, but found no evidence from these characteristics for separate reproductive units.

4. STOCK ASSESSMENT

The following biological stocks have been considered for the purpose of stock assessment:

- West Coast South Island (WCSI, part of SWA 1).
- East Coast South Island (ECSI): the northern part of SWA 3 and Chatham Rise west of 180° (part of SWA 4).
- East Chatham Rise (ECR): the Chatham Rise east of 180° (part of SWA 4).
- Southland: the southern part of SWA 3 and SWA 4 excluding the Chatham Rise.

An assessment of the East Coast South Island silver warehou stock was attempted in 2018 (McGregor 2019a, b). Although the assessment was not accepted by the Deepwater Fisheries Assessment Working Group, biomass information derived from the assessment was considered adequate to provide sustainability advice on this stock. This assessment was based on the following biological stock structure assumption: there was a break in the spatial distribution of catches between the fishery on Chatham Rise and East Coast South Island down to roughly 45.4° S, and the Stewart-Snares shelf comprising the northwestern side of QMA 4 and the northern part of QMA 3, and known timing and location of spawning.

Further work was completed in 2019–20 to describe the distribution of fish and fishing within the East Coast South Island biological stock area and to examine the hypothesis that changes in CPUE may have resulted from operational changes in the fishery (Dutilloy & Dunn in press). These analyses concluded that the inshore and offshore fisheries within the stock area should have different fishery selectivities, that the trend in revised CPUE analyses was similar to that reported by McGregor

(2019a), and that a peak in CPUE around 2006–07 was most likely a consequence of increased abundance.

4.1 Estimates of fishery parameters and abundance

Bottom trawl surveys have been conducted since the early 1990s using either the *Tangaroa* (Chatham Rise survey, Sub-Antarctic survey, and WCSI) or the *Kaharoa* (inshore east and east coasts of the South Island). These surveys all encounter silver warehou, and the station allocation for the *Tangaroa* surveys on the WCSI have taken into account SWA from 2012 (Table 4). However, for the other surveys the average CVs are high, and they have not been considered suitable for stock assessment or as good monitoring tools for these stocks. They may, nonetheless, be useful in interpreting CPUE analyses.

Table 4: Biomass indices (t) and estimated coefficients of variation (CV) for core survey areas

Fishstock	Area	Vessel	Trip code	Date	Biomass	CV (%)
SWA 3&4	Chatham Rise	*Tangaroa*	TAN9106	Jan–Feb 1992	4 489	54
			TAN9212	Jan–Feb 1993	2 694	51
			TAN9401	Jan 1994	11 640	49
			TAN9501	Jan 1995	3 737	28
			TAN9601	Jan 1996	1 707	28
			TAN9701	Jan 1997	2 101	32
			TAN9801	Jan 1998	4 708	48
			TAN9901	Jan 1999	6 760	34
			TAN0001	Jan 2000	5 425	46
			TAN0101	Jan 2001	2 728	22
			TAN0201	Jan 2002	6 410	81
			TAN0301	Jan 2003	7 815	74
			TAN0401	Jan 2004	20 548	40
			TAN0501	Jan 2005	6 671	22
			TAN0601	Jan 2006	7 704	48
			TAN0701	Jan 2007	14 646	32
			TAN0801	Jan 2008	15 546	36
			TAN0901	Jan 2009	15 061	34
			TAN1001	Jan 2010	80 469	58
			TAN1101	Jan 2011	82 075	62
			TAN1201	Jan 2012	16 055	52
			TAN1301	Jan 2013	6 945	29
			TAN1401	Jan 2014	2 658	61
			TAN1601	Jan 2016	14 983	25
			TAN1801	Jan 2018	12 953	44
			TAN2001	Jan 2020	9 659	53
SWA 3	ECSI	*Kaharoa*	KAH9105	May–Jun 1991	29	21
			KAH9205	May–Jun 1992	32	22
			KAH9306	May–Jun 1993	256	44
			KAH9406	May–Jun 1994	35	28
			KAH9606	May–Jun 1996	231	32
			KAH0705	May–Jun 2007	445	44
			KAH0806	May–Jun 2008	319	32
			KAH0905	May–Jun 2009	446	42
			KAH1207	Apr–Jun 2012	438	46
			KAH1402	Apr–Jun 2014	626	83
			KAH1605	Apr–Jun 2016	428	53
			KAH1803	Apr–Jun 2018	191	42
SWA 1	WCSI	*Tangaroa*	TAN0007	Aug 2000	1 507	25
			TAN1210	Aug 2012	617	32
			TAN1308	Aug 2013	313	23
			TAN1609	Aug 2016	271	37
			TAN1807	Aug 2018	91	21
SWA4	Subantarctic	*Tangaroa*	TAN9105	Nov–Dec 1991	1 113	47
			TAN9211	Nov–Dec 1992	225	64
			TAN9310	Nov–Dec 1993	164	63
			TAN0012	Nov–Dec 2000	21	65
			TAN0118	Nov–Dec 2001	1 069	59
			TAN0219	Nov–Dec 2002	141	62
			TAN0317	Nov–Dec 2003	22	72
			TAN0414	Nov–Dec 2004	171	34
			TAN0515	Nov–Dec 2005	1 198	99
			TAN0617	Nov–Dec 2006	71	56
			TAN0714	Nov–Dec 2007	514	38
			TAN0813	Nov–Dec 2008	4 122	55
			TAN0911	Nov–Dec 2009	3 620	98
			TAN1117	Nov–Dec 2011	136	61
			TAN1215	Nov–Dec 2012	13	75
			TAN1412	Nov–Dec 2014	29	72
			TAN1614	Nov–Dec 2016	85	115
			TAN1811	Nov–Dec 2018	2 694	41

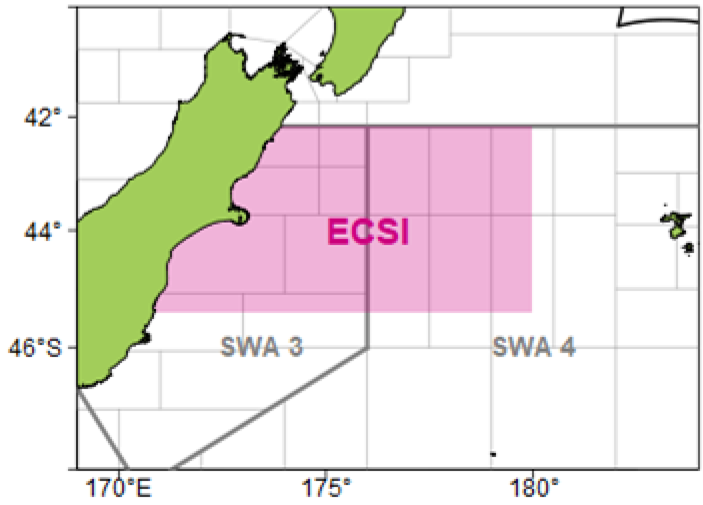


Figure 2: Map showing East Coast South Island in red and SWA 1, 3, and 4 boundaries (grey).

Merged (stratified) and unmerged (tow-level) datasets were modelled separately to derive relative biomass indices based on CPUE data (McGregor 2019a, Dutilloy & Dunn in press). McGregor (2019a) estimated CPUE for the target and bycatch trawl fisheries, including the recorded target species as a covariate in the analyses. Dutilloy & Dunn (in press) concluded that the target fishery in the ECSI stock was not well defined and estimated CPUE for silver warehou caught as bycatch in the domestic vessel offshore bottom trawl fishery (targeting hoki) and inshore bottom trawl fishery (often targeting barracouta). All analyses used the delta-lognormal generalised linear modelling approach and allowed for spatial, seasonal, and vessel influences on catch rate.

Length and age data have been collected during the course of trawl surveys and by the Observer Programme from commercial fishing vessels. A feature of these time series, especially with the Chatham Rise and ECSI surveys, is that the size distributions are extremely variable among years. The Chatham Rise survey sometimes completely lack the typical 50 cm size class, and often lacks the 25 cm or 35 cm modes even though the appropriate mode is present in the subsequent year. The variability is highest in the ECSI survey, which shows up to four distinct size modes, but usually only one or two simultaneously. Beentjes et al (2004) noted that variability in adult size classes captured in the ECSI survey had been a common feature and considered it to be a result of either environmental influences on fish distribution, fish schooling by size, or the result of problems with gear performance (Beentjes et al 2004). McGregor (NIWA unpublished 2020) noted that the relatively high catches of silver warehou in the ECSI survey were only taken close to the deep boundary (400 m) of the survey region.

East Chatham Rise (part of SWA 4)

Trawl survey and CPUE indices

The most recent update of CPUE analyses for the East Chatham Rise was by McGregor (2016), using data to the end of the 2010–11 fishing year. The Chatham Rise trawl survey index suggested an overall upward trend (Figure 3), although the 2010 and 2011 years were difficult to interpret given very large CIs.

Both the stratified and un-stratified CPUE series (Figure 3) showed a very slight increasing trend from 1998 to 2011. A large proportion of tows with zero catch were found in the tow by tow unmerged data, which has a strong influence on the combined index. CPUE was not considered likely to be a good index here, and the years in which there are peaks in the CPUE and survey biomass index do not match. However, the slight overall increase in CPUE matched the trend in the trawl survey data for eastern Chatham Rise.

Length and age data
The age and length frequency data may prove useful in interpreting trends in the trawl survey and CPUE relative abundance indices in the future.

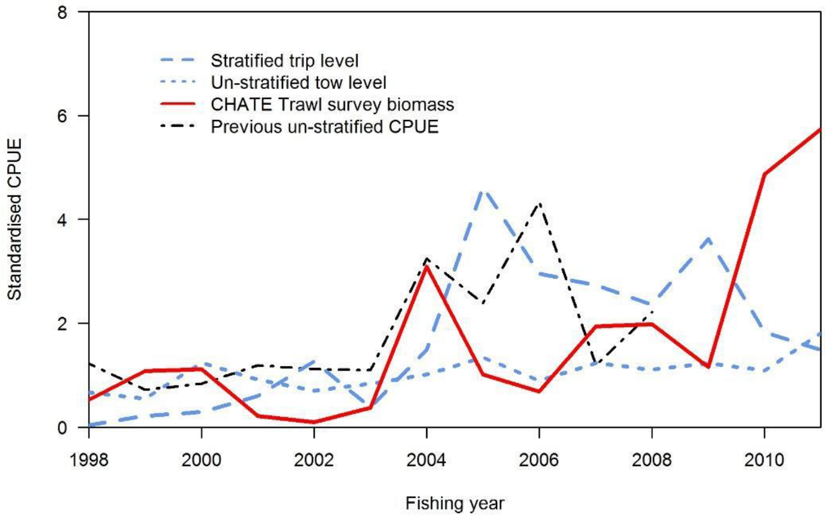


Figure 3: East Chatham Rise standardised CPUE (1998–2011) for merged (stratified, trip level) and unmerged (un-stratified, tow level) data; previous un-stratified CPUE (1998–2008) data; and biomass estimates from Chatham Rise East *Tangaroa* trawl surveys 1998–2011.

East Coast South Island (parts of SWA 3 and SWA 4)

Trawl survey and CPUE indices
The most recent update of CPUE for the ECSI was by McGregor (2019a) using data to the end of the 2015–16 fishing year, and Dutilloy & Dunn (in press) using data to the end of the 2018–19 fishing year.

All CPUE indices showed an overall slight increasing trend, with a peak around 2007–08 (Figure 4). CPUE after 2007–08 remained relatively high. The ECSI trawl survey showed a similar broad upward trend, until a decline in 2018. Biomass in the core strata (30–400 m) for the years since 2007 was higher overall than in the 1990s by about two-fold. The Chatham Rise trawl survey also showed a general increase, until very high biomass estimates in 2010 and 2011; these were associated with a small number of large catches and resulted in the estimates having a particularly high CV (Table 4). These estimates were subsequent to the increase in CPUE around 2006–07. The hoki research survey strata on the West Chatham Rise showed a similar trend to the East Chatham Rise with higher abundance and high CVs in 2010 and 2011. Because of the influence of large occasional catches of silver warehou, the trawl surveys are not currently considered a useful stock monitoring tool.

Length and age data
The *Kaharoa* trawl survey is monitoring pre-recruited cohorts, but not fish in the recruited size range. Plots of time series length frequency distributions consistently show the presence of the pre-recruited cohorts on nearly all surveys, with indications that these could be tracked through time (modal progression). Therefore, the age and length frequency data may prove useful in interpreting trends in the trawl survey and CPUE indices in the future.

Length data have been collected from the Observer Programme and some tracking of length modes is possible (Figure 5), suggesting the passage of strong and weak year classes. Otoliths collected by the Observer Programme were aged for fishing years 2000–01, 2004–05, 2006-07, 2009–10, 2010-11, 2012–13, 2013–14, and 2015–16 (Horn et al 2012, Horn & McGregor 2018), with 300 otolith pairs read for each of these years except 2004–05 which was slightly lower due to fewer samples collected in this year. The age compositions suggest strong year classes in spawned in 2000, 2005, and 2006 (Horn & McGregor 2018, McGregor 2019b; Figure 6).

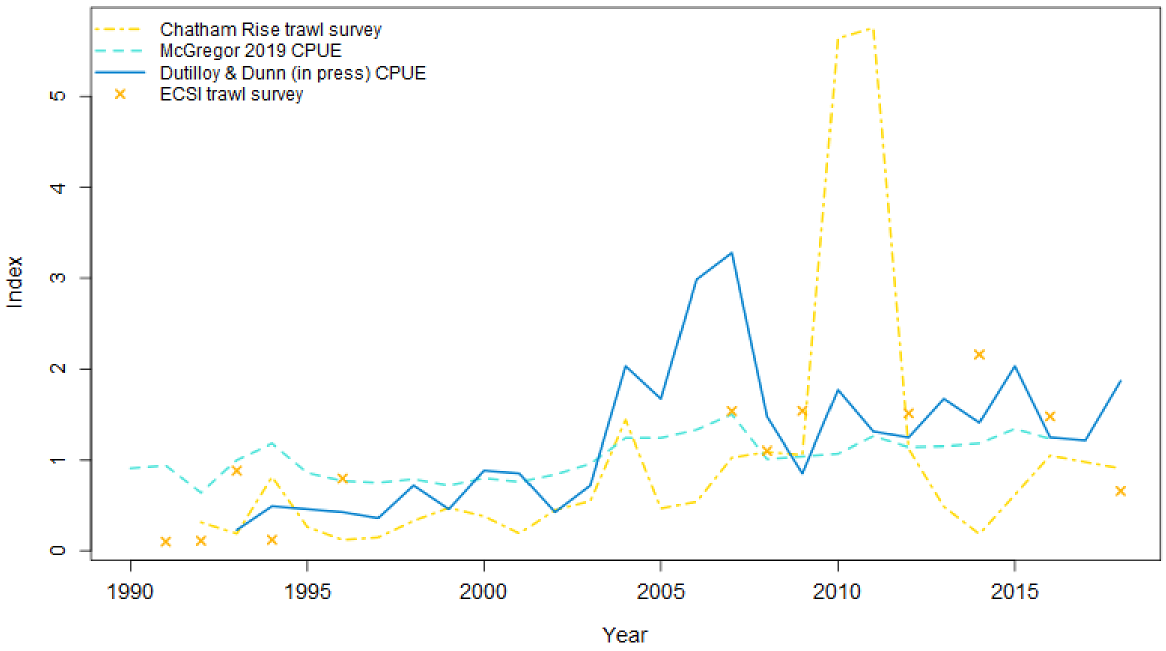


Figure 4: CPUE indices for the ECSI stock standardised CPUE (1989–90 to 2017–18) and biomass estimates from the Chatham Rise and ECSI trawl survey. Note that the Chatham Rise trawl survey series has been biennial since 2014 (see Table 4).

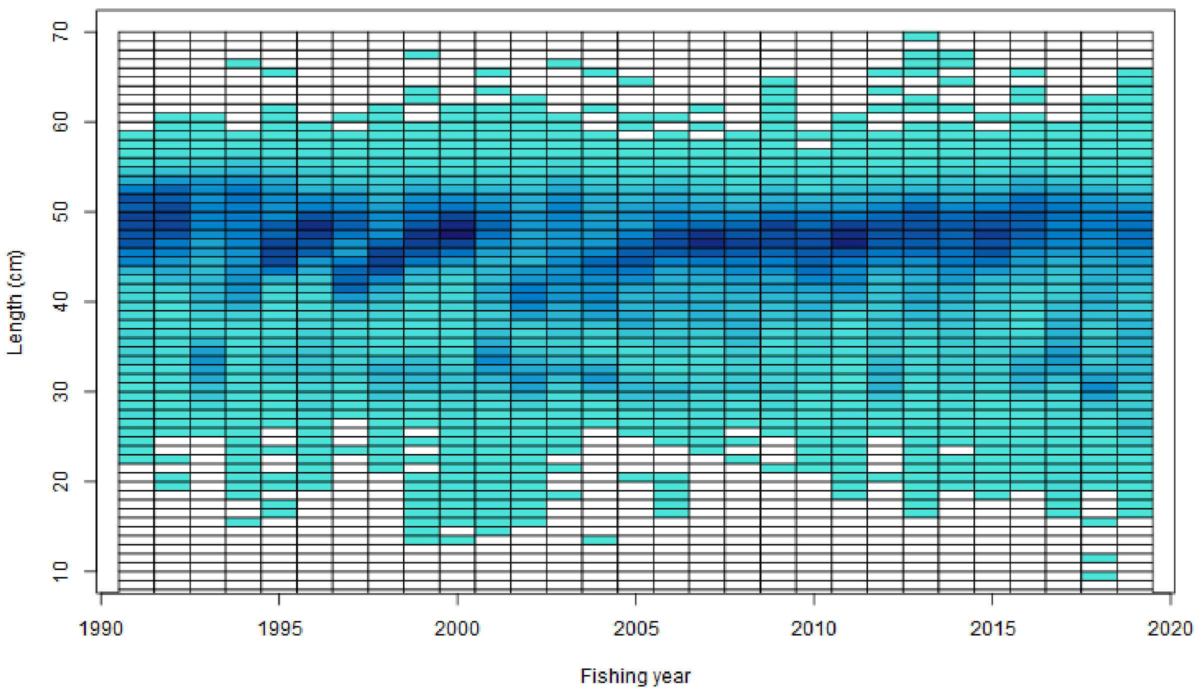


Figure 5: Raw proportions at length from observer data from East Coast South Island stock (blue rectangles). Darker blue indicates higher proportion.

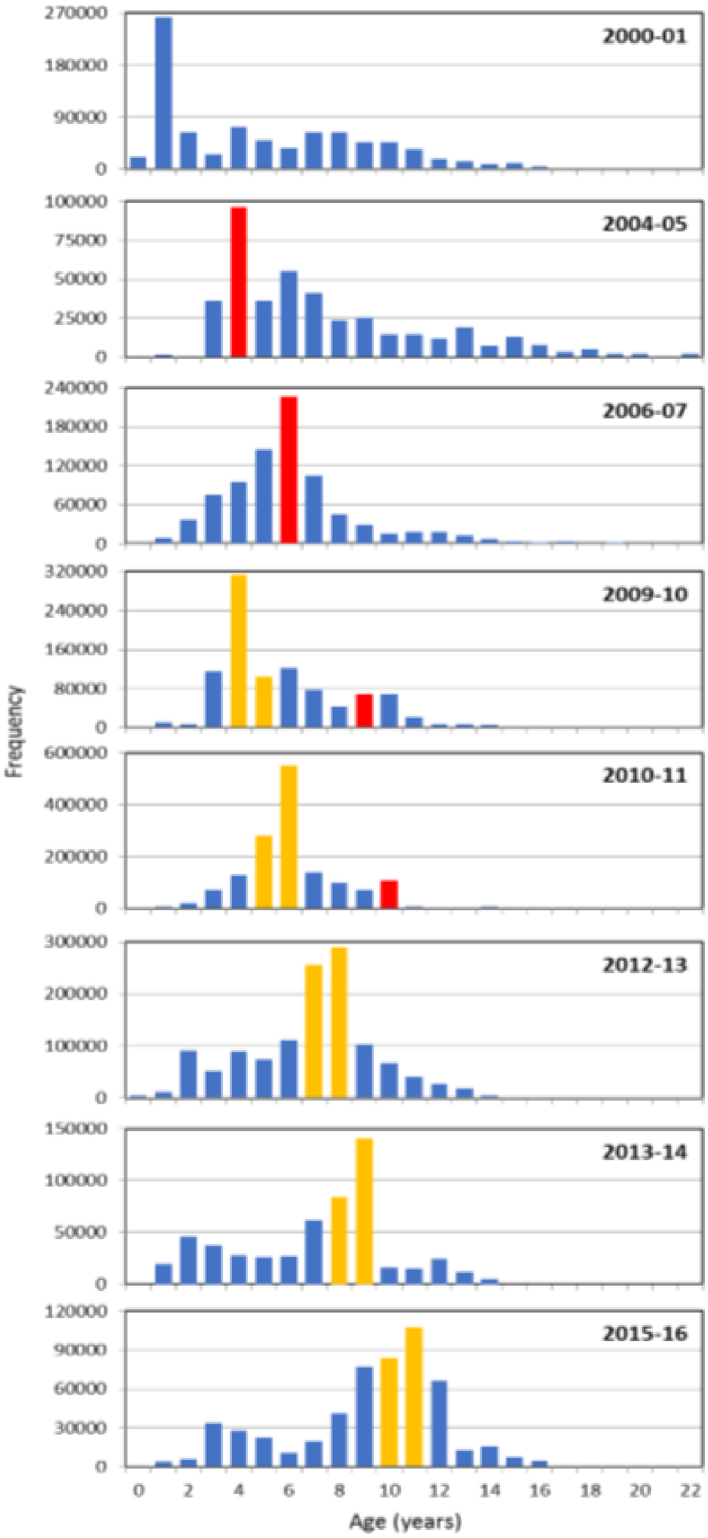


Figure 6: Scaled commercial catch-at-age distributions for the trawl catch of silver warehou sampled from the East Coast South Island (ECSI) (Horn & McGregor 2018). The 2000 (red bars), and 2005 and 2006 (orange bars) year classes are indicated.

Southland (parts of SWA 3 and SWA 4)

Trawl survey and CPUE indices

The most recent update of CPUE for the Southland stock was by McGregor (2019a) using data to the end of the 2015–16 fishing year. The Sub-Antarctic trawl survey index and CPUE indices (Figure 7) have been generally flat, except that the increase in 2008 and 2009 in the trawl survey is not reflected in the CPUE index. Intermittent peaks in biomass have occurred in the trawl survey, and the survey is not currently considered a reliable index.

Length and age data

The age and length frequency data may prove useful in interpreting trends in the trawl survey and CPUE relative abundance indices in the future. Length data from the Observer Programme show some tracking of length modes (Figure 8), and these may indicate strong and weak year classes.

Otoliths collected by the Observer Programme were aged for years 1993 to 1996, and again in 2012 and 2014 (Horn et al 2001, Horn & McGregor 2018) (Figure 9). For each of the years 2012 and 2014, 300 otolith pairs were read. The age compositions suggest strong year classes in spawned in 1991, 1992, 2003, and 2010 (Horn & McGregor 2018).

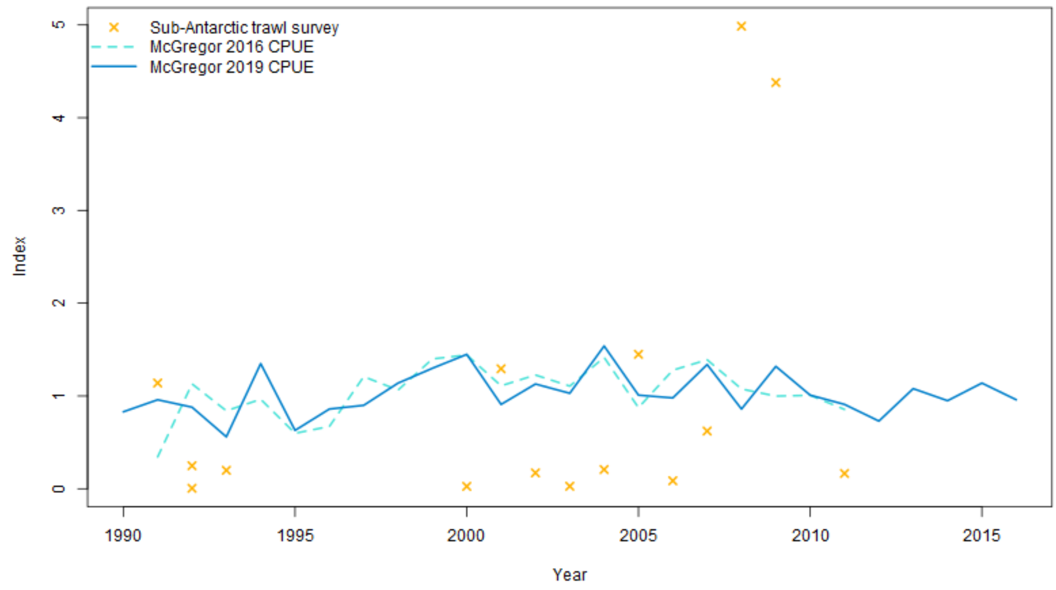


Figure 7. Southland standardised CPUE indices and trawl survey biomass estimates from Sub-Antarctic *Tangaroa* trawl surveys.

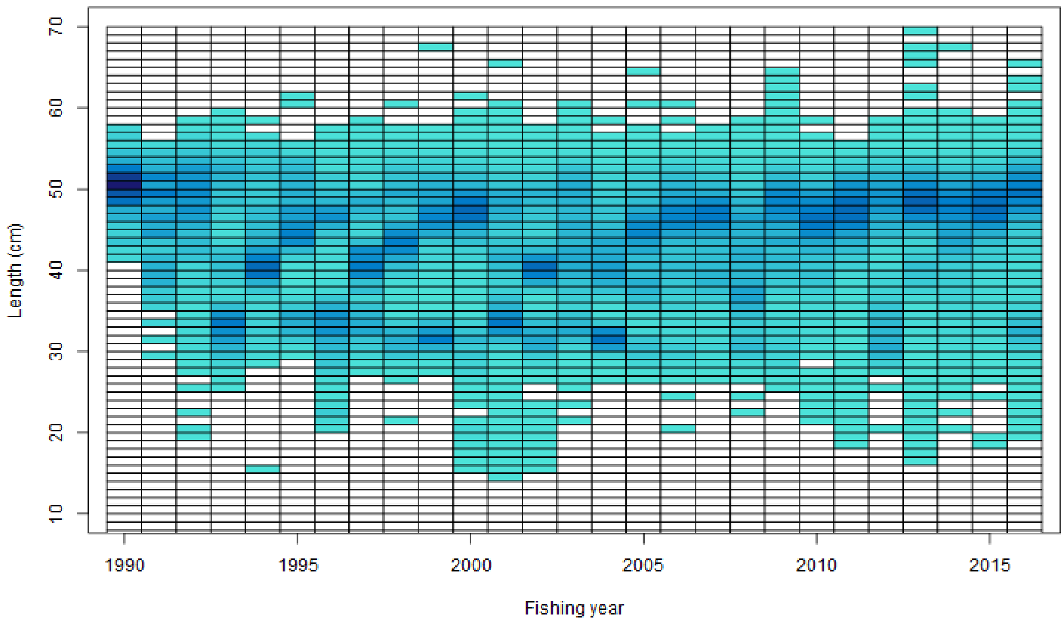


Figure 8: Raw proportions at length from observer data from Sub-Antarctic (blue rectangles).

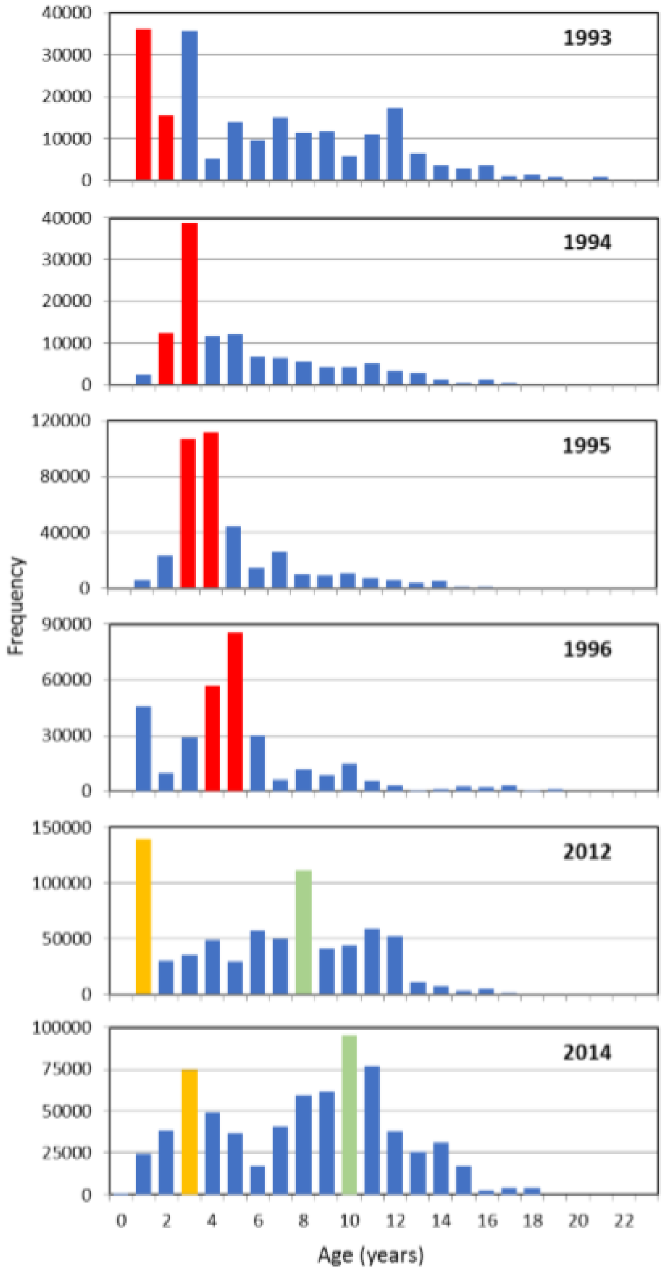


Figure 9: Scaled commercial catch-at-age distributions from samples of silver warehou off Southland. The 1991 and 1992 (red bars), 2003 (green bars), and 2010 (orange bars) year classes are indicated (Horn & McGregor 2018).

West Coast South Island (part of SWA 1)

Trawl survey and CPUE indices

CPUE analyses for the WCSI were most recently updated by McGregor (2016), using data to end of the 2010–11 fishing year (Figure 10). McGregor (2016) suggested that the West Coast South Island CPUE time series was promising as an index of abundance, and that Observer length data may help interpret patterns in the CPUE. The inshore *Kaharoa* trawl surveys were not considered a good monitoring tool or useful for stock assessment for this area.

The WCSI *Kaharoa* survey includes the TBGB (Tasman Bay and Golden Bay) area, which is a shallow area and dominated by juvenile SWA. When separated out, the TBGB index showed a downward trend while the WCSI index with TBGB omitted was fairly flat, with highly variable CIs.

The WCSI *Tangaroa* survey biomass estimate indicates a substantial biomass decline (Table 4).

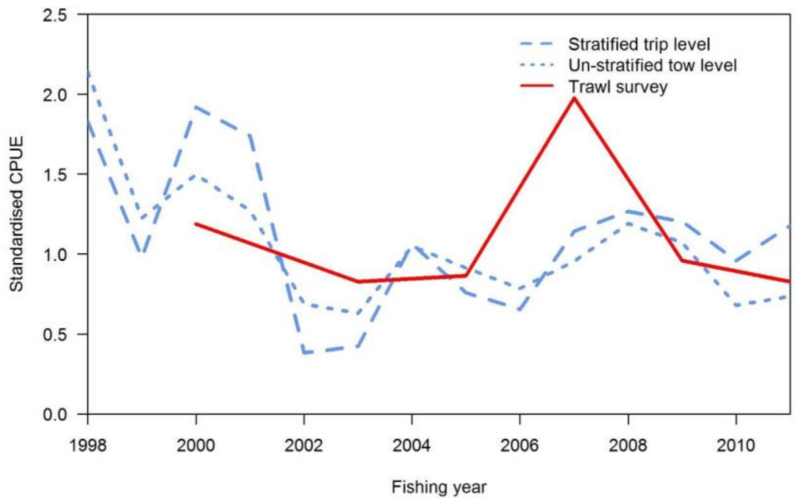


Figure 10: West Coast South Island standardised CPUE (1997–98 to 2010–11) for merged (stratified, trip level) and unmerged (un-stratified, tow level) data; and biomass estimates from Tasman Bay–Golden Bay *Kaharoa* trawl surveys 1998–2011.

A CPUE analysis for this stock, covering years before 1997–98, was also conducted in 2009 (Cordue 2009) using selected observer catch and effort data for a core fleet of vessels for positive bottom and midwater trawl SWA catches in area FMA 7 for winter fishing within a WCSI box (40.2° S–43.3° S). The resulting index (Figure 11) is noisy but shows a general trend of slow CPUE decline from 1986 to 1992, a steep increase from 1992 to 1996 and high levels through to 2000, followed by a steep decline back to low levels by 2002 and a stable trend at slightly above historically lowest levels through to 2008. This CPUE index was possibly consistent with strong year classes in 1993–94 and in 1997 (evident in the length frequency data), and the resulting increased abundance over the ensuing few years. This CPUE standardisation might be indexing SWA 1 abundance and, given the substantial amount of catch-at-age data for this stock, it was recommended that a stock assessment should now be conducted to investigate the coherence between catch-at-age data and this abundance index.

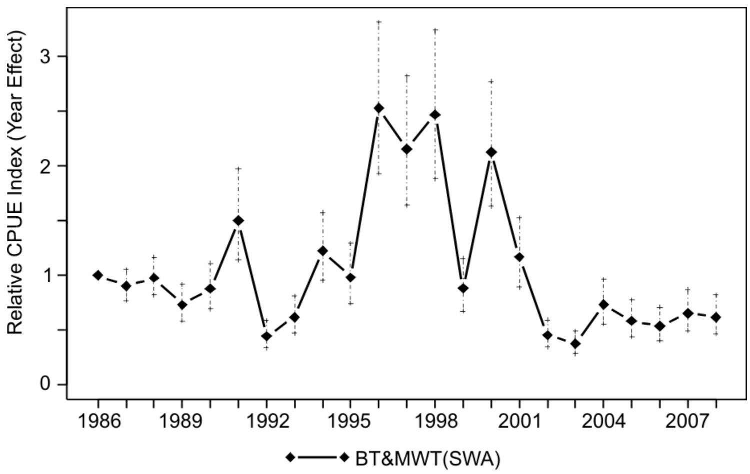


Figure 11: Standardised CPUE index (year effects) for SWA 1 from an analysis of Scientific Observer Programme trawl records (Cordue 2009).

Length and age data

The WCSI inshore trawl series typically has a dominant 20 cm mode and a smaller mode around 35 cm. Age frequency distributions from otoliths collected by the Scientific Observer Programme from the west coast South Island hoki fishery indicate that a wide range of year classes were present in the catch for all seasons 1992–96. Catch curve analysis based on the age structure of annual catches made from 1992–2005 suggested that fishing mortality was lower than natural mortality (SeaFIC 2007). Observer length data may help interpret patterns in CPUE.

The Working Group noted that this Fishstock sustained catches which averaged 2800 t y^{-1} from 1993–94 to 2000–01 without resulting in high estimates of total mortality, *Z*, but that this occurred over a period where CPUE indices indicate abundance of more than double current levels. A stock assessment is considered to be a more appropriate methodology to assess this Fishstock than relying on analyses of catch curve (Middleton 2009).

Future research considerations

- The stock structure for silver warehou remains poorly known. A holistic approach using all available information for all areas of New Zealand should be used to identify the most likely biological stocks.
- A trip level CPUE analyses for inshore fisheries, which represents about 7–18% of the total annual catch, should be investigated. Research by A. Dutilloy (NIWA in prep) suggested that the ECSI inshore trawl fishery CPUE provided a trend similar to the ECSI trawl survey when analysed at the trip level.
- The trawl survey estimates should be re-evaluated. Research by V. McGregor (NIWA in prep) indicated large catches of silver warehou in the Chatham Rise trawl surveys occurred in areas outside of the commercial trawl fishing footprint. Biomass estimated from the trawl surveys excluding these areas may provide a biomass trend more comparable with the CPUE.
- Consider updating the CPUE for the WCSI. The WCSI commercial CPUE has not been updated since 2011; the *Tangaroa* trawl survey has indicated a large biomass decline.
- Reassess the WCSI *Tangaroa* and *Kahaora* trawl surveys in light of the spatial and depth understanding developed for the surveys in SWA 3 and 4.
- Review all options and approaches to providing stock status advice (including but not limited to the possibility of again attempting a Level 1 fully quantitative stock assessment for the ECSI stock. An assessment was attempted but rejected (McGregor 2019b). Since then, further research has been conducted on the spatial structure of the fish stock and fisheries, CPUE indices have been refined, and additional age data have been collected.

6. STATUS OF THE STOCKS

- **WCSI (part of SWA 1)**

Stock Status	
Year of Most Recent Assessment	2018
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%\ B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The *Tangaroa* trawl survey indicates a substantial decline in biomass between 2000 and 2018.
Recent Trend in Fishing Intensity or Proxy	-
Other Abundance Indices	CPUE indices were relatively high between 1996 and 2001, but have not been updated since 2011.
Trends in Other Relevant Indicators or Variables	Age-frequency estimates for the period 1992–2005 indicated fishing mortality rate was lower than the assumed natural mortality rate. This has not been updated since.

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

Assessment Methodology and Evaluation		
Assessment Type	Level 3 - Qualitative Evaluation	
Assessment Method	-	
Assessment Dates	Latest assessment: 2018	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	- *Tangaroa* trawl survey index - CPUE - age frequency (up to 2005) - *Kaharoa* WCSI inshore survey	2 – Medium or Mixed Quality: only 5 data points and may not be appropriate for monitoring SWA 2 – Medium or Mixed Quality: needs to be updated 2 – Medium or Mixed Quality: needs to be updated 2 – Medium or Mixed Quality: needs further evaluation
Data not used (rank)		
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	There is currently no reliable way of tracking abundance due to the characteristics and behaviour of the fish and the fishing fleet.	

Qualifying Comments
-

Fishery Interactions
-

- **East Coast South Island (northern part of SWA 3 and west Chatham Rise part of SWA 4)**

Stock Status	
Year of Most Recent Assessment	2020
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\% B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Soft limit: Unknown Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE and biomass indices for the ECSI stock have increased or been relatively high in recent years. The total catches also increased in recent years, and are around the TACC. Age composition data suggest that the increase in catch rates and catches was consistent with the recruitment of some relatively large year classes. Preliminary stock assessment analyses suggested that stock status has not declined at recent catch levels.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity is unlikely to be increasing.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unlikely
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment.	
Assessment Method	Examination of relative abundance indices	
Assessment Dates	Latest assessment: 2020	Next assessment: Unknown
Overall assessment quality rank	2 – Medium or Mixed Quality	
Main data inputs (rank)	- *Tangaroa* trawl survey index - CPUE - age frequency (2001–2016) - *Kaharoa* ECSI inshore survey - Length frequencies	2 – Medium or Mixed Quality: high CVs 2 – Medium or Mixed Quality: mixture of verified and unverified data 1 – High Quality 2 – Medium or Mixed Quality: survey doesn't cover full depth range 1 – High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	There is currently not a reliable way of tracking abundance due to the characteristics and behaviour of the fish and the fishing fleet.	

Qualifying Comments
-

Fishery Interactions
-

- **Eastern Chatham Rise (part of SWA 4)**

Stock Status	
Year of Most Recent Assessment	2015
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%\ B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE showed a slight increasing trend from 1998 to 2011.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	The Chatham Rise trawl survey index for this area suggested an overall upward trend, although the 2010 and 2011 years were difficult to interpret given very large CIs.
Trends in Other Relevant Indicators or Variables	-

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

Assessment Methodology and Evaluation		
Assessment Type	Level 3 - Qualitative Evaluation	
Assessment Method	Examination of trends in CPUE and trawl survey estimates	
Assessment Dates	Latest assessment: 2015	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	- *Tangaroa* trawl survey index - CPUE	2 – Medium or Mixed Quality: high CVs 2 – Medium or Mixed Quality: high proportion of zero catches and may not be a reliable index of abundance
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	There is currently no reliable way of tracking abundance due to the characteristics and behaviour of the fish and the fishing fleet. Indices are only available until 2011.	

Qualifying Comments
-

Fishery Interactions
-

- **Southland (Southern part of SWA3 and Sub Antarctic SWA4)**

Stock Status	
Year of Most Recent Assessment	2019
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\% B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The CPUE index has been generally flat.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	The trawl survey biomass index has been generally flat.
Trends in Other Relevant Indicators or Variables	The age compositions suggest relatively strong year classes from 1991, 1992, 2003 and 2010.

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

Assessment Methodology and Evaluation		
Assessment Type	Level 3 - Qualitative Evaluation	
Assessment Method	Examination of trends in CPUE, trawl survey estimates and age composition data	
Assessment Dates	Latest assessment: 2019	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	- *Tangaroa* trawl survey index - CPUE - age frequency (1993–1996, 2012–2014) - length frequency	2 – Medium or Mixed Quality: high CVs 2 – Medium or Mixed Quality: not accepted as an index of abundance 1 – High Quality 1 – High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	There is currently no reliable way of tracking abundance due to the characteristics and behaviour of the fish and the fishing fleet.	

Qualifying Comments
-

Fishery Interactions
-

- **SWA 10**

No information is available for SWA 10.

7. FOR FURTHER INFORMATION

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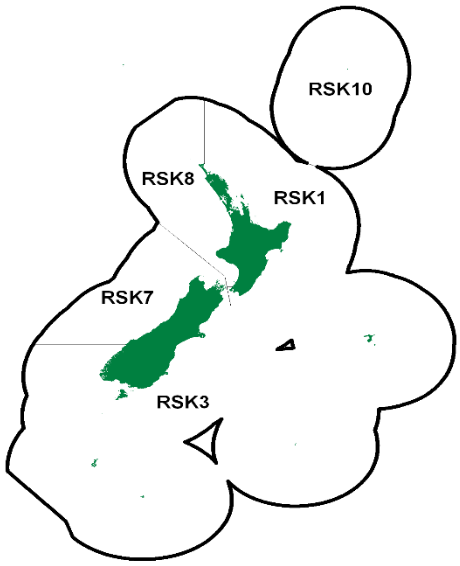
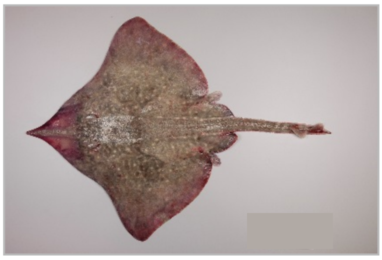
ROUGH SKATE (RSK)

(*Zearaja nasuta*)
Waewae





1. FISHERY SUMMARY

1.1 Commercial fisheries

Rough skate (*Zearaja nasuta*, RSK) are fished commercially in New Zealand in close association with smooth skates, which are also known as barndoor skates. Although rough skates grow considerably smaller than smooth skates, RSK is still landed and processed. Two other species of deepwater skate (*Bathyraja shuntovi* and *Raja hyperborea*) are large enough to be of commercial interest but are relatively uncommon and probably comprise a negligible proportion of the landings.

Skate flesh ammoniates rapidly after death, so the wings are removed at sea, and chilled or frozen. On arrival at the shore factories, the wings are machine-skinned, graded and packed for sale. Most of the product is exported to Europe, especially France and Italy. Skates of all sizes are processed, although some factories impose a minimum weight limit of about 1 kg (200 g per wing), and occasionally wings from very large smooth skates are difficult to market.

Rough skates occur throughout New Zealand, but are most abundant around the South Island in depths down to 500 m. Most of the catch is taken as bycatch by bottom trawlers, but skates are also taken by longliners. Significant longline bycatch has been reported from the Bounty Plateau in QMA 6. There is no clear separation of the depth ranges inhabited by rough and smooth skates; however, smooth skate tend to occur slightly deeper than rough skate (Beentjes & Stevenson 2000, 2001, Stevenson & Hanchet 2000).

Many fishers and processors did not previously distinguish rough and smooth skates in their landing returns, and coded them instead as "skates" (SKA). Because it is impossible to determine the species composition of the catch from landings data prior to introduction of these species into the QMS in 2003, all pre-QMS data reported here consist of the sum of the three species codes RSK, SSK and SKA. Landings have been converted from processed weight to whole weight by application of conversion factors. Further, following introduction into the QMS in 2003, the two skate species were not always correctly identified and a considerable, but unknown, catch of either species is misidentified with over-reporting of rough skate and, correspondingly, under-reporting of smooth skate (Beentjes 2005). Neither fishers nor processors were distinguishing between the two skate species or reporting catches of each species correctly at the time of the study in 2004. It is not known if reporting has improved since this time.

There have been historical changes to the conversion factors applied to skates by MAF Fisheries and Ministry of Fisheries. No record seems to have been kept of the conversion factors in use before 1987, so it is not possible to reconstruct the time series of landings data using the currently accepted factors. Consistent and appropriate conversion factors have been applied to skate landings since the end of the 1986–87 fishing year. Before that, it appears that a lower conversion factor was applied, resulting in an underestimation of landed weight by about 20%. No correction has been made for that in this report.

New Zealand annual skate landings, estimated from a variety of sources, are shown in Table 1. No FSU deepwater data were available before 1983, and it is not known whether deepwater catches, including those of foreign fishing vessels, were significant during that period. CELR and CLR data are provided by inshore and deepwater trawlers respectively. “CELR estimated” landings were always less than “CELR landed” landings, because the former include only the top five fish species (by weight) caught by trawlers, whereas the latter include all species landed. As a relatively minor bycatch, skates frequently do not fall into the top five species. The sum of the “CELR landed” and CLR data provides an estimate of the total skate landings. This estimate usually agreed well with LFRR data supplied by fish processors, especially in 1993–94 and 1994–95, but in 1992–93 the difference was 467 t. The “best estimate” of the annual historical landings comes from FSU data up to 1985–86, and LFRR data thereafter.

Table 1: New Zealand skate landings for calendar years 1974–1983, and fishing years (1 October–30 September) 1983–84 to 1995–96. Values in parentheses are based on part of the fishing year only. Landings do not include foreign catch before 1983, or unreported discards. FSU = Fisheries Statistics Unit; CELR = Catch, Effort and Landing Return; CLR = Catch Landing Return; LFRR = Licensed Fish Receivers Return; Best Estim. = best available estimate of the annual skate catch; - = no data.

			FSU		CELR		CELR Landed		
Year	**Inshore**	**Deepwater**	**Total**	**Estim.**	**Landed**	**CLR**	**+CLR**	**LFRR**	**Best Estim.**
1974	23	-	-	-	-	-	-	-	23
1975	30	-	-	-	-	-	-	-	30
1976	28	-	-	-	-	-	-	-	28
1977	27	-	-	-	-	-	-	-	27
1978	36	-	-	-	-	-	-	-	36
1979	165	-	-	-	-	-	-	-	165
1980	441	-	-	-	-	-	-	-	441
1981	426	-	-	-	-	-	-	-	426
1982	648	-	-	-	-	-	-	-	648
1983	634	178	812	-	-	-	-	-	812
1983–84	686	298	983	-	-	-	-	-	983
1984–85	636	250	886	-	-	-	-	-	886
1985–86	613	331	944	-	-	-	-	-	944
1986–87	723	285	1 007	-	-	-	-	1 019	1 019
1987–88	1 005	421	1 426	-	-	-	-	1 725	1 725
1988–89	(530)	(136)	(665)	(252)	(265)	(28)	(293)	1 513	1 513
1989–90	-	-	-	780	1 171	410	1 581	1 769	1 769
1990–91	-	-	-	796	1 334	359	1 693	1 820	1 820
1991–92	-	-	-	1 112	1 994	703	2 698	2 620	2 620
1992–93	-	-	-	1 175	2 595	824	3 418	2 951	2 951
1993–94	-	-	-	1 247	2 236	788	3 024	2 997	2 997
1994–95	-	-	-	956	1 973	829	2 803	2 789	2 789
1995–96	-	-	-	-	-	-	-	2 789	2 789

Total skate landings (based on the “best estimate” in Table 1) were negligible up to 1978, presumably because of a lack of suitable markets and the availability of other more abundant and more desirable species. Landings then increased linearly to reach nearly 3 000 t in 1992–93 and 1993–94, and remained between 2 600 and 3 100 t until the separation of skate species under the QMS. Reported landings of rough skate are provided in Table 2.

Rough skates (RSK) were introduced into the QMS as a separate species from 1 October 2003 with allowances, TACCs and TACs as in Table 3. Figure 1 shows the historical landings and TACC values for the main RSK stocks. Owing to problems associated with identification of rough and smooth skates, reported landings of each species are probably not accurate (Beentjes 2005). Initiatives to improve identification of these species begun in 2003 may have resulted in more accurate data. About 83% of rough skate landings since the fishing year 2003–04 have come from RSK 3. Landings recorded for RSK 3 have generally been below the TACC, averaging just under 1500 t annually from 2003–04 to 2018–19. In contrast RSK 8 has been consistently over caught, relative to the TACC, since it was introduced to the QMS. It was put on Schedule 6 on 1 October 2006.

Table 2: Reported landings (t) of SKA and RSK by QMA and fishing year, 1996–97 to present.

Fishstock	RSK 1		RSK 3		RSK 7		RSK 8		RSK 10		
FMA	1–2		3–6		7		8–9		10		All
Skate (SKA)*	**Land.**	**TACC**	**Land.**	**TACC**	**Land.**	**TACC**	**Land.**	**TACC**	**Land.**	**TACC**	**Total**
1996–97	43	-	894	-	380	-	30	-	0	-	1 347
1997–98	44	-	855	-	156	-	31	-	0	-	1 086
1998–99	48	-	766	-	228	-	12	-	0	-	1 054
1999–00	75	-	775	-	253	-	25	-	0	-	1 128
2000–01	88	-	933	-	285	-	28	-	0	-	1 334
2001–02	132	-	770	-	311	-	35	-	0	-	1 248
2002–03	121	-	857	-	293	-	32	-	0	-	1 303
2003–04	< 1	-	< 1	-	< 1	-	< 1	-	0	-	1
Rough skate (RSK)											
1996–97	15	-	265	-	69	-	3	-	0	-	352
1997–98	32	-	493	-	44	-	5	-	0	-	574
1998–99	22	-	607	-	33	-	4	-	0	-	666
1999–00	20	-	720	-	37	-	2	-	0	-	779
2000–01	27	-	569	-	42	-	4	-	0	-	642
2001–02	24	-	607	-	25	-	3	-	0	-	659
2002–03	18	-	1 060	-	27	-	11	-	0	-	1 118
2003–04	48	111	1 568	1 653	191	-	33	-	0	-	1 840
2004–05	72	111	1 815	1 653	173	201	55	21	0	0	2 115
2005–06	72	111	1 446	1 653	153	201	28	21	0	0	1 699
2006–07	68	111	1 475	1 653	197	201	35	21	0	0	1 768
2007–08	80	111	1 239	1 653	206	201	46	21	0	0	1 573
2008–09	79	111	1 591	1 653	226	201	46	21	0	0	1 942
2009–10	87	111	1 546	1 653	225	201	46	21	0	0	1 905
2010–11	91	111	1 547	1 653	199	201	45	21	0	0	1 882
2011–12	76	111	1 257	1 653	189	201	41	21	0	0	1 563
2012–13	92	111	1 573	1653	180	201	44	21	0	0	1 889
2013–14	105	111	1 798	1 653	166	201	54	21	0	0	2 122
2014–15	88	111	1 324	1 653	151	201	41	21	0	0	1 605
2015–16	87	111	1 263	1 653	171	201	31	21	0	0	1 553
2016–17	106	111	1 528	1 653	165	201	37	21	0	0	1 836
2017–18	120	111	1 345	1 653	153	201	39	21	0	0	1 657
2018–19	84	111	1 185	1 653	136	201	26	21	0	0	1 432

*Use of the code SKA ceased once skates were introduced into the QMS in October 2003 and rough skates and smooth skates were recognised as a separate species. From this time all landings of skates have been reported against either the RSK or SSK code.

Table 3: Recreational, customary, and other mortality allowances (t), Total Allowable Commercial Catches (TACC, t) and Total Allowable Catches (TAC, t) declared for RSK on introduction into the QMS in October 2003.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other Mortality	TACC	TAC
RSK 1 (FMAs 1–2)	1	1	1	111	114
RSK 3 (FMAs 3–6)	1	1	17	1 653	1 672
RSK 7	1	1	2	201	205
RSK 8 (FMAs 8–9)	1	1	1	21	24
RSK 10	0	0	0	0	0

Figure 1: Reported commercial landings and TACC for the four main RSK stocks. From top to bottom: RSK 1 (Auckland East), RSK 3 (South East Coast, South East Chatham Rise, Sub-Antarctic, Southland), and RSK 7 (Challenger), and RSK 8 (Central Egmont, Auckland West).

1.2 Recreational fisheries
Recreational fishing surveys indicate that rough skates are very rarely caught by recreational fishers.

1.3 Customary non-commercial fisheries
Quantitative information on the level of customary non-commercial take is not available.

1.4 Illegal catch
Quantitative information on the level of illegal catch is not available.

1.5 Other sources of mortality
Because skates are taken mainly as bycatch of bottom trawl fisheries, historical catches have probably been proportional to the amount of effort in the target trawl fisheries. Past catches were probably higher than historical landings data suggest, because of unrecorded discards and unrecorded foreign catch before 1983.

2. BIOLOGY

Little is known about the reproductive biology of rough skates. Rough skates reproduce by laying yolky eggs, enclosed in leathery cases, on the seabed. Rough skates lay their eggs in spring-summer (Francis 1997). Two eggs are laid at a time, but the number of eggs laid annually by a female is unknown. A single embryo develops inside each egg case and the young hatch at about 10–15 cm pelvic length (body length excluding the tail) (Francis 1997).

Rough skates grow to at least 79 cm pelvic length, and females grow larger than males. The greatest reported age is 9 years for a 70 cm pelvic length female, and females may live longer than males (Francis et al 2001a, b). There are no apparent differences in growth rate between the sexes. Males reach 50% maturity at about 52 cm and 4 years, and females at 59 cm and 6 years. The most plausible estimate of *M* is 0.25–0.35. Biological parameters relevant to stock assessment are shown in Table 4.

Table 4: Estimates of biological parameters for Rough skates (RSK).

Fishstock			**Estimate**	**Source**
1. Natural mortality (M)				
RSK 3			0.25–0.35	Francis et al (2001b)
2. Weight = a (length) ^{b} (weight in g, length in cm pelvic length)				
		a	b	
RSK males		0.0393	2.838	Francis (1997)
RSK females		0.0218	3.001	Francis (1997)
3. von Bertalanffy growth parameters				
	K	t_0	L_∞	
RSK 3 (both sexes)	0.16	-1.2	91.3	Francis et al (2001b)
RSK 3 (both sexes)	0.096	-0.78	151.8	Francis et al (2004)

3. STOCKS AND AREAS

Nothing is known about stock structure or movement patterns in skates. Inshore trawl surveys of the east and west coasts of the South Island used to tag and release lively rough skate but this has been discontinued. Tag returns have been low and data from what returns there have been have not been analysed. Rough skates are distributed throughout most of New Zealand, from the Three Kings Islands to Campbell Island and the Chatham Islands, including the Challenger Plateau, Chatham Rise and Bounty Plateau. Rough skates have not been recorded from QMA 10.

In this report, rough skate landings have been presented by QMA. QMAs would form appropriate management units in the absence of any information on biological stocks.

4. STOCK ASSESSMENT

This is the first stock assessment for skates. No yield estimates have been made for skates.

4.1 Estimates of fishery parameters and abundance

Relative biomass estimates are available for rough skates from a number of trawl survey series (Table 5). Biomass estimates are not provided for surveys of: (a) west coast North Island because of major changes in survey areas and strata during the series; or (b) east Northland, Hauraki Gulf and Bay of Plenty because of the low relative biomass of rough skates present (usually less than 100 t). In the first survey of each of two series -east coast South Island and Chatham Rise- the two skate species were not (fully) distinguished. Furthermore, there are doubts about the accuracy of species identification in some other earlier surveys (prior to 1996). Consequently, trends in biomass of individual species must be interpreted cautiously. To enable comparison among all surveys within each series, total skate biomass is also reported.

As the catch from the east coast South Island trawl surveys changes without wide inter-annual fluctuations and the CVs are relatively low (typically <30%) it appears that the time series may be able to track rough skate biomass in FMA 3.Fluctuations in biomass estimates of rough skate from the WCSI suggest that abundance is probably not being monitored (Stevenson & Hanchet 2000).

4.2 Biomass estimates

4.2.1 Trawl Surveys

Indices of relative biomass are available from recent *Tangaroa* and *Kaharoa* trawl surveys of the Chatham Rise, east coast South Island (ECSI) and west coast South Island (WCSI) (Table 5, and Figures 2–3).

Estimates of biomass for RSK from Chatham Rise, WCSI, and ECSI trawl surveys are provided in Figures 2–3. CVs are reasonably large and biomass appears to have fluctuated without trend for the Chatham Rise time series. Biomass estimates have fluctuated for the WCSI time series and have been relatively stable for the ECSI time series since the latter was reinstated in 2007. CVs are relatively low for both time series (generally <30%).

ECSI trawl surveys

The east coast South Island winter surveys from 1991 to 1996 (30–400 m) were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range; but these were discontinued after the fifth in the annual time series because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007, and this time were expanded to include the 10–30 m depth range, in order to monitor elephant fish and red gurnard which were officially included in the list of target species in 2012. Only the 2007, 2012, 2014, 2016 and 2018 surveys provide full coverage of the 10–30 m depth range.

The 2018 rough skate biomass estimate in the core strata (30–400 m) for the east coast South Island trawl survey was only slightly less than that in 201 and 2016, when biomass was the highest in the time series and more than double that of the highest biomass estimate of the 1990s (Table 5, Figure 3) (MacGibbon et al. 2019). The additional biomass captured in the 10–30 m depth range accounted for 30%, 20%, 38%, 27%, and 19% of the biomass in the core plus shallow strata (10–400 m) for 2007, 2012, 2014, 2016, and 2018 respectively, indicating that in terms of biomass, it is essential to monitor the core plus shallow strata (10–400 m).

The rough skate length distributions for the east coast South Island winter trawl surveys core strata (30–400 m) have no clear modes, comprise multiple year classes, and very small skate tend to be found in shallow water in some surveys (Beentjes & MacGibbon 2013, Beentjes et al 2015, 2016, McGibbon et al. 2019). The survey appears to be monitoring pre-recruited lengths down to 1+ age and the full recruited distribution, but no individual cohorts are discernible. Length frequency distributions are reasonably consistent among surveys with no lengths measured before 1996. The addition of the 10–30 m depth range has changed the shape of the length frequency distribution only slightly for some surveys, with more smaller skate present (Beentjes et al 2015, 2016, Beentjes & MacGibbon 2013, MacGibbon et al. 2019).

WCSI trawl surveys

The west coast South Island autumn trawl surveys have been undertaken since 1992 and regularly catch rough skate. However biomass has fluctuated with no apparent trend throughout the time series and CVs are relatively modest, ranging from 20–34%, making it unclear to what degree the survey monitors abundance.

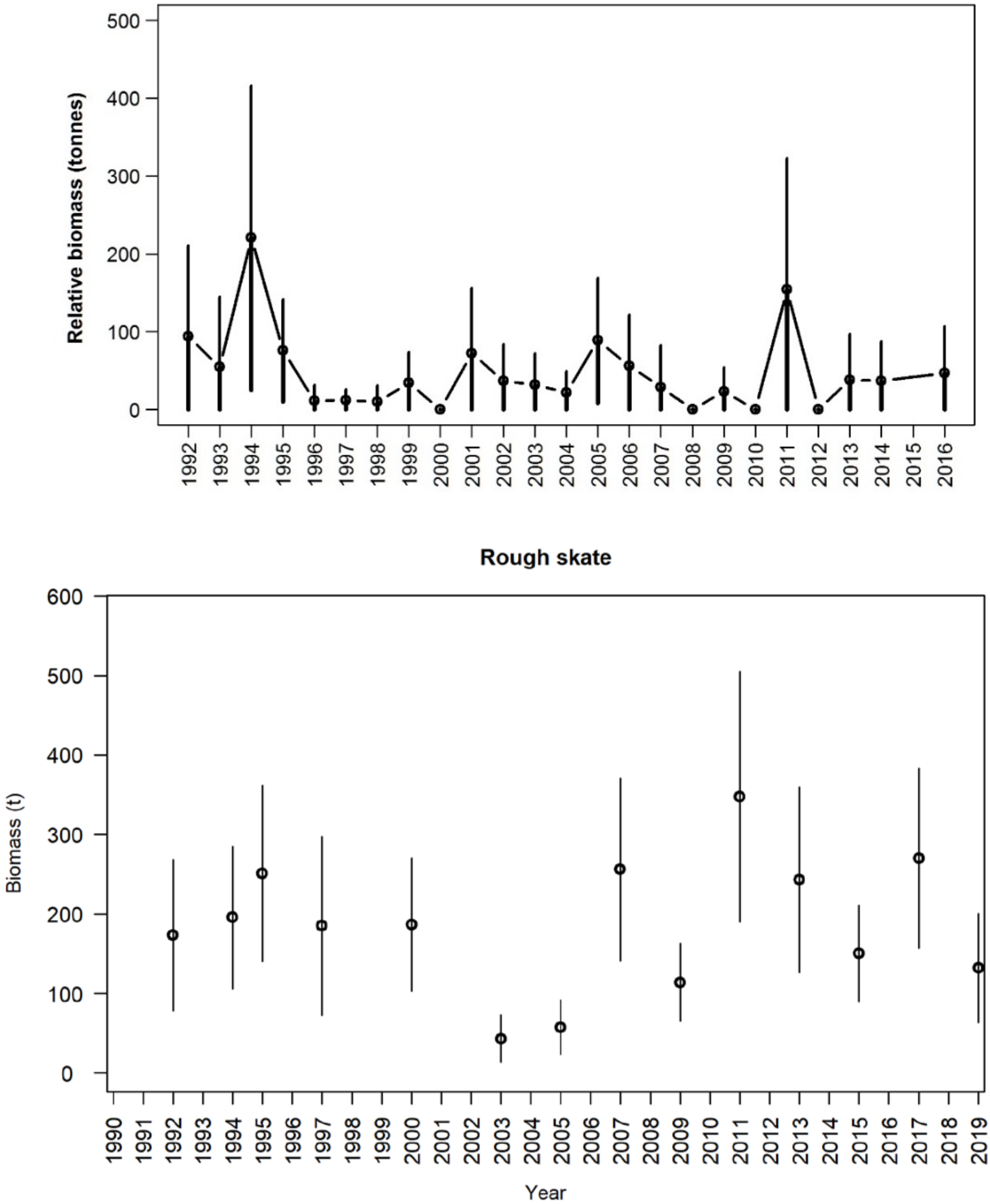


Figure 2: [Top] Rough skate biomass for the Chatham Rise trawl survey time series, [Bottom] Rough skate biomass for the west coast South Island inshore trawl survey time series (error bars are ± two standard deviations).

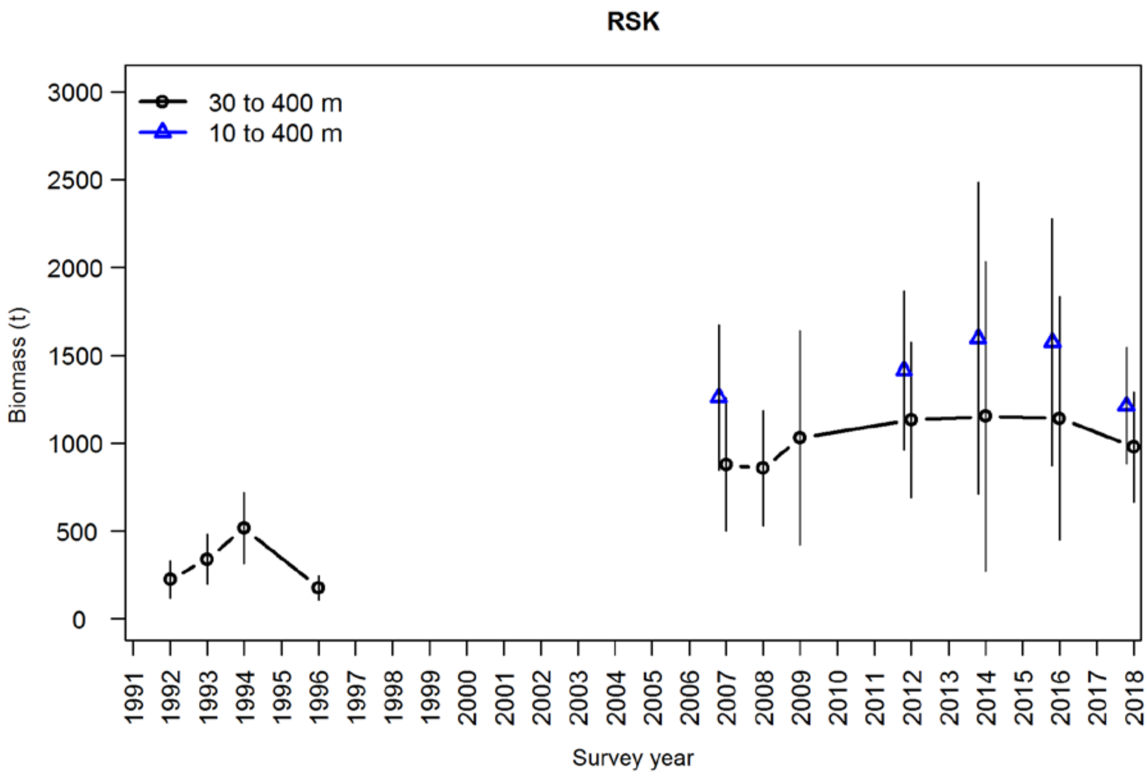


Figure 3: Rough skate total biomass for the ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m). Error bars are ± two standard deviations.

4.3 Yield estimates and projections

MCY cannot be estimated.

The *MCY* estimator that has the lowest data requirements ($MCY = cY_{AV}$; Method 4), relies on selecting a time period during which there were "no systematic changes in fishing mortality (or fishing effort, if this can be assumed to be proportional to fishing mortality)". This method was not applied because no information is currently available on skate fishing mortality, or on trawl fishing effort in the main skate fishing areas.

CAY cannot be estimated.

4.4 Other factors

Species that constitute a minor bycatch of trawl fisheries are often difficult to manage using TACCs and ITQs. Skates are widely and thinly distributed, and would be difficult for trawlers to avoid after the quota had been caught. A certain level of incidental bycatch is therefore inevitable. However, skates are relatively hardy, and frequently survive being caught in trawls (though mortality would depend on the length of the tow and the weight of fish in the cod end). Skates returned to the sea alive probably have a greater chance of survival than most other fishes.

Table 5: Doorspread biomass estimates (t) and coefficients of variation (CV %) of rough skates and total skates (both rough and smooth). **[Continued on next page]**

		Rough skate		Total skates		Rough skate	
Year	Trip Code	Biomass	CV	Biomass	CV	Biomass	CV (%)
East coast North Island							
1993	KAH9304	76	28	99	-	-	-
1994	KAH9402	189	12	333	-	-	-
1995	KAH9502	52	20	72	-	-	-
1996	KAH9602	309	24	394	-	-	-
West coast South Island and Tasman/Golden Bays							
1992	KAH9204	173	27	512	-	-	-
1994	KAH9404	196	23	537	-	-	-
1995	KAH9504	251	22	566	-	-	-
1997	KAH9701	185	30	487	-	-	-
2000	KAH0004	186	23	326	-	-	-
2003	KAH0304	43	34	134	-	-	-
2005	KAH0503	58	30	138	-	-	-
2007	KAH0704	256	23	300	-	-	-
South Island west coast and Tasman/Golden Bays (FMA 7)							
2009	KAH0904	114	21	181	-	-	-
2011	KAH1104	347	23	532	-	-	-
2013	KAH1305	243	24	431	-		
2015	KAH1503	150	20	492	-		
2017	KAH1703	270	21	333	-		
2019	KAH1902	132	26	704			
East coast South Island (FMA 3)							
Winter		30–400 m		30–400 m		10–400 m	
1991	KAH9105	-	-	1928	25	-	-
1992	KAH9205	224	24	829	16	-	-
1993	KAH9306	335	21	993	21	-	-
1994	KAH9406	517	20	823	15	-	-
1996	KAH9606	177	19	562	18	-	-
2007	KAH0705	878	22	1 580	-	1 261	16
2008	KAH0806	858	19	1 412	-	-	-
2009	KAH0905	1 029	30	1 765	-	-	-
2012	KAH1207	1 113	20	2 138	-	1 414	16
2014	KAH1402	1 153	38	1 790	-	1 597	28
2016	KAH1605	1 142	30	1 805	-	1 576	22
2018	KAH1803	978	16	1 642	-	1 213	14
East coast South Island (FMA 3) Summer							
1996–97	KAH9618	1 336	15	2 057	-	-	-
1997–98	KAH9704	1 082	13	1 567	-	-	-
1998–99	KAH9809	1 175	10	1 625	-	-	-
1999–00	KAH9917	329	23	698	-	-	-
2000–01	KAH0014	222	34	470	-	-	-
Chatham Rise							
1991–92	TAN9106	-	-	2 129	-	-	-
1992–93	TAN9212	55	83	1 126	-	-	-
1994	TAN9401	220	44	1 178	-	-	-
1995	TAN9501	76	43	845	-	-	-
1996	TAN9601	11	100	1 522	-	-	-
1997	TAN9701	12	58	1 944	-	-	-
1998	TAN9801	10	100	1 935	-	-	-
1999	TAN9901	34	60	1 772	-	-	-
2000	TAN0001	0	-	1 369	-	-	-
2001	TAN0101	72	59	2 393	-	-	-
2002	TAN0201	37	65	2 148	-	-	-
2004	TAN0401	22	60	2 066	-	-	-
2005	TAN0501	89	45	1 869	-	-	-
2006	TAN0601	56	45	1 577	-	-	-
2007	TAN0701	29	56	1 951	-	-	-
2008	TAN0801	0	-	1 376	-	-	-
2009	TAN0901	23	67	1 185	-	-	-
2010	TAN1001	-	-	1 576	-	-	-
2011	TAN1101	-	-	1 009	-	-	-
2012	TAN1201	-	-	813	-	-	-
2013	TAN1301	38	78.5				
2014	TAN1401	37	69.1				
2016	TAN1601	47	64.7				

Table 5: [Continued]

Stewart-Snares Shelf							
1993	TAN9301	592	20	1 120	-	-	-
1994	TAN9402	1 064	15	1 406	-	-	-
1995	TAN9502	801	7	1 136	-	-	-
1996	TAN9604	1 055	11	1 559	-	-	-
Survey discontinued							
Stewart-Snares Shelf and Sub-Antarctic (Summer)*							
1991	TAN9105	37	72	419	-	-	-
1992	TAN9211	52	69	165	-	-	-
1993	TAN9310	132	57	249	-	-	-
2000	TAN0012	201	56	267	-	-	-
Stewart-Snares Shelf and Sub-Antarctic (Autumn)							
1992	TAN9204	48	100	141	-	-	-
1993	TAN9304	251	57	428	-	-	-
1996	TAN9605	22	71	857	-	-	-
1998	TAN9805	71	77	607	-	-	-

*Biomass estimates are for core 300–800 m strata only

A data informed qualitative risk assessment was completed on all chondrichthyans (sharks, skates, rays and chimaeras) at the New Zealand scale in 2014 (Ford et al 2015). Rough skate was ranked number one (highest) in terms of risk of the eleven QMS chondrichthyan species. Data were described as existing but poor for the purposes of the assessment and consensus over this risk score was achieved by the expert panel. This risk assessment does not replace a stock assessment for this species but may influence research priorities across species.

5. STATUS OF THE STOCKS

No estimates of current and reference biomass are available.

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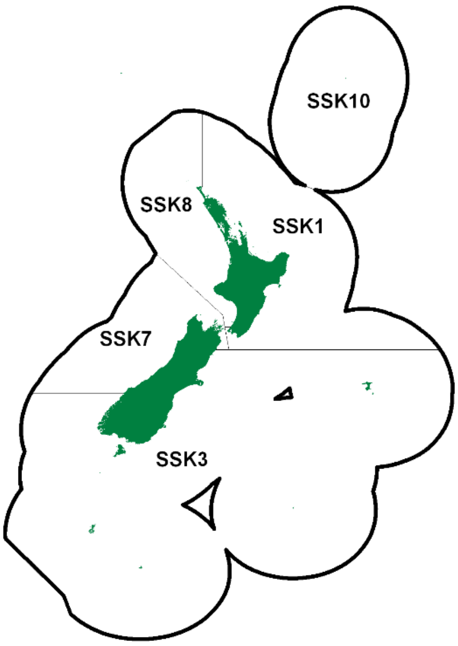
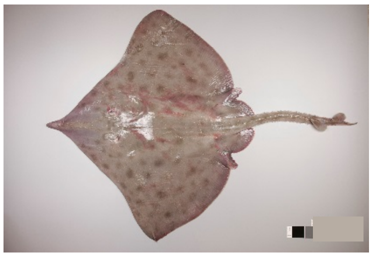
SMOOTH SKATE (SSK)
(*Dipturus innominata*)
Uku





1. FISHERY SUMMARY

1.1 Commercial fisheries

Smooth skate (*Dipturus innominata*, SSK), which are also known as barndoor skates, are fished commercially in close association with rough skates (RSK) in New Zealand. Smooth skates grow considerably larger than rough skates, but both species are landed and processed. Two other species of deepwater skate (*Bathyraja shuntovi* and *Raja hyperborea*) are large enough to be of commercial interest but are relatively uncommon and probably comprise a negligible proportion of the landings.

Skate flesh ammoniates rapidly after death, so the wings are removed at sea, and chilled or frozen. On arrival at the shore factories, the wings are machine-skinned, graded and packed for sale. Most of the product is exported to Europe, especially France and Italy. Skates of all sizes are processed, though some factories impose a minimum weight limit of about 1 kg (200 g per wing), and occasionally wings from very large smooth skates are difficult to market.

Smooth skates occur throughout New Zealand, but are most abundant around the South Island in depths down to 500 m. Most of the catch is taken as bycatch by bottom trawlers, but skates are also taken by longliners. Significant longline bycatch has been reported from the Bounty Plateau in QMA 6. While there is no clear separation of the depth ranges inhabited by rough and smooth skates, smooth skates tend to occur slightly deeper than rough skate (Beentjes & Stevenson 2000, 2001, Stevenson & Hanchet 2000).

Many fishers and processors did not previously distinguish rough and smooth skates in their landing returns, and coded them instead as “skates” (SKA). Because it is impossible to determine the species composition of the catch from landings data prior to introduction of these species into the QMS, all pre-QMS data reported here consist of the sum of the three species codes RSK, SSK and SKA. Landings have been converted from processed weight to whole weight by application of conversion factors. Further, following introduction into the QMS in 2003, the two skate species were not always correctly identified and a considerable, but unknown, catch of either species is misidentified with over-reporting of rough skate and, correspondingly, under-reporting of smooth skate (Beentjes 2005). Neither fishers nor processors were distinguishing between the two skate species or reporting catches of each species correctly at the time of the study in 2004. It is not known if reporting has improved since that time.

There have been historical changes to the conversion factors applied to skates by MAF Fisheries and Ministry of Fisheries. No record seems to have been kept of the conversion factors in use before 1987, so it is not possible to reconstruct the time series of landings data using the currently accepted factors. Consistent and appropriate conversion factors have been applied to skate landings since the end of the 1986–87 fishing year. Before that, it appears that a lower conversion factor was applied, resulting in an underestimation of landed weight by about 20%. No correction has been made for that in this report.

New Zealand annual skate landings, estimated from a variety of sources, are shown in Table 1. No FSU deepwater data were available before 1983, and it is not known whether deepwater catches, including those of foreign fishing vessels, were significant during that period. CELR and CLR data are provided by inshore and deepwater trawlers respectively. “CELR estimated” landings were always less than “CELR landed” landings, because the former include only the top five fish species (by weight) caught by trawlers, whereas the latter include all species landed. As a relatively minor bycatch, skates frequently do not fall into the top five species. The sum of the “CELR landed” and CLR data provides an estimate of the total skate landings. This estimate usually agreed well with LFRR data supplied by fish processors, especially in 1993–94 and 1994–95, but in 1992–93 the difference was 467 t. The “best estimate” of the annual historical landings comes from FSU data up to 1985–86, and LFRR data thereafter.

Table 1: New Zealand skate landings for calendar years 1974–1983, and fishing years (1 October – 30 September) 1983–84 to 1995–96. Values in parentheses are based on part of the fishing year only. Landings do not include foreign catch before 1983, or unreported discards. FSU = Fisheries Statistics Unit; CELR = Catch, Effort and Landing Return; CLR = Catch Landing Return; LFRR = Licensed Fish Receivers Return; Best Estim. = best available estimate of the annual skate catch; - = no data.

	FSU			CELR			CELR Landed		
Year	Inshore	Deepwater	Total	Estim.	Landed	CLR	+CLR	LFRR	Best Estim.
1974	23	-	-	-	-	-	-	-	23
1975	30	-	-	-	-	-	-	-	30
1976	28	-	-	-	-	-	-	-	28
1977	27	-	-	-	-	-	-	-	27
1978	36	-	-	-	-	-	-	-	36
1979	165	-	-	-	-	-	-	-	165
1980	441	-	-	-	-	-	-	-	441
1981	426	-	-	-	-	-	-	-	426
1982	648	-	-	-	-	-	-	-	648
1983	634	178	812	-	-	-	-	-	812
1983–84	686	298	983	-	-	-	-	-	983
1984–85	636	250	886	-	-	-	-	-	886
1985–86	613	331	944	-	-	-	-	-	944
1986–87	723	285	1 007	-	-	-	-	1 019	1 019
1987–88	1 005	421	1 426	-	-	-	-	1 725	1 725
1988–89	(530)	(136)	(665)	(252)	(265)	(28)	(293)	1 513	1 513
1989–90	-	-	-	780	1 171	410	1 581	1 769	1 769
1990–91	-	-	-	796	1 334	359	1 693	1 820	1 820
1991–92	-	-	-	1 112	1 994	703	2 698	2 620	2 620
1992–93	-	-	-	1 175	2 595	824	3 418	2 951	2 951
1993–94	-	-	-	1 247	2 236	788	3 024	2 997	2 997
1994–95	-	-	-	956	1 973	829	2 803	2 789	2 789
1995–96	-	-	-	-	-	-	-	2 789	2 789

Total skate landings (based on the “best estimate” in Table 1) were negligible up to 1978, presumably because of a lack of suitable markets and the availability of other more abundant and desirable species. Landings then increased linearly to reach nearly 3 000 t in 1992–93 and 1993–94, and remained between 2 600 and 3 100 t until the separation of skate species under the QMS. Reported landings of smooth skate are provided in Table 2.

Smooth skates (SSK) were introduced into the QMS as a separate species from 1 October 2003 with allowances, TACCs and TACs in Table 3. Figure 1 shows the historical landings and TACC values for the main SSK stocks. Owing to problems associated with identification of rough and smooth skates, reported catches of each species are probably not accurate (Beentjes 2005). Initiatives to improve identification of these species begun in 2003 may have resulted in more accurate data. The largest smooth skate Fishstock is SSK 3, which on average has contributed 60% of landings since the fishing year 2003-04. SSK 3 landings have always remained below the TACC, ranging between 408 t and 473 t from 2003-04 to 2007-08, before decreasing to about 300 t in 2009-10 to 2012-13. Landings then increased again, peaking at 511 t in 2017-18. SSK 8 has been consistently over caught, relative to the TACC, since the fishing year 2007-08. Most recently from 2016-17 to 2018-19 an average of 48 t of landings were recorded, exceeding the TACC by 28 t. It was put on Schedule 6 on 1 October 2006.

Table 2: Reported landings (t) of SKA and SSK by QMA and fishing year, 1996–97 to 2018–19.

Fishstock	**SSK 1**		**SSK 3**		**SSK 7**		**SSK 8**		**SSK 10**		**Total**
FMAs	**1–2**		**3–6**		**7**		**8–9**		**10**		**All**
Skate (SKA)*	Land.	TACC	Land.	TACC	Land.	TACC	Land.	TACC	Land.	TACC	Total
1996–97	43	-	894	-	380	-	30	-	0	-	1 347
1997–98	44	-	855	-	156	-	31	-	0	-	1 086
1998–99	48	-	766	-	228	-	12	-	0	-	1 054
1999–00	75	-	775	-	253	-	25	-	0	-	1 128
2000–01	88	-	933	-	285	-	28	-	0	-	1 334
2001–02	132	-	770	-	311	-	35	-	0	-	1 248
2002–03	121	-	857	-	293	-	32	-	0	-	1 303
2003–04	< 1	-	< 1	-	< 1	-	< 1	-	0	-	1
Smooth skate (SSK)											
1996–97	10	-	782	-	102	-	5	-	0	-	899
1997–98	5	-	901	-	121	-	4	-	0	-	1 031
1998–99	5	-	1 011	-	100	-	15	-	0	-	1 131
1999–00	5	-	877	-	73	-	16	-	0	-	971
2000–01	9	-	859	-	104	-	7	-	0	-	979
2001–02	17	-	794	-	89	-	7	-	0	-	907
2002–03	19	-	704	-	167	-	3	-	0	-	893
2003–04	79	37	431	579	146	213	15	20	0	0	671
2004–05	82	37	408	579	125	213	15	20	0	0	630
2005–06	72	37	468	579	163	213	12	20	0	0	715
2006–07	58	37	473	579	155	213	6	20	0	0	693
2007–08	47	37	422	579	171	213	21	20	0	0	661
2008–09	38	37	332	579	168	213	22	20	0	0	560
2009–10	36	37	290	579	194	213	26	20	0	0	546
2010–11	27	37	307	579	243	213	32	20	0	0	609
2011–12	24	37	283	579	209	213	27	20	0	0	544
2012–13	36	37	292	579	231	213	39	20	0	0	598
2013–14	43	37	336	579	225	213	39	20	0	0	641
2014–15	27	37	361	579	198	213	30	20	0	0	617
2015–16	38	37	405	579	222	213	30	20	0	0	695
2016–17	56	37	481	579	244	213	46	20	0	0	827
2017–18	58	37	511	579	198	213	52	20	0	0	819
2018–19	32	37	445	579	178	213	47	20	0	0	702

*Use of the code SKA ceased once skates were introduced into the QMS in October 2003 and rough skates and smooth skates were recognised as a separate species. From this time all landings of skates have been reported against either the RSK or SSK code.

Figure 1: Reported commercial landings and TACCs for the four main SSK stocks. From top: SSK 1 (Auckland East) and SSK 3 (South East Coast, South East Chatham Rise, Sub-Antarctic, Southland), SSK 7 (Challenger) and SSK 8 (Central Egmont, Auckland West).

1.2 Recreational fisheries
Recreational fishing surveys indicate that skates are very rarely caught by recreational fishers.

Table 3: Recreational and customary non-commercial allowances (t), Total Allowable Commercial Catches (TACC, t) and Total Allowable Catch (TAC, t) declared for SSK on introduction into the QMS in October 2003.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other Mortality	TACC	TAC
SSK 1 (FMAs 1–2)	1	1	1	37	40
SSK 3 (FMAs 3–6)	1	1	6	579	587
SSK 7	1	1	2	213	217
SSK 8 (FMAs 8–9)	1	1	1	20	23
SSK 10	0	0	0	0	0

1.3 Customary non-commercial fisheries
Quantitative information on the level of customary non-commercial take is not available.

1.4 Illegal catch
Quantitative information on the level of illegal catch is not available.

1.5 Other sources of mortality
Because skates are taken mainly as bycatch of bottom trawl fisheries, historical catches have probably been proportional to the amount of effort in the target trawl fisheries. Past catches were probably higher than historical landings data suggest because of unrecorded discards and unrecorded foreign catch before 1983.

2. BIOLOGY

Little is known about the reproductive biology of smooth skates. Smooth skates reproduce by laying yolky eggs, enclosed in leathery cases, on the seabed. Two eggs are laid at a time, but the number of eggs laid annually by a female is unknown. A single embryo develops inside each egg case and the young hatch at about 10–15 cm pelvic length (body length excluding the tail) (Francis 1997).

The greatest reported age for smooth skate is 28 years for a 155 cm pelvic length female (Francis et al 2004). Females grow larger than males, and also appear to live longer. There are no apparent differences in growth rate between the sexes. Males reach 50% maturity at about 93 cm and 8 years, and females at 112 cm and 13 years. However, the small sample size of mature animals, particularly females, means that the maturity ogives are poorly defined. The most plausible estimate of *M* is 0.10–0.20. Biological parameters relevant to stock assessment are shown in Table 4.

Table 4: Estimates of biological parameters for skates.

Fishstock			Estimate	Source
1. Natural mortality (*M*)				
SSK 3			0.12–0.15	Francis et al (2004)
2. Weight = a (length) ^{b} (weight in g, length in cm pelvic length)				
		a	b	
SSK both sexes		0.0268	2.933	Francis (1997)
3. von Bertalanffy growth parameters*				
	K	t_0	L_∞	
SSK 3 (both sexes)	0.095	-1.06	150.5	Francis et al (2001b)
SSK 3 (Males)	0.117	-1.28	133.6	Francis et al (2004)

3. STOCKS AND AREAS

Nothing is known about the stock structure or movement patterns of smooth skates. Smooth skates are distributed throughout most of New Zealand, from the Three Kings Islands to Campbell Island and the Chatham Islands, including the Challenger Plateau, Chatham Rise and Bounty Plateau. Smooth skates have not been recorded from QMA 10.

In this report, smooth skate landings have been presented by QMA. QMAs form appropriate management units in the absence of any information on biological stocks.

4. STOCK ASSESSMENT

4.1 Biomass estimates

Relative biomass estimates are available for smooth skates from a number of trawl survey series (Table 5). Biomass estimates are not provided for surveys of: (a) west coast North Island because of major changes in survey areas and strata during the series; or (b) east Northland, Hauraki Gulf and Bay of Plenty because of the low relative biomass of smooth skates present (usually less than 100 t). In the first survey of each of two series (east coast South Island and Chatham Rise) the two skate species were not (fully) distinguished. Furthermore, there are doubts about the accuracy of species identification in some other earlier surveys (prior to 1996). Consequently, trends in biomass of individual species must be interpreted cautiously. To enable comparison among all surveys within each series, total skate biomass is also reported.

As the catch from the east coast South Island trawl surveys changes without wide inter-annual fluctuations and the CVs are relatively low it appears that they are able to track smooth skate biomass in FMAs 3 and 7, and on the Chatham Rise (Figure 2). Smooth skate relative biomass on the Chatham Rise increased to 2001, and has declined since then.

West coast South Island inshore trawl surveys

West coast South Island inshore trawl surveys (Figure 2) show that the relative biomass of smooth skate in FMA 7 declined substantially from 1997 to 2009, but appears to have increased since then but fluctuates in recent years. The 2015 estimate is the second highest in the time series, 2017 the second lowest, and 2019 has the highest in the time series with relatively high associated CVs (25–37%).

Smooth skate are rarely caught in Tasman and Golden Bays with most of the smooth skate catch being from the west coast strata, particularly south of Greymouth and in depths greater than 100 metres. Too few are caught for length frequency distribution plots to be informative.

ECSI trawl surveys

The East Coast South Island winter surveys from 1991 to 1996 (30–400 m) were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range; but these were discontinued after the fifth in the annual time series because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007, and this time were expanded to include the 10–30 m depth range, in order to monitor elephant fish and red gurnard which were officially included in the list of target species in 2012. Only the 2007, 2012, 2014, 2016 and 2018 surveys provide full coverage of the 10–30 m depth range.

Smooth skate biomass estimates in the core strata (30–400 m) for the east coast South Island winter trawl surveys in recent years were higher overall than in the 1990s (Table 5, Figure 3) (MacGibbon et al. 2019). There is no trend in biomass since 2007, apart from the high estimate in 2012, the additional biomass captured in the 10–30 m depth range was negligible over the five surveys indicating that in terms of biomass, and only the existing core strata time series in 30–400 m should be monitored.

The smooth skate length distributions for the east coast South Island winter trawl surveys are not consistent between surveys and comprise multiple year classes with indications of juvenile modes corresponding to 0+ fish in some years (Beentjes & MacGibbon 2013, Beentjes et al 2015, 2016, MacGibbon et al. 2019). The rest of the distribution includes multiple year classes from about 1 to 25 years. The 30–100 m strata tend to have larger skates than the deeper strata (Beentjes & MacGibbon 2013).The surveys appears to be monitoring pre-recruited lengths down to 0+ age, but probably not the full extent of the recruited distribution.. No lengths were measured before 1996. The addition of the 10–30 m depth range has not changed the shape of the length frequency distribution (Beentjes et al 2015, 2016, MacGibbon et al. 2019).

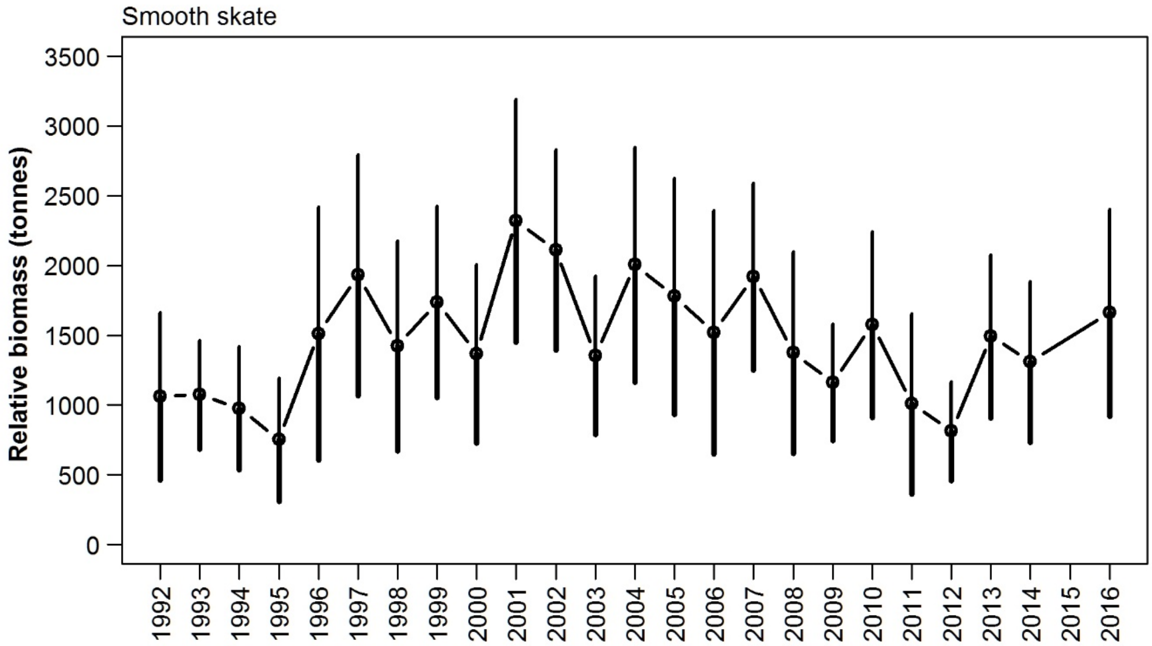


Figure 2: Smooth skate biomass for the Chatham Rise trawl surveys (error bars are ± two standard deviations).

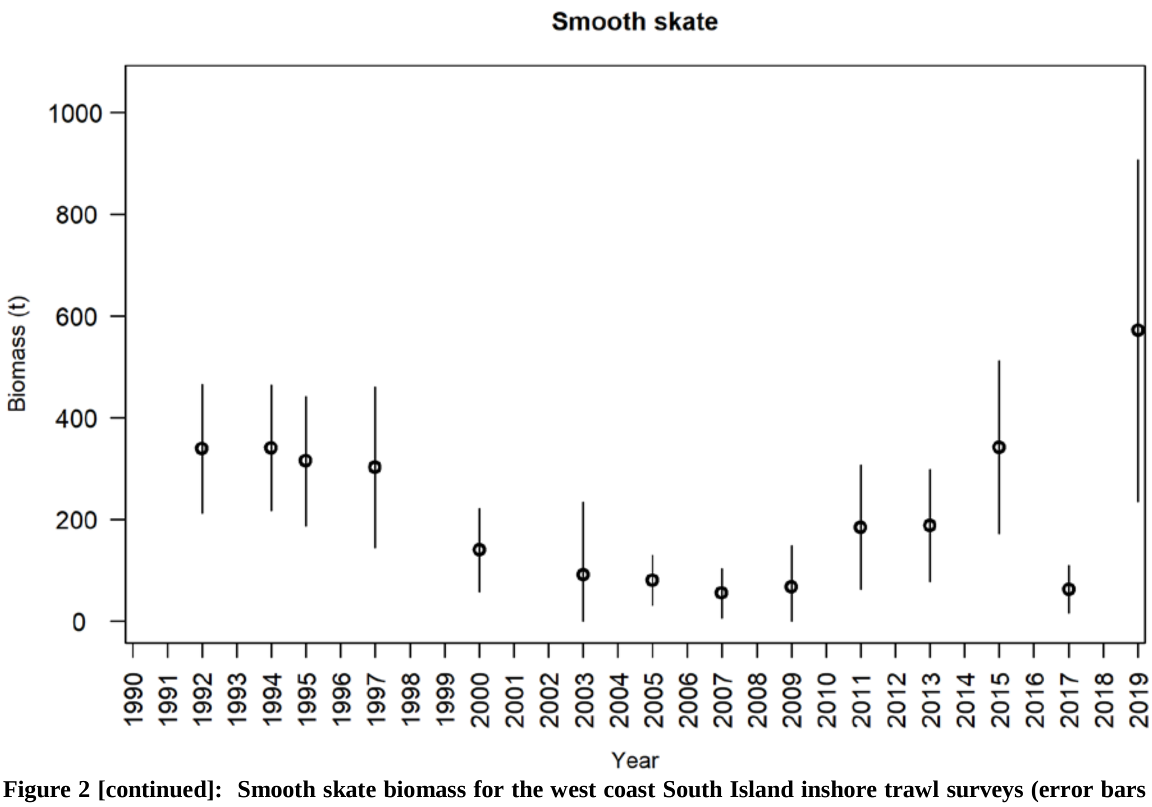


Figure 2 [continued]: Smooth skate biomass for the west coast South Island inshore trawl surveys (error bars are ± two standard deviations).

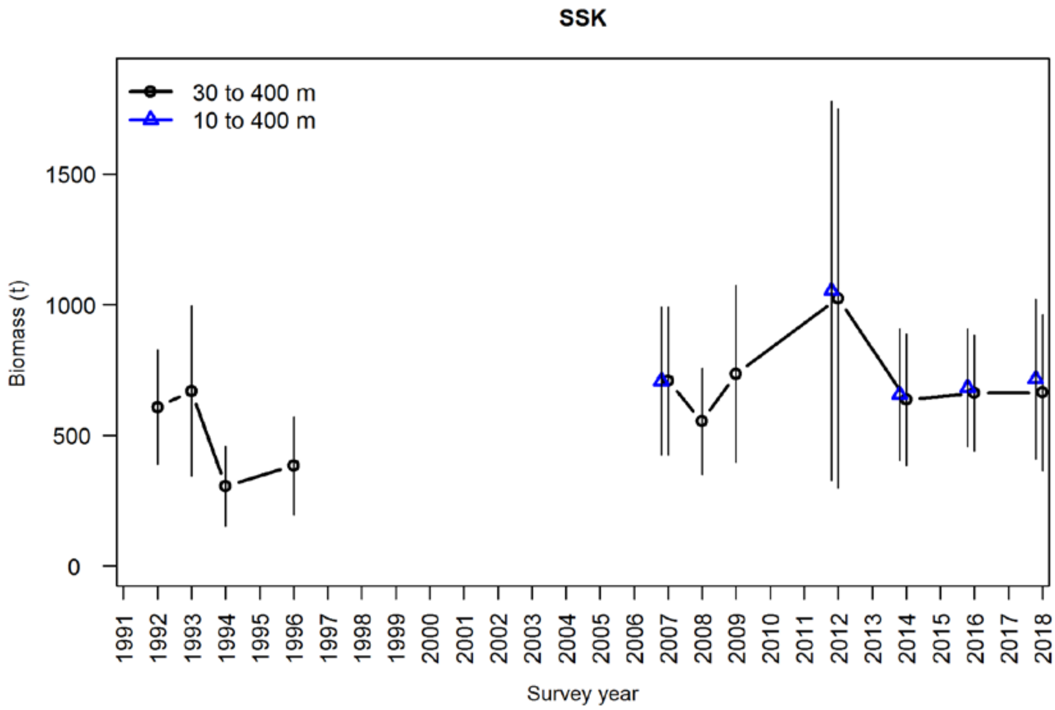


Figure 3: Smooth skate total biomass for the ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m) in 2007, 2012, 2014, 2016, and 2018. Error bars are ± two standard deviations.

4.3 Yield estimates and projections

MCY cannot be estimated.

The *MCY* estimator that has the lowest data requirements ($MCY = cY_{AV}$; Method 4), relies on selecting a time period during which there were "no systematic changes in fishing mortality (or fishing effort, if this can be assumed to be proportional to fishing mortality)". This method was not applied because no information is currently available on skate fishing mortality, or on trawl fishing effort in the main skate fishing areas.

CAY cannot be estimated.

4.4 Other factors

Species that constitute a minor bycatch of trawl fisheries are often difficult to manage using TACCs and ITQs. Skates are widely and thinly distributed, and would be difficult for trawlers to avoid after the quota had been caught. A certain level of incidental bycatch is therefore inevitable. However, skates are relatively hardy, and frequently survive being caught in trawls (although mortality would depend on the length of the tow and the weight of fish in the cod end). Skates returned to the sea alive probably have a greater chance of survival than most other fishes.

A data informed qualitative risk assessment was completed on all chondrichthyans (sharks, skates, rays and chimaeras) at the New Zealand scale in 2014 (Ford et al 2015). Smooth skate was ranked second highest in terms of risk of the eleven QMS chondrichthyan species. Data were described as existing but poor for the purposes of the assessment and consensus over this risk score was achieved by the expert panel. This risk assessment does not replace a stock assessment for this species but may influence research priorities across species.

Table 5: Doorspread biomass estimates (t) and coefficients of variation (CV %) of smooth skates and total skates (smooth and rough) [Continued on next page.]

		Smooth skate		Total skates	
Year	**Trip Code**	**Biomass**	**CV**	**Biomass**	**CV**
East coast North Island					
1993	KAH9304	23	52	99	-
1994	KAH9402	144	38	333	-
1995	KAH9502	20	59	72	-
1996	KAH9602	85	36	394	-
South Island west coast and Tasman/Golden Bays (FMA 7)					
1992	KAH9204	339	19	512	-
1994	KAH9404	341	18	537	-
1995	KAH9504	315	20	566	-
1997	KAH9701	302	26	487	-
2000	KAH0004	140	29	326	-
2003	KAH0304	91	79	134	-
2005	KAH0503	80	30	138	-
2007	KAH0704	55	44	300	-
2009	KAH0904	67	61	181	-
2011	KAH1104	185	33	532	-
2013	KAH1305	188	29	431	-
2015	KAH1503	342	25	492	-
2017	KAH1703	62	37	332	-
2019	KAH1902	572	29	704	-
East coast South Island (FMA 3) Winter		30–400 m		10–400 m	
1991	KAH9105	-	-	1 928	25
1992	KAH9205	609	18	833	16
1993	KAH9306	670	24	1 010	21
1994	KAH9406	306	25	823	15
1996	KAH9606	385	24	562	18
2007	KAH0705	705	20	1 587	-
2008	KAH0806	554	18	1 412	-
2009	KAH0905	736	23	1 765	-
2012	KAH1207	1 025	35	2 158	-
2014	KAH1402	637	20	1 790	-
2016	KAH1605	663	17	1 805	-
2018	KAH1893	664	22	1 642	-
East coast South Island (FMA 3) Summer					
1996–97	KAH9618	721	32	2 057	-
1997–98	KAH9704	485	21	1 567	-
1998–99	KAH9809	450	26	1 625	-
1999–00	KAH9917	369	30	698	-
2000–01	KAH0014	248	33	470	-
Chatham Rise					
1991–92	TAN9106	-	-	2 129	-
1992–93	TAN9212	1 071	18	1 126	-
1994	TAN9401	958	23	1 178	-
1995	TAN9501	769	31	845	-
1996	TAN9601	1 511	30	1 522	-
1997	TAN9701	1 932	22	1 944	-
1998	TAN9801	1 425	26	1 935	-
1999	TAN9901	1 738	20	1 772	-
2000	TAN0001	1 369	23	1 369	-
2001	TAN0101	2 321	19	2 393	-
2002	TAN0201	2 111	17	2 148	-
2003	TAN0301	1 355	21	1 387	-
2004	TAN0401	2 006	21	2 066	-
2005	TAN0501	1 780	24	1 869	-
2006	TAN0601	1 521	29	1 577	-
2007	TAN0701	1 922	17	1 951	-
2008	TAN0801	1 376	26	1 376	-
2009	TAN0901	1 162	18	1 185	-
2010	TAN1001	1 576	21	1 576	-
2011	TAN1101	1 009	32	1 009	-
2012	TAN1201	813	22	813	-
2013	TAN1301	1 494	20		
2014	TAN1401	1 309	22		
2016	TAN1601	1 662	22		
Stewart-Snares Shelf					
1993	TAN9301	528	20	1 120	-
1994	TAN9402	342	21	1 406	-
1995	TAN9502	335	19	1 136	-
1996	TAN9604	504	29	1 559	-
Survey discontinued					
Stewart-Snares Shelf and Sub-Antarctic (Summer)*					
1991	TAN9105	382	23	419	-
1992	TAN9211	113	47	165	-

Table 5 [Continued]

		Smooth skate		Total skates	
Year	**Trip Code**	**Biomass**	**CV**	**Biomass**	**CV**
1993	TAN9310	117	43	249	-
2000	TAN0012	434	66	267	-
Stewart-Snares Shelf and Sub-Antarctic (Autumn)*					
1992	TAN9204	93	61	141	-
1993	TAN9304	177	33	428	-
1996	TAN9605	835	39	857	-
1998	TAN9805	536	62	607	-

*Biomass estimates are for core 300–800 m strata only

5. STATUS OF THE STOCKS

No estimates of current or reference biomass are available.

Relative biomass estimates of smooth skate from the west coast South Island inshore trawl survey time series showed a strong decline between 1997 and 2009. Since then estimates increased, with the 2015 estimate the highest in the time series, followed by another decline in 2017.

Relative biomass estimates of smooth skate from the east coast South Island inshore trawl survey time series core strata indicate no trend in biomass since 2007, apart from the high estimate in 2012.

For all other skate QMAs it is Unknown if recent catch levels or the TACC will cause skate populations to decline.

6. FOR FURTHER INFORMATION

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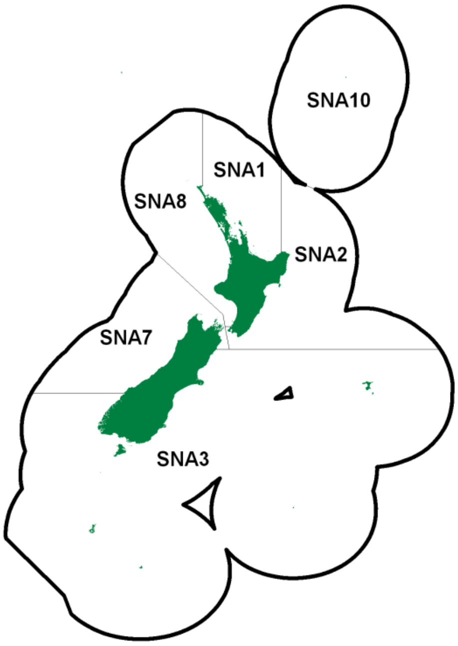
SNAPPER (SNA)

(*Pagrus 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 2018–189 and gazetted and actual TACCs (t) for 1986–87 to 2018–19. 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	<!	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

Table 2 [Continued]

Fishstock	SNA 10			Total
QMAs	10			
	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	6 350	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, with the exception of 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. Table 3 shows the TACs, TACCs, and allowances for each Fishstock from 1 October 2016. 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 2016.

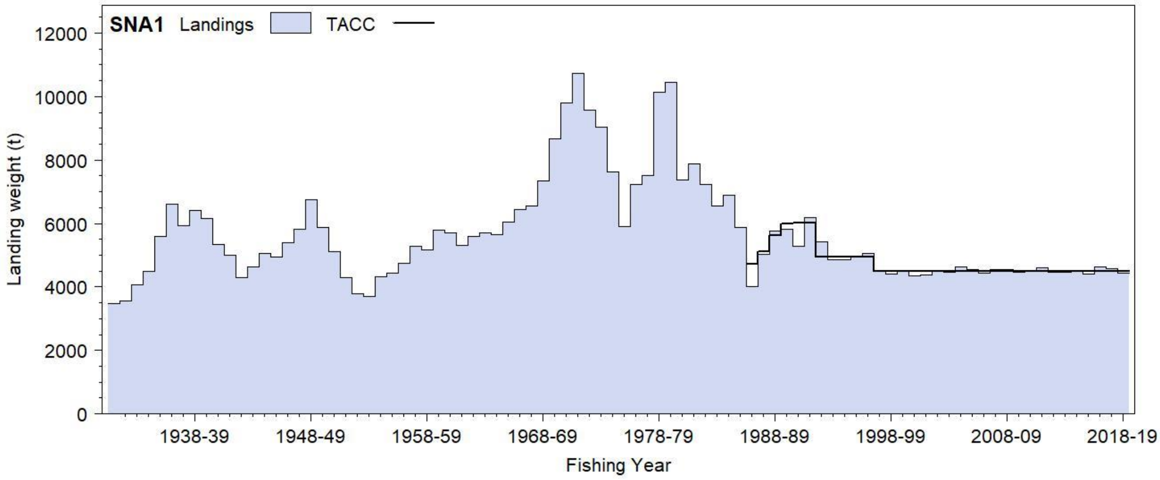
Fishstock	TAC	TACC	Customary allowance	Recreational allowance	Other mortality
SNA 1	8 050	4 500	50	3 050	450
SNA 2	450	315	14	90	31
SNA 3		32	–	–	–
SNA 7	545	250	20	250	25
SNA 8	1 785	1 300	43	312	130
SNA 10		10	–	–	–

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



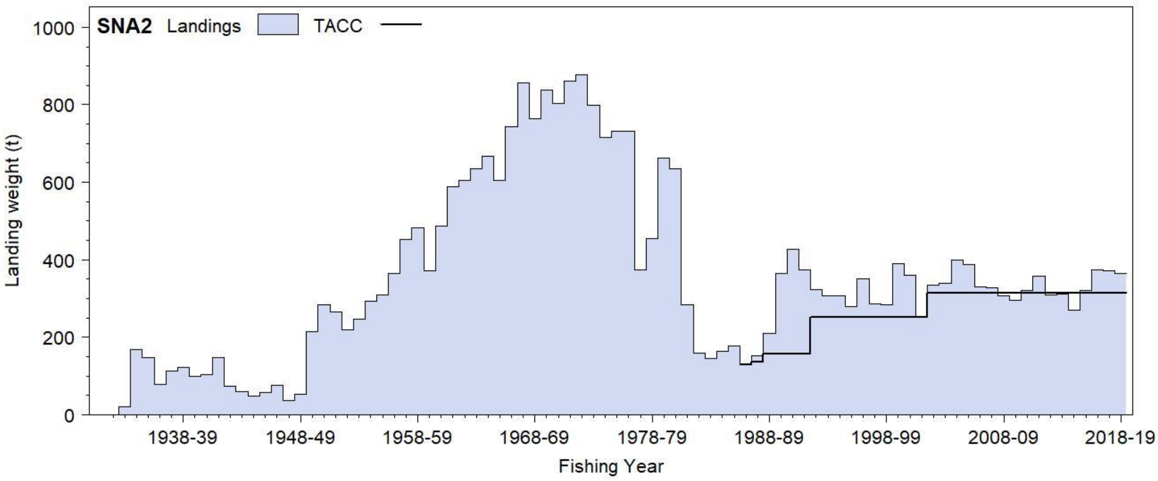
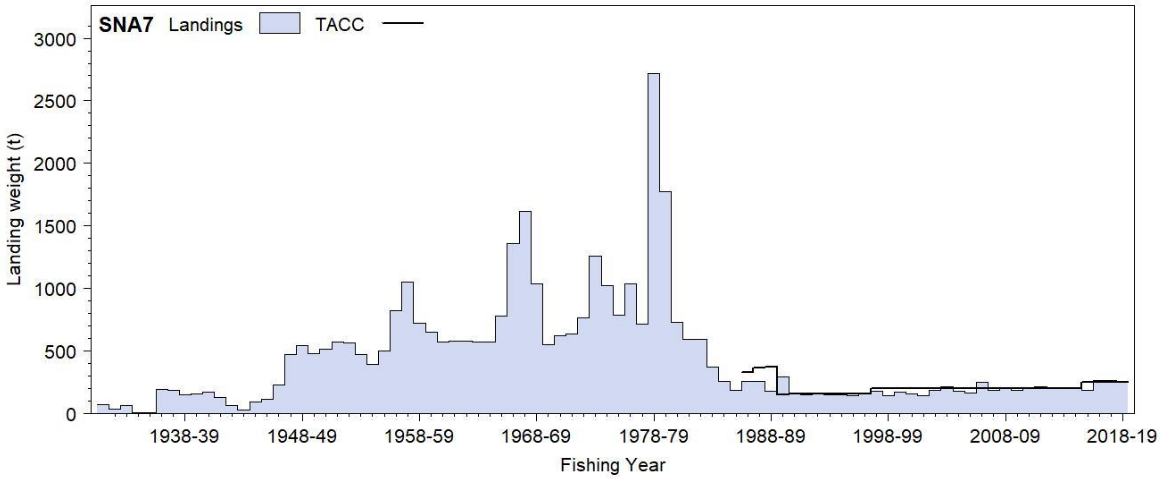


Figure 1: Total reported landings and TACCs for the four main SNA stocks. From top: SNA 1 (Central East) and SNA 2 (Central East). [Continued on next page]



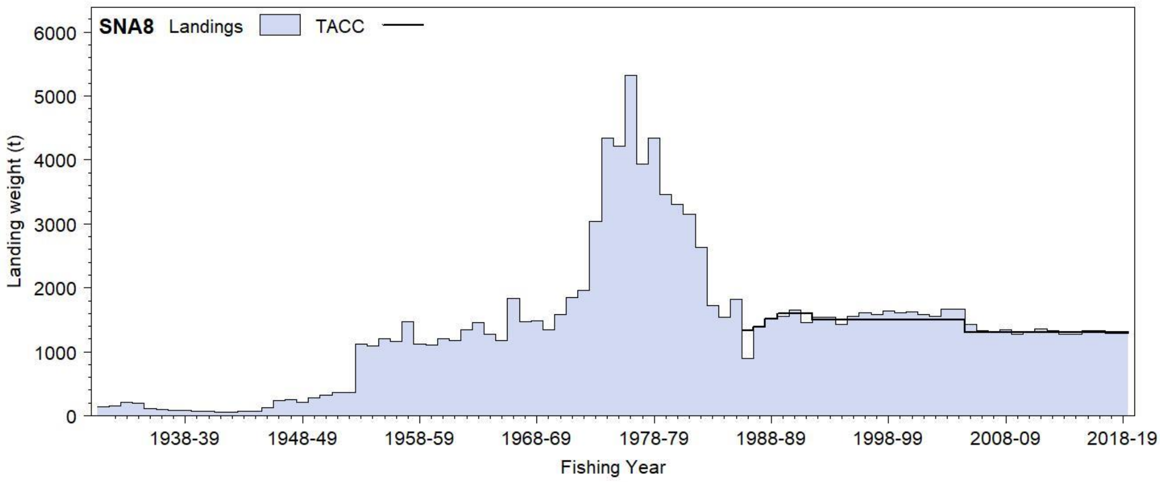


Figure 1 [Continued]: Total reported landings and TACC for the four main SNA stocks. From top to bottom: SNA 7 (Challenger) and SNA 8 (Central Egmont).

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 of these 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 2005) 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 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 (excluding the Chatham Islands) 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, finding 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 c.f. 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.

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 sized 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, including 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 the west coast of the North Island grow faster and reach a larger average size than elsewhere. Snapper have a strong seasonal growth pattern, with rapid growth from November to May, and then a slowing down or cessation of growth from June to September. They may live up to 60 years or more and have very low rates of natural mortality. An estimate of $M = 0.06\ \text{yr}^{-1}$ was made from catch curves of commercial catches from the west coast North Island pair trawl fishery in the mid-1970s. These data were re-analysed in 1997 and the resulting estimate of 0.075 yr^{-1} has been used in the base case 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	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 BayGolden 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 & Biodiversity Annual Review 2017 (MPI 2017, https://www.mpi.govt.nz/dmsdocument/27471-aquatic-environment-and-biodiversity-annual-review-aebar-2017-a-summary-of-environmental-interactions-between-the-seafood-sector-and-the-aquatic-environment).

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

4.1.2 Ecosystem Indicators

Tuck et al (2009) used data from the Hauraki Gulf trawl survey series to derive fish-based ecosystem indicators using diversity, fish size, and trophic level. This trawl survey 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 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 interactions

There were two observed captures of New Zealand fur seals in trawls targeting snapper between 2002–03 and 2016–17, but low observer coverage of inshore trawlers (average 1.47% in FMAs 1 and 9 over these years, Thompson et al 2016) means that the frequency of interactions is highly uncertain. In these same years, there were no observed marine mammal captures in snapper longline fisheries where coverage has averaged 1.75% of hooks set (3.0 and 4.3% in the two most recent years).

4.3.2 Seabird interactions

There have been seven observed captures of seabirds (three flesh-footed shearwater, one black petrel, and one common diving petrel) and eleven observed deck strikes (five common diving petrels, one flesh-footed shearwater, one New Zealand white-faced storm petrel, one Buller’s shearwater, one cape petrel, one Cook’s petrel, and one grey-faced petrel) in trawls targeting snapper between 2002–03 and 2016–17, but low observer coverage of inshore trawlers (average 1.47% in FMAs 1 and 9 between 2002–03 and 2016–17, Thompson et al 2016) means that the frequency of interactions is highly uncertain.

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 2010). The estimated number of captures between 2003–04 and 2006–07 appears to have been relatively stable at about 400–600 birds each year.

Between 2002–03 and 2016–17, there were 152 observed captures of birds in snapper bottom longline fisheries (Table 9). Estimates of the mean total seabird captures from 2002–03 to 2015–16 vary from 813 to 339 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 (52%), and black (Parkinson’s) petrel (27%), and the majority were taken in the Northland-Hauraki area (93%) (Table 10). These numbers should be regarded as only a general guide on the composition of captures because the observer coverage is low, is not uniform across the area, and may not be representative.

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

	Model-based estimates of captures					
Fishing year	**MacKenzie & Fletcher**		**Baird & Smith**		**Abraham & Thompson**	
1998–99	1 464	(271–9 392)	–	–	–	–
1999–00	2 578	(513–13 549)	–	–	–	–
2000–01	3 436	(697–17 907)	–	–	–	–
2001–02	1 856	(353–11 260)	–	–	–	–
2002–03	1 583	(299–9 980)	–	–	739	(332–1 997)
2003–04	247	(51–1 685)	546	(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 2016–17. 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. Estimates from 2002–03 to 2016–17 are based on data version 2018v1.

	Fishing effort			Observed captures		Estimated captures		
	All hooks	**No. obs**	**% obs**	**Number**	**Rate**	**Mean**	**95% c.i.**	**% included**
2002–03	13 728 152	0	0.0	0		910	682–1208	100.0
2003–04	12 267 247	187 293	1.5	10	0.05	774	578–1028	100.0
2004–05	11 544 741	244 710	2.1	13	0.05	682	514–904	100.0
2005–06	11 696 613	116 290	1.0	12	0.10	578	425–774	100.0
2006–07	10 348 391	62 360	0.6	0	0	559	410–751	100.0
2007–08	9 052 276	0	0.0	0		505	371–682	100.0
2008–09	8 980 217	318 274	3.5	25	0.08	514	381–682	100.0
2009–10	11 041 505	633 153	5.7	30	0.05	559	413–754	100.0
2010–11	11 343 582	0	0.0	0		596	440–807	100.0
2011–12	11 034 836	0	0.0	0		536	394–716	100.0
2012–13	10 501 460	362 520	3.5	2	0.01	504	367–681	100.0
2013–14	11 124 654	747 600	6.7	47	0.06	501	379–668	100.0
2014–15	10 845 582	0	0.0	0		423	304–576	100.0
2015–16	10 608 751	337 125	3.2	7	0.02	397	285–537	100.0
2016–17	10 759 916	486 700	4.5	4	0.01	398	289–544	100.0

Table 10: Number of observed seabird captures in the snapper longline fishery, 2002–03 to 2016–17, by species or species group. 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). Data version 2017v1, www.data.dragonfly.co.nz/psc.

Taxa	**Risk category**	**Northland and Hauraki**	**Bay of Plenty**	**West Coast North Island**
Black petrel	Very high	36	2	0
Flesh-footed shearwater	High	67	6	0
Northern giant petrel	Medium	1	0	0
Pied shag	Negligible	2	0	0
Fluttering shearwater	Negligible	4	0	0
Sooty shearwater	Negligible	1	0	0
Australasian gannet	Negligible	2	0	0
Buller's shearwater	Negligible	12	0	1
Southern black-backed gull	Negligible	5	0	0
Petrels	–	10	0	0
Total other birds	–	131	8	1

The snapper target bottom longline fishery contributes to the total risk posed by New Zealand commercial fishing to seabirds (see Table 11). The three species to which the fishery poses the most risk are black petrel, Salvin's albatross, and flesh-footed shearwater, with this target fishery posing 1.153, 0.78, and 0.67 of PST, respectively (Table 11). The black petrel is assessed at very high risk from commercial fishing in New Zealand waters, and both the Salvin's albatross and flesh-footed shearwater are assessed at high risk from commercial fishing in New Zealand waters (Richard & Abraham 2015).

Table 11: Risk ratio of seabirds predicted by the level two risk assessment for the snapper target bottom longline fishery and all fisheries included in the level two risk assessment, 2006–07 to 2016–17, showing seabird species with a risk ratio of at least 0.001 of PST. 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 shown (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	437.1	0.2185	1.153	Very high	Threatened: Nationally Vulnerable
Flesh-footed shearwater	1452.8	0.1854	0.669	High	Threatened: Nationally Vulnerable
Northern giant petrel	335.4	0.0048	0.138	Medium	At Risk: Naturally Uncommon
Fluttering shearwater	36198.4	0.0028	0.004	Negligible	At Risk: Relict

4.3.3 Sea turtle interactions
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.

4.4 Benthic interactions
A proportion of the commercial catch of snapper is taken using bottom trawls in Benthic Optimised Marine Environment Classification (BOMEC, Leathwick et al 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 only 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 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 2012 Aquatic Environment and Biodiversity Annual Review.

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. Hauser 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, Morrison unpublished data, Thrush et al 2002, Parsons et al 2009). The reason for this association is currently unclear, but the provision of food and shelter are likely explanations. Some potential nursery habitats appear to contribute disproportionately to their area. The Kaipara Harbour in northern New Zealand contributes a disproportionately high proportion of successful recruits to the SNA 8 fishery (Morrison unpublished data) and a similar situation exists for snapper from Port Phillip Bay in Australia (Hamer et al 2011). These habitats are subject to land-based stressors (Morrison et al 2009) that may affect their production of juvenile snapper and recruitment to the SNA 8 fishery.

4.5.3 Marine heatwave

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 (Francis 1993). The effects of significant recent warming in sea surface temperatures is unknown.

5. STOCK ASSESSMENT

The stock assessment for SNA 2 was last completed in 2009. 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 completed in 2020 following the previous assessment conducted in 2005. The SNA 8 assessment will be updated and finalised in 2021.

5.1 SNA 1 (Auckland East)

5.1.1 Model structure

The model used for the 2013 assessment was written using CASAL (Bull et al 2012) and is a development of the three-stock, three-area model used in the 2012 assessment (Francis & McKenzie 2015). 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 model covered the time period from 1900 to 2013 (i.e., fishing years 1899–1900 to 2012–13), with two time steps in each year (Table 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 (YCS) were estimated as free parameters but only for years where there was at least one observation of catch-at-age. The YCS estimation period in the model was also the period over which the 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 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). 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.

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
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
		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.

5.1.2 Catch History

Recreational catch

Direct estimates of annual recreational harvest from the three areas of SNA 1(East Northland, Hauraki Gulf, and Bay of Plenty) are available from aerial-access surveys conducted in 2004–05 and 2011–12 (Table 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).

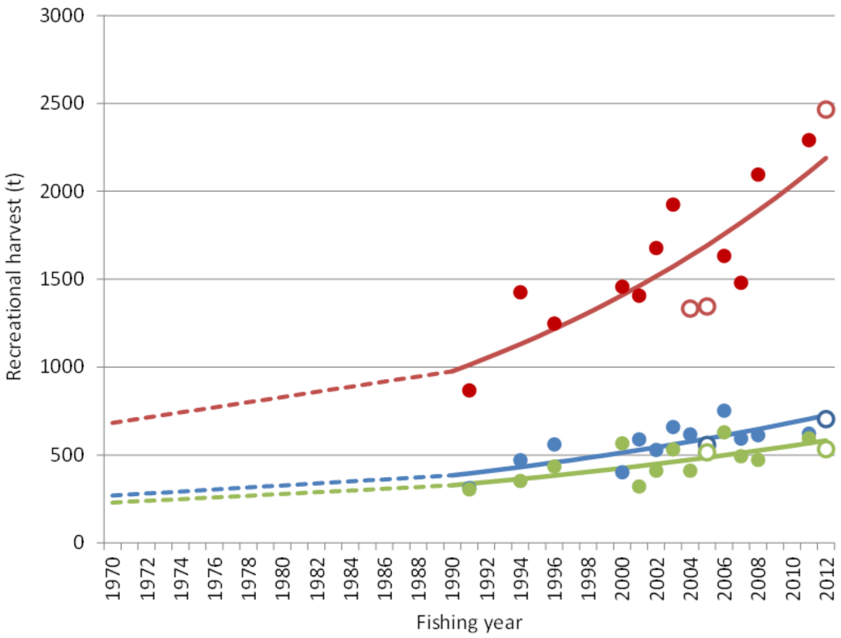


Figure 2: Recreational catch histories for the three areas of SNA 1 (Hauraki Gulf in red, East Northland in blue, and the Bay of Plenty in green). Open circles denote aerial-access survey estimates, closed circles denote recreational kilogram per trip indices scaled to the geometric mean of the aerial-access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

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).

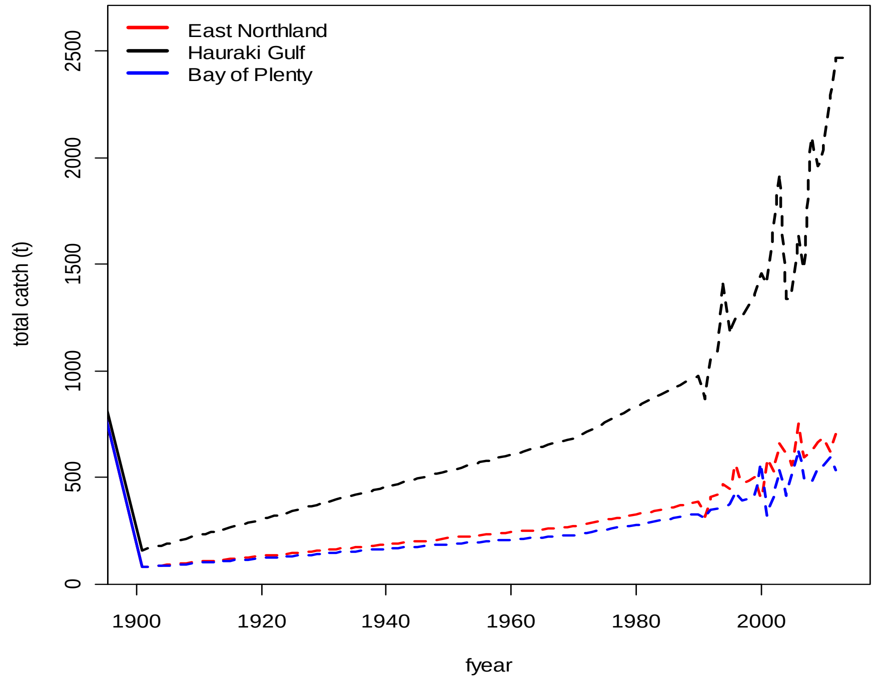


Figure 3: Assumed and derived recreational catch histories for the period 1900 to 2013 that were used in the 2013 SNA 1 assessment model.

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

Commercial catch

The SNA 1 commercial catch histories for the various method area fisheries after 1989–90 were derived from the 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 (AJHR). From 1931 to 1943 inclusive, data were tabulated by April–March years; these were equated with the main calendar year (e.g., 1931–32 landings are treated as being from 1931). From 1944 onwards, data were tabulated by calendar year.
- 1974–82: Ministry of Agriculture and Fisheries, Fisheries Statistics Unit (FSU) calendar year records published by King (1985). The available data grouped catches for all species comprising less than 1% of the port totals as "Minor species". An FSU hardcopy printout dated 23 March 1984 held by NIWA was used to provide species-specific catches in these cases (although this had little effect for snapper given that it is typically a major species in SNA 1 ports).

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

The only information available on the spatial distribution of SNA 1 landings before 1983 comes from "The Wetfish Report" (Ritchie et al 1975) in which snapper landings for old statistical areas were provided by year and month for the period 1960–1970. The boundaries of the old Statistical Areas 2, 3 and 4 are similar to those for the East Northland, Hauraki Gulf, and Bay of Plenty substocks. However, Area 4 is smaller than the Bay of Plenty substock, whereas Area 2 is larger than East Northland, and Area 3 is larger than Hauraki Gulf. Nevertheless, the match between old statistical areas and substock boundaries is likely 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.

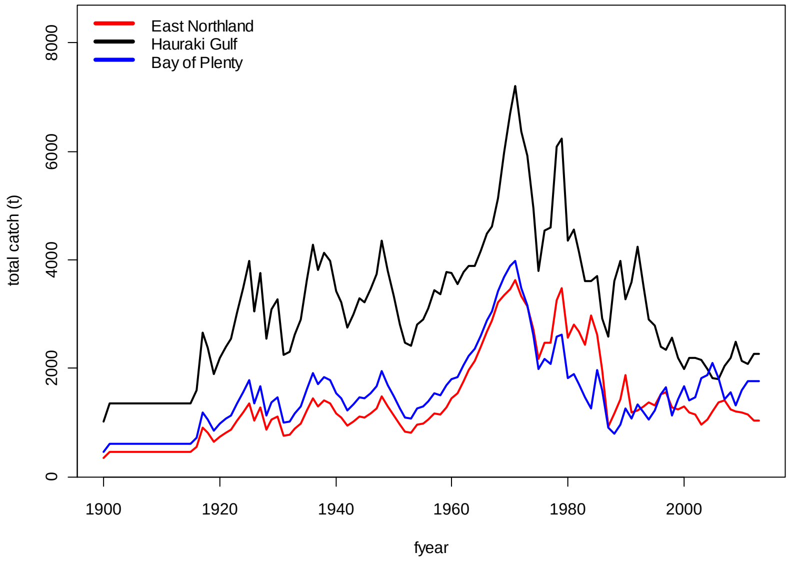


Figure 4: Commercial catch histories by area (adjusted for under-reporting) plus foreign catch used as input to the 2013 SNA 1 assessment model.

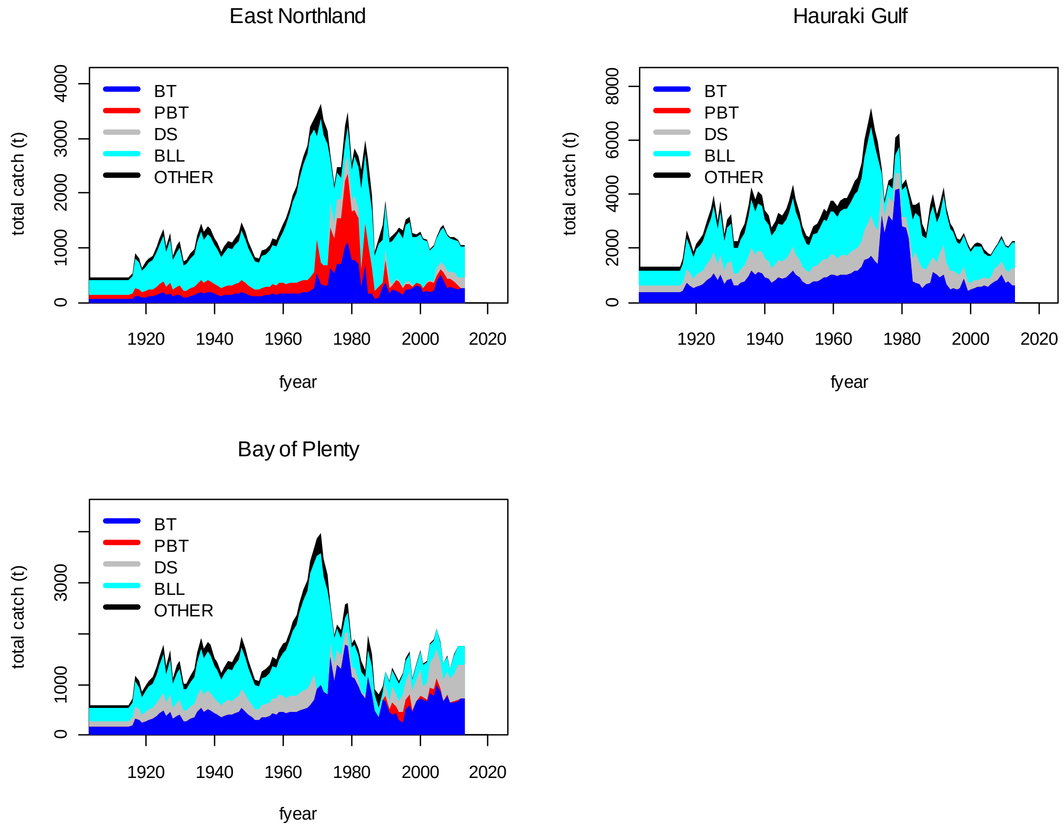


Figure 5: Commercial catch histories by method and area (adjusted for under-reporting) used as input to the 2013 SNA 1 assessment model.

5.1.3 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 (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

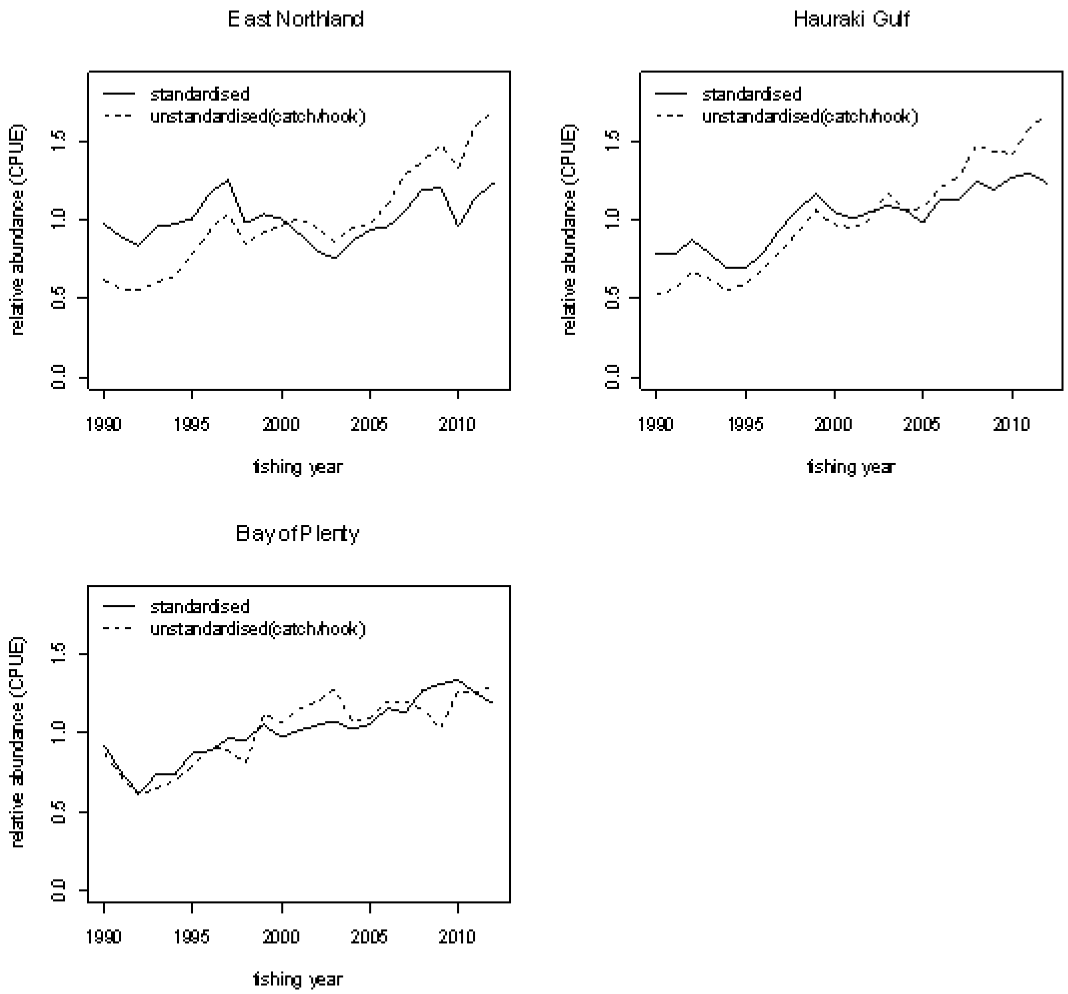


Figure 6: Longline CPUE indices of abundance (standardised and unstandardised) from 1990–2012 for the three component stocks of SNA 1.

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 1997–98 fishing year the majority of Bay of Plenty trawl fishers were using the less detailed daily CELR reporting forms. From 1995–96, however, a significant number of Bay of Plenty trawl fishers (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 8, not 5, species to be recorded. It was decided not to include the CELR data in the CPUE standardisations and only to include years where a high proportion of TCEPR and TCER data were available; specifically 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 2009–11 (Figure 7).

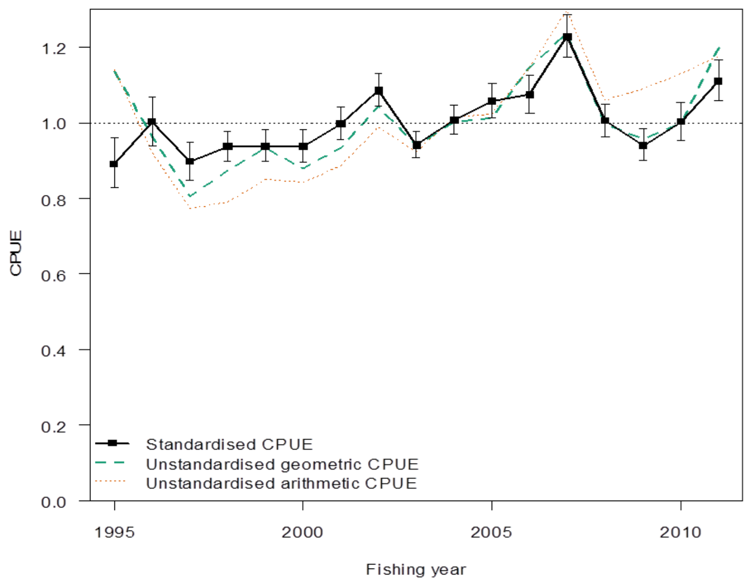


Figure 7: Single trawl CPUE indices of Bay of Plenty area abundance (standardised and unstandardised) from 1996–2012.

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

5.1.4 Catch at age and length observations

Commercial data

Catch-at-age observations from single trawl, Danish seine, and longline are available from the Bay of Plenty and Hauraki Gulf stocks; longline only for East Northland (see Table 15).

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 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).

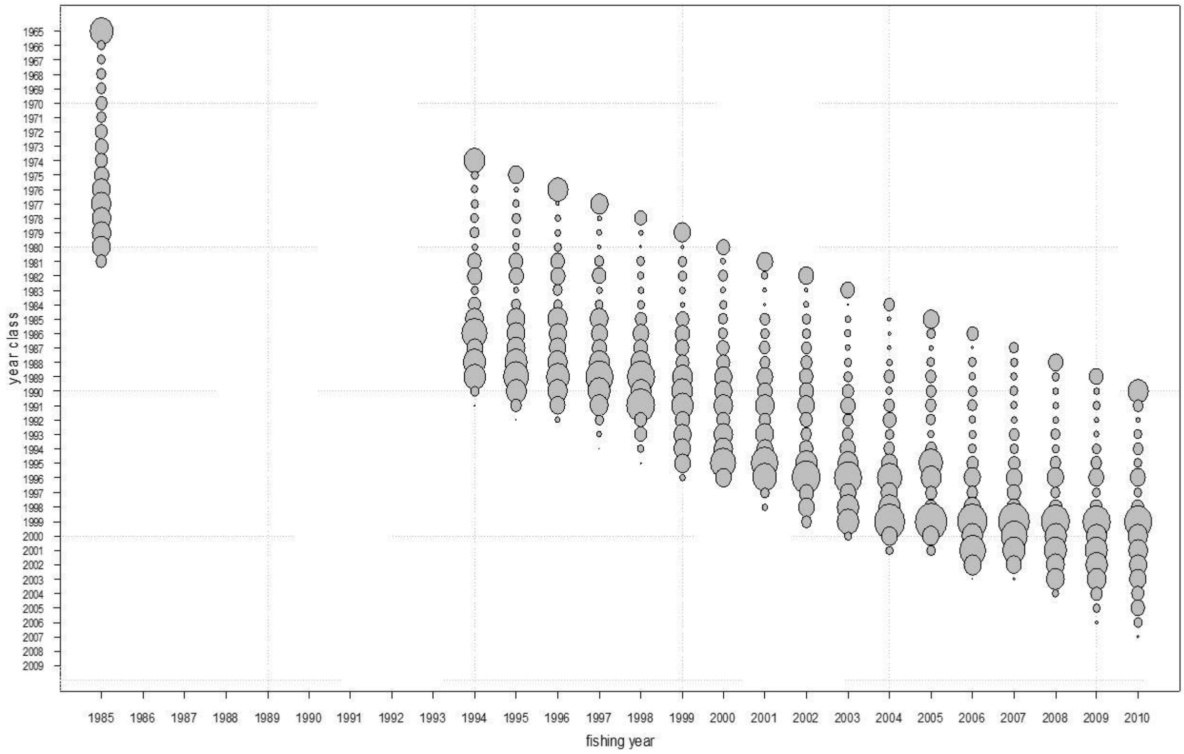


Figure 8: Relative year-class strength observed in the East Northland longline fishery 1984–85 to 2009–10. Year on the x-axis refers to the second part of the fishing year. The oldest year class is a 20+ group.

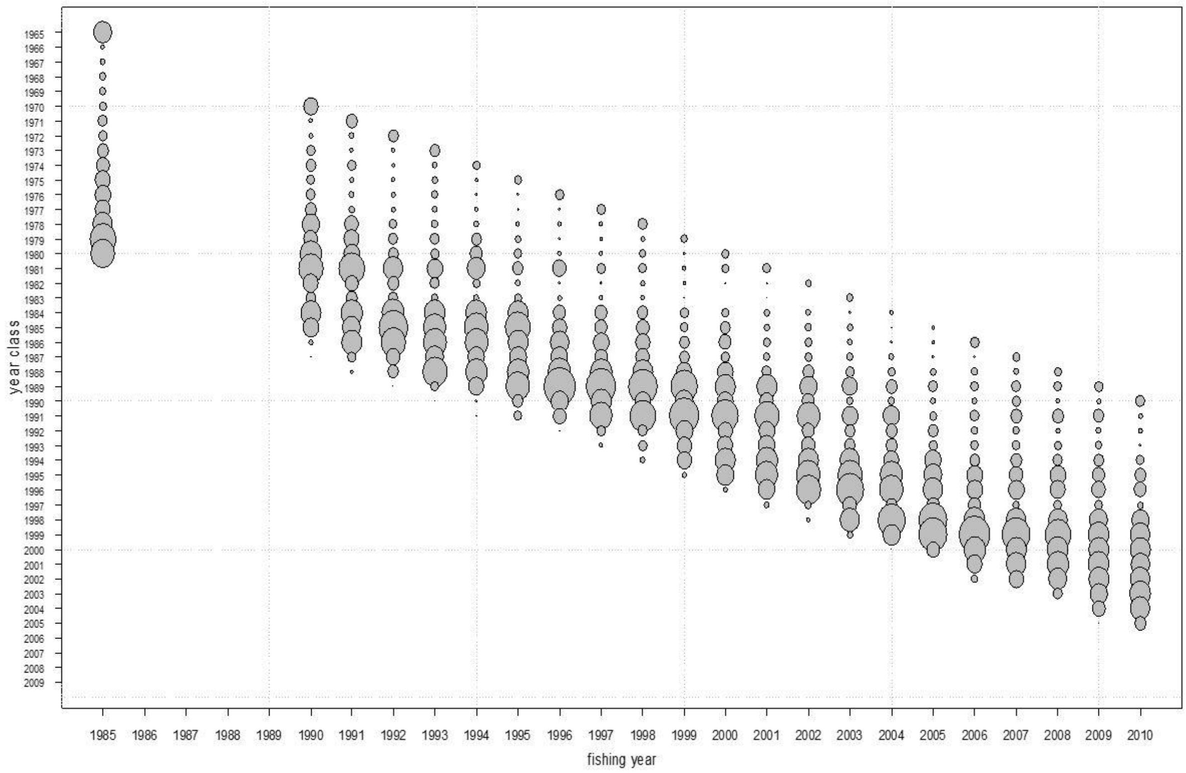


Figure 9: Relative year-class strength observed in the Hauraki Gulf longline fishery 1984–85 to 2009–10. Year on the x-axis refers to the second part of the fishing year. The oldest year class is a 20+ group.

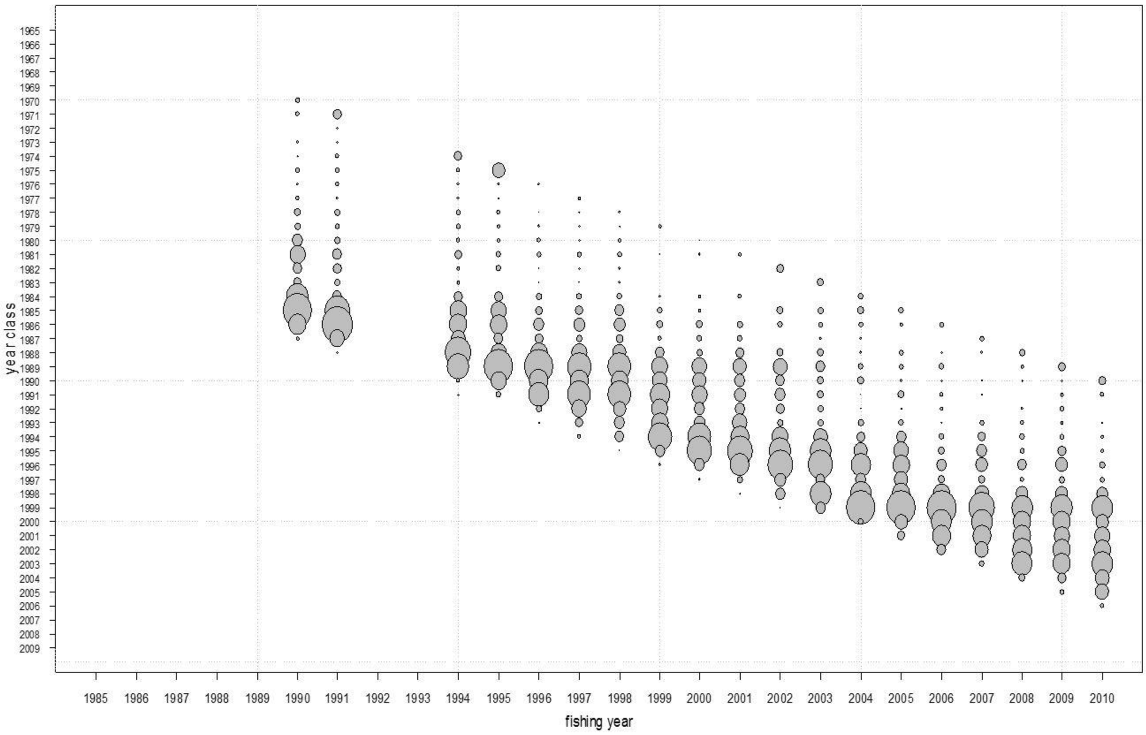


Figure 10: Relative year-class strength observed in the Bay of Plenty longline fishery 1990–91 to 2009–10. Year on the x-axis refers to the second part of the fishing year. The oldest year class is a 20+ group.

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).

5.1.5 Snapper 1983, 1985, and 1994 tagging programmes

Analysis of past snapper tagging programmes revealed a number of sources of bias that need to be accounted for if these data are to be used for assessment purposes. Data from the 1985 and 1994 tagging programmes were corrected for bias and input directly into the assessment model. Data from the 1983 Bay of Plenty tagging programme were unavailable. The published biomass estimate (6000 t, Sullivan 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.

5.1.6 Stock Assessment Results

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

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

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

All estimated spawning biomass trajectories show substantial reductions up to 1999 (for East Northland) or about 1988 (for other stocks and areas), and then some increase thereafter (Figure 11, upper panels). In terms of current biomass, both the stock BOP and area BP are estimated to be more depleted (3–10% B_0) than the other stocks and areas (15–30% B_0) (Table 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 we are considering the biomass by stock or by area.

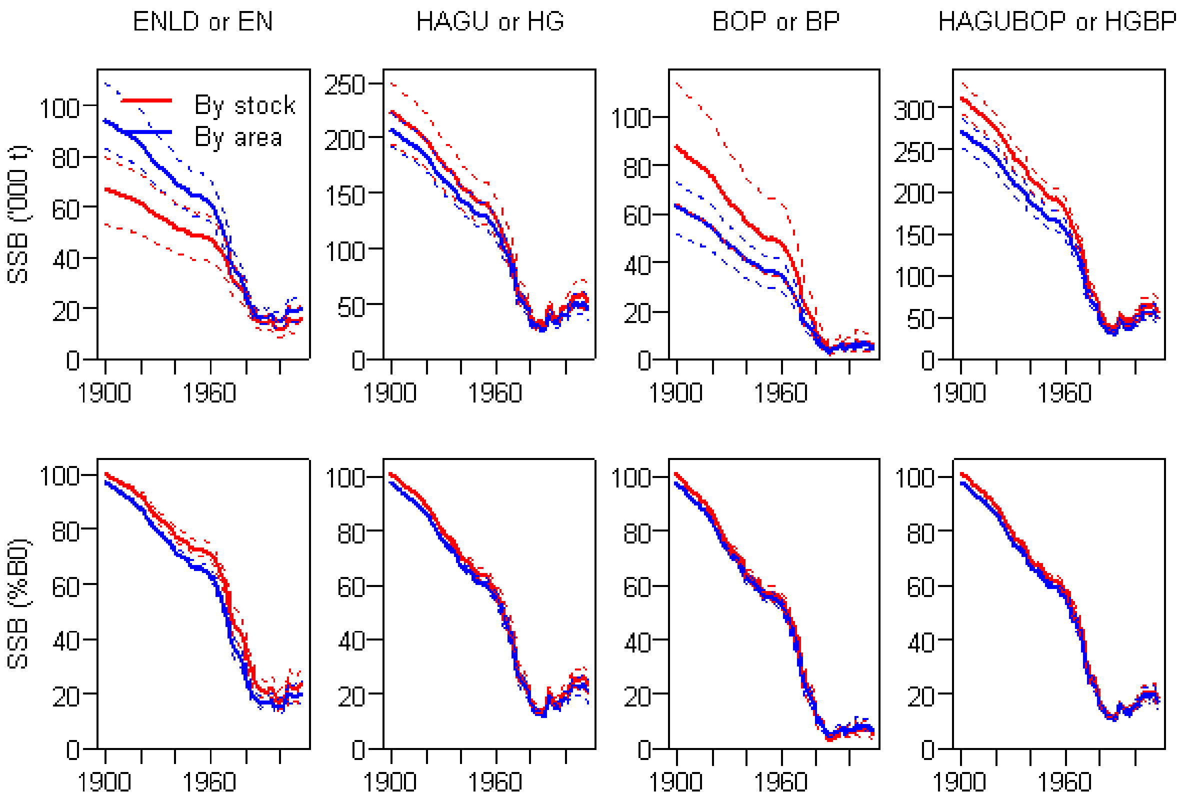


Figure 11: SSB trajectories by stock (red lines) and area (blue lines) from the base model. Solid lines are MCMC medians, broken lines are 95% confidence intervals.

Table 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.

The majority of fish do not move away from their home grounds, with migration being most common for BOP fish and least common for ENLD fish (Table 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.

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).

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)

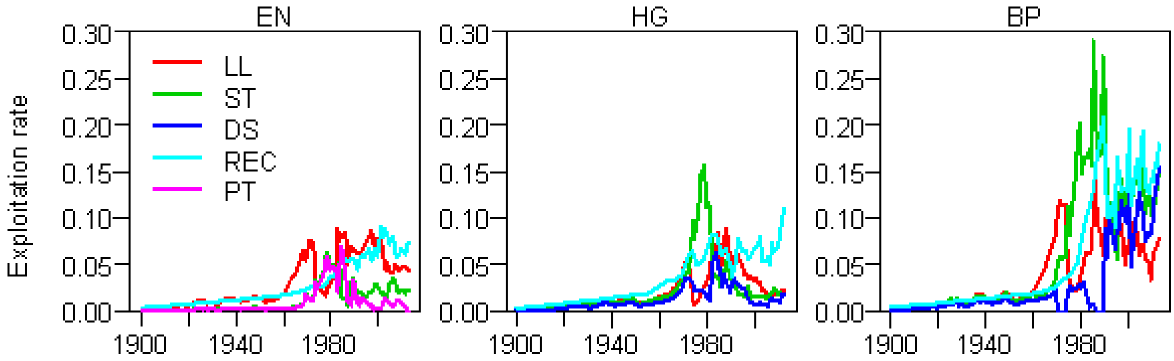


Figure 12: MPD estimates of exploitation rates by fishery and year.

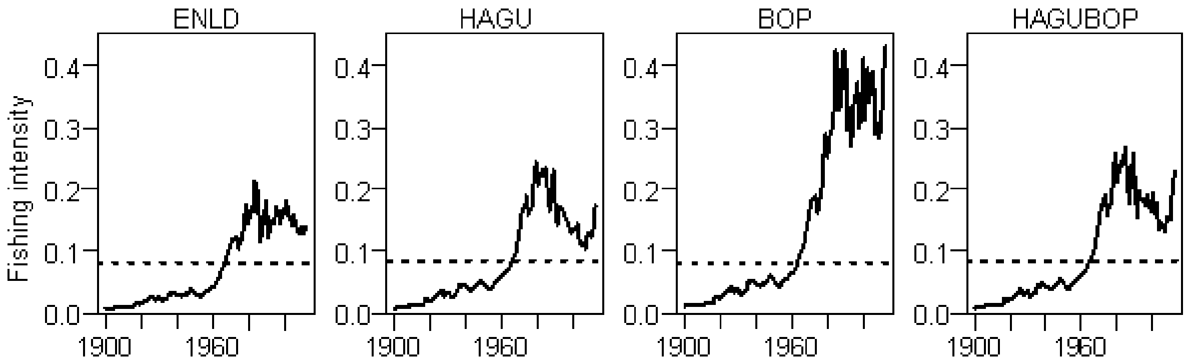


Figure 13: MPD estimates of fishing intensity by year and stock. Dotted lines show the intensity required to maintain the spawning biomass at 40%*B_0* (*$U_{40\%B_0}$*).

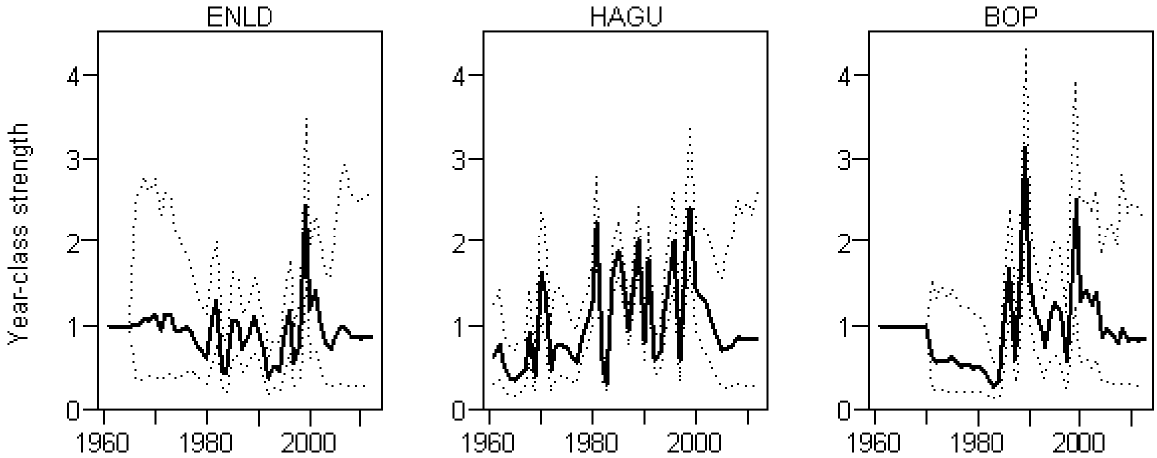


Figure 14: Estimated year-class strengths by year and stock (a value of 1 indicates that the year class has the strength predicted by the stock-recruit relationship). Estimates are MCMC medians (solid lines) and 95% confidence intervals (dotted lines).

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

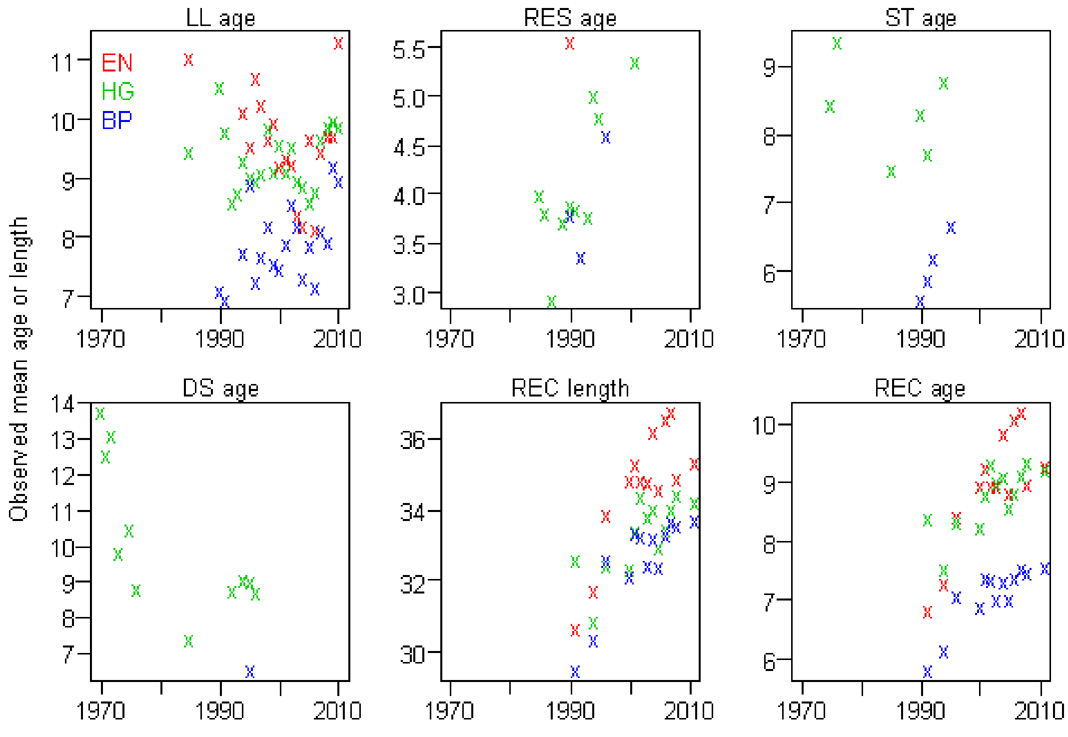


Figure 15: Observed mean age (for commercial fisheries and research surveys) or length (for recreational fisheries) by fishing method and area. In the bottom right-hand panel, the observed recreational mean lengths have been converted to ages using the mean length at age relationship (averaged over years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

Results of the sensitivity analyses are presented in terms of their effects on current status (Figure 16). Regardless of whether current status was measured by stock or by area, all models estimated the Bay of Plenty spawning biomass to be the most depleted, and most 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 to 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.

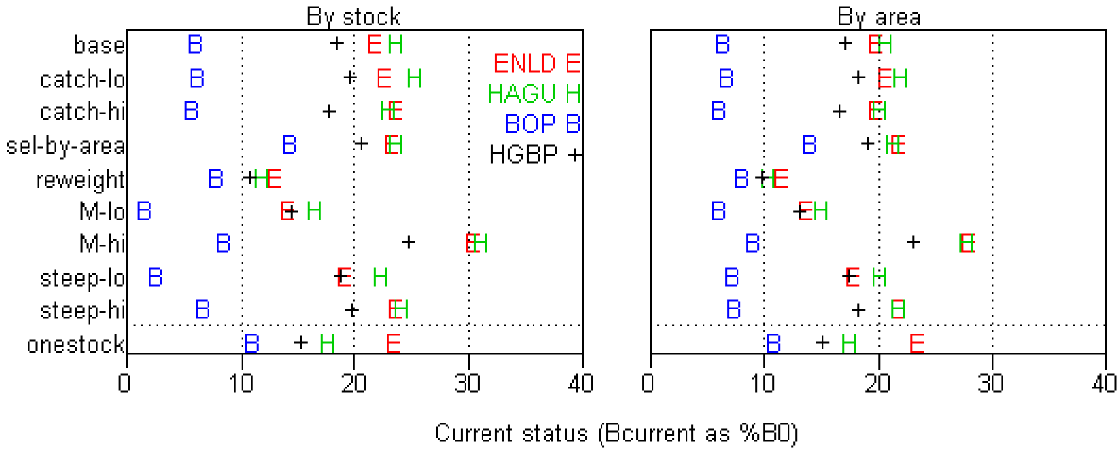


Figure 16: MPD estimates of current status (B_{2013} as $\%B_0$), by stock and area, for the base model and some sensitivity analyses. The horizontal broken line separates the one-stock estimates from the others as a reminder that there is no distinction between spawning biomass by stock and by area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

5.1.7 Yield estimates and projections

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

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

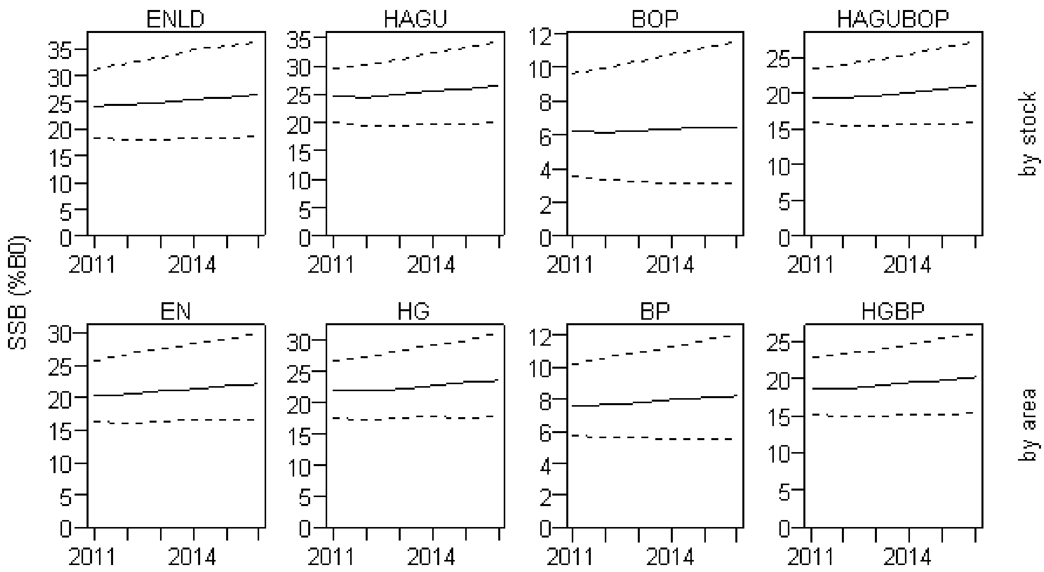


Figure 17: Projected spawning-stock biomass (SSB) by stock and by area. Estimates are MCMC medians (solid lines) and 95% confidence intervals (broken lines).

Deterministic B_{MSY}

Deterministic B_{MSY} was calculated as 25–26% B_0 for all individual stocks and areas and 30% for the combined Hauraki Gulf/Bay of Plenty. There are several reasons why B_{MSY}, as calculated in this way, is not a suitable target for management of the SNA 1 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

5.1.8 Other factors

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

5.1.9 Future research considerations

1. As 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.

5.1.10 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) were broadly comparable to the CPUE indices from the preceding five years (i.e., 2007–08 to 2011–12) (Figure 18).

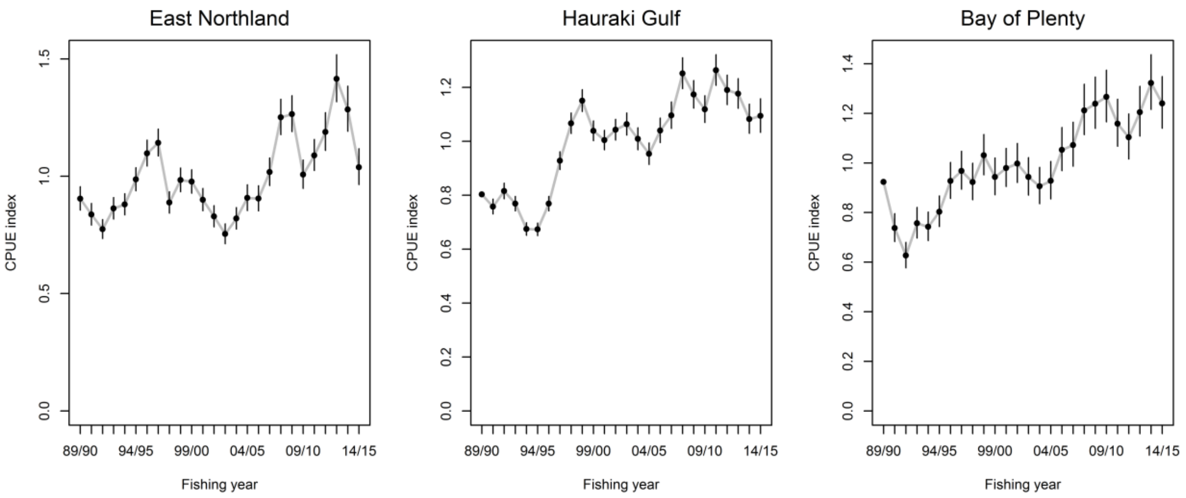


Figure 18: Longline CPUE indices (and 95% confidence intervals) updated to include 1989–90 to 2014–15 fishing years.

5.2 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).

5.2.1 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 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.

5.2.2 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.

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.

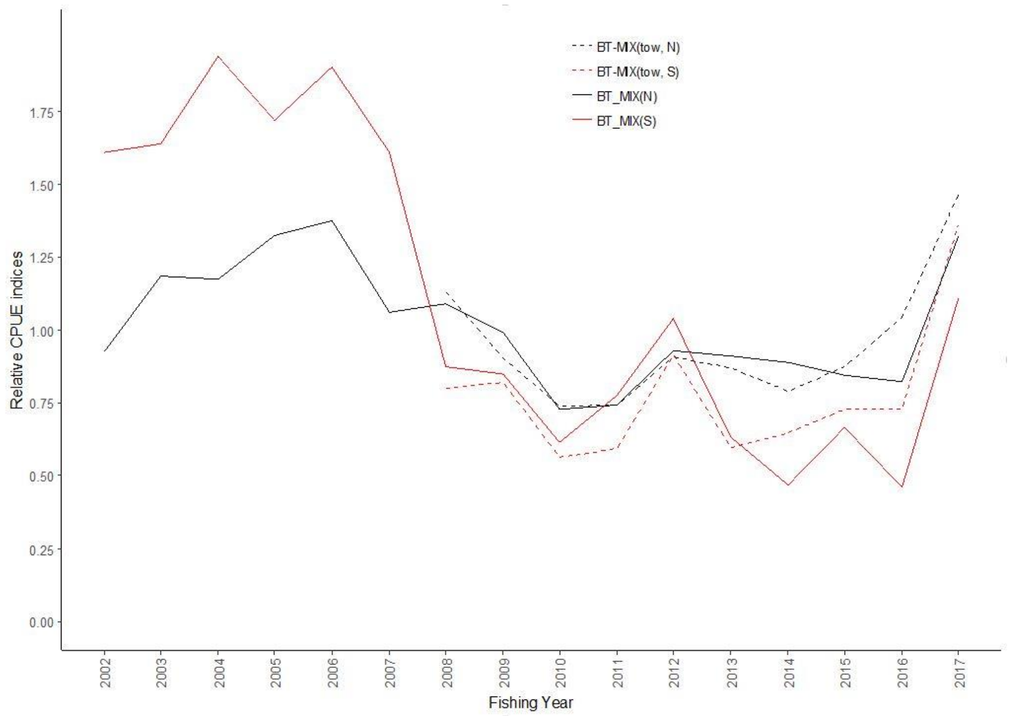


Figure 19: Comparison of standardised combined catch per unit effort (CPUE) indices for the northern and southern sub-stocks of SNA 2 from bottom trawling targeting gurnard, snapper, tarakihi, and trevally combined over all form types (BT_MIX), and more recently from data based on TCEPR/ TCER (BT_MIX(tow)) 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.

5.3 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 2020).

5.3.1 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.

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 to the indices derived from the longer-term CPUE models (all years).

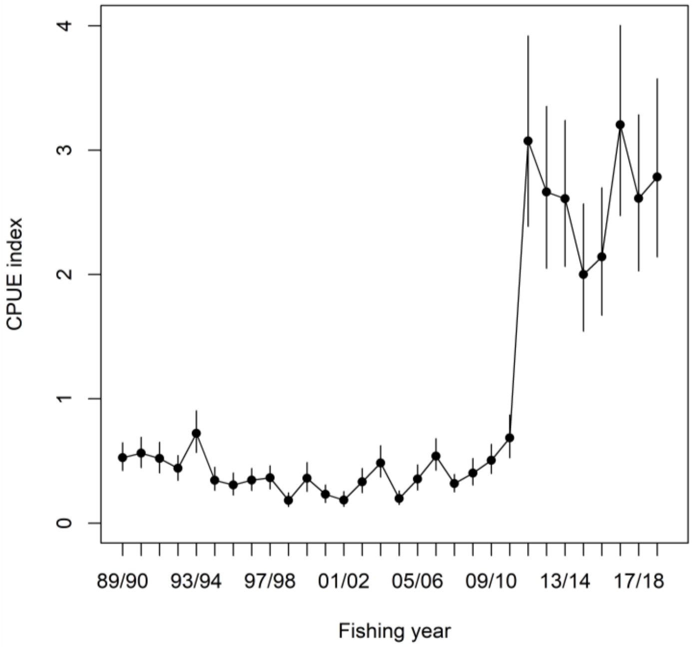


Figure 20: Relative CPUE indices derived from the delta lognormal (all years) model for the combined single trawl fishery. The vertical lines represent the 95% confidence intervals. The confidence intervals were derived using a bootstrapping procedure.

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 to 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.

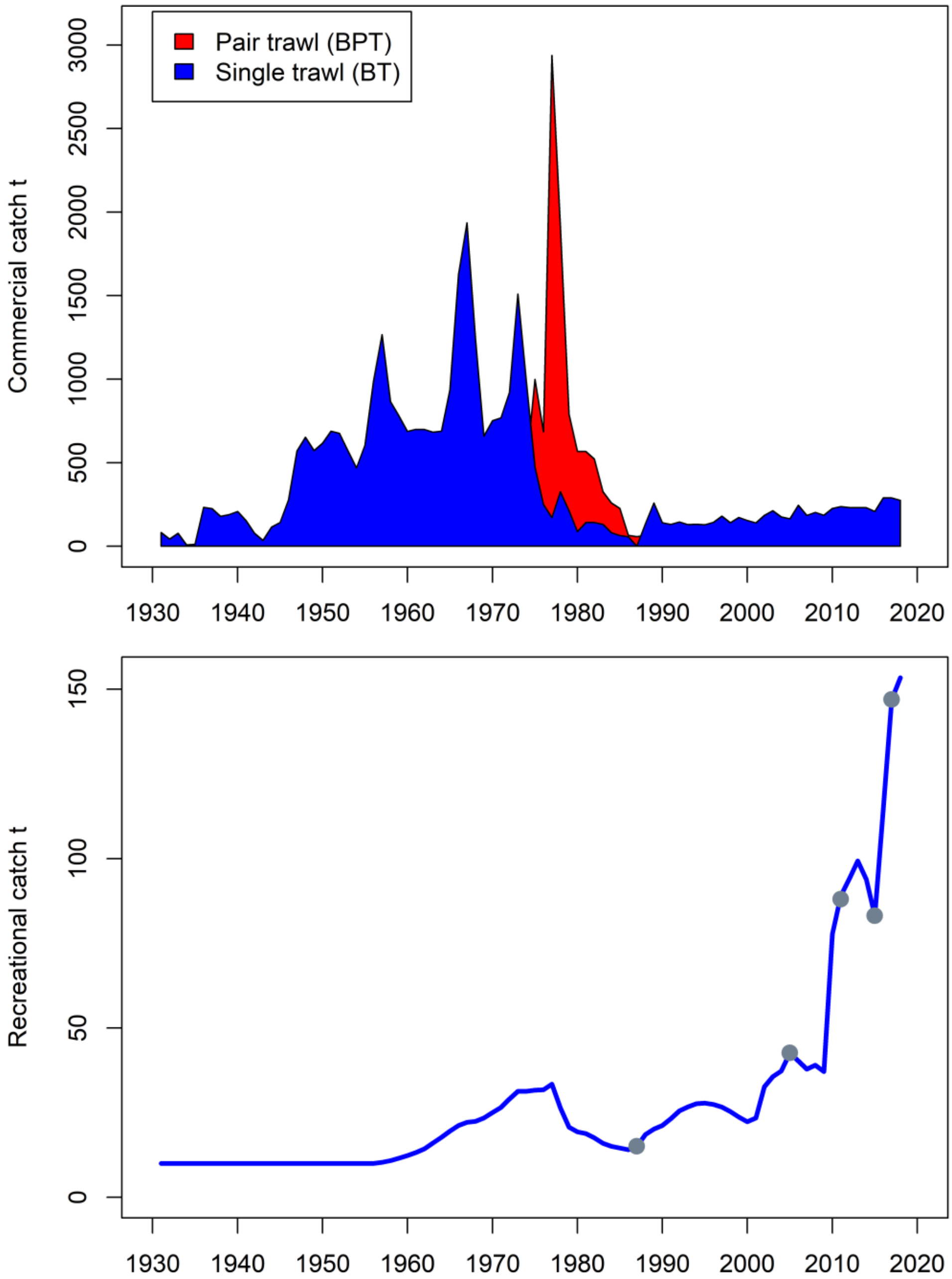


Figure 21: Commercial (top) and recreational catch histories for SNA 7 included in the stock assessment models. The commercial catch history includes an allowance for 20% unreported catch prior to the QMS and 10% allowance in the subsequent years. The grey points represent the survey estimates of recreational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

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.
1963.

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 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 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∞ = 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
LnR0	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).

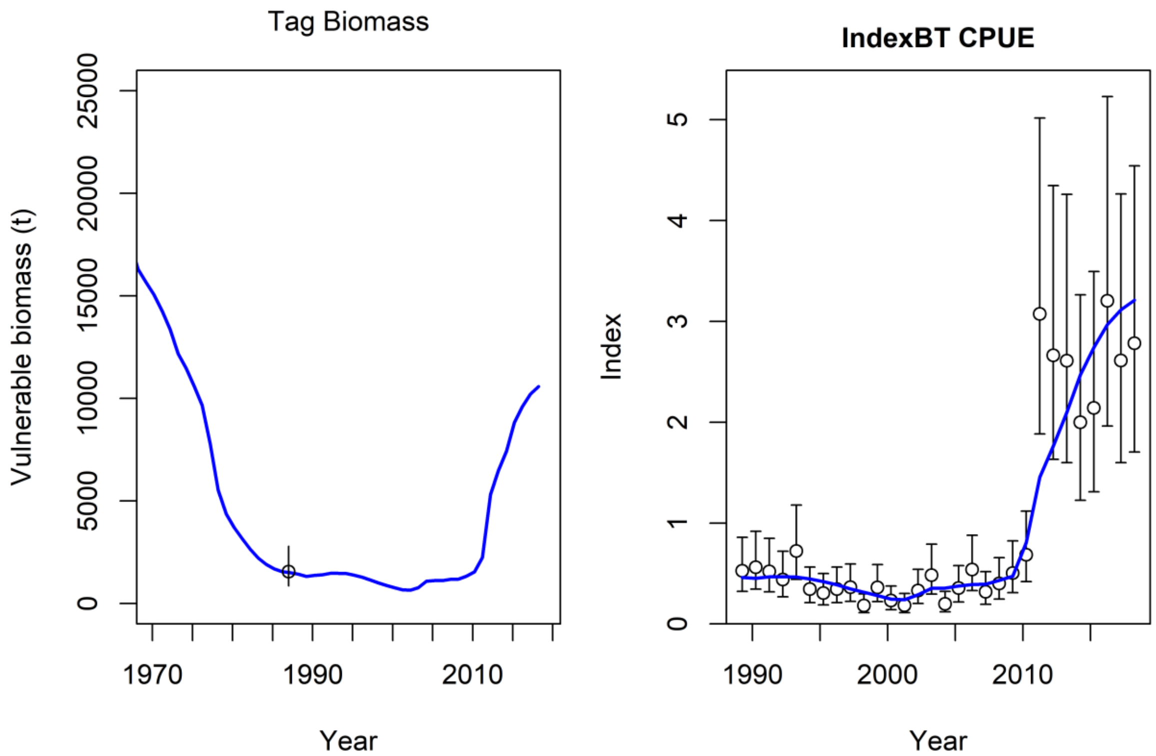


Figure 22: Biomass trajectories (MPD) for the base model option presenting the fit to the tag biomass estimate (left panel) and the CPUE indices (right panel). The point represents the biomass estimate from the 1987 tagging programme with the lognormal confidence interval (for an assumed CV of 0.30).

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.

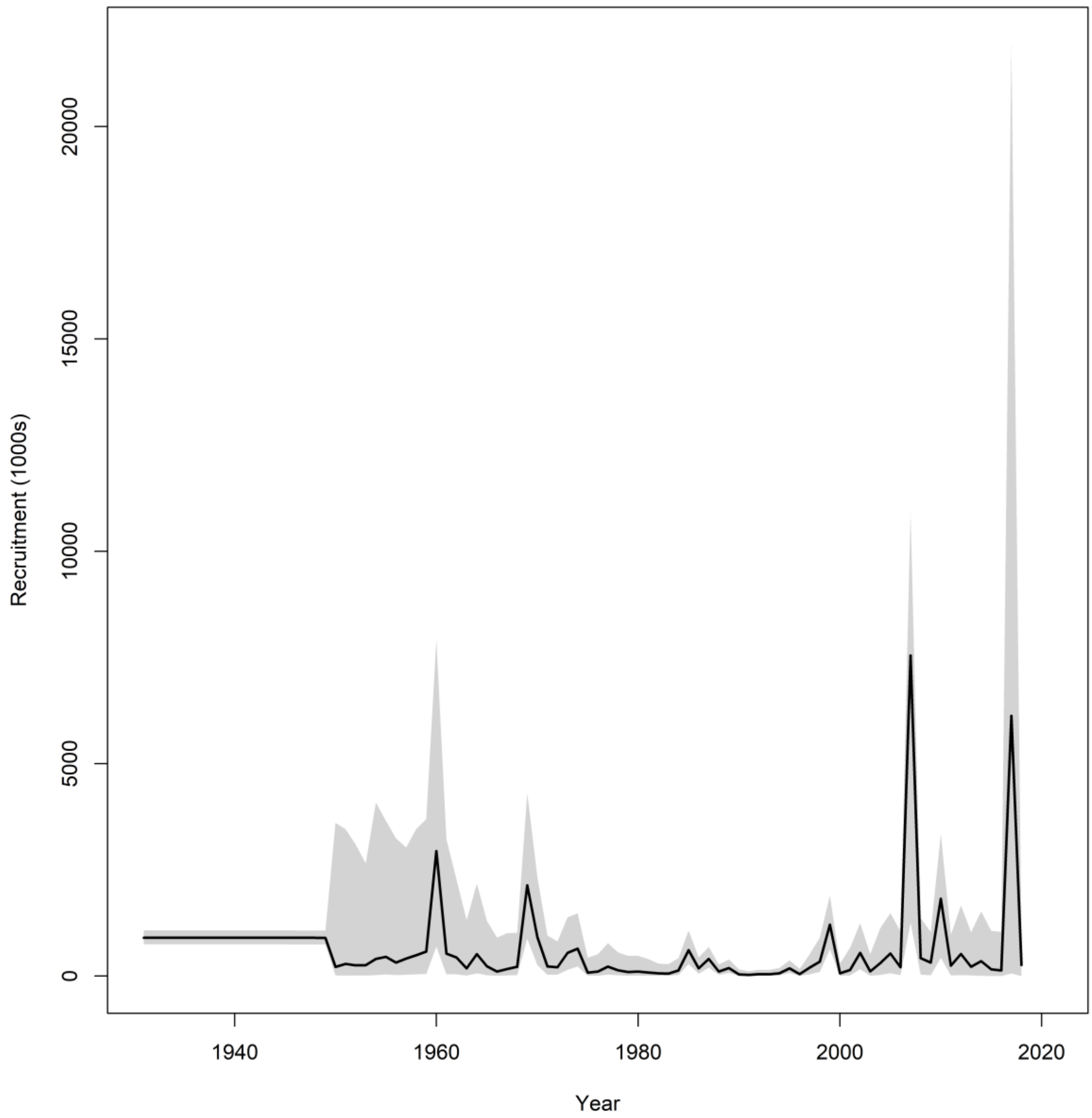


Figure 23: Annual recruitment for the base model (MCMC results). Recruitment deviates were estimated for 1950–2017. The line represents the median and the shaded area represents the 95% credible interval.

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 to 0.95), a lower value of natural mortality (0.06 compared to 0.075), and a lower value of variation in the recruitment deviates (sigmaR 1.0 compared to 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 and 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 and Table 25).

Table 25: Estimates of current (2018–19) and virgin spawning biomass (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	16,928	5,905	0.352	0.265	0.919	0.958
sensitivity	(14,719–19,486)	(19–8,609)	(0.001–0.506)			
Recruit	14,841	5,864	0.391	0.465	0.95	0.97
sensitivity	(12899–17335)	(951–8,593)	(0.066–0.567)			
SigmaR	11,107	5847	0.530	0.836	0.933	0.948
sensitivity	(9,637–12,757)	(7–8,771)	(0.001–0.774)			
Steepness	16,150	6,348	0.392	0.468	0.905	0.945
sensitivity	(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	0.048	0.76	
sensitivity	(0.035–0.050)	(0.51–6.174)	0.821
Recruit	0.056	0.674	
sensitivity	(0.037–0.059)	(0.452–3.866)	0.880
SigmaR	0.055	0.679	
sensitivity	(0.037–0.059)	(0.432–8.562)	0.847
Steepness	0.055	0.617	
sensitivity	(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 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.

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 (Figure 24a, b). 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).

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

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.

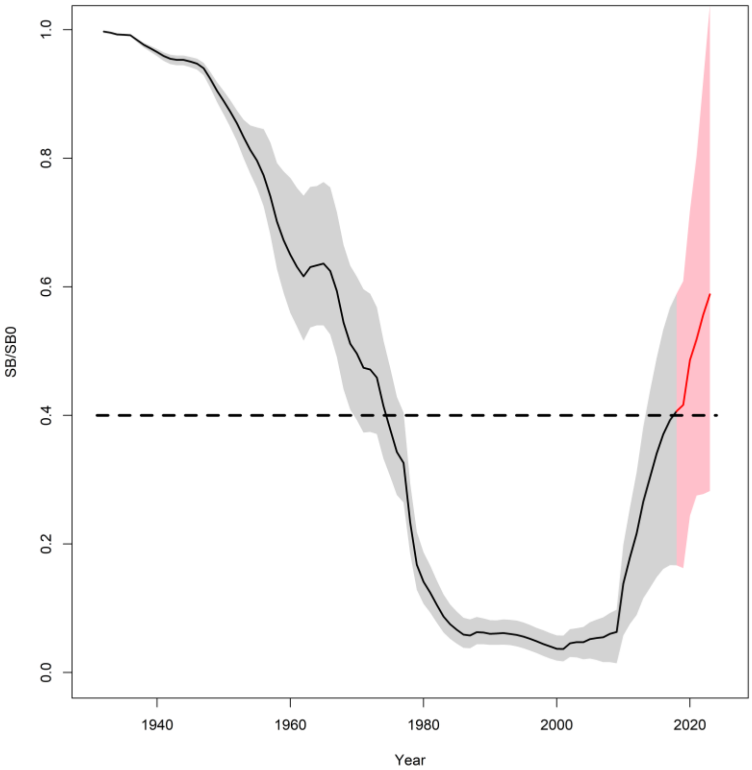


Figure 24a: Annual trend in spawning biomass relative to the 40% *SB₀* interim target biomass level for the base model, including the estimation of recruitment for the 2017 year class. The line represents the median and the shaded area represents the 95% confidence interval. The projection period (2019–2024)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

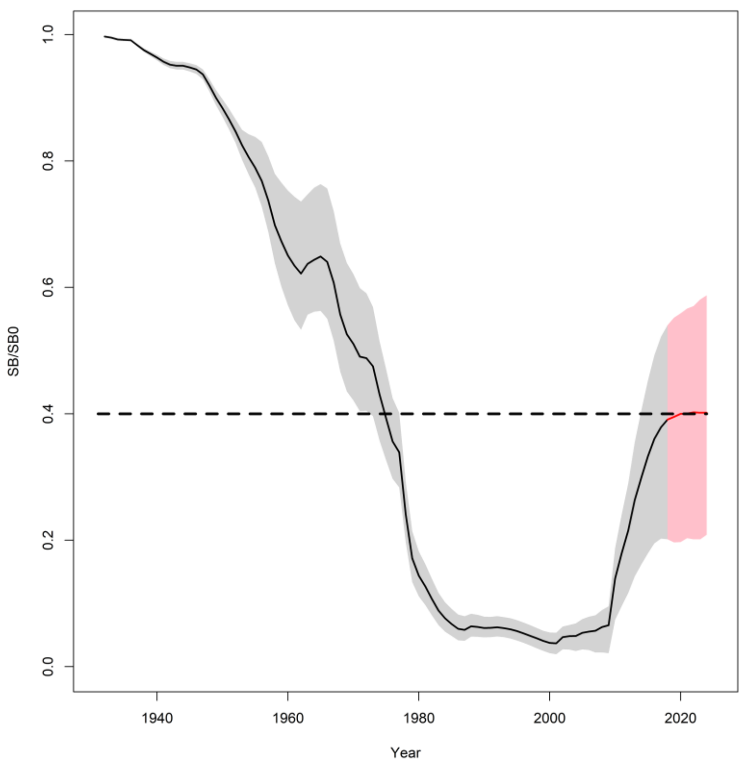


Figure 24b: Annual trend in spawning biomass relative to the 40% *SB₀* interim target biomass level for the Recruit2016 model, assuming average recruitment for the 2017 year class. The line represents the median and the shaded area represents the 95% confidence interval. The projection period (2019–2024)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

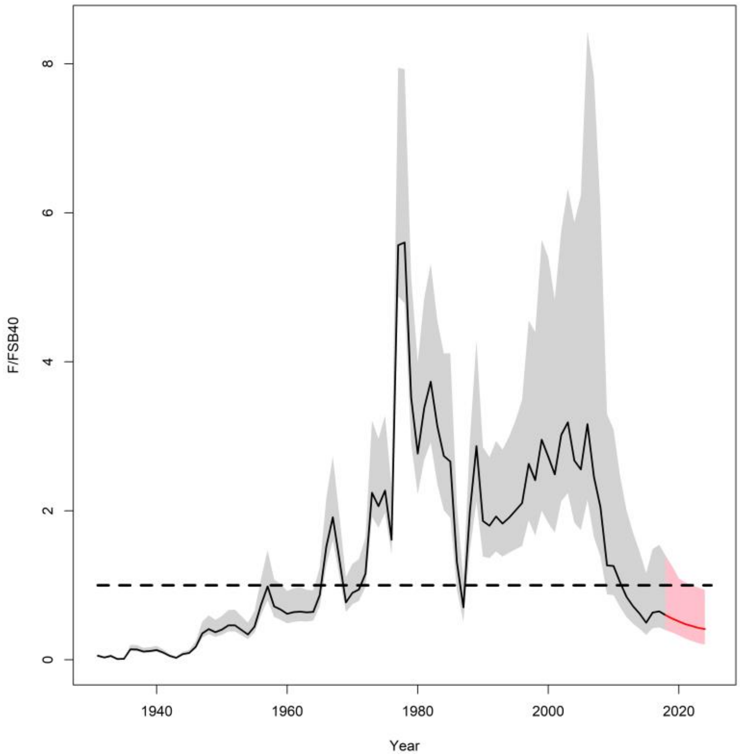


Figure 25: Annual trend in fishing mortality relative to the $F_{SB40\%}$ interim target biomass level for the base model (including estimation of the 2017/18 year class). The line represents the median and the shaded area represents the 95% credible interval. The projection period (2019–2024) is in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

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 TBGB 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 TBGB 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.

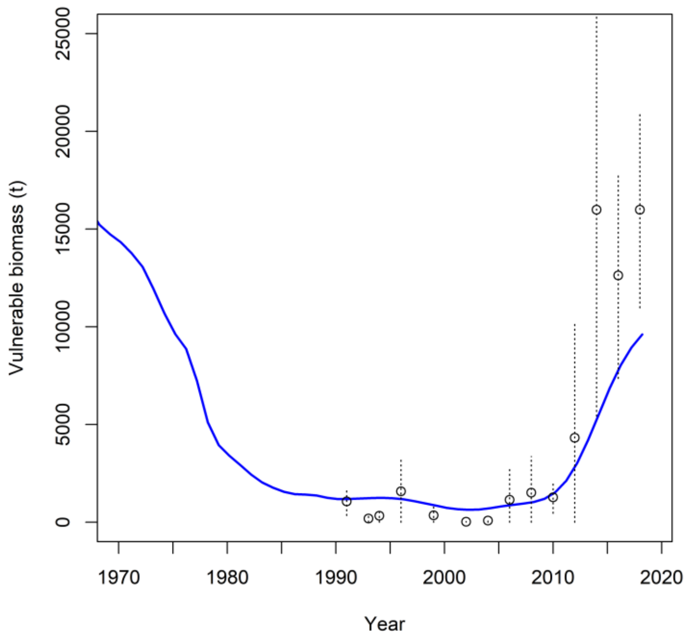


Figure 26: A comparison of the trend in trawl survey vulnerable biomass derived from the SNA 7 stock assessment (blue line) and *Kaharoa* WCSI trawl survey biomass estimates snapper from the Tasman Bay/Golden Bay area (points). The biomass indices are not included in the model likelihood.

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 will be sampled again by the next trawl survey which is scheduled for 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.

5.4 SNA 8 (Auckland West/Central West)

A stock assessment for SNA 8 was conducted in 2020 (Langley in prep), superseding the previous assessment conducted in 2005 and incorporating data from the intervening period, including recent trawl survey recruitment indices, commercial age composition data and trawl CPUE indices. The assessment will be updated and finalised in 2021.

5.4.1. Stock assessment model

The 2020 stock assessment of SNA 8 was conducted using an age-structured population model implemented in Stock Synthesis. The model incorporated data to the 2019/20 fishing year (2020 model year) including:

- Commercial catches by method, 1931–2020;
- Recreational catches, 1931–2020;
- 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 1997–2019;
- Pair trawl CPUE indices 1974–1991;
- Single trawl catch age compositions (26 observations) 1975–2019;
- Pair trawl catch age compositions (18 observations) 1975–2016;
- 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 2018–19 fishing years were available from catch reporting under the Quota Management System (QMS) (Figure 27).

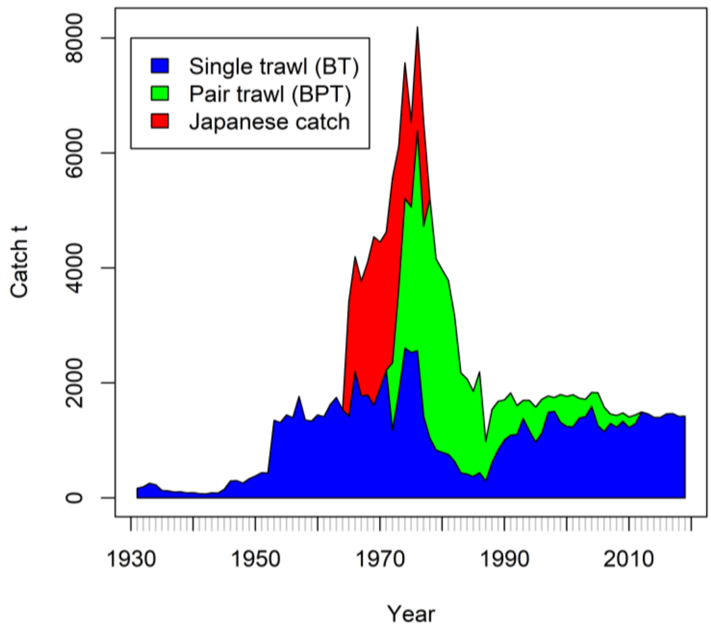


Figure 27: Annual commercial catches included in the base model, assuming unreported Japanese longline catches of 2000 t.

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 2018–19 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 (with alternative levels of 1000 t and 3000 t evaluated as model sensitivities).

Recreational catches

A time series of recreational catch for 1931–2020 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).

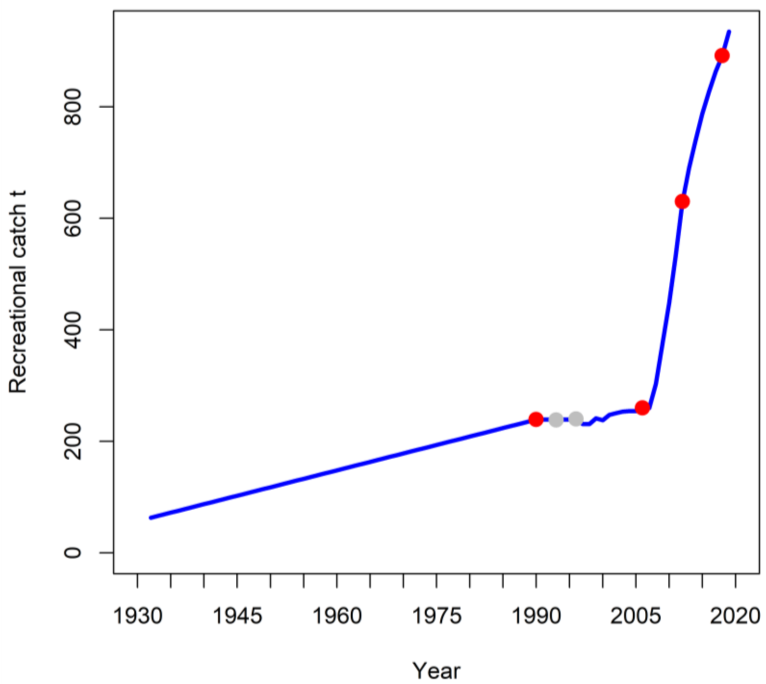


Figure 28: Recreational catch estimates from SNA 8 (red points) used in the derivation of the recreational catch history (blue line). The grey points are additional recreational catch estimates from the 1993–94 and 1995–96 telephone diary surveys (presented for comparison only).

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).

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 the previous assessment; i.e., 1990, 9505 t (CV = 0.18) and 2002, 10 442 t (CV = 0.12). The biomass estimates were derived to represent all fish in the population 3 years and older, corresponding to fish above 25 cm (FL) in length. The two tagging programmes also provided estimates of the population length composition for fish above 25 cm (FL) in length. 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 R.V. *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 a subsequent survey was conducted in 2019. A further trawl survey is scheduled for 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 Mauī dolphin trawl exclusion area which was not sampled by the 2018 and 2019 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 two recent surveys, although there is also a considerable difference in the magnitude of these two recent indices. The corresponding age compositions from the surveys reveal that the earlier surveys were dominated by 2–5 year old fish. For the recent surveys, the age compositions comprised a higher proportion of fish older than 6 years, particularly for the most recent (2019–20 survey). A comparison of the results from the two most recent surveys indicated variation in the availability of the older (mature) fish between the surveys, suggesting that these surveys might not provide a reliable index of total biomass.

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.

In contrast, there is a reasonable correspondence between successive trawl survey estimates of the number of fish in a specific year class over the 2–5 year age classes. This suggests that the trawl surveys are consistently sampling fish within those age classes.

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 8–12 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.

Because of the issues raised above, the model was deemed to be an Interim Base Case, including the four sets of age-specific abundance indices (numbers of fish at age 2, 3, 4, and 5 years) from the survey (Figure 29) (and excluding the trawl survey biomass indices and age compositions). The inclusion of the trawl survey biomass indices will be reviewed again during the 2021 stock assessment, including the additional data available from the 2020–21 survey.

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.

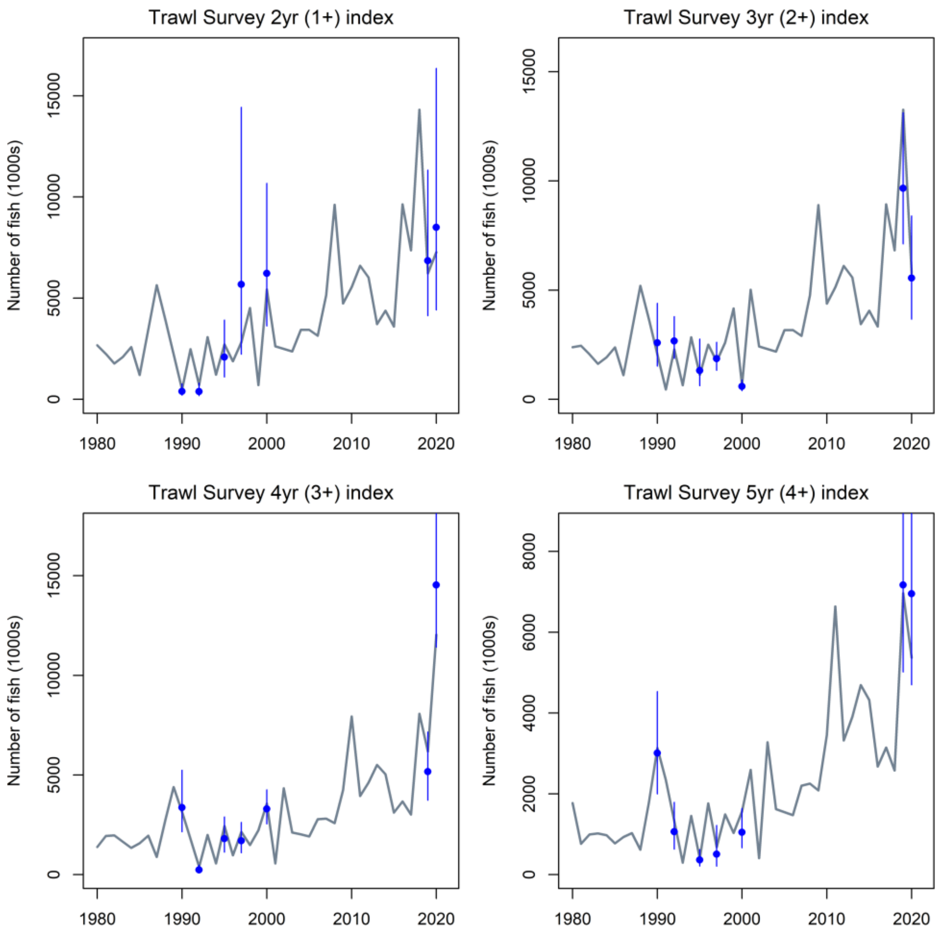


Figure 29: The four sets of age specific trawl survey abundance indices (blue points and associated 95% confidence intervals) and the model fit to each set of indices (grey lines).

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 30). 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 2018–19 (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 30). The indices remained at the higher level during 2015–16 to 2018–19. The 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.

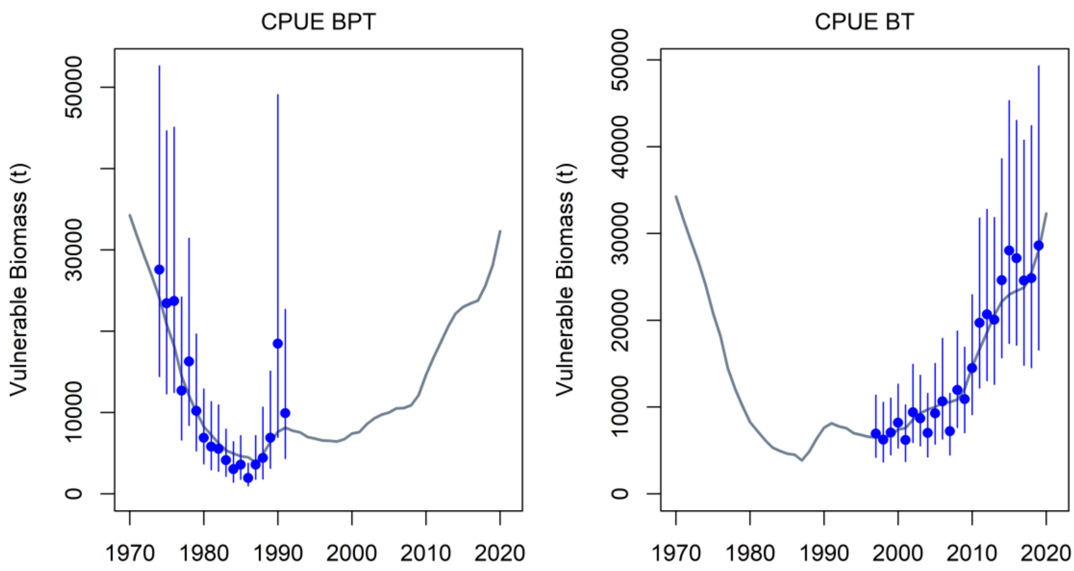


Figure 30: BPT CPUE indices (left) and recent BT CPUE indices (right). The grey line represents the model fit to the indices.

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 2020 year (2019–20 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 (unpublished).

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 2006–2020) 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
	2006–2020	*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	Ln*R0*		Estimated (1)
	B-H SRR steepness *h*	0.95	Fixed
	SigmaR σR	0.6	Fixed
	Recruitment deviates	Lognormal deviates (1960–2018)	Estimated (59)

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 (SRR) was assumed with a fixed value of steepness (*h*). Recruitment deviates (1960–2018) 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), 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 (Gilbert et al 2005). 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 most recent (2019–20) trawl survey biomass index related to a difference in the catchability of older fish between recent surveys (section 5.3).

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.

Table 29: Summary of input data sets for Interim 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	1997–2019	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	7	Lognormal	0.26–0.48	-
Trawl survey age 3yr	1990, 1992, 1995, 1997, 2000, 2019, 2020	7	Lognormal	0.16–0.38	-
Trawl survey age 4yr	1990, 1992, 1995, 1997, 2000, 2019, 2020	7	Lognormal	0.12–0.38	-
Trawl survey age 5yr	1990, 1992, 1995, 1997, 2000, 2019, 2020	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	

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 (ESS) approximating the value derived from Method TA1.8 of Francis (2011).

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

Parameter	Number of parameters	Parameterisation, priors, constraints
LnR0	1	Uniform, uninformative
Rec devs (1960–2018)	59	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

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 2020 model year (2019–20 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 (2019–20). Estimates of equilibrium yield are determined from the level of fishing mortality that produces the target biomass level ($F_{SB40\%}$).

Results

The model provided a coherent fit to all the main datasets. The trend in stock biomass is consistent with the previous stock assessment; 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 31), 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 2014–2016. The estimates of recent recruitment are informed by the age-specific trawl survey indices.

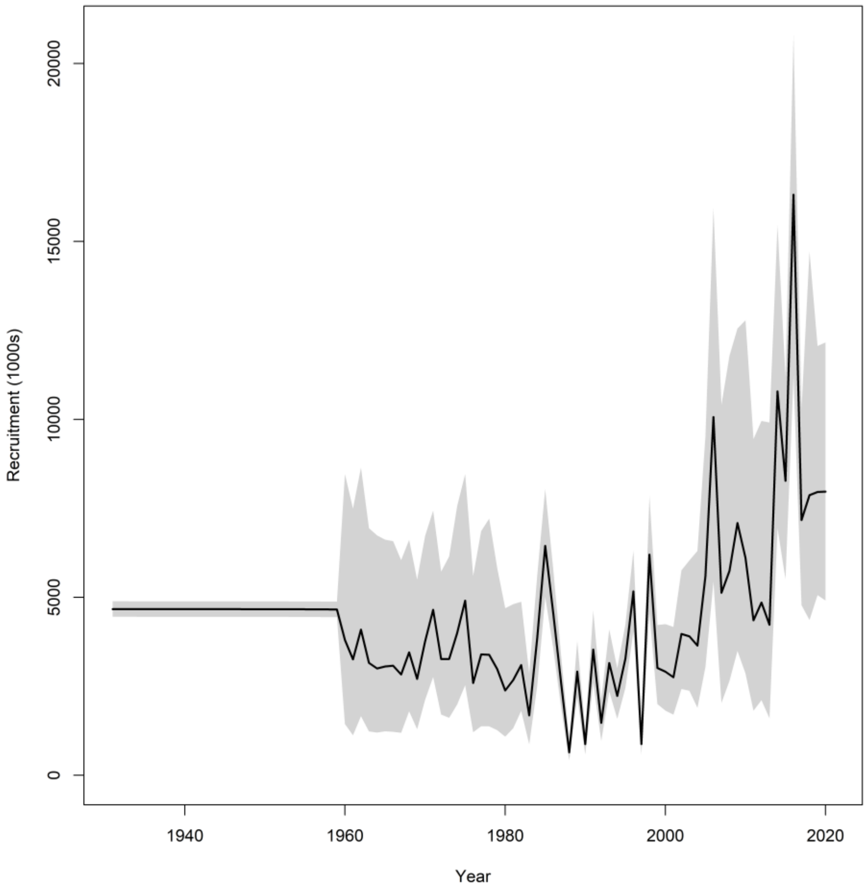


Figure 31: Annual estimates of recruitment (numbers of fish, thousands) from the Interim Base Case model (MCMCs). The black line represents the median of the MCMC estimates and the shaded error represents the 95% confidence interval.

Current (2020 = 2019–20 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 (10% SB_0) limits is negligible (Table 31). There has been a corresponding decline in fishing mortality over the last 10 years and current (2020) fishing mortality is estimated to be at about 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 Interim Base Case model (Table 31). The historical level of Japanese catch is unknown and, as in a previous assessment (Davies & McKenzie 2001), the base level of catch (2000 t) was bracketed by alternative catch levels of 1000 t (*JPcatch1000*) and 3000 t (*JPcatch3000*). 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*). Estimates of stock status for the model sensitivities were obtained from MCMC sampling, with the exception of the *Steep085* sensitivity due to the significant proportion of MCMC chains that resulted in the stock crashing at low levels of stock biomass due to the lower value of steepness of the SRR. In that case, model results were presented for the MPD only.

The two alternative Japanese catch options yielded estimates of current stock status results that were very similar to the Interim Base Case. The *SigmaR08* model also provided a very similar estimates of current stock status, although overall equilibrium yields are slightly higher than for the Interim Base Case. The two lower productivity options (*NatMort06* and *Steep085*) estimated lower levels of current biomass (relative to virgin spawning biomass) compared with the Interim Base Case, although for both model options 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. For the lower natural mortality option (*NatMort06*), current fishing mortality rates were above the reference level.

The range of model sensitivities also included an option that incorporated the time series of *Kaharoa* trawl survey biomass indices and age compositions (*TrawlSurveyBiomass*) rather than the age specific indices included in the Interim Base Case. The fit to the recent trawl survey biomass indices in the *TrawlSurveyBiomass* model was poor, with the model considerably under-estimating the most recent (2019–20) trawl survey biomass index. The estimate of current stock status from the *TrawlSurveyBiomass* was very similar to the Interim Base Case.

Table 31: Estimates of current (2020 = FY 2019–20) and virgin spawning biomass (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. X is Pr($F_{2020} < F_{SB40\%}$). The results from the Steepness 0.85 sensitivity are from MPD only due to poor performance of MCMCs.

Model option	SB_0	SB_{2020}	SB_{2020}/SB_0	Pr(SB_{2020} > X% SB_0)		
				40%	20%	10%
Interim Base	97,517 (93,004–102,080)	47,321 (28,317–60,429)	0.487 (0.296–0.600)	0.872	0.994	1.000
JPcatch1000	92,717 (88,697–97,004)	45,229 (28,609–57,132)	0.487 (0.317–0.597)	0.886	0.996	1.000
JPcatch3000	102,407 (97,637–107,228)	50,017 (28,231–64,571)	0.489 (0.281–0.606)	0.869	0.987	0.998
NatMort06	109,268 (105,049–113,968)	41,163 (21,142–54,202)	0.377 (0.195–0.487)	0.355	0.974	0.994
SigmaR08	106,500 (101,342–111,527)	48,362 (29,531–62,232)	0.454 (0.286–0.567)	0.778	0.995	0.998
*Steep085**	108,752 (104,268–113,236)	45,540 (35,223–55,856)	0.419 (0.334–0.503)	NA	NA	NA
TrawlSurveyBiomass	98,486 (94,208–103,063)	49,652 (31,432–65,199)	0.507 (0.325–0.639)	0.899	0.999	1.000
	$F_{SB40\%}$	$F_{2020}/F_{SB40\%}$	X			
Interim Base	0.053 (0.052–0.055)	0.907 (0.720–1.485)	0.722			
JPcatch1000	0.053 (0.052–0.055)	0.955 (0.758–1.467)	0.635			
JPcatch3000	0.054 (0.052–0.055)	0.855 (0.678–1.458)	0.823			
NatMort06	0.042 (0.040–0.044)	1.321 (1.00–2.523)	0.025			
SigmaR08	0.053 (0.051–0.055)	0.894 (0.698–1.424)	0.756			
*Steep085**	0.049 (0.048–0.051)	1.018 (0.798–1.238)	NA			
TrawlSurveyBiomass	0.054 (0.052-0.055)	0.865 (0.665-1.339)	0.805			

Projections

Two-year stock projections (to the 2021–22 fishing year) were conducted using the Interim Base Case model assuming annual catches equivalent to the 2020 catch; i.e., a commercial catch equivalent to the TACC (1300 t) and an allowance of 10% for unreported catches (total 1430 t) and a recreational catch of 935 t (total 2356 t). Annual recruitment deviates for the 2-year projection period were resampled from the average level of the last 10 years estimated in the model (2009–2018) with the standard deviation equivalent in sigmaR (0.6). The average level of estimated recruitment in the recent (10 year) period was considerably higher (~70% higher) than the long-term average level of recruitment.

The projections indicate that the stock biomass will continue to increase during the 2-year projection period, with the biomass at the end of the period (2022) projected to be 34% higher than current (2019–20) biomass ($SB_{2022}/SB0$ = 0.653, C.I. 0.49–0.77) (Table 32). The increase in spawning biomass during the projection period is partly attributable to the maturation of the exceptionally large 2016 year class.

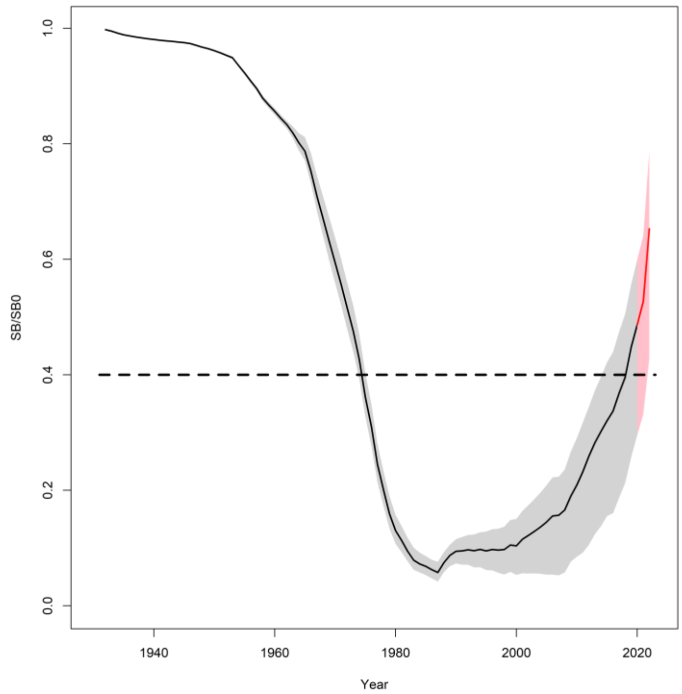


Figure 32: Annual spawning biomass relative to virgin biomass (equilibrium, unexploited) estimated from the Interim Base Case model (black) and the two-year projection (red) assuming annual catches equivalent to the 2020 catch. The solid line represents the median of the MCMCs and the shaded areas represent the 90 and 95% confidence intervals. 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 2022 (FY 2021–22) for the base case.

Projected $SB_{2022}/SB0$	$Pr(SB_{2022} > X\% \, SB_0)$		
	10%	**20%**	**40%**
0.653 (0.486–0.770)	1.000	0.999	0.984

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. A reliable time series of indices of stock abundance from the trawl survey would reduce the reliance on the CPUE indices over the recent period (last 15 years) and forthcoming years, especially since it appears unlikely that an additional tag based estimate of stock biomass will be available in the foreseeable future.

Since 1989–90, the area north of Cape Egmont has accounted for 90–95% of the SNA 8 commercial catch. Most of the 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, potentially, linkages between the southern area of SNA 8 and the SNA 7 (Tasman Bay/Golden Bay) stock. These issues will be further investigated during the next iteration of the stock assessment scheduled for 2021. 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 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 and 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.

Future research considerations

Further refinements to the current assessment are scheduled for the next year and will be incorporated into the 2021 assessment. It is intended that the updated assessment will incorporate an additional set of data from the *Kaharoa* inshore trawl survey scheduled for October–November 2020, representing the third survey in the recent series. These data will enable a more thorough evaluation of the utility of the current trawl survey programme for the monitoring of the total SNA 8 stock biomass. Specifically, the additional survey may provide additional information to elucidate the differences in the magnitude of the biomass estimates obtained from the two recent surveys. At a minimum, the 2020–21 trawl survey will provide additional estimates of the abundance of recent year classes (surveyed as 2–5 year old fish). The age compositions derived from the recent inshore trawl surveys will also be applied 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.

The updated stock assessment will include updated CPUE indices and will investigate the integration of the tag release recovery data sets in the model framework. The model will also include a number of other refinements; specifically: refinement of the modelling of time variation in growth (potentially including the "platoons" feature of Stock Synthesis), more explicit modelling of the tag length composition based on a direct translation of the length structure of the original estimates, accounting for the change in the trawl selectivity associated with the increase in minimum cod-end mesh size (from 100 to 125 mm in 1995–96), and accounting for the change in the MLS for recreational catches (from 25 cm to 28 cm). It is recommended that the age composition data from the 1970s be 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.

Major sources of uncertainty will also be investigated through a concurrent study that will apply a simulation approach to evaluate current model assumptions. That project will focus on the potential biases associated with key structural assumptions of the assessment, particularly related to the spatial structure of the snapper population within SNA 8 and non-stationarity in recruitment and the potential for variation in growth rates to be related to stock abundance (i.e., density dependence). It is anticipated that the results of the simulation study will be available for the 2021 assessment.

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.

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 two recent trawl surveys (at ages 3 and 4 years). This year class will be recruiting to the commercial fisheries over the next 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 of future sampling should be conducted following an evaluation of the efficacy of the trawl survey sampling of the snapper population.

The recent increase in the catch from the recreational fishery highlights the importance of this component of the fisheries 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 or the following year, 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.

Projections indicate a large 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.

6. STATUS OF THE STOCKS

Stock Structure Assumptions

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

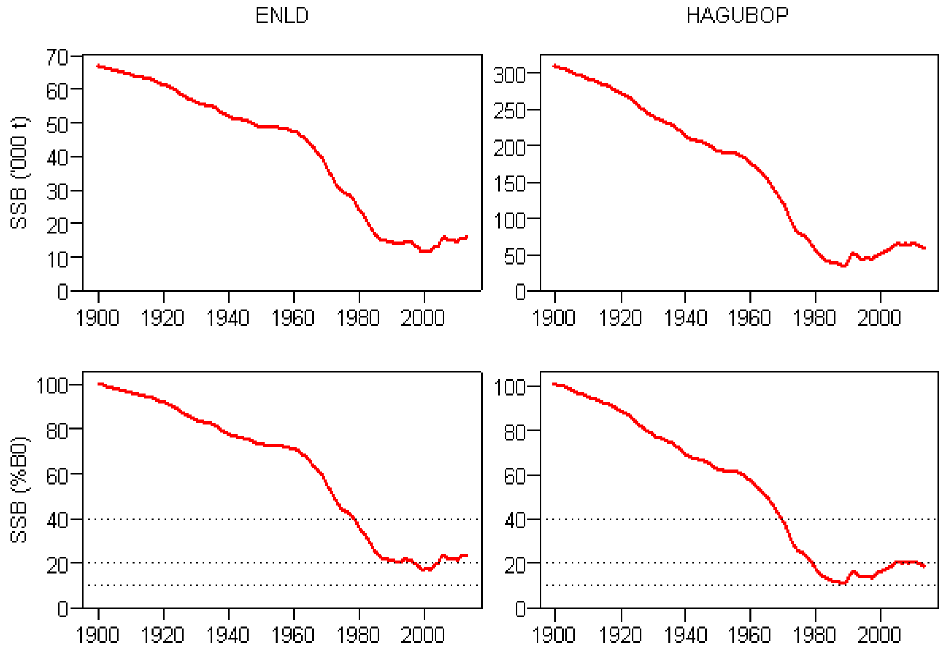
- **SNA 1**

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.

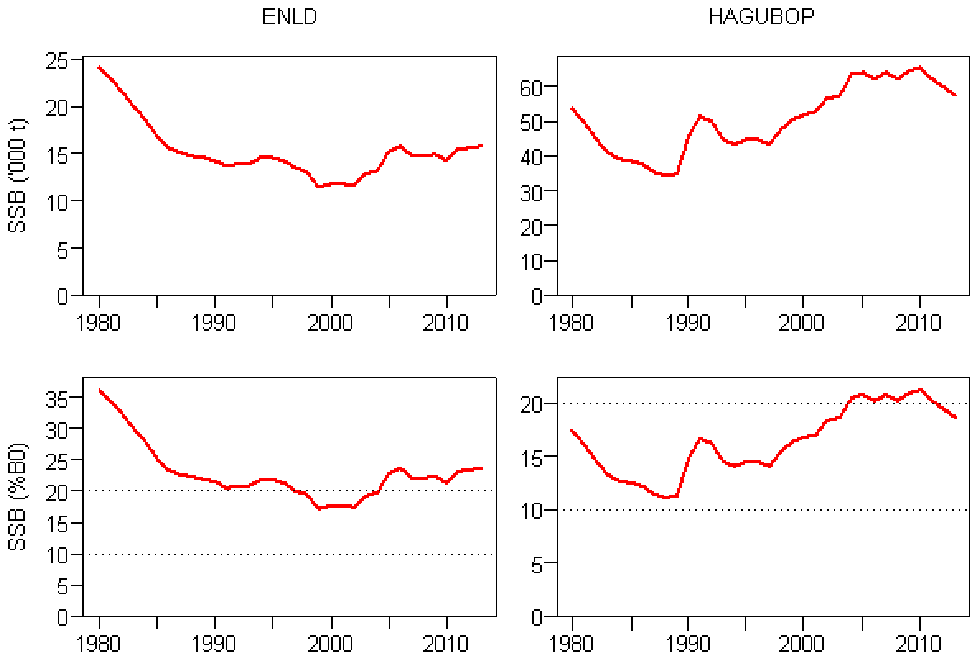
Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	Base case models (M = 0.075, h = 0.85) for East Northland and the Hauraki Gulf and Bay of Plenty to 2012–13
Reference Points	Interim target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $U_{40\%B0}$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

	Hauraki Gulf + Bay of Plenty B_{2013} is About as Likely as Not (40–60%) to be below the soft limit B_{2013} is Very Unlikely (< 10%) to be below the hard limit
Status in relation to Overfishing	East Northland Overfishing is Likely (> 60%) to be occurring Hauraki Gulf+Bay of Plenty Overfishing is Likely (> 60%) to be occurring

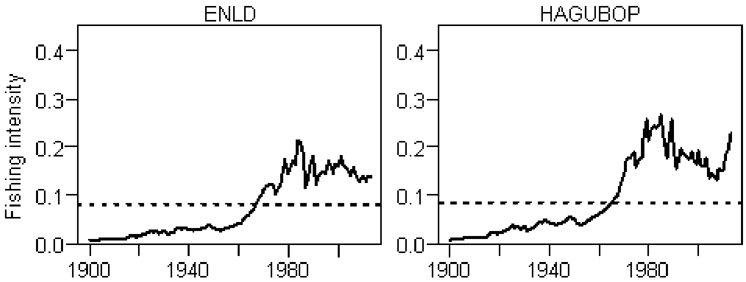
Historical Stock Status Trajectory and Current Status



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



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

Fisheries and Stock Trends	
Recent Trend in Biomass or Proxy	<u>East Northland</u> Stock biomass was estimated to have experienced a long steep decline from about 1960 to 1985, and has fluctuated without trend since then. <u>Hauraki Gulf+Bay of Plenty</u> 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	 <u>East Northland</u> The fishing intensity for this stock rose sharply from the early 1960s, reached a peak in the early 1980s, and has since declined slightly. <u>Hauraki Gulf + Bay of Plenty</u> 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 2012/13–2014/15. The most recent indices were broadly comparable to the indices from 2007/08–2011/12, 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 SSBs in East Northland and in the Hauraki Gulf-Bay of Plenty combined.
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits (5 years)	<u>Soft limit</u> East Northland: Very Unlikely (< 10%) Hauraki Gulf + Bay of Plenty: Unlikely (< 40%) <u>Hard limit</u> 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	<u>East Northland</u> Current catch is Very Likely (> 90%) to cause overfishing to continue <u>Hauraki Gulf + Bay of Plenty</u> 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: 2020
Overall assessment quality rank	1 - High Quality	
Main data inputs (rank)	- Proportions-at-age from the commercial fisheries, and historic trawl surveys	1 – High Quality
	- Proportions-at-length from the recreational fishery	1 – High Quality
	- Estimates of biological parameters (e.g. growth, age-at-maturity and length/weight)	1 – High Quality
	- Standardised longline CPUE indices	1 – High Quality
	- Standardised single trawl for the BoP	1 – High Quality
	- Estimates of recreational harvest	1 – High Quality
	- Commercial catch	1 – High Quality
	- Tag-based biomass estimates (BoP - 1983)	2 – Medium or Mixed Quality: data no longer available
	- Data from tagging experiments in 1985 (HG, EN)	1 – High Quality
	- Data from tagging in 1994 (all areas)	1 – High Quality
Data not used (rank)	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, as 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, while 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]

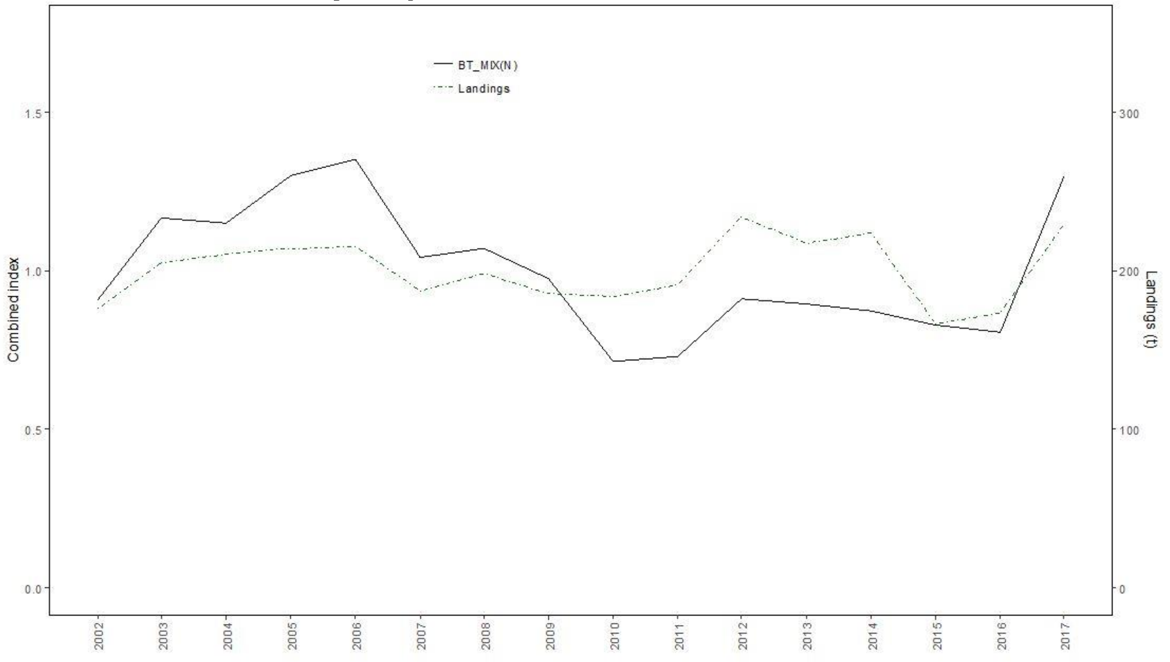
[1] The risk was defined as the ratio of the estimated annual number of fatalities of birds due to bycatch in fisheries to the Potential Biological Removal (PBR), which is an estimate of the number of seabirds that may be killed without causing the population to decline below half the carrying capacity.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

- **SNA 2**

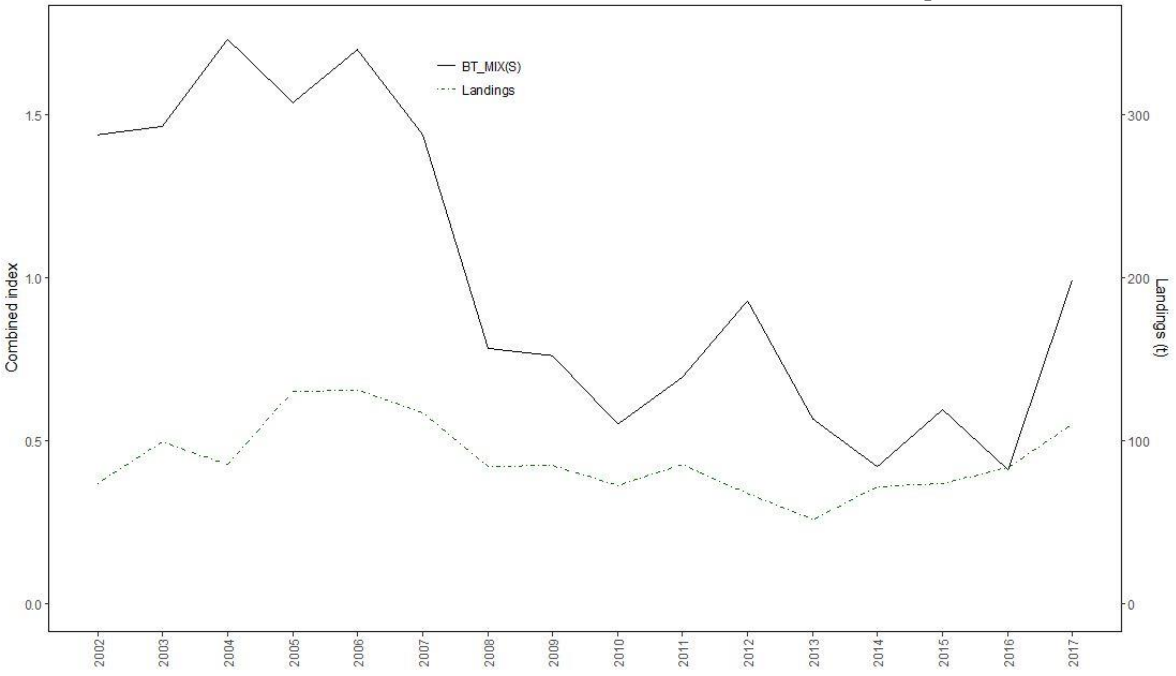
SNA 2 is assumed to occur in two sub-stocks. The northern sub-stock occurs between the southern tip of the Mahia Peninsula and Cape Runaway, and is likely to be associated with the SNA 1 Bay of Plenty stock. The southern sub-stock occurs within Hawke Bay, and may be peripheral to the northern stock rather 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: BMSY-compatible proxy based on CPUE: not determined Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: FMSY <u>Southern Stock</u> Target: BMSY-compatible proxy based on CPUE: not determined Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: FMSY
Status in relation to Target	<u>Northern Stock</u>: Unknown <u>Southern Stock</u>: Unknown
Status in relation to Limits	<u>Northern Stock</u> Soft: Unknown Hard: Unknown <u>Southern Stock</u> Soft: Unknown Hard: Unknown
Status in relation to Overfishing	<u>Northern Stock</u>: Unknown <u>Southern Stock</u>: Unknown

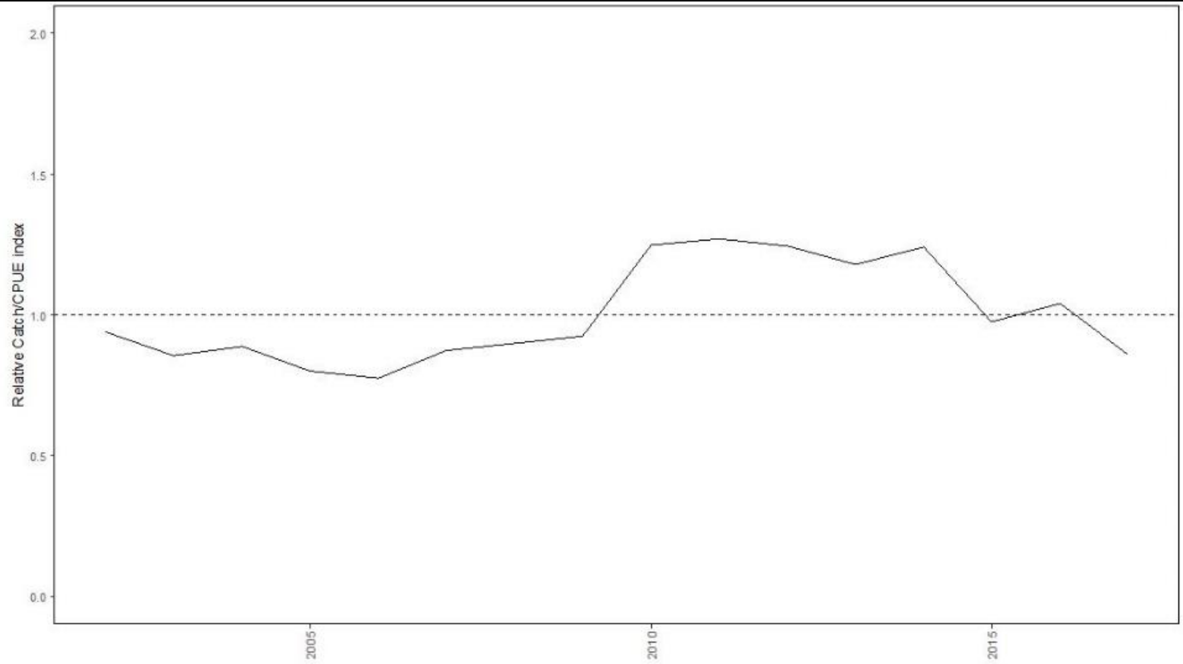
Historical Stock Status Trajectory and Current Status



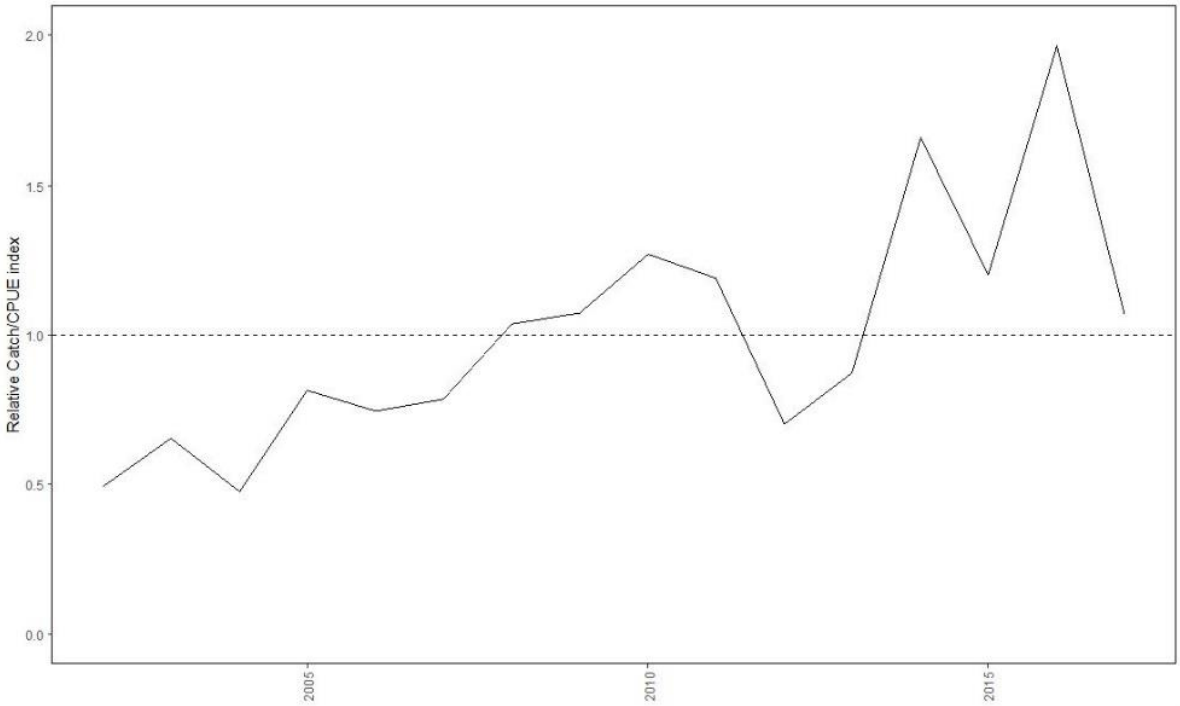
Standardised combined catch per unit effort (CPUE) indices for SNA 2 from bottom trawling targeting gurnard, snapper, tarakihi and trevally (BT_MIX(north)) that combines all form types at a daily aggregation (Schofield et al 2018b). In the occurrence of positive catch model a binomial distribution was 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: 2019
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 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.

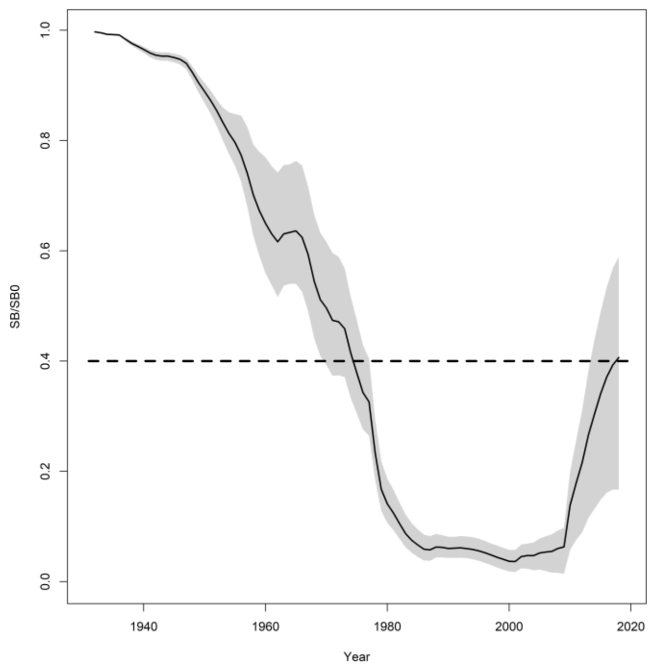
- **SNA 7**

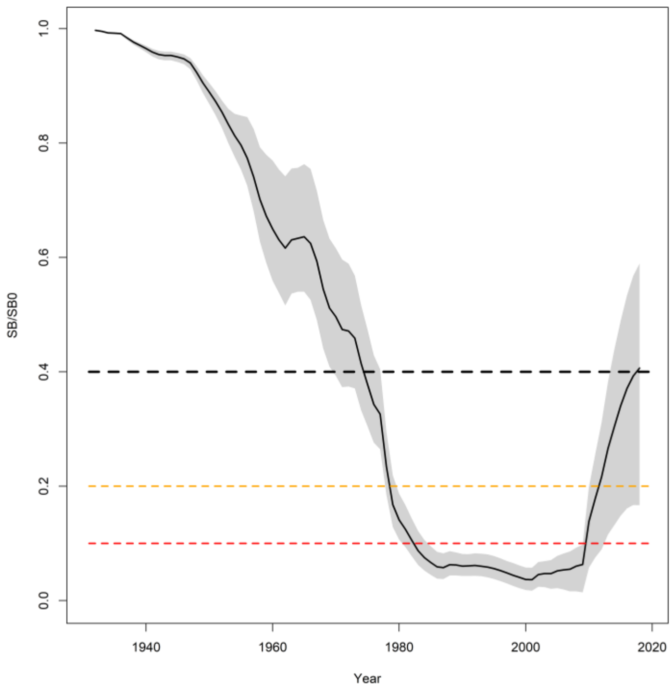
The assessment is for the Tasman Bay, Golden Bay and west coast South Island stock unit of SNA 7. The Marlborough Sounds is considered to support a separate stock of snapper within SNA 7.

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

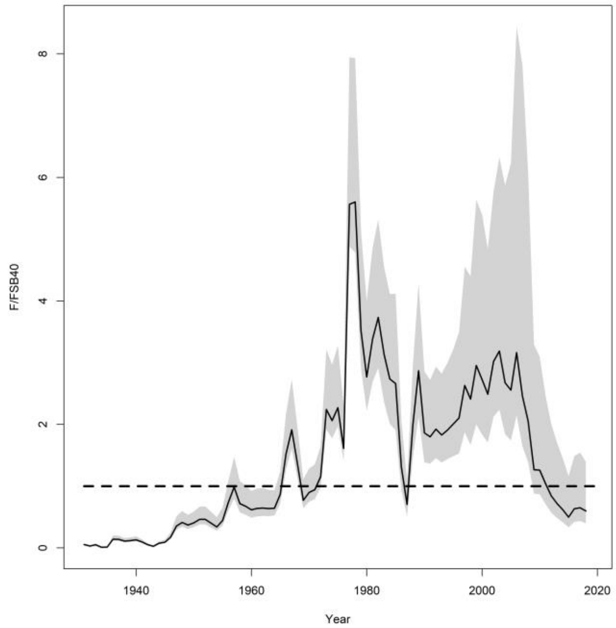
Historical Stock Status Trajectory and Current Status



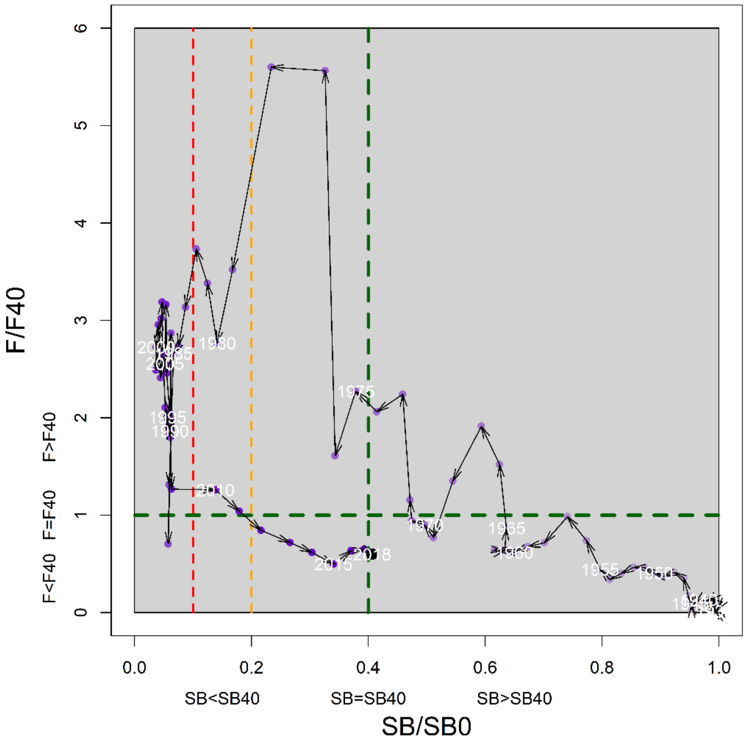


Annual trend in spawning biomass relative to the 40% SB_0 interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% credible interval. The black dashed line represents the interim target level. The red and orange dashed lines represent the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

<table>
<tr><th colspan="2">Fisheries and Stock Trends</th></tr>
<tr><td>Recent Trend in Biomass or Proxy</td><td>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.</td></tr>
<tr><td>Recent Trend in Fishing Intensity or Proxy</td><td>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.</td></tr>
</table>

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.

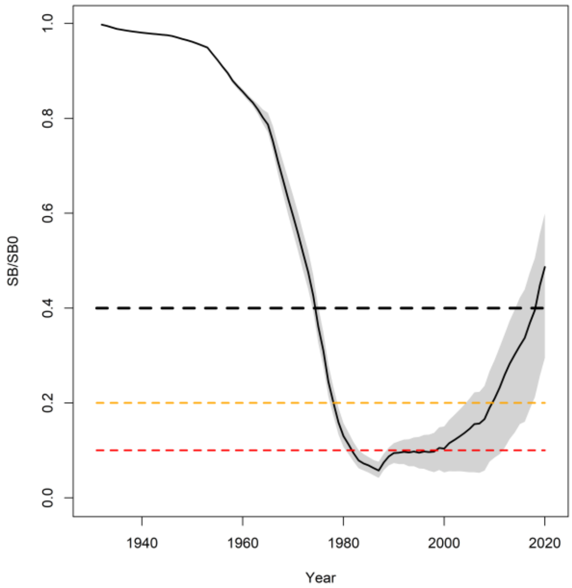
- **SNA 8**

Stock Structure Assumptions

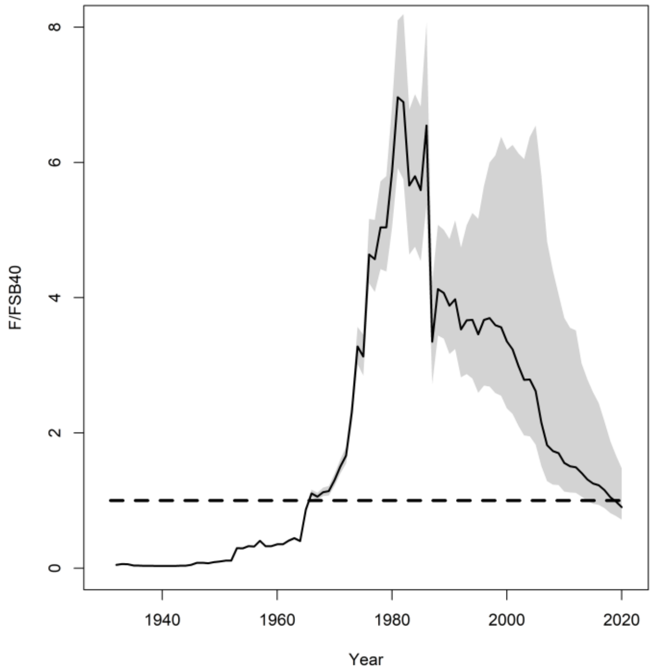
Tagging, genetic and morphological studies have revealed that snapper off the west coast of the North Island (i.e. SNA 8) are likely to comprise a separate biological unit.

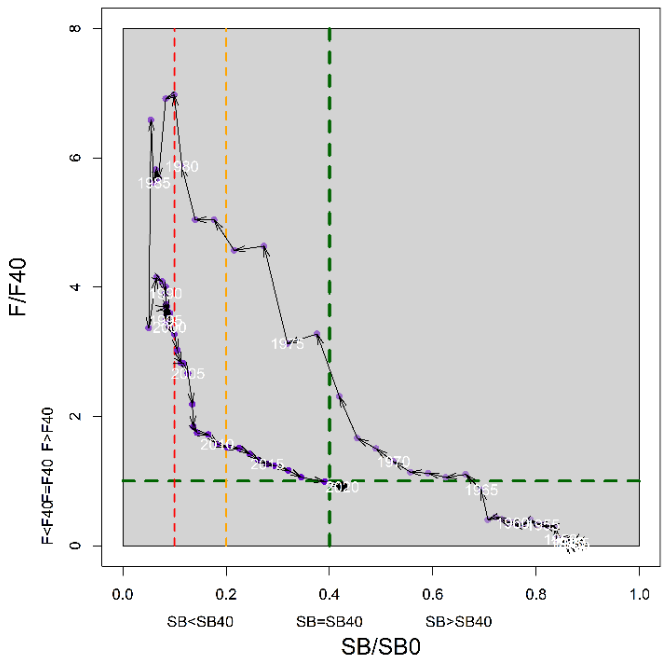
Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Interim Base Case model
Reference Points	Interim Target: 40% B_0 (HSS default) Soft Limit: 20% B_0 (HSS default) Hard Limit: 10% B_0 (HSS default) Overfishing threshold: $F_{SB40\%}$
Status in relation to Target	$B_{2019–20}$ was estimated to be 49% 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	$F_{2019–20}$ was estimated to be 91% $F_{SB40\%}$. Unlikely (< 40%) to be above the overfishing threshold.

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 year class).
Recent Trend in Fishing Mortality or Proxy	Fishing mortality is estimated to have declined steeply from 2000 onwards.  **Annual fishing mortality compared to the $SB_{40\%}$ interim target fishing mortality level for the interim base case model (median values from MCMCs).**

<table>
<tr><td></td><td>


Annual spawning biomass and fishing mortality compared to the *SB40%* 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.
</td></tr>
<tr><td>Other Abundance Indices</td><td>The increase in the trawl survey total biomass indices between 1989-1999 and 2018-2019 corroborates the recent increase in biomass.</td></tr>
<tr><td>Trends in Other Relevant Indicators or Variables</td><td>Estimates of recreational catch have increased considerably since 2006. The increase in catch is likely to be related to an increase in stock abundance.</td></tr>
</table>

Projections and Prognosis	
Stock Projections or Prognosis	Abundance is likely to increase over the next two years at current levels of catch (2,356 t compared to a TAC of 1,785 t and a TACC of 1,300 t). The magnitude of the subsequent increase is uncertain.
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: 2020	Next assessment: 2021
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-at-maturity and length/ weight), including temporal variation in growth	1 – High Quality 1 – High Quality

	- 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 3 – Low 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 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 two most recent trawl surveys
Changes to Model Structure and Assumptions	- 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 - new single trawl CPUE time series from 1997–2019	

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 these changes; however, some bias in the CPUE indices may persist. - 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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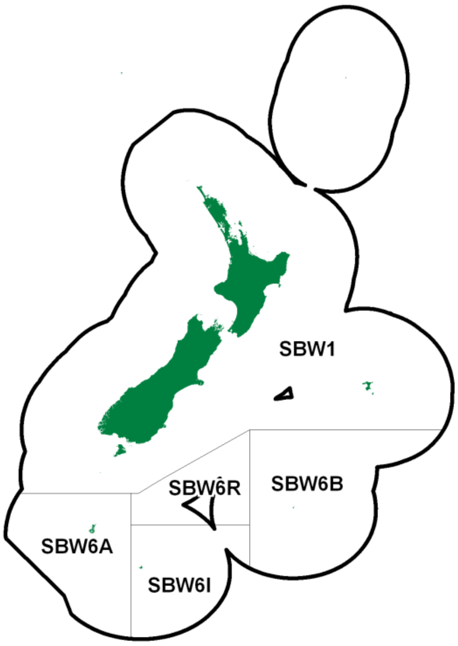
SOUTHERN BLUE WHITING (SBW)

(*Micromesistius australis*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

Southern blue whiting are almost entirely restricted in distribution to Sub-Antarctic waters. They are dispersed throughout the Campbell Plateau and Bounty Platform for much of the year, but during August and September they aggregate to spawn near the Campbell Islands, on Pukaki Rise, on Bounty Platform, and near the Auckland Islands over depths of 250–600 m. During most years, fish in the spawning fishery range between 35 and 50 cm fork length (FL), although occasionally a smaller size class of males (29–32 cm FL) is also present.

Reported landings for the period 1971 to 1977 are shown in Table 1. Estimated landings by area from the trawl catch and effort logbooks and QMRs are given from 1978 to the present in Table 2, and Figure 1 shows the historical landings and TACC values for the main southern blue whiting stocks. Landings were chiefly taken by the Soviet foreign licensed fleet during the 1970s and early 1980s, and the fishery fluctuated considerably peaking at almost 50 000 t in 1973 and again at almost 30 000 t in 1979. The Japanese surimi vessels first entered the fishery in 1986, and catches gradually increased to a peak of 76 000 t in 1991–92. A catch limit of 32 000 t, with area sub-limits, was introduced for the first time in the 1992–93 fishing year (Table 2). The total catch limit increased to 58 000 t in 1996–97 for three years. The southern stocks of southern blue whiting were introduced to the Quota Management System on 1 November 1999, with the TACCs given in Table 2. The fishing year was also changed to 1 April to 31 March to reflect the timing of the main fishing season. TACC changes since 2000–01 are shown in Table 2. A nominal TACC of 8 t (SBW 1) was set for the rest of the EEZ, and typically less than 10 t per year were reported from SBW 1 most years from 2000–01 to 2012–13 (Table 2). However, landings ranged between 21 t and 86 t from 2013–14 to 2016–17 and the TACC for SBW 1 was increased to 98 t for the 2017–18 season. Landings were 51 t in 2017–18 and 33 t in 2018–19.

Landings for other stocks have been between 20 000 t and 40 000 t since 2000, with the majority of the catch currently taken by foreign owned vessels (predominantly large factory trawlers) producing headed and gutted or dressed frozen product and waste to fishmeal. On the Bounty Platform the TACC has been almost fully caught in each year since 2002–03, but landings have been decreasing in recent years with only 1101 t of the 3145 t TACC landed in 2018–19. The TACC on the Campbell Island Rise has been increasingly under-caught since 2014–15, most recently by 20 866 t in 2017–18 and 24 053 t in 2018–19. On the other grounds, the catch limits have been under-caught in most years since their introduction. This reflects the economic value of the fish and difficulties experienced by operators in both timing their arrival on the grounds and locating the aggregations of fish. On the Pukaki Rise and Auckland Islands Shelf, operators have generally found it difficult to justify expending time to locate fishable aggregations, given the small allocation available in these areas, the small fish size and relatively low value of the product, and the more certain option available to fish southern blue whiting near Campbell Island where aggregations are concurrent.

The TACC for the Bounty Platform stock was increased to 9800 t for the 2008–09 season and further increased to 14 700 t for the 2009–10 and 2010–11 seasons but decreased to 6860 t for the 2011–12 season. In 2013–14, 2832 t were shelved, leaving the effective catch limit at 4028 t. The TACC for the Bounty Platform stock was reduced to 2940 t for the 2015–16 and 2016–17 seasons, further reduced to 2377 t for the 2017–18 season, and then increased to 3145 t for the 2018–19 season. The TACC for the Campbell Island Rise stock was reduced from 25 000 t to 20 000 t in 2006–07, where it remained until 2009–10. For the 2010–11 season the catch limit for the Campbell stock was raised to 23 000 t, in 2011–12 to 29 400 t, and in 2014–15 it was raised to 39 200 t. Catch limits for Pukaki Rise and Auckland Islands have remained unchanged since 1997.

Table 1: Reported annual landings (t) of southern blue whiting for all areas

Fishing year	All fishing areas	Fishing year	All fishing areas
1971	10 400	1975	2 378
1972	25 800	1976	17 089
1973	48 500	1977	26 435
1974	42 200		

Table 2: Estimated catches (t) and actual TACCs (or catch limits) of southern blue whiting by area from vessel logbooks and QMRs. – no catch limit in place. Before 1997–98 there was no separate catch limit for Auckland Islands.

	SBW6B		SBW6I		SBW6R		SBW6A		SBW1			
	Bounty Platform		Campbell Rise		Pukaki Rise		Auckland Is.		Rest of NZ			Total
Fish. year	Catch	Limit	Catch	Limit	Catch	Limit	Catch	Limit	Catch	Limit	Catch	Limit
1978*f*	0	–	6 403	–	79	–	15	–	–	–	6 497	–
1978–79+	1 211	–	25 305	–	601	–	1 019	–	–	–	28 136	–
1979–80+	16	–	12 828	–	5 602	–	187	–	–	–	18 633	–
1980–81+	8	–	5 989	–	2 380	–	89	–	–	–	8 466	–
1981–82+	8 325	–	7 915	–	1 250	–	105	–	–	–	17 595	–
1982–83+	3 864	–	12 803	–	7 388	–	184	–	–	–	24 239	–
1983–84+	348	–	10 777	–	2 150	–	99	–	–	–	13 374	–
1984–85+	0	–	7 490	–	1 724	–	121	–	–	–	9 335	–
1985–86+	0	–	15 252	–	552	–	15	–	–	–	15 819	–
1986–87+	0	–	12 804	–	845	–	61	–	–	–	13 710	–
1987–88+	18	–	17 422	–	157	–	4	–	–	–	17 601	–
1988–89+	8	–	26 611	–	1 219	–	1	–	–	–	27 839	–
1989–90+	4 430	–	16 542	–	1 393	–	2	–	–	–	22 367	–
1990–91+	10 897	–	21 314	–	4 652	–	7	–	–	–	36 870	–
1991–92+	58 928	–	14 208	–	3 046	–	73	–	–	–	76 255	–
1992–93+	11 908	15 000	9 316	11 000	5 341	6 000	1 143	–	–	–	27 708	32 000
1993–94+	3 877	15 000	11 668	11 000	2 306	6 000	709	–	–	–	18 560	32 000
1994–95+	6 386	15 000	9 492	11 000	1 158	6 000	441	–	–	–	17 477	32 000
1995–96+	6 508	8 000	14 959	21 000	772	3 000	40	–	–	–	22 279	32 000
1996–97+	1 761	20 200	15 685	30 100	1 806	7 700	895	–	–	–	20 147	58 000
1997–98+	5 647	15 400	24 273	35 460	1 245	5 500	0	1 640	–	–	31 165	58 000
1998–00†	8 741	15 400	30 386	35 460	1 049	5 500	750	1 640	–	–	40 926	58 000
2000–01#	3 997	8 000	18 049	20 000	2 864	5 500	19	1 640	9	8	24 804	‡35 140
2001–02#	2 262	8 000	29 999	30 000	230	5 500	10	1 640	1	8	31 114	‡45 140
2002–03#	7 564	8 000	33 445	30 000	508	5 500	262	1 640	16	8	41 795	‡45 140
2003–04#	3 812	3 500	23 718	25 000	163	5 500	116	1 640	3	8	27 812	‡35 640
2004–05#	1 477	3 500	19 799	25 000	240	5 500	95	1 640	9	8	21 620	‡35 640
2005–06#	3 962	3 500	26 190	25 000	58	5 500	66	1 640	2	8	30 287	‡35 640
2006–07#	4 395	3 500	19 763	20 000	1 115	5 500	84	1 640	7	8	25 363	‡30 640
2007–08#	3 799	3 500	20 996	20 000	513	5 500	278	1 640	1	8	25 587	‡30 640
2008–09#	9 863	9 800	20 483	20 000	1 377	5 500	143	1 640	21	8	31 867	‡36 948
2009–10#	15 468*	14 700	19 040	20 000	4 853	5 500	174	1 640	5	8	39 540	‡42 148
2010–11#	13 913	14 700	20 224	23 000	4 433	5 500	131	1 640	8	8	38 708	‡44 848
2011–12#	6 660	6 860	30 971	29 400	686	5 500	92	1 640	2	8	38 412	‡43 400
2012–13#	6 827	6 860	21 321	29 400	1 702	5 500	49	1 640	8	8	29 906	‡43 400
2013–14#	4 278˜	4 028	28 607	29 400	14	5 500	47	1 640	21	8	32 950	‡43 400
2014–15#	7 054	6 860	24 592	39 200	34	5 500	156	1 640	29	8	31 887	‡53 208
2015–16#	2 405	2 940	22 100	39 200	12	5 500	181	1 640	35	8	24 733	‡49 228
2016–17#	2 569	2 940	19 875	39 200	11	5 500	46	1 640	86	8	22 588	‡49 280
2017–18#	2 423	2 377	18 334	39 200	36	5 500	202	1 640	51	98	20 821	‡48 717
2018–19#	1 101	3 145	15 147	39 200	36	5 500	218	1 640	33	98	16 502	‡49 485
2019–20#	788	3 145	26 517	39 200	3 631	5 500	136	1 640	38	98	31 110	‡49 485

f 1 April–30 September.`　　+ 1 October–30 September.
† 1 October 1998–31 March 2000.　　# 1 April–31 March.
* Reported catch total for 2009–10 does not include fish lost when FV *Oyang 70* sank on 18 August 2010.
˜ In 2013, although the TACC remained at 6860 t, the ACE available to balance against catch was limited to 4028 t because 2832 t was shelved under a voluntary agreement with industry.

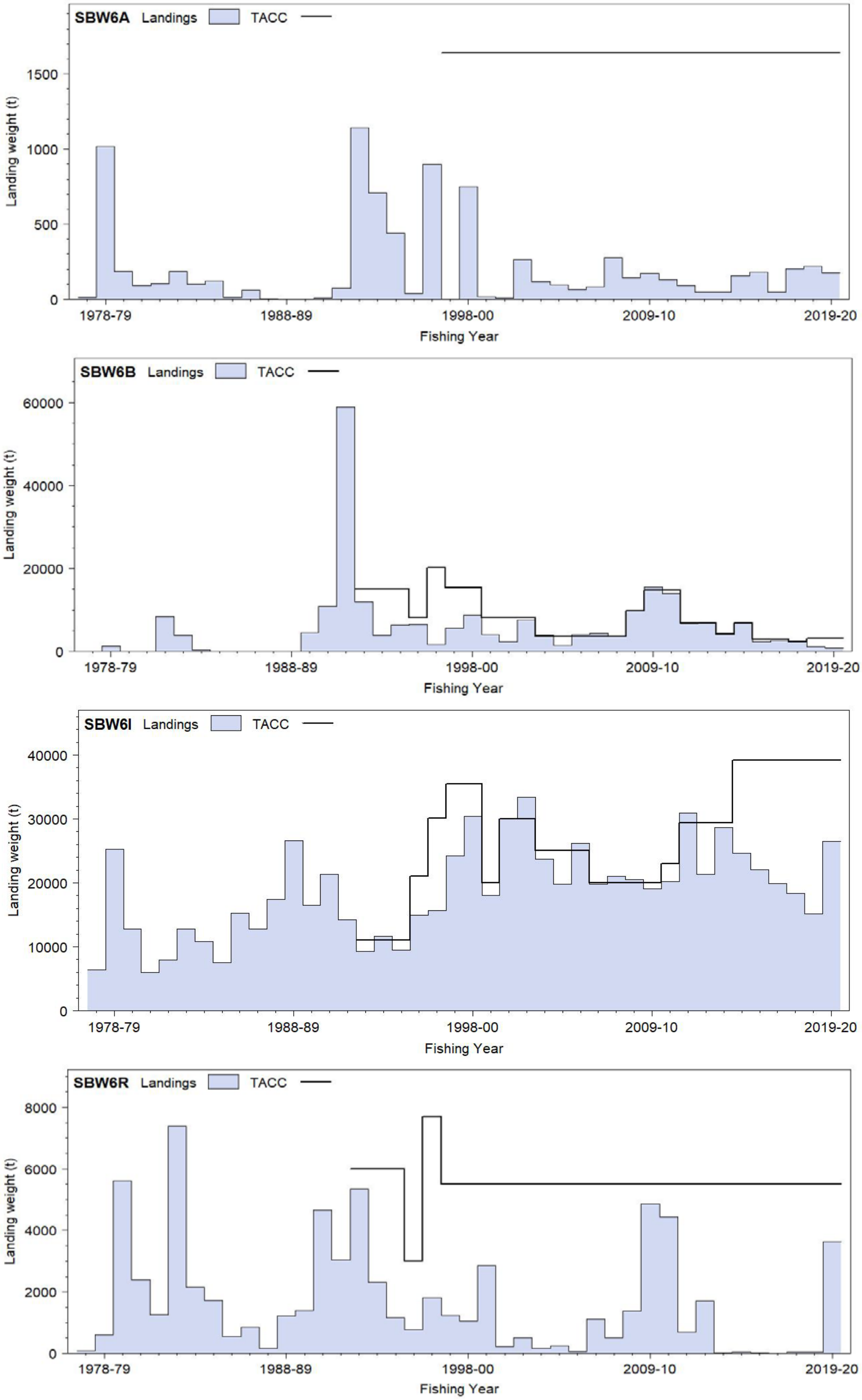


Figure 1: Reported commercial landings and TACC for the four main SBW stocks. From top: SBW 6A (Auckland Islands), SBW 6B (Bounty Platform), SBW 6I (Campbell Island Rise), and SBW 6R (Pukaki Rise). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries
There is no recreational fishery for southern blue whiting.

1.3 Customary non-commercial fisheries
Customary non-commercial take is not known to occur for southern blue whiting.

1.4 Illegal catches
The level of illegal and unreported catch is thought to be low. However, a number of operators have been convicted for area misreporting; where the catch returns have been revised, the corrected totals by area are given in Table 2. In addition, the operators of a vessel were convicted for discarding fish without reporting the catch in 2004, and crew members estimated that between 40 and 310 t of southern blue whiting were illegally discarded during the two and a half week period fishing on the Campbell Island Rise.

1.5 Other sources of mortality
Scientific observers have occasionally reported discards of undersize fish and accidental loss from torn or burst cod-ends. The amount of possible discarding was estimated by Clark et al (2000) and Anderson (2004, 2009). Anderson (2004) quantified total annual discard estimates (including estimates of fish lost from the net at the surface) as ranging between 0.4% and 2.0% of the estimated southern blue whiting catch over all the southern blue whiting fisheries. Anderson (2009) reviewed fish and invertebrate bycatch and discards in the southern blue whiting fishery based on observer data from 2002 to 2007. He estimated that 0.23% of the catch was discarded from observed vessels. The low levels of discarding occur primarily because most catch came from vessels that targeted spawning aggregations.

In August 2010, the FV *Oyang 70* sank while fishing for SBW on the Bounty Platform. It was fishing an area between 48°00’ S and 48°20’ S, and 179°20’ E and 180°FL between 15 and 17 August 2010, before sinking on 18 August 2010. The Ministry of Fisheries estimated that it had taken a catch of between 120 t and 190 t that was lost with the vessel.

2. BIOLOGY

Southern blue whiting is a schooling species that is confined to Sub-Antarctic waters. Early growth has been well documented with fish reaching a length of about 20 cm FL after one year and 30 cm FL after two years. Growth slows down after five years and virtually ceases after ten years. Ages have been validated up to at least 15 years by following strong year classes, but ring counts from otoliths suggest a maximum age of 25 years.

The age and length of maturity, and recruitment to the fishery, varies between areas and between years. In some years a small proportion of males mature at age 2, but the majority do not mature until age 3 or 4, usually at a length of 33–40 cm FL. The majority of females also mature at age 3 or 4 at a length of 35–42 cm FL. Ageing studies have shown that this species has very high recruitment variability.

Southern blue whiting are highly synchronised batch spawners. Four spawning areas have been identified: on Bounty Platform, Pukaki Rise, Auckland Islands Shelf, and Campbell Island Rise. The Campbell Island Rise has two separate spawning grounds, to the north and south respectively. Fish appear to recruit first to the southern ground but thereafter spawn on the northern ground. Spawning on Bounty Platform begins in mid-August and finishes by mid-September. Spawning begins 3–4 weeks later in the other areas, finishing in late September/early October. Spawning appears to occur at night, in midwater, over depths of 400–500 m on Campbell Island Rise but shallower elsewhere.

Natural mortality (M) was estimated using the equation $\log_e(100)$/maximum age, where maximum age is the age to which 1% of the population survives in an unexploited stock. Using a maximum age of 22 years, M was estimated to equal 0.21. The value of 0.2 is assumed to reflect the imprecision of this value. Campbell Island stock assessments have estimated M within the model in 2016 and 2020, using an informed prior with a mean of 0.2 (see Table 3, and Roberts & Dunn 2017).

Table 3: Estimates of biological parameters for the Campbell Island Rise southern blue whiting stock.

Fishstock				**Estimate**	**Source**
1. Natural mortality (*M*)					
			Males	Females	
Campbell Island Rise			0.2	0.2	Hanchet (1991)
			0.17	0.18	Roberts & Hanchet (2019)
			0.16	0.17	Doonan (in.prep.)
2. Weight = a (length)^b (Weight in g, length in cm fork length)					
	Males		Females		
	a	b	a	b	
Campbell Island Rise	0.00515	3.092	0.00407	3.152	Hanchet (1991)

Note: Estimates of natural mortality and the length-weight coefficients are assumed to be the same for the other stocks. Observed length-at-age data are used for all stocks.

3. STOCKS AND AREAS

Hanchet (1999) reviewed the stock structure of southern blue whiting. He examined historical data on southern blue whiting distribution and abundance, reproduction, growth, and morphometrics. There appear to be four main spawning grounds of southern blue whiting; on the Bounty Platform, Pukaki Rise, Auckland Islands Shelf, and Campbell Island Rise. There are also consistent differences in the size and age distributions of fish, in the recruitment strength, and in the timing of spawning between these four areas. Multiple discriminant analysis of data collected in October 1989 and 1990 showed that fish from Bounty Platform, Pukaki Rise, and Campbell Island Rise could be distinguished on the basis of their morphometric measurements. The Plenary concluded that this constitutes strong evidence that fish in these areas return to spawn on the grounds to which they first recruit. No genetic studies have been carried out, but given their close proximity, it is unlikely that there would be detectable genetic differences in the fish between these four areas.

For the purposes of stock assessment it is assumed that there are four stocks of southern blue whiting with fidelity within stocks: the Bounty Platform stock, the Pukaki Rise stock, the Auckland Islands stock, and the Campbell Island stock.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

Tables and accompanying text in this section were updated for the southern blue whiting fishery 2020 Fishery Assessment Plenary. A more detailed summary from an issue-by-issue perspective is available in the 2018 Aquatic Environment & Biodiversity Annual Review (Fisheries New Zealand 2019, https://www.mpi.govt.nz/dmsdocument/34854-aquatic-environment-and-biodiversity-annual-review-aebar-2018-a-summary-of-environmental-interactions-between-the-seafood-sector-and-the-aquatic-environment).

4.1 Role in the ecosystem

Southern blue whiting are one of the dominant (in terms of biomass) middle depth fish species found on the Campbell Plateau and Bounty Platform, over depths f 250–600 m. Francis et al (2002) categorised southern blue whiting as part of an upper slope assemblage and estimated its distribution to be centred on about 500 m depth and latitude 51° S. During August and September, southern blue whiting form large dense spawning aggregations on the Campbell Island Rise and Bounty Platform and, to a lesser extent, on the Pukaki Rise and near the Auckland Islands. The species is also found in much lower numbers on the Stewart-Snares shelf and Chatham Rise.

These stocks are characterised by highly variable year class strengths, with the strong year classes growing at a significantly lower rate than others (i.e., showing signs of density dependent growth). Their substantial abundance suggests that southern blue whiting are probably an important part of the Campbell Rise and Bounty Platform ecosystems, but their variability suggests that these systems may function differently at different times. For instance, very large changes have been observed in the abundance of southern blue whiting on the Bounty Plateau, with a 7-fold increase between 2005 and 2007 followed by a 4-fold decrease to 2009 (Dunn & Hanchet 2011). The large increase was due to the very strong 2002 year class recruiting to the fishery, but the rapid decline is not easily explained.

Whatever the reason, there are likely to be implications for the role of the southern blue whiting population in the ecosystem during such events.

4.1.1 Trophic interactions

Crustaceans and teleosts are the dominant prey groups for southern blue whiting. Stevens et al (2011) showed that in the Sub-Antarctic (and similarly from the Chatham Rise), crustaceans occurred in 70% of stomachs, mainly euphausiids (37%), natant decapods (24%), and amphipods (11%). Teleosts occurred in 32% of stomachs, mainly myctophids (10%). Salps (7%) and cephalopods (2%) were of lesser importance.

Predation by marine mammals and large teleosts is probably the main source of mortality for adults, and juveniles are frequently taken by seabirds (MPI 2013). Large hake and ling taken as bycatch in the fishery have usually been feeding on southern blue whiting, and large hoki caught during Sub-Antarctic trawl surveys have occasionally been feeding on juvenile southern blue whiting. Juvenile (90–130 mm FL) southern blue whiting were found to be the main prey item of black-browed albatross at Campbell Island during its chick rearing period in January 1997 (Cherel et al 1999) and are also regularly taken by grey-headed albatross and rockhopper penguins breeding at Campbell Island (Cherel et al 1999).

4.1.2 Ecosystem Indicators

Tuck et al (2009) used data from the Sub-Antarctic trawl survey series to derive fish-based ecosystem indicators using diversity, fish size, and trophic level. This trawl survey has run regularly using the same vessel since 1991 and covers much of the area inhabited by southern blue whiting. Tuck et al (2009) showed generally increasing trends in the proportion of threatened fish species and those with low resilience (from FishBase, Froese & Pauly 2000) and indices of fish diversity often showed positive trends. The proportion of piscivorous and demersal species and the mean trophic level generally declined over the time period, especially in areas where southern blue whiting are more common. Highly variable recruitment of dominant species like southern blue whiting may strongly influence such trends. Changes in fish size were less consistent, and Tuck et al (2009) and Tuck et al (2014) did not find size-based indicators as useful as they have been overseas. Routine measurement of all fish species in New Zealand trawl surveys since 2008 may increase the utility of size-based indicators in the future.

4.2 Bycatch (fish and invertebrates)

4.2.1 Fish

The southern blue whiting fishery is characterised by large, “clean” catches of the target species with minimal fish bycatch. Anderson (2009) estimated that, for southern blue whiting target tows, southern blue whiting accounted for more than 99% of the total estimated catch recorded by observers and more than 99% of the total reported catch from the fishery based on catch-effort forms.

A total of 120 bycatch species have been recorded by observers (Anderson 2009), of which the main bycatch species have been ling, hake, and hoki, with smaller amounts of porbeagle shark, opah, silverside, and pale ghost shark (Finucci et al 2019), with a decreasing trend in hake bycatch.

Given the high proportion of target species catch, discards in this fishery are correspondingly low, composed mainly by target catch and mostly related to loss of catch during the haul (Anderson 2009).

4.2.2 Invertebrates

There is little invertebrate bycatch in this fishery even though most trawls are on or close to the seabed for at least part of the time (Cole et al 2007). Protected coral bycatch has been negligible in this fishery (Ramm 2012).

4.3 Incidental capture of protected species (seabirds, mammals, and protected fish)

Southern blue whiting trawlers occasionally capture marine mammals (pinnipeds), including New Zealand sea lions and New Zealand fur seals (which were classified as “Nationally Critical” and “Not Threatened”, respectively, under the New Zealand Threat Classification System in 2010, Baker et al 2016). Vessels in the southern blue whiting fishery also interact with and incidentally capture seabirds and, at least in one occasion, have captured a protected shark species.

Ramm (2012) summarised observer data for bottom trawl fisheries of seabirds, mammals, and coral catch for the 2010–11 fishing year. Coral impacts are discussed under Invertebrates (section 4.2.2).

4.3.1 Marine mammal interactions

The New Zealand sea lion (rāpoka) *Phocarctos hookeri*, is the rarest sea lion in the world. The estimated total population of around 11 800 sea lions in 2015 is classified by the Department of Conservation as 'Nationally Vulnerable' under the New Zealand Threat Classification System (Baker et al 2019). Pup production at the main Auckland Island rookeries showed a steady decline between 1998 and 2009 and has subsequently stabilised (details can be found in the Aquatic Environment and Biodiversity Annual Review, Ministry for Primary Industries 2019).

Sea lions forage in depths down to 600 m and overlap with trawling down to 500 m depth for arrow squid. Sea lions interact with some trawl fisheries which can result in incidental capture and subsequent drowning (Smith & Baird 2005, 2007a & b, Thompson & Abraham 2010a, Thompson & Abraham 2012, Abraham & Thompson 2011, Abraham et al 2016). Since 1988, incidental captures of sea lions have been monitored by government observers on-board an increasing proportion of the fishing fleet.

Annual sea lion pup counts at breeding sites are used to index trends in the total sea lion population. The Auckland Islands is the largest breeding site for sea lions: 68% of all sea lion pups are born there; 30% are born at Campbell Island/Motu Ihupuku, and the remaining 2% at Stewart Island/Rakiura and the South Island/Te Waipounamu (currently restricted to the Otago and Catlins coasts). Between 1998 and 2009 the number of sea lion pups born annually at the Auckland Islands declined by 50%. In 2014, the Minister of Conservation and the Minister for Primary Industries asked officials to develop a New Zealand sea lion/rāpoka Threat Management Plan (NZSL TMP) which is available online: https://www.fisheries.govt.nz/protection-and-response/sustainable-fisheries/managing-our-impact-on-marine-life/new-zealand-sea-lion/.

Captures of New Zealand sea lions in the Campbell Island southern blue whiting trawl fishery have been variable between years (Table 4). The sea lion captures occur close to Campbell Island in SBW 6I and are mostly males (91%). There were 21 captures in 2012–13, mostly early in the season, which led to the development of an operational plan that includes observers being placed on all trips and compulsory use of sea lion exclusion devices (SLEDs) on all tows in SBW 6I (MPI 2015).

Table 4: Number of tows by fishing year and observed and model-estimated total New Zealand sea lion captures in southern blue whiting trawl fisheries, 2002–03 to 2017–18. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described by Abraham et al (2016) and are available via https://data.dragonfly.co.nz/psc. Estimates for 2002–03 to 2014–15 are based on data version 2017v01.

				Observed captures		Estimated captures	
	Tows	No.obs	% obs	Captures	Rate	Mean	95%c.i.
2002–03	638	275	43.1	0	0.0	1	0–3
2003–04	740	241	32.6	1	0.4	3	1–9
2004–05	870	335	38.5	2	0.6	5	2–13
2005–06	624	217	34.8	3	1.4	10	3–22
2006–07	630	224	35.6	3	1.3	15	6–30
2007–08	818	331	40.5	5	1.5	8	5–14
2008–09	1 188	300	25.3	0	0.0	1	0–7
2009–10	1 114	396	35.5	11	2.8	24	15–37
2010–11	1 171	433	37.0	6	1.4	15	8–25
2011–12	951	669	70.3	0	0.0	1	0–4
2012–13	790	790	100.0	21	2.7	21	21–21
2013–14	809	808	99.9	2	0.2	2	2–2
2014–15	677	670	99.0	6	0.9	6	6–6
2015–16	442	442	100.0	3	0.7		
2016–17	539	539	100.0	0	0.0		
201718	455	455	100.0	2	0.4		

The New Zealand fur seal was classified as "Least Concern" by IUCN in 2008 and as "Not Threatened" under the New Zealand Threat Classification System in 2010 (Baker et al 2016).

Southern blue whiting has one of the highest observed capture rates of New Zealand fur seals for any observed fishery. The capture rate of fur seals in the southern blue whiting fishery has varied considerably between years ranging without trend from a high of 11.8 fur seals per 100 tows in 2008–09 to a low of 2 fur seals per 100 tows in 2016–17, (Thompson et al 2010a, Abraham & Thompson 2011, Thompson et al 2012, Thompson et al 2013, Abraham et al 2016, Table 5). Almost all fur seals captured in this fishery have been caught at the Bounty Platform in August and September when the southern blue whiting are in dense spawning aggregations. Estimated captures from Abraham et al (2016) (available via https://data.dragonfly.co.nz/psc) are not reproduced here pending resolution of identified structural issues in the model related to the partition between model strata with contrasting capture rates, resulting in implausibly high estimates of uncertainty despite high observer coverage.

Table 5: Number of tows (commercial and observed) by fishing year and observed New Zealand fur seal captures and capture rate in southern blue whiting trawl fisheries, 2002–03 to 2017–18 (Abraham et al 2016).

				Observed captures	
	Tows	**No. obs**	**% obs**	**Captures**	**Rate**
2002–03	638	275	43.1	8	2.9
2003–04	740	241	32.6	13	5.4
2004–05	870	335	38.5	33	9.9
2005–06	624	217	34.8	52	24.0
2006–07	630	224	35.6	13	5.8
2007–08	818	331	40.5	24	7.3
2008–09	1 188	300	25.3	17	5.7
2009–10	1 114	396	35.5	16	4.0
2010–11	1 171	433	37.0	36	8.3
2011–12	951	669	70.3	25	3.7
2012–13	790	790	100.0	27	3.4
2013–14	809	808	99.9	95	11.8
2014–15	677	670	99.0	41	6.1
2015–16	442	442	100.0	51	11.5
2016–17	539	539	100.0	11	2.0
201718	455	455	100.0	17	3.7

4.3.2 Seabird interactions

Vessels are legally required to use seabird mitigation devices and also to adhere to industry Operating Procedures in regards to managing risk of environmental interactions. For protected species, capture estimates presented 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 on board the vessel; Middleton & Abraham 2007, Brothers et al 2010).

Mitigation methods such as streamer (tori) lines, Brady bird bafflers, and offal management are used in the southern blue whiting trawl fishery. Warp mitigation was voluntarily introduced from about 2004 and made mandatory in April 2006 (Department of Internal Affairs 2006). The 2006 notice mandated that all trawlers over 28 m in length use a seabird scaring device while trawling (being "paired streamer lines", "bird baffler" or "warp deflector" as defined in the Notice).

In each of the 2016–17 and 2017–18 fishing years, there were 6 observed captures of birds in southern blue whiting trawl fisheries at a rate of 1.1 and 1.3 birds per 100 observed tows (Table 6). The average capture rate in southern blue whiting trawl fisheries for the period from 2002–03 to 2017–18 is about 1.17 birds per 100 tows, a low rate relative to some other New Zealand trawl fisheries, e.g., for scampi (4.02 birds per 100 tows) and squid (13.31 birds per 100 tows) over the same years.

Overall, the impact that the southern blue whiting fisheries have on seabirds is relatively small. This can be seen in the proportions of the overall fisheries Population Sustainability Threshold (PST) that are attributable to the southern blue whiting fisheries for each species (Table 7). Observed seabird captures since 2002–03 have been dominated by grey petrels (58 of the 95 observed seabird captures since 2002–03), a negligible risk species where the southern blue whiting fisheries are estimated to be responsible for about 20% of the risk ratio (Table 7).

Table 6: Number of tows by fishing year and observed seabird captures in southern blue whiting trawl fisheries, 2002–03 to 2017–18. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. 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. Estimates for 2002–03 to 2017–18 are based on data version 2019v01.

	Fishing effort			Observed captures		Estimated captures	
	Tows	No. obs	% obs	Captures	Rate	Mean	95% c.i.
2002–03	638	275	43.1	0	0.0	4	0–9
2003–04	740	241	32.6	1	0.4	7	2–13
2004–05	870	335	38.5	2	0.6	10	4–18
2005–06	624	217	34.8	1	0.5	6	2–12
2006–07	630	224	35.6	3	1.3	8	4–13
2007–08	819	331	40.4	3	0.9	9	4–15
2008–09	1 189	301	25.3	0	0.0	11	4–21
2009–10	1 113	396	35.6	11	2.8	23	16–34
2010–11	1 171	433	37.0	11	2.5	21	15–31
2011–12	951	669	70.3	3	0.4	6	3–11
2012–13	791	791	100.0	19	2.4	19	19–19
2013–14	809	808	99.9	16	2.0	16	16–16
2014–15	677	669	98.8	7	1.0	7	7–9
2015–16	441	441	100.0	6	1.4	6	6–6
2016–17	539	539	100.0	6	1.1	6	6–7
2017–18	455	455	100.0	6	1.3	6	6–6

Table 7: Risk ratio for seabirds predicted by the level two risk assessment for the target southern blue whiting (SBW) fishery and all fisheries included in the level two risk assessment, 2006–07 to 2016–17, showing seabird species with a risk ratio of at least 0.001 of PST. 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 and Richard et al 2020, where full details of the risk assessment approach can be found). The DOC threat classifications are shown (Robertson et al 2017 at http://www.doc.govt.nz/documents/science-and-technical/nztcs19entire.pdf).

		Risk ratio			
Species	PST (mean)	SBW trawl*	Total	Risk category	DOC Threat Classification
Salvin's albatross	3 460	0.009	0.765	High	Threatened: Nationally Critical
Grey petrel	5 460	0.006	0.03	Negligible	At Risk: Naturally Uncommon
Campbell black-browed albatross	2 000	0.002	0.06	Low	At Risk: Naturally Uncommon

*SWB trawl from Richard et al 2017

4.3.3 Protected fish species

The basking shark (*Cetorhinus maximus*) was classified as "Endangered" by IUCN in 2013 and as "Threatened – Nationally Vulnerable" in 2016, under the New Zealand Threat Classification System (Duffy et al 2018). Basking shark has been a protected species in New Zealand since 2010, under the Wildlife Act 1953, and is also listed in Appendix II of the CITES convention.

One basking shark individual was incidentally captured in 2016 by the southern blue whiting fishery.

4.4 Benthic interactions

Southern blue whiting is principally taken using midwater trawls (99% for fishing years 2012–13 to 2015–16). Target southern blue whiting tows accounted for only 1% of all tows reported on TCEPR forms to have been fished on or close to the bottom between 1989–90 and 2004–05 (Baird et al 2011). Almost all southern blue whiting catch is reported on TCEPR forms (Black et al 2013). Tows are located in Benthic-optimised Marine Environment Classification (BOMEC, Leathwick et al 2012) classes F (upper slope), I, and L (mid-slope), and M (mid-deep slope) (Baird & Wood 2012), and 95% were between 300 and 600 m depth (Baird et al 2011).

During 1989–90 to 2015–16, about 15 470 southern blue whiting bottom-contacting trawls were reported on TCEPRs (Baird & Wood 2018): about 1000–2000 tows were reported annually during 1989–90 to 1991–92; 300–500 in most other years, except in 1997–98 , 1998–99, 2009–10, and 2010–11 when about 700 tows were reported each year. The total footprint generated from these tows was estimated at about 21 000 km^2. This footprint represented coverage of 0.5% of the seafloor of the combined EEZ and the Territorial Sea areas, and 1.5% of the 'fishable area', that is, the seafloor area open to trawling, in depths of less than 1600 m. For the 2016–17 fishing year, 307 southern blue whiting bottom tows had an estimated footprint of 748 km^2 which represented coverage of < 0.1% of the EEZ and Territorial Sea and 0.1% of the fishable area (Baird & Mules 2019). There was no change to these percentages in 2017–18 (Baird & Mules 2020b).

The overall trawl footprint for southern blue whiting (1989–90 to 2015–16) covered 3.0% of seafloor in 200–400 m, 6% in 400–600 m, and 0.2% of 600–1600 m seafloor (Baird & Wood 2018). In 2016–17 and 2017–18, the southern blue whiting footprint contacted < 0.1%, 0.3%, and < 0.1% of those depth ranges, respectively (Baird & Mules 2019, 2020b), although no effort was reported deeper than 800 m. The BOMEC areas with the highest proportion of area covered by the southern blue whiting footprint were classes F (sub-Antarctic island shelves), I (Chatham Rise slope and shelf edge of the east coast South Island), and L (deeper waters off the Stewart-Snares shelf and around the main sub-Antarctic islands). The 2016–17 southern blue whiting footprint covered 0.25% of the 38 608 km^2 of class F, 0.02% of the 52 224 km^2 of class I, and almost 1% of the 198 577 km^2 of class L (Baird & Mules 2019). In 2017–18, the footprint covered 0.03% of class F, 0.08% of class I, and 0.35% of class L (Baird & Mules 2020b).
Where trawls for southern blue whiting are fished on the bottom, they are likely to have effects on benthic community structure and function (e.g., Cole et al 2007, Rice 2006) and there may be consequences for benthic productivity (e.g., Jennings 2001, Hermsen et al 2003, Hiddink et al 2006, Reiss et al 2009). However, any consequences from southern blue whiting fishing, due to the gear type and scale of the fishery (typically less than 600 tows fished on the bottom per year), are likely to be relatively minor. A more general review of habitat interactions can be found in the Aquatic Environment and Biodiversity Annual Review 2019 (Fisheries New Zealand 2020).

4.5 Other considerations

4.5.1 Spawning disruption
Fishing during spawning may disrupt spawning activity or success. Canadian research carried out on Atlantic cod (*Gadus morhua*) concluded that "Cod exposed to a chronic stressor are able to spawn successfully, but there appears to be a negative impact of this stress on their reproductive output, particularly through the production of abnormal larvae" (Morgan et al 1999). Morgan et al (1997) also reported disruption of a spawning shoal of Atlantic cod: "Following passage of the trawl, a 300-m-wide "hole" in the aggregation spanned the trawl track. Disturbance was detected for 77 min after passage of the trawl." There has been no research carried out on the disruption of spawning southern blue whiting by fishing in New Zealand but fishing occurs almost entirely on spawning aggregations.

4.5.2 Genetic effects
Fishing, environmental changes such as altered average sea temperatures (climate change), or pollution could alter the genetic composition or diversity of a species. There are no known studies of the genetic diversity of southern blue whiting from New Zealand. Genetic studies for stock discrimination are reported above under "Stocks and Areas".

4.5.3 Habitat of particular significance to fisheries management
Habitat of particular significance for fisheries management does not have a policy definition (MPI 2013). Studies have identified areas of importance for spawning and juvenile southern blue whiting where distribution plots highlight hotspot areas for the 0+, 1+, immature, and adult fish (O'Driscoll et al 2003). These are the Campbell Plateau and Bounty Platform, with minimal numbers recorded on the Chatham Rise.

5. STOCK ASSESSMENT

An updated assessment of the Campbell Island Rise stock was completed in 2020, using research time series of abundance indices from wide-area acoustic surveys from 1993 to 2019 and proportion-at-age data from the commercial fishery. New information included a wide-area acoustic survey of the Campbell Island Rise carried out in August–September 2019, which produced a biomass estimate of 91 000 t (Ladroit et al in press). The general purpose stock assessment program, CASAL (Bull et al 2012) was used and the approach, which used Bayesian estimation, was the same as that adopted by Roberts & Hanchet (2019). Roberts & Hanchet (2019) introduced an initial equilibrium age structure in 1960 rather than using a non-equilibrium age structure in 1979 which was used in previous assessments (e.g., Dunn & Hanchet 2017). Therefore, year class strengths were estimated from 1958 (instead of 1977), the catch history was extended back to 1971, the first year of reported catches (1979 previously, see Table 1). The new 2020 model produced similar estimates of status to the old model, but it also produced stable estimates of natural mortality when using Markov Chain Monte Carlo (MCMC) methods.

A stock assessment was also completed for the Bounty Platform stock in 2014 using data up to 2013 from local area acoustic surveys of aggregations. The general purpose stock assessment program, CASAL (Bull et al 2012) with Bayesian estimation was used. Preliminary model runs did not provide a satisfactory fit to both the high local area aggregation acoustic biomass estimates observed in 2007–2008 and the lower local area aggregation biomass estimates observed since 2009. Development of the assessment then focused on evaluating models with different assumptions that allowed a comparison of the extent to which the high biomass and subsequent decline were fitted. However, these have not proven successful, and the stock assessment has now been rejected by the Working Group in favour of developing a harvest control rule. An HCR that would lead to a low risk of the stock falling below the soft limit reference point was developed and used the most recent acoustic index of abundance as an absolute measure of abundance. Four further acoustic surveys were completed at the Bounty Platform from 2014 to 2017, but surveys in 2018 and 2019 were unsuccessful.

No new assessment is available for the Pukaki Rise stock due to the paucity of useful abundance data. No assessment has been made of the Auckland Islands Shelf stock. The years given in the biomass and yield sections of this report refer to the August–September spawning/fishing season.

5.1 Estimates of fishery parameters and abundance indices

(i) Bounty Platform

Between 1993 and 2001, a series of wide-area acoustic surveys for southern blue whiting were carried out by the RV *Tangaroa*. From 2004 to 2017, a series of local area aggregation surveys were carried out from industry vessels (O'Driscoll 2015, O’Driscoll & Dunford 2017, O’Driscoll & Ladroit 2017, O’Driscoll 2018). The fishing vessels opportunistically collected acoustic data from the Bounty Platform fishing grounds using a random survey design over an ad hoc area that encompassed an aggregation of southern blue whiting (O'Driscoll 2015). The local area aggregation surveys have had mixed levels of success (Table 8).

Table 8: Estimates of biomass (t) for immature and mature fish from wide-area acoustic surveys of the Bounty Platform from 1993–2001 (from Fu et al 2013); and mature fish from local aggregation surveys in 2004–2016 (O’Driscoll 2015, O’Driscoll & Dunford 2017, O’Driscoll & Ladroit 2017); and the proportion of catch that occurred before the biomass estimate in each year (based on catch effort data, and sample dates for the acoustic snapshots). Sampling CVs for the surveys are given in parentheses. [Continued on next page]

	Wide-area surveys		Local aggregation surveys	
Year	Immature	Mature	Mature	Proportion
1993	15 269 (33%)	43 338 (58%)	–	–
1994	7 263 (27%)	17 991 (25%)	–	–
1995	0 (–)	17 945 (24%)	–	–
1997	3 265 (54%)	27 594 (37%)	–	–
1999	344 (37%)	21 956 (75%)	–	–
2001	668 (28%)	11 784 (35%)	–	–
2004		–	8 572 (69%)	0.73
2005		–	–	–
2006		–	11 949 (12%)	0.78
2007		–	79 285 (19%)	0.93
2008		–	75 889 (34%)	0.68

Table 8 [Continued]

	Wide-area surveys		Local aggregation surveys	
Year	**Immature**	**Mature**	**Mature**	**Proportion**
2009		–	16 640 (21%)	0.29
2010		–	18 074 (36%)	0.35
2011		–	20 990 (28%)	0.89
2012		–	16 333 (7%)	0.84
2013		–	28 533 (27%)	0.76
2014		–	11 852 (31%)	0.75
2015		–	6 726 (42%)	0.44
2016		–	6 201 (35%)	0.93
2017			7 719 (24%)	0.61

Acoustic data collected in 2005 could not be used because of inadequate survey design and acoustic interference from the scanning sonar used by the vessel for searching for fish marks. There was some concern that the surveys in 2006 and 2009 may not have sampled the entire aggregation because fish marks extended beyond the area being surveyed on some transects. However, the surveys in 2010–2012 appeared to have sampled the entire aggregation and gave a similar estimate of biomass to that in 2009. The 2013 aggregation survey was higher than the preceding four surveys, but since then biomass estimates have progressively declined, supporting the view that biomass has declined in this stock. Surveys in 2018 and 2019 were unsuccessful and did not produce indices of abundance. It is possible that the first spawning in 2018 and 2019 was earlier than in 2016 and 2017, and therefore that the acoustic data collection was too late (e.g., Large et al 2019).

A standardised CPUE analysis was carried out for the Bounty Platform for data up to 2002. However, the results of this analysis were not consistent with the acoustic survey estimates, and the model structure and assumptions were inadequate to reliably determine the indices or associated variance. The indices were therefore rejected by the Working Group as indices of abundance and have not been used in assessments.

(ii) Campbell Island Rise

Wide-area acoustic surveys of the Campbell Island Rise have been carried out from RV *Tangaroa* since 1995, with the most recent survey in August–September 2019 (Ladroit et al in press). The estimate of mature biomass in 2019 was similar to that in 2016, and the 4th highest in the time series (Table 9).

Table 9: Estimates of biomass (t) for immature and mature fish from wide-area acoustic surveys of the Campbell Island Rise 1993–2019 (from Ladroit et al in press). Sampling CVs for the surveys are given in parentheses.

	Wide-area surveys	
Year	**Immature**	**Mature**
1993	35 208 (25%)	16 060 (24%)
1994	8 018 (38%)	72 168 (34%)
1995	15 507 (29%)	53 608 (30%)
1998	6 759 (20%)	91 639 (14%)
2000	1 864 (24%)	71 749 (17%)
2002	247 (76%)	66 034 (68%)
2004	5 617 (16%)	42 236 (35%)
2006	3 423 (24%)	43 843 (32%)
2009	24 479 (26%)	99 521 (27%)
2011	14 454 (17%)	53 299 (22%)
2013	8 004 (55%)	65 801 (25%)
2016	4 456 (19%)	97 117 (16%)
2019	4 020 (18%)	91 145 (27%)

A standardised CPUE analysis of the Campbell Island stock was completed up until the 2002 fishing season. In the past there has been concern that because of the highly aggregated nature of the fishery, and the associated difficulty in finding and maintaining contact with the highly mobile schools in some years, the CPUE series may not be monitoring abundance. The indices have therefore not been used in the stock assessment since 1998.

(iii) Pukaki Rise

Wide-area surveys of the Pukaki Rise were carried out between 1993 and 2000 (Fu et al 2013) from RV *Tangaroa*, and more recently (2009 to 2012) local area aggregation estimates were obtained by industry vessels (Table 10). The biomass estimates from the last two surveys (2010, 2012) were considered too small to be plausible (Table 10).

Table 10: Estimates of biomass (t) for immature and mature fish from wide-area acoustic surveys of the Pukaki Rise 1993–2000 (from Fu et al 2013 and O'Driscoll 2013) and local area aggregation surveys from 2009–2012. Sampling CVs for the surveys are given in parentheses.

	Wide-area surveys				Local aggregation surveys		
Year	Immature		Mature	Vessel	Transects	Area (km^2)	Biomass (%cv)
1993	9 558 (25%)		26 298 (32%)			–	
1994	125 (100%)	3 591 (48%)	21 506 (44%)			–	
1995	0 (–)		6 552 (18%)			–	
1997	1 866 (12%)		16 862 (34%)			–	
2000	1 868 (62%)	8 363 (74%)	6 960 (37%)			–	
2009			–	*Meridian 1*	4	50	188 (29%)
			–		5	283	9 459 (30%)
			–		5	71	6 272 (41%)
			–	*Aleksandr Buryachenko*	6	60	2 361 (12%)
			–		7	117	7 903 (26%)
			–		6	19	11 321 (38%)
2010			–	*Meridian 1*	10	364	1 085 (17%)
2012			–	*San Waitaki*	–	–	3 272 (21%)

5.2 Biomass estimates

(i) Campbell Island stock (2020 stock assessment)

The stock assessment model

An updated stock assessment for the Campbell Island stock was completed for the 2019–20 year (Doonan in prep).

Table 11: Annual cycle of the stock model, showing the processes taking place at each step, and the available observations. Fishing mortality (*F*) and natural mortality (*M*) that occur within a time step occur after all other processes. *M*, proportion of *M* occurring in that time step.

Period	Process	*M*	Length at age	Observations
1. Nov–Aug	Natural mortality	0.9	–	–
2. Sep–Oct	Age, recruitment, F, M	0.1	Matrix applies here	Proportion at age, acoustic indices

A two-sex, single stock and area Bayesian statistical catch-at-age model for the Campbell Island southern blue whiting stock was implemented in CASAL (Bull et al 2012). The model partitioned the stock into immature and mature fish with two sexes and age groups 2–15, with a plus group at age 15. The model was run for the years 1960–2019. Five year projections were run for the years 2020–2025. The annual cycle was partitioned into two time steps (Table 11). In the first time step (nominally the non-spawning season), 90% of natural mortality was assumed to have taken place. In the second time step (spawning season), fish matured and were migrated to a spawning area where fish ages were incremented; the 2-year-olds were recruited to the population, and mature fish were subjected to fishing mortality. The remaining 10% of natural mortality was then applied to the entire population following fishing. A two sex model was used because there are significant differences observed between males and females in both the proportions at age in the commercial catch for fished aged 2–4 (see later) and their mean size at age (Hanchet & Dunn 2010). The stock recruitment relationship was assumed to be Beverton-Holt with a steepness of 0.9, with the proportion of males at recruitment (at age 2) assumed to be 0.5 of all recruits.

Southern blue whiting exhibit large interannual differences in growth, presumably caused by local environmental factors but also closely correlated with the occurrence of strong and weak year classes. Hence, an empirical size-at-age matrix was used which was derived by qualitatively reviewing the empirically estimated mean sizes-at-age from the commercial catch-at-length and -age data (Hanchet & Dunn 2010). Missing mean sizes in the matrix were inferred from the relative size of their cohort and the mean growth of similar ages in other years; and cohorts with unusually small or large increments were similarly adjusted. For projections, the mean sizes-at-age were assumed to be equal to the average of the estimated sizes-at-age from 2015 to 2019 (5 years).

In general, southern blue whiting on the Campbell Island Rise are assumed to be mature when on the fishing ground, because they are spawning when they are fished. Hence, it was assumed that all mature fish were equally selected by fishing, and that no immature fish were selected. The maximum exploitation rate (U_{max}) was assumed to be 0.8. The proportion of immature fish that mature in each year was estimated for ages 2–5, with fish aged 6 and above assumed to be fully mature.

The updated model was started in 1960 and assumed an equilibrium age distribution. The model estimated year class strengths back to 1958, which allowed the flexibility to fit to strongly non-equilibrium age composition observed in the commercial trawl catches since 1979. Catches for the Campbell Rise in years 1971–1977 were estimated by assuming the proportion of the catch from all areas taken at the Campbell Rise was equal to the proportion across the period since 1978, following Roberts & Dunn (2019) (see Table 12).

Table 12: Estimated catches for Campbell Rise from 1971 to 1977 (see Roberts & Hanchet 2019).

Fishing year	Estimated catch (t)
1971	7 260
1972	18 010
1973	33 856
1974	29 458
1975	1 660
1976	11 929
1977	18 453

Observations
The model was fitted to a single time series of acoustic biomass estimates and the catch-at-age data from the fishery; the time series of acoustic biomass estimates came from a wide-area survey series conducted by the research vessel *Tangaroa* for immature and for mature fish. The acoustic survey estimates were used as relative estimates of mid-season biomass (i.e., after half the catch has been removed), with associated CVs estimated from the survey analysis (Table 9).

Catch-at-age observations by sex were available for most years from the commercial fishery for the period 1979 to 2019. These catch-at-age data were fitted to the model as proportions-at-age, where estimates of the proportions-at-age by age were estimated by bootstrap using the NIWA catch-at-age software (Bull & Dunn 2002).

Estimation
Model parameters were estimated using Bayesian methods implemented using the NIWA stock assessment program CASAL v2.30 (Bull et al 2012). For initial runs only the mode of the joint posterior distribution was estimated. For the final runs presented here, the full posterior distribution was sampled using MCMC methods, based on the Metropolis-Hastings algorithm.

An initial MCMC chain was estimated using a burn-in length of 1 million iterations, with every 10 000th sample taken from the next 10 million iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior). To improve mixing at MCMC (following the approach of Roberts & Doonan 2016) the covariance matrix was recalculated empirically from the 1000 samples obtained from the initial MCMC chain and the chain started afresh with the new covariance matrix out to a length 3.3×10^6 iterations (no burn-in). The initial chain was discarded.

Equilibrium “virgin” biomass is equal to the population that there would have been if all the YCS were equal to one and there was no fishing. Year class strengths were estimated for all years from 1958 to 2016, under the assumption that the estimates from the model should average one.

Prior distributions and penalty functions
In general, the assumed prior distributions used in the assessment were intended to be non-informative with wide bounds (Table 13). The exceptions to this were the priors and penalties on the mature biomass catchability coefficient and on relative year class strengths. The prior assumed for the relative year class strengths was lognormal, with mean 1.0 and CV 1.3.

Before the 2016 assessment, the log-normal prior for the wide-area acoustic survey catchability coefficient was revised following the adoption of a new TS-length relationship for SBW (O’Driscoll et al 2013). The revised prior had a mean of 0.54 and CV of 0.44. The old prior had a mean of 0.87 and a CV of 0.30.

Natural mortality was parameterised by the average of male and female, with the difference estimated with an associated normal prior with mean zero and standard deviation 0.05. Penalty functions were used to constrain the model so that any combinations of parameters that did not allow the historical catch to be taken were strongly penalised. A small penalty was applied to encourage the estimates of year class strengths to average to 1.

Table 13: The distributions, priors, and bounds assumed for the various parameters being estimated for the Campbell Island stock assessment.

			Values		Bounds	
Parameter	***N***	**Distribution**	**Mean**	**CV**	**Lower**	**Upper**
B_0	1	Uniform-log	–	–	30 000	800 000
Male maturity	4	Uniform	–	–	0.001	0.999
Female maturity	4	Uniform	–	–	0.001	0.999
Year class strength	56	Lognormal	1.0	1.3	0.001	100
Wide-area catchability mature *q*	1	Lognormal	0.54	0.44	0.1	1.5
Wide-area catchability immature *q*	1	Uniform	–	–	0.01	1.5
*Natural mortality (average)	1	Lognormal	0.2	0.2	0.075	0.325
*Natural mortality (difference)	1	Normal	0.0	0.05	-0.05	0.05

*Natural mortality was estimated for a sensitivity run

Model runs

The Working Group considered a base case and 4 sensitivities (Table 14). The base case assumed a fixed natural mortality of 0.2 and an equilibrium age distribution in 1960. The sensitivities included an update of the 2015–16 base case model (with non-equilibrium age estimated in the model start year of 1979) and models with alternative assumptions of natural mortality (*M*), including estimating *M*. Model outputs were relatively insensitive to alternative catch histories for the period 1971–1977.

Lognormal errors, with known CVs, were assumed for the relative biomass indices, and multinomial errors were assumed for the proportions-at-age data. However, the error terms allowed for sampling error only and additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance. This additional variance, termed process error, was estimated in the initial MPD runs using all the available data and fixed at these values for the MCMCs. Process errors were estimated separately for the proportion-at-age data using the method of Francis (2011) and for the acoustic estimates from the wide-area surveys (but was estimated to be nil for mature biomass at MPD).

Table 14: MCMC model runs, labels, and descriptions.

Model type	**Model label**	**Description**
Base case	Base	Model with equilibrium age distribution for the year 1960, YCSs estimated for years 1958–2013, catch history for years 1971–2019, natural mortality equal to 0.20.
Sensitivity	Mfree	Model Bass, but with natural mortality estimated.
Sensitivity	Tvary	Model Base, but with time varying adjustment to maturity from 1990 to 2019.

Results

The estimated MCMC marginal posterior distributions for spawning stock biomass trajectories are shown for the base case model run in Figure 2, and the results summarised in Tables 15 and 16. The run suggests that the stock biomass increased above B_0 in the mid-1970s, due to strong year classes in the mid-1960s. This was followed by 20 years of below average recruitment which led to a steep decline in stock biomass. There was a large increase from 1994 to 1996 in response to the very strong 1991 year class. The population then declined until stronger 2006, 2009, and 2011 year classes recruited to the fishery. From 2012 to 2016 (last estimated YCS), recruitment has fluctuated about the average. Exploitation rates and relative year class strengths are shown in Figure 3. Estimates of the adult acoustic *q* and *M* are given in Table 16.

Table 15: Bayesian median and 95% credible intervals of equilibrium (B_0) and current biomass (% B_0) for the base and sensitivities.

Model	B_0 (`000 t)	B_{2019} (% B_0)
Base	329 (299–372)	58 (42–76)
Mfree	321 (294–360)	51 (35–71)
Tvary	331 (300–373)	54 (40–72)

Table 16: Bayesian median and 95% credible intervals of the catchability coefficients (*q*) and natural mortality parameters for the wide-area acoustic biomass indices for the base case model run and the sensitivity cases.

Model	Catchability		Natural mortality	
	Immature	Mature	Male	Female
Base	0.26 (0.22–0.32)	0.40 (0.33–0.48)	–	–
Mfree	0.35 (0.24–0.49)	0.49 (0.35–0.62)	0.164 (0.126–0.208)	0.170 (0.135–0.213)
Tvary	0.26 (0.21–0.31)	0.42 (0.35–0.50)	–	–

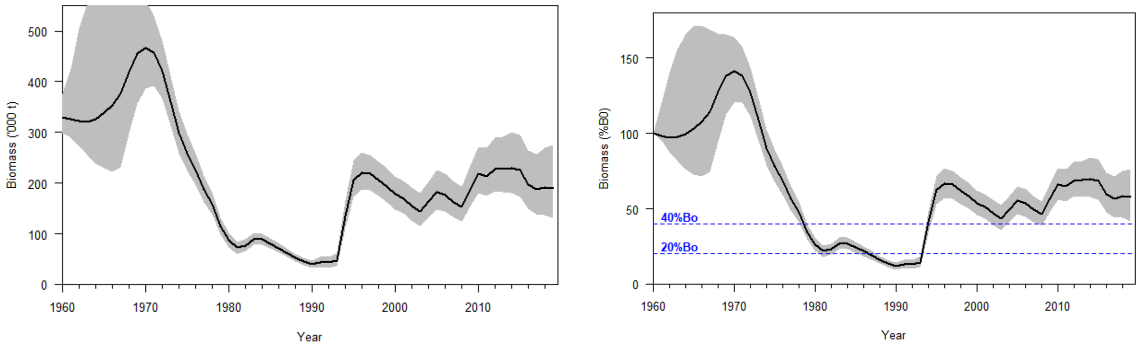


Figure 2: MCMC posterior plots of the trajectories of biomass (left) and current stock status (% B_{2013}/B_0) (right) for the Campbell Island stock for the base case model. The shaded regions are the 95% credible intervals.

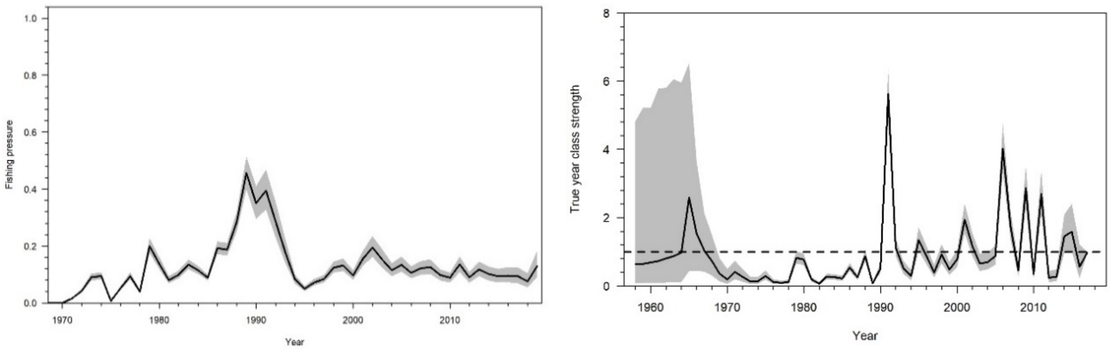


Figure 3: Estimated posterior distributions of exploitation rates (left) and relative year class strength (right) for the Campbell Island stock for the base case model.

Projections were made assuming fixed catch levels of 21 059 t (average of catches in 2015–16 to 2019–20) and 39 200 t (TACC) for the years 2021 to 2025. Projections were made using the MCMC samples, with recruitments drawn randomly from the distribution of year class strengths for the period 1958–2016 estimated by the model and applied from year 2017 onwards. An alternative recruitment distribution used estimated YCS from 2007 to 2016 (last 10 years). For projections, the mean sizes-at-age were assumed to be equal to the average sizes-at-age from 2015 to 2019 (five year average). This gave four scenarios.

For each scenario, the probability that the mid-season biomass for the specified year will be less than the soft limit (20% B_0) is given in Table 17. The probability of dropping below the soft limit at annual catch levels of 21 059 t is between 2 and 7% depending on recruitment distribution. Under both recruitment conditions the biomass is expected to decline over the next 5 years, but remain above the soft limit. However, if catches are at 39 200 t (TACC), then there is a 24 to 48% chance that the biomass is below the soft limit depending on recruitment conditions.

Table 17: Probability that the projected mid-season vulnerable biomass for 2020–2025 will be greater or equal to 40% B_0, less than 20% B_0, less than 10% B_0, and the median projected biomass (%B_0), at a projected catch of 21 059 t or 39 200 t, for the base case model assuming average recruitment over the period 1958–2016 for 2017+, and assuming recruitment from 2007–2016

		Fishing year				
	2019–20	**2020–21**	**2021–22**	**2022–23**	**2023–24**	**2024–25**
Catch 39 200 t + YCS 1958– 2016						
Median SSB (%Bo)	55	49	40	33	26	20
%[SSB >= 40 %Bo]	95	78	51	35	26	22
%[SSB < 20 %Bo]	0	0	3	18	37	49
%[SSB < 10 %Bo]	0	0	0	3	13	29
Catch 39 200 t + YCS 2007– 2016						
Median SSB (%Bo)	57	54	48	43	38	35
%[SSB >= 40 %Bo]	96	85	70	57	47	40
%[SSB < 20 %Bo]	0	0	2	8	16	24
%[SSB < 10 %Bo]	0	0	0	2	5	10
Catch 21 059 t + YCS 1958– 2016						
Median SSB (%Bo)	55	51	48	45	43	41
%[SSB >= 40 %Bo]	95	85	73	62	56	52
%[SSB < 20 %Bo]	0	0	0	1	4	7
%[SSB < 10 %Bo]	0	0	0	0	0	1
Catch 21 059 t + YCS 2007– 2016						
Median SSB (%Bo)	57	57	56	55	55	55
%[SSB >= 40 %Bo]	96	90	85	82	80	78
%[SSB < 20 %Bo]	0	0	0	1	2	2
%[SSB < 10 %Bo]	0	0	0	0	0	0

(ii) Bounty Platform stock

A stock assessment for the Bounty Platform stock was completed for 2014. Preliminary model runs did not provide a satisfactory fit to both the high local area aggregation acoustic biomass estimates observed in 2007–2008 and the lower local area aggregation biomass estimates observed since 2009. Development of the assessment then focused on evaluating models with different assumptions that allowed a comparison of the extent to which the high biomass and subsequent decline were fitted. However, these have not proven successful, and the stock assessment was rejected by the Working Group and a harvest control rule was developed.

Development of a harvest control rule (HCR)

An HCR that would lead to a low risk of the stock falling below the soft limit reference point was developed, and used the most recent acoustic index of abundance as an absolute measure of abundance. In the HCR, risk was defined as the probability of the SSB being below 20% SSB0 (the soft limit). The HCR is given by TACC t+1 = HCR-p (B_t – C_t/ 2), where B_t is acoustic abundance, C_t is catch, and HCR-p is a fixed proportion in year t.

Results of simulations for different levels of harvest (HCR-p) and assumptions of natural mortality are given in Table 18 (Doonan 2017).

For 2017, the currently accepted HCR for SBW 6B, Bounty Platform, was applied using the abundance estimate from the industry acoustic survey completed in the 2017 fishing season (O'Driscoll 2018). The HCR depends on the values of natural mortality and steepness and these were specified by Fisheries New Zealand to be 0.2 y^{-1} and 0.9, respectively. The HCR gave a yield for the 2018 fishing season of 3209 t (Doonan 2018). This yield assumes that there will not be a very large cohort entering the mature population. No further work was conducted developing or exploring assumptions underlying the current HCR, e.g., what procedures should be undertaken to detect and respond to another very large recruitment event (which is excluded from the current HCR), or, whether the HCR is more robust if it is based on the end-of-year biomass rather than that at the start of the fishing season.

Table 18: Case-2: Risk for a combination of *M* and HCR-p values with steepness set to 0.90 and survey process CV at 0% (probability of SSB_0 being below 0.20 B_0 over a 120-year projection). Risk is the probability of SSB_0 being below 0.2 B_0 over a 120-year projection. Mean over 2 runs. Standard simulation error was about 0.0025. Acceptable risks are below the thick black border.

M	HCR-p				
	0.1	0.15	0.2	0.25	0.3
0.1	0.037	0.151	0.305	0.460	0.589
0.15	0.010	0.053	0.131	0.229	0.332
0.2	0.003	0.021	0.058	0.113	0.180
0.25	0.002	0.012	0.035	0.070	0.117
0.3	0.001	0.007	0.020	0.042	0.071

The HCR has not been updated since 2018 because acoustic indices were not available from the 2018 or 2019 acoustic surveys.

(iii) Pukaki Rise stock

An assessment of the Pukaki Rise stock was carried out in 2002. The age structured separable Sequential Population Analysis (sSPA) model was used to estimate the numbers at age in the initial population in 1989 and subsequent recruitment. The model estimates selectivity for ages 2, 3, and 4 and assumes that the selectivity after age 4 is 1.0. No stock-recruitment relationship is assumed in the sSPA.

Preliminary runs of the model were fitted to proportion-at-age data from 1989 to 2000, and the acoustic indices given in Table 19, which differ from those in Table 10 because they were calculated with an older estimate of target strength and sound absorption. The indices were fitted in the model as relative estimates of mid-season biomass (i.e., after half the catch has been removed), with the CVs as shown in Table 20. The proportion-at-age data are assumed to be multinomially distributed with a median sample size of 50 (equivalent to a CV of about 0.3). Details of the input parameters for the initial and sensitivity runs are given in Table 20.

Table 19: RV *Tangaroa* age 2, 3, and 4+ acoustic biomass estimates (t) for the Pukaki Rise used in the 2002 assessment. Estimates differ from those in Table 10 because they were calculated with old estimates of target strength and sound absorption.

Year	Age 1	Age 2	Age 3	Age 4+
1993	578	26 848	9 315	31 152
1994	13	1 193	6 364	35 969
1995	0	102	775	11 743
1997	22	2 838	864	34 086
2000	58	7 268	5 577	24 931

Table 20: Values for the input parameters to the separable Sequential Population Analysis for the initial run and sensitivity runs for the Pukaki Rise stock.

Parameter	Initial run	Sensitivity runs
M	0.2	0.15, 0.25
Acoustic age 3 and 4+ indices *CV*	0.3	0.1, 0.5
Acoustic age 1, 2 indices *CV*	0.7	0.5, 1.0
Weighting on proportion-at-age data	50	5, 100
Years used in analysis	1989–2000	1979–2000
Acoustic *q*	estimated	0.68, 1.4, 2.8

Biomass estimates in the initial run and also in the sensitivity runs all appeared to be over-pessimistic because the adult (4+) acoustic *q* was very high. For example, for the initial run the 4+ acoustic *q* was estimated to be 2.7. The Working Group did not accept this initial run as a base case assessment, but agreed to present a range of possible biomass estimates. The Plenary agreed to present a range, based on assumptions concerning the likely range of the value for the acoustic *q*.

Bounds for the adult (4+) acoustic *q* were obtained using the approach of Cordue (1996). Uncertainty over various factors including mean target strength, acoustic system calibration, target identification, shadow or dead zone correction, and areal availability were all taken into account. In addition to obtaining the bounds, a 'best estimate' for each factor was also calculated. The factors were then multiplied together. This independent evaluation of the bounds on the acoustic *q* suggested a range of 0.65–2.8, with a best estimate of 1.4. Clearly the *q* from the initial run is almost at the upper bound and probably outside the credible range. When the model was run fixing the acoustic *q* at 0.65 and 2.8, estimates of B_0 were 18 000 t and 54 000 t, and estimates of B_{2000} were 8000 t and 48 000 t respectively (Table 21, Figure 4). Within these bounds current biomass is greater than B_{MAY}. Assuming the 'best estimate' of *q* of 1.4 gave B_0 equal to 22 000 t and B_{2000} equal to 13 000 t.

Based on the range of stock biomass modelled in the assessment, the average catch level since 2002 (380 t) is unlikely to have made much impact on stock size. A more intensive fishery or more consistent catches from year to year would seem to be required to provide any contrast in the biomass indices. This stock has been only lightly exploited since 1993, when over 5000 t was taken in the spawning season.

An assessment was planned for the Pukaki Rise stock in 2014 but the Working Group did not accept that the 2012 acoustic survey provided an acceptably realistic biomass estimate for the stock, so an assessment was not possible.

Table 21: Parameter estimates for the Pukaki stock as a result of fixing the adult 4+ acoustic *q* at various values. B_{mid}, mid-season spawning stock biomass; $N_{2,1992}$ size of the 1990 year class (millions). All values in t x 10^3.

Fixing the acoustic *q* value	B_0	$B_{mid\ 89}$	$B_{mid\ 00}$	$N_{2,1992}$	$B_{mid\ 00}$ (% B_0)	$B_{mid\ 00}$ (% B_{may})
q = 0.65	54	36	48	63	88	246
q = 1.4	22	22	13	28	58	161
q = 2.8	18	19	8	23	44	123

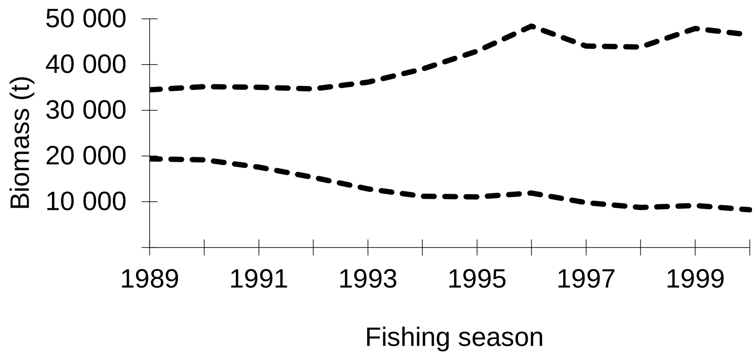


Figure 4: Mid-season spawning stock biomass trajectory bounds for the Pukaki Rise stock. Bounds based on acoustic *q* of 0.65 and 2.8.

(iv) Auckland Islands stock

No estimate of current biomass is available for the Auckland Islands Shelf stock. The acoustic estimate of the adult biomass in 1995 was 7800 t.

5. STATUS OF THE STOCKS

Stock Structure Assumptions

Southern blue whiting are assessed as four independent biological stocks, based on the presence of four main spawning areas and some differences in biological parameters and morphometrics between these areas (Hanchet 1999).

The four main stocks SBW 6A (Auckland Islands), SBW 6B (Bounty Platform), SBW 6I (Campbell Island Rise), and SBW 6R (Pukaki Rise) cover the four main bathymetric features in the Sub-Antarctic QMA6. SBW 1 is a nominal stock covering the rest of the New Zealand EEZ where small numbers of fish may occasionally be taken as bycatch.

- **Auckland Islands (SBW 6A)**

Stock Status	
Year of Most Recent Assessment	-
Assessment Runs Presented	-
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Catches have fluctuated without trend
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	No reliable indices of abundance
Trends in Other Relevant Indicators or Variables	Catch in 2007 and 2008 was dominated by large (40–50 cm long) fish - no sign of recent strong year classes.

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	-

Assessment Methodology		
Assessment Type	Level 4: Low information	
Assessment Method	None	
Assessment Dates	-	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs	- Catch history - erratic catches with no trend Limited catch-at-age data (1993–1998) and 2008	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- No reliable time series of data available. - Catches have been erratic for the past 10 years and have been taken as bycatch in other middle depth fisheries so unlikely to provide reliable CPUE indices.	

Qualifying Comments
There were several years of high catches (700–1100 t) during the mid-1990s but since then annual catches have averaged about 100 t. Good recruitment in southern blue whiting tends to be episodic and it is likely that the period of high catches was due to the presence of the strong year 1991 year class. Catches will probably remain low until another strong year class enters the fishery.

Fishery Interactions
Fish bycatch is low in the SBW target fishery. There are some interactions with New Zealand sea lions and seabirds.

- **Bounty Platform (SBW 6B)**

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Harvest control rule simulations
Reference Points	Management Target: A fishing mortality rate calculated from the harvest control rule Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: A fishing mortality rate calculated from the harvest control rule
Status in relation to Target	Likely (> 60%) to be below the target *F*
Status in relation to Limits	Unknown
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Intensity or Proxy	Fishing mortality is likely to have fluctuated around the target *F* in recent years.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Recruitment was estimated to be low from 1995 to 2001 but was extremely high in 2002 and has been low since then. The 2007 year class appears to be above average.

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Harvest Control Rule based on simulations of an age structured model	
Assessment Dates	Latest assessment: 2018	Next assessment: 2021
Overall assessment quality rank	2 – Medium Quality	
Main data inputs (rank)	- Wide-area acoustic abundance indices - Acoustic abundance indices from local area aggregation surveys - Proportions at age data from the commercial fisheries and trawl surveys - Estimates of biological parameters	1 – High Quality 2 – Medium Quality (uncertainty in the proportion of the spawning aggregation covered by the surveys) 1 – High Quality 1 – High Quality

	- Estimates of acoustic target strength	1 – High Quality
Data not used (rank)	- Commercial CPUE	3 – Low Quality: does not track stock biomass
Changes to Model Structure and Assumptions	- Previous (2014) assessment rejected and replaced with a harvest control rule	
Major Sources of Uncertainty	- The proportion of the spawning biomass that is indexed by the local area aggregation survey in each year is variable and uncertain. - Estimates of fishing mortality assume the catchability coefficient of the acoustic biomass estimates is known.	

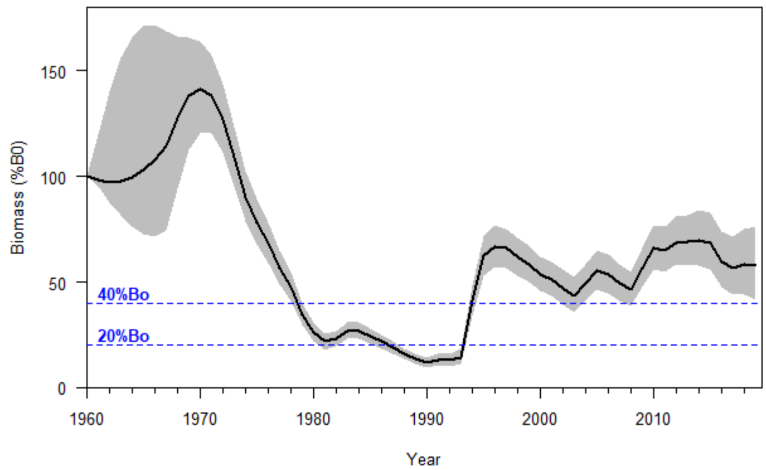
Qualifying Comments
Three surveys from 2014 to 2016 showed a progressive decline in stock biomass to low levels, but increased slightly in 2017. Acoustic surveys in 2018 and 2019 were unsuccessful and did not produce indices of abundance.

Fishery Interactions
There is relatively low non-target catch in this fishery. Protected species interactions have been recorded for New Zealand fur seals and seabirds. Southern blue whiting is caught using midwater trawl gear, which sometimes interact with benthic habitats.

- **Campbell Island Rise (SBW 6I)**

Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Base case stock assessment model
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\% B0}$
Status in relation to Target	B_{2020} was estimated at 56% B_0 and is Very Likely (> 90%) to be at or above the target
Status in relation to Limits	B_{2020} is Exceptionally Unlikely (< 1%) to be below soft or hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectory over time of spawning biomass (%B_0) for the Campbell Island Rise southern blue whiting stock from the start of the assessment period in 1960 to 2019. The blue horizontal lines show the management target (40% B_0) and the soft limit (20% B_0). Biomass estimates are based on Base case MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	With strong recent recruitment the biomass has increased well above the management target.
Recent Trend in Fishing Intensity or Proxy	Fishing pressure has declined with the increase in stock size.

Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	The 2006, 2009 and 2011 year classes appear to be very strong, but not as strong as the 1991 year class.

Projections and Prognosis	
Stock Projections or Prognosis	At a TACC of 39 200 t, the biomass of the Campbell stock is expected to decrease over the next 1–5 years. At current catches, the biomass will remain above the target (40% B_0) until 2022–23 or 2023–24 depending on recruitment.
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits	At the current catch: Soft Limit: Exceptionally Unlikely (< 1%) over next 3 years Hard Limit: Exceptionally Unlikely (< 1%) over next 4–5 years At the TACC: Soft Limit: Exceptionally Unlikely (< 1%) over next 2 years Hard Limit: Exceptionally Unlikely (< 1%) over next 3 years
Probability of Current Catch or TACC causing Overfishing to continue or commence	At the current catch: Very Unlikely (< 10%) At the TACC: Unlikely (< 40%)

Assessment Methodology		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2020	Next assessment: 2023
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Research time series based on acoustic indices - Proportions-at-age data from the commercial fisheries and trawl surveys - Estimates of biological parameters	1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	- Commercial CPUE	3 – Low Quality: does not track stock biomass
Changes to Model Structure and Assumptions	- None	
Major Sources of Uncertainty	- Uncertainty about the size of future age classes affects the reliability of stock projections - Future mean weight at age in the projections	

Qualifying Comments
-

Fishery Interactions
There is relatively low non-target catch in this fishery. Protected species interactions have been recorded for New Zealand sea lions, New Zealand fur seals and seabirds. Southern blue whiting is caught using midwater trawl gear, which sometimes interacts with benthic habitats.

- **Pukaki Rise (SBW 6R)**

Stock Status	
Year of Most Recent Assessment	2002
Assessment Runs Presented	The results of three runs were presented assuming different values for the adult acoustic *q*.
Reference Points	Interim Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Current status unknown. Believed to be only lightly exploited between 1993 and 2002
Status in relation to Limits	Current status unknown. Believed to be only lightly exploited between 1993 and 2002
Status in relation to Overfishing	-

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Catches over the last 10 years have fluctuated without trend.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	No current reliable indices of abundance (wide-area surveys were discontinued in 2000)
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2002)	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	-

Assessment Methodology		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age structured separable Sequential Population Analysis (sSPA) with maximum likelihood estimation	
Assessment Dates	Last assessment: 2002	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	- Abundance indices from wide-area acoustic surveys - Catch-at-age data	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	The adult acoustic q was estimated in the model to be 2.7 which the Working Group thought was unrealistically high. A run based on a more plausible value for *q* suggested the 2000 biomass was above 50% B_0.	

Qualifying Comments
Fishers reported large aggregations of fish and made good catches in 2009. However, aggregation surveys by industry vessels in 2009 yielded generally low biomass estimates which were at a level consistent with that during the 1990s. The Sub-Antarctic trawl surveys may provide an index of abundance for this stock, but this has yet to be determined. Catch at age data are available for 2007 and 2009 and suggest the catch is dominated by relatively young fish from the 2003–2006 year classes. Catch in 2019 was the highest since 2012.

Fishery Interactions
There is relatively low non-target catch in this fishery. Protected species interactions and interactions with benthic habitats are negligible.

6. FUTURE RESEARCH CONSIDERATIONS

For Campbell Island Rise southern blue whiting, a candidate for further research or investigation would be to determine how to best represent mean weights at age in the projections given the negative relationship between year class strength and growth.

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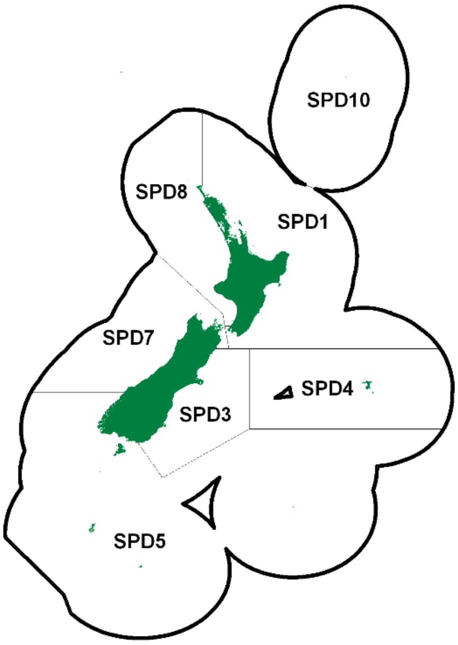
SPINY DOGFISH (SPD)

(*Squalus acanthias*)
Makohuarau, Pioke, Kāraerae



1. FISHERY SUMMARY

1.1 Commercial fisheries

Spiny dogfish are found throughout the southern half of New Zealand, extending to East Cape and Manakau Harbour on the east and west coasts of the North Island respectively. A related species, the northern spiny dogfish (*Squalus mitsukurii*), is mainly restricted to North Island waters, overlapping with its conspecific in the central west coast area and around the Chatham Islands. Although they have different species codes for reporting purposes it is probable that some misidentification and misreporting occurs - particularly in FMAs 1, 8 and 9.

The best estimate of reported catch from the fishery is shown in the final column in Table 1. For the period 1980–81 to 1986–87 the best estimate of landings is the sum of the FSU data. For the period 1987–88 to 1996–97 it is the sum of the LFRR and the discards from the CELR and CLR. It has been assumed here that all the fish which have been caught and discarded will die, and that all the discarded fish have been recorded. Although neither assumption is likely to be true, and the biases they produce will at least partially cancel each other out, it is likely that the true level of discards is considerably higher. However, these figures are currently the best estimates of total removals from the fishery from 1980-81 to 1996-97.

Before 1980–81 landings of rig and both *Squalus* species were included together and catches of the latter were probably small. Since then the reported landings of spiny dogfish has fluctuated between about 3 000 and 7 000 t in most years, averaging about 5 600 t from 2010-11 to 2018-19. The reported catch by the deepwater fleet has remained fairly constant during most of the period, averaging 2 000-4 000 t, with a slight decrease in recent years. The reported catch by the inshore fleet has shown a steady increase throughout the period and is now at a similar level to the catch from the deepwater fleet.

Most of the spiny dogfish caught by the deepwater fleet are taken as a bycatch in the jack mackerel, barracouta, hoki, red cod, and arrow squid fisheries, in depths from 100 to 500 m. Some are packed whole but most are trunked and exported to markets in Asia and Europe.

Table 1: Reported catches of spiny dogfish (t) by fishing year. FSU (Fisheries Statistics Unit), LFRR (Licensed Fish Receiver Return). Discards reported from CELR (Catch Effort Landing Return), and CLR (Catch Landing Return). Numbers in brackets are probably underestimates. (- no data).

	FSU				Best
	Inshore	Deepwater	LFRR	Discards	Estimate
1980–81	-	(196)	-	-	196
1981–82	-	1 881	-	-	1 881
1982–83	(107)	2 568	-	-	2 675
1983–84	309	2 949	-	-	3 258
1984–85	303	3 266	-	-	3 569
1985–86	311	2 802	-	-	3 113
1986–87	870	2 277	2 608	-	3 147
1987–88	834	3 877	4 823	-	4 823
1988–89	(351)	(500)	3 573	(16)	3 589
1989–90	(14)	0	2 952	321	3 273
1990–91	-	-	5 983	333	6 316
1991–92	-	-	3 274	521	3 795
1992–93	-	-	4 157	616	4 773
1993–94	-	-	6 150	1 063	7 213
1994–95	-	-	4 793	628	5 421
1995–96	-	-	6 230	1 920	8 150
1996–97	-	-	4 887	2 572	7 459

Spiny dogfish are also taken as bycatch by inshore trawlers, setnetters and longliners targeting flatfish, snapper, tarakihi and gurnard. Because of processing problems due to their spines, sandpaper-like skin, and short shelf life, and their low economic value, many inshore fishers are not interested in processing and landing them. Furthermore, because of their sheer abundance they can at times severely hamper fishing operations for other commercial species and they are regarded by many fishers as a major nuisance. Trawlers working off Otago during the summer months often reduce towing times and headline heights, and at times leave the area altogether to avoid having to spend hours pulling hundreds of meshed dogfish out of trawl nets. Setnetters and longliners off the Otago coast, and in Tasman Bay and the south Taranaki Bight have also complained about spiny dogfish taking longline baits, attacking commercial fish caught in the nets or lines, and rolling up nets.

The catch by FMA from the FSU, CELR and CLR databases is shown in Table 3. Substantial landings have been reported from FMAs 3, 5, 6, and 7 since 1982–83; landings from FMA 4 have increased substantially since the mid-1990s. In the early 1980s landings were highest in FMA 5 and 6, with 1 000–2 000 t taken annually by factory trawlers. By the 1990s landings from FMA 3, and to a lesser extent, FMA 7 become more important. The catch in both these areas was taken equally by factory trawlers and inshore fleets. Since the fishing year 2013-14 the highest landings have been reported from SPD 3, 4, and 5, which together contributed 82% of total spiny dogfish landings in 2018-19. The catch in FMA 1 is unlikely to be spiny dogfish which is considered to be virtually absent from the area, and so these catches should probably be attributed to *S. mitsukurii*.

Competitive quotas of 4 075 t for FMA 3, and of 3 600 t for FMAs 5 and 6, were introduced for the first time in the 1992–93 fishing year. These quotas were based on yields derived from trawl surveys using a method that is now considered obsolete, and harvest levels which are now considered unreliable. The reported catches exceeded the FMA 3 quota in 1997–98, 2000–01 and 2001–02 and the FMA 5/6 quota in 2001–02.

Spiny dogfish was introduced into the QMS in October 2004. Catches and TACCs are shown in Table 4, while Figure 1 depicts historical landings and TACC values for the main SPD stocks. Landings for all Fishstocks have generally remained well below the TACC limits.

Prior to their introduction into the QMS, spiny dogfish were legally discarded at sea (provided that total catch was reported). Although discard rates increased dramatically through the 1990s (Table 5), this is believed to reflect a change in reporting practise rather than an increase in the proportion of catch discarded. Spiny dogfish were placed on Schedule 6 when they were introduced to the QMS.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	SPD 1	SPD 3	SPD 4	SPD 5	Year	SPD 1	SPD 3	SPD 4	SPD 5
1931	0	0	0	0	1957	0	0	0	0
1932	0	0	0	0	1958	0	0	0	0
1933	0	0	0	0	1959	0	0	0	0
1934	0	0	0	0	1960	0	0	0	0
1935	0	0	0	0	1961	0	0	0	0
1936	0	0	0	0	1962	0	0	0	0
1937	0	0	0	0	1963	0	0	0	0
1938	0	0	0	0	1964	0	0	0	0
1939	0	0	0	0	1965	0	0	0	0
1940	0	0	0	0	1966	0	0	0	0
1941	0	0	0	0	1967	0	0	0	0
1942	0	0	0	0	1968	0	0	0	0
1943	0	0	0	0	1969	0	0	0	0
1944	0	0	0	0	1970	0	0	0	0
1945	0	0	0	0	1971	0	0	0	0
1946	0	0	0	0	1972	0	0	0	0
1947	0	0	0	0	1973	0	0	0	0
1948	0	0	0	0	1974	0	0	0	0
1949	0	0	0	0	1975	0	0	0	0
1950	0	0	0	0	1976	0	0	0	0
1951	0	0	0	0	1977	0	0	0	0
1952	0	0	0	0	1978	1	20	0	38
1953	0	0	0	0	1979	2	130	67	74
1954	0	0	0	0	1980	0	39	13	149
1955	0	0	0	0	1981	2	123	92	203
1956	0	0	0	0	1982	20	291	31	2228

Year	SPD 7	SPD 8	Year	SPD 7	SPD 8
1931	0	0	1957	0	0
1932	0	0	1958	0	0
1933	0	0	1959	0	0
1934	0	0	1960	0	0
1935	0	0	1961	0	0
1936	0	0	1962	0	0
1937	0	0	1963	0	0
1938	0	0	1964	0	0
1939	0	0	1965	0	0
1940	0	0	1966	0	0
1941	0	0	1967	0	0
1942	0	0	1968	0	0
1943	0	0	1969	0	0
1944	0	0	1970	0	0
1945	0	0	1971	0	0
1946	0	0	1972	0	0
1947	0	0	1973	0	0
1948	0	0	1974	0	0
1949	0	0	1975	0	0
1950	0	0	1976	0	0
1951	0	0	1977	0	0
1952	0	0	1978	124	41
1953	0	0	1979	128	40
1954	0	0	1980	11	31
1955	0	0	1981	73	150
1956	0	0	1982	113	84

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. 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 includes both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 3: Reported landings of spiny dogfish by FMA. Proportions by area have been taken from CELR and CLR and pro-rated to the best estimate from Table 1. Competitive quotas of 4075 t for FMA 3, and of 3600 t for FMAs 5 and 6, were introduced for the first time in the 1992–93 fishing year.

Year	FMA 1	FMA 2	FMA 3	FMA 4	FMA 5	FMA 6	FMA 7	FMA 8	FMA 9	FMA 10	Other	Total
1982–83	4	0	151	131	2 089	81	145	66	7			2 675
1983–84	22	18	409	347	565	1 700	119	63	16			3 258
1984–85	21	12	557	481	451	1 899	90	48	10			3 569
1985–86	13	11	892	411	537	1 017	120	92	20			3 113
1986–87	64	18	1 048	162	1 002	29	501	296	27			3 147
1987–88	50	9	1 664	172	642	16	1 402	841	27			4 823
1988–89	341	16	1 510	168	771	7	633	132	11			3 589
1989–90	36	14	2 243	136	241	2	521	80	0			3 273
1990–91	129	14	2 987	513	1 708	14	883	67	0			6 316
1991–92	54	23	1 801	66	538	33	1 031	249	0			3 795
1992–93	50	9	2 128	218	817	22	1 163	366	0			4 773
1993–94	51	34	3 165	358	1 158	21	2 212	214	0			7 213
1994–95	84	47	2 883	363	606	37	1 205	196	0			5 421
1995–96	68	177	2 558	969	1 147	152	1 205	186	15			7 052
1996–97	30	159	2 428	1 287	764	120	1 517	235	7	1	1	6 555
1997–98	52	165	5 042	917	428	223	2 389	1 172	34	0	11	10 433
1998–99	45	488	3 148	1 048	1 996	154	1 902	74	< 1	0	< 1	8 424
1999–00	15	328	3 309	994	1 163	189	1 505	25	7	0	5	7 540
2000–01	38	336	4 355	1 075	1 389	212	1 310	54	16	0	28	8 811
2001–02	12	222	4 249	1 788	3 734	487	961	71	12	0	-	11 530
2002–03	10	245	3 553	1 010	2 621	413	772	85	19	0	0	8 727
2003–04	12	91	2 077	516	1 032	302	423	20	5	0	0	4 477

Table 4: Reported domestic landings (t) of spiny dogfish by Fishstock and TACC from 2004–05.

Fishstock	SPD 1		SPD 3		SPD 4		SPD 5		SPD 7	
FMA	1&2		3		4		5&6		7	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2004–05	234	331	2 707	4 794	839	1 626	2 479	3 700	842	1 902
2005–06	186	331	3 831	4 794	1 055	1 626	2 298	3 700	832	1 902
2006–07	239	331	2 712	4 794	822	1 626	2 165	3 700	1 125	1 902
2007–08	156	331	2 082	4 794	1 397	1 626	1 501	3 700	928	1 902
2008–09	229	331	1 981	4 794	866	1 626	2 071	3 700	929	1 902
2009–10	128	331	1 855	4 794	667	1 626	2 205	3 700	1 116	1 902
2010–11	176	331	1 976	4 794	825	1 626	1 443	3 700	1 436	1 902
2011–12	187	331	1 607	4 794	740	1 626	1 390	3 700	1 704	1 902
2012–13	193	331	1 302	4 794	442	1 626	1 547	3 700	1 298	1 902
2013–14	226	331	1 411	4 794	1 090	1 626	2 068	3 700	914	1 902
2014–15	212	331	1 860	4 794	1 380	1 626	1 715	3 700	1 022	1 902
2015–16	178	331	1 284	4 794	1 002	1 626	1 092	3 700	858	1 902
2016–17	225	331	1 725	4 794	1 377	1 626	1 604	3 700	897	1 902
2017–18	163	331	2 007	4 794	1 756	1 626	1 534	3 700	920	1 902
2018–19	179	331	1 887	4 794	1 149	1 626	1 268	3 700	608	1 902

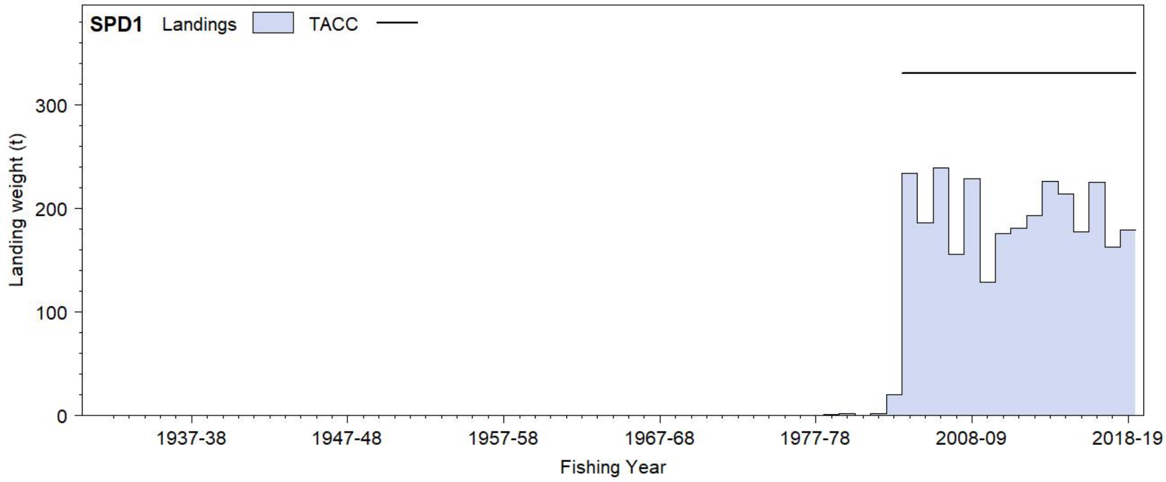
Fishstock	SPD 8			
FMA	8&9		Total	
	Landings	TACC	Landings	TACC
2004–05	121	307	7 222	12 660
2005–06	108	307	8 311	12 660
2006–07	118	307	7 181	12 660
2007–08	124	307	6 188	12 660
2008–09	150	307	6 226	12 660
2009–10	194	307	6 166	12 660
2010–11	221	307	6 077	12 660
2011–12	252	307	5 880	12 660
2012–13	182	307	4 965	12 660
2013–14	122	307	5 831	12 660
2014–15	123	307	6 312	12 660
2015–16	148	307	4 525	12 660
2016–17	181	307	5 112	12 660
2017–18	149	307	6 528	12 660
2018–19	160	307	5 251	12 660

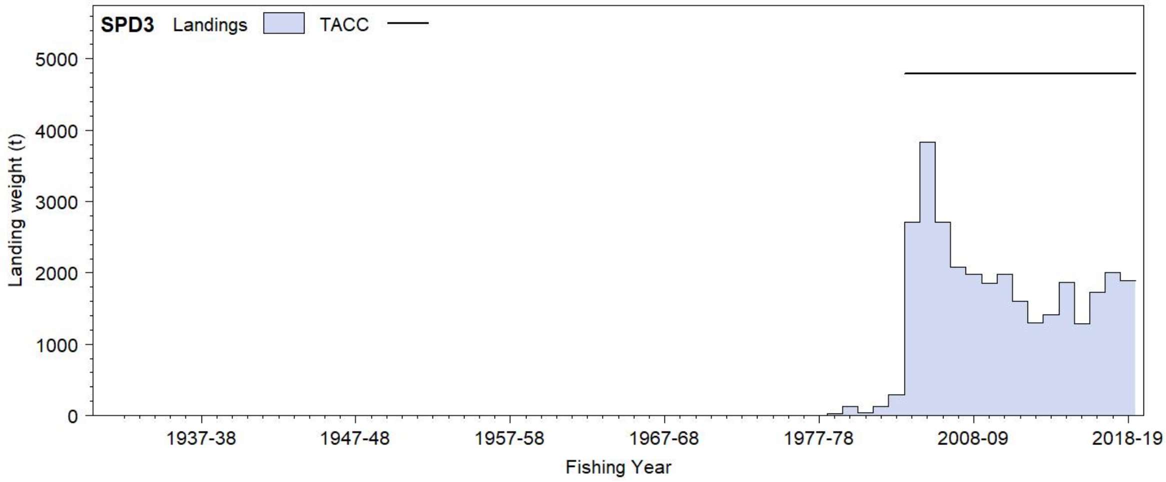
Table 5: Discard rates (% of catch) by FMA and fishing year (after Manning et al 2004). **[Continued on next page]**

FMA Fishing year	1	2	3	4	5	6	7	8	9	10	Other	Average
1989–90	11	17	18	4	46	100	13	34	0	0	0	18
1990–91	7	0	6	2	29	11	21	24	0	0	0	11
1991–92	9	3	8	13	34	90	42	18	0	0	0	20
1992–93	13	47	5	51	39	43	20	80	0	0	0	21
1993–94	5	65	13	42	21	34	29	66	0	0	0	23
1994–95	2	52	8	31	20	74	29	64	98	0	5	19
1995–96	7	39	18	55	39	94	45	72	100	0	11	36

Table 5 [Continued]

FMA Fishing year	1	2	3	4	5	6	7	8	9	10	Other	Average
1996–97	15	61	26	40	70	68	59	89	93	0	16	44
1997–98	53	83	51	53	72	86	81	92	100	0	16	64
1998–99	20	92	57	60	29	78	82	63	0	0	16	58
1999–00	9	86	60	55	39	68	81	84	35	0	0	62
2000–01	37	70	60	77	57	77	72	56	29	0	87	64
Average	15	74	35	53	42	78	54	68	78	0	16	45
1996–97	15	61	26	40	70	68	59	89	93	0	16	44





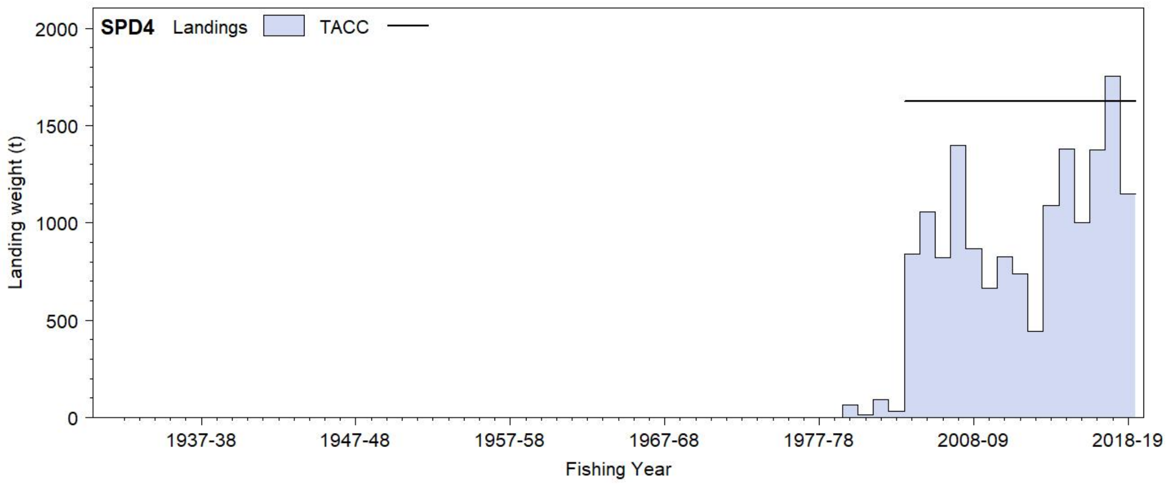


Figure 1: Reported commercial landings and TACCs for the six main SPD stocks SPD 1 (Auckland East, Central East), SPD 3 (South East Coast) and SPD 4 (South East Chatham Rise)

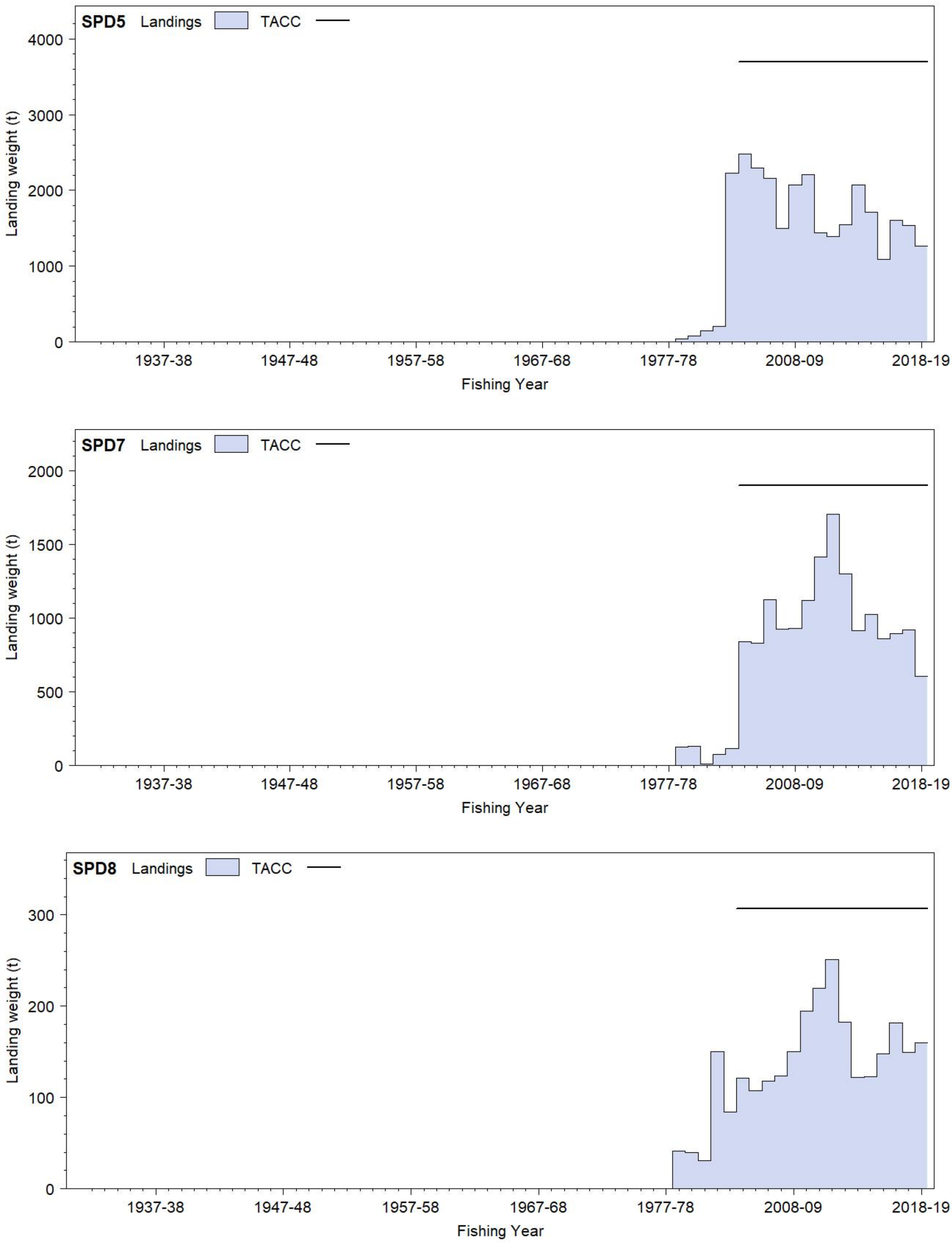


Figure 1 [Continued]: Reported commercial landings and TACCs for the six main SPD stocks SPD 5 (Sub-Antarctic, Southland), SPD 7 (Challenger), and SPD 8 (Central Egmont, Auckland West).

1.2 Recreational fisheries

Spiny dogfish are caught by recreational fishers throughout their geographical range in New Zealand. They are mainly taken as bycatch when targeting other more valued species using rod and line and setnet. In many parts of New Zealand, spiny dogfish are regarded by recreational anglers as a pest, often clogging nets and taking baits from hooks. Estimates of recreational landings obtained from telephone-diary surveys in 1991–92 to 1993–94, 1996 and 1999–00 are given in Table 6.

Table 6: Number and weight of spiny dogfish harvested by recreational fishers by Fishstock from telephone-diary surveys. Surveys were carried out in different years in the MAF Fisheries regions: South in 1991–92, Central in 1992–93, North in 1993–94 (Teirney et al 1997) and nationally in 1996 (Bradford 1998) and 1999–00 (Boyd & Reilly 2002). Survey harvests are presented as a range to reflect the uncertainty in the estimates.

Fishstock	Survey	Number	CV%	Harvest Range (t)	Point estimate (t)
1991–92					
FMA 3	South		23		120
FMA 5	South		-		2
FMA 7	South		92		11
1992–93					
FMA 2	Central		42		133
FMA 7	Central		35		46
FMA 8	Central		45		143
1993–94					
FMA 1,9	North		-		< 10
1996					
FMA 1	National	1 000	-	-	-
FMA 2	National	5 000	-	-	-
FMA 3	National	21 000	17	25–40	33
FMA 5	National	9 000	-	-	-
FMA 7	National	24 000	21	30–45	37
FMA 9	National	15 000	-	-	-
1999–00					
FMA 1	National	9 000	61	4.4–17.9	11
FMA 2	National	22 000	37	17.3–37.8	28
FMA 3	National	93 000	27	83.2–145.9	115
FMA 5	National	7 000	47	4.4–12.3	8
FMA 7	National	25 000	35	20.4–41.9	31
FMA 8	National	21 000	52	12.7–40.3	27
FMA 9	National	12 000	82	2.7–26.2	14

The harvest estimates provided by telephone-diary surveys between 1991 and 2001 are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year. 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 (Wynne-Jones et al 2014). The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 7. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

1.3 Customary non-commercial fisheries

Maori fishers traditionally caught large numbers of “dogfish” and this included rig, school shark, and spiny dogfish. Quantitative information on the current level of customary non-commercial fisheries take is not available.

1.4 Illegal catch

It is unlikely that there is an illegal catch of spiny dogfish as the quota for this species has never been reached, and it has low commercial value.

Table 7: Recreational harvest estimates for spiny dogfish stocks from national panel surveys (Wynne-Jones et al 2014, 2019). Mean fish weights were obtained from boat ramp surveys (Hartill & Davey 2015, Davey et al 2019).

Stock	Year	Method	Number of fish	Total weight (t)	CV
SPD 1	2011/12	Panel survey	5 211	5.3	0.29
	2017/18	Panel survey	2 759	4.2	0.43
SPD 3	2011/12	Panel survey	4 130	4.2	0.29
	2017/18	Panel survey	2 912	4.5	0.46
SPD 5	2011/12	Panel survey	466	0.5	0.81
	2017/18	Panel survey	1 504	2.3	0.70
SPD 7	2011/12	Panel survey	6 035	6.1	0.54
	2017/18	Panel survey	5 019	7.7	0.34
SPD 8	2011/12	Panel survey	6 358	6.5	0.26
	2017/18	Panel survey	1 791	2.7	0.43

1.4 Illegal catch

It is unlikely that there is an illegal catch of spiny dogfish as the quota for this species has never been reached, and it has low commercial value.

1.5 Other sources of mortality

It is likely that a large amount of spiny dogfish is discarded by fishers and never reported. The level of mortality and any temporal trends from non-reported discards have not been estimated. The introduction of cost recovery charges in 1994–95 may account for the decline in reported discards in that year.

2. BIOLOGY

Spiny dogfish are widely distributed around the South Island and extend as far north as Manukau Harbour and East Cape on the west and east coasts of the North Island respectively. They are most abundant on the east coast of the South Island and the Stewart/Snares Shelf. They are found on the continental shelf and upper slope down to a depth of at least 500 m, but are most common in depths of 50–150 m. Schools are strongly segregated by size and sex. The size of fish in the commercial fishery is not known but will depend to a large extent on the method of capture and the area fished.

Spiny dogfish are born at a size of 18–30 cm total length (TL). They have been aged using fin spines, and early growth has been validated by following modes in length-frequency and eye lens weight frequency data. Males mature at 58 cm TL at age 6, and females mature at 73 cm TL at age 10. The maximum ages and lengths in a study of east coast South Island dogfish were 21 years and 90 cm TL for males, and 26 years and 111 cm TL for females.

M was estimated using the equation $\log_e 100$/maximum age, where maximum age is the age to which 1% of the population survive in an unexploited stock. Using a maximum age of 26 gave an estimate of M of 0.18. This has been revised up to 0.2 to reflect the imprecision with which this estimate is known. A similar estimate of M was obtained using a survivorship table approach (Hanchet 1986). At an instantaneous mortality rate of 0.2 year^{-1} an initial population of 1000 females would replace themselves over their lifespan (given their length-at-age, length-at-maturity and fecundity-length relationships).

Female spiny dogfish give birth to young over an extended period between April and September, mainly on the shelf edge in depths of 200–300 m. Mating also occurs in deeper water (coincident with a movement of mature males offshore), after which females with young "candled" embryos move into shallower waters of 100 m or less. They remain there for 12 months until the embryos are 15 cm long after which they return to deeper water. Parturition occurs after a gestation period approaching 24 months, and is closely followed by mating and ovulation and the biennial cycle is repeated. Both the number and the size of the young increase linearly with the length of the mother. The number of young per litter ranges from 1 to 19.

Young of the year move inshore into shallower waters shortly after birth. Over the next few years they move steadily into deeper water but remain in size segregated schools comprising up to 2 or 3 age classes. Once maturity is reached both males and females undergo inshore/offshore migrations associated with reproductive activity. A north/south migration along the east coast South Island during autumn/spring has also been postulated but the full extent of this migration is unknown.

Spiny dogfish are found both on the bottom and in mid-water and feed on a very wide range of species, including *Munida*, krill, fish, squid, and crabs.

Biological parameters relevant to the stock assessment are shown in Table 8.

3. STOCKS AND AREAS

No specific research on the stock structure of spiny dogfish has been carried out. Limited tagging has been conducted, so the only available data come from seasonal trawl surveys, and fisheries landings data.

The analysis of *W.J. Scott* and *James Cook* surveys carried out from 1978 to 1983 clearly showed seasonal migrations of spiny dogfish along the east coast of South Island (ECSI). Spiny dogfish were most abundant in the southern part of the coast from October to April, and more abundant to the north in May to September. It is also clear from summer trawl surveys of the area that there is a resident part of the population of spiny dogfish on the Stewart/Snares Shelf over the summer months. However, there have been no comparable series of seasonal surveys there and so it is presently unclear whether the east coast South Island (ECSI) fish migrate south as far as the Stewart/Snares Shelf. Until more data become available fish from the two areas should be treated as separate stocks.

Table 8: Estimates of biological parameters of spiny dogfish for QMA 3 (Hanchet 1986).

1. Natural mortality (M)

0.2

2. Weight = a (length)^b (Weight in g, length in cm fork length)

Males		Females	
a	b	a	b
0.00275	3.05	0.00139	3.25

3. von Bertalanffy growth parameters

Males			Females		
K	t_0	L_∞	K	t_0	L_∞
0.116	-2.88	89.5	0.069	-3.45	120.1

4. Maturity ogive

Age (years)	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**➢ 12**
Males	0.00	0.02	0.21	0.68	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Females	0.00	0.00	0.00	0.00	0.04	0.04	0.23	0.52	0.75	1.00	1.00

Seasonal trawl surveys were also carried out on west coast South Island (WCSI) between June 1981 and April 1983 using the *W.J. Scott.* The catches showed a strong seasonal component being highest in summer and autumn and lowest in winter and spring. It is likely that some fish migrate north in winter, perhaps to the northern and southern Taranaki Bights, and Tasman Bay and Golden Bay. However, it is also clear from summer trawl surveys of the areas that there is a resident part of the population of spiny dogfish in the Taranaki Bights over the summer months. It may therefore be appropriate to treat fish from FMAs 7 and 8 as a single stock.

There is little commercial catch in FMAs 1, 2, 4, and 9, and little data on movement in or between the areas. Until more data have been obtained it would seem appropriate to manage spiny dogfish with the following five fishstocks:

- SPD 1: FMAs 1 & 2
- SPD 3: FMA 3
- SPD 4: FMA 4
- SPD 5: FMAs 5 & 6

- SPD 7 and SPD 8: FMAs 7, 8 & 9

4. STOCK ASSESSMENT

There are no estimates of current or virgin biomass.

4.1 Estimates of fishery parameters and abundance

Biomass indices of spiny dogfish from recent trawl surveys using *Tangaroa* and *Kaharoa* are summarised in Table 9 and Figures 2–4. Based on a combination of CVs, variability in biomass indices and the time span of each series, it is concluded that surveys provide reliable indices of dogfish abundance off the west coast of the South Island (WCSI), the east coast of the South Island, and on the Chatham Rise. Relative biomass indices suggest that spiny dogfish became more abundant on the Chatham Rise during the early to mid-1990s. Apart from a temporary increase during the mid-1990s, the abundance of spiny dogfish off the west coast South Island appears to have been fairly stable. On the east coast of the South Island spiny dogfish biomass increased in the early 1990s and has fluctuated without trend since then.

West coast South Island Inshore Trawl Survey

Biomass estimates of spiny dogfish for the WCSI inshore trawl survey have been relatively stable through most of the time series with the exception of 2013 which was the highest in the time series (Figure 2). This is due to a single large catch and the associated CV is high (MacGibbon 2019). The 2015 biomass estimate of 7 613 tonnes was similar to previous years while the 2017 and 2019 estimates are the lowest in the time series. This decrease came entirely from the west coast strata whereas the Tasman and Golden Bay strata saw a slight increase in biomass in both 2017 and 2019. However in 2019 adult females contributed less biomass than any other group. The decrease in biomass though most pronounced in adult females is seen in juveniles and adults of both sexes. Most of the biomass is found off the west coast within the 100–200 m strata. Adults usually comprise slightly more of the biomass than juveniles and females usually contribute more of the biomass than males.

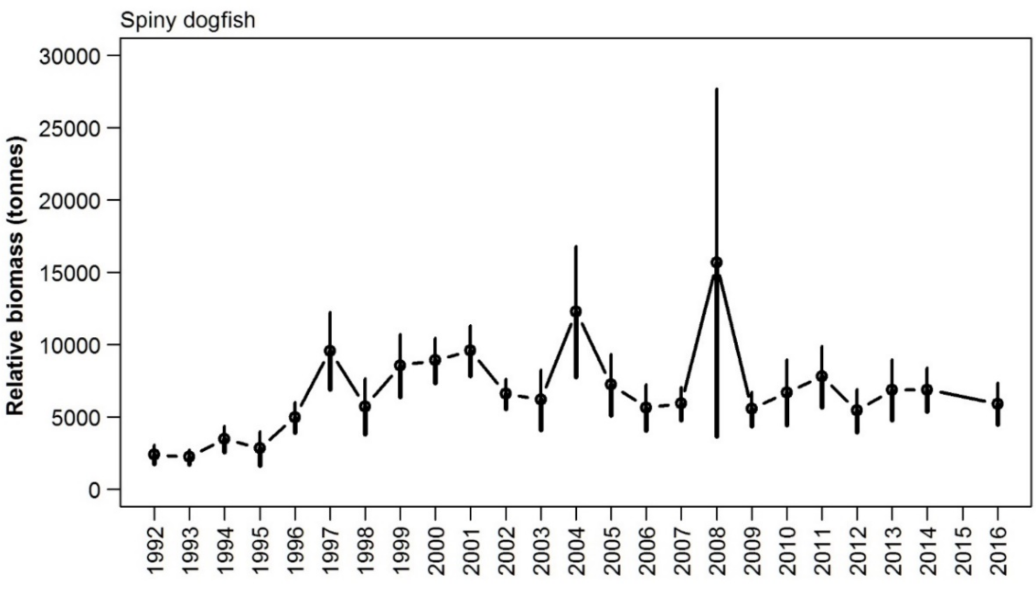


Figure 2: Spiny dogfish biomass for the Chatham Rise and west coast South Island inshore (next page) trawl survey time series (error bars are ± two standard deviations). [Continued on next page]

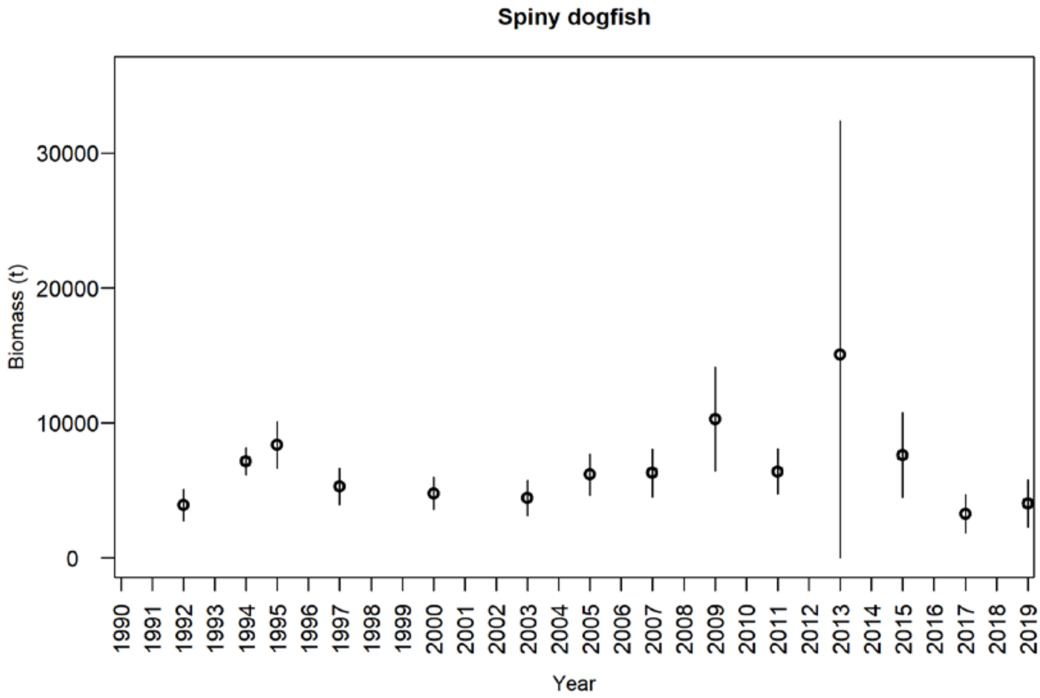


Figure 2 [Continued]: Spiny dogfish biomass for the Chatham Rise (previous page) and west coast South Island inshore trawl survey time series (error bars are ± two standard deviations).

The size distributions of spiny dogfish has been similar and generally bimodal throughout the time series. For males, there is usually a mode from around 30–50 cm and a larger second mode from around 50–75 cm. The female distribution is often bimodal but less well defined than males with modes from around 30–60 cm and 60–90 cm. Within Tasman and Golden Bays almost all spiny dogfish are males, and unimodal from 50–70 cm.

Chatham Rise Trawl Survey

The Chatham Rise Trawl Survey was designed primarily for hoki and covers the depth range 200–400 m. It therefore excludes a small portion of SPD habitat around the Mernoo Bank in less than 200 m. The survey biomass estimates for SPD increased from 1991 to 1995, and have cycled around the series mean since then (Figure 2). The Chatham rise SPD survey catch is dominated by mature females (60–100 cm), while that of the ECSI survey consists mostly of males and females < 60 cm (Beentjes et al 2016; Stevens et al 2015).

East coast South Island inshore trawl survey

The East Coast South Island winter surveys from 1991 to 1996 (30–400 m) were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range; but these were discontinued after the fifth in the annual time series because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007, and this time were expanded to include the 10–30 m depth range, in order to monitor elephant fish and red gurnard which were officially included in the list of target species in 2012. Only the 2007, 2012, 2014, 2016 and 2018 surveys provide full coverage of the 10–30 m depth range.

Spiny dogfish biomass in the core strata increased markedly in 1996 and has fluctuated over the last seven surveys with indications of a declining trend, although the magnitude of the CVs indicate that this may not be significant (Table 9, Figure 3) (MacGibbon et al. 2019). Biomass in 2018 was slightly less than in 2016. Pre-recruited biomass was a small component of the total biomass estimate in the 1992 to 1994 surveys at 1–3% of total biomass, but since 1996 it ranged from 7 to 30%, and in 2018 it was 30% (Table 9, Figure 3). This is also reflected in the biomass of juvenile spiny dogfish (based on the length-at-50% maturity; which increased markedly from about 14% of total biomass before 1996, to between 32 and 57% in the last seven surveys, and in 2018 it was 55% juvenile (Figure 4).

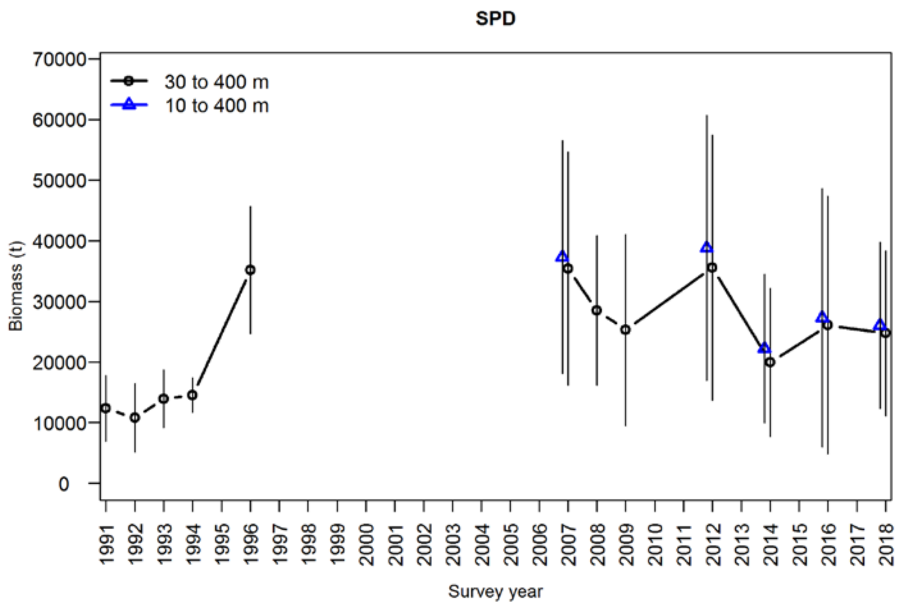


Figure 3: Spiny dogfish total biomass for ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m). Error bars are ± two standard deviations.

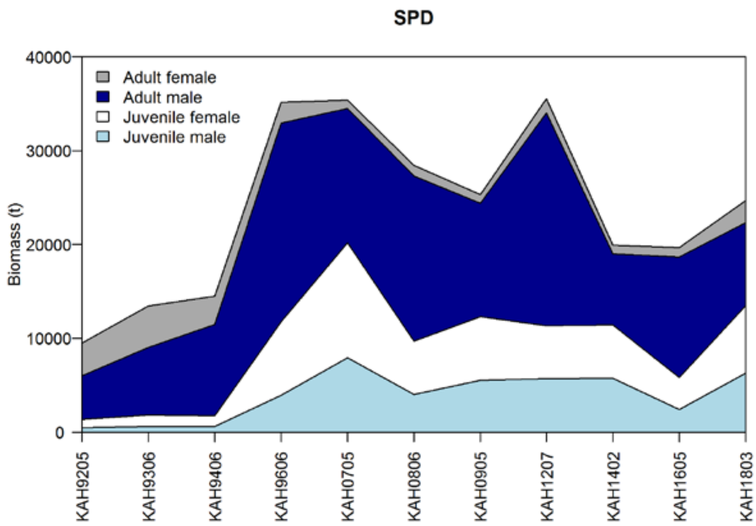


Figure 4: Spiny dogfish juvenile and adult biomass for ECSI winter surveys in core strata (30–400 m), where juvenile is below and adult is equal to or above length at which 50% of fish are mature.

The additional spiny dogfish biomass captured in the 10–30 m depth range accounted for 5%, 8%, 10%, 5% and 5% of the biomass in the core plus shallow strata (10–400 m) for 2007, 2012, 2014, 2016 and 2018 respectively, indicating that it is useful to monitor the shallow strata for spiny dogfish biomass (Table 9, Figure 3). Further, the addition of the 10–30 m depth range may be important for monitoring the small fish. The spatial distribution of spiny dogfish hotspots varies, but overall this species is consistently well represented over the entire survey area, most commonly from 30 m to about 350 m. Spiny dogfish are consistently the most commonly caught species on the ECSI trawl survey and occurred in 96–100% of core strata tows (99% in 2018) and comprised 18–46% of the total catch (28% in 2018) on the surveys.

The size distributions of spiny dogfish in the 1992 to 1994 surveys were similar and generally bimodal for males, but less defined for females which are less numerous than males throughout the core strata time series. From 1996 onwards, smaller fish were more abundant, particularly in the last five surveys. The large increase in biomass observed post-1996 is in part a result of the change in the population size composition. Spiny dogfish on the ECSI sampled on these surveys were considerably smaller than those from the Chatham Rise, Southland, and the sub-Antarctic surveys (Bagley & Hurst 1996, O'Driscoll & Bagley 2001, Livingston et al. 2002, Stevens et al. 2017) suggesting that this area may be an important nursery ground for juvenile spiny dogfish and there may be movement in and out of the ECSI survey area.

Table 9: Relative biomass indices (t) and coefficients of variation (CV) for spiny dogfish for east coast North Island (ECNI), east coast South Island (ECSI) - summer and winter, Chatham Rise, Stewart-Snares Shelf, Sub-Antarctic, west coast South Island (WCSI) and west coast North Island (WCNI) survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16 and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (50 cm).

Region	Fishstock	Year	Trip number	Biomass estimate	CV (%)	Biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
ECNI	SPD 2	1993	KAH9304	963	78	-	-	-	-	-	-	-	-	-	-
		1994	KAH9402	988	47	-	-	-	-	-	-	-	-	-	-
		1995	KAH9502	658	25	-	-	-	-	-	-	-	-	-	-
		1996	KAH9602	1 026	51	-	-	-	-	-	-	-	-	-	-
ECSI(winter)	SPD 3			30–400 m		10–400 m		30–400 m		10–400 m		30–400 m		10–400 m	
		1991	KAH9105	12 873	22	-	-	-	-	-	-	-	-	-	-
		1992	KAH9205	10 787	26	-	-	266	27	-	-	9 212	31	-	-
		1993	KAH9306	13 949	17	-	-	343	72	-	-	13 122	17	-	-
		1994	KAH9406	14 530	10	-	-	205	49	-	-	14 325	10	-	-
		1996	KAH9606	35 169	15	-	-	3 412	23	-	-	31 757	16	-	-
		2007	KAH0705	35 386	24	37 299	26	5 831	46	-	-	29 554	27	-	-
		2008	KAH0806	28 476	22	-	-	1 886	50	-	-	26 590	22	-	-
		2009	KAH0905	25 311	31	-	-	2 398	30	-	-	22 913	32	-	-
		2012	KAH1207	35 546	31	38 821	28	3 804	58	-	-	31 742	34	-	-
		2014	KAH1402	19 949	31	22 188	28	5 683	34	-	-	14 266	36	-	-
		2016	KAH1605	26 063	41	27 300	39	2 639	34			18 299	50		
		2018	KAH1803	24 758	28	26 049	26	7 423	55	-	-	17 336	29	-	-
ECSI(summer)	SPD 3	1996–97	KAH9618	35 776	28	-	-	-	-	-	-	-	-	-	-
		1997–98	KAH9704	29 765	25	-	-	-	-	-	-	-	-	-	-
		1998–99	KAH9809	22 842	16	-	-	-	-	-	-	-	-	-	-
		1999–00	KAH9917	49 832	37	-	-	-	-	-	-	-	-	-	-
		2000–01	KAH0014	30 508	34	-	-	-	-	-	-	-	-	-	-
Chatham Rise	SPD 4	1991	TAN9106	2 390	14	-	-	-	-	-	-	-	-	-	-
		1992	TAN9212	2 220	11	-	-	-	-	-	-	-	-	-	-
		1994	TAN9401	3 449	13	-	-	-	-	-	-	-	-	-	-
		1995	TAN9501	2 841	21	-	-	-	-	-	-	-	-	-	-
		1996	TAN9601	4 969	11	-	-	-	-	-	-	-	-	-	-
		1997	TAN9701	8 905	9	-	-	-	-	-	-	-	-	-	-
		1998	TAN9801	9 586	9	-	-	-	-	-	-	-	-	-	-
		1999	TAN9901	6 334	8										
		1999–00	TAN0001	6 191	17	-	-	-	-	-	-	-	-	-	-
		2000–01	TAN0101	12 289	18	-	-	-	-	-	-	-	-	-	-
		2001–02	TAN0201	2 390	14	-	-	-	-	-	-	-	-	-	-

*Assuming areal availability, vertical availability and vulnerability equal 1.0. Biomass is only estimated outside 10 m depth except for COM9901 and CMP0001. Note: because trawl survey biomass estimates are indices, comparisons between different seasons (e.g., summer and winter ECSI) are not strictly valid.

Table 9 [Continued]: Relative biomass indices (t) and coefficients of variation (CV) for spiny dogfish for east coast North Island (ECNI), east coast South Island (ECSI) - summer and winter, Chatham Rise, Stewart-Snares Shelf, Sub-Antarctic, west coast South Island (WCSI) and west coast North Island (WCNI) survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16 and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (50 cm).

Region	Fishstock	Year	**Trip number**	**Total Biomass estimate**	**CV (%)**	**Total Biomass estimate**	**CV (%)**	**Pre-recruit**	**CV (%)**	**Pre-recruit**	**CV (%)**	**Recruited**	**CV (%)**	**Recruited**	**CV (%)**
Chatham Rise	SPD 4	2002–03	TAN0301	2 220	11	-	-	-	-	-	-	-	-	-	-
		2004	TAN0401	3 449	13	-	-	-	-	-	-	-	-	-	-
		2005	TAN0501	7 227	15	-	-	-	-	-	-	-	-	-	-
		2006	TAN0601	5 650	14	-	-	-	-	-	-	-	-	-	-
		2007	TAN0701	5 906	10	-	-	-	-	-	-	-	-	-	-
		2008	TAN0801	15 674	38	-	-	-	-	-	-	-	-	-	-
		2009	TAN0901	5 548	11	-	-	-	-	-	-	-	-	-	-
		2010	TAN1001	6 698	17	-	-	-	-	-	-	-	-	-	-
		2011	TAN1101	7 794	14	-	-	-	-	-	-	-	-	-	-
		2012	TAN1201	5 438	14	-	-	-	-	-	-	-	-	-	-
		2013	TAN1301	6 884	15	-	-	-	-	-	-	-	-	-	-
		2014	TAN1401	6 886	11										
		2016	TAN1601	5 908	12										
Stewart-Snares Shelf	SPD 5	1993	TAN9301	35 776	28	-	-	-	-	-	-	-	-	-	-
		1994	TAN9402	29 765	25	-	-	-	-	-	-	-	-	-	-
		1995	TAN9502	22 842	16	-	-	-	-	-	-	-	-	-	-
		1996	TAN9604	49 832	37	-	-	-	-	-	-	-	-	-	-
Sub-Antarctic (*Spring*)	SPD 5	1991	TAN9105	8 502	55	-	-	-	-	-	-	-	-	-	-
		1992	TAN9211	1 150	15	-	-	-	-	-	-	-	-	-	-
		1993	TAN9310	1 585	21	-	-	-	-	-	-	-	-	-	-
		2000	TAN0012	4 173	12	-	-	-	-	-	-	-	-	-	-
		2001	TAN0118	8 528	31	-	-	-	-	-	-	-	-	-	-
		2002	TAN0219	3 505	19	-	-	-	-	-	-	-	-	-	-
		2003	TAN0317	2 317	17	-	-	-	-	-	-	-	-	-	-
		2004	TAN0414	3 378	27										
		2005	TAN0515	4 344	19	-	-	-	-	-	-	-	-	-	-
		2006	TAN0617	3 039	19	-	-	-	-	-	-	-	-	-	-
Sub-Antarctic (*Autumn*)	SPD 5	1992	TAN9204	926	30	-	-	-	-	-	-	-	-	-	-
		1993	TAN9304	440	38	-	-	-	-	-	-	-	-	-	-
		1996	TAN9605	207	56	-	-	-	-	-	-	-	-	-	-
		1998	TAN9805	1 532	36	-	-	-	-	-	-	-	-	-	-

*Assuming areal availability, vertical availability and vulnerability equal 1.0. Biomass is only estimated outside 10 m depth except for COM9901 and CMP0001. Note: because trawl survey biomass estimates are indices, comparisons between different seasons (e.g., summer and winter ECSI) are not strictly valid.

Table 9 [Continued]: Relative biomass indices (t) and coefficients of variation (CV) for spiny dogfish for east coast North Island (ECNI), east coast South Island (ECSI) - summer and winter, Chatham Rise, Stewart-Snares Shelf, Sub-Antarctic, west coast South Island (WCSI) and west coast North Island (WCNI) survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16 and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (50 cm).

Region	Fishstock	Year	**Trip number**	**Total Biomass estimate**	**CV (%)**	**Total Biomass estimate**	**CV (%)**	**Pre-recruit**	**CV (%)**	**Pre-recruit**	**CV (%)**	**Recruited**	**CV (%)**	**Recruited**	**CV (%)**
WCSI	SPD 7	1992	KAH9204	3 919	15	-	-	-	-	-	-	-	-	-	-
		1994	KAH9404	7 145	7	-	-	-	-	-	-	-	-	-	-
		1995	KAH9504	8 370	10	-	-	-	-	-	-	-	-	-	-
		1997	KAH9701	5 275	13	-	-	-	-	-	-	-	-	-	-
		2000	KAH0004	4 777	12	-	-	-	-	-	-	-	-	-	-
		2003	KAH0304	4 446	15	-	-	-	-	-	-	-	-	-	-
		2005	KAH0503	6 175	12	-	-	-	-	-	-	-	-	-	-
		2007	KAH0704	6 219	14	-	-	-	-	-	-	-	-	-	-
		2009	KAH0904	10 270	19	-	-	-	-	-	-	-	-	-	-
		2011	KAH1104	6 402	13	-	-	-	-	-	-	-	-	-	-
		2013	KAH1305	15 087	57	-	-	-	-	-	-	-	-	-	-
		2015	KAH1503	7 613	21	-	-	-	-	-	-	-	-	-	-
		2017	KAH1703	3 255	22	-	-	-	-	-	-	-	-	-	-
		2019	KAH1902	4 031	22										
WCNI	SPD 9	1991	KAH9111	443*	34	-	-	-	-	-	-	-	-	-	-
		1994	KAH9410	381*	30	-	-	-	-	-	-	-	-	-	-
		1996	KAH9615	634*	68	-	-	-	-	-	-	-	-	-	-
		1999	KAH9915	106*	15	-	-	-	-	-	-	-	-	-	-

*Assuming areal availability, vertical availability and vulnerability equal 1.0. Biomass is only estimated outside 10 m depth except for COM9901 and CMP0001. Note: because trawl survey biomass estimates are indices, comparisons between different seasons (e.g., summer and winter ECSI) are not strictly valid.

Manning et al (2004) evaluated the usefulness of commercial CPUE, commercial length composition, trawl survey relative biomass estimates and trawl-survey-catch length-composition for monitoring all major SPD stocks (Table 10).

Table 10: Catch and effort data sets and analyses evaluated as monitoring tools for major SPD stocks.

QMA	Data set and analysis
SPD 3 - East coast South Island	1. Standardised setnet CPUE for core vessels targeting SPD.
	2. Standardised setnet CPUE for core vessels targeting all species.
	3. Standardised bottom trawl CPUE for core vessels targeting all species.
	4. Relative abundance indices from East Coast South Island trawl surveys (discontinued after 2001)
SPD 4 - Chatham Rise	5. Standardised bottom trawl CPUE for core Korean vessels
	6. Standardised bottom trawl CPUE for core domestic vessels
	7. Standardised bottom longline CPUE for core domestic vessels
	8. Relative abundance indices from Chatham Rise trawl surveys.
SPD 5 - Stewart Snares Shelf	9. Standardised bottom trawl CPUE.
	10. Relative abundance indices from Stewart-Snares shelf surveys (discontinued after 1996)
SPD 7 - West Coast South Island	11. Standardised bottom trawl CPUE for core vessels
	12. Relative abundance indices from West coast South Island Trawl Surveys.

Based on the results of the analyses listed in Table 10, the following methods were recommended for monitoring SPD:

QMA	Recommended Monitoring Tools
SPD 3 - East coast South Island	Standardised setnet CPUE using model 2 (core vessels targeting all species)
SPD 4 - Chatham Rise	Chatham Rise Trawl Survey and length composition of commercial catch
SPD 5 - Stewart Snares Shelf	*Standardised bottom trawl CPUE and length composition of commercial catch.
SPD 7 - West Coast South Island	West coast South Island Trawl survey and length composition of commercial catch

* Information on historical changes in reporting rates is required before this index can be used.

4.2 Biomass estimates

Lack of suitable information has precluded estimation of virgin and current biomass for spiny dogfish. Although most of the necessary biological parameters (Hanchet 1986, 1988, Hanchet & Ingerson 1997), relative indices of abundance and data required to estimate fishing selectivity for most important fisheries (with the exception of FMA 4 bottom longline and FMA 3 setnet fisheries) are now available, robust stock assessments will also require estimates of historical, unreported discarding and discard mortality so that an accurate history of fishery related removals can be constructed.

4.3 Yield estimates and projections

MCY cannot be estimated.

CAY cannot be determined.

4.5 Other factors

The ability to withstand harvesting depends on the strength of a number of compensatory mechanisms. For example, under exploitation individuals may grow faster, show increased fecundity, or suffer reduced natural mortality. In elasmobranchs the number of young born is related directly to the number of adult females, and, because of the relatively large size and hence good survival of the young at birth, it is presumed that there is a strong stock recruit relationship for these species.

Several methods of estimating *MCY* involve the multiplication of a harvest level by an estimate of B_0 or B_{av}. Francis & Francis (1992) used Monte Carlo simulation to estimate harvest levels for calculating *MCY* for a rig stock. No stock-recruitment data were available for elasmobranchs at the time and so they used values for the Beverton & Holt steepness parameter ranging from 0.35 to 0.50, and recruitment variability of 0.4. These values were all at the low range of values used for teleost species and which they considered appropriate for rig. The results of their simulation studies showed that the estimates of *MCY* obtained using the harvest levels given in the equations in the Guide to Biological Reference Points were overly optimistic for rig. Given that spiny dogfish have a slower growth rate and are less fecund than rig, it seems reasonable to assume that those harvest levels are also unsuitable for spiny dogfish.

A data informed qualitative risk assessment was completed on all chondrichthyans (sharks, skates, rays and chimaeras) at the New Zealand scale in 2014 (Ford et al 2015). Spiny dogfish was ranked seventh highest in terms of risk of the eleven QMS chondrichthyan species. Data were described as existing and sound for the purposes of the assessment and consensus over this risk score was achieved by the expert panel. This risk assessment does not replace a stock assessment for this species but may influence research priorities across species.

5. STATUS OF THE STOCKS

No estimates of current or reference biomass are available, but trawl survey estimates of abundance have been calculated for a number of years (Table 9).

Although reported commercial catches of spiny dogfish were observed to increase in all major FMAs during the 1990s, the extent to which these increases can be attributed to changes in reporting practice (i.e., more accurate reporting of discards in recent times) is uncertain. Trawl surveys, on the other hand, indicate that there was a general increase in the abundance of spiny dogfish, particularly around the South Island, in the mid-1990s.

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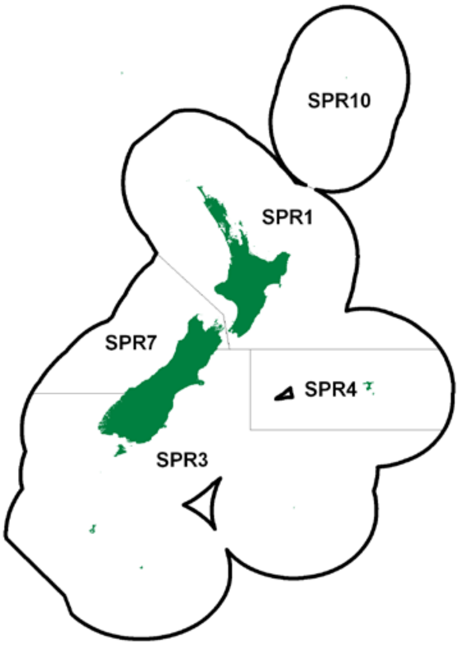
SPRAT (SPR)

(*Sprattus antipodum, S. muelleri*)
Kupae



1. FISHERY SUMMARY

There are two species of sprats in New Zealand, *Sprattus antipodum* (slender sprat) and *S. muelleri* (stout sprat). They can be distinguished by body shape, colour, and some morphological features, but since they are very similar it is impractical to separate them in large catches.

Sprats were introduced into the QMS on 1 October 2002, with the allowances, TACCs and TACs shown in Table 1, which have not been changed since.

Table 1: Recreational and customary non-commercial allowances, TACCs and TACs for sprats by Fishstock.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other mortality	TACC	TAC
SPR 1	20	10	0	70	100
SPR 3	10	5	0	285	300
SPR 4	3	2	0	10	15
SPR 7	10	5	0	85	100
SPR 10	0	0	0	0	0
Total	43	22	0	450	515

1.1 Commercial fisheries

The sprat “fishery” is minor and intermittent. There is no information on catches or landings of sprats prior to 1990, although occasional catches were made during exploratory fishing projects on small pelagic species, mainly in the 1960s and 1970s. Sprats have undoubtedly been caught in most years, but were either not reported, reported as “bait”, or included in the category “mixed species”. The name “sprat” is used in a general sense for several unrelated small fishes, and the juveniles of some larger species. This may have introduced errors into catch records. Reported landings since 1990 have ranged from less than 1 t to 7 t (Table 2); no landings were reported in 2017-18 and 2018-19. The most consistent (but small) catches have been by bottom trawl. Reported landings by setnet and beach seine could be of true sprats, but may also be of yellow-eyed mullet (*Aldrichetta forsteri*), known colloquially as sprats. This is particularly likely in the upper North Island where the presence of sprats is considerably reduced or non-existent.

Table 2: Reported landings (t) of sprat by Fishstock and fishing year. No catches reported for SPR 10, which has a TACC of 0.

FMA	SPR 1 1, 2, 8 & 9		SPR 3 3, 5 & 6		SPR 4 4		SPR 7 7		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1990–91†	3	-	< 1	-	0	-	< 1	-	3	-
1991–92†	1	-	0	-	0	-	0	-	1	-
1992–93†	< 1	-	< 1	-	0	-	0	-	< 1	-
1993–94†	< 1	-	< 1	-	0	-	< 1	-	1	-
1994–95†	< 1	-	< 1	-	0	-	< 1	-	1	-
1995–96†	< 1	-	6	-	0	-	< 1	-	7	-
1996–97†	< 1	-	1	-	0	-	< 1	-	1	-
1997–98†	< 1	-	< 1	-	0	-	< 1	-	< 1	-
1998–99†	2	-	< 1	-	0	-	< 1	-	4	-
1999–00†	< 1	-	< 1	-	0	-	1	-	2	-
2000–01†	< 1	-	< 1	-	0	-	< 1	-	< 1	-
2001–02	< 1	-	< 1	-	0	-	< 1	-	< 1	-
2002–03	< 1	70	< 1	285	0	10	0	85	< 1	450
2003–04	< 1	70	3	285	0	10	0	85	3	450
2004–05	< 1	70	0	285	0	10	0	85	< 1	450
2005–06	< 1	70	0	285	0	10	0	85	< 1	450
2006–07	< 1	70	< 1	285	0	10	0	85	< 1	450
2007–08	< 1	70	0	285	0	10	0	85	< 1	450
2008–09	< 1	70	< 1	285	0	10	< 1	85	1	450
2009–10	< 1	70	0	285	0	10	0	85	0	450
2010–11	< 1	70	0	285	0	10	0	85	< 1	450
2011–12	< 1	70	0	285	0	10	0	85	< 1	450
2012–13	<1	70	<1	285	0	10	<1	85	<1	450
2013–14	<1	70	0	285	<1	10	0	85	<1	450
2014–15	<1	70	<1	285	0	10	<1	85	<1	450
2015–16	<1	70	0	285	0	10	0	85	<1	450
2016–17	0	70	<1	285	0	10	<1	85	<1	450
2017–18	0	70	0	285	0	10	0	85	0	450
2018–19	0	70	0	285	0	10	0	85	0	450

† CELR

1.2 Recreational fisheries
There is no known recreational fishery, but small numbers are caught in small-mesh setnets and beach seines.

1.3 Customary non-commercial fisheries
Quantitative information on the current level of customary non-commercial take is not available.

1.4 Illegal catch
Estimates of illegal catch are not available, but are probably insignificant or nil.

1.5 Other sources of mortality
Some accidental captures of sprats by vessels purse seining for other small pelagic species may be discarded if no market is available.

2. BIOLOGY

Sprats occur in coastal waters from the Bay of Islands to Stewart Island, and are present at the Auckland Islands. It is not known whether the two species have different distributions. Sprats appear to be most abundant off the southeastern coast of the South Island, where anchovies are absent. Their vertical distribution within the water column is not known.

Spawning occurs in areas of reduced salinity when water temperatures are coolest 9–10.5 ^{o} C; there are consequently regional differences in spawning season with spawning peaks occurring between June and November (Taylor & Marriott 2004). The eggs are pelagic.

No reliable ageing work has been undertaken. Sprats are assumed to feed on zooplankton, and are preyed upon by larger fishes, seabirds, and marine mammals.

There have been no biological studies that are directly relevant to the recognition of separate stocks, or to yield estimates. Consequently no estimates of biological parameters are available. There is an extensive international literature base on sprats, mainly *Sprattus sprattus*, but the relevance of this to the New Zealand species is unknown.

3. STOCKS AND AREAS

There is no biological information on which to make an assessment on whether separate stocks exist. However, there are two species, and their relative distributions are unknown. As presently understood, both species are more common around southern New Zealand. If their distributions do differ, and the biomass of each species fluctuates independently, there are unknown implications for localised stock depletion.

4. STOCK ASSESSMENT

There have been no previous stock assessments of sprats. There have been two very general estimates of biomass in the Canterbury Bight region: 50 000 t (Robertson 1978), and 60 000 t (Colman 1979), with a possible yield of 10 000 t. No information on biomass variability is available.

4.1 Estimates of fishery parameters and abundance

No fishery parameters are available.

4.2 Biomass estimates

No estimates of biomass (B_0, B_{MSY}, or $B_{CURRENT}$) are available.

4.3 Yield estimates and projections

Estimation of Maximum Constant Yield (*MCY*)

MCY cannot be determined.

Estimation of Current Annual Yield (*CAY*)

Current biomass cannot be estimated, so *CAY* cannot be determined.

Yield estimates are summarised in Table 3.

Other yield estimates and stock assessment results

No information is available.

4.4 Other factors

Data from some ichthyoplankton surveys show one or both sprat species to be locally abundant. However, it is unlikely that the biomass is comparable to the very large stocks in the northern hemisphere where there are large sprat fisheries.

It is not known whether the biomass of sprats is stable or variable, but the latter is considered more likely.

In some localities around the South Island, sprats are a major food source for many fishes, seabirds, and marine mammals. Excessive localised harvesting may disrupt ecosystems.

5. STATUS OF THE STOCKS

No estimates of current biomass are available. At the present level of minimal catches, stocks are at or close to their natural level. This is nominally a virgin biomass, but not necessarily a stable one.

Yield estimates, reported landings, and TACCs for the 2017–18 fishing year are summarised in Table 3.

Table 3: Summary of yield estimates (t), TACCs (t), and reported landings (t) for the most recent fishing year.

Fishstock		FMA	*MCY*	2018–19 Actual TACC	2018–19 Reported Landings
SPR 1	North Island	1, 2, 8, 9	–	70	0
SPR 3	South-east + Southland/Sub-Antarctic	3, 5, 6	–	285	0
SPR 4	Chatham	4	–	10	0
SPR 7	Challenger	7	–	85	0
SPR 10	Kermadec	10	–	0	0
Total				450	0

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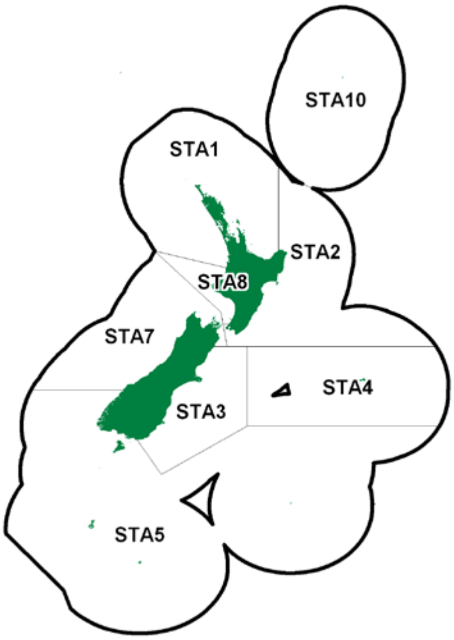
1STARGAZER (STA)

(*Kathetostoma giganteum*)
Puwhara



1. FISHERY SUMMARY

1.1 Commercial fisheries

Giant stargazer (*Kathetostoma giganteum*, Uranoscopidae) is a moderate-sized benthic teleost distributed widely in New Zealand waters. It is found on muddy and sandy substrates to depths of 500 m, but is most common between 50–300 m on the continental shelf around the South Island (Anderson et al 1998), where it supports a moderate-value, commercial trawl fishery. It was incorporated into the QMS on 1 October 1997 and is managed as eight separate Quota Management Areas (QMAs) or Fishstocks at this time: STA 1–5, 7–8, and 10.

It is caught by both directed fishing and as bycatch of fisheries targeting other species. The main target fishery is on the Stewart-Snares shelf west of Stewart Island (Statistical Areas 029–030). Other target fisheries exist off the west coast of the South Island (WCSI) and off Cape Campbell on the east coast of the South Island (ECSI). It is also caught by small domestic trawl vessels targeting red cod (*Pseduophycis baccus*), tarakihi (*Nemadactylus macropterus*), flatfishes (*Colistum* spp., *Peltorhamphus* spp., and *Rhombosolea* spp.), and scampi (*Metanephrops challengeri*) on the continental shelf throughout its range and by larger, foreign-licensed and New Zealand-chartered foreign vessels targeting barracouta (*Thyrsites atun*), jack mackerels (*Trachurus* spp.), and squid (*Nototodarus* spp.) in deeper waters, in particular on the western Chatham Rise and on the continental slope surrounding the Stewart-Snares shelf. Giant stargazer is an important bycatch of scampi fishing in STA 2–4. Catches by methods other than bottom trawling are minimal. Reported landings from 1979 to 1987–88 are given in Table 1. Reported landings for the main QMAs for 1931 to 1982 are given in Table 2.

Table 1: Reported landings (t) of giant stargazer by vessel flag from 1979 to 1987–88.

	New Zealand		Foreign-			New Zealand		Foreign-	
Year	**Domestic**	**Chartered**	**licensed**	**Total**	**Year**	**Domestic**	**Chartered**	**licensed**	**Total**
1979*	387	155	159	701	1983–84†	1 463	525	360	2 348
1980*	723	–	–	723	1984–85†	1 027	321	178	1 526
1981*	1 010	314	84	1 408	1985–86†	1 304	386	142	1 832
1982*	902	340	283	1 526	1986–87†	1 126	379	63	1 568
1983*	1 189	329	465	1 983	1987–88†	839	331	26	1 196

*MAF data. †FSU data.

The total landings between 1979 and 1986–87 were variable, ranging between 701 and 2348 t and averaging 1481 t per year. Different trends are apparent for domestic and foreign vessels. The domestic and chartered catch was relatively stable throughout the middle and later half of the series, which probably reflects the stability of effort in the red cod, tarakihi, flatfish, and barracouta fisheries at this time as well as better reporting compliance. However, landings by foreign-licensed vessels declined steadily from a high of 465 t in 1983 to a low of 26 t in 1986–87, probably reflecting the declining importance of foreign-licensed vessels in New Zealand's deepwater fisheries following the phasing-in of the QMS, which began in 1983 and which was fully implemented by 1986–87. Reported landings since 1983 by Fishstock are given in Table 3 and Figure 1 graphs the historical landings and TACC values for the main STA stocks. The total catches for 1986–87 and 1987–88 in Table 1 are less than those in Table 3 because of under-reporting to the FSU during those years.

After 1983, the catch began to increase rapidly, reaching 3 426 t in 1990–91, and averaging about 3 000 t thereafter. The increase in catch is due to a number of factors, including: (a) increased target fishing in Southland (STA 5); (b) the availability of more quota through the decisions of the Quota Appeal Authority; (c) better management of quotas by quota owners; (d) quota trading in STA 3, 4, 5, and 7; (e) changes in fishing patterns in the Canterbury Bight (STA 3) and the west coast of the South Island (STA 7); (f) a possible increase in abundance of stargazer in STA 7; and (g) increases in the STA 3, 5, and 7 TACCs introduced under the Adaptive Management Programme (AMP) in the 1991–92 fishing year.

The Adaptive Management Programme (AMP) was a management regime within the QMS for data-poor New Zealand Fishstocks that were considered able to sustain increased exploitation. Under the AMP, quota owners collected additional data from the fishery (typically fine-scale catch-effort data and rudimentary, but necessary, biological data such as fish length and sex) in return for an increased TACC. Under the AMP, TACCs for five giant stargazer Fishstocks (STA 1–3, 5, and 7) were increased at the start of the 1991–92 fishing year, and a sixth (STA 8) was increased in 1993–94. However, the TACCs for Fishstocks STA 1–3, 5, and 8 reverted to their pre-AMP levels in 1997–98 following the removal of these Fishstocks from the AMP in July 1997 because of the failure of quota owners to meet the data-collection requirements of the AMP. Subsequently, landings in three of these Fishstocks (STA 1, 2, and 5) exceeded their reduced, post-AMP TACCs; although of these, STA 5 was the only one with a TACC greater than 40 t at this time. STA 3 and STA 7 were reviewed in 1998 and retained in the AMP until the end of the 2002–03 fishing year. The TACC in STA 7 was further increased to 997 t at the start of the 2002–03 fishing year with a TAC of 1000 t (which included a 2 t recreational and a 1 t customary allowance). STA 7 was reviewed again in 2007 (Starr et al 2007b) and retained in the AMP. In October 2010 the TACC was increased to 1042 t, increasing the TAC to 1072 t, and in October 2015 the TACC was further increased to 1122 t. STA 3 was reviewed in 2008 (Starr et al 2008) and retained at the existing TACC of 902 t, with customary and recreational allocations of 1 t and 2 t respectively, giving a total TAC of 905 t. All AMP programmes ended on 30 September 2009.

STA 5, STA 7, and STA 3 are the most important Fishstocks, in terms of the recorded landed catch, among the eight Fishstocks, with smaller contributions from STA 2 and STA 4. The STA 4 TACC is set at 2158 t, the highest among the eight STA Fishstocks, although landings are only a tenth of this level in most years and the TACC has never been approached or exceeded. Most of the STA 4 catch is caught as bycatch of fishing directed at other target species. A relatively high recorded landed catch in 1990–91 (790 t) was due to exploratory fishing for these target species which has since ceased. Landings exceeded 100 t in STA 2 from 1990–91 to 1992–93 due to the development of the scampi fishery in this FMA. Landings subsequently decreased and averaged just 15 t in 2010–11 to 2018–19. Landings in STA 8 have also been lower than the TACC throughout the time series.

Although the TACC in STA 7 was increased to 700 t in 1991–92 under the terms of the AMP, it was over-caught in nearly every subsequent fishing year up to 2002–03, when the TACC was further increased to 997 t. Landings reached a high of 1440 t in 2000–01, before dropping back to 800 t in 2001–02. These high recorded landings resulted mainly from the use of bycatch trades with barracouta and flatfish. With the removal of the bycatch trade system in October 2001, fishers now face the penalty of high deemed values for any over-catch, and it is likely that these penalties have been the cause of the reduction in the over-catch in this Fishstock.

With the exception of STA 1, landings in recent years have generally not exceeded TACCs.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	STA 1	STA 2	STA 3	STA 4	Year	STA 1	STA 2	STA 3	STA 4
1931–32	0	0	0	0	1957	0	15	5	0
1932–33	0	0	0	0	1958	0	25	11	0
1933–34	0	0	0	0	1959	0	23	13	0
1934–35	0	0	0	0	1960	0	18	17	0
1935–36	0	0	0	0	1961	0	7	16	0
1936–37	0	0	0	0	1962	0	6	22	0
1937–38	0	0	0	0	1963	0	10	15	0
1938–39	0	0	0	0	1964	0	9	22	0
1939–40	0	0	0	0	1965	0	12	17	0
1940–41	0	0	0	0	1966	0	12	31	0
1941–42	0	0	0	0	1967	0	24	32	0
1942–43	0	0	0	0	1968	0	28	32	0
1943–44	0	0	0	0	1969	0	40	25	0
1944	0	0	0	0	1970	0	42	80	0
1945	0	0	0	0	1971	0	37	72	0
1946	0	0	0	0	1972	0	30	71	0
1947	0	0	0	0	1973	0	36	78	0
1948	0	0	0	0	1974	0	31	73	7
1949	0	0	0	0	1975	0	10	75	3
1950	0	1	0	0	1976	0	26	99	10
1951	0	1	0	0	1977	0	17	70	0
1952	0	8	0	0	1978	0	29	72	8
1953	0	2	0	0	1979	1	23	230	104
1954	0	7	0	0	1980	3	28	331	57
1955	0	2	3	0	1981	15	25	487	95
1956	0	12	4	0	1982	4	22	565	89

Year	STA 5	STA 6	STA 7	Year	STA 5	STA 6	STA 7
1931–32	0	0	0	1957	0	2	2
1932–33	0	0	0	1958	0	4	3
1933–34	0	0	0	1959	0	4	3
1934–35	0	0	0	1960	0	4	2
1935–36	0	0	0	1961	0	2	1
1936–37	0	0	0	1962	5	2	1
1937–38	0	0	0	1963	1	3	1
1938–39	0	0	0	1964	0	3	1
1939–40	0	0	0	1965	2	4	1
1940–41	0	0	0	1966	27	4	2
1941–42	0	0	0	1967	6	38	2
1942–43	0	0	0	1968	7	24	3
1943–44	0	0	0	1969	21	14	3
1944	0	0	0	1970	124	78	2
1945	0	0	0	1971	87	50	3
1946	0	0	0	1972	70	41	2
1947	0	0	0	1973	38	36	2
1948	0	0	0	1974	128	29	3
1949	0	0	0	1975	92	34	1
1950	0	0	0	1976	348	54	2
1951	0	0	0	1977	293	53	1
1952	0	1	1	1978	268	61	2
1953	0	0	0	1979	245	86	1
1954	0	1	1	1980	467	132	1
1955	0	0	0	1981	557	322	2
1956	0	2	2	1982	500	270	3

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: data from 1986 to 1990 are from Quota Management Reports.
3. 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. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 3: Reported landings (t) of giant stargazer by QMS Fishstock (QMA) from 1983 to 2018–19. TACCs from 1986–87 to 2018–19 are also provided. * MAF data. [Continued on next page]

Fishstock	STA 1		STA 2		STA 3		STA 4		STA 5	
FMA(s)	1 & 9		2		3		4		5 & 6	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983*	8	–	34	–	540	–	168	–	843	–
1984*	5	–	24	–	588	–	143	–	1023	–
1985*	9	–	15	–	438	–	82	–	695	–
1986*	12	–	24	–	415	–	95	–	566	–
1986–87	10	20	31	30	644	560	72	2 000	738	1 060
1987–88	3	20	46	33	783	581	110	2 005	886	1 144
1988–89	3	20	41	37	675	591	134	2 005	1 215	1 173
1989–90	9	21	53	37	747	703	218	2 009	1 150	1 175
1990–91	8	21	125	37	674	734	790	2 014	1 061	1 239
1991–92	18	50	105	100	756	900	366	2 014	1 056	1 500
1992–93	19	50	115	101	811	901	231	2 014	1 247	1 500
1993–94	8	50	73	101	871	902	113	2 014	1 327	1 500
1994–95	10	50	74	101	829	902	223	2 014	1 216	1 525
1995–96	17	50	69	101	876	902	259	2 014	1 159	1 525
1996–97	22	50	77	101	817	902	149	2 014	977	1 525
1997–98	29	21	54	38	667	902	263	2 014	544	1 264
1998–99	27	21	46	38	641	902	137	2 014	1 145	1 264
1999–00	36	21	42	38	719	902	161	2 014	1 327	1 264
2000–01	26	21	45	38	960	902	233	2 014	1 439	1 264
2001–02	34	21	58	38	816	902	391	2 158	1 137	1 264
2002–03	31	21	41	38	863	902	308	2 158	967	1 264
2003–04	23	21	27	38	578	902	186	2 158	1 193	1 264
2004–05	27	21	28	38	646	902	366	2 158	1 282	1 264
2005–06	34	21	30	38	824	902	359	2 158	1 347	1 264
2006–07	22	21	31	38	719	902	292	2 158	1 359	1 264
2007–08	36	21	26	38	572	902	436	2 158	1 171	1 264
2008–09	35	21	22	38	574	902	139	2 158	1 137	1 264
2009–10	17	21	26	38	576	902	198	2 158	1 339	1 264
2010–11	21	21	19	38	570	902	134	2 158	1 235	1 264
2011–12	21	28	17	38	397	902	213	2 158	1 288	1 264
2012–13	19	21	13	38	439	902	133	2 158	1 140	1 264
2013–14	20	21	14	38	499	902	133	2 158	1 274	1 264
2014–15	12	21	10	38	497	902	172	2 158	1 144	1 264
2015–16	10	21	11	38	490	902	115	2 158	1 264	1 264
2016–17	19	21	12	38	543	902	99	2 158	992	1 264
2017–18	25	21	18	38	669	902	108	2 158	1 151	1 264
2018–19	26	21	17	38	601	902	122	2 158	938	1 264

Fishstock	STA 7		STA 8		STA 10			
FMA(s)	7		8		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983*	323	–	3	–	0	–	1 919	–
1984*	444	–	3	–	0	–	2 230	–
1985*	328	–	4	–	0	–	1 571	–
1986*	362	–	3	–	0	–	1 477	–
1986–87	487	450	7	20	0	10	1 990	4 150
1987–88	505	493	5	20	0	10	2 338	4 306
1988–89	520	499	5	20	0	10	2 593	4 355
1989–90	585	525	1	22	0	10	2 763	4 502
1990–91	762	528	6	22	0	10	3 426	4 605
1991–92	920	700	18	22	0	10	3 239	5 296
1992–93	861	702	5	22	0	10	3 289	5 300
1993–94	715	702	4	50	0	10	3 111	5 329
1994–95	730	702	7	50	0	10	3 089	5 354
1995–96	877	702	4	50	0	10	3 261	5 354
1996–97	983	702	10	50	0	10	3 034	5 354
1997–98	564	702	10	22	0	10	2 132	4 973
1998–99	949	702	2	22	0	10	2 946	4 973
1999–00	1 184	702	3	22	0	10	3 472	4 973
2000–01	1 440	702	4	22	0	10	4 146	4 973
2001–02	802	702	4	22	0	10	3 238	5 117
2002–03	957	997	4	22	0	10	3 171	5 412
2003–04	934	997	6	22	0	10	2 947	5 412
2004–05	1 028	997	5	22	0	10	3 381	5 412
2005–06	1 010	997	3	22	0	10	3 606	5 412
2006–07	1 051	997	4	22	0	10	3 478	5 412
2007–08	1 014	997	3	22	0	10	3 258	5 412
2008–09	1 001	997	5	22	0	10	2 913	5 412
2009–10	1 093	997	6	22	0	10	3 247	5 456
2010–11	1 037	1 042	7	22	0	10	3 023	5 456
2011–12	1 056	1 042	7	22	0	10	3 006	5 456
2012–13	1 097	1 042	7	22	0	10	2 849	5 456
2013–14	1 062	1 042	6	22	0	10	3 007	5 456

Table 3 [Continued]

Fishstock	STA 7		STA 8		STA 10			
FMA(s)	7		8		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2014–15	1 093	1 042	5	22	0	10	2 933	5 456
2015–16	1 132	1 122	5	22	0	10	3 027	5 536
2016–17	1 114	1 122	3	22	0	10	2 782	5 536
2017–18	1 030	1 122	4	22	0	10	3 004	5 536
2018–19	1 131	1 122	5	22	0	10	2 840	5 536

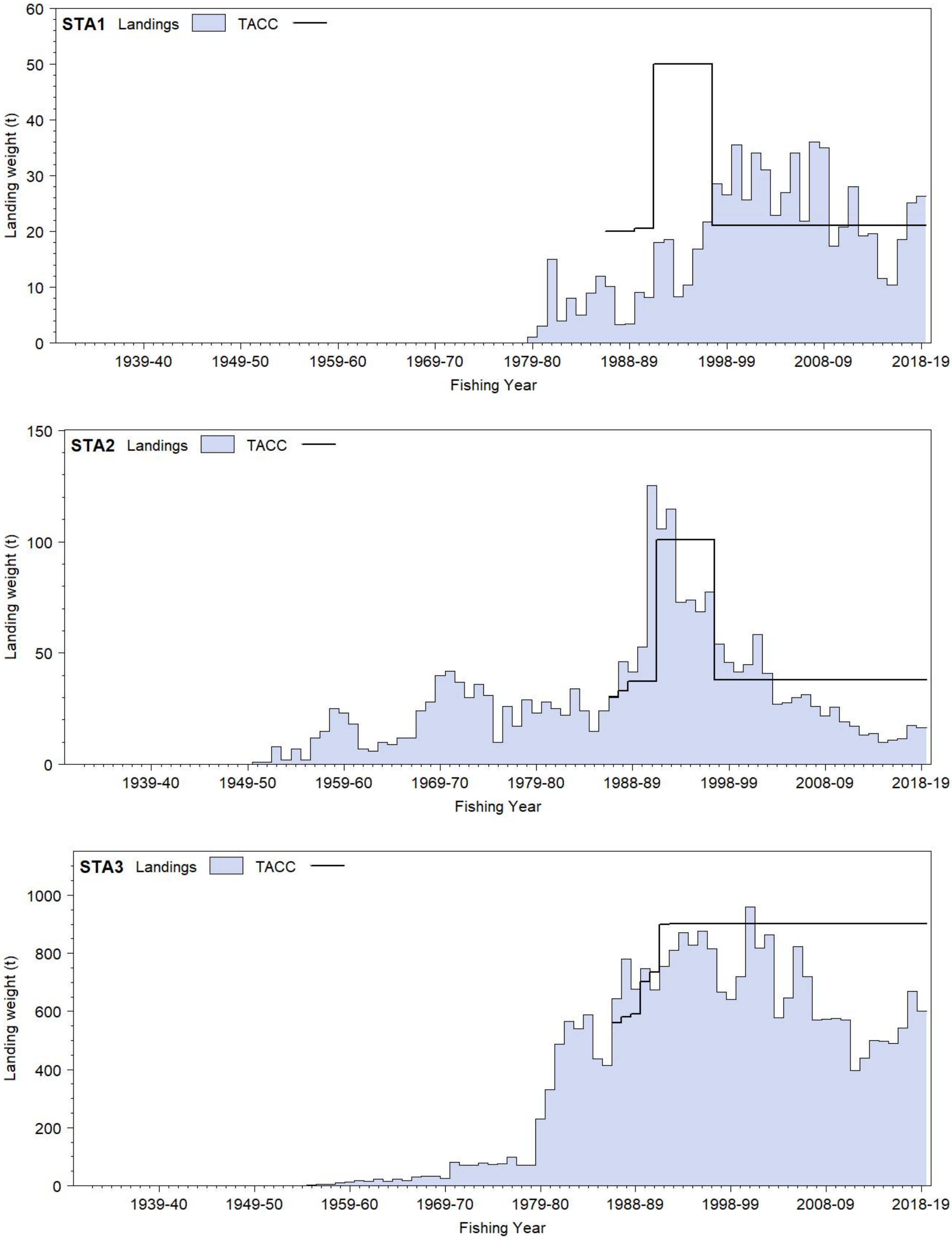


Figure 1: Reported commercial landings and TACC for the seven main STA stocks. From top to bottom: STA 1 (Auckland East), STA 2 (Central East), and STA 3 (South East Coast). [Continued on next page]

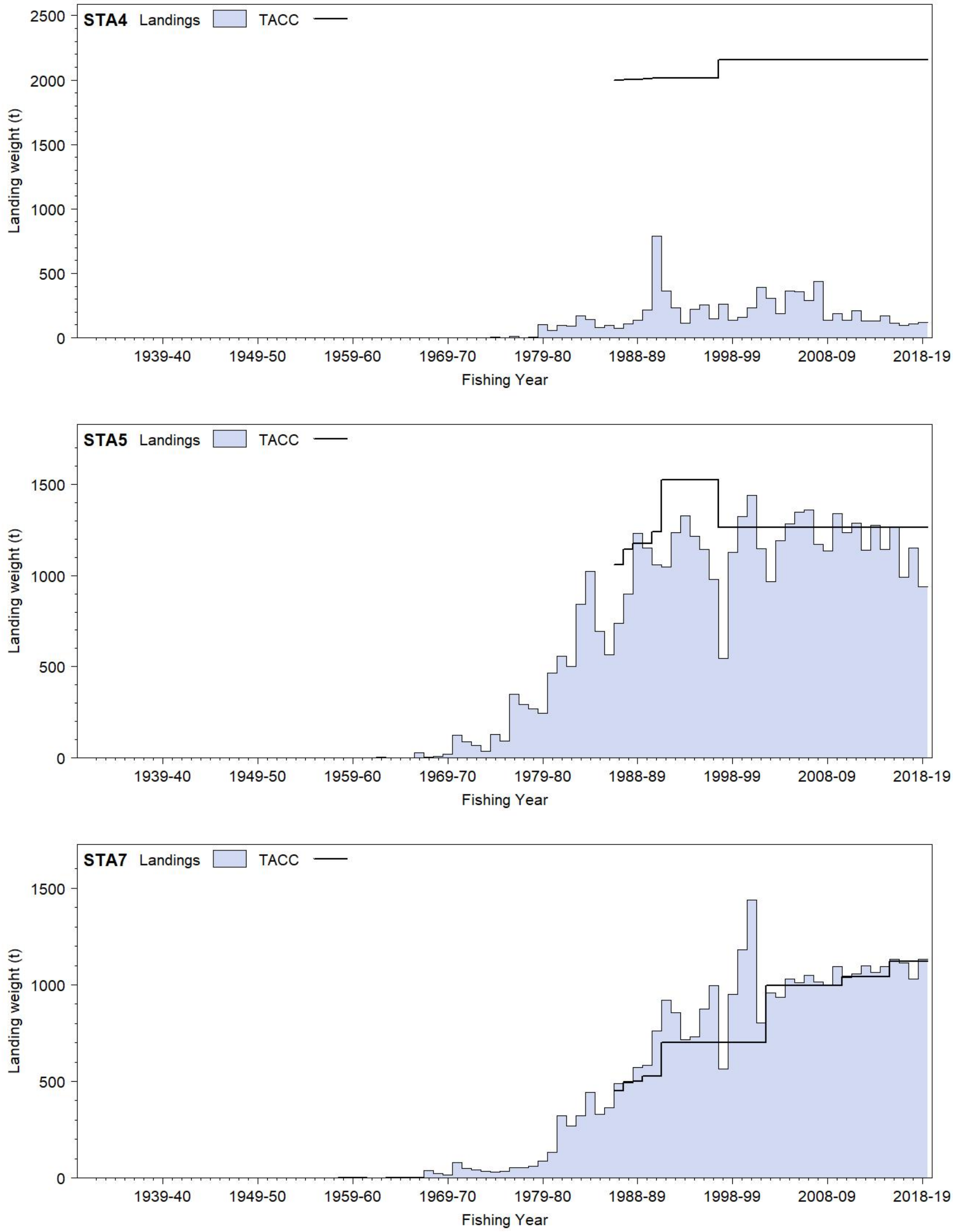


Figure 1 [Continued]: Reported commercial landings and TACC for the seven main STA stocks. From top to bottom: STA 4 (Chatham Rise), STA 5 (Southland), and STA 7 (Challenger). [Continued on next page]

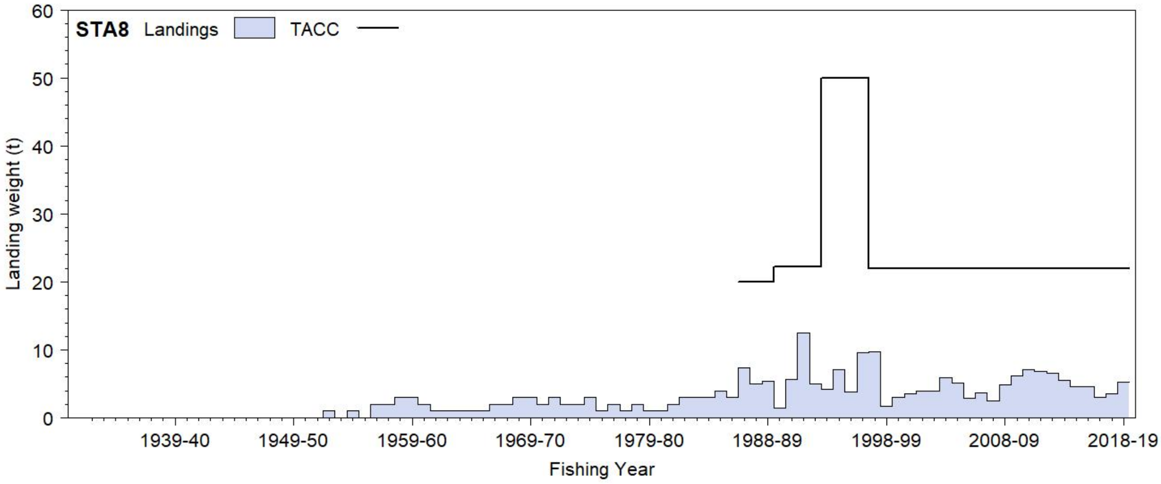


Figure 1 [Continued]: Reported commercial landings and TACC for the seven main STA stocks. STA 8 (Central Egmont).

Most of the stargazer catch is landed in a processed state. The conversion factors for giant stargazer were revised during the early 1990s to determine a conversion factor that was consistent with the main processed state (DVC). Recent analyses of catch and effort data from the STA 5 and STA 7 fisheries have taken these changes in the conversion factors into account in determining the landed catch (in greenweight). For STA 5, the correction for the changes in the conversion factors resulted in an increase (9–34%) in the annual landed catch from 1989–90 to 1996–97 (Langley & Bentley 2014). Similarly, for STA 7 the correction resulted in an increase (17–37%) in the annual landed catches from 1989–90 to 1996–97 (Langley 2015). These changes in conversion factor have not been applied to the total reported landings from the stargazer Fishstocks in Tables 1 and 2 and Figure 1.

The landings data (Tables 1–3) probably include an unknown quantity of catch from other uranoscopid species misidentified as *K. giganteum*. Fishers in STA 1–3 and 8 have been known to report brown (*Gnathagnus innotabilis*) and spotted stargazer (*Genyagnus monopterygius*) as *K. giganteum* in the past. Landings in STA 4 and 5 probably include an unknown amount of an undescribed sister species, banded stargazer (*Kathetostoma* sp.). Although the true extent of misreporting due to misidentification is unknown, it is likely to be small.

1.2 Recreational fisheries

Stargazer were not reported as being caught by recreational fishers in surveys conducted in the MAF Fisheries South region in 1991–92, Central region in 1992–93 and North region in 1993–94. In a national survey in 1996, a few giant stargazer were reported in STA 1 and 3, with an estimated take of 1000 fish in STA 1 and less than 500 fish taken in STA 3 (Bradford 1998). No giant stargazer catch was recorded for the recreational fishers during the 1999–2000 national diary survey (Boyd & Reilly 2002). In the 2011–12 National Panel Survey (Wynne-Jones et al 2014), only four fishers reported catching stargazer and the estimated catches were 53 fish in STA 1 (CV = 100%) and 481 fish in STA 7 (CV = 71%). In the 2017–18 National Panel Survey (Wynne-Jones et al 2019), again only four fishers reported catching stargazer and the estimated catches were 156 fish in STA 1 (CV = 58%) and 399 fish in STA 7 (CV = 100%). Recreational catch thus appears to be negligible.

1.3 Customary non-commercial fisheries

No quantitative information is available on the level of customary non-commercial take.

1.4 Illegal catch

No quantitative information is available on the level of illegal catch.

1.5 Other sources of mortality

No quantitative information is available on the level of other sources of mortality.

2. BIOLOGY

Giant stargazer is found throughout the New Zealand EEZ. It is most plentiful around the South Island (STA 3, 5, & 7) and on the Mernoo Bank on the Chatham Rise (STA 4).

Using data collected from the West Coast South Island trawl survey series (Drummond & Stevenson, 1995a, 1995b, 1996; Stevenson 1998; Stevenson & Hanchet 2000; Stevenson 2002, 2004), Manning (2008) found that giant stargazer reach sexual maturity at a length of about 40–55 cm in total length (TL), depending on sex, at an age of between 5–7 years. Age and growth studies suggest that some individuals reach a maximum age of at least 25 years (Sutton 1999, Manning & Sutton 2004, Sutton 2004, Manning & Sutton 2007a, 2007b). Otolith growth zones have not been validated. A number of attempts at growth zone validation have been undertaken unsuccessfully. A tag and release programme was initiated with all released fish being injected with oxytetracycline as part of the East Coast South Island trawl survey. A single fish has been recaptured but the otoliths were not recovered. Andrews (2009) investigated the feasibility of using lead-radium dating of otoliths as a means of validating age. However, the levels of radium-226 in stargazer otoliths were too low (nearly 10 times lower than expected) to generate meaningful results. Using maximum-likelihood methods, Manning & Sutton (2004) found that giant stargazer growth differs significantly between the east, south, and west coasts of the South Island. They suggested that these differences represented different biological stock units in these areas, although the true stock structure is unclear (Tate 1987). Manning (2005) investigated the effect of assuming alternative growth models with different functional forms on the data and conclusions presented by Manning & Sutton (2004). His results were consistent with the earlier results.

M was estimated using the equation $M = \ln 100 / t_{\max}$, where $t_{\max}$ is the maximum age to which 1% of the population survives in an unexploited stock. Using an unvalidated maximum age of 26 years, yields $M = 0.18$. Preliminary results of the STA 7 quantitative stock assessment (Manning 2008) suggested 0.18 was an underestimate of the unknown true value. A revised estimate based on applying Hoenig's (1983) regression to the age composition data from the West Coast South Island survey series suggested that a value of 0.23 is more reasonable (Manning 2008). Although the West Coast South Island age composition data were collected from an exploited stock, 0.23 is considered to be closer to the true value than 0.18.

Stargazer have an annual reproductive cycle with a winter spawning season. Spawning probably occurs in mid and outer shelf waters all around New Zealand. The generalised spawning date assumed in the age and growth studies cited above is 1 July in any given calendar year.

Biological parameters relevant to the stock assessment are given in Table 4.

Table 4: Estimates of giant stargazer biological parameters

Fishstock	**Estimate**	**Source**
1. Natural mortality (*M*)		
STA 5	0.20	Sutton (2004)
STA 7	0.18	Manning & Sutton (2007a)

2. Weight = a(length)^{b} (Weight in g, length in cm fork length).

	Females		Males		All fish		
	a	b	a	b	a	b	
STA 3	-	-	-	-	0.015	3.01	McClatchie (uppub.data)
STA 5	-	-	-	-	0.024	2.92	McGregor (unpub. data)
STA 7	0.018	2.97	0.013	3.07	-	-	Manning & Sutton (2007a)

3. Length at maturity (cm total length)

	Females		Males		
	L_{50}	L_{95}	L_{50}	L_{95}	
STA 7	54.37	11.24	40.98	14.90	Manning (2008)

4. Age at maturity (years)

	Females		Males		
	A_{50}	A_{95}	A_{50}	A_{95}	
STA 7	7.23	4.34	5.53	4.38	Manning (2008)

Table 4 [Continued]

5. von Bertalanffy length-at-age model parameter estimates

	Females			Males			
	L_∞	K (yr^{-1})	t_0 (yr)	L_∞	K (yr^{-1})	t_0 (yr)	
STA 3	78.11	0.14	-1.25	61.49	0.2	-0.97	Sutton (1999)
STA 5	73.92	0.18	-0.22	59.12	0.19	-1.19	Sutton (1999)
STA 5	72.61	0.17	-0.02	60.76	0.18	-1.16	Sutton (2004)
STA 7	85.74	0.13	-0.666	71.00	0.15	-0.664	Manning & Sutton (2007a); a revision of earlier results presented by Manning & Sutton (2004)

3. STOCKS AND AREAS

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

It is not known if there is more than one giant stargazer stock in New Zealand. The present QMAs were used as a basis for Fishstocks, except for QMAs 5 and 6, which were combined (STA 5). The basis for choosing these boundaries was a general review of the distribution and relative abundance of stargazer within the fishery.

As noted, length-at-age differs significantly between the east, south, and west coasts of the South Island (Manning & Sutton 2004, Manning 2005). This is consistent with the Fishstock boundaries.

4. STOCK ASSESSMENT

An integrated assessment for STA 7 was updated in 2008 with data that included the commercial catch, trawl survey biomass, and proportions-at-age estimates, and commercial catch proportions-at-age.

4.1 Trawl surveys

4.1.1 Relative biomass

Indices of relative biomass are available from recent *Tangaroa* and *Kaharoa* trawl surveys of the Chatham Rise, east coast South Island, and west coast South Island (Table 5, Figures 2–4).

Chatham Rise Trawl Survey

The Chatham Rise Trawl Survey was designed primarily for hoki and covers the depth range 200–400 m. It therefore excludes stargazer habitat around the Mernoo Bank in less than 200 m. The survey biomass estimates for STA have fluctuated without any trend since the series began in 1991 (Figure 2).

West Coast South Island (WCSI) Inshore Trawl Survey

Biomass estimates for the West Coast South Island Inshore Trawl Survey time series are presented in Figure 3. Estimates declined from 1995 to a low in 2003 but have been steadily increasing since. The 2019 estimate is second highest in the time series, down slightly from the time series high in 2015 (MacGibbon 2019). Most of the biomass has come from the west coast, with only minor contributions from Tasman Bay and Golden Bay. Most trawl stations capture stargazer, but strata in 100–200 m and south of Cape Foulwind contribute most of the total biomass. Throughout the time series most of the biomass has comprised adult fish with females contributing most of the adult biomass. For juveniles most of the biomass consists of male fish.

Most fish are between 40 and 70 cm, and virtually all are between 10 and 70 cm. There are often what appear to be small modes at 20–25 cm and 25–30 cm, but these are not thought to contain discrete year classes, rather they include fish aged 1–2 and 1–3 years respectively (Manning & Sutton 2007a). Few fish over 40 cm are caught in Tasman Bay and Golden Bay.

East Coast South Island (ECSI) Trawl Survey (STA 3)

The ECSI winter surveys from 1991 to 1996 in 30–400 m were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range, but these were discontinued after the fifth in the annual time series because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007 and this time included additional 10–30 m strata in an attempt to index elephant fish and red gurnard which were officially included in the list of target species in 2012. Only the 2007, 2012, 2014, 2016, and 2018 surveys provide full coverage of the 10–30 m depth range.

Overall there is no consistent trend in giant stargazer core strata biomass in ECSI survey series (Table 4, Figure 4) (MacGibbon et al 2019). Pre-recruited biomass (< 30 cm) has been a small but consistent component of the total biomass estimate on all surveys (range 2–7% of total biomass) and in 2018 it was 7%. The juvenile to adult biomass ratio (based on length-at-50% maturity) was relatively constant over the time series at about 1 to 1, and in 2018 biomass was 55% juvenile.

The distribution of giant stargazer hotspots varies between years, but overall this species is consistently well represented over the entire survey area (71–92% of core strata tows), most commonly from 30 m to about 200 m with highest catch rates in 2018 in 30–100 m. There were no giant stargazer caught in 10–30 m on any of the five surveys and hence the addition of the shallow strata (10–30 m) is of no value for monitoring giant stargazer.

The size distributions of giant stargazer in each of the twelve core strata surveys were similar and generally had one large mode comprising multiple age classes and in some years a small juvenile mode. The 2016 survey appeared to have a relatively abundant mode from 15–25 cm which tracked through to 2018 and is now around 25–38 cm. Giant stargazer sampled on these ECSI surveys are generally smaller than those from the Chatham Rise, Southland, and WCSI inshore surveys (Bagley & Hurst 1996a, Stevenson & Hanchet 2000, Livingston et al 2002, Stevenson & MacGibbon 2018, Stevens et al 2015), suggesting that this area may be an important nursery ground for juvenile giant stargazer.

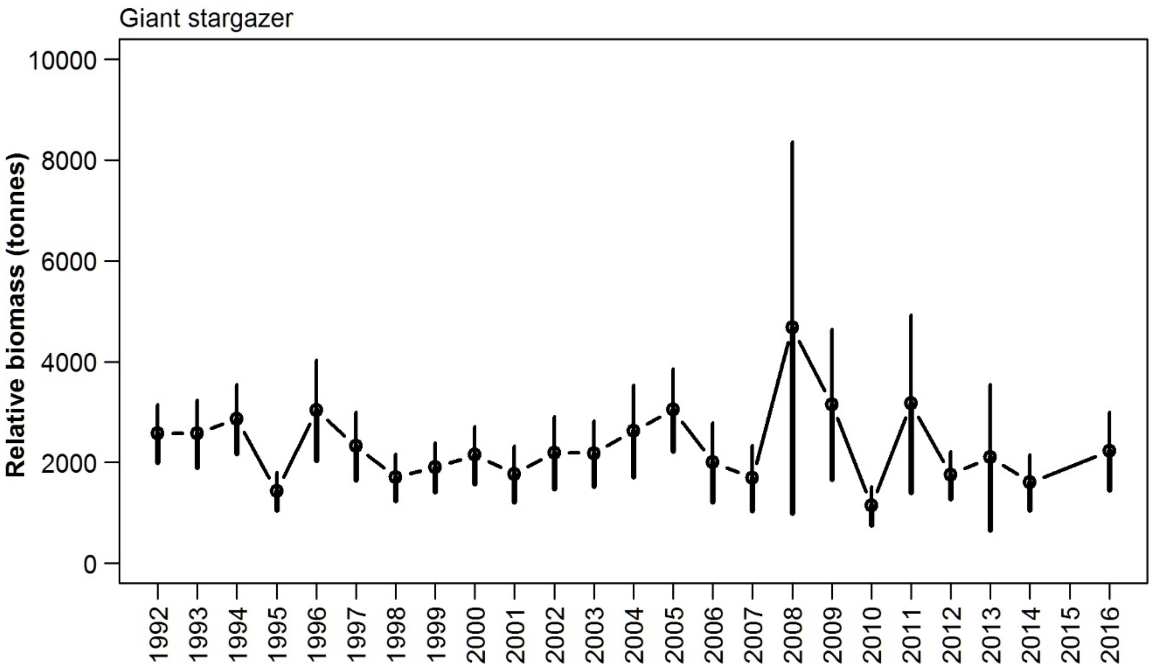


Figure 2: Giant stargazer biomass estimated from the Chatham Rise trawl survey. Error bars are ± two standard deviations.

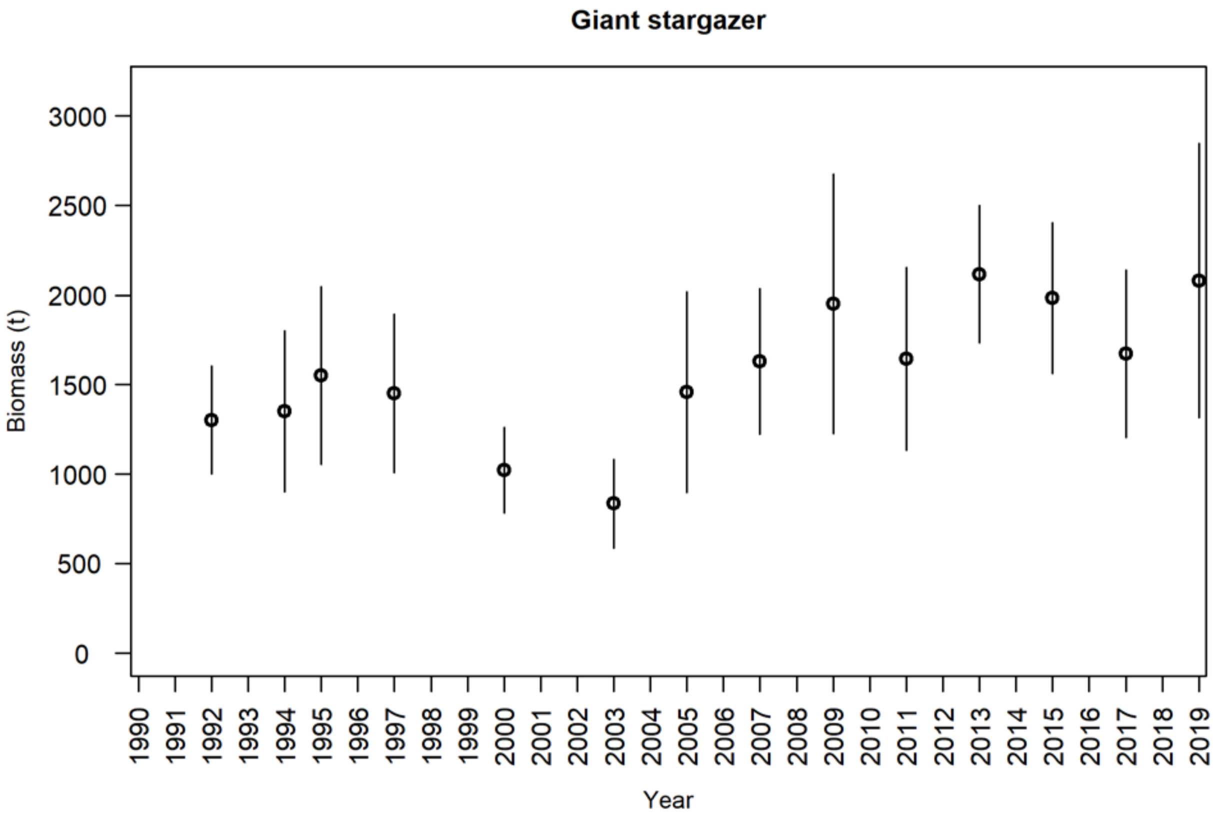


Figure 3: Giant stargazer biomass estimates for the West Coast South Island Inshore Trawl Survey time series. Error bars are ± two standard deviations.

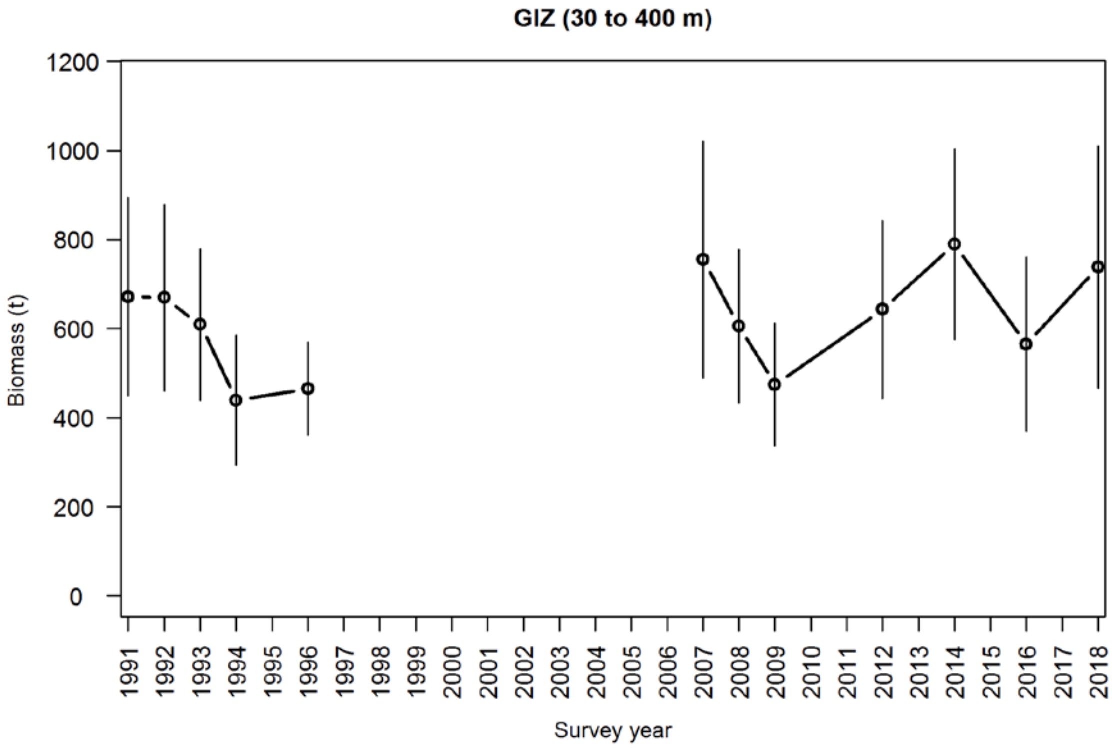


Figure 4: Giant stargazer (GIZ) total biomass for the all ECSI winter surveys in core strata (30–400 m). Error bars are ± two standard deviations.

Table 5: Relative biomass indices (t) and coefficients of variation (CV) for giant stargazer for the East Coast North Island (ECNI), East Coast South Island (ECSI) — summer and winter, Chatham Rise, West Coast South Island (WCSI), and the Stewart Island-Snares Island survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16, & 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. –, not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (30 cm).

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
ECNI (inshore)	STA 2	1993	KAH9304	184	22	–	–	–	–	–	–	–	–	–	–
		1994	KAH9402	58	47	–	–	–	–	–	–	–	–	–	–
		1995	KAH9502	44	35	–	–	–	–	–	–	–	–	–	–
		1996	KAH9602	57	17	–	–	–	–	–	–	–	–	–	–
ECNI(scampi)	STA 2	1993	KAH9301	250	16	–	–	–	–	–	–	–	–	–	–
		1994	KAH9401	215	20	–	–	–	–	–	–	–	–	–	–
		1995	KAH9501	122	17	–	–	–	–	–	–	–	–	–	–
				30–400m		10–400m		30–400m		10–400m		30–400m		10–400m	
ECSI (winter)	STA 3	1991	KAH9105	672	17	–	–	26	22	–	–	646	17	–	–
		1992	KAH9205	669	16	–	–	35	14	–	–	634	16	–	–
		1993	KAH9306	609	14	–	–	19	16	–	–	591	14	–	–
		1994	KAH9406	439	17	–	–	10	25	–	–	429	17	–	–
		1996	KAH9606	466	11	–	–	13	34	–	–	452	11	–	–
		2007	KAH0705	755	18	–	–	33	24	–	–	722	18	–	–
		2008	KAH0806	606	14	–	–	13	28	–	–	592	14	–	–
		2009	KAH0905	475	14	–	–	10	34	–	–	464	15	–	–
		2012	KAH1207	643	16	–	–	26	22	–	–	617	16	–	–
		2014	KAH1402	790	14	–	–	39	17	–	–	751	14	–	–
		2016	KAH1605	565	17	–	–	22	24	–	–	543	18	–	–
		2018	KAH1803	738	18	–	–	53	33	–	–	685	18	–	–
ECSI (summer)	STA 3	1996	KAH9618	897	12	–	–	–	–	–	–	–	–	–	–
		1997	KAH9704	543	11	–	–	–	–	–	–	–	–	–	–
		1998	KAH9809	999	10	–	–	–	–	–	–	–	–	–	–
		1999	KAH9917	472	14	–	–	–	–	–	–	–	–	–	–
		2000	KAH0014	214	16	–	–	–	–	–	–	–	–	–	–
Chatham Rise	STA 4	1992	TAN9106	2 570	11	–	–	–	–	–	–	–	–	–	–
		1993	TAN9212	2 560	13	–	–	–	–	–	–	–	–	–	–
		1994	TAN9401	2 853	12	–	–	–	–	–	–	–	–	–	–
		1995	TAN9501	1 429	13	–	–	–	–	–	–	–	–	–	–
		1996	TAN9601	3 039	16	–	–	–	–	–	–	–	–	–	–
		1997	TAN9701	2 328	15	–	–	–	–	–	–	–	–	–	–
		1998	TAN9801	1 702	14	–	–	–	–	–	–	–	–	–	–
		1999	TAN9901	1 903	13	–	–	–	–	–	–	–	–	–	–
		2000	TAN0001	2 148	13	–	–	–	–	–	–	–	–	–	–
		2001	TAN0101	1 772	16	–	–	–	–	–	–	–	–	–	–

*Assuming areal availability, vertical availability and vulnerability equal 1.0. Biomass is only estimated outside 10 m depth. Note: because trawl survey biomass estimates are indices, comparisons between different seasons (e.g., summer and winter ECSI) are not strictly valid.

Table 5 [continued]: Relative biomass indices (t) and coefficients of variation (CV) for giant stargazer for the East Coast North Island (ECNI), East Coast South Island (ECSI) - summer and winter, Chatham Rise, West Coast South Island (WCSI), and the Stewart Island-Snares Island survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16, & 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. –, not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (30 cm). Note: WCSI total biomass estimates are updated (P. Starr pers. comm.) to match the values given for GIZ in table 4, MacGibbon (2019).

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)
Chatham Rise	STA 4	2002	TAN0201	2 195	16	–	–	–	–	–	–
		2003	TAN0301	1 380	15	–	–	–	–	–	–
		2005	TAN0501	3 045	13	–	–	–	–	–	–
		2006	TAN0601	2 007	19	–	–	–	–	–	–
		2007	TAN0701	1 684	12	–	–	–	–	–	–
		2008	TAN0801	4 677	40	–	–	–	–	–	–
		2009	TAN0901	3 154	24	–	–	–	–	–	–
		2010	TAN1001	1 140	17	–	–	–	–	–	–
		2011	TAN1101	3 169	28	–	–	–	–	–	–
		2012	TAN1201	1 751	13	–	–	–	–	–	–
		2013	TAN1301	2 108	34	–	–	–	–	–	–
		2014	TAN1401	1 601	17						
		2016	TAN1601	2 228	17						
WCSI	STA 7	1992	KAH9204	1 450	14			–	–	–	–
		1994	KAH9404	1 358	17			–	–	–	–
		1995	KAH9504	1 556	16			–	–	–	–
		1997	KAH9701	1 450	15			–	–	–	–
		2000	KAH0004	1 023	12			–	–	–	–
		2003	KAH0304	834	15			–	–	–	–
		2005	KAH0503	1 458	19			–	–	–	–
		2007	KAH0704	1 630	13			–	–	–	–
		2009	KAH0904	1 952	19			–	–	–	–
		2011	KAH1104	1 620	16			–	–	–	–
		2013	KAH1305	2 118	9			–	–	–	–
		2015	KAH1503	1 984	11			–	–	–	–
		2017	KAH1703	1 674	14			–	–	–	–
		2019	KAH1902	2 081	18						
Stewart & Snares	STA 5	1993	TAN9301	2 650	20	–	–	–	–	–	–
		1994	TAN9402	3 755	11	–	–	–	–	–	–
		1995	TAN9502	2 452	11	–	–	–	–	–	–
		1996	TAN9604	1 733	11						
Stewart & Snares	Banded Stargazer BGZ 5	1993	TAN9301	409	27	–	–	–	–	–	–
		1994	TAN9402	250	21	–	–	–	–	–	–
		1995	TAN9502	316	29	–	–	–	–	–	–
		1996	TAN9604	232	34	–	–	–	–	–	–

4.2 CPUE analysis

STA 2 and 3

CPUE indices have been calculated for STA 2 (Vignaux 1997) and STA 3 (SEFMC 2002, SeaFIC 2005a, Starr et al 2008). The currently accepted CPUE series for STA 3 (Figure 5) is based on a mixed target species fishery including red cod, barracouta, tarakihi, and stargazer and shows no trend from about 2000–01 to the most recent year in 2006–07 (Starr et al 2008).

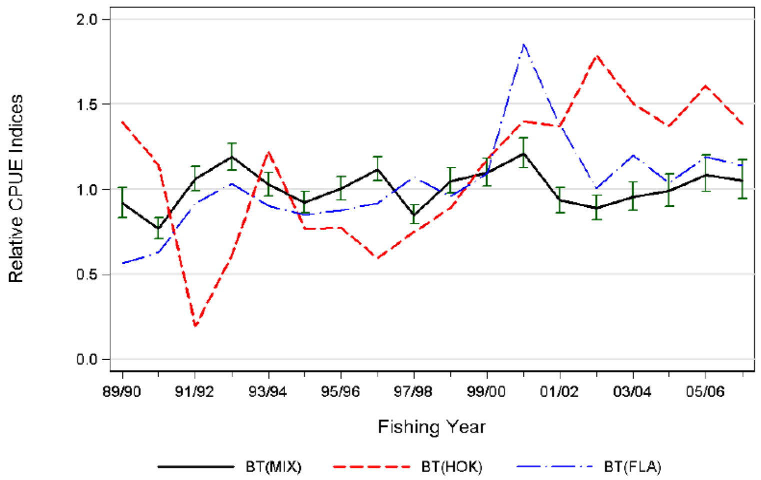


Figure 5: Comparison of the lognormal indices from the three bottom trawl CPUE series for STA 3; a) BT(MIX): mixed species target trawl fishery; b) BT(HOK): hoki target trawl fishery; c) BT(FLA): target flatfish trawl fishery. Each series is scaled to the geometric mean = 1 (Starr et al 2008).

STA 5

About 80% of the STA 5 catch is caught by small (< 43 m) inshore bottom trawl vessels targeting giant stargazer. The remainder of the catch is caught mostly by large (≥ 43 m) deepwater bottom trawl vessels targeting other species such as barracouta, jack mackerels, and squids. Catches by methods other than bottom trawling are very small.

Standardised CPUE indices currently represent the only available information for monitoring STA 5 abundance. There have been previous analyses of the CPUE data from this fishery by Vignaux (1997), Phillips (2001) and Manning (2007). In 2014, a new CPUE analysis was conducted that included catch and effort data from the inshore target stargazer trawl fleet operating in Statistical Areas 030, 029, and 025 during 1989–90 to 2012–13.

Data processing was similar to the approach of Manning (2007), whereby the declared landed catches were corrected for changes in the conversion factor of giant stargazer during the early 1990s. Landed catches from individual fishing trips were apportioned to the associated fishing effort records in proportion to the reported estimated catch of giant stargazer. An attempt to replicate the analysis of Manning (2007) yielded comparable CPUE indices for the 1989–90 to 2003–04 period.

Changes in statutory reporting in 2007–08 (from CELR to TCER forms) required that the more recent, location based TCER trawl effort data be aggregated into a format consistent with the CELR data format to configure a comparable times series. The aggregation procedure is described in detail by Langley & Bentley (2014). The final CPUE data set was limited to a core set of 14 vessels that accounted for 80% of the total target stargazer catch. One of the main vessels changed fishing gear from single trawl to a twin rig trawl in the mid-2000s and, on that basis, was assigned to a different vessel category depending on the fishing gear deployed.

The final CPUE data set included a trivial number of zero stargazer catches and those records were ignored in the final analysis. A generalised linear model, based on positive catch and effort targeted at stargazer, was formulated using an AIC based step-wise fitting procedure and investigated a number of alternative distributional assumptions. The final model included the natural logarithm of catch as the dependent variable; fishing year, vessel, and month as categorical predictor variables; and the effort variables: natural log of the number of trawls and fishing duration, included as third order polynomial functions. The Weibull error distribution was accepted as the most suitable of those which were investigated (Langley & Bentley 2014).

In 2017, the CPUE model was updated to include three additional years: 2013–14 to 2015–16 (Langley 2017). The updated CPUE indices were virtually identical to the previous CPUE indices for the corresponding period, i.e., 1989–90 to 2012–13. The CPUE indices from the model have fluctuated without trend with peaks in 1991–92 to 1993–94 and 2006–07 to 2009–08 (Figure 6). The 2013–14 to 2015–16 indices are slightly below the average for the series. CPUE indices were also derived from the short time series of high resolution TCER data from 2007–08 to 2015–16. These indices had a similar trend to the corresponding annual indices from the primary CPUE model (Figure 6).

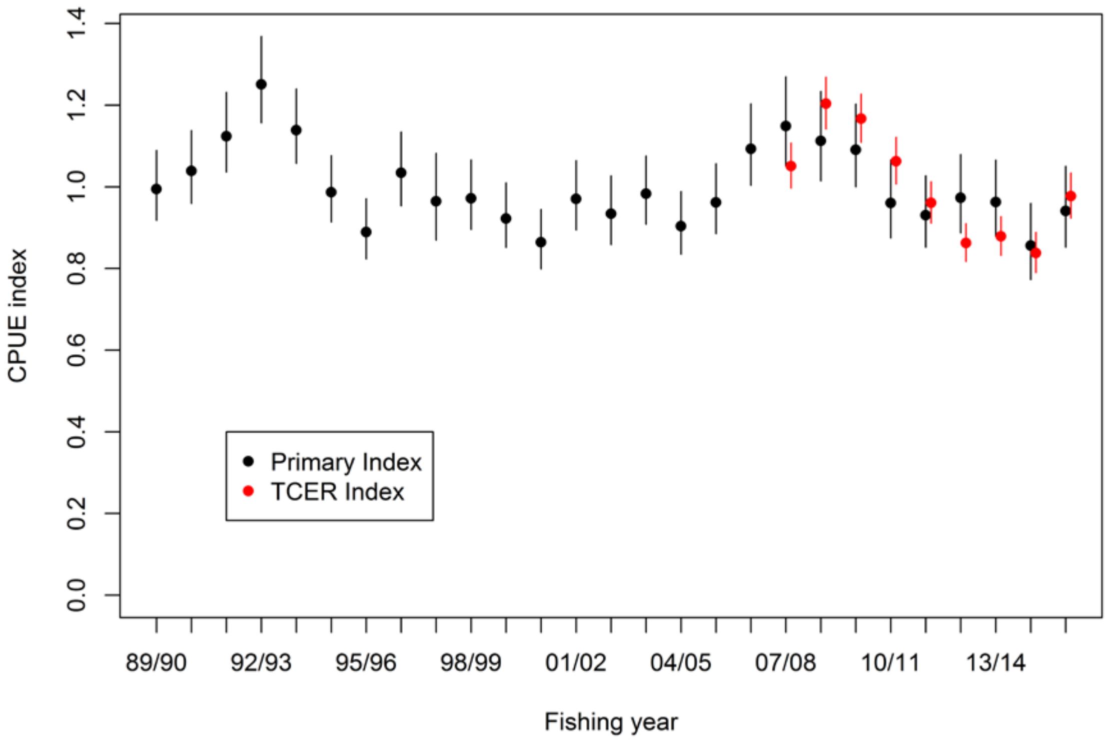


Figure 6: A comparison of STA 5 CPUE indices from the base model and indices derived from the high resolution, location based TCER data and the associated 95% confidence intervals.

<u>Establishing B_{MSY} compatible reference points</u>

In 2014, the Southern Inshore Working Group (SINSWG) accepted mean standardised CPUE for the period 1989–90 to 2012–13 as a B_{MSY}-compatible proxy for STA 5. The working group accepted the default Harvest Strategy Standard definitions that the Soft and Hard Limits would be one half and one quarter the target, respectively.

STA 7

A CPUE series calculated for STA 7 (SeaFIC 2002, 2003b, 2005b, Starr et al 2007b), based on a mixed west coast South Island target species fishery (stargazer, barracouta, red cod, and tarakihi), was not accepted by the AMP WG as an indicator of STA 7 abundance. The Southern Inshore and AMP Fishery Assessment Working Groups had concerns over using bycatch fisheries to monitor stargazer abundance in these areas due to possible changes in recording and fishing practices. A characterisation of the STA 7 fishery, including detailed trawl location data, identified a number of areas of higher stargazer abundance along the WCSI and it was speculated that the previous trends in STA 7 CPUE could have been influenced by the extent of fishing in these localised areas (Langley 2015). The SINSWG reaffirmed the previous conclusions regarding the utility of the aggregated (CELR based) CPUE time series.

An additional time series of CPUE indices was derived from the detailed trawl location data set. The data set included trawl records from bottom trawl fishing effort targeting barracouta, tarakihi, blue warehou, stargazer, or red cod in the WCSI inshore trawl fishery (Langley 2015) from 2007–08 to 2012–13. The standardised CPUE analysis included both positive catch and presence/absence models that incorporated fishing location and fishing depth variables. The resulting Combined indices were relatively stable, increasing slightly (5–8%) over the 6 year period (Table 6). The trawl survey biomass indices were also relatively stable over that period. The SINSWG concluded that the trawl location based CPUE indices have potential to monitor the relative abundance of STA 7; however, the utility of the CPUE indices can only be evaluated once a longer time series of CPUE indices are available for comparison with the relative abundance indices from the WCSI trawl survey.

Table 6: Annual combined STA 7 trawl location based CPUE indices, including the lower and upper bounds of the confidence intervals.

Fishing year	Index	LCI	UCI
2007–08	0.969	0.909	1.025
2008–09	0.956	0.905	1.010
2009–10	1.029	0.975	1.087
2010–11	0.982	0.926	1.037
2011–12	1.052	0.995	1.110
2012–13	1.013	0.954	1.069

4.3 Stock Assessment Models

STA 7

An age-structured model partitioned by age (0–25 years) and sex was fitted to the WCSI trawl survey relative abundance indices (1992–2005), WCSI survey proportions-at-age data (1992–2005), and WCSI fishery catch-at-age data (Manning 2008). This assessment has not been updated and the WCSI trawl survey is currently used to monitor the status of STA 7.

Establishing B_{MSY} compatible reference points

In 2018, the working group accepted the average WCSI trawl survey biomass estimates for the period 2005 to 2017 as the B_{MSY}-compatible proxy for STA 7, with the rationale that catches had been stable over that period while abundance remained high. The 2003 index was excluded because of extreme catchability values among a range of species (Stevenson & MacGibbon 2018). The working group accepted the default Harvest Strategy Standard definitions that the Soft and Hard Limits would be one half and one quarter the target, respectively.

4.4 Other factors

The use of a single conversion factor for deepwater and inshore vessels has resulted in about a 5–10% under-estimate pre 1990–91 of the reported greenweight landings. In 1990–91, separate deepwater and inshore conversion factors were introduced.

Stargazer landings have been influenced by changes in fishing patterns and fishing methods in the target species fisheries and indirectly by the abundance of those target species. Landings have also been influenced by changes in reporting behaviour for the different species. Stargazer were also taken historically in substantial quantities by foreign-licensed and chartered trawlers fishing offshore grounds for other species (see Table 1). Because stargazer was mainly a bycatch in these early fisheries, there may be under-reporting in these data. Therefore, any estimate of *MCY* based on catch data is likely to be conservative.

5. STATUS OF THE STOCKS

No estimates of current and reference biomass are available.

- **STA 1**

The TACC for STA 1 was increased from 21 t to 50 t in the 1991–92 fishing year under the AMP. In 1997, the TACC was reduced to 21 t upon its removal from the programme. Recent catches have exceeded this level. It is not known if recent catch levels and current TACC are sustainable. The status of STA 1 relative to B_{MSY} is unknown.

- **STA 2**

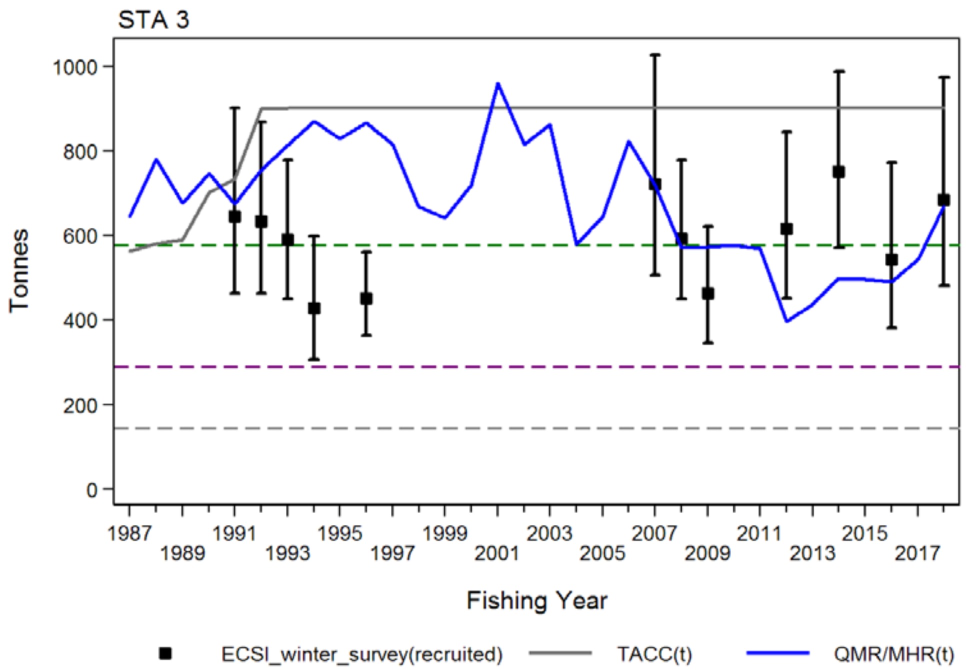
The TACC for STA 2 was increased from 37 t to 100 t in the 1991–92 fishing year under the AMP. Landings in the early 1990s peaked in the range of 105–125 t, but have subsequently declined.

The TACC was reduced to 38 t in the 1997–98 fishing year, upon the removal of STA 2 from the AMP. Landings have been below the TACC since 2003–04. It is not known whether recent catches and the current TACC will cause the STA 2 stock size to decline. The status of STA 2 relative to B_{MSY} is unknown.

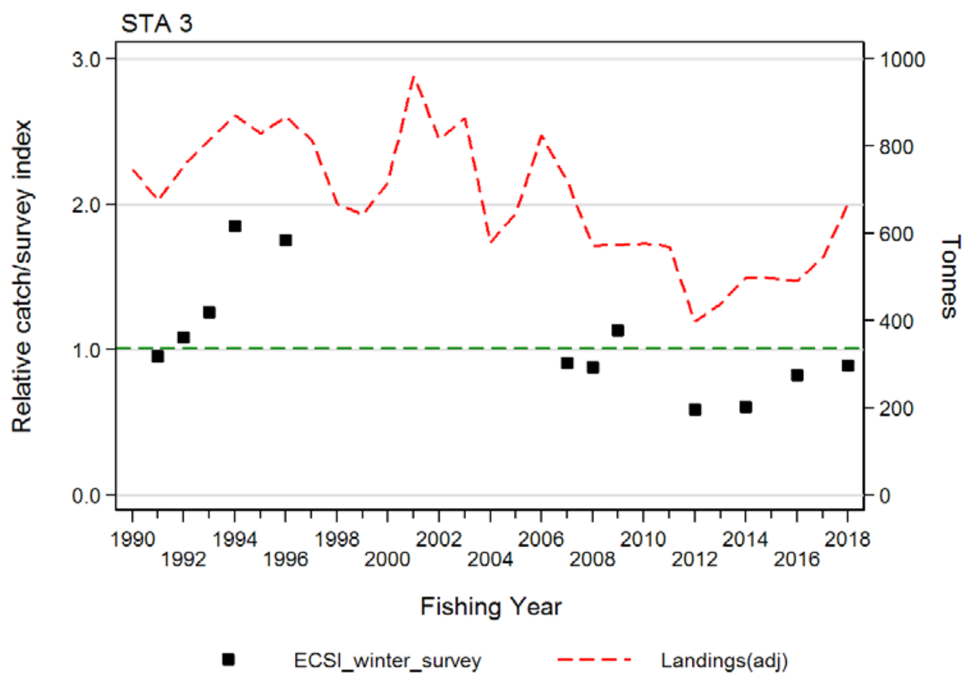
- **STA 3**

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	The series of biomass indices from the East Coast South Island trawl survey
Reference Points	Target: B_{MSY}-compatible proxy based on mean biomass from the East Coast South Island trawl survey for the period 1991 to 2016 Soft Limit: 50% of target Hard Limit: 25% of target Overfishing Threshold: Mean relative exploitation rate for the period 1991 to 2016
Status in relation to Target	About as Likely as Not (40–60%) to be at or above the target
Status in relation to Limits	Very Unlikely (< 10%) to be below both soft and hard limits
Status in relation to Overfishing	Unlikely (< 40%) to be overfishing

Historical Stock Status Trajectory and Current Status



Comparison of the GIZ ECSI recruited trawl survey indices with the QMR/MHR landings and TACC for STA 3. The agreed B_{MSY} proxy (geometric average: 1991–2016 ECSI winter survey biomass estimates=577 t) is shown as a green line; the calculated Soft Limit (=50% B_{MSY} proxy) is shown as a purple line; the calculated Hard Limit (=25% B_{MSY} proxy) is shown as a grey line.



Relative fishing pressure for STA 3 based on the ratio of QMR/MHR landings relative to the ECSI recruited winter trawl survey which has been normalised so that its geometric mean=1.0. Horizontal green line is the geometric mean fishing pressure from 1991 to 2016.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass appears to be fluctuating around the long-term mean, with the 2018 ECSI survey estimate above the long-term mean.
Recent Trend in Fishing Intensity or Proxy	Relative exploitation rate has increased steadily since 2012, but remained below the overfishing threshold in 2018.
Other Abundance Indices	A standardised CPUE series from 1989–90 to 2006–07 shows no trend, suggesting that there was little change during the period when no surveys were conducted.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	STA 3 remains primarily a bycatch in the mixed-species inshore trawl fishery. STA 3 stock size is Likely (> 60%) to remain near current levels at current catch levels (2007–08 to 2015–16). It is Unknown if catches near the TACC would cause the stock to decline.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Current catch: Soft Limit: Unlikely (< 40%) Hard Limit: Unlikely (< 40%) TACC: Unknown
Probability of Current Catch or TACC causing overfishing to continue or to commence	Current Catch: Unlikely (< 40%)TACC: Unknown

Assessment Methodology and Evaluation	
Assessment Type	Level 2 - Partial Quantitative Stock Assessment
Assessment Method	Trawl survey biomass and standardised CPUE based on lognormal error distribution and positive catches

Assessment Dates	Latest assessment: 2019	Next assessment: 2021
Overall assessment quality (rank)	1 – High Quality	
Main data inputs (rank)	- ECSI trawl survey series	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
-

Fishery Interactions
STA 3 are caught in fisheries for flatfish, barracouta, hoki, red cod, and tarakihi. Target STA only accounted for about 4% of total landings from 1989–90 to 2007–08. Interactions with other species are currently being characterised.

- **STA 4**

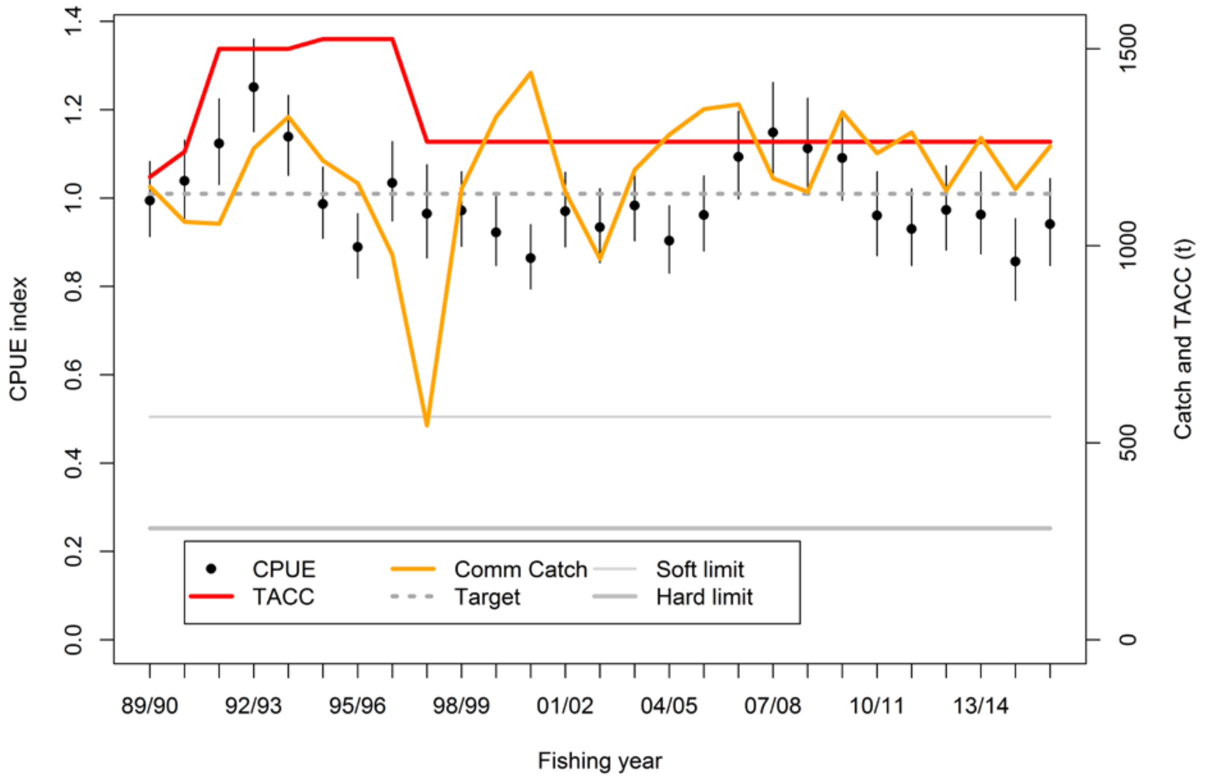
Stargazer in this Fishstock occur mainly on the Chatham Rise on the shelf around the Chatham Islands, but are sparsely distributed over the rest of the Chatham Rise. In most of this Fishstock they may not be economic to target. However, if fishing is overly concentrated in those areas where stargazer can be targeted, such as close to the Chatham Islands, there are concerns that local depletion may occur.

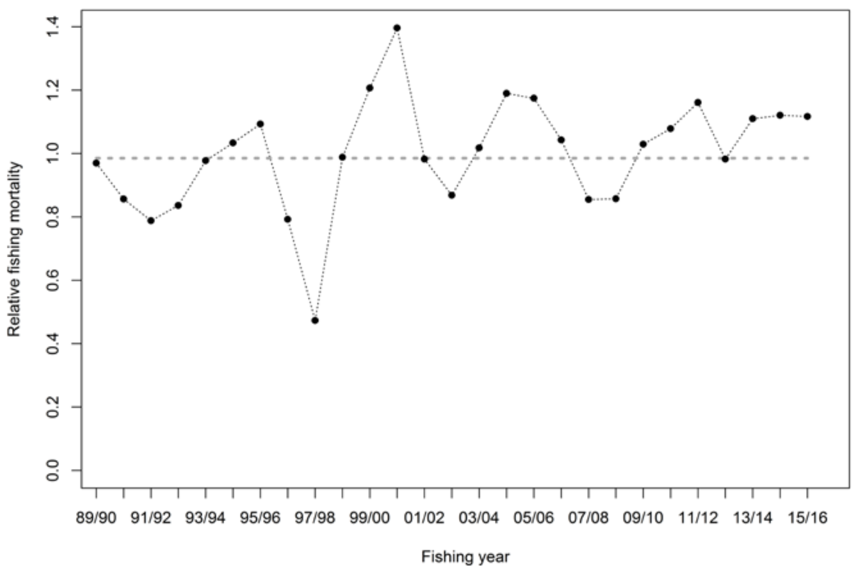
The 2011 estimate of biomass from the Chatham Rise trawl survey was above the long-term mean (1991–2011). The original TACC of 2014 t for STA 4 was based on a yield estimate from a single trawl survey in 1983. This method is now considered obsolete. The TACC was increased in 2000–01 to 2158 t. Catches have always been substantially less than the TACC. The average catch since the TACC increase has been 300 t. It is not known if catches at the level of the current TACC would be sustainable.

- **STA 5**

Stock Structure Assumptions
For the purpose of this summary STA 5 is considered to be a single stock.

Stock Status	
Year of Most Recent Assessment	2017
Assessment Runs Presented	Standardised CPUE based on bottom trawl positive catches and effort targeting STA 5
Reference Points	Target: B_{MSY}-compatible proxy based on mean CPUE for the period 1989–90 to 2012–13 Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: Mean relative exploitation rate for the period 1989–90 to 2012–13
Status in relation to Target	About As Likely As Not (40–60%) to be at or above the target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing is About as Likely as Not (40–60%) to be Occurring

Historical Stock Status Trajectory and Current Status

A comparison of the CPUE indices and the annual catch and TACC. The horizontal grey line represents the average of the CPUE indices from 1989–90 to 2012–13 (target reference point).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has fluctuated without trend (1989–90 to 2012–13) with peaks in 1991–92 to 1993–94 and 2006–07 to 2009–08. The 2015–16 value is at 94% of the target reference level.
Recent Trend in Fishing Intensity or Proxy	 Fishing mortality proxy is Standardised Fishing Effort = Total catch/CPUE (normalised). The dashed line represents the average of the series from 1989–90 to 2012–13 (corresponding to the target reference point). Fishing mortality has fluctuated about the long term average and recent levels of fishing mortality were slightly higher than the target level.

Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Catches have been maintained near the current level for the last 28 years and there has been no indication of a decline in CPUE over that period, indicating that the current level of catch is probably sustainable, at least in the 3–5 year period.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) for both catch and TACC Hard Limit: Very Unlikely (< 10%) for both catch and TACC
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Current Catch: About as Likely as Not (40–60%) TACC: About as Likely as Not (40–60%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE indices	
Assessment Dates	Latest assessment: 2017	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	No change from previous (2014) assessment	

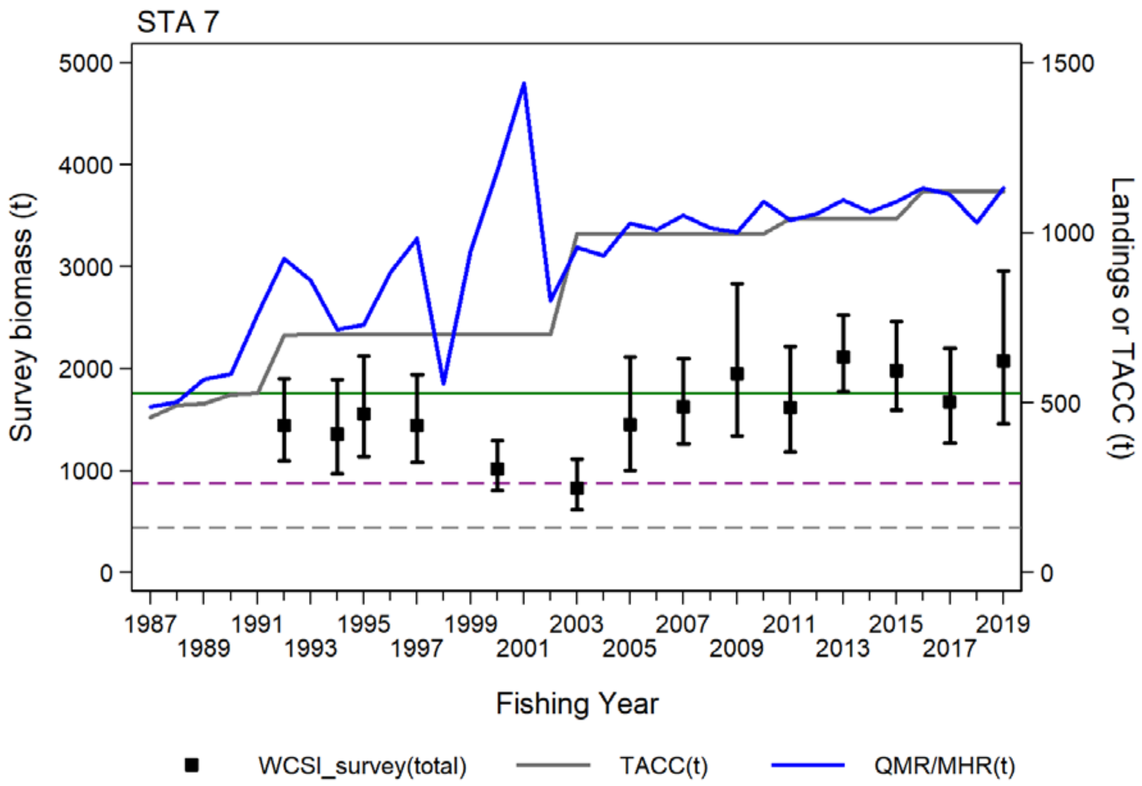
Qualifying Comments
-

Fishery Interactions
Most (70–80%) of the STA 5 catch is taken by the target trawl fishery with a smaller component of the catch taken by a flatfish trawl fishery. The species composition of the landed catch from the target fishery is dominated by stargazer with a small associated catch of ling, tarakihi, and spiny dogfish. Vessels participating in the target fishery may also conduct trawls in shallower water with associated catches of flatfish, red gurnard, and elephant fish. Interactions with other species are currently being characterised.

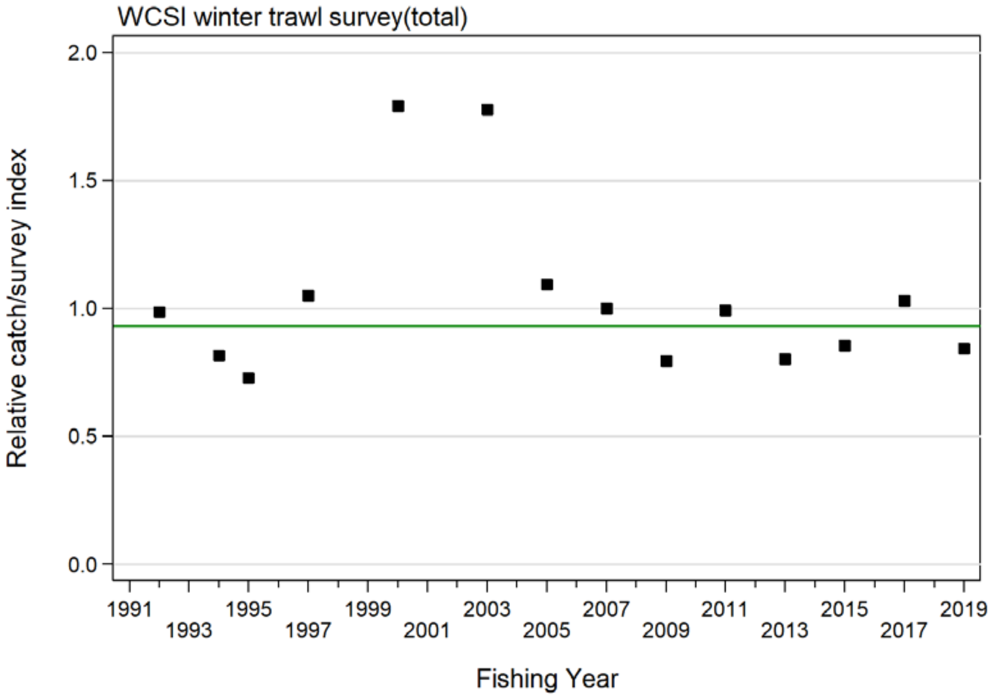
- **STA 7**

Stock Status	
Year of Most Recent Assessment	2020 - Analysis of WCSI survey indices of abundance
Assessment Runs Presented	Total biomass estimates from the WCSI trawl survey to 2019
Reference Points	Target: Mean WCSI trawl survey biomass estimates for the period 2005–2017 Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: Mean Fishing Intensity during the reference period (above)
Status in relation to Target	About as Likely as Not (40–60%) to be at or above 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	Overfishing is About as Likely as Not (40–60%) to be occurring

Historical Stock Status Trajectory and Current Status



Comparison of the STA WCSI total trawl survey indices with the QMR/MHR landings and TACC for STA 7. The agreed B_{MSY} proxy (geometric average: 2005–2017 WCSI survey biomass estimates=1777 t) is shown as a green line; the calculated Soft Limit (=50% B_{MSY} proxy) is shown as a purple line; the calculated Hard Limit (=25% B_{MSY} proxy) is shown as a grey line.



Relative fishing pressure for STA 7 based on the ratio of QMR/MHR landings relative to the WCSI recruited winter trawl survey which has been normalised so that its geometric mean=1.0. Horizontal green line is the geometric mean fishing pressure from 2005 to 2017.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The WCSI trawl survey indices have been high since 2009, compared to those in the early 90s.
Recent Trend in Fishing Intensity or Proxy	Overfishing is About as Likely as Not (40–60%) to be occurring
Other Abundance Indices	CPUE indices from the WCSI mixed trawl fishery derived from individual trawl data (from 2007–08)
Trends in Other Relevant Indicators or Variables	CPUE indices were relatively stable from 2007–08 to 2012–13.

Assessment Methodology		
Assessment Type	Level 2 – Based on WCSI trawl survey series of abundance estimates	
Assessment Method	Evaluation of recent trawl survey indices (up to 2019)	
Assessment Dates	Latest assessment: 2020	Next assessment: 2022
Overall assessment quality (rank)	1 – High Quality	
Main data inputs (rank)	- Biomass estimates from the biennial WCSI Trawl survey up to 2019	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Assessment based only on WCSI trawl survey	
Major Sources of Uncertainty	-	

Projections and Prognosis	
Stock Projections or Prognosis	The STA 7 stock is About as Likely as Not (40-60%) to remain at or above the target at current catch levels.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)

Fishery Interactions
Smooth skates are caught as a bycatch in this fishery. Interactions with other species are currently being characterised.

- **STA 8**

The TACC for STA 8 increased from 22 t to 50 t in the 1993–94 fishing year under the AMP. Landings increased to 18 t in 1991–92 but have since declined to less than 5 t. The TACC was reduced back to 22 t in 1997, upon the removal of STA 8 from the programme. It is not known if recent catch levels and current TACC are sustainable. The status of STA 8 relative to B_{MSY} is unknown.

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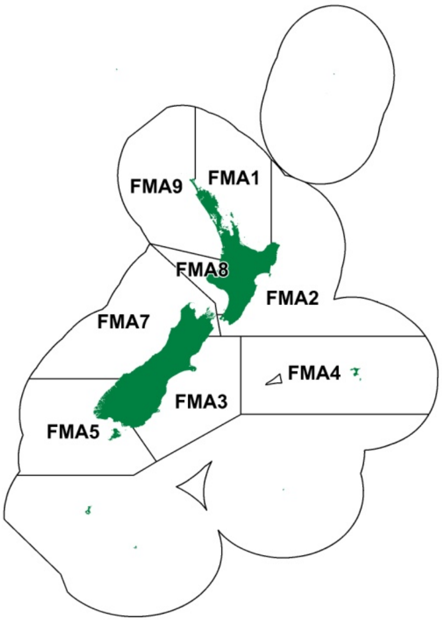
SURF CLAMS

Surf clam is a generic term used here to cover the following seven species:

Deepwater tuatua	*Paphies donacina*	(PDO)
Fine (silky) dosinia	*Dosinia subrosea*	(DSU)
Frilled venus shell	*Bassina yatei*	(BYA)
Large trough shell	*Mactra murchisoni*	(MMI)
Ringed dosinia	*Dosinia anus*	(DAN)
Triangle shell	*Spisula aequilatera*	(SAE)
Trough shell	*Mactra discors*	(MDI)

The same FMAs apply to all these species and this introduction will cover issues common to all of these species.



1. INTRODUCTION

All surf clams were introduced into the Quota Management System on 1 April 2004. The fishing year is from 1 April to 31 March and commercial catches are measured in greenweight. There is no minimum legal size (MLS) for surf clams. Surf clams are managed under Schedule 6 of the Fisheries Act 1996. This allows them to be returned to the sea soon after they are taken, provided they are likely to survive.

Commercial surf clam harvesting before 1995–96 was managed using special permits. From 1995–96 to 2002–03 no special permits were issued because of uncertainty about how best to manage these fisheries. Fishing subsequently resumed.

New Zealand operates a mandatory shellfish quality assurance programme for all bivalve shellfish grown and harvested in areas for human consumption. Shellfish caught outside this programme can only be sold for bait. This programme is based on international best practice and is managed by New Zealand Food Safety, in cooperation with the District Health Board Public Health Units and the shellfish industry[1]. This involves surveying the water catchment area for pollution, sampling water and shellfish microbiologically over at least 12 months, classifying and listing areas for harvest, regular monitoring

[1] For full details of this programme, refer to the Animal Products (Regulated Control Scheme-Bivalve Molluscan Shellfish) Regulations 2006 and the Animal Products (Specifications for Bivalve Molluscan Shellfish) Notice 2006 (both referred to as the BMSRCS) at: http://www.nzfsa.govt.nz/industry/sectors/seafood/bms/page-01.htm

of the water and shellfish, biotoxin testing, and closure after rainfall and when biotoxins are detected. Products are traceable by source and time of harvest in case of contamination.

2. BIOLOGY

Three families of surf clams dominate the biomass in different regions of New Zealand. At the northern locations, the venerids *D. anus* and *D. subrosea* make up the major proportion of the surf clam biomass, and *D. anus* is abundant at all other North Island locations. The mactrids and mesodesmatid become increasingly abundant south of Ohope (Bay of Plenty). The mesodesmatid *P. donacina* is most abundant around central New Zealand from Nuhaka on the east coast south to the Kapiti Coast, Cloudy Bay, and as far south as Pegasus Bay. The mactrids *M. murchisoni* and *M. discors* dominate in southern New Zealand (Blueskin Bay, Te Waewae, and Oreti), where they account for more than 80% of the total biomass (Cranfield et al 1994, Cranfield & Michael 2001).

Each species grows to a larger size in the South Island than in the North Island (Cranfield & Michael 2002). Growth parameters are available for many surf clam species from up to two locations. Length frequencies of sequential population samples were analysed by Cranfield et al (1993) using MULTIFAN to estimate the von Bertalanffy growth parameters (Table 1). MULTIFAN simultaneously analyses multiple sets of length frequency samples using a maximum likelihood method to estimate the proportion of clams in each age class and the von Bertalanffy growth parameters (see Fournier et al 1990, and Francis & Francis 1992).

Incremental growth of recaptured marked clams at Cloudy Bay was analysed using GROTAG to confirm the MULTIFAN estimates (Cranfield et al 1993). GROTAG uses a maximum-likelihood method to estimate growth rate (Francis 1988, Francis & –Francis 1992). The estimates and annual mean growth estimates at lengths α and β are shown in Table 2.

Table 1: Von Bertalanffy growth parameter estimates from Cranfield et al (1993) for surf clams estimated using MULTIFAN (SE in parentheses). – Indicates where estimates were not generated.

Stock	Site	L_∞ (mm)	K
BYA 7	Cloudy Bay	–	–
BYA 8	Kapiti Coast	–	–
DAN 7	Cloudy Bay	0.10 (0.03)	77.5 (0.71)
DAN 8	Kapiti Coast	0.13 (0.02)	58.7 (0.28)
DSU 7	Cloudy Bay	–	–
DSU 8	Kapiti Coast	–	–
MDI 7	Cloudy Bay	0.41 (0.03)	68.0 (0.35)
MDI 8	Kapiti Coast	0.42 (0.02)	56.0 (0.95)
MMI 7	Cloudy Bay	0.57 (0.01)	88.0 (0.44)
MMI 8	Kapiti Coast	0.35 (0.01)	75.2 (0.30)
PDO 7	Cloudy Bay	0.33 (0.01)	94.1 (0.29)
PDO 8	Kapiti Coast	–	–
SAE 7	Cloudy Bay	1.01 (0.02)	60.3 (0.92)
SAE 8	Kapiti Coast	0.80 (0.03)	52.1(0.25)

The maximum ages for these species were estimated from the number of age classes indicated in MULTIFAN analyses, and from shell sections. Estimates of natural mortality come from age estimates (Table 3). Higher mortality is seen where the surf clams are subject to higher wave energies, e.g., *S. aequilatera* and *M. murchisoni* are distributed within the primary wave break and hence show higher mortality (Cranfield et al 1993). Kapiti shells show higher mortality than Cloudy Bay, perhaps because these shells have a higher chance of being eroded out of the bed by storms because the Kapiti Coast is more exposed (Cranfield et al 1993). Surf clam populations are subject to catastrophic mortality from erosion during storms, high temperatures and low oxygen levels during calm summer periods, blooms of toxic algae, and excessive freshwater outflow (Cranfield & Michael 2001).

Less confidence should be placed in the estimates from MULTIFAN for Cloudy Bay relative to the Kapiti Coast because there was a small sample size at Cloudy Bay and a lack of juveniles.

Table 2: Mean annual growth estimates (mm/year) at lengths α and β (95% confidence intervals in parentheses for mean growth values) from Cloudy Bay (Cranfield et al 1996). L^* is the transitional length, at which point the model allows an asymptotic reduction in growth rate and values of L_∞ are included for reference.

Species	α (mm)	g_α (mm year^{-1})	β (mm)	g_β (mm year^{-1})	L^* (mm)	L_∞ (mm)	Residual error (mm)
Paphies donacina	50.0	10.26 (9.7 – 10.8)	80.0	1.41 (1.1 – 1.7)	80.0	84.8	1.25
Spisula aequilatera	30.0	22.71 (22.2 – 23.0)	50.0	6.23 (6.0 – 6.4)	55.0	57.6	2.04
Mactra murchisoni	40.0	17.83 (17.4 – 18.2)	70.0	4.65 (4.3 – 4.9)	80.0	80.6	1.42
Mactra discors	35.0	11.01 (10.5 – 11.7)	55.0	2.69 (2.4 – 2.9)	62.0	61.5	0.63
Dosinia anus	20.0	12.5 (12.0 – 13.2)	55.0	1.99 (1.8 – 2.2)	63.0	61.6	0.44

Table 3: Estimates of the instantaneous natural mortality rate, M. A = minimum number of year classes indicated by MULTIFAN; B = maximum age indicated by shell sections; M1 = mortality range estimated from using two equations: $lnM = 1.23\text{-}0.832\ln(t_{max})$ and $1nM = 1.44\text{-}0.9821n(t_{max})$, (Hoenig 1983); M2 mortality estimated from $M = \ln100/(t_{max})$; t_{max} is the estimate of maximum age.

	A	B	M1	M2
Cloudy Bay				
	A	B	M1	M2
Mactra murchisoni	8	11	0.40–0.46	0.42
Mactra discors	7	14	0.32–0.38	0.33
Spisula aequilatera	5	7	0.63–0.68	0.66
Paphies donacina	10	17	0.26–0.32	0.27
Dosinia anus	16	22	0.20–0.26	0.21
Kapiti Coast				
	A	B*	M1	M2
Mactra murchisoni	8	11	0.40–0.46	0.42
Mactra discors	8	16	0.28–0.34	0.29
Spisula aequilatera	3	5	0.87–0.89	0.92
Paphies donacina†				
Dosinia anus	19	26	0.17–0.23	0.18

*Shell sections not yet examined. Ages are inferred from Cloudy Bay data.
†Growth data could not be analysed.

3. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was new for the May 2011 Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of the surf clam fisheries; a more detailed summary from an issue-by-issue perspective is available in the Aquatic Environment and Biodiversity Annual Review.

3.1 Ecosystem role

Only two published papers examine aspects of the role of surf clams in the ecosystem in New Zealand. Predation of *Dosinia* spp. by rock lobsters has been documented from the reef/soft sediment interface zones (Langlois et al 2005, Langlois et al 2006), notably surf clams are usually harvested from exposed beaches, not reef/soft sediment interface zones.

Surf clams are filter-feeders; recent research suggests that most of their food is obtained from microalgae from the top 2 cm of the sediment and the bottom 2–3 cm of the water column (Sasaki et al 2004). The effects of predation are difficult to study on exposed sandy beaches and it is believed internationally that there are no keystone species in this environment and predation is not important in structuring the community (McLachlan & Brown 2006).

3.2 Fishery interactions (fish and invertebrates)

The only bycatch caught in large quantities associated with surf clam dredging in New Zealand is *Fellaster zelandiae* — the sand dollar or sea biscuit (Haddon et al 1996). Other species caught in association with surf clams include paddle crabs (*Ovalipes catharus*), a number of bivalves including the lance shell (*Resania lanceolata*), otter clams (*Zenatia acinaces*), battle axe (*Myadora striata*), olive tellinid (*Hiatula nitidia*), the wedge shell (*Peronaea gairmadi*), and the gastropods the olive shell (*Baryspira australis*) and ostrich foot shell (*Struthiolaria papulosa*). Fish are rarely caught, but include juvenile common soles (*Peltorhamphus novaezeelandiae*) and stargazers (*Kathetostoma* spp.) (NIWA, unpublished data).

3.3 Fishery interactions (seabirds and mammals)
Not relevant to surf clam fisheries.

3.4 Benthic impacts
Surf clams mainly inhabit the surf zone, a high-energy environment characterised by high sand mobility (Michael et al 1990). Divers observed that the rabbit dredge (which has been used for surf clam surveys) formed a well-defined track in the substrate, but within 24 hours the track was could not be distinguished, indicating that physical recovery of the substrate was rapid (Michael et al 1990). Commercially, a different dredge is used and its impacts should theoretically be less, but the impacts of this dredge have not been tested. Shallow water environments such as the surf zone or those subjected to frequent natural disturbance tend to recover faster from the effects of mobile fishing gears compared with those in deeper water (Kaiser et al 1996, Collie et al 2000, Hiddink et al 2006, Kaiser et al 2006).

Surf clam species show zonation by substrate type which is generally, although not always, correlated with depth and wave exposure. Species with good burrowing ability are generally found in shallow, mobile sediment zones (for example, *Paphies donacina*), and those species less able to burrow (for example, *Dosinia subrosea* and *Bassina yatei*) are generally found in softer, more stable sediments. The present high-value species (*Spisula aequilatera, Mactra murchisoni*, *Paphies donacina* and *Mactra discors*) generally occur in shallower zones. Mobile fishing gear effects will be primarily determined by the characteristics of the beach and target species. Little fishing presently takes place in the most vulnerable areas characterised by stable, soft fine sediment communities.

An Italian study showed that widespread intensive hydraulic dredging can adversely modify some depths within this environment (4–6 m), although recovery in this study occurred within 6 months (Morello et al 2006). The applicability of this study's finding to New Zealand is unknown.

3.5 Other considerations
None.

3.6 Key information gaps
The impacts of widespread and intensive dredging in New Zealand, which is not presently occurring, are unknown.

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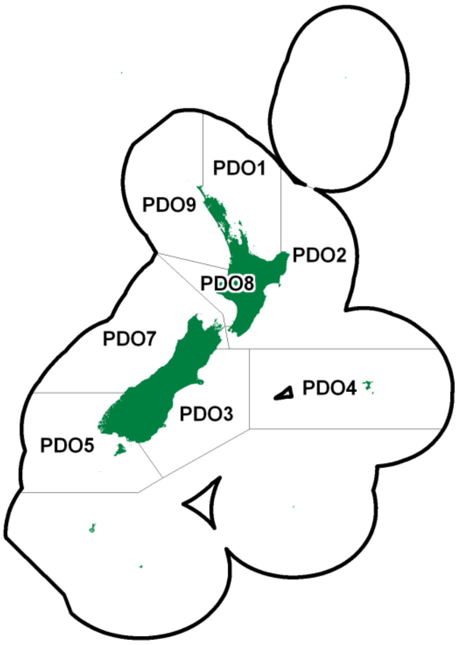
DEEPWATER TUATUA (PDO)

(*Paphies donacina*)
Tuatua



1. FISHERY SUMMARY

This species is part of the surf clam fishery and the reader is guided to the surf clam introductory chapter for information common to all relevant species.

1.1 Commercial fisheries

Deepwater tuatua (*Paphies donacina*) were introduced into the Quota Management System on 1 April 2004 with a total TACC of 168 t. Biomass surveys in QMA 2 supported a TAC increase from April 2010. This increased the TAC for PDO from 2 t to 509 t. In April 2013 a biomass survey in QMA 8 supported a further increase. This increased the TAC in PDO 8 from 19 t to 296 t and the total PDO TAC from 791 t to 1215 t. An additional biomass survey supported an increase in the TAC of PDO 7 in April 2016 to 200 t and the national TAC of PDO to 1215 t (Table 1).

Table 1: Current TAC, TACC, and allowances for other sources of mortality for *Paphies donacina*.

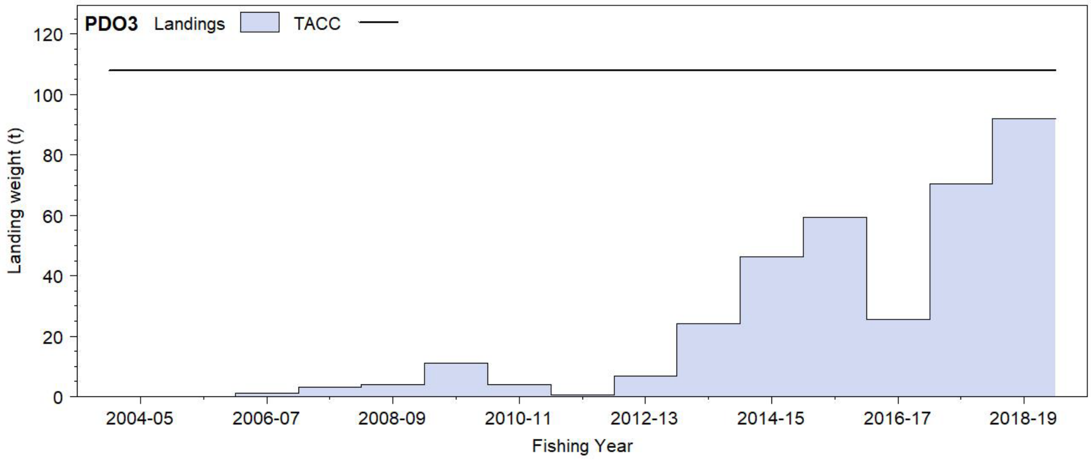
QMA	TAC (t)	TACC (t)	Recreational catch	Customary catch	Other sources of mortality (t)
1	1	1	0	0	0
2	509	466	9	9	25
3	150	108	21	21	0
4	3	1	1	1	0
5	3	1	1	1	0
7	200	184	1	5	10
8	296	262	9	10	15
9	53	1	26	26	0
Total	1 215	1 024	68	73	50

Reported landings and TACCs are shown for Fishstocks with historical landings in Table 2 and in Figure 1 for PDO 3 and PDO 7. Landings have been reported from PDO 3, PDO 5, PDO 7, and PDO 8. Between the years 1992–93 and 1995–96, reported landings ranged from a few kilograms to about 6 t; no further landings were reported until 2002–03. Reported total landings subsequently varied, with recent years showing a marked upward trend in PDO 3, PDO 7, and PDO 8 landings. Landings in PDO 3 ranged from 0.0 t to 11.21 t between 2006–07 and 2012–13 and increased to 92.12 t in 2018–19. Since 2002–03, landings in PDO 7 have ranged between 2.2 t and 182 t (in 2016–17). Less than one tonne has been landed in PDO 5. Total PDO landings peaked at 282 t in 2018–19, with over 50% of catches originating in PDO 7.

Table 2: TACCs and reported landings (t) of deepwater tuatua by Fishstock from 1992–93 to the present day from CELR and CLR data. PDO areas where catch has never been reported are not tabulated. See Table 1 for TACC of stocks not landed.

	PDO 3		PDO 5		PDO 7		PDO 8		Total	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1992–93	0	–	0	–	0.29	–	0	–	0.29	–
1993–94	0	–	0.005	–	3.38	–	0	–	3.38	–
1994–95	0	–	0	–	5.04	–	0	–	5.04	–
1995–96	4.44	–	0	–	1.67	–	0	–	6.11	–
1996–97	0	–	0	–	0	–	0	–	0	–
1997–98	0	–	0	–	0	–	0	–	0	–
1998–99	0	–	0	–	0	–	0	–	0	–
1999–00	0	–	0	–	0	–	0	–	0	–
2000–01	0	–	0	–	0	–	0	–	0	–
2001–02	0	–	0	–	0	–	0	–	0	–
2002–03	0	–	0	–	2.25	–	0	–	2.25	–
2003–04	0	108	0	1	10.14	50	0	1	10.14	168
2004–05	0	108	0	1	12.53	50	0	1	12.69	168
2005–06	0	108	0	1	10.63	50	0.148	1	13.73	168
2006–07	1.17	108	0	1	20.00	50	0	1	21.16	168
2007–08	3.17	108	0	1	21.15	50	0	1	24.32	168
2008–09	4.09	108	0	1	4.32	50	0	1	8.41	168
2009–10	11.21	108	0	1	1.50	50	0	1	12.71	168
2010–11	3.93	108	0	1	38.80	50	0	1	42.73	629
2011–12	0	108	0	1	17.10	50	0	1	17.05	629
2012–13	6.95	108	0	1	30.13	50	0	1	37.08	629
2013–14	24.16	108	0	1	39.12	50	0	262	63.28	890
2014–15	46.22	108	0	1	54.01	184	0	262	112.91	890
2015–16	59.49	108	0	1	98.03	184	2.22	262	207.44	890
2016–17	25.61	108	0	1	182.12	184	8.61	262	214.34	890
2017–18	70.48	108	0	1	180.40	184	8.42	262	259.30	890
2018–19	92.12	108	0	1	159.20	184	30.79	262	282.11	890

*In 2004–05 and 2005–06, 0.16 and 2.953 t respectively were reportedly landed, but the QMA was not recorded. These amounts are included in the total landings for those years.



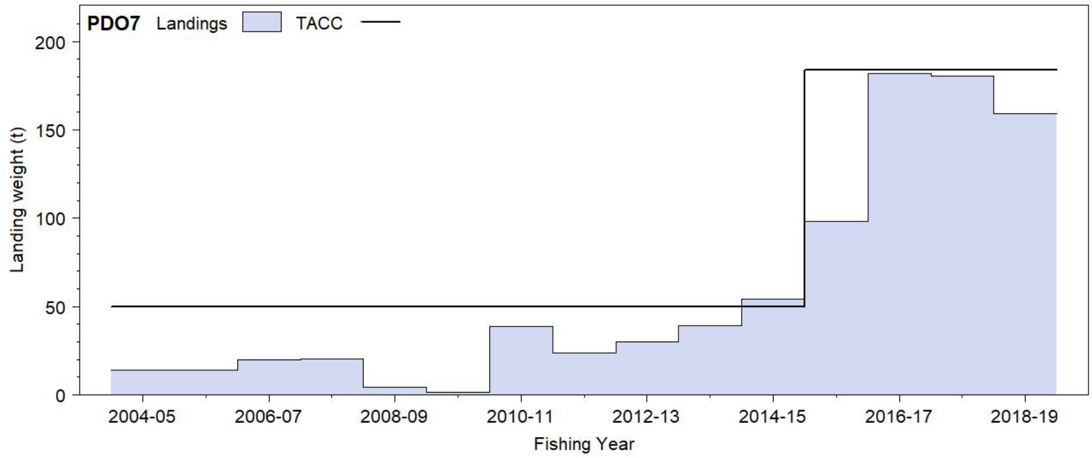


Figure 1: Reported commercial catch and TACC for the two main PDO stocks from when the TACC was introduced in the 2004–05 fishing year to 2018-19: PDO3 (South-East Coast) and PDO7 (Challenger).

1.2 Recreational fisheries
Deepwater tuatua inhabit the shallowest part of the subtidal zone compared with other surf clams, and therefore are potentially the most vulnerable to shore-based harvesting. However, neither the telephone-diary surveys in the 1990s nor the two National Panel Surveys in 2011–12 (Wynne-Jones et al 2014) and in 2017–18 (Wynne-Jones et al 2019) differentiated species of tuatua, and the harvest is thought to comprise mostly intertidal tuatua *P. subtriangulata* (Cranfield & Michael 2001). On beaches where *P. donacina* extends to just below low water, some recreational catch of this species may occur during spring low tides.

1.3 Customary fisheries
P. donacina is an important handpicked resource of local iwi, especially in Pegasus Bay, Canterbury. Extremely limited quantitative information on the level of customary take is available from Fisheries New Zealand (Table 3). These numbers are likely to be an underestimate of customary harvest because only the numbers are reported in the table.

Table 3: Fisheries New Zealand records of customary harvest of deepwater tuatua in PDO 2 (reported in numbers), between 2011–12 and 2013–14. No records since. – no data.

	PDO 2 Numbers	
Fishing year	**Approved**	**Harvested**
2011–12	2 000	500
2012–13	–	–
2013–14	1 000	390

1.4 Illegal catch
There is no documented illegal catch of this clam.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality, although this clam is subject to localised catastrophic mortality from erosion during storms, high temperatures and low oxygen levels during calm summer periods, blooms of toxic algae, and excessive freshwater outflow (Cranfield & Michael 2001).

2. BIOLOGY

P. donacina occurs mainly around the lower half of the North Island, the South Island, and Stewart Island. It is found from low tide to about 4 m depth, although juveniles may extend to the mid-tide mark. Maximum length is variable between areas, ranging from 73 mm to 109 mm (Cranfield et al 1993). The sexes are separate and they are broadcast spawners; the larvae are thought to be planktonic for between 18 and 21 days (Cranfield et al 1993). Settlement and early juveniles occur in the intertidal zone; these animals are mobile and migrate offshore as they grow. The deepwater tuatua (*Paphies donacina*) showed seasonal adjustment in its oxygen uptake and filtration rates to compensate for seasonal temperature variation in the habitat (Marsden 1999).

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, the boundaries of stocks of surf clams are likely to be the continuous lengths of exposed sandy beaches between geographical features (rivers, headlands, etc.). Circulation patterns may isolate surf clams genetically as well as ecologically.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

For further information on environmental and ecosystem considerations refer to the Surf Clam Working Group Report.

5. STOCK ASSESSMENT

MCY is estimated from the survey biomass estimates. All stocks were considered as an effectively virgin state in 1993–94 when the initial biomass estimates were made (Cranfield et al 1993).

5.1 Estimates of fishery parameters and abundance

No fisheries parameters or abundance estimates are available for any deepwater tuatua stocks.

5.2 Biomass estimates

Biomass has been estimated for PDO 2, 3, 7 and 8 at various times during 1994 to 2015. A stratified random survey using a hydraulic dredge was employed for all these surveys. Survey size has been expressed either as length of beach (Table 3), or as area (Table 4), which makes comparisons difficult.

Table 3: A summary of biomass estimates in tonnes green weight (with standard deviation in parentheses) from exploratory surveys of Cloudy Bay, Marlborough (Cranfield et al 1994b, White et al 2015, respectively), Clifford Bay, Marlborough (Michael et al 1994), Foxton Beach, Manawatu coast (White et al 2012), and Rabbit Island, Nelson (Michael & Olsen 1988).

Area	Cloudy Bay (PDO 7)	Clifford Bay (PDO 7)	Foxton Beach (PDO 8)	Rabbit Island (PDO 7)
Length of beach (km)	11, 11	21	46	8
Biomass (t)	154 (60), 1541 (247)	284 (123)	3289 (546)	108

Table 4: A summary of biomass estimates in tonnes green weight from the surveys in PDO 2 and 3 (Triantifillos 2008a, 2008b). Note: unless otherwise stated the CV is less than 20%.

Location	Five sites (PDO 2)	Ashley River to 6 n.mile south of the Waimakariri River (PDO 3)
Area surveyed (km^2)	28.0	13.4
Biomass (t)	5651.8	320.8

5.3 Yield estimates and projections

Estimation of Maximum Constant Yield (*MCY*)

Growth and mortality data from Cloudy Bay, Marlborough and the Kapiti Coast, Manawatu (Cranfield et al 1993) have been used in a yield per recruit model to estimate the reference fishing mortality $F_{0.1}$ (Cranfield et al 1994b). The Shellfish Working Group (SFWG) did not accept these estimates of $F_{0.1}$ because there was considerable uncertainty in both the estimates and the method used to generate them. The *MCY* estimates of Triantifillos (2008a, 2008b) and White et al (2012, 2015) used the full range of $F_{0.1}$ estimates from Cranfield et al (1993) and are shown in Table 5. Estimates of *MCY* are available from numerous locations and were calculated using Method 1 for a virgin fishery (Ministry for Primary Industries 2015) with an estimate of virgin biomass B_0, where:

$$MCY = 0.25 \times F_{0.1}\ B_0$$

The SFWG recommended that *MCY* estimates are adequate to use to inform management decisions relevant to all surf clam fisheries, with the following caveats: 1) due to the uncertainty in $F_{0.1}$ values, for all species other than SAE, the *MCY* estimates should use the $F_{0.1}$ values toward the higher end of the range, and 2) there is a need to account for any substantial catch that has already come out of any surf clam fishery when estimating *MCY*; however there was no consensus on the best way to do this.

Table 5: Mean *MCY* estimates (t) for *P. donacina* from virgin biomass at locations sampled around New Zealand (Triantifillos 2008a, 2008b; White et al 2012, 2015). The two $F_{0.1}$ values, which are subsequently used to estimate *MCY*, are the minimum and maximum estimates from Cranfield et al. (1993).

Location	$F_{0.1}$	*MCY*
Five sites (PDO 2)	0.36/0.52	508.7/734.7
Ashley River to 6 n. mile south of the Waimakariri River (PDO 3)	0.36/0.52	28.9/41.7
Foxton Beach (PDO 8)	0.36/0.52	296.1/427.6
Cloudy Bay (PDO 7)	0.36/0.52	138.7/200.3

Estimation of Current Annual Yield (*CAY*)
CAY has not been estimated for *P. donacina*.

The SFWG recommended moving all surf clam fisheries away from an *MCY* management strategy and towards an exploitation rate management strategy. The SFWG recognised that an exploitation rate approach is more survey intensive, but better allows for the variable nature of biomass for surf clams because it allows greater flexibility in catch (to take greater landings from available biomass) whilst keeping catches sustainable.

6. STATUS OF THE STOCKS

- PDO 2 & 8 - *Paphies donacina*

Stock Status	
Year of Most Recent Assessment	2008 for PDO 2 and 2012 for PDO 8
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Because of the relatively low levels of exploitation of *P. donacina*, it is likely that PDO 2 and 8 stocks are still effectively in a virgin state, therefore they are Very Likely (> 90%) to be at or above the target.
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Fishing is minimal
Other Abundance Indices	-
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	For all stocks current catches are Very Unlikely (< 10%) to cause declines below soft or hard limits in the short to medium term.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2008 for PDO 2 and 2012 for PDO 8	Next assessment: Unknown
Overall assessment quality rank	-	

Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review the fishery parameters for this species.

Fishery Interactions
PDO can be caught together with other surf clam species and non-QMS bivalves.

- PDO 3

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Unknown in 2018-19 as the available information in too out of date to inform stock status
Status in relation to Limits	Unknown in 2018-19 as the available information in too out of date to inform stock status
Status in relation to Overfishing	Unknown in 2018-19 as the available information in too out of date to inform stock status

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Catches in PDO 3 have ranged from 0 to 11.21 t between 2006–07 and 2012-13 and overall increased since to reach 92.12 t in 2018-19.
Other Abundance Indices	-
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	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2008	Next assessment: Unknown
Overall assessment quality rank	-	

Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review the fishery parameters for this species.

Fishery Interactions
PDO can be caught together with other surf clam species and non-QMS bivalves.

- **PDO 7**

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Very Likely (> 90%) to be at or above the target
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Intensity or Proxy	Fishing has increased from 17.10 t in 2011-12 to 182.12 t in 2016-17 and reduced to 159.2 t in 2018-19.
Other Abundance Indices	-
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	Current catches at the TACC are Very Unlikely (< 10%) to cause declines below soft or hard limits.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2015	Next assessment: Unknown
Overall assessment quality rank		

Main data inputs (rank)	- Abundance and length frequency information	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review the fishery parameters for this species.

Fishery Interactions
PDO can be caught together with other surf clam species and non-QMS bivalves.

7. FOR FURTHER INFORMATION

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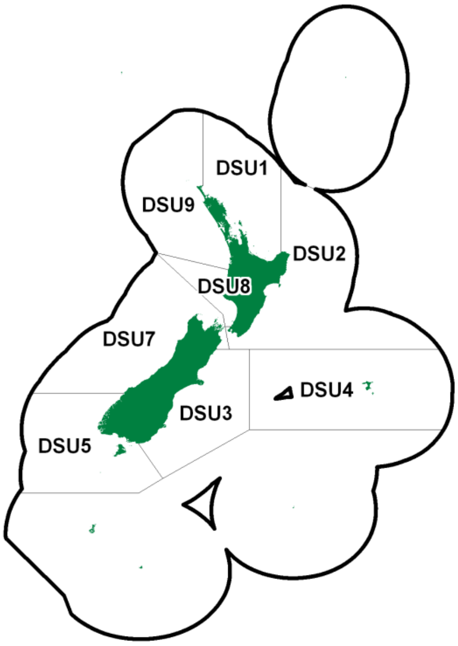
FINE (SILKY) DOSINIA (DSU)

(*Dosinia subrosea*)



1. FISHERY SUMMARY

This species is part of the surf clam fishery and the reader is guided to the surf clam introductory chapter for information common to all relevant species.

Fine Dosinia (*Dosinia subrosea*) were introduced into the Quota Management System on 1 April 2004 with a TAC of 8 t and TACC of 8 t (Table 1). There were no allowances for customary, recreational, or other sources of mortality and no changes to any of these values have occurred since.

Table 1: Current TAC and TACC for *Dosinia subrosea*.

QMA	TAC (t)	TACC (t)
1	1	1
2	1	1
3	1	1
4	1	1
5	1	1
7	1	1
8	1	1
9	1	1
Total	8	8

1.1 Commercial fisheries

Landings have only ever been reported from DSU 1 and DSU 7. In 1993–94 total landings were 235 kg, with half originating in DSU 1, and half originating in DSU 7. In 1994–95 and 1995–96 reported landings came entirely from DSU 7, with 26 kg and 38 kg recorded respectively. No further landings were reported until after 2002–03. In 2003–04 total landings of 89 kg were recorded, which increased to 110 kg in 2004–05, and 169 kg in 2005–06. By the 2006–07 fishing year, only 3 kg of landings were reported, and after the 2008–09 fishing year landings ceased completely (Table 2).

Table 2: TACCs and reported landings (t) of *Dosinia subrosea* by Fishstock from 1993–94 to the present day from CELR and CLR data for Fishstocks where landings have been reported. See Table 1 for TACC of stocks not landed. [Continued on next page]

Fishing	DSU 1		DSU 7		Total	
year	Landings	TACC	Landings	TACC	Landings	TACC
1993–94	0.123	-	0.112	-	0.235	-
1994–95	0	-	0.026	-	0.026	-

Table 2 [Continued]

Fishing year	DSU 1 Landings	DSU 1 TACC	DSU 7 Landings	DSU 7 TACC	Total Landings	Total TACC
1995–96	0	-	0.011	-	0.038	-
1996–97	0	-	0	-	0	-
1997–98	0	-	0	-	0	-
1998–99	0	-	0	-	0	-
1999–00	0	-	0	-	0	-
2000–01	0	-	0	-	0	-
2001–02	0	-	0	-	0	-
2002–03	0	-	0	-	0	-
2003–04	0	1.0	0.089	1.0	0.089	-
2004–05	0	1.0	0.078	1.0	0.110*	8.0
2005–06	0	1.0	0.061	1.0	0.169*	8.0
2006–07	0	1.0	0.003	1.0	0.003	8.0
2007–08	0	1.0	0	1.0	0	8.0
2008–09	0	1.0	0.001	1.0	0.001	8.0
2009–10	0	1.0	0	1.0	0	8.0
2010–11	0	1.0	0	1.0	0	8.0
2011–12	0	1.0	0	1.0	0	8.0
2012–13	0	1.0	0	1.0	0	8.0
2013–14	0	1.0	0	1.0	0	8.0
2014–15	0	1.0	0	1.0	0	8.0
2015–16	0	1.0	0	1.0	0	8.0
2016–17	0	1.0	0	1.0	0	8.0
2017–18	0	1.0	0	1.0	0	8.0
2018–19	0	1.0	0	1.0	0	8.0

*In 2004–05 and 2005–06 32.4 and 90 kg were reported but the QMA was not recorded. This amount is included in the total landings for these years.

1.2 Recreational fisheries
There are no known records of recreational use of this surf clam.

1.3 Customary fisheries
Offshore clams such as *D. subrosea* are likely to have been harvested for customary use only when washed ashore after storms (Carkeek 1966). There are no estimates of current customary use of this clam.

1.4 Illegal catch
There is no known illegal catch of this clam.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality, although this clam is probably sometimes taken as a bycatch in inshore trawling. Harvesters claim that the hydraulic clam rake does not damage surf clams and minimises damage to the few species of other macrofauna captured. Surf clam populations are also subject to localised catastrophic mortality from erosion during storms, high temperatures and low oxygen levels during calm summer periods, blooms of toxic algae, and excessive freshwater outflow (Cranfield & Michael 2001).

2. BIOLOGY

D. subrosea has not been found in high densities in any survey work. It is found around the New Zealand coast in deeper softer sediment habitats. Around the North Island it is found between 6 m and 10 m in depth, and around the South Island between 5 m and 8 m (Cranfield & Michael 2002). It is smaller and smoother than *D. anus* and is usually found in more stable habitats. Maximum length is variable between areas, ranging from 41 mm to 68 mm (Cranfield et al 1993). The sexes are believed to be separate, and they are likely to be broadcast spawners with planktonic larvae (Cranfield & Michael 2001). Anecdotal evidence suggests that spawning is likely to occur in the summer months. Recruitment of surf clams is thought to be highly variable between years.

For information on growth, age, and natural mortality of this species and general statements about relative biomass of all surf clam species around the country (excluding *Bassinia yatei)* see the introductory surf clam chapter.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, the boundaries of stocks of surf clams are likely to be the continuous lengths of exposed sandy beaches between geographical features (such as rivers and headlands). Circulation patterns may isolate surf clams genetically as well as ecologically.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

See the introductory surf clam chapter.

5. STOCK ASSESSMENT

All stocks are considered in effectively virgin state and an *MCY* is estimated from the survey biomass estimates. All stocks were considered in an effectively virgin state in 1993–94 when the initial biomass estimates were made (Cranfield et al 1993). Total catches of DSU have not exceeded 1 t in any Fishstock since then.

5.1 Estimates of fishery parameters and abundance

No fisheries parameters or abundance estimates are available for any DSU stocks.

5.2 Biomass estimates

Biomass has been estimated from 11 km of beach at Cloudy Bay (DSU 7) with a stratified random survey using a hydraulic dredge (Cranfield et al 1994b). The virgin biomass for this area was estimated to be 21 t. Subsequent surveys estimated biomass from one site in DSU 3 and a number of sites in DSU 2 (Table 3).

Table 3: A summary of biomass estimates greenweight (t) from the surveys in DSU 2 and 3 (Triantifillos 2008a, Triantifillos 2008b). Note: unless otherwise stated the CV is less than 0.2.

Location	Five sites (DSU 2)	Ashley River to 6 n. mile south of the Waimakariri River (DSU 3)
Area surveyed (km^2)	28.0	13.4
Biomass (t)	5.9	12.2*

* CV is 0.29.

5.3 Yield estimates and projections

Estimation of Maximum Constant Yield (*MCY*)

Growth and mortality data from Cloudy Bay in Marlborough and the Kapiti Coast in Manawatu (Cranfield et al 1993) have been used in a yield per recruit model to estimate the reference fishing mortality $F_{0.1}$ (Cranfield et al 1994b, Triantifillos 2008a, 2008b). The Shellfish Working Group (SFWG) did not accept these estimates of $F_{0.1}$ because there was considerable uncertainty in both the estimates and the method used to generate them. The *MCY* estimates of Triantifillos (2008b) that use the full range of $F_{0.1}$ estimates from Cranfield et al (1993) are shown in Table 4, but should be interpreted with caution.

Estimates of *MCY* were calculated using Method 1 for a virgin fishery (Annala et al 2001) with an estimate of virgin biomass B_0, where:

$$MCY = 0.25 * F_{0.1} B_0$$

Table 4: Mean *MCY* estimates (t) for *D. subrosea* from virgin biomass at DSU 2 (Triantifillos 2008a, 2008b). The two $F_{0.1}$ values, which are subsequently used to estimate MCY, are the minimum and maximum estimates from Cranfield et al. (1993).

Location	$F_{0.1}$	***MCY***
Five sites (DSU 2)	0.27/0.54	0.4/0.8

Estimation of Current Annual Yield (*CAY*)

CAY has not been estimated for *D. subrosea*.

The SFWG recommended moving all surf clam fisheries away from an *MCY* management strategy and towards an exploitation rate management strategy. The SFWG recognised that an exploitation rate approach is more survey intensive, but better allows for the variable nature of biomass for surf clams because it allows greater flexibility in catch (to take greater landings from available biomass) whilst keeping catches sustainable.

6. STATUS OF THE STOCKS

- DSU-*Dosinia subrosea*

There is no evidence of appreciable biomass of this species in any area.

7. FOR FURTHER INFORMATION

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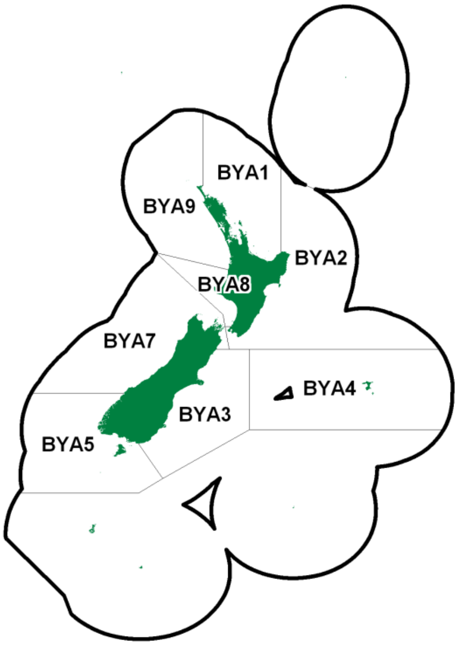
FRILLED VENUS SHELL (BYA)

(*Bassina yatei*)



1. FISHERY SUMMARY

This species is part of the surf clam fishery and the reader is guided to the surf clam introductory chapter for information common to all relevant species.

1.1 Commercial fisheries

The frilled venus shell (*Bassina yatei*) was introduced into the Quota Management System on 1 April 2004 with a combined TAC of 16 t and a TACC of 16 t. There were no allowances for customary, recreational, or other sources of mortality. These limits have not been changed (Table 1).

Table 1: Current TAC and TACC for *Bassina yatei*.

QMA	TAC (t)	TACC (t)
1	1	1
2	1	1
3	1	1
4	1	1
5	1	1
7	9	9
8	1	1
9	1	1
Total	16	16

Small BYA 7 landings (all around 1 t or less) were reported from 1992–93 to 1994–95, 2001–02 to 2004–05, 2008–09, and 2011–12 to 2015–16, and landings of over 7 t were reported from BYA 1 in 2002–03 (Table 2). No frilled venus shell landings have been recorded since the fishing year 2015–16.

Table 2: TACCs and reported landings (t) of frilled venus shell by Fishstock from 1992–93 to 2018–19 from CELR and CLR data. See Table 1 for TACC of stocks not landed. [Continued on next page]

Fishing	BYA 1		BYA 7		Total	
year	Landings	TACC	Landings	TACC	Landings	TACC
1992–93	0	–	0.026	–	0.026	–
1993–94	0	–	0.007	–	0.007	–
1994–95	0	–	0.001	–	0.001	–
1995–96	0	–	0	–	0	–
1996–97	0	–	0	–	0	–

*

Table 2 [Continued]

Fishing	BYA 1		BYA 7		Total	
year	Landings	TACC	Landings	TACC	Landings	TACC
1997–98	0	–	0	–	0	–
1998–99	0	–	0	–	0	–
1999–00	0	–	0	–	0	–
2000–01	0	–	0	–	0	–
2001–02	7.473	–	0.049	–	7.522	–
2002–03	0	–	1.132	9	1.132	–
2003–04	0	1	1.295	9	1.296	–
2004–05	0	1	0.207	9	0.207	16
2005–06*	0	1	0	9	0.036*	16
2006–07	0	1	0	9	0	16
2007–08	0	1	0	9	0	16
2008–09	0	1	0.003	9	0.003	16
2009–10	0	1	0	9	0	16
2010–11	0	1	0	9	0	16
2011–12	0	1	0.350	9	0.350	16
2012–13	0	1	1.174	9	1.174	16
2013–14	0	1	1.106	9	1.106	16
2014–15	0	1	0.931	9	0.931	16
2015–16	0	1	0.998	9	0.998	16
2016–17	0	1	0	9	0	16
2017–18	0	1	0	9	0	16
2018–19	0	1	0	9	0	16

In 2005–06 36.4 kg were reportedly landed, but the QMA was not recorded. This amount is included in the total landings for that year.

1.2 Recreational fisheries
There are no known records of recreational use of this surf clam.

1.3 Customary fisheries
Offshore clams such as *B. yatei* are likely to have been harvested for customary use only when washed ashore after storms. Shells of this clam have been found irregularly and in small numbers in a few middens. There are no estimates of current customary use of this clam.

1.4 Illegal catch
There is no documented illegal catch of this clam.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality, although this clam is subject to localised catastrophic mortality from erosion during storms, high temperatures and low oxygen levels during calm summer periods, blooms of toxic algae, and excessive freshwater outflow (Cranfield & Michael 2001).

2. BIOLOGY

B. yatei is endemic to New Zealand and is found around the coast in sediments at depths between 6 m and 9 m. Maximum length is variable between areas, ranging from 48 mm to 88 mm (Cranfield & Michael 2002).The sexes are likely to be separate, and they are likely to be broadcast spawners with planktonic larvae. Anecdotal evidence suggests spawning is likely to occur in the summer months. Recruitment of surf clams is thought to be highly variable between years.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, the boundaries of stocks of surf clams are likely to be the continuous lengths of exposed sandy beaches between geographical features (rivers, headlands, etc). Circulation patterns may isolate surf clams genetically as well as ecologically.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

See the introductory surf clam chapter.

5. STOCK ASSESSMENT

5.1 Estimates of fishery parameters and abundance

No estimates of fisheries parameters or abundance are available for this species.

5.2 Biomass estimates

Biomass has been estimated for two sites in the Marlborough Sounds with a stratified random survey using a hydraulic dredge. Estimates are shown in Table 3.

Table 3: A summary of biomass estimates in tonnes greenweight (with standard deviation in parentheses) from exploratory surveys of Cloudy Bay (Cranfield et al 1994b and White et al 2015) and Clifford Bay (Michael et al 1994), both in Marlborough.

Area	Cloudy Bay (BYA 7)	Clifford Bay (BYA 7)
Length of beach (km)	11, 11	21
Biomass (t)	123 (50), 193 (72)	0.2 (0.8)

5.3 Yield estimates and projections

Growth and mortality data from Cloudy Bay in Marlborough and the Kapiti Coast in Manawatu (Cranfield et al 1993) have been used in a yield per recruit model to estimate the reference fishing mortality $F_{0.1}$ (Cranfield et al 1994b). The Shellfish Working Group (SFWG) did not accept these estimates of $F_{0.1}$ because there was considerable uncertainty in both the estimates and the method used to generate them. The *MCY* estimates of White et al (2015) used the full range of $F_{0.1}$ estimates from Cranfield et al (1993) and are shown in Table 4. Estimates of *MCY* were calculated using Method 1 for a virgin fishery (Ministry for Primary Industries 2015) with an estimate of virgin biomass B_0, where:

$$MCY = 0.25 * F_{0.1} B_0$$

The SFWG recommended that *MCY* estimates are adequate to use to inform management decisions relevant to all surf clam fisheries, with the following caveats: 1) due to the uncertainty in $F_{0.1}$ values, for all species other than SAE, the *MCY* estimates should use the $F_{0.1}$ values toward the higher end of the range, and 2) there is a need to account for any substantial catch that has already come out of any surf clam fishery when estimating *MCY*; however there was no consensus on the best way to do this**.**

Table 4: Mean *MCY* estimates (t) for *B. yatei* from virgin biomass at Cloudy Bay (BYA 7) from White et al (2015). The two $F_{0.1}$ values, which are subsequently used to inform *MCY*, are the minimum and maximum estimates from Cranfield et al. (1993).

Location	$F_{0.1}$	*MCY*
Cloudy Bay (BYA 7)	0.25/0.42	12.1/20.3

CAY has not been estimated for *B. yatei*.

The SFWG recommended moving all surf clam fisheries away from an *MCY* management strategy and towards an exploitation rate management strategy. The SFWG recognised that an exploitation rate approach is more survey intensive, but better allows for the variable nature of biomass for surf clams because it allows greater flexibility in catch (to take greater landings from available biomass) whilst keeping catches sustainable.

6. STATUS OF THE STOCKS

- BYA 7 - *Bassina yatei*

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold:-
Status in relation to Target	Because of the relatively low levels of exploitation of *B. yatei*, it is likely that the stock is still effectively in a virgin state, therefore it is Very Likely (> 90%) to be at or above the target.
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring
Historical Stock Status Trajectory and Current Status Unknown	
Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Landings have averaged 0.51 t between the 2001–02 and 2015–16 fishing years.
Other Abundance Indices	-
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	Fishing is Very Unlikely (< 10%) to cause declines below soft or hard limits in the short to medium term.	
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)	
Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2015	Next assessment: Unknown
Overall assessment quality rank		
Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review fishery parameters for this species. Virgin stock size in areas sampled has been small. It is not known if peak abundances may be outside the surveyed areas.

Fishery Interactions
BYA can be caught together with other surf clam species and non-QMS bivalves.

For all other BYA stocks there is no current evidence of appreciable biomass.

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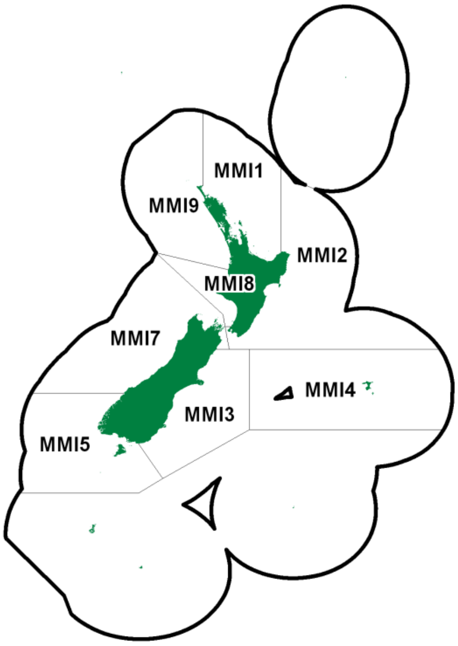
LARGE TROUGH SHELL (MMI)

(*Mactra murchisoni*)



1. FISHERY SUMMARY

This species is part of the surf clam fishery and the reader is guided to the surf clam introductory chapter for information common to all relevant species.

1.1 Commercial fisheries

Large trough shells (*Mactra murchisoni*) were introduced into the Quota Management System on 1 April 2004 with a total TACC of 162 t. No allowances were initially made for customary, recreational, or other sources of mortality; some allowances were introduced for MMI 8 and 7 in 2013 and 2016, respectively. Biomass surveys in QMA 3 supported a TACC increase from April 2010. This increased the TACC for MMI 3 from 3 t to 62 t. A subsequent biomass survey in 2012 supported a TAC increase in MMI 8 from 25 t to 631 t in April 2013. Another biomass survey supported a TAC increase in MMI 7 from 61 t to 144 t in April 2016. The current total TAC is 872 t (Table 1).

Table 1: Current TAC, TACC, and allowances for other sources of mortality for *Mactra murchisoni*.

Fishstock	TAC (t)	TACC (t)	Recreational Allowance (t)	Customary Allowance (t)	Other sources of mortality (t)
MMI 1	2	2	0	0	0
MMI 2	3	3	0	0	0
MMI 3	65	62	0	0	3
MMI 4	1	1	0	0	0
MMI 5	1	1	0	0	0
MMI 7	144	131	1	5	7
MMI 8	631	589	0	10	32
MMI 9	25	25	0	0	0
Total	872	814	1	15	35

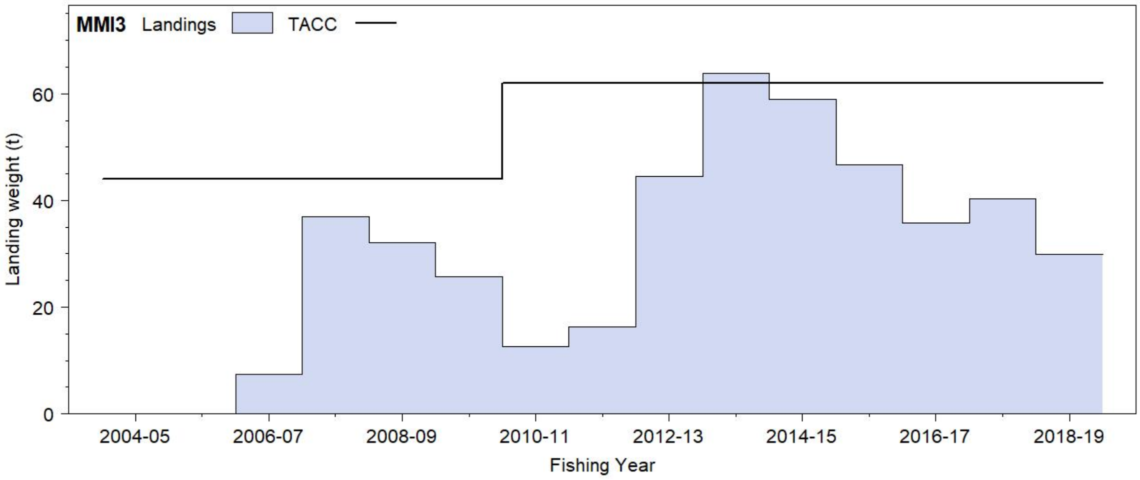
All reported landings have been from MMI 3 and MMI 7. Between the 1991–92 and 1995–96 fishing years landings were small and confined to MMI 7. No further landings were reported until 2002–03. Since then the reported total landings have ranged between about 23 t and 77 t, with an equal amount of landings recorded from 2002–03 to 2018–19 coming from each of the two stocks (Table 2).

MMI 3 landings slightly exceeded the TACC in 2013–14, but have since decreased to levels well below the TACC. MMI 1 landings were close to the TACC from 2004–05 to 2006–07, but have since dropped to levels well below the TACC. Figure 1 shows the historical landings and TACCs for the two main MMI stocks.

Table 2: TACCs and reported landings (t) of large trough shell by Fishstock from 1991–92 to 2018–19 from CELR and CLR data. Fishstocks where no catch has been reported are not tabulated. See Table 1 for TACC of stocks not landed.

Fishstock	MMI 3		MMI 7		Total	
	Landings	TACC	Landings	TACC	Landings	TACC
1991–92	0	0	0.35	–	0.35	–
1992–93	0	0	1.54	–	1.54	–
1993–94	0	0	8.33	–	8.33	–
1994–95	0	0	10.43	–	10.43	–
1995–96	0	0	0.14	–	0.14	–
1996–97	0	0	0	–	0	–
1997–98	0	0	0	–	0	–
1998–99	0	0	0	–	0	–
1999–00	0	0	0	–	0	–
2000–01	0	0	0	–	0	–
2001–02	0	0	0	–	0	–
2002–03	0	0	22.62	–	22.62	–
2003–04	0	44	29.68	61	29.68	162
2004–05*	0	44	60.02	61	60.86	162
2005–06*	0	44	53.96	61	57.92	162
2006–07	7.48	44	54.09	61	61.57	162
2007–08	36.90	44	15.04	61	51.94	162
2008–09	32.15	44	6.66	61	38.81	162
2009–10	25.76	44	3.42	61	29.18	162
2010–11	12.60	62	17.43	61	30.03	180
2011–12	0	62	47.34	61	47.34	180
2012–13	44.45	62	32.81	61	77.27	180
2013–14	63.87	62	4.89	61	68.75	744
2014–15	59.00	62	9.69	61	68.64	744
2015–16	46.72	62	23.98	131	71.77	814
2016–17	35.79	62	25.62	131	62.59	814
2017–18	40.39	62	29.43	131	71.87	814
2018–19	29.23	62	32.43	131	62.93	814

*In 2004–05 and 2005–06, 0.84 and 3.9554 t respectively were reportedly landed, but the QMA was not recorded. These amounts are included in the total landings for these years.



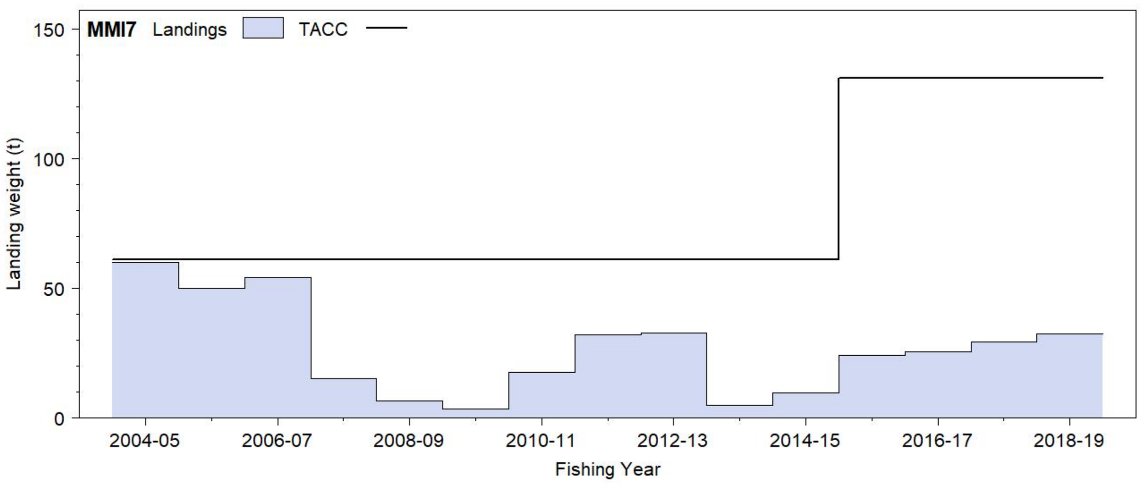


Figure 1: Reported commercial landings and TACC for MMI 3 (South East Coast), and MMI 7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries
Offshore clams such as *M. murchisoni* are likely to have been harvested for recreational use only when washed ashore after storms. There are no estimates of recreational take for this surf clam.

1.3 Customary fisheries
Offshore clams such as *M. murchisoni* are likely to have been harvested for customary use only when washed ashore after storms. Shells of this clam have been found irregularly, and in small numbers, in a few middens (Conroy et al 1993). There are no estimates of current customary catch of this clam.

1.4 Illegal catch
There is no documented illegal catch of this clam.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality, although this clam is subject to localised catastrophic mortality from erosion during storms, high temperatures and low oxygen levels during calm summer periods, blooms of toxic algae, and excessive freshwater outflow (Cranfield & Michael 2001).

2. BIOLOGY

M. murchisoni is most abundant around the lower half of the North Island and the South Island. It is found most commonly between about 4 m and 8 m in depth. Maximum length is variable between areas, ranging from 63 mm to 102 mm (Cranfield et al 1993). The sexes are separate, they are broadcast spawners, and the larvae are thought to be planktonic for between 20 and 30 days (Cranfield & Michael 2001). Recruitment of spat is to the same depth zone that adults occur in, although recruitment between years is highly variable (Conroy et al 1993).

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however the boundaries of stocks of surf clams are likely to be the continuous lengths of exposed sandy beaches between geographical features (rivers, headlands, etc). Circulation patterns may isolate surf clams genetically as well as ecologically.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

See the introductory surf clam chapter.

5. STOCK ASSESSMENT

5.1 Estimates of fishery parameters and abundance
No estimates of fisheries parameters or abundance are available for this species.

5.2 Biomass estimates
Biomass has been estimated from MMI 2, 3, 7, and 8 at various times between 1994 and 2015 with stratified random surveying using a hydraulic dredge. Survey size has been expressed either as length of beach (Table 3), or as area (Table 4), which makes comparisons difficult.

Table 3: A summary of biomass estimates in tonnes greenweight (with standard deviation in parentheses) from exploratory surveys of Cloudy Bay (Cranfield et al 1994a) and Clifford Bay in Marlborough (Michael et al 1994), and Foxton beach on the Manawatu coast (White et al 2012).

Area	**Cloudy Bay (MMI 7)**	**Clifford Bay (MMI 7)**	**Foxton Beach (MMI 8)**
Length of beach (km)	11	21	46[#]
Biomass (t)	248 (96)	192 (79)	3603 (342)[#]

[#] Biomass was estimated at Foxton Beach from a mix of a systematic survey to the north and a stratified survey to the south of this location.

Table 4: A summary of biomass estimates in greenweight (t) from the surveys in MMI 2 (Triantifillos 2008b), MMI 3 (Triantifillos 2008a) and MMI 7 (White et al 2015). Note: unless otherwise stated the CV is less than 20%.

Location	**Five sites (MMI 2)**	**Ashley River to 6 nm south of the Waimakariri River (MMI 3)**	**Cloudy Bay (MMI 7)**
Area surveyed (km^2)	28.0	13.4	5.7
Biomass (t)	33.8	444.1	1008.8

5.3 Yield estimates and projections

Growth and mortality data from Cloudy Bay in Marlborough and the Kapiti Coast in Manawatu (Cranfield et al 1993) have been used in a yield per recruit model to estimate the reference fishing mortality $F_{0.1}$ (Cranfield et al 1994a, Triantifillos 2008a, 2008b). The Shellfish Working Group (SFWG) did not accept these estimates of $F_{0.1}$ because there was considerable uncertainty in both the estimates and the method used to generate them. The *MCY* estimates of Triantafillos (2008a, 2008b) and White et al (2012) using the full range of $F_{0.1}$ estimates from Cranfield et al (1993) are shown in Table 5. The SFWG recommended that *MCY* estimates are adequate to use to inform management decisions relevant to all surf clam fisheries, with the following caveats: 1) due to the uncertainty in $F_{0.1}$ values, for all species other than SAE, the *MCY* estimates should use the $F_{0.1}$ values toward the higher end of the range, and 2) there is a need to account for any substantial catch that has already come out of any surf clam fishery when estimating *MCY*; however there was no consensus on the best way to do this.

Estimates of *MCY* are available from numerous locations (Table 5) and were calculated using Method 1 for a virgin fishery (MPI 2015) with an estimate of virgin biomass B_0, where:

$$MCY = 0.25 * F_{0.1}\ B_0$$

Table 5: *MCY* estimates (t) for *M. murchisoni* from virgin biomass at locations sampled around New Zealand (Triantifillos 2008a, 2008b, White et al 2012). The two $F_{0.1}$ values, which are subsequently used to estimate *MCY*, are the minimum and maximum estimates from Cranfield et al (1993).

Location	$F_{0.1}$	***MCY***
Five sites (MMI 2)	0.43/0.57	47.7/63.3
Ashley River to 6 nm south of the Waimakariri River (MMI 3)	0.70/0.89	5.9/7.5
Cloudy Bay (MMI 7)	0.43/0.57	108.4/143.7
46km of coast north and south of the Manawatu River (MMI 8)	0.70/0.89	630.6/801.7

Estimation of Current Annual Yield (*CAY*)

CAY has not been estimated for *M. murchisoni*.

The SFWG recommended moving all surf clam fisheries away from an *MCY* management strategy and towards an exploitation rate management strategy. The SFWG recognised that an exploitation rate approach is more survey intensive, but better allows for the variable nature of biomass for surf clams because it allows greater flexibility in catch (to take greater landings from available biomass) whilst keeping catches sustainable.

6. STATUS OF THE STOCKS

- MMI 3- *Mactra murchisoni*

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed

	Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Unknown in 2018-19 as the available information in too out of date to inform stock status
Status in relation to Limits	Unknown in 2018-19 as the available information in too out of date to inform stock status
Status in relation to Overfishing	Unknown in 2018-19 as the available information in too out of date to inform stock status

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	In MMI 3, landings have been decreasing from 63.87 t in 2013-14 to 29.23 t in 2018-19.
Other Abundance Indices	-
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	Current catches are Unlikely (< 40%) to cause declines below soft or hard limits in the short to medium term.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%)

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Last assessment: 2008	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)		
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review fishery parameters for this species.

Fishery Interactions
MMI can be caught together with other surf clam species and non-QMS bivalves.

- MMI 7

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Very Likely (> 90%) to be at or above the target.
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	In MMI 7 landings have been variable but averaged 27.6 t since 2002.
Other Abundance Indices	-
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	Current catches are Very Unlikely (< 10%) to cause declines below soft or hard limits in the short to medium term.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Last assessment: 2015	Next assessment: Unknown
Overall assessment quality rank		
Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review fishery parameters for this species.

Fishery Interactions
MMI can be caught together with other surf clam species and non-QMS bivalves.

- MMI 8

Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Because of the relatively low levels of exploitation of *M. muchisoni*, it is likely that MMI 8 is still effectively in a virgin state, therefore Very Likely (> 90%) to be at or above the target.
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Fishing is light in MMI 8.
Other Abundance Indices	-
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	Current catches are Very Unlikely (< 10%) to cause declines below soft or hard limits in the short to medium term.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2012	Next assessment: Unknown
Overall assessment quality rank		
Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)		
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review fishery parameters for this species.

Fishery Interactions
MMI can be caught together with other surf clam species and non-QMS bivalves.

For all other MMI stocks there is no current evidence of appreciable biomass.

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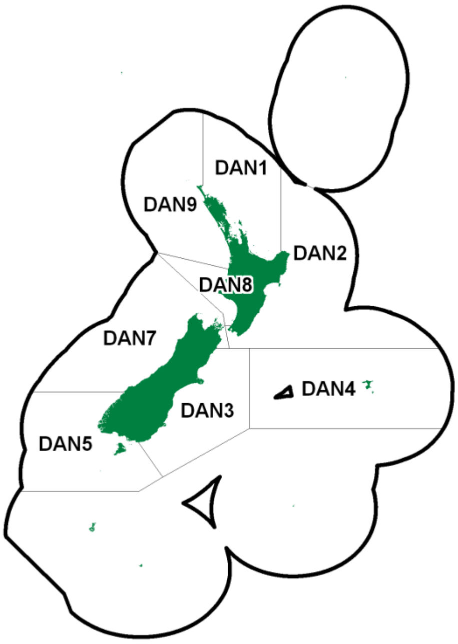
RINGED DOSINIA (DAN)

(*Dosinia anus*)



1. FISHERY SUMMARY

This species is part of the surf clam fishery and the reader is guided to the surf clam introductory chapter for information common to all relevant species.

1.1 Commercial fisheries

Ringed dosinia (*Dosinia anus*) were introduced into the Quota Management System on 1 April 2004 with a combined TAC of 112 t, with catches measured in greenweight. Biomass surveys in QMA 2 and 3 supported a TACC increase from April 2010. This increased the TACC for DAN 2 from 18 t to 61 t and DAN 3 from 4 t to 52 t. A subsequent biomass survey in DAN 8 resulted in a TACC increase in DAN 8 from 33 t to 214 t in April 2013. At the same time, allowances for customary, recreational, or other sources of mortality were introduced for DAN 8, increasing the TAC from 33 t to 236 t. Another biomass survey increased the DAN 7 TACC from 15 t to 120 t in April 2016, and allowances for customary, recreational, or other sources of mortality were introduced in 2016 increasing the TAC from 15 t to 133 t. The overall TAC is now 530 t (Table 1). There are no allowances for customary, recreational, or other sources of mortality for the other stocks.

Table 1: Current TAC, TACC and allowances for other sources of mortality for *Dosinia anus.*

Fishstock	TAC (t)	TACC (t)	Recreational Allowance (t)	Customary Allowance (t)	Other sources of mortality (t)
DAN 1	7	7	0	0	0
DAN 2	64	61	0	0	3
DAN 3	55	52	0	0	3
DAN 4	1	1	0	0	0
DAN 5	1	1	0	0	0
DAN 7	133	120	1	5	7
DAN 8	236	214	0	10	12
DAN 9	33	33	0	0	0
Total	530	489	1	15	25

Prior to 2006–07 landings had only been reported in DAN 7 and ranged from about 10 kg to 300 kg. Small amounts of landings (less than 1 t) were reported in DAN 3 before 2008–09, but increased to 7 t in 2014–15 and 2015–16. Since then landings have declined again, with only 60 kg recorded in 2017–18. From 2002–03 until 2014–15, landings in DAN 7 fluctuated between 100 kg and 5000 kg. Since 2015–16 landings increased sharply, to 25 t in 2018–19 (Table 2). Landings have remained well below the allocated TACCs in all years.

Table 2: TACCs and reported landings (t) of ringed dosinia by Fishstock from 1991–92 to the present day from CELR and CLR data. Fishstocks where no catch has been reported are not tabulated. See Table 1 for TACCs of stocks that are not landed.

Fishstock	DAN 3		DAN 7		Total	
	Landings	TACC	Landings	TACC	Landings	TACC
1991–92	0	–	0	–	0	
1992–93	0	–	0.16	–	0.16	–
1993–94	0	–	0.29	–	0.29	–
1994–95	0	–	0.07	–	0	–
1995–96	0	–	0.01	–	0	–
1996–97	0	–	0	–	0	–
1997–98	0	–	0	–	0	–
1998–99	0	–	0	–	0	–
1999–00	0	–	0	–	0	–
2000–01	0	–	0	–	0	–
2001–02	0	–	0	–	0	–
2002–03	0	–	0.11	–	0.11	–
2003–04	0	4	0.90	15	0.90	–
2004–05	0	4	1.98	15	2.02*	112
2005–06	0	4	1.10	15	1.02*	112
2006–07	0.09	4	2.46	15	2.55	112
2007–08	0.77	4	0.82	15	1.59	112
2008–09	1.40	4	0.16	15	1.56	112
2009–10	0.84	4	0.21	15	1.05	112
2010–11	0.77	52	2.20	15	3.02	203
2011–12	0	52	5.30	15	5.30	203
2012–13	0.55	52	3.53	15	4.08	203
2013–14	5.48	52	0.73	15	6.21	384
2014–15	7.12	52	0.31	15	7.43	384
2015–16	7.01	52	9.51	120	16.74	489
2016–17	2.11	52	8.80	120	11.79	489
2017–18	1.77	52	17.00	120	18.88	489
2018–19	0.06	52	25.55	120	26.61	489

*In 2004–05 and 2005–06, 32.4 and 90 kg were reported but the QMA was not recorded. This amount is included in the total landings for these years.

1.2 Recreational fisheries
There are no known records of recreational use of this surf clam.

1.3 Customary fisheries
Offshore clams such as *D. anus* are likely to have been harvested for customary use only when washed ashore after storms. Shells of this clam have been found irregularly, and in small numbers in a few middens (Carkeek 1966). There are no estimates of current customary use of this clam.

1.4 Illegal catch
There is no known illegal catch of this clam.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality, although this clam is probably sometimes taken as a bycatch in inshore trawling. Harvesters claim that the hydraulic clam rake does not damage surf clams and minimises damage to the few species of other macrofauna captured. Surf clam populations also are subject to localised catastrophic mortality from erosion during storms, high temperatures and low oxygen levels during calm summer periods, blooms of toxic algae, and excessive freshwater outflow (Cranfield & Michael 2001).

2. BIOLOGY

Dosinia anus is found around the New Zealand coast in sediments at depths between 5 m and 8 m around the North Island, and between 6 m and 10 m around the South Island. It is larger and rougher than *D. subrosea*, and is usually found on more exposed beaches shallower in the substrate. Maximum length is variable between areas, ranging from 58 mm to 82 mm (Cranfield et al 1993). The sexes are likely to be separate, and they are likely to be broadcast spawners with planktonic larvae. Anecdotal evidence suggests that spawning is likely to occur in the summer months and spat probably recruit to the deeper water of the outer region of the surf zone. Recruitment of surf clams is thought to be highly variable between years.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, the boundaries of stocks of surf clams are likely to be the continuous lengths of exposed sandy beaches between geographical features (such as rivers and headlands). Circulation patterns may isolate surf clams genetically as well as ecologically.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

See the introductory surf clam chapter.

5. STOCK ASSESSMENT

5.1 Estimates of fishery parameters and abundance

No estimates of fisheries parameters or abundance are available for this species.

5.2 Biomass estimates

Biomass has been estimated at Cloudy Bay and Clifford Bay in DAN 7 and Foxton Beach in DAN 8 with a stratified random survey using a hydraulic dredge (Table 3). Survey size has been recorded as either length of beach or area, which makes comparison difficult.

Table 3: A summary of biomass estimates for *D. anus* in tonnes green weight (with standard deviation in parentheses) from exploratory surveys of Cloudy Bay (Cranfield et al 1994b[1], White et al 2015[2]), and Clifford Bay, both in Marlborough (Michael et al 1994) as well as on the Manawatu coastline (White et al 2012).

Area	Cloudy Bay[1] (DAN 7)	Cloudy Bay[2] (DAN 7)	Clifford Bay (DAN 7)	Foxton Beach (DAN 8)
Length of beach (km)	11		21	46
Area (km^2)		5.7		
Biomass (t)	72 (30)	1270 (156)	5 (3)	3498 (329)

5.3 Yield estimates and projections

Growth and mortality data from Cloudy Bay in Marlborough and the Kapiti Coast in Manawatu (Cranfield et al 1993) have been used in a yield per recruit model to estimate the reference fishing mortality $F_{0.1}$ (Cranfield et al 1994b, Triantifillos 2008a, 2008b). The Shellfish Working Group (SFWG) did not accept these estimates of $F_{0.1}$ because there was considerable uncertainty in both the estimates and the method used to generate them. The *MCY* estimates of Triantifillos (2008a, 2008b) and White et al (2012**,** 2015) that use the full range of $F_{0.1}$ estimates from Cranfield et al (1993) are shown in Table 4. The SFWG recommended that *MCY* estimates are adequate to use to inform management decisions relevant to all surf clam fisheries, with the following caveats: 1) due to the uncertainty in $F_{0.1}$ values, for all species other than SAE, the *MCY* estimates should use the $F_{0.1}$ values toward the higher end of the range, and 2) there is a need to account for any substantial catch that has already come out of any surf clam fishery when estimating *MCY*; however there was no consensus on the best method.

Estimates of *MCY* were calculated using Method 1 for a virgin fishery (MPI 2015) with an estimate of virgin biomass B_0, where:

$$MCY = 0.25 * F_{0.1} B_0$$

CAY has not been estimated for *D. anus*.

The SFWG recommended moving all surf clam fisheries away from an *MCY* management strategy and towards an exploitation rate management strategy. The SFWG recognised that an exploitation rate approach is more survey intensive, but better allows for the variable nature of biomass for surf clams because it allows greater flexibility in catch (to take greater landings from available biomass) whilst keeping catches sustainable.

Table 4: Mean *MCY* estimates (t) for *D. anus* from virgin biomass from DAN 2 (Triantifillos 2008b), DAN 3 (Triantifillos 2008a), DAN 7 (White et al 2015), and DAN 8 (White et al 2012). The two $F_{0.1}$ values, which are subsequently used to estimate *MCY*, are the minimum and maximum estimates from Cranfield et al. (1993).

Location	$F_{0.1}$	*MCY*
Five sites (DAN 2)	0.25/0.42	52.8/88.7
Ashley River to 6 n. mile south of the Waimakariri River (DAN 3)	0.27/0.54	63.8/127.7
Cloudy Bay (DAN 7)	0.25/0.42	79.4/133.4
Foxton Beach (DAN 8)	0.27/0.54	236.1/472.2

6. STATUS OF THE STOCKS

- DAN 2, 3, 7 & 8- *Dosinia anus*

Stock Status	
Year of Most Recent Assessment	2008 for DAN 2 and 3, 2015 for DAN 7 and 2012 for DAN 8
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Because of the relatively low levels of exploitation of *D. anus*, it is likely that all stocks are still effectively in a virgin state, therefore they are Very Likely (> 90%) to be at or above the target.
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Intensity or Proxy	Fishing is minimal in all Fishstocks other than DAN 3 and 7. In DAN 7 fishing has been light with landings averaging 1.5 t from 2002–03 to 2014–15 but increasing since, reaching 25.55 in 2018-19.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing decline below Limits	For all stocks current catches are Very Unlikely (< 10%) to cause declines below soft or hard limits in the short to medium term.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Main data inputs	Abundance and length frequency information	
Period of Assessment	Latest assessment: 2008 for DAN 2 and 3, 2015 for DAN 7, 2012 for DAN 8	Next assessment: Unknown

Changes to Model Structure and Assumptions	-
Major Sources of Uncertainty	-

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review fishery parameters for this species

Fishery Interactions
DAN can be caught together with other surf clam species and non-QMS bivalves.

For all other DAN stocks there is no current evidence of appreciable biomass.

7. FOR FURTHER INFORMATION

Brierley, P (Convenor) (1990) Management and development of the New Zealand sub-tidal clam fishery. Report of the surf clam working group, MAF Fisheries. (Unpublished report held in NIWA library, Wellington). 57 p.

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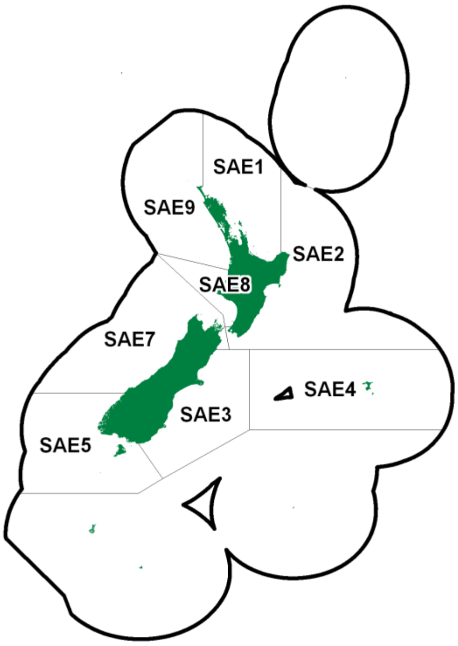
TRIANGLE SHELL (SAE)

(*Spisula aequilatera*)



1. FISHERY SUMMARY

This species is part of the surf clam fishery and the reader is guided to the surf clam introductory chapter for information common to all relevant species.

1.1 Commercial fisheries

Triangle shells (*Crassula aequilatera*, also known as *Spisula aequilatera*) were introduced into the QMS on 1 April 2004 with a total TACC of 406 t. No allowances were initially set for customary, non-commercial, recreational, or other sources of mortality, but some allowances were introduced to SAE 8 and 7 in 2013 and 2016, respectively. Biomass surveys supported an increase in TAC in SAE 2 and SAE 3 from 1 April 2010 from 1 t and 264 t respectively to 132 t and 483 t, respectively. A subsequent biomass survey in SAE 8 resulted in a TAC increase from 8 t to 1821 t in April 2013. Another biomass survey resulted in an increase in the SAE 7 TAC from 112 t to 235 t in April 2016, with a current total national TAC of 2692 t (Table 1).

Table 1: Current TAC, TACC, and allowances for other sources of mortality for *Spisula aequilatera*

Fishstock	TAC (t)	TACC (t)	Recreational allowance (t)	Customary Allowance (t)	Other sources of mortality (t)
SAE 1	9	9	0	0	0
SAE 2	132	125	0	0	7
SAE 3	483	459	0	0	24
SAE 4	1	1	0	0	0
SAE 5	3	3	0	0	0
SAE 7	235	217	1	5	12
SAE 8	1821	1720	0	10	91
SAE 9	8	8	0	0	0
Total	2692	2542	1	15	134

Apart from a small catch in SAE 2 in 2003–04 and small catches in SAE 8 since 2014–15, all reported landings have been from SAE 3 and SAE 7. For SAE 3, there were no landings until 2006–07. Between 2006–07 and 2014–15, landings in SAE 3 fluctuated between 0.6 t and 11 t, with no landings reported in 2011–12. From 2014–15 onwards, landings increased to 203 t in 2018–19. For SAE 7, there were minimal landings from 1991–92 to 1995–96; no further landings were reported until 2002–03. Since then, SAE 7 landings steadily increased to a peak at 319 t in 2015–16, before declining again; in 2017–18 just 86 t were recorded. Reported landings and TACCs are shown for the Fishstocks with historical landings in Table 2. Figure 1 shows historical landings and TACCs for the two main SAE stocks. Landings are market-driven and have not been constrained by the TACCs.

Table 2: TACCs and reported landings (t) of triangle shell by Fishstock from 1990–91 to 2018–19 from CELR and CLR data. See Table 1 for TACCs of stocks not landed.

Fishstock	SAE 2		SAE 3		SAE 7		SAE 8		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1991–92	0	–	0	–	0.18	–	0	–	0.18	–
1992–93	0	–	0	–	0.40	–	0	–	0.40	–
1993–94	0	–	0	–	2.85	–	0	–	2.85	–
1994–95	0	–	0	–	2.10	–	0	–	2.10	–
1995–96	0	–	0	–	0.12	–	0	–	0.12	–
1996–97	0	–	0	–	0	–	0	–	0	–
1997–98	0	–	0	–	0	–	0	–	0	–
1998–99	0	–	0	–	0	–	0	–	0	–
1999–00	0	–	0	–	0	–	0	–	0	–
2000–01	0	–	0	–	0	–	0	–	0	–
2001–02	0	–	0	–	0	–	0	–	0	–
2002–03	0	–	0	–	52.15	–	0	–	52.15	–
2003–04	0.20	1	0	264	9.58	112	0	8	9.78	406
2004–05	0	1	0	264	18.53	112	0	8	19.36*	406
2005–06	0	1	0	264	28.07	112	0	8	31.02*	406
2006–07	0	1	0.61	264	45.96	112	0	8	46.56	406
2007–08	0	1	3.91	264	5.02	112	0	8	8.93	406
2008–09	0	1	10.91	264	2.51	112	0	8	13.42	406
2009–10	0	1	8.62	264	1.46	112	0	8	10.08	406
2010–11	0	125	4.04	459	16.92	112	0	8	20.96	725
2011–12	0	125	0	459	82.27	112	0	8	82.27	725
2012–13	0	125	9.83	459	161.20	112	0	1 720	171.03	2 437
2013–14	0	125	3.61	459	191.07	112	0	1 720	195.32	2 437
2014–15	0	125	5.92	459	241.04	112	0.45	1 720	246.96	2 437
2015–16	0	125	34.97	459	319.09	217	21.02	1 720	375.09	2 867
2016–17	0	125	150.40	459	186.47	217	9.51	1 720	346.38	2 867
2017–18	0	125	133.98	459	157.49	217	5.05	1 720	296.52	2 867
2018–19	0	125	202.88	459	86.34	217	3.84	1 720	293.06	2 867

*In 2004–05 and 2005–06, 0.837 t and 2.952 t respectively were reported landed, but the QMA was not recorded. These amounts are included in the total landings for these years.

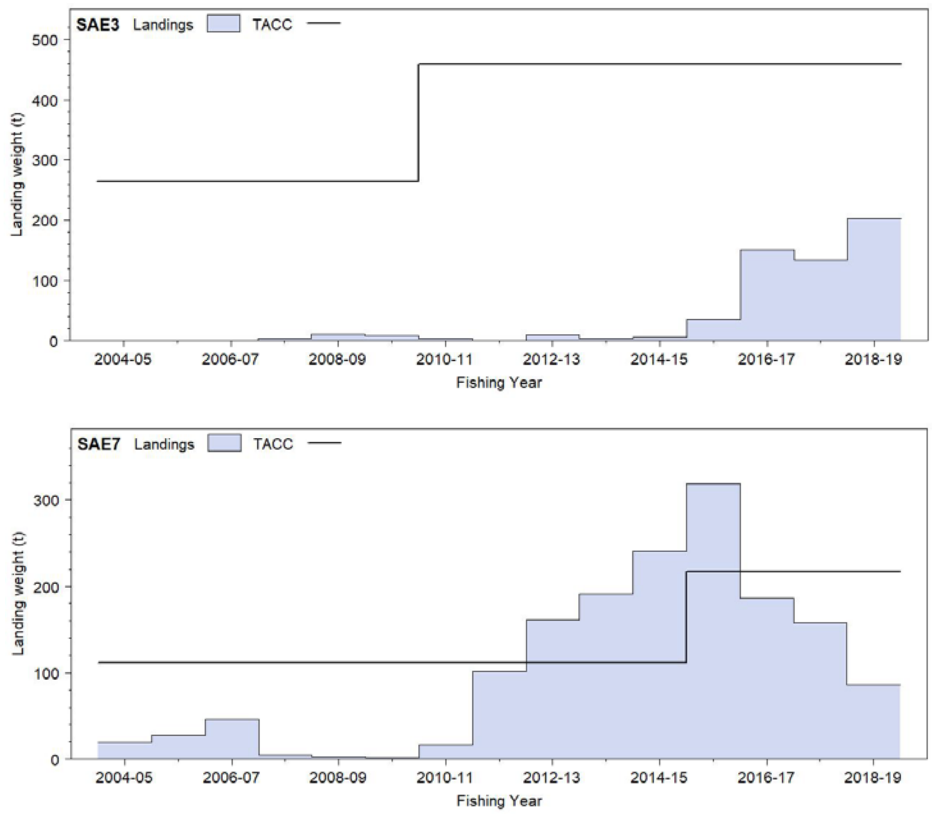


Figure 1 Reported commercial landings and TACC for the two main triangle shell stocks, SAE3 and SAE7.

1.2 Recreational fisheries
There are no estimates of recreational take for this surf clam.

1.3 Customary fisheries
Shells of this species have been found irregularly, and in small numbers in a few middens (Carkeek 1966). There are no estimates of current customary catch of this species.

1.4 Illegal catch
There is no documented illegal catch of this species.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality, although this clam is subject to localised catastrophic mortality from erosion during storms, high temperatures and low oxygen levels during calm summer periods, blooms of toxic algae, and excessive freshwater outflow (Cranfield & Michael 2001).

2. BIOLOGY

Spisula. aequilatera occurs from the Bay of Plenty southwards on the east coast of both islands, and on the Wellington-Manawatu coast. No information is available concerning its distribution on the west coast of the South Island. In the North Island this species is most abundant between 3 m and 5 m depths, and in the South Island between 4 m and 8 m depths. Maximum length is variable between areas, ranging from 39 mm to 74 mm (Cranfield & Michael 2002). The sexes are separate and they are broadcast spawners; they are reasonably fast growing and reach maximum size in 2–3 years. Nothing is known of their larval life.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, the boundaries of stocks of surf clams are likely to be the continuous lengths of exposed sandy beaches between geographical features (rivers, headlands, etc). Circulation patterns may isolate surf clams genetically as well as ecologically.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

See the introductory surf clam chapter.

5. STOCK ASSESSMENT

5.1 Estimates of fishery parameters and abundance
No estimates of fisheries parameters or abundance are available for this species. Early estimates were made of M and $F_{0.1}$, but the Shellfish Working Group considers that the methods were not well documented, and the estimates should not be used.

5.2 Biomass estimates
Biomass has been estimated from SAE 2, 3, 7, and 8 at various times between 1994 and 2015 using stratified random surveying with a hydraulic dredge. Survey size has been expressed either as length of beach (Table 3), or as area (Table 4), which makes comparisons difficult.

Table 3: A summary of biomass estimates in tonnes greenweight (with standard deviation in parentheses) from exploratory surveys of Cloudy Bay (Cranfield et al 1994b) and Clifford Bay in Marlborough (Michael et al 1994), and Foxton Beach on the Manawatu coast (White et al 2012).

Area	Cloudy Bay (SAE 7)	Clifford Bay (SAE 7)	Foxton Beach (SAE 8)
Length of beach (km)	11	21	46#
Biomass (t)	53 (22)	358 (152)	7993 (759) #

Biomass was estimated at Foxton Beach from a mix of a systematic survey to the north and a stratified survey to the south of this location.

Table 4: A summary of biomass estimates in tonnes greenweight from the surveys in SAE 2 (Triantifillos 2008b), SAE 3 (Triantifillos 2008a), and Cloudy Bay (White et al 2015). Unless otherwise stated the CV is less than 20%.

Location	Five sites (SAE 2)	Ashley River to 6 nm south of the Waimakariri River (SAE 3)	Cloudy Bay (SAE 7)
Area surveyed (km^2)	28.0	13.4	5.7
Biomass (t)	471.1	1567.2	887

5.3 Yield estimates and projections

Estimation of Maximum Constant Yield (*MCY*)

Growth and mortality data from Cloudy Bay in Marlborough and the Kapiti Coast in Manawatu (Cranfield et al 1993) have been used in a yield per recruit model to estimate the reference fishing mortality $F_{0.1}$ (Cranfield et al 1994b). The Shellfish Working Group (SFWG) did not accept these estimates of $F_{0.1}$ because there was considerable uncertainty in both the estimates and the method used to generate them. The *MCY* estimates of Triantifillos (2008a, 2008b) and White et al (2012, 2015) that use the full range of $F_{0.1}$ estimates from Cranfield et al (1993) are shown in Table 5. The SFWG recommended that *MCY* estimates are adequate to use to inform management decisions relevant to all surf clam fisheries, with the following caveats: 1) due to high uncertainty in the $F_{0.1}$ values for SAE, the SFWG advised using the lower $F_{0.1}$ values when estimating a sustainable *MCY* for this species; 2) there is a need to account for any substantial catch that has already come out of any surf clam fishery when estimating *MCY*, however there was no consensus on the best way to do this; and 3) an exploitation rate of 34% for SAE 7 (as suggested by the higher *MCY* value) was not recommended due to the current limited knowledge of the dynamics of surf clam species.

Estimates of *MCY* are available from a number of locations and were calculated using Method 1 for a virgin fishery (MPI 2015) with an estimate of virgin biomass B_0, where:

$$MCY = 0.25 * F_{0.1} B_0$$

Table 5: *MCY* estimates (t) for *S. aequilatera* from virgin biomass at locations sampled around New Zealand (Triantifillos 2008a, 2008b). The two $F_{0.1}$ values, which are subsequently used to estimate *MCY*, are the minimum and maximum estimates from Cranfield et al. (1993).

Location	$F_{0.1}$	*MCY*
Five sites (SAE 2)	1.12/1.56	131.9/183.7
Ashley River to 6 nm south of the Waimakariri River (SAE 3)	1.06/1.37	415.3/536.8
Cloudy Bay (SAE 7)	1.06/1.37	235.0/303.8
Foxton beach (SAE 8)	1.06/1.37	2238/3117.2

Estimation of Current Annual Yield (*CAY*)

CAY has not been estimated for *S. aequilatera*.

The SFWG recommended moving all surf clam fisheries away from an *MCY* management strategy and towards an exploitation rate management strategy. The SFWG recognised that an exploitation rate approach is more survey intensive, but better allows for the variable nature of biomass for surf clams because it allows greater flexibility in catch (to take greater landings from available biomass) whilst keeping catches sustainable.

6. STATUS OF THE STOCKS

- SAE 2, 3 & 8- *Spisula aequilatera*

Stock Status	
Year of Most Recent Assessment	2008 for SAE 2 and 3, 2012 for SAE 8
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Because of the relatively low levels of exploitation of *S. aequilatera*, it is likely that all stocks are still effectively in a virgin state, therefore they are Very Likely (> 90%) to be at or above the target.
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Fishing is light in all QMAs
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing decline below Limits	For all stocks current catches are Very Unlikely (< 10%) to cause declines below soft or hard limits in the short to medium term.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2008 for SAE 2 and 3, 2012 for SAE 8.	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	Abundance and length frequency information	
Data not used		
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review the fishery parameters for this species. SAE have slower digging ability relative to PDO therefore are at higher relative risk of mortality during storms.

Fishery Interactions
SAE can be caught together with other surf clam species and non-QMS bivalves.

- **SAE 7**

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Very Likely (> 90%) to be at or above the target
Status in relation to Limits	Unlikely (< 40%) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Fishing was variable between 52 t and 1 t landed between 2002–03 and 2009–10, with single digit tonnages taken between 2007–08 and 2009–10. Since then landings have increased dramatically from 1 t in 2009–10 to 241 t in 2014–15, which was more than double the TACC. Landings reached 319.09 t when the TACC was increased to 217 t in 2015-16 and then continuously declined to 86.34 in 2018-19
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing decline below Limits	Current catches at or below the TACC are Unlikely (< 40%) to cause declines below soft or hard limits in the short to mid-term.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%)

Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2015	Next assessment: Unknown

Overall assessment quality rank	-	
Main data inputs	Abundance and length frequency information	
Data not used	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review the fishery parameters for this species. SAE have slower digging ability relative to PDO therefore are at higher relative risk of mortality during storms.

Fishery Interactions
SAE can be caught together with other surf clam species and non-QMS bivalves.

For all other SAE stocks there is no current evidence of appreciable biomass.

7. FOR FURTHER INFORMATION

Beentjes, M P; Baird, S J (2004) Review of dredge fishing technologies and practice for application in New Zealand. *New Zealand Fisheries Assessment Report 2004/37*. 40 p.

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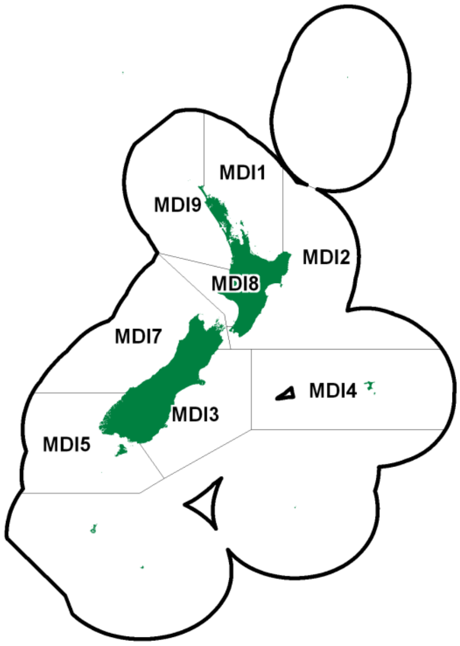
TROUGH SHELL (MDI)

(*Mactra discors*)



1. FISHERY SUMMARY

This species is part of the surf clam fishery and the reader is guided to the surf clam introductory chapter for information common to all relevant species.

1.1 Commercial fisheries

Trough shells (*Mactra discors*) were introduced into Quota Management System on 1 April 2004 with a total TACC of 98 t. No allowances were made for customary or recreational usage, or for other sources of mortality. New survey information for QMA 2 and 3 resulted in increases to a number of surf clam TACCs in these areas from 1 April 2010, including MDI 2. This change included an increase in TACC and a new allowance for other sources of mortality. The total TAC is currently 163 t (Table 1).

Table 1: Current TAC, TACC, and allowances for other sources of mortality for *Mactra discors.*

Fishstock	TAC (t)	TACC (t)	Other sources of mortality (t)
MDI 1	1	1	0
MDI 2	66	63	3
MDI 3	1	1	0
MDI 4	1	1	0
MDI 5	14	14	0
MDI 7	26	26	0
MDI 8	27	27	0
MDI 9	27	27	0
Total	163	160	3

Most reported landings have been from MDI 7. Between 1994 and 1996, landings of a few kilograms were also reported from MDI 3 and MDI 5. No further landings were reported from any of the MDI stocks until 2002–03. Since then the only significant reported catch has been from MDI 7 during the period 2003–04 to 2007–08 when landings ranged between about 1 t and 4 t. Since 2008–09 MDI 7 landings have decreased to very low levels, with no landings recorded during several years including 2018–19. Only very low and sporadic landings of a few kg have been recorded from MDI 1, MDI 3, and MDI 5 since 2003–04. Landings and TACCs for Fishstocks with historical landings are shown in Table 2. The recent landings and TACC values for MDI 7 are depicted in Figure 1; landings have always remained well below the TACC.

Table 2: TACCs and reported landings (t) of trough shell for Fishstocks with landings from 1992–93 to present from CELR and CLR data. See Table 1 for TACCs of stocks that are not landed.

Fishstock	MDI 1		MDI 3		MDI 5		MDI 7		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1992–93	0	–	0	–	0	–	0.25	–	0.25	–
1993–94	0	–	0	–	0	–	2.20	–	2.20	–
1994–95	0	–	0	–	0.03	–	2.40	–	2.43	–
1995–96	0	–	0.05	–	0	–	0.02	–	0.07	–
1996–97	0	–	0	–	0	–	0	–	0	–
1997–98	0	–	0	–	0	–	0	–	0	–
1998–99	0	–	0	–	0	–	0	–	0	–
1999–00	0	–	0	–	0	–	0	–	0	–
2000–01	0	–	0	–	0	–	0	–	0	–
2001–02	0	–	0	–	0	–	0	–	0	–
2002–03	0	–	0	–	0	–	0.69	–	0.69	–
2003–04	0	1	0	1	0	14	2.69	26	2.69	98
2004–05	0	1	0	1	0	14	3.30	26	3.38*	98
2005–06	0.041	1	0	1	0	14	3.21	26	3.53*	98
2006–07	0	1	0	1	0	14	3.89	26	3.89	98
2007–08	0	1	0.02	1	0	14	1.05	26	1.06	98
2008–09	0	1	0	1	0	14	0.01	26	0.01	98
2009–10	0	1	0.06	1	0	14	0.12	26	0.18	98
2010–11	0	1	0	1	0	14	0.01	26	0	160
2011–12	0	1	0	1	0	14	0	26	0	160
2012–13	0	1	0	1	0	14	0.13	26	0.13	160
2013–14	0	1	0.01	1	0	14	0	26	0.01	160
2014–15	0	1	0	1	0	14	0	26	0	160
2015–16	0	1	0	1	0	14	0	26	0	160
2016–17	0	1	0	1	0	14	0.01	26	0.01	160
2017–18	0	1	0	1	0	14	0.03	26	0.03	160
2018–19	0	1	0	1	0	14	0	26	0	160

*In 2004–05 and 2005–06, 71 kg and 277 kg respectively were reportedly landed, but the QMA was not recorded. This amount is included in the total landings for that year.

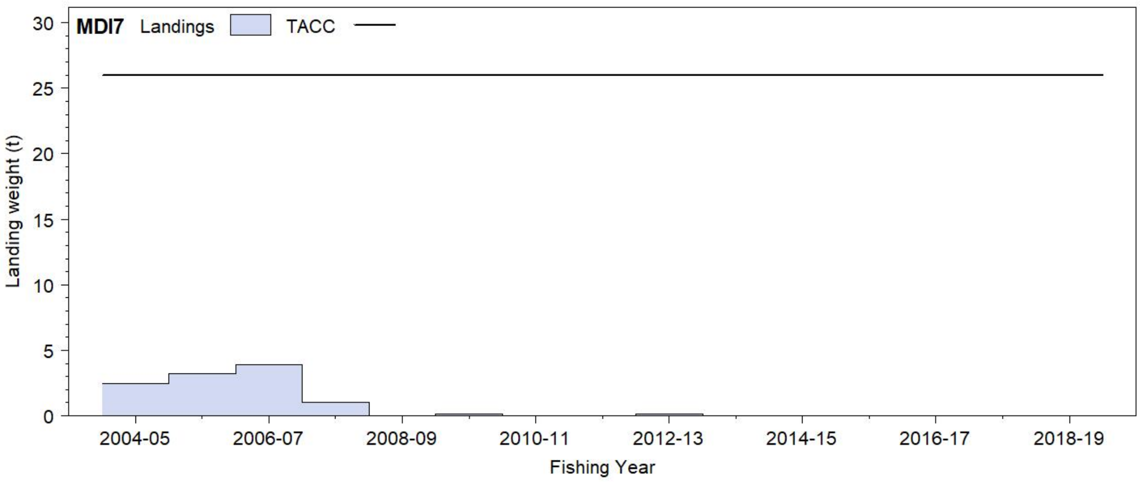


Figure 1: Reported commercial landings and TACC for MDI 7 (Challenger).

1.2 Recreational fisheries

Offshore clams such as *M. discors* are likely to have been harvested for recreational use only when washed ashore after storms. There are no estimates of recreational take for this surf clam.

1.3 Customary fisheries

Offshore clams such as *M. discors* are likely to have been harvested for customary use only when washed ashore after storms (Carkeek 1966). There are no estimates of current customary use of this clam.

1.4 Illegal catch

There is no known illegal catch of this clam.

1.5 Other sources of mortality

There is no quantitative information on other sources of mortality. This clam is subject to localised catastrophic mortality from erosion during storms, high temperatures and low oxygen levels during calm summer periods, blooms of toxic algae,and excessive freshwater outflow (Cranfield & Michael 2001).

2. BIOLOGY

M. discors is most abundant in Southland (Te Waewae and Oreti), Otago (Blueskin Bay), Wellington, Manawatu, and Cloudy Bay. Maximum length is variable between areas, ranging from 63 mm to 95 mm (Cranfield et al 1993). The sexes are separate and the species is a broadcast spawner; the larvae are thought to be planktonic for between 20 and 30 days (Cranfield & Michael 2001). Recruitment of spat is to the same depth zone that adults occur in and recruitment between years is highly variable (Conroy et al 1993).

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, the boundaries of stocks of surf clams are likely to be the continuous lengths of exposed sandy beaches between geographical features (rivers, headlands, etc). Circulation patterns may isolate surf clams genetically as well as ecologically.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

See the introductory surf clam chapter.

5. STOCK ASSESSMENT

5.1 Estimates of fishery parameters and abundance

No estimates of fisheries parameters or abundance are available for this species.

5.2 Biomass estimates

Biomass has been estimated from MDI 2, 3, 7, and 8 at various times between 1994 and 2015 using stratified random surveying with a hydraulic dredge. Survey size has been expressed either as length of beach, in the earlier surveys (Table 3), or as area, in the latter surveys (Table 4), which makes comparisons over time difficult.

Table 3: A summary of biomass estimates in tonnes green weight (with standard deviation in parentheses) from exploratory surveys in Cloudy Bay (Cranfield et al 1994b) and Clifford Bay in Marlborough (Michael et al 1994) and Foxton Beach on the Manawatu coast (Haddon et al 1996). – = not estimated

Area	Cloudy Bay (MDI 7)	Clifford Bay (MDI 7)	Foxton Beach (MDI 8)
Length of beach (km)	11	21	27.5
Biomass (t)	55 (11)	89 (3)	195 (–)

Table 4: A summary of biomass estimates in tonnes green weight from the surveys in MDI 2 (Triantifillos 2008b), MDI 3 (Triantifillos 2008a) and MDI 7 (White et al 2015). Note: unless otherwise stated the CV is less than 20%.

Location	Five sites (MDI 2)	Ashley River to 6 nm. miles south of the Waimakariri River (MDI 3)	Cloudy Bay (MDI 7)
Area surveyed (km^2)	28.0	13.4	5.7
Biomass (t)	471.2	0.0	5.9

5.3 Yield estimates and projections

Growth and mortality data from Cloudy Bay, Marlborough and the Kapiti Coast, Manawatu (Cranfield et al 1993) have been used in a yield per recruit model to estimate the reference fishing mortality $F_{0.1}$ (Cranfield et al 1994b, Triantifillos 2008a, 2008b). The Shellfish Working Group (SFWG) did not accept these estimates of $F_{0.1}$ because there was considerable uncertainty in both the estimates and the method used to generate them. The *MCY* estimates of Triantafillos (2008b) that use the full range of $F_{0.1}$ estimates from Cranfield et al (1993) are shown in Table 5. The SFWG recommended that *MCY* estimates are adequate to use to inform management decisions relevant to all surf clam fisheries, with the following caveats: 1) due to the uncertainty in $F_{0.1}$ values, for all species other than SAE, the *MCY* estimates should use the $F_{0.1}$ values toward the higher end of the range, and 2) there is a need to account for any substantial catch that has already come out of any surf clam fishery when estimating *MCY*; however there was no consensus on the best method.

All estimates of *MCY* were calculated using Method 1 for a virgin fishery (MPI 2015) from an estimate of virgin biomass B_0, where:

$$MCY = 0.25 * F_{0.1} B_0$$

Table 5: *MCY* estimates (t) for *M. discors* from virgin biomass at locations within MDI 2 (Triantifillos 2008b) and MDI 7 (White et al 2015). The two $F_{0.1}$ values, which are subsequently used to calculate *MCY*, are the minimum and maximum estimates from Cranfield et al. (1993).

Location	$F_{0.1}$	*MCY*
Five sites (MDI 2)	0.46/0.64	66.1/102.7
Cloudy Bay (MDI 7)	0.46/0.64	0.7/1.0

CAY has not been estimated for *M. discors*.

The SFWG recommended moving all surf clam fisheries away from an *MCY* management strategy and towards an exploitation rate management strategy. The SFWG recognised that an exploitation rate approach is more survey intensive, but better allows for the variable nature of biomass for surf clams because it allows greater flexibility in catch (to take greater landings from available biomass) whilst keeping catches sustainable.

6. STATUS OF THE STOCKS

- MDI 2, 7 & 8 - *Mactra discors*

Stock Status	
Year of Most Recent Assessment	2008 for MDI 2, 2015 for MDI 7 and 1996 for MDI 8
Assessment Runs Presented	Survey biomass
Reference Points	Target: Not defined, but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Because of the relatively low levels of exploitation of *M. discors*, it is likely that all stocks are still effectively in a virgin state, therefore they are Very Likely (> 90%) to be at or above the target. Unknown in 2018-19 for MDI 8 as the available information in too out of date to inform stock status
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits Unknown in 2018-19 for MDI 8 as the available information in too out of date to inform stock status
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring Unknown in 2018-19 for MDI 8 as the available information in too out of date to inform stock status

Historical Stock Status Trajectory and Current Status
Unknown

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Catches are minimal in all QMAs other than MDI 7. In MDI 7 catches have been light, averaging 1.16 t from 2002–03 to 2014-15
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing decline below Limits	For all stocks current catches are Very Unlikely (< 10%) to cause declines below soft or hard limits in the short to medium term.
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2008 for MDI 2, 2015 for MDI 7 and 1996 for MDI 8	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	Abundance and length frequency information	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Stock size could fluctuate markedly as a result of catastrophic mortality from a number of causes. There is a need to review fishery parameters for this species.

Fishery Interactions
MDI can be caught together with other surf clam species and non-QMS bivalves.

For all other MDI stocks there is no current evidence of appreciable biomass.

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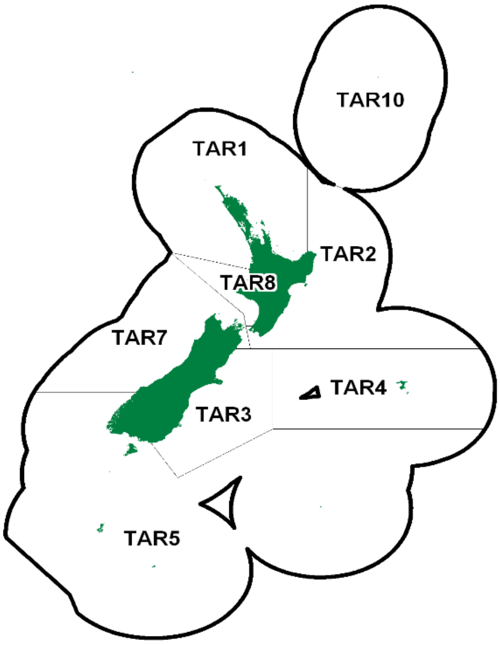
TARAKIHI (TAR)

(*Nemadactylus macropterus, Nemadactylus* sp.)
Tarakihi, King tarakihi



1. FISHERY SUMMARY

1.1 Commercial fisheries

Tarakihi are caught in the coastal waters of the North and South Islands, Stewart Island and the Chatham Islands, down to depths of about 250 m. The fishery for tarakihi developed with the introduction of steam trawlers in the 1890s, and by the mid-1930s annual catches had increased to reach about 2000 t. Annual catches increased substantially from the mid-1940s, until stabilising at about 5000–6000 t per annum during 1950–1981 (Table 1).

Figure 1 shows the historical landings and TACC values for the main tarakihi stocks. Since the introduction of the QMS in 1986, total landings increased from 4446 t to 6119 t in 2001–02 and remained at around 5000–6 000 t until 2018–19 (Table 3).

In October 2001, the TAR 7 TACC was increased slightly to 1088 t although no allocations were made for recreational, customary, or other sources of fishing mortality. In October 2004 the TACCs for TAR 2 and TAR 3 were increased to 1796 t and 1403 t respectively. From 1 October 2007, the TAC for TAR 1 was increased to 2029 t and the TACC was increased from 1399 to 1447 t. Under the new TAR 1 TAC, the allowances for customary non-commercial, recreational and other sources of mortality were increased to 73 t, 487 t, and 22 t respectively. TAR 1, 2, and 3 TACCs were lowered to 1097 t, 1500 t, and 1040 t respectively from the fishing year 2018–19. TAR 4, 5, 8, and 10 have never been assessed and after some initial adjustments undertaken during the late 1980s their TACCs and TACs remained unchanged.

TAR 1 landings exceeded the TACC slightly for most years during the period 1991–92 to 2005–06. Landings decreased after the TACC was increased in 2007–08, and have generally failed to reach the TACC since. TAR 1 landings dropped below 1000 t for the first time since the fishing year 1989–90 in 2018–19, failing to reach the new TACC limit of 1097 t. For TAR 2, 7, and 8, annual catches were maintained at about the level of the TACCs since 1999–2000 or earlier. For TAR 3, annual catches did not increase following the increase in TACC in 2004–05 and fluctuated around 900–1300 t per annum until 2018–19. In most years, the annual catch from TAR 4 has been well below the level of the TACC.

Table 1: Reported total landings (t) of tarakihi from 1968 to 1982–83.

Year	Landings	Year	Landings	Year	Landings
1968	5 683	1974	5 294	1980–81*	4 990
1969	4 082	1975	4 941	1981–82*	5 193
1970	5 649	1976	4 689	1982–83*	4 666
1971	5 702	1977	6 444		
1972	5 430	1978–79*	4 427		
1973	4 439	1979–80*	4 344		

Source - MAF data.
* Sums of domestic catch for calendar years 1978 to 1982, and foreign and chartered vessel catch for fishing year April 1 to March 31.

Tarakihi are caught by commercial vessels in all areas of New Zealand from the Three Kings Islands in the north to Stewart Island in the south. The main fishing method is bottom trawling. The major fishing grounds are east and west Northland (FMAs 1 and 9), the western Bay of Plenty to Cape Turnagain (FMAs 1 and 2), Cook Strait to the Canterbury Bight (mainly QMA 3), and Jackson Head to Cape Foulwind (QMA 7). The depth distribution of the tarakihi catch tends to increase northwards; most of the catch from the Canterbury Bight is taken within 50–120 m compared to 130–220 m in the east Northland fishery.

Within TAR 1, annual catches from Bay of Plenty declined during 2010–11 to 2015–16, while catches increased from the west coast North Island and east Northland. The target trawl fishery accounts for about 60% of the annual catch from each of these areas. Most of the remainder of the catch is taken as a bycatch from other inshore trawl fisheries. In TAR 2, the target trawl fishery has consistently accounted for about 90% of the annual catch.

For TAR 3, approximately 50% of the tarakihi catch was taken by the target trawl fishery, while 10–15% of the catch was from the small target setnet fishery operating off Kaikoura. Most of the remainder of the catch was taken by the target barracouta, red cod and flatfish trawl fisheries. Annual catches of tarakihi from TAR 7 are dominated by the trawl fisheries targeting tarakihi, barracouta, blue warehou, red cod and giant stargazer. The catch of tarakihi from TAR 8 is dominated by the target trawl fishery.

The commercial minimum legal size (MLS) for all TAR stocks is 25 cm.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982. **[Continued on next page]**

Year	TAR 1	TAR 2	TAR 3	TAR 4	Year	TAR 1	TAR 2	TAR 3	TAR 4
1931–32	1146	123	0	0	1957	1423	2200	1150	0
1932–33	588	481	0	0	1958	1300	1952	1400	0
1933–34	534	415	152	0	1959	1697	2464	1315	0
1934–35	691	672	127	0	1960	1489	2867	862	0
1935–36	854	969	284	0	1961	1456	2864	1002	0
1936–37	1165	673	283	0	1962	1266	3126	1073	0
1937–38	1130	758	208	0	1963	1417	2632	968	0
1938–39	1044	788	445	0	1964	1304	2656	1250	0
1939–40	990	780	239	0	1965	1324	3027	1122	0
1940–41	637	674	624	0	1966	1100	2964	1539	0
1941–42	611	779	594	0	1967	1066	2548	657	0
1942–43	791	691	491	0	1968	888	1907	837	0
1943–44	573	477	391	0	1969	863	1727	720	0
1944	923	837	466	0	1970	1129	1932	1120	0
1945	1189	1340	269	0	1971	1125	2006	1153	0
1946	1410	1618	383	0	1972	996	1912	2169	12
1947	1162	1831	970	0	1973	804	1568	1455	0
1948	1075	2129	793	0	1974	687	1889	1913	24
1949	1575	2157	973	0	1975	584	1743	1106	10
1950	1925	2011	743	0	1976	620	1645	1927	21
1951	1948	2097	772	0	1977	849	1994	1648	835
1952	1990	2090	948	0	1978	1059	1718	373	6
1953	2066	2045	809	0	1979	1236	1375	717	362
1954	1697	1529	578	0	1980	1506	1391	1098	246
1955	2124	2039	599	0	1981	1213	1339	1242	137
1956	1850	2312	384	0	1982	1210	1277	953	72

Table 2 [Continued]

Year	TAR 5	TAR 7	TAR 8	Year	TAR 5	TAR 7	TAR 8
1931–32	0	4	2	1957	12	735	18
1932–33	0	424	2	1958	8	625	20
1933–34	0	215	1	1959	7	666	17
1934–35	0	306	2	1960	10	732	15
1935–36	0	475	2	1961	15	573	23
1936–37	0	555	0	1962	6	759	52
1937–38	0	480	0	1963	8	630	43
1938–39	27	412	0	1964	7	593	61
1939–40	0	480	0	1965	11	470	58
1940–41	31	316	0	1966	24	549	64
1941–42	26	220	0	1967	2	1981	73
1942–43	15	87	0	1968	8	1941	100
1943–44	17	24	0	1969	8	592	173
1944	16	29	0	1970	19	1293	154
1945	1	432	0	1971	25	1192	202
1946	0	545	2	1972	15	741	279
1947	51	643	2	1973	27	747	190
1948	43	688	9	1974	31	1234	192
1949	49	873	13	1975	482	887	237
1950	35	803	8	1976	143	936	287
1951	42	747	7	1977	53	1337	465
1952	44	949	8	1978	54	1021	225
1953	30	896	20	1979	89	1125	109
1954	1	470	72	1980	107	748	109
1955	0	833	84	1981	137	1174	167
1956	0	699	28	1982	117	813	151

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. 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 includes both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 3: Reported landings (t) of tarakihi by Fishstock from 1983–84 to 2018–19 and TACCs (t) from 1986–87 to 2018–19. QMS data from 1986–present. [Continued on next page]

Fishstock	TAR 1		TAR 2		TAR 3		TAR 4		TAR 5	
FMA (s)	1 & 9		2		3		4		5 & 6	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	1 326	-	1 118	-	902	-	287	-	115	-
1984–85*	1 022	-	1 129	-	1 283	-	132	-	100	-
1985–86*	1 038	-	1 318	-	1 147	-	173	-	48	-
1986–87	912	1 210	1 382	1 410	938	970	83	300	42	140
1987–88	1 093	1 286	1 386	1 568	1 024	1 036	227	314	88	142
1988–89	940	1 328	1 412	1 611	758	1 061	182	314	47	147
1989–90	973	1 387	1 374	1 627	1 007	1 107	190	315	60	150
1990–91	1 125	1 387	1 729	1 627	1 070	1 148	367	316	35	153
1991–92	1 415	1 387	1 700	1 627	1 132	1 148	213	316	55	153
1992–93	1 477	1 397	1 654	1 633	813	1 168	45	316	51	153
1993–94	1 431	1 397	1 594	1 633	735	1 169	82	316	65	153
1994–95	1 390	1 398	1 580	1 633	849	1 169	71	316	90	153
1995–96	1 422	1 398	1 551	1 633	1 125	1 169	209	316	73	153
1996–97	1 425	1 398	1 639	1 633	1 088	1 169	133	316	81	153
1997–98	1 509	1 398	1 678	1 633	1 026	1 169	202	316	21	153
1998–99	1 436	1 398	1 594	1 633	1 097	1 169	104	316	51	153
1999–00	1 387	1 398	1 741	1 633	1 260	1 169	98	316	80	153
2000–01	1 403	1 398	1 658	1 633	1 218	1 169	242	316	58	153
2001–02	1 480	1 399	1 742	1 633	1 244	1 169	383	316	75	153
2002–03	1 517	1 399	1 745	1 633	1 156	1 169	218	316	92	153
2003–04	1 541	1 399	1 638	1 633	1 089	1 169	169	316	53	153
2004–05	1 527	1 399	1 692	1 796	905	1 403	262	316	57	153
2005–06	1 409	1 399	1 986	1 796	1 010	1 403	339	316	62	153
2006–07	1 193	1 399	1 729	1 796	1 080	1 403	263	316	94	153
2007–08	1 286	1 447	1 715	1 796	843	1 403	348	316	50	153
2008–09	1 398	1 447	1 901	1 796	1 017	1 403	77	316	45	153
2009–10	1 332	1 447	1 858	1 796	757	1 403	138	316	81	153
2010–11	1 349	1 447	1 660	1 796	1 207	1 403	180	316	135	153
2011–12	1 134	1 447	1 702	1 796	897	1 403	54	316	151	153
2012–13	1 184	1 447	1 900	1 796	1 026	1 403	31	316	144	153
2013–14	1 425	1 447	1 816	1 796	991	1 403	179	316	126	153
2014–15	1 463	1 447	1 947	1 796	1 112	1 403	154	316	136	153
2015–16	1 229	1 447	1 820	1 796	1 262	1 403	59	316	158	153
2016–17	1 390	1 447	1 967	1 796	1 287	1 403	193	316	151	153
2017–18	1 258	1 447	1 896	1 796	1 144	1 403	51	316	123	153
2018–19	950	1 097	1 562	1 500	1 025	1 040	198	316	122	153

Table 3 [Continued]

FMA (s)	TAR 7		TAR 8		TAR 10			
	7		8		10			Total
	Landings	TACC	Landings	TACC	Landings	TACC	Landings§	TACC
1983–84*	896	-	109	-	0	-	5 430	-
1984–85*	609	-	102	-	0	-	4 816	-
1985–86*	519	-	122	-	0	-	5 051	-
1986–87	904	930	185	190	0	10	4 446	5 160
1987–88	840	1 046	197	196	0	10	4 855	5 598
1988–89	630	1 059	121	197	0	10	4 090	5 727
1989–90	793	1 069	114	208	0	10	4 473	5 873
1991–92	710	1 087	190	225	2	10	5 417	5 953
1992–93	929	1 087	189	225	0	10	5 158	5 989
1990–91	629	1 087	131	225	< 1	10	5 086	5 953
1993–94	780	1 087	191	225	0	10	4 878	5 990
1994–95	978	1 087	171	225	0	10	5 129	5 991
1995–96	890	1 087	105	225	0	10	5 375	5 991
1996–97	1 013	1 087	133	225	0	10	5 512	5 991
1997–98	685	1 087	153	225	0	10	5 287	5 991
1998–99	1 041	1 087	175	225	0	10	5 501	5 991
1999–00	964	1 087	189	225	0	10	5 719	5 991
2000–01	1 178	1 087	178	225	0	10	5 935	5 991
2001–02	1 000	1 088	223	225	0	10	6 119	5 993
2002–03	1 069	1 088	211	225	0	10	6 008	5 993
2003–04	1 116	1 088	197	225	0	10	5 723	5 993
2004–05	1 056	1 088	184	225	0	10	5 683	6 390
2005–06	1 114	1 088	285	225	0	10	6 205	6 390
2006–07	1 116	1 088	254	225	0	10	5 729	6 390
2007–08	990	1 088	196	225	0	10	5 428	6 438
2008–09	977	1 088	169	225	0	10	5 584	6 438
2009–10	1 162	1 088	226	225	0	10	5 553	6 438
2010–11	983	1 088	194	225	0	10	5 708	6 439
2011–12	1 173	1 088	235	225	0	10	5 346	6 439
2012–13	1 058	1 088	209	225	0	10	5 552	6 439
2013–14	1 073	1 088	248	225	0	10	5 857	6 439
2014–15	1 002	1 088	224	225	0	10	6 038	6 439
2015–16	1 105	1 088	238	225	0	10	5 870	6 439
2016–17	1 139	1 088	210	225	0	10	6 337	6 439
2017–18	1 054	1 088	215	225	0	10	5 742	6 439
2018–19	1 049	1 042	243	225	0	10	5 150	5 383

* FSU data. § Includes landings from unknown areas before 1986–87.

Table 4: Total allowable catches (TAC, t) allowance for customary non-commercial fishing, recreational fishing, and other sources of mortality (t), as well as the total allowable commercial catch (TACC, t) for tarakihi as of 1 October 2018.

Fishstock	TAC	TACC	Customary non-commercial	Recreational	Other Mortality
TAR 1 (FMA 1 & 9)	1 390	1 097	73	110	110
TAR 2	1 823	1 500	100	73	150
TAR 3	1 174	1 040	15	15	104
TAR 4	316	316	0	0	0
TAR 5 (FMA 5 & 6)	153	153	0	0	0
TAR 7	1 174	1 042	5	23	104
TAR 8	225	225	0	0	0
TAR 10	10	10	0	0	0

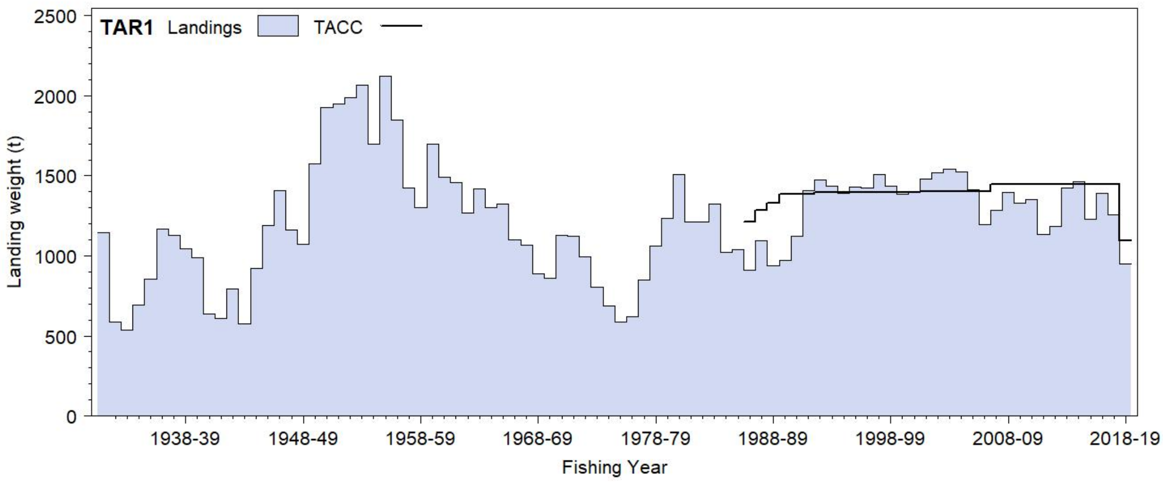
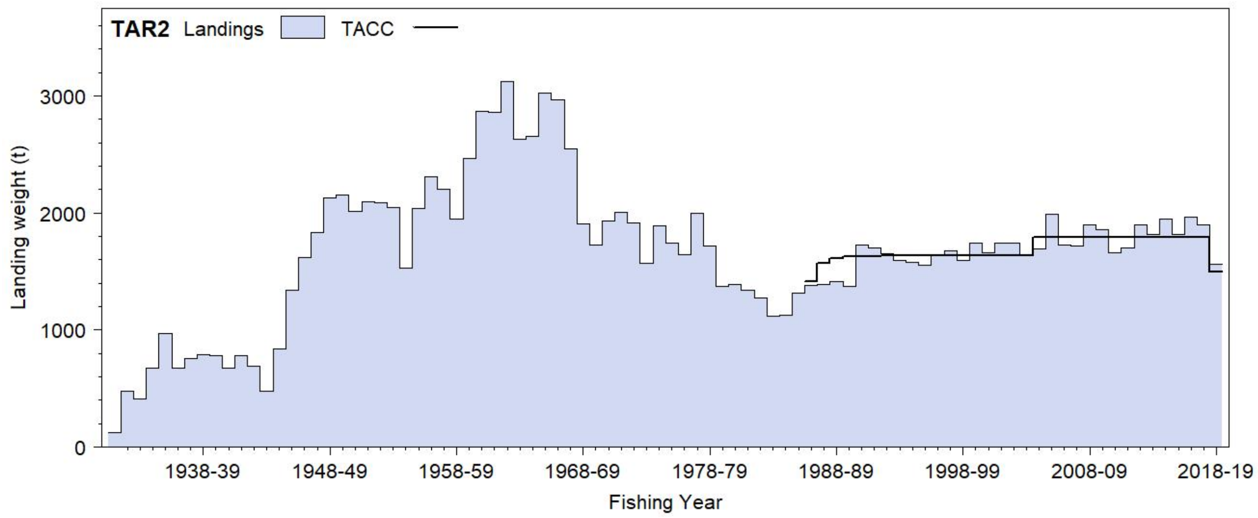
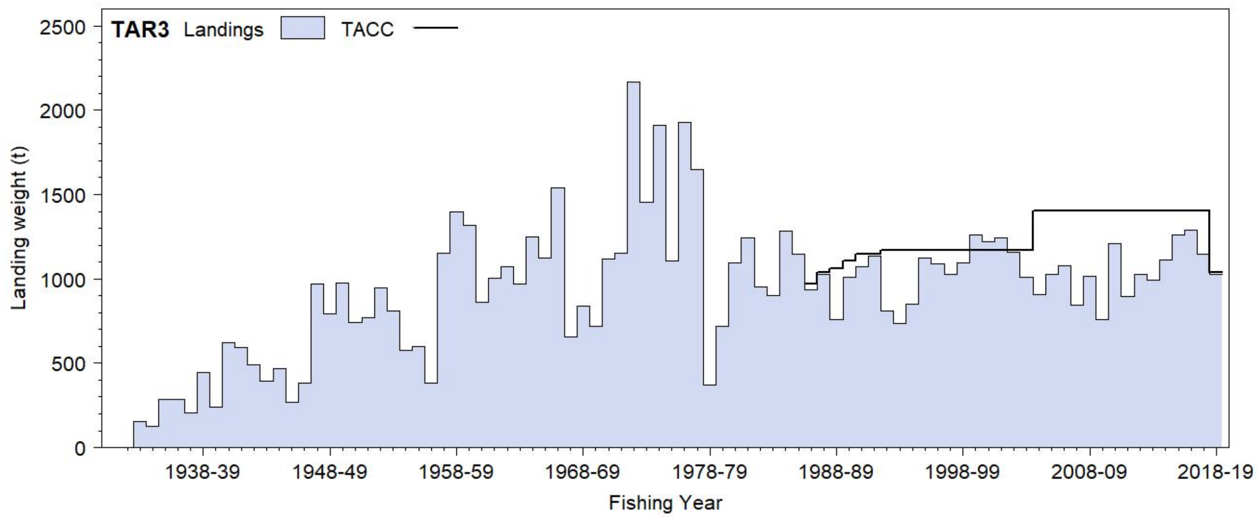


Figure 1: Historical landings and TACCs for the seven main TAR stocks. TAR 1 (Auckland). [Continued on next page].





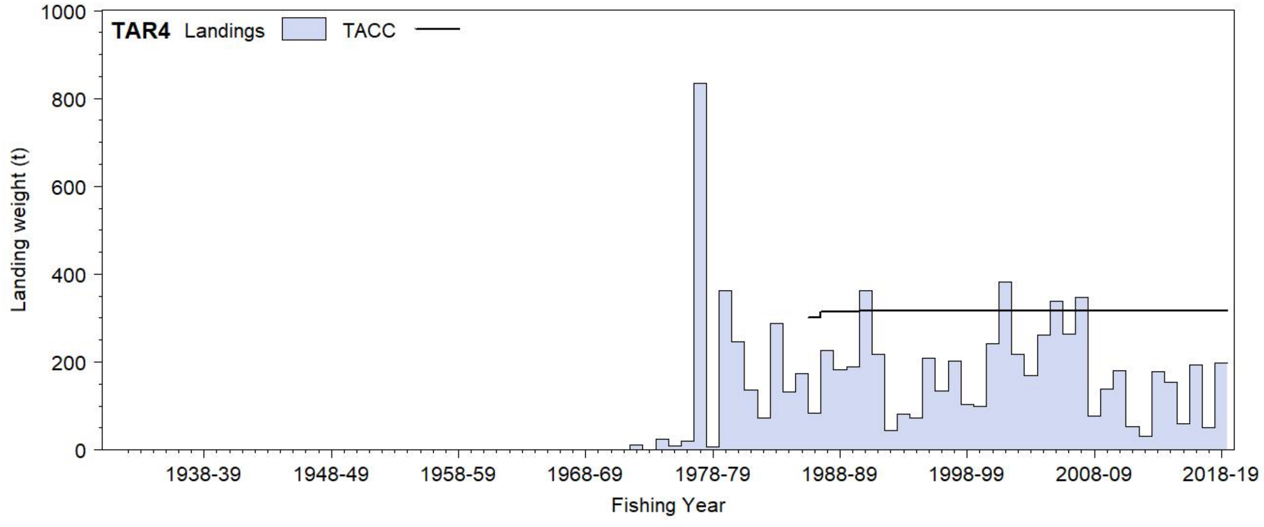
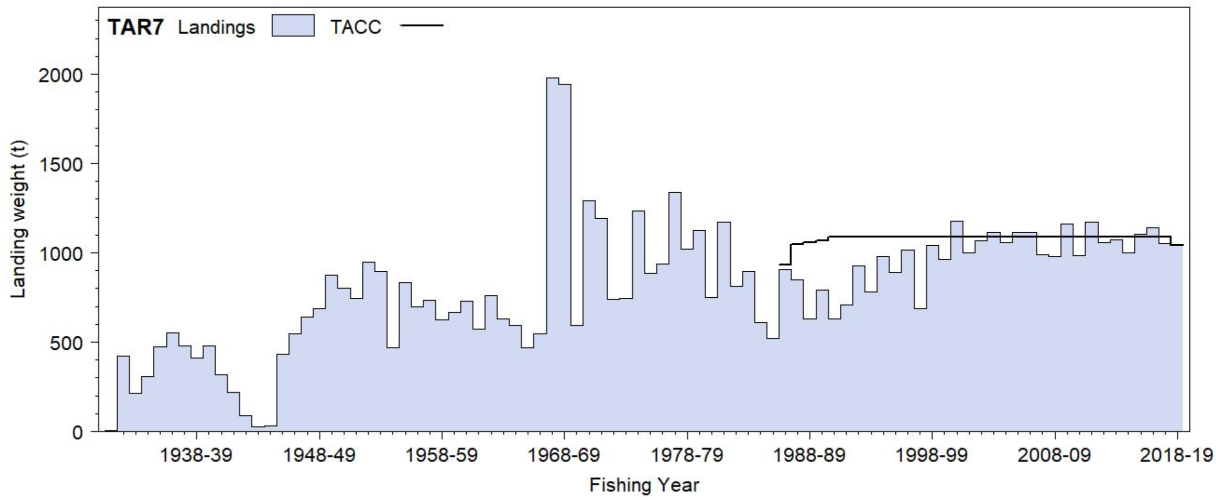


Figure 1: Historical landings and TACCs for the seven main TAR stocks. From top to bottom: TAR 2 (Central East), TAR 3 (South-East Coast) and TAR 4 (Chatham). [Continued on next page].



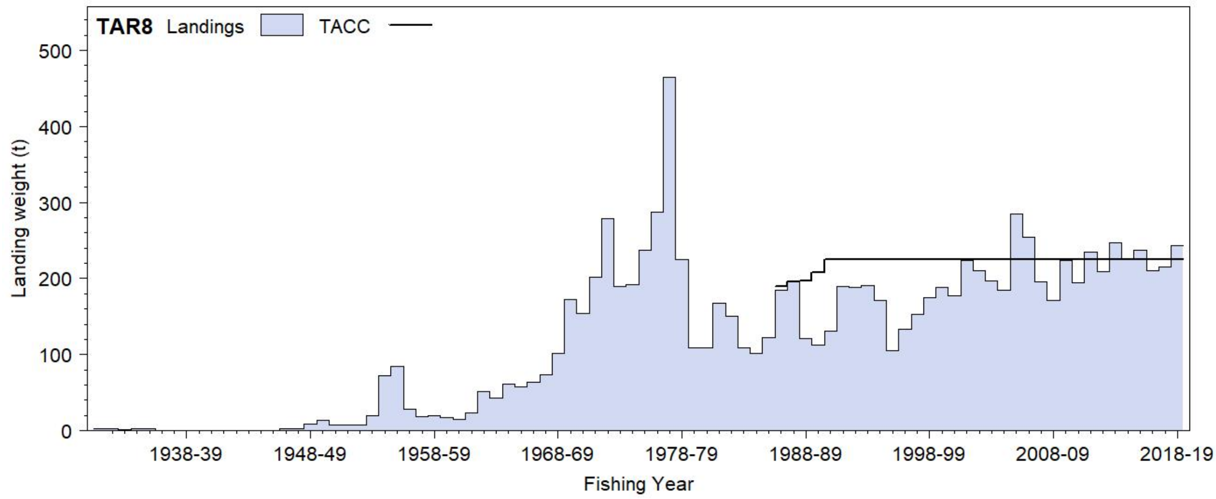


Figure 1 [continued]: Historical landings and TACCs for the seven main TAR stocks. From top to bottom: TAR 7 (Southland Sub-Antarctic) and TAR 8 (Central West).

1.2 Recreational fisheries

Tarakihi are taken by recreational fishers using lines and setnets. They are often taken by fishers targeting snapper and blue cod, particularly around the North Island. The allowances within the TAC for each Fishstock are shown in Table 4.

1.2.1 Management controls

The main methods used to manage recreational harvests of tarakihi are minimum legal size limits (MLS), method restrictions and daily bag limits. Fishers can take up to 20 tarakihi as part of their combined daily bag limit (except in the South-East and Southland fisheries management areas including the Fiordland Marine Area where the limit is 15 within a combined daily bag limit of 30 finfish) and the MLS is 25 cm in all areas.

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 for tarakihi were calculated using offsite regional or national telephone-diary surveys (Table 5, Bradford 1998, Boyd & Reilly 2002, Boyd et al 2004). The early telephone-diary method was prone to “soft refusal” bias during recruitment and overstated catches during reporting (Wright et al 2004). Estimates of harvest from the later telephone-diary surveys were found to be implausibly high for many species. None of the harvest estimates from these telephone-diary surveys are now thought reliable.

Onsite surveys provide a more direct means of estimating recreational harvest, but are expensive and suited to relatively few fisheries. Hartill et al (2007a) developed a maximum count aerial-access method to combine data from concurrent creel surveys of recreational fishers returning to key ramps and aerial counts of vessels observed to be fishing. 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 is used to scale up harvests observed at surveyed ramps, to estimate harvest taken by all fishers returning to all ramps. This approach was first used to estimate snapper harvest in the Hauraki Gulf in 2003–04. It was then extended to cover the whole of FMA 1 in 2004–05 and to provide estimates for other species, including tarakihi (FMA 1 only) (Hartill et al 2007b). This survey was repeated in 2011–12 (Hartill et al 2013) and 2017–18 (Hartill et al 2019).

Problems with the earlier offsite telephone-diary surveys led to the development of a rigorously-designed National Panel Survey (NPS) which was first used for the 2011–12 fishing year (Heinemann et al 2015). The 2011–12 NPS used face-to-face interviews of a random sample of 30 390 households to recruit a panel of 7013 fishers and a further sample of 3000 putative non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information collected in standardised computer assisted telephone interviews (CATI). Harvest estimates from the NPS (Wynne-Jones et al 2014) and the 2011–12 aerial-access survey (Hartill et al 2013) are similar for the FMA 1 portion of TAR 1 (and other key recreational fisheries in FMA 1) and are, therefore, considered to be reasonably accurate and fit for management purposes (Edwards & Hartill 2015). The NPS and a parallel FMA 1 aerial-access survey were repeated for the 2017–18 fishing year and harvest estimates are included in Table 5.

Table 5: Recreational harvest estimates (including catch on amateur charter vessels but excluding catch under customary permits and s111 approvals) for tarakihi stocks (Bradford 1998, Boyd & Reilly 2002, Boyd et al 2004, Hartill et al 2007b, Hartill et al 2013, 2019, Wynne-Jones et al 2014, 2019). The telephone/diary surveys and earlier aerial-access survey ran from December to November but are denoted by the January calendar year. Surveys since 2010 have run through the October to September fishing year but are denoted by the January calendar year. Mean fish weights for offsite surveys were obtained from boat ramp surveys (e.g., Hartill & Davey 2015).

Stock	Year	Method	Number of fish	Total weight (t)	CV
TAR 1	1996	Telephone/diary	498 000	305	0.08
	2000	Telephone/diary	1 035 000	636	0.19
	2001	Telephone/diary	679 000	417	0.16
	2012	Panel survey	166 540	117	0.22
FMA 1 only	2005	Aerial-access*	-	90	0.18
FMA 1 only	2012	Aerial-access*	-	67	0.15
FMA 1 only	2012	Panel survey	160 414	113	0.22
	2012	Panel survey	166 449	117	0.22
FMA 1 only	2018	Aerial-access*	-	46	0.13
FMA 1 only	2018	Panel survey	59 000	50	0.16
	2018	Panel survey	73 289	62	0.14
TAR 2	1996	Telephone/diary	114 000	65	0.14
	2000	Telephone/diary	310 000	191	0.27
	2001	Telephone/diary	484 000	298	0.18
	2012	Panel survey	110 920	72	0.22
	2018	Panel survey	148 159	110	0.22
TAR 3	1996	Telephone/diary	3 000	-	-
	2000	Telephone/diary	25 000	15	0.51
	2001	Telephone/diary	7 000	4	0.37
	2012	Panel survey	4 208	3	0.42
	2018	Panel survey	6 622	5	0.32
TAR 5	1996	Telephone/diary	3 000	-	-
	2000	Telephone/diary	10 000	6	0.57
	2001	Telephone/diary	13 000	7	0.37
	2012	Panel survey	141	<1	0.73
	2018	Panel survey	5 545	4	0.35

Table 5 [Continued]

Stock	Year	Method	Number of fish	Total weight (t)	CV
TAR 7	1996	Telephone/diary	69 000	24	0.13
	2000	Telephone/diary	87 000	33	0.18
	2001	Telephone/diary	9 000	3	0.15
	2012	Panel survey	48 107	23	0.38
	2018	Panel survey	31 668	21	0.18
TAR 8	1996	Telephone/diary	46 000	28	0.17
	2000	Telephone/diary	66 000	30	0.38
	2001	Telephone/diary	78 000	36	0.28
	2012	Panel survey	31 340	23	0.30
	2018	Panel survey	37 706	22	0.29

* Aerial-access surveys did not include catches from charter vessels whereas these are included in the panel survey estimates. The estimates for FMA 1 in this table are not, therefore, directly comparable. See Edwards & Hartill 2015 for details.

1.3 Customary non-commercial fisheries
No quantitative information on the level of customary non-commercial fishing is available.

1.4 Illegal catch
No quantitative information on the level of illegal tarakihi catch is available.

1.5 Other sources of mortality
No information is available.

2. BIOLOGY

Juvenile tarakihi grow relatively fast, reaching 25 cm fork length (FL) at 4 years of age. Sexual maturity was initially estimated at 25–35 cm FL, and an age of 4–6 years (Annala 1987), but more recent studies indicate 50% maturity is attained at about 33 cm FL and an age of 6 years (Parker & Fu 2011). Growth rates attenuate from an age of 5–6 years (Annala et al 1990).

Growth rates are generally similar for the main tarakihi fishstocks, although recent studies have indicated that the growth rates of tarakihi older than 6 years of age are lower in the Bay of Plenty and east Northland compared to other fishery areas. Tarakihi reach a maximum age of 40+ years (Annala et al 1990).

Tarakihi spawn in summer and autumn. Three main spawning grounds have been identified: Cape Runaway to East Cape, Cape Campbell to Pegasus Bay, and the west coast of the South Island near Jackson Bay. Spawning fish have also been sampled from the Bay of Plenty and east Northland and limited spawning probably occurs throughout the distributional range of tarakihi around New Zealand.

Few larval and post-larval tarakihi have been caught and identified. The post-larvae appear to be pelagic, occur in offshore waters, and are found in surface waters at night. Post-larval metamorphosis to the juvenile stage occurs in spring or early summer when the fish are 7–9 cm FL and 7–12 months old.

Several juvenile nursery areas have been identified in shallower, inshore waters, including the southwest coast of the North Island, Tasman Bay, near Kaikoura, northern Pegasus Bay, Canterbury Bight, Otago and the Chatham Islands. Juveniles move out to deeper water at a length of about 25 cm FL at an age of 3–4 years. Recent sampling of the TAR 3 trawl catch revealed that a high proportion of the landed catch is comprised of immature fish. Conversely, TAR 3 set net and TAR 2 trawl landed catches were comprised mainly of mature fish.

The results of tagging experiments carried out near Kaikoura during 1986 and 1987 indicate that some tarakihi are capable of moving long distances. Fish have been recaptured from as far away as the Kaipara Harbour on the west coast of the North Island, south of Whangarei on the east coast of the North Island, and Timaru on the east coast of the South Island. Age composition of commercial bottom trawl and survey catches along the east coast of New Zealand suggest that juvenile tarakihi move progressively northward from the Canterbury Bight to East Northland as they grow older (McKenzie et al 2017).

An estimate of natural mortality for tarakihi was derived from the age structures of lightly exploited populations sampled from the west coast of the South Island in 1971 and 1972. A catch curve analysis yielded total mortality estimates of 0.13 from both samples (Vooren 1973). Estimates of Z for the area near Kaikoura made during 1987 ranged from 0.12–0.16 for fish between 8 and 20 years old (Annala et al. 1990). An approximation of M was derived from the oldest age observed in the Kaikoura sample (42 years), yielding an estimate of $M = 0.11$. It was concluded that M was no greater than 0.10 and that this value was also the best available estimate of M.

Biological parameters relevant to the stock assessment are shown in Table 6.

Table 6: Estimates of biological parameters of tarakihi.

Fishstock							**Estimate**	**Source**
1. Natural mortality (M)								
							0.10 considered best estimate for all areas for both sexes	Annala et al (1989, 1990)
2. Weight = a (length)^b (Weight in g, length in cm fork length)								
	Females			Males				
	a		b	a		b		
TAR 3	0.04		2.79	0.0433		2.77		Annala et al (1990)
TAR 4	0.023		2.94	0.017		3.02		Annala et al (1989)
TAR 7	0.015		3.058	0.0141		3.07		Manning et al (2008)
3. von Bertalanffy growth parameters								
	Females			Males				
	K	t_0	$L\infty$	K	t_0	$L\infty$		
TAR 3	0.2009	- 1.103	44.6	0.2085	- 1.397	42.1		Annala et al (1990)
TAR 4	0.2205	- 1.026	44.6	0.1666	- 2.479	44.7		Annala et al (1989)
TAR 7	0.234	- 0.57	45.6	0.252	- 0.41	42.7		Manning (2008)

3. STOCKS AND AREAS

The results of tagging experiments have shown that tarakihi are capable of moving large distances around the coasts of the main islands of New Zealand. The long pelagic larval phase of 7–12 months indicates that larvae will also be widely dispersed. Previously these two factors, in addition to the lack of any evidence of genetic isolation, had been used to suggest that tarakihi around the main islands of New Zealand consist of one continuous stock. Further, because of the large distance between the mainland and the Chatham Islands, and the separation of these two areas by water deeper than that which is usually inhabited by adult tarakihi, the tarakihi around the Chatham Islands were considered to be a separate stock.

Trends in CPUE indices and age compositions from the TAR 1, 2 and 3 fisheries were examined to investigate the stock structure of tarakihi along the east coasts of mainland New Zealand. The fisheries in Canterbury Bight/Pegasus Bay are dominated by younger fish and there is a progressive increase in the proportion of older fish in the catches from TAR 2, Bay of Plenty and east Northland, while the relative strength of individual year classes is comparable amongst these areas. Trends in CPUE indices are also comparable among these fisheries, lagged by the relative age of recruitment to the respective fishery.

There are distinct spawning grounds in each of the two main islands (off East Cape in the northern area and off Cape Campbell in the south), while there is a preponderance of juvenile fish in Canterbury Bight/Pegasus Bay and low densities of juvenile tarakihi in East Northland, Bay of Plenty and TAR 2. The long pelagic phase of tarakihi may provide a mechanism for the transfer of larvae to the nursery grounds in Canterbury Bight/Pegasus Bay.

These observations indicate considerable connectivity of tarakihi along the east coast of the South and North Islands. The current stock hypothesis is that the Canterbury Bight/Pegasus Bay area represents the main nursery area for the eastern stock unit. At the onset of maturity, a proportion of the fish migrate northwards to recruit to the East Cape area and, subsequently, the Bay of Plenty and east Northland areas. This hypothesis is further supported by the northward movement of tagged fish from the Kaikoura coast to the Wairarapa, East Cape and Bay of Plenty areas.

The results from previous tagging studies also indicate some connectivity between Kaikoura and the west coast North Island. However, limited data are available from the west coast North Island to elucidate the degree of the linkage between these areas. Recent age composition data from the west coast North Island revealed similarities and differences in the relative strength of individual year classes compared to the east coast South and North Island fisheries. Further, growth rates of older fish (more than 6 yrs) sampled from the west coast North Island differed from east Northland, suggesting a lack of connectivity between the fisheries around the north of the North Island.

Limited direct comparisons are available between the age compositions from the east coast tarakihi fisheries and the west coast South Island (TAR 7) fishery. The age composition data from the WCSI trawl surveys (in 1995, 1997, 2000, 2003 and 2005) and 2004–05 TAR 7 commercial catches indicate the presence of a strong year class in 1991 and weak year classes in 1989, 1999, 2003 and 2004. These limited observations are broadly consistent with estimates of recruitment strength derived from the stock assessment modelling of the east coast tarakihi stock. Nonetheless, a more comprehensive analysis of the available data sets is required to further investigate the stock structure between tarakihi in TAR 7 and the east coast areas, especially around the South Island.

Smith et al (1996) used two genetic techniques to determine that king tarakihi from northern New Zealand is a separate species from tarakihi (*N. macropterus*). King tarakihi are caught at the northern extent of the range of tarakihi (North Cape and Three Kings Islands). Due to concerns that some tarakihi catches were being misreported, as from December 2010, king tarakihi was included within the species definition of the tarakihi QMS fishstocks (under Fisheries (Commercial Fishing) Regulations 2001). All subsequent catches of king tarakihi should have be included within the TAR 1 TACC. However, modest commercial catches (20–30 t per annum) of king tarakihi (KTA) were reported from FMA 1 in the 2002–03 to 2004–05 fishing years. No additional annual catches of king tarakihi have been reported separately since then.

The magnitude of king tarakihi catches reported within TAR 1 is considered to be small due to the distribution of the main fisheries relative to the known distribution of king tarakihi. Similarly, the magnitude of tarakihi catch misreported as king tarakihi is also considered to have been small.

4. STOCK ASSESSMENT

An integrated assessment for TAR 7 was conducted in 2008 with data that included the commercial catch, trawl survey biomass and proportions-at-age estimates, CPUE indices, and commercial catch proportions-at-age.

In 2017, a stock assessment was conducted for east coast tarakihi combining eastern TAR 1 (Bay of Plenty and East Northland), TAR 2 and TAR 3.

4.1 Trawl Surveys

4.1.1 Relative abundance

Indices of relative biomass are available from *Kaharoa* trawl surveys in TAR 2, TAR 3 and TAR 7 (Table 7, Figure 2, 3 and 3a). Note that these estimates were revised in 1996 as a result of new doorspread estimates becoming available from SCANMAR measurements. In TAR 2 and TAR 3 no trend is apparent in the biomass estimates. The TAR 2 survey was conducted for four consecutive years: 1993–1996 and then discontinued.

West Coast South Island Inshore Trawl Survey

For TAR 7, trawl survey biomass estimates for pre-recruit (less than 25 cm F.L.) and recruited (≥ 25 cm) tarakihi were derived for the west coast South Island and Tasman Bay/Golden Bay (TBGB) areas of the WCSI trawl survey. The TBGB area is considered to be a primary nursery ground for tarakihi in

TAR 7. A substantial proportion of the TAR 7 commercial catch is taken from the west coast portion of the survey area. For comparability with the commercial CPUE indices it is appropriate to partition the trawl survey biomass indices by area and size category.

Biomass estimates for the west coast strata of the survey ground are relatively stable through the time series aside from higher than usual estimates in 2005 and 2017 (Figure 2). The most recent estimate from 2019 is more similar to the time series mean (MacGibbon 2019). Most of the survey biomass is recruited fish. In contrast, more of the survey biomass in TBGB is comprised of pre-recruited fish. Biomass estimates in TBGB fluctuate more than those for the west coast and the CVs for pre-recruited fish are often high. Throughout the time series, total biomass of the west coast has been substantially greater than for TBGB. Similar to the west coast, the 2019 estimates for TBGB are substantially lower than in 2017 and more in line with the time series mean. Most of the fish in TBGB are pre-recruited fish.

East coast South Island Trawl Survey

The ECSI winter surveys from 1991 to 1996 (depth range 30–400 m) were replaced by summer trawl surveys (1996–97 to 2000–01) which also included the 10–30 m depth range; but these were discontinued after the fifth in the annual time series, because of the extreme fluctuations in catchability between surveys (Francis et al 2001). The winter surveys were reinstated in 2007, and this time included strata in the 10–30 m depth range, in order to monitor elephant fish and red gurnard which were officially included in the list of target species in 2012. Only the 2007, 2012, 2014, 2016 and 2018 surveys provide full coverage of the 10–30 m depth range.

Tarakihi biomass in the core strata peaked in 1993 due to a single large catch off Timaru resulting in a high CV of 55%. Overall, however, there is no trend in the core strata time series, although the 2018 biomass was the third lowest survey estimate, down slightly from the 2016 estimate (Table 7, Figure 3). Pre-recruit core strata biomass was a major but variable component of tarakihi total biomass estimates on all surveys, ranging from 18% to 60% of total biomass, and 29% in 2018. Similarly, juvenile core strata biomass (based on length-at-50% maturity) was also a large component of total biomass, but the proportion was relatively constant over the time series, 60–80%, and in 2018 it was 62% (Figure 4). There was virtually no tarakihi caught in the 10–30 m strata in any of the five surveys, and hence the shallow strata are of no value for monitoring tarakihi. The distribution of tarakihi hotspots varies, but overall this species is consistently well represented over the entire survey area, most commonly from 30 to about 150 m.

The size distributions of tarakihi in each of the twelve ECSI core strata winter trawl surveys were similar and were multi-modal, with smaller modes representing individual cohorts (Beentjes et al 2016). In 2012, 2016 and 2018, the 0+, 1+, 2+, and possibly 3+ cohorts were particularly evident, but were less defined in 2014. Tarakihi on the ECSI, overall, were generally smaller than those from the west coast South Island (Stevenson & MacGibbon 2018) and the east coast North Island (Parker & Fu 2011), suggesting that, like Tasman/Golden Bays, Pegasus Bay and the Canterbury Bight are important nursery grounds for juvenile tarakihi (Beentjes et al 2012, McKenzie et al 2017). The tarakihi sampled by the ECSI trawl surveys are dominated by 2–5 year old fish (MacGibbon et al 2019). There is considerable variation in the relative abundance of individual age classes amongst surveys, indicating high inter-annual variability in recruitment.

North Island Trawl Surveys

Summer surveys in the Bay of Plenty (from Mercury Islands to Cape Runaway) were carried out from 1983 to 1999. These surveys were extended to 250 m, in February 1996 (KAH9601) and 1999 (KAH9902), so that tarakihi depths would be covered. However, the estimates of biomass were low (35 t CV 46% in 1996 and 50 t CV 27% in 1999). Most of the catch in the 1999 survey was taken in depths of 150 to 200 m.

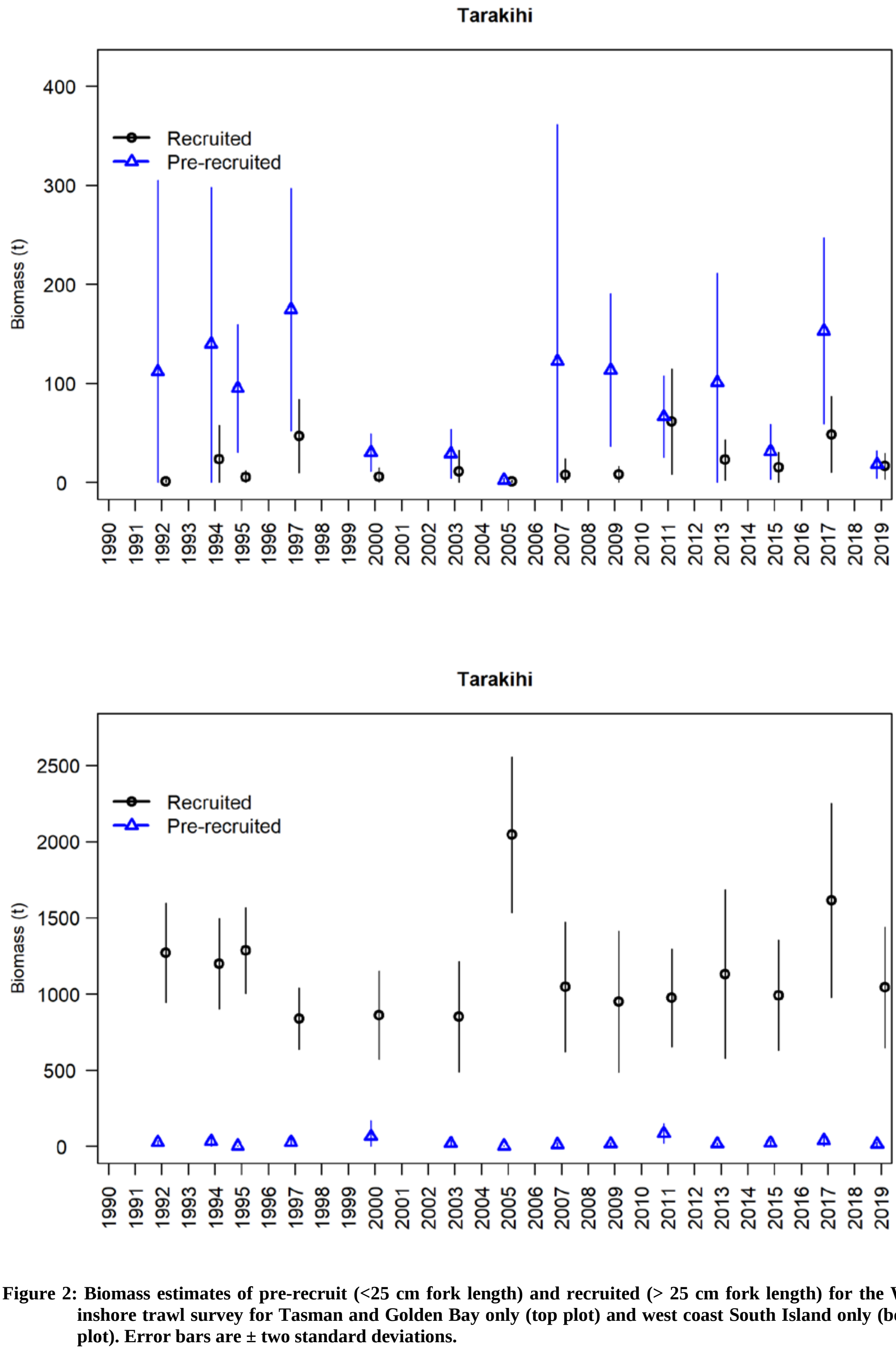


Figure 2: Biomass estimates of pre-recruit (<25 cm fork length) and recruited (> 25 cm fork length) for the WCSI inshore trawl survey for Tasman and Golden Bay only (top plot) and west coast South Island only (bottom plot). Error bars are ± two standard deviations.

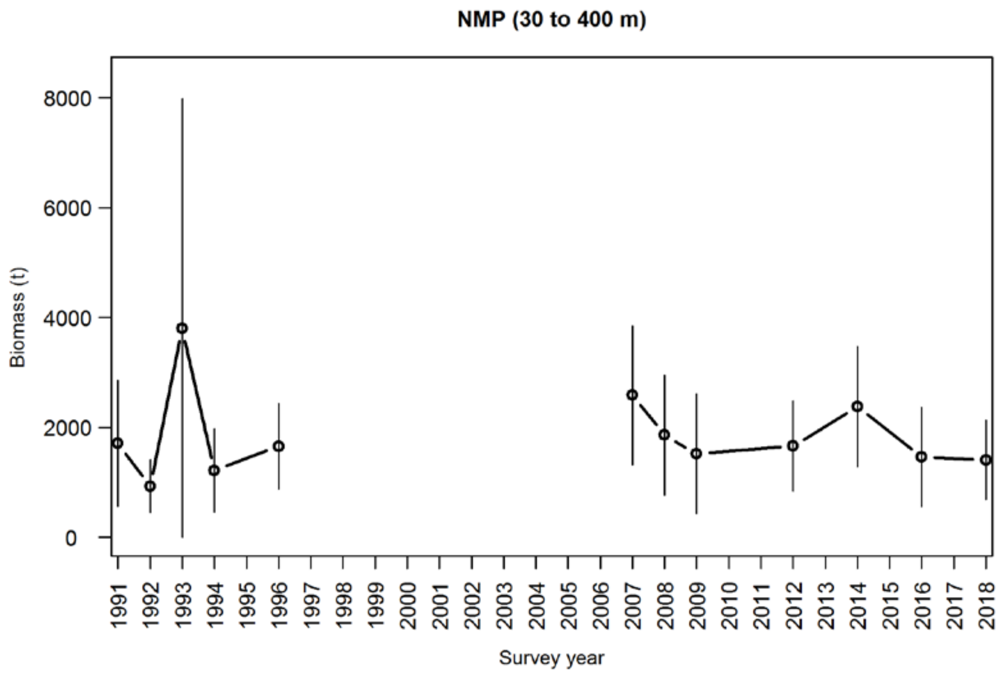


Figure 3: Tarakihi total biomass for the ECSI winter surveys in core strata (30–400 m). Error bars are ± two standard errors.

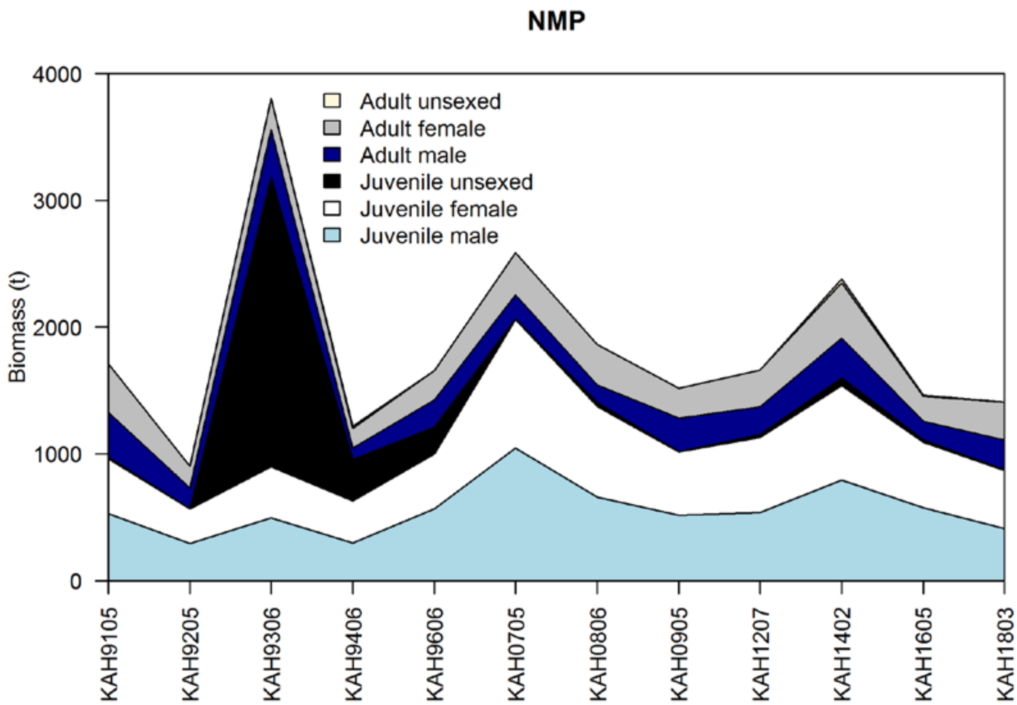


Figure 2a: Tarakihi juvenile and adult biomass for ECSI winter surveys in core strata (30–400 m), where juvenile is below and adult is equal to or above the length at which 50% of fish are mature.

Table 7: Relative biomass indices (t) and coefficients of variation (CV) for tarakihi for Cape Runaway to Cook Strait, ECSI – summer and winter, and Tasman Bay to Haast survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 and 9 equivalent to current strata 13, 16 and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (25 cm).

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
Cape Runaway to Cook Strait	TAR 2	1991	KAH9304	885	27	-	-	-	-	-	-	-	-	-	-
		1992	KAH9402	1 128	20	-	-	-	-	-	-	-	-	-	-
		1993	KAH9502	791	23	-	-	-	-	-	-	-	-	-	-
		1994	KAH9602	943	15	-	-	-	-	-	-	-	-	-	-
ECSI (winter)	TAR 3			30–400 m		10–400m		30–400m		10–400m		30–400m		10–400m	
		1991	KAH9105	1 712	33	-	-	305	38	-	-	1 414	33	-	-
		1992	KAH9205	932	26	-	-	288	26	-	-	614	28	-	-
		1993	KAH9306	3 805	55	-	-	2 282	62	-	-	1522	46	-	-
		1994	KAH9406	1 219	41	-	-	494	31	-	-	725	35	-	-
		1996	KAH9606	1 656	24	-	-	519	30	-	-	1137	27	-	-
		2007	KAH0705	2 589	24	-	-	822	30	-	-	1766	24	-	-
		2008	KAH0806	1 863	29	-	-	739	44	-	-	1123	25	-	-
		2009	KAH0905	1 519	36	-	-	525	42	-	-	994	42	-	-
		2012	KAH1207	1 661	25	-	-	584	34	-	-	1077	29	-	-
		2014	KAH1402	2 380	23	-	-	818	26	-	-	1562	26		
		2016	KAH1605	1 462	31			342	40			1 121	33		
		2018	KAH1803	1 409	26	-	-	409	28	-	-	1000	28	-	-
ECSI (summer)	TAR 3	1996	KAH9618	3 818	21	-	-	-	-	-	-	-	-	-	-
		1997	KAH9704	2 036	24										
		1998	KAH9809	4 277	24	-	-	-	-	-	-	-	-	-	-
		1999	KAH9917	2 606	15	-	-	-	-	-	-	-	-	-	-
		2000	KAH0014	1 510	13	-	-	-	-	-	-	-	-	-	-
Tasman Bay to Haast	TAR 7	1992	KAH9204	1 409	14	-	-	-	-	-	-	-	-	-	-
		1994	KAH9404	1 420	14	-	-	-	-	-	-	-	-	-	-
		1995	KAH9504	1 389	11	-	-	-	-	-	-	-	-	-	-
		1997	KAH9701	1 087	12	-	-	-	-	-	-	-	-	-	-
		2000	KAH0004	964	19	-	-	-	-	-	-	-	-	-	-
		2003	KAH0304	912	20										
		2005	KAH0503	2 050	12	-	-	-	-	-	-	-	-	-	-
		2007	KAH0704	1 089	21	-	-	-	-	-	-	-	-	-	-
		2009	KAH0904	1 088	22	-	-	-	-	-	-	-	-	-	-
		2011	KAH1104	1 188	15	-	-	-	-	-	-	-	-	-	-
		2013	KAH1305	1 272	22	-	-	-	-	-	-	-	-	-	-
		2015	KAH1503	1 058	17	-	-	-	-	-	-	-	-	-	-
		2017	KAH1703	1 857	18	-	-	-	-	-	-	-	-	-	-
		2019	KAH1902	1 094	19										

*Assuming areal availability, vertical availability and vulnerability equal 1.0. Biomass is only estimated outside 10 m depth except for COM9901 and CMP0001. Note: because trawl survey biomass estimates are indices, comparisons between different seasons (e.g., summer and winter ECSI) are not strictly valid.

4.2 CPUE analyses

4.2.1 East Coast (TAR 1E, TAR 2, TAR 3) and West Coast North Island (TAR 1W) CPUE analyses

CPUE indices have routinely been derived for tarakihi from the main inshore fisheries in TAR 1, TAR 2 and TAR 3. The CPUE indices were updated in 2012 and the Working Group adopted the CPUE indices as the best available indicators of tarakihi abundance for each fishstock. In 2017, the CPUE indices were updated again, with some refinements (Langley 2017). In 2018, the CPUE indices for the TAR 1E, TAR 2, TAR 3 fisheries were updated for inclusion in an update of the eastern stock assessment. The TAR 1W CPUE indices were not updated at that time.

The six sets of CPUE series are defined in Table 8. The individual CPUE data sets either maintained the individual trawl event records or aggregated daily catch and effort data (approximating the CELR data format). Event based catch and effort data were available for the TAR 1 trawl fisheries from 1993–94. These event based data were utilised for those fisheries where there had been appreciable changes in the spatial distribution of fishing effort which had influenced the catch rates of tarakihi. The daily aggregated catch and effort data were available from 1989–90 to 2016–17 for all fisheries.

For the trawl fisheries, CPUE was modelled as two components: 1) the magnitude of the positive tarakihi catch (assuming either a lognormal or Weibull error distribution) and 2) the presence/absence of tarakihi in the catch (binomial model). Combined annual CPUE indices were derived from the year effects determined from the two models. For the TAR 3 set net fishery, the CPUE indices were derived from the lognormal CPUE model of positive tarakihi catch.

The BPLE-BT, TAR2-BT, TAR3-BT and TAR3-SN CPUE indices derived in 2017 were very similar to the sets of CPUE indices from 2012. In 2017, there were changes in the definition of the CPUE data sets for the WCNI-BT and ENLD-BT fisheries which resulted in considerable differences in the CPUE indices compared to the 2012 analysis.

Table 8: Names and descriptions of the six tarakihi CPUE series accepted by the WG in 2017. Also shown is the error distribution that had the best fit to the distribution of standardised residuals for the positive catch component of the model.

Name	Code	QMA	Method	Statistical areas	Target species	Data format	Distribution
West coast North Island	WCNI-BT	TAR 1	BT	045, 046, 047	TAR, SNA, TRE	Event	Lognormal
East Northland	ENLD-BT	TAR 1	BT	002, 003	TAR	Event	Weibull
Bay of Plenty	BPLE-BT	TAR 1	BT	008, 009, 010	TAR, SNA, TRE, SKI, JDO, GUR	Daily	Weibull
East coast North Island	TAR2-BT	TAR 2	BT	011, 012, 013, 014, 015	TAR, SNA, BAR, SKI, WAR, GUR	Daily	Lognormal
East coast South Island	TAR3-BT	TAR 3	BT	017, 018, 020, 022, 024, 026	TAR, BAR, RCO, WAR, GUR	Daily	Lognormal
Area 18 target setnet	TAR3-SN	TAR 3	SN	018	TAR	Daily	Lognormal

Both the BPLE-BT and TAR2-BT CPUE indices reached a peak during 2000–01 to 2004–05 (Figure 5). There were corresponding peaks in the CPUE indices from the ENLD-BT and TAR3-SN fisheries at about the same time. The increase in the CPUE indices was preceded by a peak in the TAR3-BT CPUE indices during 1999–2000 to 2001–02. More recently, the CPUE indices from the TAR3-BT fishery increased during 2009–10 to 2016–17, while the TAR2-BT CPUE indices also increased during the last five years. This is contrasted by a sharp decline in the CPUE indices from BPLE-BT and ENLD-BT during 2009–10 to 2015–16. For 2016–17, the BPLE-BT increased, while the index from ENLD-BT continued the declining trend. The CPUE indices from the northern WCNI trawl fishery (WCNI-BT) generally declined between 1998–99 to 2003–04 and 2013–14 to 2015–16 (Figure 5).

The CPUE indices (with the exception of WCNI-BT) were used as inputs to the stock assessment of tarakihi off the east coast of the North and South Islands.

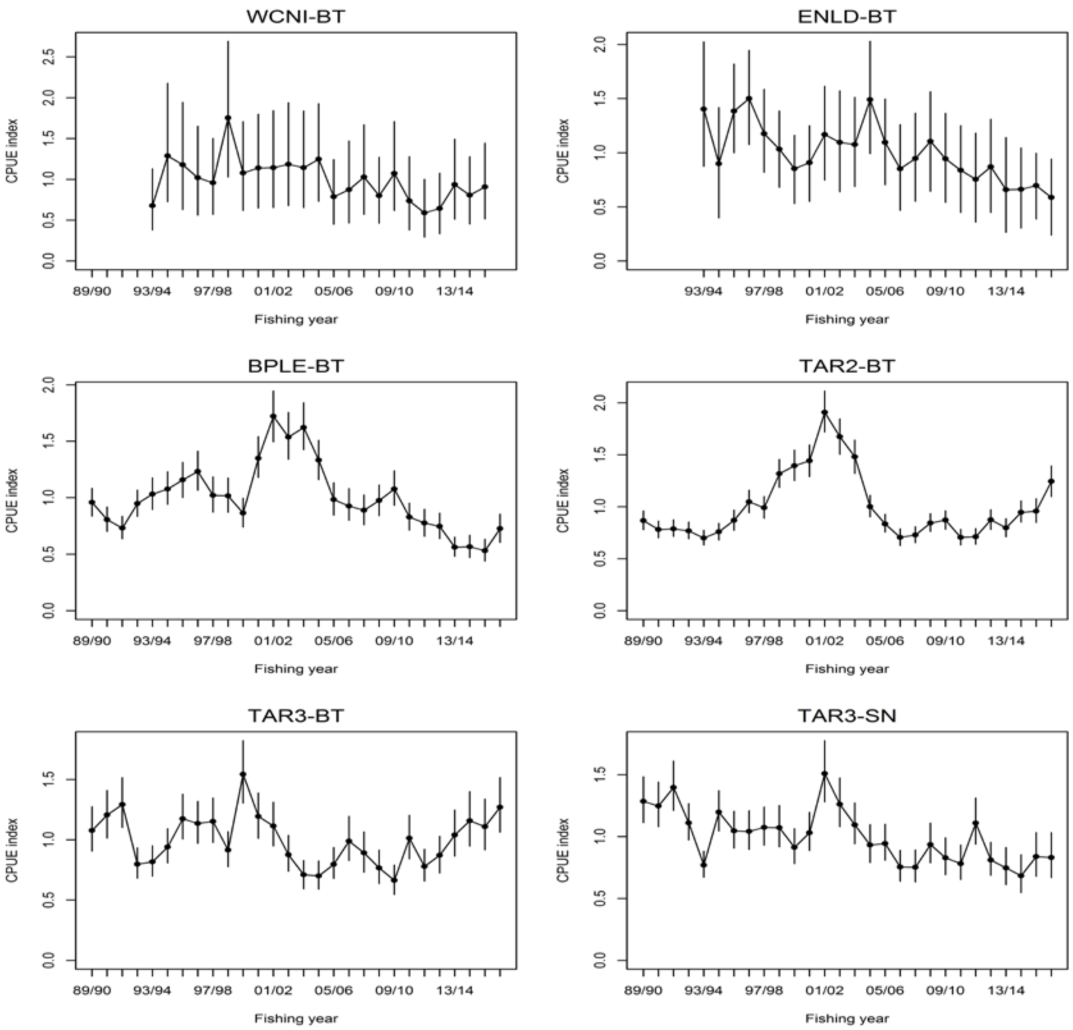


Figure 5. A comparison of the six sets of CPUE indices from TAR 1, TAR 2 and TAR 3 (combined indices, except for TAR3-SN). The error bars represent 95% confidence intervals.

4.2.2 Eastern Cook Strait (TAR 7)

CPUE indices of abundance were developed for the mixed trawl fishery targeting TAR, BAR, WAR, GSH, STA off the northeastern coast of the South Island (Statistical Areas 017, 018). A GLM approach was used to model the probability of catching tarakihi during a fishing day (binomial model) and the magnitude of the positive catch of tarakihi (lognormal model). The main explanatory variables included in both models were fishing year, target species, month, vessel and fishing duration. The annual coefficients from both models were combined to derive the CPUE indices (delta-lognormal indices).

The CPUE indices fluctuate over the time series with peaks in CPUE during 1993–94 to 1995–96 and 2000–01 to 2002–03. For the last decade, CPUE indices were relatively stable, at about the average for the series (Figure 6).

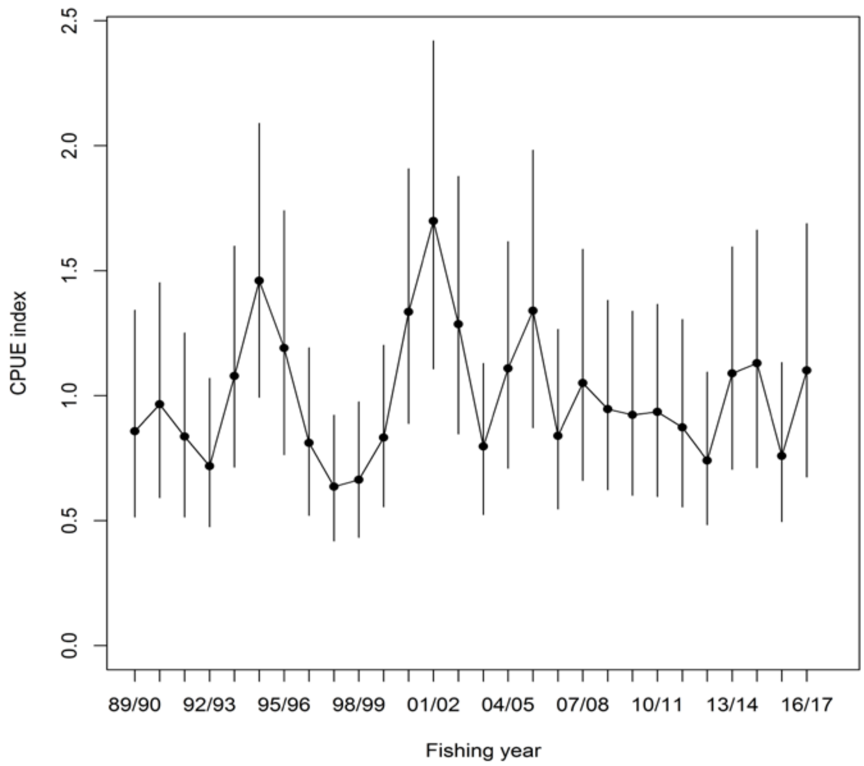


Figure 6: CPUE indices from the eastern Cook Strait mixed inshore trawl fishery.

4.2.3 West coast South Island (TAR 7)

Previously, CPUE indices were developed for the mixed trawl fishery targeting TAR, BAR, WAR, RCO, STA off the west coast of the South Island (Statistical Areas 033, 034, 035, 036). The CPUE indices were updated in 2018. The indices were evaluated by comparing them with the biomass estimates derived from the *Kaharoa* west coast South Island trawl survey for a comparable area and the length range of fish comparable to the commercial catch. The trends in the two sets of indices were comparable during 2006–07 to 2016–17; however, the indices deviated markedly during 1989–90 to 2003–04 and, on that basis, the entire time series of CPUE indices was rejected as an index of stock abundance.

4.2 Stock Assessment Models

East coast North and South Islands (TAR 1E, 2, 3 and eastern TAR 7)

In 2017, an assessment of the east coast mainland New Zealand tarakihi stock was conducted. The assessment was based on the hypothesis of a single east coast stock of tarakihi, as described in Section 3. The area included within the assessment encompasses the east coast of the South Island (TAR 3), eastern Cook Strait (including a portion of TAR 7), the central east coast of the North Island (TAR 2), Bay of Plenty (TAR 1) and east Northland (TAR 1).

The assessment was conducted using an integrated age structured population model implemented in Stock Synthesis. The assessment models incorporated the available catch, CPUE indices, trawl survey biomass estimates and age/length frequency distributions, and recent commercial age composition data.

The current stock hypothesis assumes a relatively complex spatial structure for the east coast tarakihi population: juvenile tarakihi reside predominately in the Canterbury Bight/Pegasus Bay area and, coinciding with the onset of sexual maturity, a proportion of the population migrates along the east coast, extending progressively northwards with increased age and terminating in the East Northland area. During the model development phase, a range of options were investigated to determine the appropriate degree of spatial stratification for the assessment model, given the spatial scale and information content of the various input data sets. The final model options structured the input data into three model regions: east coast South Island (including eastern Cook Strait), central east coast North Island and Bay of Plenty combined (BPLE-TAR2), and East Northland. The east coast South Island region included three commercial fisheries: the Canterbury Bight/Pegasus Bay trawl fishery (TAR3-BT), Kaikoura set net fishery (TAR3-SN) and the eastern Cook Strait trawl fishery (CS-BT). The other two regions each included a commercial trawl fishery and a relatively small non-commercial fishery.

The main input data sets included in the assessment model(s) are as follows:

- Fishery specific annual catches 1932–2016 (2016 = 2015–16 fishing year), including an allowance for unreported catch (an additional 20% of the reported catch prior to the introduction of the QMS in 1986 and an additional 10% of the unreported catch from 1986 onwards) (Figure 7).
- Recent CPUE indices: TAR3-BT, TAR3-SN, combined TAR2-BT and BPLE-BT, ENLD-BT.
- Historical CPUE indices: East Cape (BPLE-TAR2 region) 1961–1970, Canterbury Bight (ECSI region) 1963–1973 (only included in full catch history models).
- Kaharoa inshore ECSI trawl survey biomass estimates and age/length compositions (both winter (n=11) and summer (n=5) time-series).
- Kaharoa inshore ECNI trawl survey biomass estimates and length compositions (n = 3).
- Recent commercial age composition data: TAR3-BT (n=4), TAR3-SN (n=4), CS-BT (n=1), combined TAR2-BT and BPLE-BT combined (n=5), and ENLD-BT (n=2).
- Age composition derived from the James Cook trawl survey of Pegasus Bay-Cape Campbell in 1987.

In addition, a number of age compositions from early trawl surveys were considered in the model development phase. These data were uninformative and were excluded from the final model options.

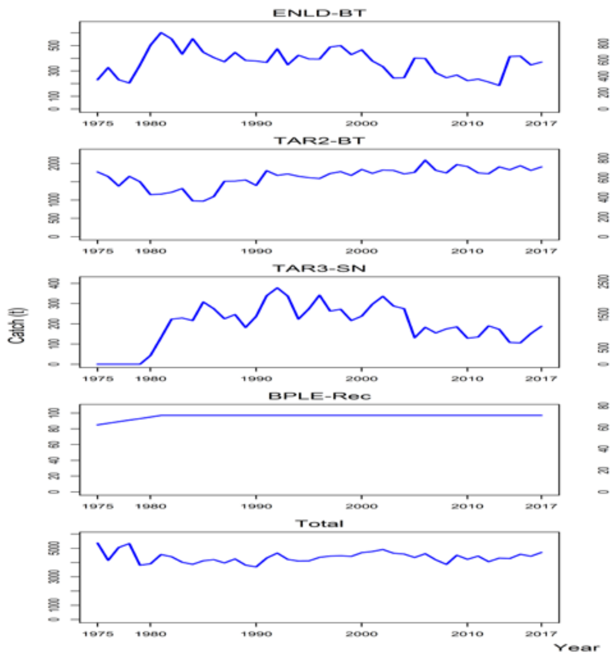


Figure 7: Annual catches of tarakihi by fishery and total included in the base eastern tarakihi stock assessment (1975–2016 and updated to include 2017). The specific commercial fisheries are: TAR3-BT (TAR 3), TAR3-SN (TAR 3), Cook-BT (includes catch from TAR 2 and eastern TAR7), TAR2-BT (TAR 2) and BPLE-BT (TAR 1), ENLD-BT (TAR 1).

The assessment models were structured to include 40 age classes combining both sexes. The key biological parameters are presented in Table 9.

Table 9: Biological parameters included in the east coast tarakihi assessment model for the base model.

Parameter	Value (fixed)
Natural mortality	0.10 y^{-1}
Growth parameters	Length Age 1 = 15.37, k = 0.2009, Linf = 44.6
Proportion mature	Age based
	Ages 1-3 0, Age 4 0.25, Age 5 0.5, Ages 6+ 1.0
SRR steepness	0.9
SigmaR	0.6

For the final model options, two contrasting models were configured: a three region, spatially disaggregated model and a single region, spatially aggregated model (Table 10). The three region model was configured to approximate the stock hypothesis; i.e., each region included a discrete population with recruitment in the southern (ECSI) region only and age-specific movement of fish northwards between adjacent regions. Within each region, the oldest age classes in the population were assumed to be fully vulnerable to the key fisheries (TAR3-BT, CS-BT, TAR2BPLE-BT and ENLD-BT). Fishery catches were taken from the population in each respective region and the abundance indices (CPUE and trawl survey) were taken to represent trends in relative abundance in that region.

In contrast, the single region model comprised a single population. The age composition of the catch from each fishery was mediated by the selectivity of the individual fisheries. For the ENLD-BT fishery, the oldest age classes were assumed to be fully vulnerable (logistic selectivity) based on the high proportion of older age classes observed in the fishery age composition compared to the other fisheries. The selectivity of these other fisheries (and surveys) was parameterised using a double normal function, allowing for lower vulnerability of the older age classes. Thus, all sets of CPUE indices and surveys monitored the relative abundance of the single population mediated by the selectivity.

Annual recruitment was derived from a Beverton-Holt spawner-recruit relationship (SRR). The base model options assumed a high value for steepness (h = 0.9) on the basis that recruitment was considered to be most strongly influenced by the prevailing oceanographic conditions during the long pelagic phase of post larval tarakihi. Inter-annual variability in recruitment was estimated as deviates from the SRR for the period that was informed by the age composition data and recent abundance indices (i.e. 1980–2015). Recruitment deviates were assumed to have a relatively high degree of variability (*sigmaR* = 0.6).

The relative weightings applied to the main data sets were equivalent for the final range of model options, allowing a direct comparison of the model fits (likelihood components) among the individual models. For the recent CPUE indices, each series was assigned a coefficient of variation (CV) of 20%, while the individual trawl survey biomass estimates were weighted by the CV from the individual survey. Most of the recent commercial age composition data sets were assigned a moderate weighting (Effective Sample Sizes of 30). Substantial changes in the relative weightings of individual data sets did not substantially change the model results, indicating broad consistency amongst the key input data sets.

Initial model options included the entire catch history from 1932 and estimated initial levels of fishing mortality for the two fisheries that caught modest quantities of tarakihi during the early 1930s. However, for the three region model, the fits to the CPUE and age composition data from the East Northland model were very poor and the model estimated an implausibly large biomass for the East Northland region. These issues could not be resolved within the modelling framework and appeared to be attributable to the large catches allocated to the East Northland fishery prior to 1965. For this period, the allocation of catches to each region was based on port of landing and all landings in Auckland were attributed to East Northland. This assumption is likely to be incorrect, although no other information is available to apportion the early catch amongst the East Northland and Bay of Plenty fisheries. On that basis, the full catch history, three region model was rejected. In contrast, the full catch history, single region model yielded credible results, including a good fit to the East Northland CPUE and age composition data. It appears that the constraints imposed by the spatial structure of the three region model resulted in conflict between the distribution of catch (and therefore biomass) and the other data sets. These constraints do not exist in the single region model (*1Region_Start1932*).

The regional distribution of catch is considered to be more reliable from about 1965 onwards. Additional model options were configured that were initialised in 1975 (*1Region_Start1975* and *3Region_Start1975*). Initial (1975) conditions were determined by estimating (five) fishery specific levels of fishing mortality (Initial Fs) that were informed by an assumed equilibrium level of catch in the initialisation period. The fishery specific levels of equilibrium catch were set at the average fishery catch from the preceding 10 years (i.e. 1965–1974). For the main model options, equilibrium catches were assumed to be known with a high level of precision. The influence of these assumptions was investigated by increasing the uncertainty associated with the values of the equilibrium catches (model sensitivity InitialCatchVar).

Table 10: The number of estimated parameters included in each of the main model options.

Parameter			Model option
	1Region_Start1932	1Region_Start1975	3Region_Start1975
Ln R0	1	1	1
RecDevs	37	37	37
Selectivity	28	28	18
Initial F	2	5	5
Movement	0	0	4
Total	68	71	65

Overall, the model options that commenced in 1975 yielded very similar results to the full catch history model (*1Region_Start1932*) in terms of the biomass trajectory from 1985–2016 and the estimate of equilibrium, unexploited biomass (SB_0) (Figure 8). Some differences existed between the three region model and the single region models following the initialisation of the population(s) although the biomass trajectories converged during the subsequent period. The comparative model options both had a relatively poor fit to the CPUE indices from ENLD-BT and TAR2BPLE-BT during the early 1990s although the lack of fit was more pronounced for the three region model. Overall fits to some of the other abundance indices (CPUE and survey) were also somewhat worse for the three region model. The fits to the age composition data sets were also considerably worse for the three region model. The greater flexibility of the parameterisation of the selectivity functions (Table 10) for the single region model appears to be the main reason for the improved fit to the two main data components.

The two single region model options yielded very similar estimates of stock biomass (Figure 8). The two model options yielded very similar fits to the individual data sets, excluding the two additional sets of CPUE indices from the 1960s and early 1970s that were only included in the full catch history model. The *1Region_Start1975* model was selected as the base model option as the model was most directly comparable to the *3Region_Start1975* model, while yielding results that were not substantively different from the *1Region_Start1932* model.

Overall, the model results indicate the stock has been in a depleted state since the mid-1970s. This followed a period of relatively high catches (5000–7000 t) during the 1950s and early 1960s. The recent CPUE indices and the associated levels of catch are highly influential in determining the estimate of average recruitment (*R0*) and, hence, equilibrium, unexploited biomass (SB_0). The overall levels of depletion are strongly influenced by the cumulative catch from the earlier period of the model (*1Region_Start1932*) or the estimates of Initial F informed by the assumed level of initial equilibrium catch (*1Region_Start1975* and *1Region_Start1932*).

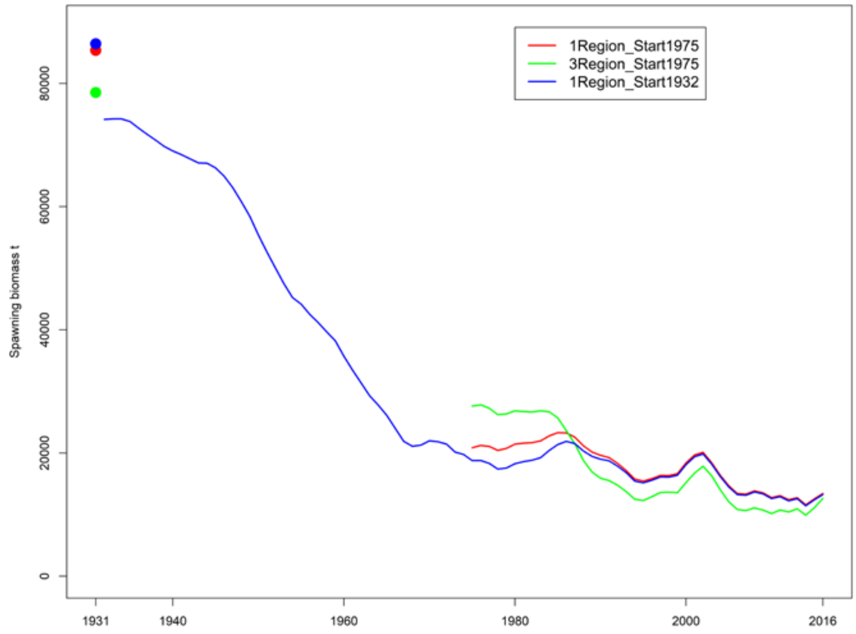


Figure 8: A comparison of the biomass trajectories from the three main model options and the corresponding estimates of the equilibrium, unexploited biomass SB_0 (points) plotted (arbitrarily) at 1931.

Estimates of stock status were determined for each model option using an MCMC approach (sampling from 1 million MCMC draws at an interval of 1000). Model sensitivities were conducted for the base model option (*1Region_Start1975*) to investigate the influence of four key assumptions (Table 11). Current stock status was defined as the mid-year spawning biomass (male and female fish) in 2015–16 relative to equilibrium, unexploited biomass (SB_{2016}/SB_0). Current fishing mortality was estimated relative to a reference fishing mortality that corresponds to the default target biomass of 40% of SB_0 (i.e., $F_{2016}/F_{SB40\%}$).

Table 11: Description of model sensitivities

Sensitivity	Description
InitialCatchVar	Uncertainty associated with Initial Equilibrium Catches
	SE of ln(Catch) = 1.0
LowM	$M = 0.08$
Maturity	Length based maturity OGIVE
	Logistic function parameters Mat50 = 33.56, Matslp = -0.45
Steepness 0.8	$h = 0.8$

Spawning biomass is estimated to have declined to about the default soft limit of 20% SB_0 by the initial period of the assessment model in 1975 (Table 12). Spawning biomass tended to decline over the subsequent years, following an increase in total catches during the 1990s and moderated by variation in recruitment, especially a period of higher recruitment during the mid-late 1990s. Since the mid-2000s, spawning biomass is estimated to have been below the default soft limit and, for the base model, current spawning biomass is estimated to be at 17% of the unexploited, equilibrium biomass level (SB_{2016}/SB_0 = 0.170) (Table 12). Spawning biomass increased slightly from the lowest level in 2014, following above average recruitment in 2011–2012 (Figure 9).

The stock status is similar for the range of model options, although the stock status is slightly more pessimistic for the model sensitivities with lower productivity parameters. For the base case, the model estimates a high probability (89%) that the spawning biomass is below the soft limit, and a low probability (0.3%) of being below the hard limit of 10% SB_0 (Table 12).

Table 12: Estimates of current (*SB_{2016}* 2015–16) and equilibrium, unexploited spawning biomass (*SB_0*) (median and the 95% confidence interval from the MCMCs) and probabilities of current biomass being above specified levels.

Model option	SB_0	SB_{2016}	SB_{2016}/SB_0	Pr (SB_{2016} > X%SB0)		
				40%	20%	10%
Base Region1_Start1975	86 321 (81 977–91 907)	14 620 (10 685–19 413)	0.170 (0.126–0.219)	0.000	0.112	0.997
Region3_Start1975	79 796 (77 016–82 957)	14 170 (10 281–17 850)	0.178 (0.131–0.222)	0.000	0.163	0.998
Region1_Start1932	86 988 (83 194–91 140)	14 614 (11 021–19 283)	0.168 (0.127–0.218)	0.000	0.102	0.999
InitialCatchVar	84 281 (78 864–90 153)	14 172 (10 314–18 749)	0.169 (0.125–0.22)	0.000	0.096	0.999
LowM	102 094 (97 065–107 398)	12 832 (8 295–16 878)	0.126 (0.081–0.166)	0.000	0.000	0.890
Maturity	73 392 (70 030–77 494)	10 350 (7 062–13 780)	0.14 (0.099–0.184)	0.000	0.001	0.970
Steepness 0.8	93 638 (88 334–99 012)	14 464 (8 907–19 488)	0.156 (0.097–0.205)	0.000	0.040	0.969

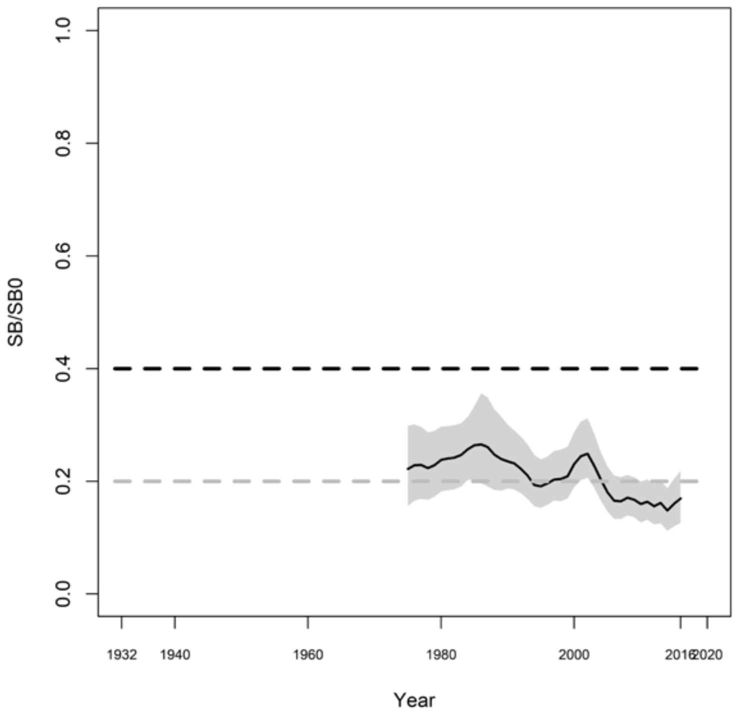


Figure 9: Annual trend in spawning biomass relative to the 40% *SB_0* interim target biomass level and 20% *SB_0* soft limit for the base model. The line represents the median and the shaded area represents the 95% confidence interval.

Annual fishing mortality rates are estimated to have exceeded the level of fishing mortality that corresponds to default target biomass level (i.e. $F_{SB40\%}$) throughout the model period (from 1975) (Figure 10). From 2000, fishing mortality rates are estimated to have increased steadily and for the base model current fishing mortality rates are estimated to be more than double the reference level (i.e. $F_{2016}/F_{SB40\%}$ = 2.23) (Table 13). The estimates of current fishing mortality rates are similar for the range of model options.

Equilibrium yields at the target biomass level are estimated to be about 4100 t. Fishing at the $F_{SB40\%}$ level of fishing mortality would have yielded considerably lower levels of catch in 2016. However, estimates of recent potential yields are relatively uncertain due to the uncertainty associated with estimates of recent recruitment.

Table 13. Estimates of current (F_{2016} 2015–16) and reference levels of fishing mortality ($F_{SB40\%}$) (median and the 95% confidence interval from the MCMCs) and the probability of fishing mortality being below the level of fishing mortality associated with the interim target biomass level. The associated levels of $F_{SB40\%}$ equilibrium yield and 2016 yield at $F_{SB40\%}$ are also presented.

Model option	$F_{SB40\%}$	$F_{2016}/F_{SB40\%}$	Pr(F_{2016}<$F_{SB40\%}$)	$F_{SB40\%}$ Yield	Yield 2016
Base	0.0839	2.231	0.00	4 175	2 448
(Region1_Start1975)	(0.0801–0.0877)	(1.791–2.785)		(3 979–4 379)	(1 819–3 216)
Region3_Start1975	0.0924	2.055	0.00	4 166	2 616
	(0.0896–0.0946)	(1.72–2.629)		(4 003–4 340)	(1 889–3 318)
Region1_Start1932	0.0839	2.231	0.00	4 202	2 451
	(0.0802–0.0873)	(1.816–2.741)		(4 068–4 355)	(1 839–3 201)
InitialCatchVar	0.0838	2.293	0.00	4 072	2 371
	(0.0799–0.0871)	(1.851–2.906)		(3 825–4 319)	(1 730–3 163)
LowM	0.0722	2.905	0.00	4 186	1 842
	(0.0687–0.0752)	(2.37–3.866)		(3 979–4 408)	(1 217–2 411)
Maturity	0.076	2.504	0.00	4 055	1 569
	(0.0732–0.0784)	(2.034–3.166)		(3 855–4 250)	(1 096–2 078)
Steepness 0.8	0.0781	2.451	0.00	4 187	2 264
	(0.0747–0.0811)	(1.918–3.449)		(3 978–4 406)	(1 412–3 034)

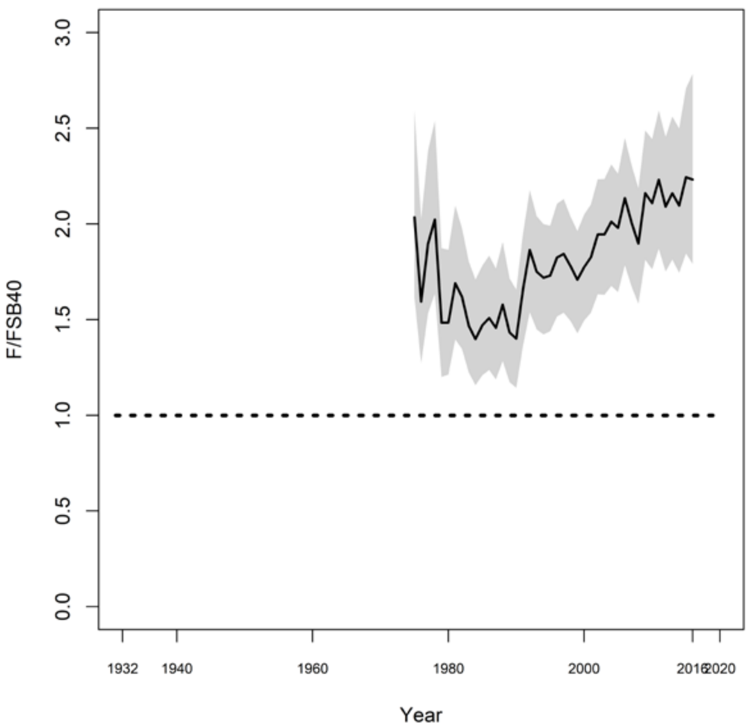


Figure 10: Annual trend in fishing mortality relative to the $F_{SB40\%}$ interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% credible interval.

Projections

For the base model option, stock projections were conducted for the 10-year period following the terminal year of the model (i.e. 2017–2026). During the projection period, recruitments were generated from the lognormal distribution around the geometric mean of the estimated recruitments.

Stock projections were based on multiples of the status quo (2016) commercial and recreational catches: i.e., 40%, 60%, 80% and 100% of the total 2016 catch of 4442 t, including the 10% allowance for unreported catch. The minimum period required to rebuild the stock to the target biomass level (*Tmin*) was determined from a stock projection with no catch. *Tmin* was estimated to be 4 years for a target biomass of 35% SB_0 and 5 years for a target biomass of 40% SB_0. Projections were also conducted at specified levels of fishing mortality levels: $F_{SB35\%}$, $F_{SB40\%}$, and the level of fishing mortality required to rebuild the stock to the target biomass level by twice *Tmin* (i.e., 8 years for 35% SB_0 and 10 years for 40% SB_0).

The projections indicate that a catch reduction of at least 20% is required to reduce the risk of the stock falling below the hard limit (10% SB_0) during the next 10 years and increase the probability that the stock will rebuild to above the soft limit (20% SB_0) (Table 14). However, substantially larger reductions in catch (approaching a reduction of 60%) are required to rebuild the stock to the 40% SB_0 default target level within the 10-year projection period.

Table 14: Estimated stock status (and 95% confidence intervals) and the probabilities of the spawning biomass being above default biomass limits and interim target level in 2021 (5 years) and 2026 (10 years) from catch based projections for the base case.

Percent of 2016 catch	SB_{2021}/SB_0	Pr (SB_{2021} > X%SB_0)			
		10%	20%	35%	40%
100%	0.149 (0.062–0.277)	0.850	0.206	0.002	0.001
80%	0.201 (0.117–0.331)	0.988	0.504	0.014	0.002
60%	0.253 (0.169–0.383)	1.000	0.859	0.062	0.014
40%	0.304 (0.220–0.433)	1.000	0.994	0.220	0.063
	SB_{2026}/SB_0	Pr (SB_{2026} > X%SB_0)			
		10%	20%	35%	40%
100%	0.148 (0.0–0.399)	0.681	0.290	0.041	0.026
80%	0.253 (0.089–0.477)	0.966	0.700	0.156	0.084
60%	0.347 (0.192–0.574)	1.000	0.963	0.482	0.278
40%	0.436 (0.279–0.669)	1.000	1.000	0.828	0.632

Projections that reduced the level of fishing mortality to $F_{SB35\%}$ or $F_{SB40\%}$ from 2017 onwards resulted in a very high probability of the stock rebuilding to above the soft limit within 5 years (Table 15) due to a large initial reduction in catch (approx. 40–50% reduction). Under the constant fishing mortality scenarios, annual catches increased as the biomass increased and the rate of rebuild attenuated as the biomass approached the corresponding target level (35% SB_0 or 40% SB_0). Consequently, target biomass levels were not achieved within the 10-year projection period (Table 15). To attain the target biomass levels within a period of twice *Tmin* a larger reduction in fishing mortality was required, equating to a reduction in fishing mortality to approximately 25% of the F_{2016} level.

Table 15: Estimated stock status (and 95% confidence intervals) and the probabilities of the spawning biomass being above default biomass limits and interim target level in 2021 (5 years) and 2026 (10 years) from fishing mortality based projections for the base case.

Fishing mortality	SB_{2021}/SB_0	Pr (SB_{2021} > X%SB_0)			
		10%	20%	35%	40%
$F_{SB35\%}$	0.246 (0.191–0.34)	1.000	0.942	0.020	0.003
$F_{SB40\%}$	0.264 (0.206–0.364)	1.000	0.983	0.042	0.007
25% of F_{2016}	0.304 (0.238–0.417)	1.000	0.999	0.159	0.036
	SB_{2026}/SB_0	Pr (SB_{2026} > X%SB_0)			
		10%	20%	35%	40%
$F_{SB35\%}$	0.283 (0.156–0.52)	1.000	0.870	0.240	0.129
$F_{SB40\%}$	0.311 (0.188–0.553)	1.000	0.953	0.347	0.202
25% of F_{2016}	0.384 (0.25–0.638)	1.000	0.998	0.658	0.431

The stock assessment is strongly dependent on CPUE indices as the primary indices of stock abundance. Fishery independent surveys are conducted within the ECSI area only and principally monitor the abundance of juvenile tarakihi. Consequently, the CPUE indices and trawl survey data are not directly comparable. Nevertheless, the assessment model indicates that the trends in the various sets of CPUE indices are generally consistent with the data from the trawl surveys (biomass and age/length compositions) and commercial age composition data. This indicates that the various sets of CPUE indices probably provide a reasonable index of stock abundance in each of the fishery areas.

There is sufficient information available to support the current hypothesis that tarakihi along the east coast of the North and South Island belong to a single stock. However, the broader stock structure around mainland New Zealand, including the west coast of the North and South Islands, is poorly understood. There is evidence from tagging studies that some tarakihi migrate from the ECSI to the west coast of the North Island. In addition, there is the possibility that tarakihi off the west coast of the North and South Islands could contribute recruits to the ECSI nursery grounds, contributing to the abundance of tarakihi in the area.

The current stock assessment assumes that east coast tarakihi represents a discrete stock. The level of recruitment estimated for the stock determines the overall level of reference biomass (SB_0) and stock status. Biases in the estimation of recruitment due to the mis-specification of recruitment processes could influence the estimates of stock status for east coast tarakihi. Some preliminary modelling was conducted to investigate the sensitivity of the model results to more complex stock relationships. However, these issues were not fully investigated due to limitations in the data available from the other (west coast) areas and the scope of the assessment project.

Stock assessment update 2018

In 2018, the base assessment model (Region1_Start1975) was updated to include catches and CPUE indices for 2017 (2016–17 fishing year). There were no other changes to the model configuration or treatment of the data sets (i.e. equivalent data weightings). The updated model yielded virtually identical estimates of stock status for the 2016 year (SB_{2016}/SB_0 = 0.167 CI 0.126–0.211) compared to the 2017 assessment. For the updated model, stock status in 2017 was estimated to be SB_{2017}/SB_0 = 0.173 (CI 0.130–0.223) (Table 16).

Table 16: Estimates of current (SB_{2017} 2016–17) and equilibrium, unexploited spawning biomass (SB_0) (median and the 95% confidence interval from the MCMCs), probabilities of current biomass being above specified levels, and current fishing mortality relative to the reference level from the 2018 update of the base assessment model.

SB_0	SB_{2017}	SB_{2017}/SB_0	Pr (SB_{2017} > X%SB0)			$F_{2017}/F_{SB40\%}$
			40%	20%	10%	
86 663 (82 361–91 337)	15 054 (11 163–19 789)	0.173 (0.130–0.223)	0.000	0.126	1.000	2.303 (1.851–2.836)

The updated assessment model was used to conduct stock projections to 2027–28 (10+1 years) at various levels of catch (Table 17). The baseline level of catch from the constituent model fisheries represented a total catch of 4619 t (including a 10% allowance for unreported commercial catch) based on recent catches and/or current (2017–18) TACCs. Recreational and customary catches were held constant at current levels in the projections.

Table 17: Estimated stock status (median) and the probabilities of the spawning biomass being above default biomass limits and interim target level in 2028 (10+1 years) from catch based projections for the base case.

Percent of baseline commercial catch	Projected catch (t)	SB_{2028}/SB_0	Pr (SB_{2028} > X%SB_0)			
			10%	20%	30%	40%
100%	4 619	0.136	0.623	0.295	0.101	0.026
80%	3 728	0.237	0.924	0.642	0.912	0.094
60%	2,838	0.333	0.999	0.920	0.626	0.282
40%	1,949	0.425	1.000	0.998	0.912	0.592

Future research considerations

- Continue and possibly intensify monitoring of the stock while it rebuilds. Increased emphasis should be on the collection of data from the East Northland fishery to ensure monitoring of the full age structure of the population.
- Improve the understanding of the stock relationships of tarakihi around mainland New Zealand. This could be progressed by extending the current model to develop a whole of New Zealand stock assessment model, including several plausible stock structure and migration hypotheses. Such a model would integrate the data available from west coast South Island (catch, trawl surveys, CPUE indices and age compositions), Tasman Bay/Golden Bay (trawl surveys) and west coast North Island (catch, CPUE indices and age compositions). This would provide a framework to evaluate the extent of variation in recruitment dynamics amongst regions and, thereby provide an indication of the potential stock linkages between the east coast and other regions. The study would also highlight limitations of the data currently available from the other main fishery areas.
- Investigate the potential utility of a WCNI or ECNI trawl survey for obtaining further fisheries-independent indices for tarakihi.
- Consider conducting more tagging studies to obtain better information about stock movements.
- Expand the catch sampling programme to obtain fish ages for more parts of the distribution of the species:
    - Investigate the utility of ageing existing samples from the fisheries and trawl surveys to augment the number of aged fish, especially from important areas or those with poor representation.
    - Request that observers on the west coast of the North Island start collecting otoliths.
    - Additional sampling of the age composition of the eastern Cook Strait fishery (Cook-BT) would also be beneficial as limited data are currently available from this area.
- Take changing fishing technology into account when designing catch sampling schemes and analysing CPUE.
- Increase biological sampling during the spawning season and examine gonads to obtain better staging information to inform the maturity ogive.
- Investigate mechanisms for estimating the discard rate and/or level of return to the sea of sub-MLS fish in Area 3, which has a relatively large number of small tarakihi.
- Investigate the potential of currents and gyres (especially the one off ECNI) to act as dispersal or retention mechanisms for larval and juvenile tarakihi, especially in terms of the observation that Area 3 receives most of the recruitment.

TAR 7

An integrated statistical catch-at-age stock assessment for TAR 7 was carried out in 2008 for data up to the end of the 2006–07 fishing year (Manning 2008). The model partitioned by age (0–45 years) and sex was fitted to the trawl survey relative abundance indices (1992–07), survey proportions-at-age data (1995–07), and WCSI fishery catch-at-age data (2005–2007). The stock boundary assumed in the model included the west coast of the South Island, Tasman and Golden Bays, but not eastern Cook Strait (a catch history was compiled for the model stock that excluded eastern Cook Strait). A summary of the model's annual cycle is given in Table 18. The base case model (R4.1) was fit to trawl survey biomass indices (lognormal likelihood) and proportion at age data (multinomial likelihood), U_{max} was set at 0.8, steepness was assumed to be 0.75, and M was fixed at 0.1. The base case model assumed an equilibrium biomass at the beginning of the population reconstruction in 1940. One sensitivity R4.5 was the same as R4.1 but was also fit to the CPUE data (lognormal likelihood). The other sensitivity (R4.6) also included the CPUE data; however, the model was started in 1985 from a non-equilibrium start. Model run 4.5 was very similar to the base case (4.1) in terms of biomass trajectory and stock status, but sensitivity 4.6 was more pessimistic in terms of stock status (Table 19). None of the three estimated a mean or median stock status that is below B_{MSY} and the stock is expected to rebuild, on average, for all three runs under current levels of removals and with average recruitment (Figure 11).

Table 18: The TAR 7 model's annual cycle (Manning 2008). Processes within each time step are listed in the time step in which they occur in particular order (e.g., in time step 3, new recruits enter the model partition first followed by the application of natural and fishing mortality to the partition). *M*, the proportion of natural mortality assumed during each time step. *F*, the nominal amount of fishing mortality assumed during each time step as a proportion of the total catch in the stock area. Age, the proportion of fish growth that occurs during each time step in each model year.

			Proportions			
Time step	**Duration**	**Process applied**	***M***	***F***	**Age**	**Observations**
1	Oct–Apr	Mortality (*M*, *F*)	0.58	0.74	0.90	Survey relative biomass (KAH) Survey proportions-at-age (KAH) Survey proportions-at-age (JCO) Survey proportions-at-length (KAH) Fishery catch-at-age Fishery relative abundance (CPUE)
2	May (instantaneaous)	Spawning Age incrementation	0.00	0.00	0.00	NIL
3	May–Sept	Recruitment Mortality (*M*, *F*)	0.42	0.26	0.10	Fishery catch-at-age

Table 19: **MCMC initial and current biomass estimates for the TAR 7 model runs R4.1, 4.5, and 4.6. B_0, virgin or unfished biomass; B_{2007}, mid-year biomass in 2007 (current biomass); (B_{2007} / B_0) %, B_0 as a percentage of B_{2007}; Min, minimum; Max, maximum; *Q*i, ith quantile. The interval ($Q_{0.025}$, $Q_{0.975}$) is a Bayesian credibility interval (a Bayesian analogue of frequentist confidence intervals).**

	R4.1			R4.5		
	B_0	B_{2007}	(B_{2007} / B_0) %	B_0	B_{2007}	(B_{2007} / B_0) %
Min	13 010	4 340	33.4	12 810	4 180	32.6
$Q_{0.025}$	14 290	6 060	42.3	13 780	5 350	39.1
Median	16 440	9 010	54.7	15 640	7 880	50.4
Mean	16 570	9 180	54.9	15 730	8 020	50.6
$Q_{0.975}$	19 630	13 410	68.3	18 310	11 500	63.0
Max	22 030	16 510	75.0	21 430	15 420	72.0

	R4.6		
Min	14 660	4 150	28.3
$Q_{0.025}$	18 350	6 490	34.7
Median	24 540	10 190	41.6
Mean	25 680	10 940	41.9
$Q_{0.975}$	40 600	19 890	50.5
Max	63 300	34 700	58.3

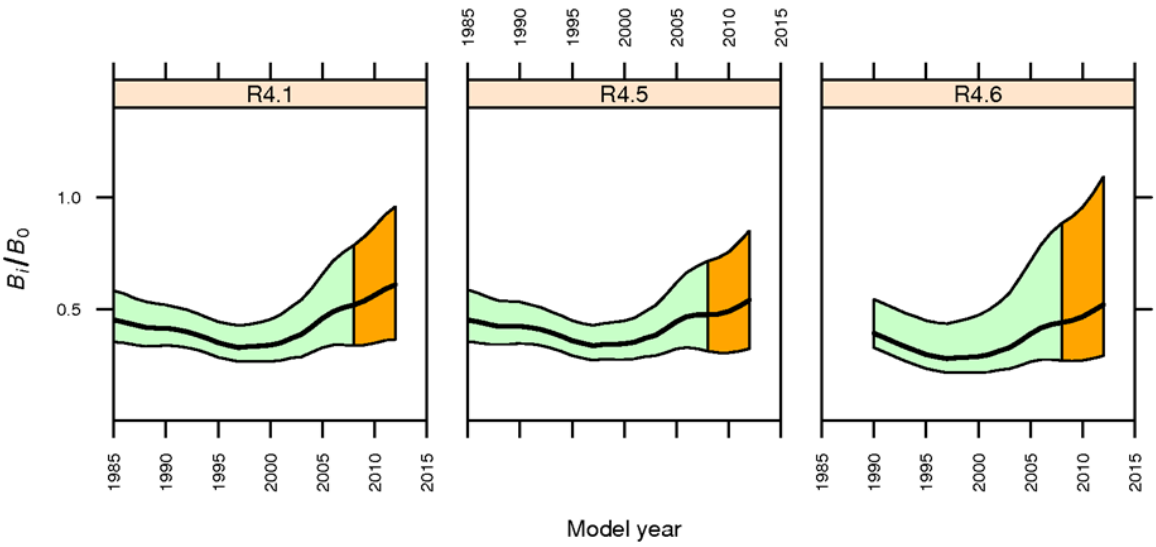


Figure 11: **Relative SSB trajectories (green) and projected status assuming a future constant catch equal to the current catch (orange) calculated from the MCMC runs for model runs 4.1, 4.5, and 4.6 in the quantitative stock assessment of TAR 7. The shaded region indicates the 95% credibility region about median SSB (dotted lines) calculated from each model's SSB posterior distribution.**

The east coast stock assessment includes the eastern area of the TAR 1 fishstock (QMA 1) but does not include the western area of TAR 1 (QMA 9).

***B_{MSY}* proxy**
Tarakihi is classified as a Low Productivity stock which, according to the Operational Guidelines for the Harvest Strategy Standard for New Zealand Fisheries, corresponds to a B_{MSY} proxy of 40% B_0. This decision was made taking all factors into account, but with greatest emphasis on the HSS Operational Guidelines, and considering the three Low Productivity parameters for TAR were attributed greater weight than the two Medium Productivity parameters for determining productivity.

TAR 1W, 4, 5, 8
Estimates of current absolute biomass for TAR 4, 5, 8 are not available.

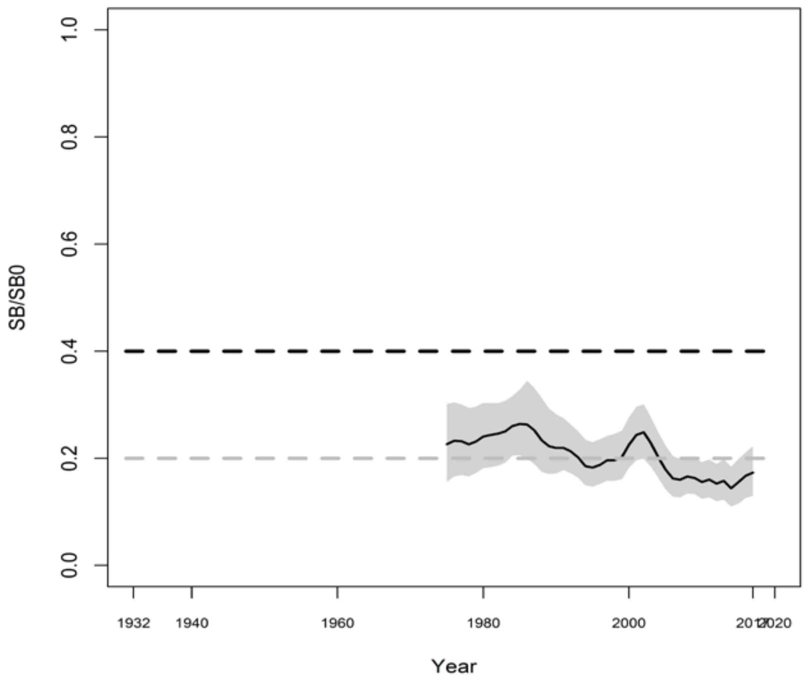
5. STATUS OF THE STOCKS

- **TAR 1E, TAR 2, TAR 3, TAR 7 (Eastern Cook Strait)**

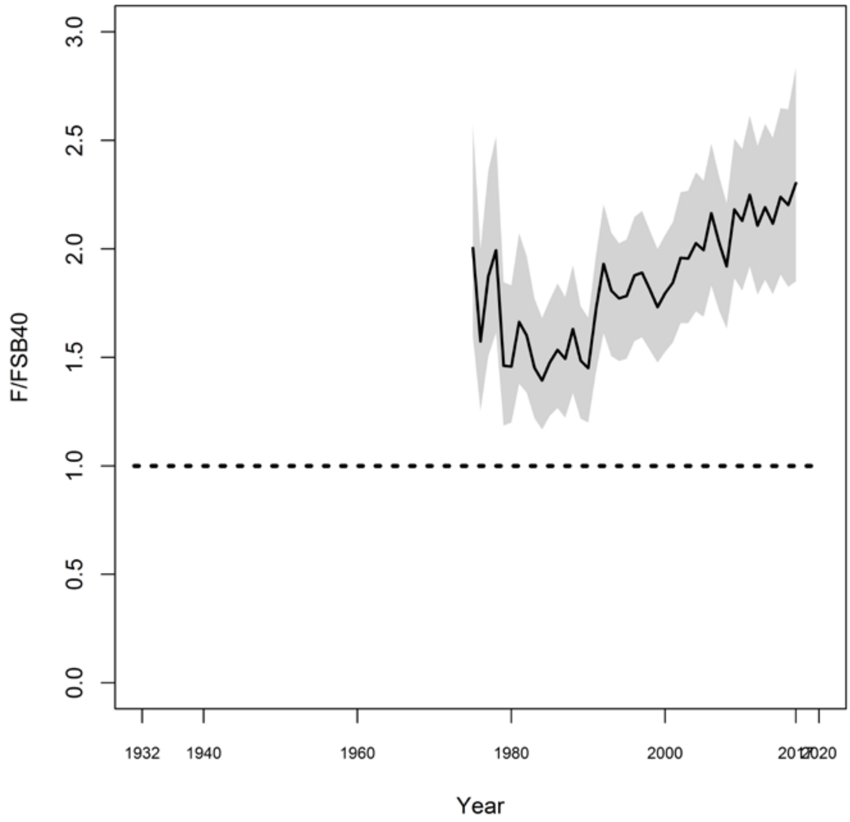
Tarakihi off the east coast of the North and South Islands are considered to represent a single stock. The eastern area of TAR 1 accounted for approximately 60% of the annual TAR 1 catch in recent years.

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Base case model
Reference Points	Target: Interim target 40% SB_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Interim overfishing threshold: $F_{SB40\%}$
Status in relation to Target	$SB_{2016–17}$ was estimated to be 17.3% SB_0; Exceptionally Unlikely (< 1%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Likely (> 90%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Interim overfishing threshold: Virtually Certain (> 99%) that overfishing is occurring

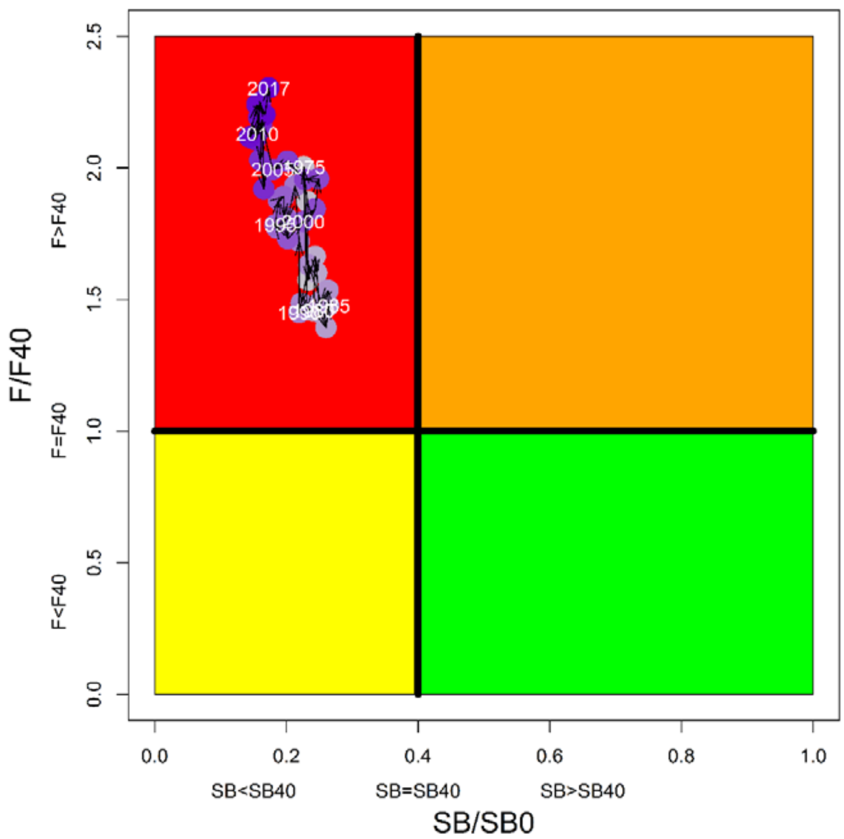
Historical Stock Status Trajectory and Current Status



Annual trend in spawning biomass relative to the 40% SB_0 interim target biomass level and 20% SB_0 soft limit for the updated base model. The line represents the median and the shaded area represents the 95% confidence interval.



Annual trend in fishing mortality relative to the *F*$_{SB40\%}$ interim target biomass level for the updated base model. The line represents the median and the shaded area represents the 95% credible interval.



Annual spawning biomass and fishing mortality compared to the *SB40%* interim target biomass level and corresponding fishing mortality reference for the updated base model (median values from MCMCs).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	There has been a general decline in spawning biomass since the late 1980s, moderated by fluctuations in recruitment. Spawning biomass is estimated to have been below the soft limit (20% SB_0) since the early 2000s.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality rates have increased since 2000. For the base model, current fishing mortality rates are estimated to be 2.30 times the level of fishing mortality that corresponds to the interim target biomass level ($F_{SB40\%}$).
Other Abundance Indices	- Trawl CPUE indices from eastern Cook Strait
Trends in Other Relevant Indicators or Variables	The trend in CPUE indices from eastern Cook Strait are consistent with the trends in vulnerable biomass for the Cook Strait fishery derived from the eastern stock assessment.

Projections and Prognosis	
Stock Projections or Prognosis	Stock projections were conducted for a 10-year period assuming multiples of the current level and distribution of catch across fisheries. Spawning biomass was projected to decline slightly at the current level of catch.
Probability of Current Catch or TACC causing decline biomass to remain below or to decline below Limits	<u>Current Catch</u> Soft Limit: Very Likely (> 90%) to remain below Hard Limit: Unlikely (< 40%) to decline below <u>TACC</u> Not included because the assessed stock boundaries do not match QMA boundaries.
Probability of Current Catch or TACC causing overfishing to continue or to increase	Virtually Certain (> 99%) that current catch levels will cause overfishing to continue or increase

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: 2018	Next assessment: 2022
Overall assessment of quality rank	1 – High Quality	
Main data inputs (rank)	- Commercial catch history - CPUE indices - Recent commercial age frequency - Kaharoa trawl survey abundance estimates and age/length frequencies	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	- James Cook survey age compositions	3 – Low Quality: Not representative
Changes to Model Structure and Assumptions	- New assessment. Previous assessments of individual fishery areas based on trends in CPUE indices - Refinement to CPUE indices incorporated in the assessment model	
Major Sources of Uncertainty	- Uncertainty in the stock structure	

Qualifying Comments
Projections are based on the distribution of catch across fisheries remaining constant. If the ratio of catch across fisheries changes, the projections will change. There is a poor match between the assessed stock area, and the TAR QMAs.

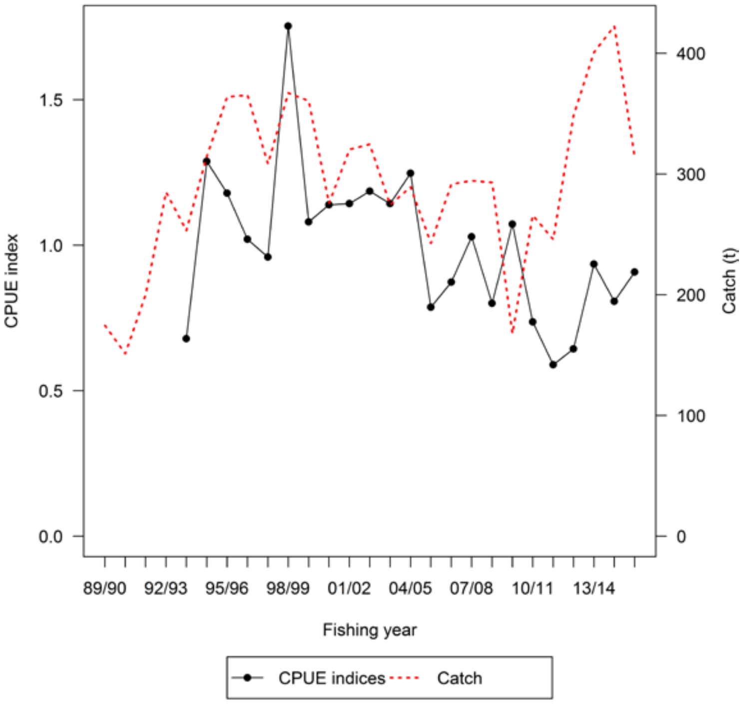
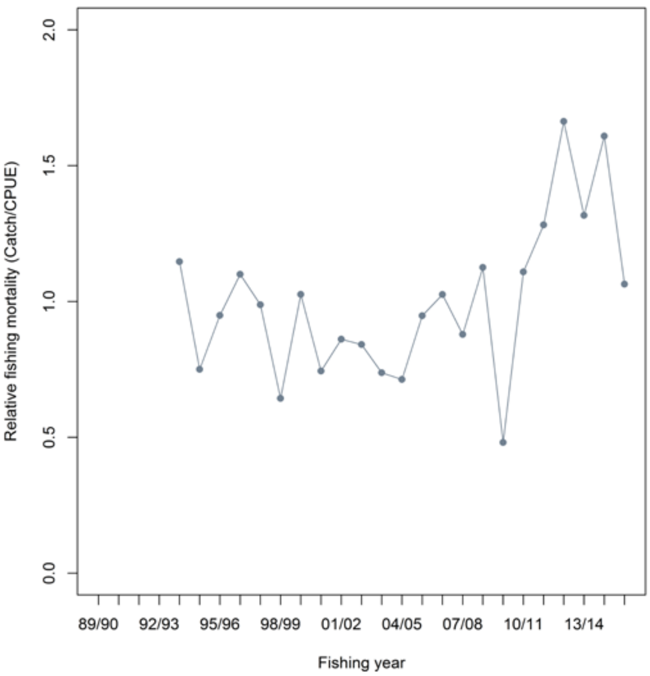
Fishery Interactions
TAR 1. The main fishing method is trawling. Target tarakihi trawls catch snapper, John dory, gemfish and trevally in East northland; and snapper, trevally and gemfish in the Bay of Plenty. Incidental captures of seabirds occur in the bottom longline and setnet fisheries, including black petrel which is ranked as at very high risk in the Seabird Risk Assessment.[1] Interactions with other species are currently being characterised. TAR 2. This is mostly (83%) a TAR target fishery. The main fishing method is trawling. The following species are the main fish bycatch in this fishery: GUR, SKI and WAR. Interactions with other species are currently being characterised. TAR 3. The main fishing method is trawling. The following species are the main fish bycatch in this fishery: RCO, BAR and FLA. The tarakihi target setnet fishery bycatch includes very small amounts of LIN and SPD. Interactions with other species are currently being characterised.

- **TAR 1W**

The eastern area of TAR 1 is included within the east coast stock assessment. The western area of TAR 1 accounted for approximately 40% of the annual TAR 1 catch in recent years.

Stock Status	
Year of Most Recent Assessment	2017
Assessment Runs Presented	Standardised delta-lognormal CPUE indices derived from trawls targeting tarakihi, snapper or trevally in the northern area of TAR 1W (Stat Areas 045–047), 1993/94–2015/16
Reference Points	Target: B_{MSY} (value to be determined) Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY} (value to be determined)
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown
Status in relation to Overfishing	Unknown

[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).

Historical Stock Status Trajectory and Current Status
 **Standardised delta-lognormal CPUE indices for the northern area of TAR 1W and the annual tarakihi catch from the corresponding area.**  **Fishing intensity (catch/CPUE) for the northern WCNI tarakihi fishery.**

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE indices generally declined from 2000/01-2004/05 to 2013/14-2015/16 (by 25%).
Recent Trend in Fishing Intensity or Proxy	Fishing mortality increased (by 70%) from 2000/01-2004/05 to 2011/12-2015/16.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing decline biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing overfishing to continue or to increase	-

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	CPUE analysis of trawl catch and effort data	
Assessment Dates	Latest assessment: 2017	Next assessment: 2022
Overall assessment of quality rank	1 – High Quality	
Main data inputs (rank)	- Bottom trawl catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Change to trawl event based data set from trip stratum roll-up - Delta-lognormal CPUE models, including zero catches - Restriction of CPUE analysis to the northern area of the fishery	
Major Sources of Uncertainty	- Uncertainty in the stock structure - Relative abundance prior to 1993–95	

Qualifying Comments
The CPUE indices were derived for the northern area of the fishery only (Stat Areas 045–047). This area accounted for most of the TAR 1W catch. Since the mid-1990s, a target trawl fishery has developed in the North Taranaki Bight in the southern area of TAR 1W. CPUE trends from this area differed markedly from the northern area of the fishery. Thus, the CPUE indices represent the trends in abundance for the northern area of the fishery and do not represent the overall trends in tarakihi abundance in TAR 1W. Reference points based on CPUE were not determined because, based on the east coast TAR stock assessment, biomass may have declined substantially before the start of the series.

Fishery Interactions
The main fishing method is trawling. Target tarakihi trawls catch snapper and trevally as bycatch. Interactions with other species are currently being characterised.

- **TAR 4**

For TAR 4, the fishery around the Chatham Islands appears to have been lightly for several years.

- **TAR 5**

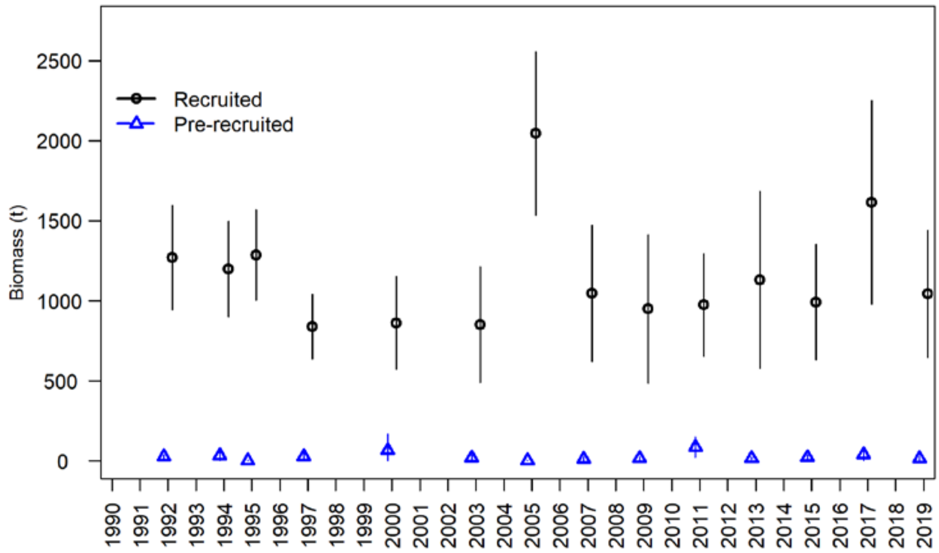
Insufficient information is available to determine the status of TAR 5.

- **TAR 7**

Stock Structure Assumptions
For the purpose of this assessment the west coast South Island and Tasman Bay areas of TAR 7 are assumed to be a discrete stock. The eastern Cook Strait area of TAR 7 is considered to be part of the eastern stock of tarakihi.

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	Time series of WCSI trawl survey biomass, most recent survey 2019
Reference Points	Target: Not established but B$_{MSY}$ assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	In 2007 the range of model results for TAR 7 estimated that the stock was Likely (> 60%) to be at or above B_{MSY} (40% B_0). Trawl survey recruited biomass index for WCSI 2017 was higher than in 2007, suggesting the stock is still Likely (> 60%) to be above B_{MSY} level.
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	Unknown

Historical Stock Status Trajectory and Current Status



Trawl survey biomass estimates from the west coast South Island area of TAR 7 (excluding Tasman Bay/Golden Bay).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The WCSI trawl survey biomass index has remained stable since 2006/07.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Biomass (WCSI) is expected to stay steady over the next 3–5 years assuming current (2012/13) catch levels
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) for current catch and TACC Hard Limit: Very Unlikely (< 10%) for current catch and TACC
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	-West coast South Island trawl survey biomass	
Assessment Dates	Latest assessment: 2018	Next assessment: 2020?
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Survey biomass and length frequency	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- The time-series of CPUE indices from the TAR 7 WCSI fishery is no longer used as it was considered not to represent a reliable index of stock abundance, at least during 1989/90-2006/07.	
Major Sources of Uncertainty	- Stock structure is currently uncertain. The eastern Cook Strait area of the TAR 7 fish stock is considered to be part of the eastern stock of tarakihi, although the extent of the interaction between tarakihi around coastal New Zealand is unknown.	

Qualifying Comments
-

Fishery Interactions
The main fishing method is trawling. The major target trawl fisheries occur at depths of 100–200 m and tarakihi are taken as a bycatch at other depths as well. TAR 7 is reported as bycatch in target barracouta and red cod bottom trawl fisheries. Smooth skates are caught as a bycatch in this fishery. Interactions with other species are currently being characterised.

- **TAR 8**

Insufficient information is available to determine the status of TAR 8.

7. FOR FURTHER INFORMATION

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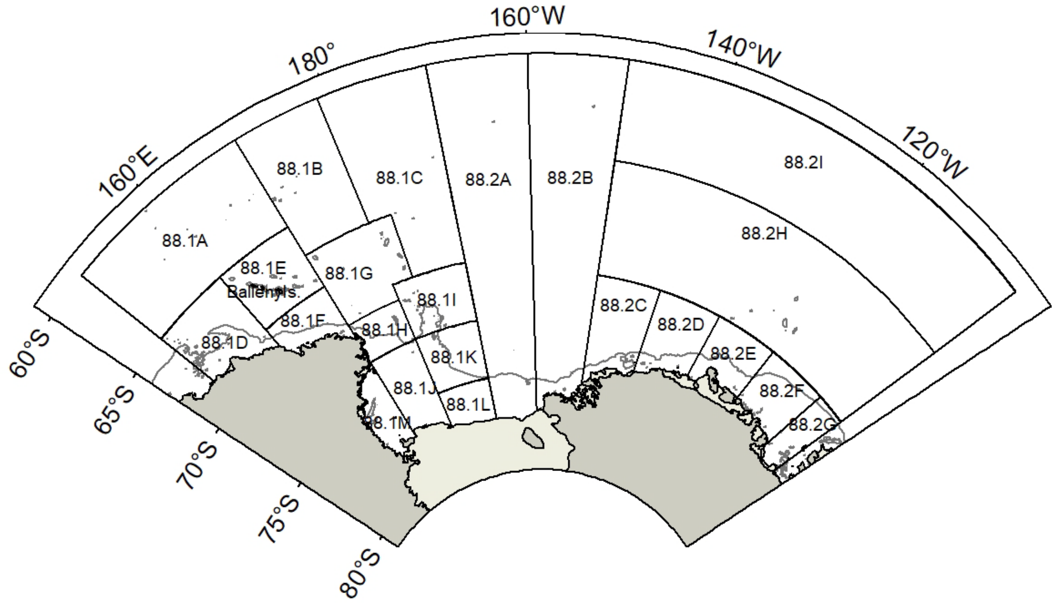
TOOTHFISH (TOT)
(outside EEZ)

(*Dissostichus mawsoni* and *Dissostichus eleginoides*[1])



The Ross Sea Region (CCAMLR Statistical Subareas 88.1 and small-scale research units (SSRUs) 88.2A and 88.2B), and the Amundsen Sea Region (SSRUs 88.2C-I) used for management and the 1000 m depth contour.

1. FISHERY SUMMARY

This working group report is a summary of the Ross Sea and Amundsen Sea toothfish fisheries in CCAMLR (Statistical Subareas 88.1 and 88.2) and includes the catches of all participating countries. These fisheries occur entirely on the high seas within the area covered by the Convention for the Conservation of Antarctic Marine Living Resources (the Convention Area). They are managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

Finfish fisheries in Antarctic waters are managed in accordance with the CAMLR Convention, in particular the objective and principles defined in Article II. The Convention Area covers the area south of the Antarctic Convergence (varying from 60° S in the Pacific Sector to 45° S in the western Indian Ocean Sector) (Figure 1). In 2016, CCAMLR adopted a Marine Protected Area in the Ross Sea Region (CCAMLR 2016c), which came into effect on 1st December 2017.

1.1 Commercial fisheries

Toothfish are large nototheniids endemic to Antarctic and Sub-Antarctic waters. There are two species: Antarctic toothfish (*Dissostichus mawsoni*) and Patagonian toothfish (*Dissostichus eleginoides*). Both have a circumpolar distribution, although *D. mawsoni* has a more southern distribution.

Commercial bottom longline fisheries targetting Patagonian toothfish occur around many of the Sub-Antarctic islands and plateaus south of the Sub-Antarctic Front[2]. To date, the main Olympic longline fishery for Antarctic toothfish outside of an EEZ and within the Convention Area has taken place in Statistical Subarea 88.1, with smaller fisheries scattered around the Antarctic continental slope except for the Weddell Sea. Statistical Subarea 88.1 is divided into three broad ecological regions: a region of northern seamounts, ridges and banks;

[1] Note that this report does not cover the Patagonian toothfish (*Dissostichus eleginoides*) fishery within the New Zealand Exclusive Economic Zone.
[2] Zone found between 48°S and 58°S in the Indian and Pacific Ocean and between 42°S and 48°S in the Atlantic Ocean.

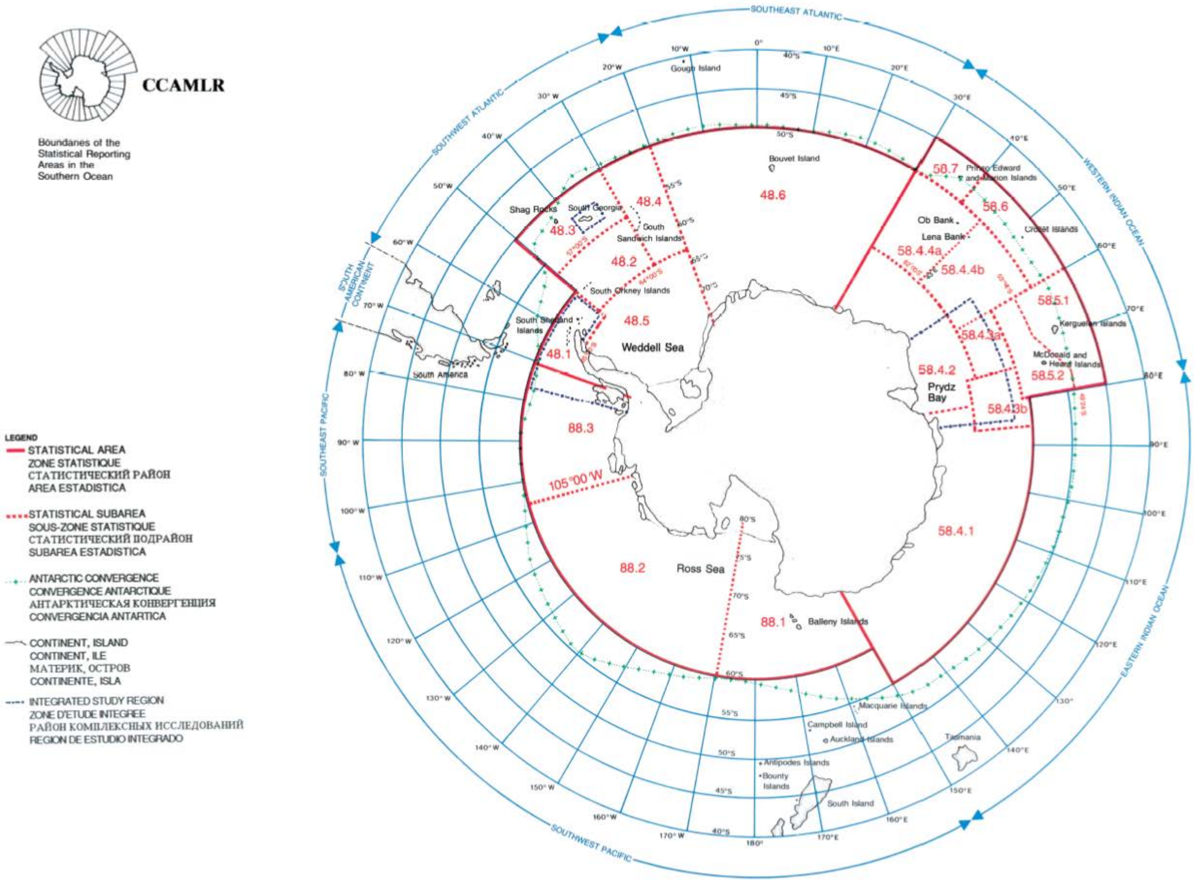


Figure 1: Map of CAMLR Convention area (https://www.ccamlr.org/en/organisation/convention-area) showing Statistical Subareas and Divisions.

a region of shallow water (< 800 m) on the Ross Sea shelf in the extreme south; and a region in between covering the continental slope (800–2000 m). The main longline fishery occurs on the continental slope.

The longline fishery for *Dissostichus* spp. in Statistical Subarea 88.1 was initiated as a new fishery by New Zealand in 1996–97, using a single longline vessel (Table 1). Since then, vessels from a number of countries have returned each summer to fish in this area and the adjacent Statistical Subarea 88.2 fishery. The exploratory longline fishing season in Statistical Subarea 88.1 and 88.2 begins on the 1st December and with most fishing completed by February.

The catch of toothfish in Statistical Subarea 88.1 and SSRUs 88.2A&B (the Ross Sea region) showed a steady increasing trend during the early period of the fishery, almost reaching the Total Allowable Catch (TAC) of about 3000 t between 2004–05 and 2006–07. In 2007–08 and 2008–09, the TAC was under-caught in Statistical Subarea 88.1 due to the severe ice conditions in 2007–08 and the early closure of the fishery by the CCAMLR Secretariat in 2008–09 due to overestimation of projected catch rates. The catches have been close to the catch limits since 2009–10, with the closure of the fishery by CCAMLR based on catch projections using daily catch reports (CCAMLR Secretariat 2016b). In 2017–18 and in 2018–19, the TAC was again under-caught in the Ross Sea region due to the early closure of the fishery by the CCAMLR Secretariat, due to difficulties in projecting catch for many vessels competing for a relatively small catch limit. In the 2018–19 season, the total catch was within 5% of the TAC.

The catch of toothfish in Statistical Subarea 88.2 began in 2003–04, and exceeded catch limits in 2004–05 and 2005–06. Failure to reach the catch limit in the following four years was primarily due to the low fishing effort in the southern SSRUs 88.2C–G due to ice conditions. The catch has been close to the catch limit since 2010–11, with the closure of the fishery by CCAMLR based on the daily catch reports. Figure 2 shows historical landings and TACs for Statistical Subareas 88.1 and 88.2.

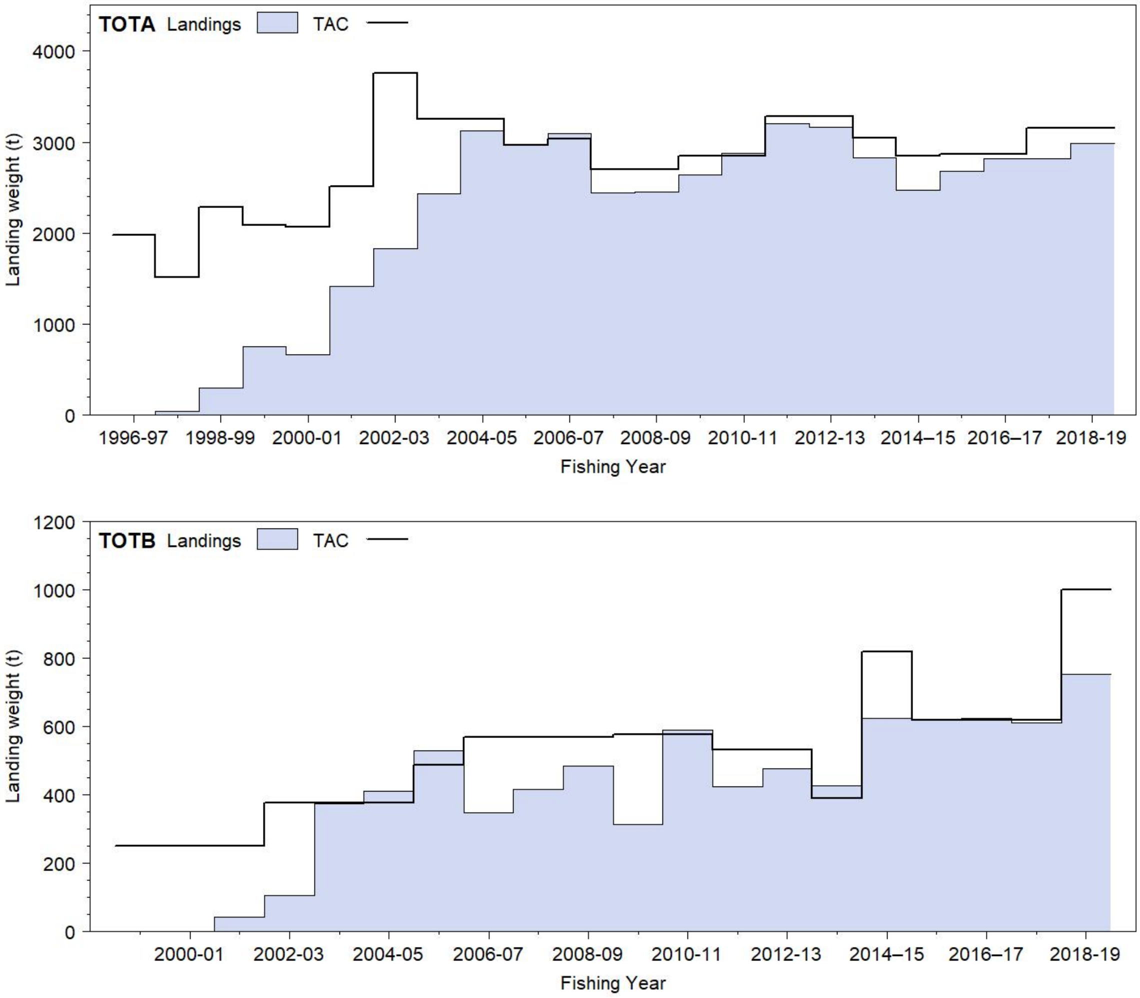


Figure 2: The landings of toothfish and catch limits (TACs) from 1997–98 to 2018–19 in Statistical Subarea 88.1 and SSRUs 88.2A-B (TOTA), and 1999–00 to 2018–19 in SSRUs 88.2C–H (TOTB).

The toothfish catch from these areas is comprised almost entirely of Antarctic toothfish. Since the start of the fishery 153 t of Patagonian toothfish has been caught in Statistical Subareas 88.1 and 88.2, almost entirely from the north of Statistical Subarea 88.1 (SSRUs 88.1A, 88.1B and 88.1C) (CCAMLR 2017a). The data in Table 1 are collated from monthly reporting (vessel to flag state to CCAMLR) and annual reporting (FAO STATLANT reports to CCAMLR from flag state).

The number, size, and related catch limits of the Ross Sea region have varied through time (see also Delegations of New Zealand, Norway, and the United Kingdom 2014). On 1 December 2017, three new management zones resulting from the implementation of the Ross Sea region MPA were defined: A General Protection Zone (GPZ), a Special Research Zone (SRZ on the slope area), and a Krill Research Zone (KRZ) (Figure 3). Catch limits were applied to the region outside the MPA and North of 70° S, outside the MPA and South of 70° S, and the SRZ. Spatial management, including allocation of catch among regions, will be reconsidered following evaluation of fishing effort redistribution after implementation of the MPA.

Although the total catch limit in Statistical Subarea 88.1 has rarely been exceeded, the local catch limits in 88.1B, 88.1C and 88.1G have been exceeded in various years, due to relatively small catch limits, a large number of vessels, and high but variable catch rates (CCAMLR Secretariat 2016a).

Ice conditions and bycatch limits are important factors influencing the spatial distribution of fishing effort. In 2002–03, 2003–04 and 2007–08 heavy ice conditions meant that little catch was taken in

SSRUs 88.1J–L. An ice-index was created for the Ross Sea region indicating the proportion of fishing grounds clear of sea ice (CCAMLR 2016a, Fenaughty & Parker 2015).

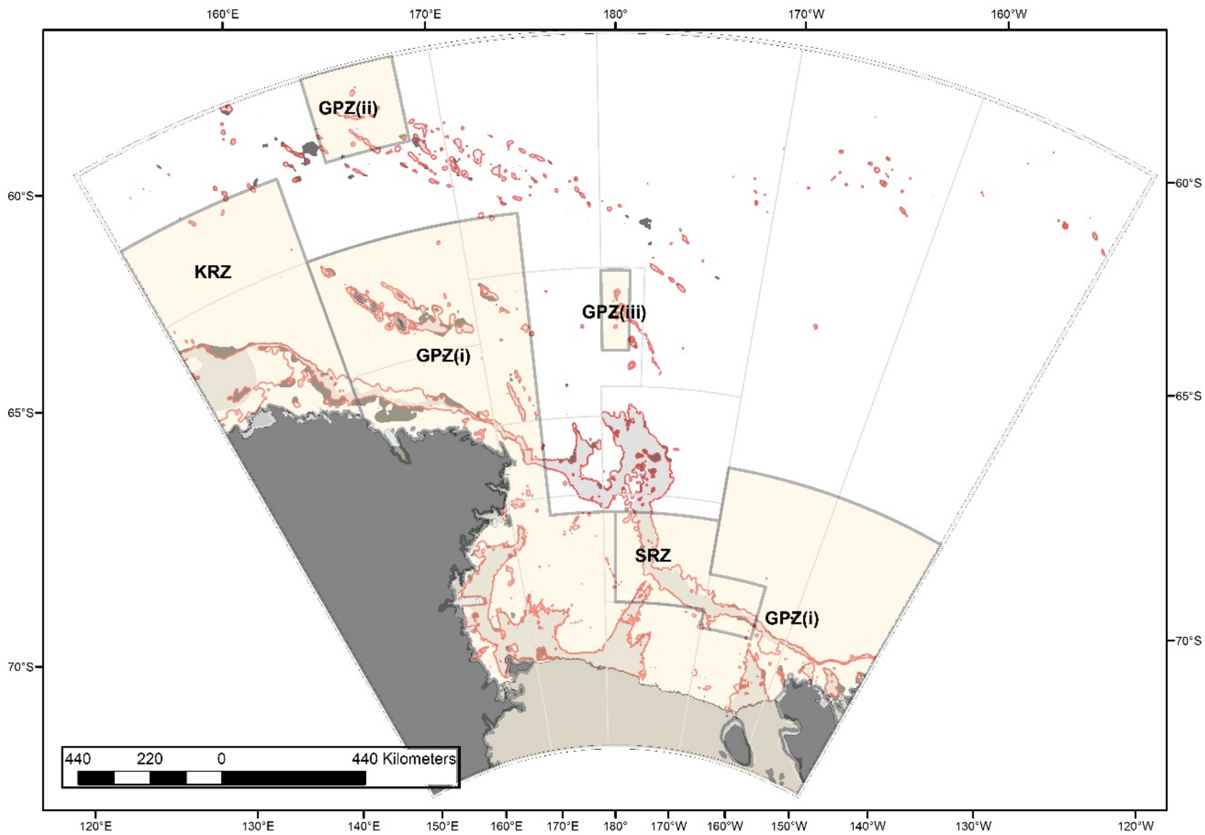


Figure 3: Ross Sea region Marine Protected Area in effect as of 1 December 2017 (CM 91-05).

Table 1: Estimated catches (t) of *Dissostichus* sp. by area for the period 1996–97 to 2018–19 (Source: FAO STATLANT data; CAMLR 2017a, 2017b). – denotes has not been estimated, but likely to be 0 t.

	Statistical Subarea 88.1				Statistical Subarea 88.2			
Season	Reported catch	Estimated IUU catch	Total	Catch limit**	Reported catch	Estimated IUU catch	Total	Catch limit
1996–97	< 1	0	< 1	1 980*	0	0	0	1 980*
1997–98	42	0	42	1 510	0	0	0	63
1998–99	297	0	297	2 281	0	0	0	0
1999–00	751	0	751	2 090	0	0	0	250
2000–01	660	0	660	2 064	0	0	0	250
2001–02	1 325	92	1 417	2 508	41	0	41	250
2002–03	1 831	0	1 831	3 760	106	0	106	375
2003–04	2 197	240	2 437	3 250	374	0	374	375
2004–05	3 105	28	3 133	3 250	411	0	411	375
2005–06	2 969	0	2 969	2 964	514	15	529	487
2006–07	3 091	0	3 091	3 032	347	0	347	547
2007–08	2 259	272	2 531	2 700	416	0	416	567
2008–09	2 448	0	2 448	2 700	484	0	484	567
2009–10	2 869	0	2 869	2 850	314	0	314	575
2010–11	2 839	0	2 839	2 850	590	0	590	575
2011–12	3 178	–	3 178	3 282	424	–	424	530
2012–13	3 006	–	3 006	3 282	475	–	475	530
2013–14	2 823	–	2 823	3 044	426	–	426	390
2015–16	2 684	–	2 684	2 870	618	–	618	619
2016–17	2 821	–	2 821	2 870	624	–	624	619
2017–18	2 822	–	2 822	3 157	610	–	610	619
2018–19	2 988	–	2 988	3 157	733	–	733	1 000

* A single catch limit in 1996/97 applied to all of Statistical Subareas 88.1 and 88.2.
** Catch limits include catch set aside for research activities.

The SSRUs in Statistical Subarea 88.2 were redefined for the 2011–12 season with the northern boundaries of SSRUs 88.2C–G truncated at 70º 50’ S to separate a region of seamounts in the north from the shelf/slope grounds in the south. The northern parts of those SSRUs were then amalgamated to form a new SSRU 88.2H and a separate catch limit was set for each of the northern and southern regions. The area north of 65°S (SSRU 88.2I) has always been closed to fishing.

In addition to the catch limits on the target toothfish species, other management rules have been adopted by CCAMLR via conservation measures. These include:

- gear restrictions (CCAMLR Conservation Measure (CM) 10-05 (2018));
- daily reporting requirements (CM 23-07 (2016));
- a Catch Documentation Scheme (CM 10-05 (2018));
- restrictions on bycatch (CM 33-03 (2019));
- measures to minimise local depletion of toothfish (CM 41-09 (2019));
- measures to minimise impacts to identified Vulnerable Marine Ecosystems (CM 22-09 (2012));
- non-fish bycatch mitigation measures (CM 25-02 (2019)); and
- the Ross Sea region MPA (CM 91-05 (2016)).

In 2005–06, the macrourid (rattail) bycatch limits were exceeded for SSRUs 88.2C–G resulting in the area being closed before the toothfish catch limit was reached.

The CCAMLR Convention Area extends to 60°S in the Pacific Basin but the bathymetric features and oceanographic conditions that toothfish inhabit extend north of this boundary. The northern extent of the range of Antarctic toothfish is not well known in the area. Two research surveys in the south Pacific under the auspices of the South Pacific Regional Fisheries Management Organisation (SPRFMO) were conducted in 2016 and 2017 with catch limits of 30 t in each year and were restricted to two small research areas between near 150° W longitude and 59°S latitude (COMM-04-WP-09_rev4). Twenty-nine tons were landed in each year and all were Antarctic toothfish, except for two small Patagonian toothfish in 2017. This catch was included as removals from the Ross Sea region stock assessment (Mormede 2017, Dunn 2019).

In 2018 a proposal for an exploratory longline fishery was made by New Zealand in the area to better determine the distribution and population characteristics of Antarctic toothfish on the Pacific-Antarctic Ridge system within the SPFRMO Convention Area between 140–155°W and 52–60°S over three years (SC6-DW03-Rev2-NZ, COMM7-Prop13.1, Figure 1). The total allowable catch was set at 140 t each year for 2019, 2020, 2021, and was agreed by the Commission in 2019 (ANNEX-7l-COMM7-CMM-14a-2019-Exploratory-Toothfish-NZ). An EU proposal for a one-year exploratory fishery in the southern SPRFMO area on the South Tasman Rise (COMM7-Prop14.1-rev-1) was also approved for 2019–20 with a catch limit of 45 t of toothfish (likely to be Patagonian toothfish in that area, ANNEX -7m-COMM7-CMM-14c-2019). The framework for fishing, tagging, and data collection for both exploratory fisheries closely mirrors that of CCAMLR making the data comparable for analysis.

1.2 Recreational fisheries

There is no recreational toothfish fishery in Statistical Subareas 88.1 and 88.2.

1.3 Customary non-commercial fisheries

There is no customary toothfish fishery in Statistical Subareas 88.1 and 88.2.

1.4 Illegal catches

Based on aerial surveillance and other sources of intelligence, the level of illegal and unreported catch is thought to be low (Table 1). CCAMLR stopped estimating the level of IUU catch from 2011, but estimated the level of IUU effort instead. IUU effort in recent years in the Convention Area has typically been comprised of vessels using gillnets which is currently prohibited under CM 22-04 and the catch rates for this method cannot be reliably estimated. However, CCAMLR has estimated that there has been no IUU effort in Statistical Subareas 88.1 and 88.2 since 2010–11 (CCAMLR 2017a).

1.5 Other sources of mortality

Any longline gear that is baited and set, but not successfully retrieved, may result in unaccounted mortality of toothfish or other species. Bottom longline gear is most often lost due to interactions of downlines with moving sea ice, but may also result from tidal currents submerging floats, or gear failure during line retrieval.

Webber & Parker (2011) estimated line loss from 2008 to 2011 to be in the range 3–8% (expressed in terms of percent of all hooks set that are lost attached to sections of lines). Longline hooks only have the potential to catch once. Once a fish is on the hook, or the bait is gone, the hooks are effectively not able to fish anymore. Assuming that these hooks caught toothfish at the same rate as those on lines that were retrieved, and that all the toothfish caught on lost lines die as a result of being caught, then an additional 175–244 tonnes of Antarctic toothfish fishing related mortality from the commercial fishery may be unaccounted for annually.

A small quantity of toothfish is taken by other scientific research programmes in most years, typically less than 5 tonnes.

Observers monitor discards, with up to 40% of all hooks hauled being directly observed, and no discarding of dead toothfish has been reported to date. However, in 2014 it was reported that some small toothfish had been released untagged but alive by Ukrainian vessels in Statistical Subarea 88.2 because they were too small for processing. Fish are occasionally lost from the line near the surface and recorded as lost.

Antarctic toothfish are occasionally caught with evidence of squid depredation (i.e., sucker marks and large flesh wounds), but the amount of depredation due to large squid is insignificant at the scale of the fishery. To date, there have been no reported instances of depredation of toothfish by cetaceans or pinnipeds in the Ross Sea region.

2. BIOLOGY

The Antarctic toothfish has a circumpolar distribution south of the Antarctic convergence (~ 60° S). A summary of the biology of Antarctic toothfish, and related references, are given in detail in Hanchet et al (2015). Although it is primarily a demersal species, adults can be neutrally buoyant and are known to inhabit the pelagic zone at times (Near et al 2003). Early growth has been well documented (Horn 2002, Horn et al 2003) with fish reaching about 60 cm TL after five years and about 100 cm TL after ten years. Growth slows after about 10 years as fish reach the adult stage. The maximum recorded age is 48 years and maximum length recorded is 250 cm. Ages have been validated by following modes: in juvenile fish by tetracycline marking, and lead-radium dating in adult fish (Horn et al 2003, Brooks et al 2011). There is a significant difference in growth between sexes with maximum average lengths of 170 cm and 180 cm for males and females respectively (Horn 2002).

Hanchet et al (2008) developed a hypothetical life history of Antarctic toothfish in the Ross Sea. Fish spawn to the north of the Antarctic continental slope, mainly on the ridges and banks of the Pacific-Antarctic Ridge during winter or spring.

The first winter longline survey of Antarctic toothfish in the northern Ross Sea region was successfully completed during June and July 2016 and confirmed toothfish spawning in this region (Stevens et al 2016). Fertilised Antarctic toothfish eggs were found to be large (greater than 3.5 mm diameter) and pelagic (found in the upper 200 m of the water column). Spawning may occur from mid-July through August (Stevens et al 2016). A second winter survey was conducted in September and October 2019 with results to be reported in late 2020. Additional information on the timing, distribution, stock structure, and potentially early life history will be derived from the exploratory fishery in the SPRFMO area. The SPRFMO fishery will also have some fishing during August – October, which will greatly enhance information about spawning, which occurs in the winter and is typically inaccessible further south due to sea ice. SPRFMO samples have already shown that the fish inhabiting seamounts just north of the CCAMLR Convention Area are abundant, mostly Antarctic toothfish, all adult sizes, and in spawning or post-spawning condition during late winter. The spatial distribution of spawning has not yet been determined.

Hanchet et al (2008) postulated that depending on the exact location of spawning, eggs and larvae become entrained by the Ross Sea gyres (a counter-clockwise rotating western gyre located around the

Balleny Islands and a larger clockwise rotating eastern gyre covering the rest of the Ross Sea region), and move either west settling out around the Balleny Islands and adjacent Antarctic continental shelf, south onto the Ross Sea shelf, or eastwards with the eastern Ross Sea gyre settling out along the continental slope and shelf to the east of the Ross Sea in Statistical Subarea 88.2.

As the juveniles grow in size, it is hypothesised that they move west, back towards the Ross Sea shelf, and then move out into deeper water (greater than 1000 m). The fish gradually move northwards as they mature, feeding in the slope region in depths of 1000–1500 m, where they gain condition before moving north onto the Pacific-Antarctic ridge to start the cycle again. It is not known how long spawning fish remain in the northern area. It is currently thought that toothfish remain in the Pacific-Antarctic ridge region for up to 2–3 years (although this pattern may be different for males versus females) and then they move southwards back onto the shelf and slope where productivity is higher and food is more plentiful. A multidisciplinary approach incorporating otolith chemistry, age data and LaGrangian particle simulations reached similar conclusions (Ashford et al 2012). The authors further postulated that the entire life cycle is structured by ocean circulation such that not just eggs and larvae, but also juvenile and adult fish, are transported downstream by ocean currents between nursery grounds, feeding grounds, and spawning grounds.

The age and length at recruitment to the Ross Sea fishery varies between areas and between years. In the northern SSRUs (88.1A–88.1G), toothfish recruit at a length of about 130 cm to the fishery. In the southern SSRUs (88.1H–88.1M), the length at recruitment depends on the depth of fishing. In some years fish have been fully recruited at a length of about 80 cm (age 7–8), whereas in other years fish have not been fully recruited until at least 100 cm (age 10). In Statistical Subarea 88.2, toothfish recruit at a length of about 130 cm in the northern SSRU (88.2H) but at a length of about 60–80 cm (age 5–8) in the southern SSRUs (88.2C–G) (Stevenson et al 2014).

Estimates of maturity, based on hindcasting from the presence of post-ovulatory follicles in the ovaries and forecasting from the assessment of oocyte developmental stage, suggested that the mean age and length at 50% spawning for females on the Ross Sea slope were 16.6 y and 133.2 cm and the mean age and length at 50% maturity for males were 12.8 y and 120.4 cm (Parker & Grimes 2010). These estimates were updated in 2012 to 16.9 y and 135 cm for females and 12.0 y and 109 cm for males on the Ross Sea slope (Parker & Marriott, 2012). Regional spawning ogives show similar relationships for the Ross Sea north and shelf areas and for Statistical Subarea 88.2.

The natural mortality rate *M* was estimated by Dunn et al (2006) using the methods of Chapman-Robson (1960), Hoenig (1983), and Punt et al (2005). Estimates of *M* derived from these methods ranged from 0.11 to 0.17 y^{-1}. After a consideration of possible biases, Dunn et al (2006) proposed that a value of 0.13 y^{-1} be used for stock modelling with a range of 0.11–0.15 y^{-1} for sensitivity analyses. They noted that further work is required on values of *M* and in possible changes of *M* with age. Biological parameters relevant to the stock assessment are shown in Table 2.

Table 2: Estimates of biological parameters for Antarctic toothfish.

Biological parameters							**Reference**
1. Natural mortality (M)							
	Males	Females					
	0.13	0.13					Dunn et al (2006)
2. Weight = a(length)^b (Weight in kg, length in cm fork length)							
	Males		Females				
	a	b	a	b			
	0.00001387	2.965	0.000007154	3.108			Dunn et al (2006)
3. von Bertalanffy growth parameters							
	Males			Females			
	K	t_0	L_∞	K	t_0	L_∞	
	0.093	-0.26	169.1	0.090	0.021	180.2	Dunn et al (2006)
4. Maturity							
	Males		Females				
	A_{50}	$\pm A_{to95}$	A_{50}	$\pm A_{to95}$			
	11.99	5.25	16.92	7.68			Parker & Marriott (2012)

Antarctic toothfish feed on a wide range of prey but are primarily piscivorous with the observed diet varying by location (Fenaughty et al 2003, Stevens et al 2014). The most important prey species of fish caught in the main fishery are grenadiers (*Macrourus* spp.). In continental slope waters, *Macrourus* spp., the icefish *Chionobathyscus dewitti*, eel cods (*Muraenolepis* spp.) and cephalopods predominate in the diet, while on oceanic seamounts *Macrourus* spp., violet cod (*Antimora rostrata*) and cephalopods are important. In the southern Ross Sea, subadult and adult toothfish feed mainly on nototheniids (*Trematomus* spp.) and icefish, whilst in McMurdo Sound, the stomachs of adult toothfish sampled through holes in the ice have been observed to contain mainly Antarctic silverfish (*Pleuragramma antarcticum*) (Eastman, 1985, Parker et al 2016). In the open oceanic waters in the north of the Ross Sea region, Antarctic toothfish feed on small squid (Yukhov 1971). The diet of Antarctic toothfish also varies with their size. Crustaceans are more common prey items in smaller toothfish, whereas squid are more common in larger toothfish, likely reflecting the different spatial distributions of small versus large toothfish.

The main predators of toothfish are likely to be odontocetes (sperm whales (historically)), type C killer whales, and pinnipeds (Weddell seals) (Eisert et al 2013, 2014; Pinkerton et al 2010; Torres et al 2013). The scale or spatial distribution of predation is unknown.

3. STOCKS AND AREAS

The number of stocks or populations of *D. mawsoni* in the Southern Ocean is currently unknown. However, several studies looking at genetics, parasites, otolith microchemistry, stable isotopes, larval dispersal simulations and movements of fish from tag-recapture data have produced information leading to improved knowledge of stock structure.

A genetic analysis was carried out by Parker et al (2002) using random amplified polymorphic DNA (RAPD) markers. They concluded that samples taken from McMurdo Sound (Statistical Subarea 88.1) and the Bellingshausen Sea (Statistical Subarea 88.3 (Figure 1)) were from two different genetic groups. Smith & Gaffney (2000) detected little genetic diversity in mitochondrial DNA (mtDNA) samples between the Pacific (Statistical Subarea 88.1), Indian Ocean (Division 58.4.2), and Atlantic Ocean (Statistical Subarea 48.1) sectors. One mtDNA method showed no genetic variation, while two other mtDNA methods showed only weak genetic diversity between regions. Smith & Gaffney (2000) also found only weak genetic variation using nuclear DNA introns. They concluded that despite the weak genetic diversity in Antarctic toothfish there was evidence for differentiation between the ocean sectors. Kuhn & Gaffney (2008) expanded the work of Smith & Gaffney (2000) by examining nuclear and mitochondrial single nucleotide polymorphisms (SNPs) on tissue samples collected from Statistical Subareas 48.1, 88.1, and 88.2 and Division 58.4.1. They found broadly similar results to those of the earlier studies, with some evidence for significant genetic differentiation between the three ocean sectors but limited evidence for differentiation within ocean sectors. Suggestions of weak diversity were also reported by Mugue et al (2013).

The assumption of separate stocks is supported by oceanic gyres, which may act as juvenile retention systems, and by the location of recaptures of adult tagged fish (Hanchet et al 2008, Parker et al 2014). Most adult tagged fish have been recaptured close to where they were originally tagged, often within 100 km (Parker & Mormede 2015). However, tagged fish have also been recaptured having moved longer distances within Statistical Subarea 88.1(Parker & Mormede 2017a). Few fish have been observed to move between Statistical Subareas 88.1 and 88.2: Ten fish have moved from Statistical Subarea 88.1 to Statistical Subarea 88.2, and nine moved from Statistical Subarea 88.2 to Statistical Subarea 88.1. Additionally, some long distance movements of more than 2000 km been observed: one fish tagged in McMurdo Sound in SSRU 88.1M was recaptured after 18 years at liberty almost 2500 km to the northeast, in SSRU 88.2H; one fish was released in Statistical Subarea 48.4 and recaptured in Statistical Subarea 88.2 and one fish was released in Statistical Subarea 88.1 and recaptured in Statistical Subarea 58.4.1 (CCAMLR Secretariat 2016a).

Tana et al (2014) compared otolith microchemistry signatures between the north of the Ross Sea (88.1B-C) and north of the Amundsen Sea (88.2H). Preliminary results found differences in the microchemistry of both edges and nuclei between the two areas, providing some evidence for separate Ross Sea and

Amundsen Sea stocks. Pinkerton et al (2014a) compared carbon and nitrogen stable isotope values in muscle tissue samples collected from the slope and north of the Ross Sea and north of the Amundsen Sea. Carbon signatures were similar within the Ross Sea, but different between the Ross Sea and Amundsen Sea suggesting that they form separate spawning populations. Parker (2014) reviewed the stock structure of Antarctic toothfish in Statistical Area 88 including information from genetic studies, otolith microchemistry, stable isotopes, tagging, size and age structure, growth dynamics, and egg and larval dispersal simulations and concluded that there was no evidence to change existing stock boundaries.

For stock assessment purposes all of Statistical Subarea 88.1 and SSRUs 88.2A and 88.2B are treated as a single Ross Sea region stock (‘Ross Sea’ typically refers to the Ross Sea shelf area). SSRUs 88.2C–H) are treated as a second Amundsen Sea region stock. Both Statistical Subareas include closed SSRUs from which fishing has been excluded for varying numbers of years. The stock affinity of the assessed stocks with toothfish in surrounding areas is not well understood, and assessments in the medium term will consider alternative stock structures including developing a combined Statistical Subareas 88.1 and 88.2 assessment.

Information about stock structure will be collected from the exploratory fishery in the SPRFMO Area as well, including genetic samples, size and age distributions, and otoliths for microchemistry. Surveying in discrete spatial strata will enable mapping of fish density (through CPUE) and documentation of movement patterns through tagging.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

4.1 Incidental catch (fish and invertebrates)

The bycatch of fish species in the Statistical Subareas 88.1 and 88.2 fisheries was last characterised by Stevenson et al (2012). The main bycatch species in these fisheries are macrourids, which contributed up to 21% of the total annual toothfish catch by weight from 1997–98 to 2016–17 (Table 3, Table 4). Taxonomic studies have shown that specimens originally identified in the Ross Sea region as *Macrourus whitsoni* comprise two sympatric species: *Macrourus whitsoni* and *Macrourus caml* (McMillan et al 2012) with different biology and ecology (Pinkerton et al 2013). Work is in progress to determine the degree of overlap of these two species both within the Ross Sea region and circum-Antarctic. The other major bycatch group is skates (rajids, mainly *Amblyraja georgiana* and *Bathyraja* cf. *eatonii*). Skates made up about 10% of the total landings by weight in 1997–98 and 1998–99, but the reported catches of skates then decreased due to a tag release programme and the live release of untagged skates. In both programmes, all live skates are released and as a result are not included in catch data. Other fish bycatch species, including moray cods (*Muraenolepis* spp.), morid cods (mainly *Antimora rostrata*), icefish (mainly *Chionobathyscus dewitti*), and rock cods (*Trematomus* spp.) each contribute 1% or less of the overall catch (Stevenson et al 2014).

Table 3: Catches of managed by-catch species (macrourids, rajids and other species) in the Ross Sea region. Rajids cut from the longlines and released are not included in these estimates. Source: fine-scale data. [Continued on next page]

Season	Macrourids		Rajids			Other species	
	Catch limit (t)	Reported catch (t)	Catch limit (t)	Reported catch (t)	Number released	Catch limit (t)	Reported catch (t)
1996–97	-	0	-	0	-	-	0
1997–98	-	9	-	5	-	50	1
1998–99	-	22	-	39	-	50	5
1999–00	-	74	-	41	-	50	7
2000–01	-	61	-	9	-	50	11
2001–02	100	158	-	25	-	50	10
2002–03	610	65	250	11	966	100	12
2003–04	520	319	163	23	1 745	180	23
2004–05	520	462	163	69	5 057	180	22
2005–06	474	266	148	5	14 640	160	17
2006–07	485	153	152	38	7 336	160	41
2007–08	426	112	133	4	7 190	160	18
2008–09	430	183	135	7	7 088	160	15
2009–10	430	119	142	8	6 796	160	15

Table 3 [Continued]

Season	Macrourids		Rajids			Other species	
	Catch limit (t)	Reported catch (t)	Catch limit (t)	Reported catch (t)	Number released	Catch limit (t)	Reported catch (t)
2010–11	430	190	142	4	5 439	160	8
2011–12	430	143	164	1	2 238	160	4
2012–13	430	127	164	4	5 675	160	10
2013–14	430	129	152	2	5 534	160	15
2014–15	430	92	142	6	12 978	160	26
2015–16	430	93	143	6	5 562	160	21
2016–17	430	67	143	4	3 857	160	11
2017–18	485	82	157	8	5 924	157	14
2018–19	485	147	157	9	8 870	157	25

Current catch limits for macrourids in Statistical Subarea 88.1 were derived from biomass estimates from the IPY-2008 trawl survey for the slope of the Ross Sea (see below). In each of the 2003–04, 2004–05, and 2005–06 seasons, the bycatch limit for *Macrourus* spp. was exceeded in at least one of the SSRUs leading to the closure of the fishery in those areas. No bycatch limit has been exceeded since then. The catch limit for macrourids in Statistical Subarea 88.2 remains at 16% of the toothfish catch limit for each management area.

Current catch limits for rajids and other species in Statistical Subarea 88.2 are proportional to the catch limit of *Dissostichus* species in each small-scale research unit (SSRU) based on CM 33-03 (Table 4). Catch limits for rajids or for other species have never been exceeded.

Table 4: Catches of managed by-catch species (macrourids, rajids and other species) in Statistical Subarea 88.2. Rajids cut from the longlines and released are not included in these estimates. Source: fine-scale data.

Season	Macrourids		Rajids			Other species	
	Catch limit (t)	Reported catch (t)	Catch limit (t)	Reported catch (t)	Number released	Catch limit (t)	Reported catch (t)
1996–97	-	0	-	0	-	-	0
1997–98	-	0	-	0	-	-	0
1998–99	-	0	-	0	-	-	0
1999–00	-	0	-	0	-	-	0
2000–01	-	0	-	0	-	-	0
2001–02	40	0	-	0	-	20	0
2002–03	60	18	-	0	-	140	8
2003–04	60	37	50	0	107	140	8
2004–05	60	21	50	0	-	140	3
2005–06	78	84	50	<1	923	100	12
2006–07	88	54	50	<1	-	100	13
2007–08	88	17	50	0	–	100	4
2008–09	90	58	50	<1	265	100	13
2009–10	92	49	50	0	-	100	15
2010–11	92	52	50	<1	169	100	13
2011–12	84	29	50	<1	-	120	11
2012–13	84	25	50	0	-	120	8
2013–14	62	7	50	<1	28	120	3
2014–15	99	19	50	1	192	120	6
2015–16	99	52	50	<1	861	120	3
2016–17	99	22	31	1	314	99	2
2017–18	99	22	31	0	104	99	3
2018–19	143	21	45	<1	217	143	3

4.2 Population assessments for rajids and macrourids

Rajids

Preliminary estimates of the age and growth of *Amblyraja georgiana* in the Ross Sea suggested that these skates initially grow very rapidly for about five years, after which growth almost ceases (Francis & Ó Maolagáin, 2005). However, Francis & Gallagher (2008) presented an alternative interpretation of age and growth in *A. georgiana* that is radically different from the published interpretation. By counting fine growth bands in the caudal thorns instead of broad diffuse bands, they generated growth curves that suggest much slower growth, greater ages at maturity (about 20 years compared with 6–11 years) and greater maximum ages (28–37 years compared with 14 years). Several pieces of circumstantial evidence support the new interpretation, but a validation study is required to determine which growth scenario is correct. Updated length-weight relationships for skates were provided by Francis (2010).

An experimental skate tagging programme in the Ross Sea fishery was started in 2000, and a preliminary assessment of skates completed by Dunn et al (2007). A fishery-wide tagging programme and sampling programme for skates was instituted by CCAMLR in 2008–09. It was anticipated that this initiative would lead to more Antarctic skates being tagged in Statistical Subareas 88.1 and 88.2. However, only 1907 and 99 skates were tagged in Statistical Subareas 88.1 and 88.2 respectively in 2008–09. This programme was extended for the 2009–10 season but discontinued in 2010–11. A 2-year skate tagging and age validation programme was implemented for the 2019/20 and 2020/21 fishing seasons (SC-CAMLR XXXVII paragraph 5.7).

Mormede & Dunn (2010) provided a characterisation of skate catches in the Ross Sea region. The paper concluded that aspects of the catch history were very uncertain, including the species composition, the weight and number of skates caught, the proportion discarded, and the survival of those fish that were tagged. While the size composition of the commercial catch was uncertain before 2009 because of the low numbers sampled each year, data collected in 2008–10 resulted in improved estimates of the length frequency of the catch. Tag data were also improved, with a total of about 3300 *Amblyraja georgiana* and 700 *Bathyraja* cf. *eatoni* tagged and a total of 179 skates recaptured as of 2010. Additional characterisation of skate bycatch, the skate tagging programme and trends in biomass is underway as part of the 2019/20 tagging programme.

Macrourids

In 2011, it was recognised that specimens originally identified in the Ross Sea region as *M. whitsoni* did in fact comprise two sympatric species: *M. whitsoni* and *M. caml* (Smith et al 2011, McMillan et al 2012). *M. caml* grows larger than *M. whitsoni* and is about 20% heavier for a given length (Pinkerton et al 2013). The two species can be distinguished morphologically through two main characters (number of rays in the left pelvic fin; number of rows of teeth in the lower jaw). The distribution of *M. whitsoni* and *M. caml* seems to almost completely overlap by depth and area, with both appearing to be abundant between depths of 900 and 1900 m. Catches of females of both species exceed that of males (especially for *M. caml*) and this sex-selectivity cannot be explained by size or age of fish (Pinkerton et al 2013). It is almost certain that previous work which was presumed to have been carried out on *M. whitsoni* would actually have been carried out on a mix of the two species. However, it is now possible to distinguish between the species based on their otolith morphometrics (Pinkerton et al 2014b), so otoliths collected in previous years of the fishery or from toothfish stomachs can be identified to species.

Otolith ageing data show that the two species have very different growth rates (Pinkerton et al 2013). *M. whitsoni* approaches full size at about 10–15 years of age and can live to at least 27 years, whereas *M. caml* reaches full size at about 15–20 years and can live in excess of 60 years. Sexual maturity in female *M. whitsoni* is reached at 52 cm and 16 years, but in female *M. caml* at 46 cm and 13 years. Gonad staging data imply that the spawning period of both species is protracted extending from before December to after February.

The IPY trawl survey of the Ross Sea slope was carried out in 2008 leading to a biomass estimate of macrourids for the first time. Biomass and yield estimates of *Macrourus* spp. for the Ross Sea fishery based on extrapolations under three different density assumptions from the trawl survey were given by Hanchet et al (2008) (Table 5). The resulting biomass estimates had a CV of about 0.3.

Table 5: Biomass estimates of *Macrourus* spp. from the trawl surveys for the BioRoss 400–600 and 600–800 m and IPY-CAML 600–1200 and 1200–2000 m strata and extrapolated biomass estimates (with CVs) for the remaining strata based on three methods of extrapolation. [Continued on next page]

Survey	Depth range (m)	Biomass (t)	Extrapolated biomass (t) constant density	CPUE (all vessels)	CPUE (NZ vessels)
BioRoss – 88.1H	400–600	230	230 (49)	230 (49)	230 (49)
BioRoss – 88.1H	600–800	3 531	3 531 (38)	3 531 (38)	3 531 (49)
SSRU 88.1H west	800–1200		92 (50)	83 (54)	103 (55)
SSRU 88.1H west	1200–2000		713 (40)	1 114 (49)	1 038 (47)
IPY - 88.1H	600–1200	975	975 (50)	975 (50)	975 (50)
IPY - 88.1H	1200–2000	3 356	3 356 (40)	3 356 (40)	3 356 (40)
SSRU 88.1 I	600–1200		3 297 (50)	7 883 (51)	5 992 (50)
SSRU 88.1 I	1200–2000		4 670 (40)	11 168 (42)	8 576 (41)
SSRU 88.1 K	600–1200		1 539 (50)	5 027 (51)	2 774 (51)
SSRU 88.1 K	1200–2000		2 998 (40)	5 995 (45)	9 111 (43)
HIK Sub-total			21 410		

Table 5 [Continued]

Survey	Depth	Biomass	Extrapolated biomass (t)		
SSRU 88.2 A+B	600–1200		1 404 (50)	1 396 (58)	857 (60)
SSRU 88.2 A+B	1200–2000		4 087 (40)	525 (70)	—
88.2 A, B Sub-total			5 491		
Total			26 892 (29)	41 823(28)	36 542(30)

Yield estimates were calculated using the constant density assumption when extrapolating the biomass estimate across the slope region, noting that this would provide a more precautionary estimate of yield than one based on extrapolations using longline CPUE data. The resulting biomass estimate for SSRUs 88.1HIK was 21 410 t which gave a yield estimate of 388 t. This yield estimate was then apportioned across the 5 SSRUs taking into account maximum historical catches (Table 6). The catch limits per SSRU detailed in Table 6 have been used by CCAMLR since the 2009–10 season.

Table 6: Estimated yield, maximum historic catch, and revised catch limit of *Macrourus spp*. for the Ross Sea fishery.

Region	Estimated yield	Maximum historic catch	Revised catch limit
88.1BCG	-	34	40
88.1HIK	}388	390	320
88.1JL		52	70
88.1M	0	0	0
88.2AB	100	8	0
Total	488		430

Additional trawl-based surveys (18 tows in 4 strata) were carried out in 2015 on TAN1502 (O'Driscoll & Double 2015) and in 2019 (TAN1901) but the new information has not yet been used to develop updated biomass estimates for *Macrourus* spp (or other bycatch species) on the Ross Sea slope.

The use of acoustic data to monitor trends in relative abundance of macrourids has also been explored (O'Driscoll et al 2012, Ladroit et al 2014). These studies have shown positive correlations between acoustic targets and longline catches of grenadiers, and the acoustic target strength distribution of single targets is similar to that predicted, based on the expected size range of grenadiers. However, variability in spatial coverage between years means that it is currently not possible to obtain a consistent time-series of relative abundance estimates for grenadiers from acoustic data collected opportunistically by New Zealand vessels in the fishery. Recent acoustic research on toothfish suggests that the target strength of toothfish may overlap that of grenadiers (O'Driscoll et al. 2018).

Identification of levels of risk from bycatch

Risk categorisation tables were prepared for rajids and macrourids by O'Driscoll (2005) based on the risk status categories of Castro et al (1999). *Amblyraja georgiana* were categorised as risk category 3, which are "species that are exploited by directed fisheries or bycatch, and have a limited reproductive potential, and/or other life history characteristics that make them especially vulnerable to overfishing, and/or that are being fished in their nursery areas". The risk to *A. georgiana* is mitigated due to the requirement to cut rajids from longlines while still in the water and release them.

Macrourus whitsoni were categorised as between risk category 2 and 3 but this analysis predates the realisation of two species of *Macrourus* in the Ross Sea. Risk category 2 includes "species pursued in directed fisheries, and/or regularly found in bycatch, whose catches have not decreased historically, probably due to their higher reproductive potential".

Ecosystem effects associated with bycatch are thought to be less likely than those associated with predation release (see Section 4.6).

Mitigation measures

Since the start of the 2000–01 season, rajids likely to survive have been cut free and released at the surface as a measure to reduce rajid mortality. The survival of at least some of these skates has been demonstrated by the recapture of over 130 tagged skates as of 2010 (Mormede & Dunn 2010), and by the results of survivorship experiment in tanks carried out by the UK.

There is a 'move-on' rule in place to help prevent excessive fishing in localised areas of high abundance of bycatch species. This rule requires a vessel to move to another location at least 5 n. miles distant if the bycatch of any one species is equal to or greater than 1 tonne in any one set. The vessel is not allowed to return to within 5 n. miles of the location where the bycatch exceeded 1 tonne for a period of at least five days.

4.3 Incidental capture of Protected Species (seabirds and marine mammals)

Only two seabirds have ever been caught in this toothfish fishery: both were Southern giant petrels (*Macronectes giganteus*). One was caught in 2003–04 and the second in 2013–14 (Table 7). None have been reported since 2014. Considerable effort has been put into mitigation of seabird captures in the fishery, through implementation of CCAMLR Conservation Measures regarding line sink rate, use of streamer lines, seasonal restrictions on fishing, prohibition of offal dumping, line weighting and only allowing daytime setting under strict conditions.

Table 7: Seabird incidental mortality limit, reported seabird incidental mortality, incidental mortality rate, and estimated incidental mortality in Statistical Subareas 88.1 and 88.2.

Season	Incidental mortality limit	Incidental mortality rate (seabirds/thousand hooks)	Estimated incidental mortality
1997–98		0	0
1998–99		0	0
1999–00		0	0
2000–01		0	0
2001–02	3*	0	0
2002–03	3*	0	0
2003–04	3*	0.0001	1
2004–05	3*	0	0
2005–06	3*	0	0
2006–07	3*	0	0
2007–08	3*	0	0
2008–09	3*	0	0
2009–10	3*	0	0
2010–11	3*	0	0
2011–12	3*	0	0
2012–13	3*	0	0
2013–14	3*	0.0001	1
2014–15	3*	0	0
2015–16	3*	0	0
2016–17	3*	0	0
2017–18	3*	0	0
2018-19	3*	0	0

* Per vessel during daytime setting.

Assessments of the potential risk of interaction between seabirds and longline fisheries (ranging from low to high) have remained unchanged since 2007. The risk levels of seabirds in the fishery in Statistical Subarea 88.1 is category 1 (low) south of 65°S, category 3 (average) north of 65°S and overall is category 3 (SC-CAMLR-XXX, Annex 8, paragraph 8.1).

Implementation of the required CCAMLR Conservation Measures has meant that seabird captures have been successfully avoided during this toothfish longline fishery. There is a high degree of certainty in the estimates provided of seabird captures, given the high level of observer coverage (100% of vessels covered by two observers, up to 40% of all hooks hauled directly observed).

4.4 Maintenance of ecological relationships

FEMA workshops

Developments in evaluating ecosystem effects of the Antarctic toothfish fishery were discussed at the FEMA (Fisheries and Ecosystem Models in the Antarctic) and FEMA II workshops (SC-CAMLR-XXVI/BG/6, paragraphs 45 to 48 and SC-CAMLR-XXVIII/3). The FEMA and FEMA II workshops noted that the fishery for Antarctic toothfish may affect ecological relationships in the Ross Sea region by influencing interactions between toothfish and its predators or interactions between toothfish and its prey. Effects of fishing may also “cascade” through marine food-webs as indirect effects.

The FEMA II workshop also noted that the escapement level of 50% is the proportion of spawning biomass permitted to escape the fishery over the long term, and that as a consequence, the sub-mature fish would have a much higher escapement (e.g., > 90% for fish < 100 cm) (SC-CAMLR-XXVIII, Annex 3, figure 1). However, the FEMA II workshop noted that the escapement level in the decision rule for the spawning biomass may need to be modified upwards if the size/age classes of *Dissostichus* spp. that are important prey for predators are reduced below the level needed to safeguard predators.

Effects on predators of toothfish

The predators of toothfish include Type C killer whales, odontocetes (sperm whales (historically)) and Weddell seals (Eisert et al 2013, 2014; Torres et al 2013; Pinkerton et al 2010). A mass-balance food-web model suggested that toothfish formed about 6–7% of the diet of its predators at the scale of the Ross Sea averaged over a year (Pinkerton et al 2010). The model does not exclude the possibility that the consumption of toothfish in particular locations at particular times of the year, or by particular components of predator populations may be important to some predators, even though the model suggests that the total consumption of toothfish by all individuals of a predator species is relatively low. Few data are available on consumption of toothfish by marine mammals, and results derived from this model should be treated as preliminary until better information can be obtained.

With respect to Weddell seals, Pinkerton et al (2008) and Eisert et al (2013) reviewed information on interactions with toothfish from habitat overlap estimates, diver observations, animal-mounted cameras, stomach contents, vomit and scat (faecal) analysis, stable isotopes of carbon and nitrogen, and also compared natural mortality rates of Antarctic toothfish in McMurdo Sound with potential consumption by Weddell seals. Energetic analyses of other potential Weddell seal preys in McMurdo Sound compared to Weddell seal seasonal dietary requirements suggest that toothfish are likely to be important preys during particular times of year and in particular locations but are unlikely to be a major dietary component throughout the year (Eisert et al 2013). The contribution of toothfish to Weddell seal diets is being investigated over two time scales, (1) using scat DNA analysis during the post-breeding/moult period (identified as a period potentially requiring increased food intake to recover body condition lost during lactation), and (2) using stable isotope analysis of whiskers to obtain a dietary record for an entire annual cycle. Seals have been marked by injection of ^{15}N-labelled glycine in the 2013–14 season for recapture in the 2014–15 season. The ^{15}N-label is detectable as a spike in the values for whiskers and provides a time-stamp for the stable isotope pattern preserved in whiskers. In addition, winter foraging areas are being investigated using satellite-linked data loggers deployed on Weddell seals to investigate potential spatial overlap with the fishery and to identify areas of particular importance to these predators.

Torres et al (2013) considered the available evidence regarding the importance of toothfish as prey for killer whales in the Ross Sea. Killer whales with toothfish in their mouths have been observed in McMurdo Sound (Eisert et al 2014), but the proportion of toothfish consumed by killer whales in the Ross Sea in general is not known. The available data – on habitat overlap, stable isotopes, and a comparison between natural mortality rates of Antarctic toothfish in McMurdo Sound and potential consumption by killer whales – were limited and inconclusive. At present, the balance of evidence suggests that toothfish are likely to be significant in the diet of type C killer whales in McMurdo Sound in summer, but it is not possible to say whether toothfish are an important prey item to type C killer whales in other locations on the Ross Sea shelf or at the scale of the whole Ross Sea shelf and slope (Torres et al 2013). An important consideration for type C killer whales, as for Weddell seals, is that toothfish, due to their large mass and high energy content, may be a unique food resource that is required to support periods of high energy demand such as lactation (Eisert et al 2014). Field work has occurred on this issue by (a) collecting dart (small tissue) biopsies for stable isotope analysis and (b) compiling a photo-identification catalogue of killer whales that can be used to study habitat use, migration patterns, and to estimate abundance from mark-recapture analysis.

Effects on prey of toothfish

The mass-balance food-web model suggested that toothfish consumed 64% of the annual production of demersal species as prey items (Pinkerton et al 2010), and so a reduction of the toothfish population might lead to a large reduction on the mortality of these species through a "predation release" effect. As toothfish are large and mobile, their prey species are long-lived, and functional predator diversity seems to be low, then the potential predation release effect is likely to be high in the Ross Sea region (Pinkerton & Bradford-Grieve 2014). Mormede et al (2014d) described the development of a spatially explicit minimum realistic model of demersal fish population dynamics, predator–prey interactions, and fishery removals based on the spatial population model (SPM) for toothfish in the Ross Sea. The model includes *D. mawsoni* as well as macrourids and channichthyids, the two groups that make up about 50%

of *D. mawsoni* prey. The model indicates that channichthyids, with a relatively high productivity, would be expected to substantially increase in abundance within fished locations as predation pressure by toothfish is decreased, particularly in SSRU 88.1H where historical fishery removals have been most concentrated. Macrourids would be expected to show a modest increase in biomass based on their lower productivity.

Cascading ecological effects

Changes to the abundance of toothfish prey species may have effects on other species in the food-web through second-order effects (e.g. a "keystone" effect[3] or trophic cascades[4]), however, these are likely to be dependent on the particular ecosystem and are difficult to predict. The potential ecosystem effects of fishing in the Ross Sea region were investigated using mixed trophic impact (MTI) analysis (Pinkerton & Bradford-Grieve 2014). Overall, Antarctic toothfish had moderate trophic importance in the Ross Sea food web as a whole and the MTI analysis did not support the hypothesis that changes to toothfish will cascade through the ecosystem by simple trophic effects. Because of limitations to MTI analysis, cascading effects on the Ross Sea ecosystem due to changes in the abundance of toothfish cannot be ruled out, but, for such changes to occur, a mechanism other than simple trophic interactions is likely to be involved.

Between 2001 and 2013 the number of breeding pairs of Adélie penguins at colonies in the southwestern Ross Sea more than doubled. It has been suggested that this increase was caused by the fishery for Antarctic toothfish leading to mesopredator release of Antarctic silverfish (*Pleuragramma antarctica*), a shared prey of toothfish and Adélie penguins (Lyver et al 2014; Ainley et al 2016). The study of Pinkerton et al (2016) brought together information from multiple models to estimate the biomass of silverfish that could be released from predation through the effects of the toothfish fishery. New (unpublished) diet data for toothfish over the Ross Sea shelf were used. The results of the modelling were inconsistent with predation release of silverfish due to the toothfish fishery being responsible for recent increases in the number of Adélie penguins breeding in the southwestern Ross Sea (Pinkerton et al 2016). The cause of the increase in Adélie penguins breeding in the Ross Sea region remains unknown.

4.5 Effects of fishing on biogenic habitats

In 2006, the United Nations General Assembly (UNGA) agreed the Sustainable Fisheries Resolution (61/105), which calls on States and RFMOs or other arrangements to ensure fish stocks are managed sustainably and to prevent significant adverse impacts on vulnerable marine ecosystems (VMEs, UNGA Resolution 61/105, OP80–OP91). The 23 taxa included as VME indicator taxa (Parker & Bowden 2010) are defined in the CCAMLR VME taxa classification guide, which is available on the CCAMLR website (http://www.ccamlr.org/pu/e/sc/obs/vme-guide.pdf).

CCAMLR has implemented several Conservation Measures pertaining to VMEs that form an approach to constrain gear types used, constrain areas fished, monitor fishing effort for evidence of VMEs, and to provide information in order to evaluate the potential effects of fishing on VMEs.

Sharp et al (2009) developed a bottom fishing impact assessment method, which was revised by Sharp (2010), and subsequently adopted by the Commission and used to summarise the current spatially-resolved fishing footprint and potential impact (% mortality) within the fishing footprint. This assessment method has demonstrated that regardless of the distribution of VMEs within the fishing footprint, the level of impact is exceptionally low.

Parker et al (2010) analysed spatial patterns of VME taxa from fishery bycatch in the Ross Sea region. Some taxa are relatively common as bycatch (e.g. Porifera, anemones, stylasterid hydrocorals) and the detectability of habitats containing these taxa with autoline longline gear is moderate to high (e.g., 70+%), enabling the use of fishery longline bycatch as a monitoring tool. This study also showed that VME taxa distributions vary spatially within the Ross Sea, and that some areas have shown no evidence of VME taxa despite consistent fishing effort.

[3] Keystone predators maintain biodiversity by preferentially consuming competitively dominant prey species. If keystone predators are removed or their biomass reduced, abundance of some prey species can increase to levels where they start to exclude subordinate competitors.
[4] Trophic cascade: reorganisation of the lower trophic levels of an ecosystem due to the change in abundance of a predator.

Following fishery impacts, the potential recovery times for the VME taxa in the Ross Sea with the lowest productivities were evaluated with a spatially explicit production model (Dunn et al 2010). This model also showed that with current understandings of fishing gear performance, fishing effort distribution, and VME taxon life history, fishery impacts are low and recovery is likely to take place under the current management response to high bycatch levels. However, methods to determine the presence of high densities of rare taxonomic groups or unique community assemblages specific to the Ross Sea Region may need to be developed.

CCAMLR maintains a register of designated VMEs with two designated on the Admiralty seamount in the Ross Sea as well as several shallow water VMEs in Terra Nova Bay. VME Risk Areas have also been designated based on an observed fishery bycatch of over 10 kg or litres of VME taxa in a 1200-m longline segment. A total of 59 VME Risk Areas have been designated in Statistical Subarea 88.1 and 16 in Statistical Subarea 88.2, each closing a 1 nautical mile radius area surrounding the location of the bycatch observation to bottom fishing until reviewed by the Commission.

4.6 Ecosystem indicators

At present our ability to predict the effects of the toothfish fishery on ecosystem relationships in the Ross Sea region is limited. There is a need to develop and implement appropriate monitoring in the Ross Sea to ascertain how species and ecological relationships are affected by the fishery as a main objective of the Ross Sea MPA (CM 91-05). Monitoring should focus on species most likely to be affected by the toothfish fishery in the first instance. Baseline data on toothfish diet have been developed for some areas. Periodic analysis of the stomach contents of toothfish can be used to look for changes in toothfish diet that may be indicative of changes to the demersal fish community, although power analysis is needed to determine the effect size detectable. Better direct information is required on the abundance of *Macrourus* spp. and icefish on the Ross Sea slope, which will require significant trawl survey effort. Research continues to test the extent to which acoustic methods could be used to detect changes in *Macrourus* spp. abundance at the fishery scale (O'Driscoll et al 2012, Ladroit et al 2014).

Annual surveys of toothfish abundance in the southwest Ross Sea have been carried out since the 2011–12 season and the intention is for these to continue annually. As well as providing an index of abundance of 5–10 year old toothfish this survey will provide information on changes to the availability of toothfish to predators in this region, especially in McMurdo Sound and Terra Nova Bay.

5. STOCK ASSESSMENT

Estimates of biomass and long term yield (using the CCAMLR Decision Rules) were provided in 2019 for Antarctic toothfish for the Ross Sea region stock (Statistical Subarea 88.1 and Statistical Subarea 88.2 SSRUs 88.2A and B) based on analyses using catch-at-age from the commercial fishery, tag-recapture data, and estimates of biological parameters as reported below (Dunn 2019). This was the ninth stock assessment of the Ross Sea fishery.

In 2014, the approach used in previous assessments of the Amundsen Sea stock (Statistical Subarea 88.2 SSRUs 88.2C–H) was rejected by CCAMLR because the models were unable to fit the patterns in the tag recapture data. Instead, a two-year research plan was developed by CCAMLR to collect the data required to address uncertainties in the previous assessment model. Two area models for the Amundsen Sea stock have been developed (Mormede et al 2013, Mormede et al 2014a, Mormede et al 2014b, Mormede et al 2015b, Mormede et al 2016), and the two-year research plan was extended through the 2019-20 season). The key aspects of the plan, including derivation of catch limits are discussed below under Section 5.2(ii).

5.1 Estimates of fishery parameters and abundance indices

CPUE indices

A standardised CPUE analysis of Antarctic toothfish in the Ross Sea fishery showed a gradually increasing trend through 2006 followed by a decrease over the course of the fishery for the South of

70°S management area (S70) while the North of 70°S management area has shown an trend of increasing CPUE throughout the fishery (Devine et al 2019, Figure 4). The pattern for the Ross Sea fishery overall was similar to the slope fishery.

The patterns of increase and declines in the annual CPUE indices are thought to reflect a combination of either good or poor ice conditions, vessel crowding, increasing fisher experience, improved knowledge of optimum fishing practice, improvements in gear, and regulation changes (i.e. move-on rules and research set requirements), and will also be affected by movement patterns of toothfish rather than toothfish abundance (Maunder et al 2006).

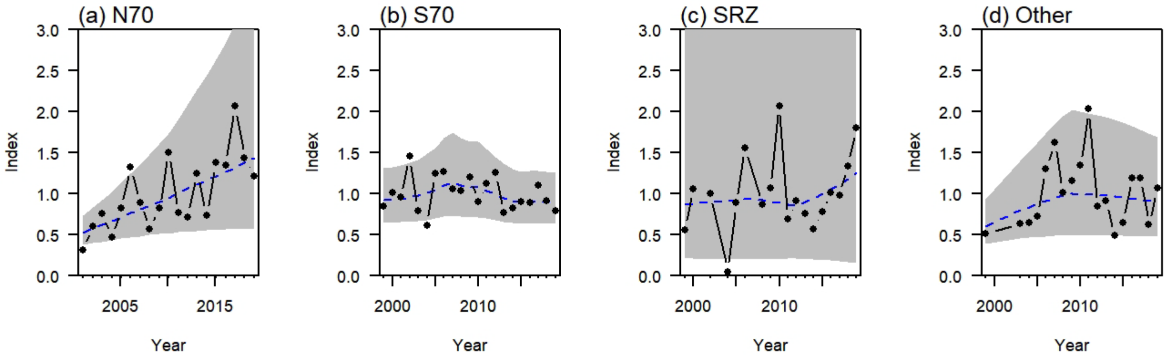


Figure 4: Relative CPUE (scaled to have mean of one) for the Ross Sea fishery showing CPUE indices for the management areas North of 70°S, South of 70°S, the Special Research Zone, and areas not currently open fishing, 1999–2019. Blue dashed lines show smoothed fit with 95% confidence intervals (grey area).

A standardised CPUE analysis of Antarctic toothfish in SSRU 88.2H showed a steep decline at the beginning of the fishery when there had still been little fishing in the area followed by a more recent increase. Standardised CPUE in SSRUs 88.2C–G shows an increase over time with levelling off in the most recent years. In both SSRU 88.2H and SSRUs 88.2C–G the confidence bounds were very wide for the first part and later part of the time series (Large et al 2015) (Figure 5). There has been little consistent fishing effort in Statistical Subarea 88.2 until recent years and, as for the Ross Sea, the patterns of increase and declines in the CPUE indices are thought to reflect a combination of fishery and environmental factors rather than toothfish abundance (Maunder et al 2006). The CPUE analysis in 88.2H has not been updated since 2015.

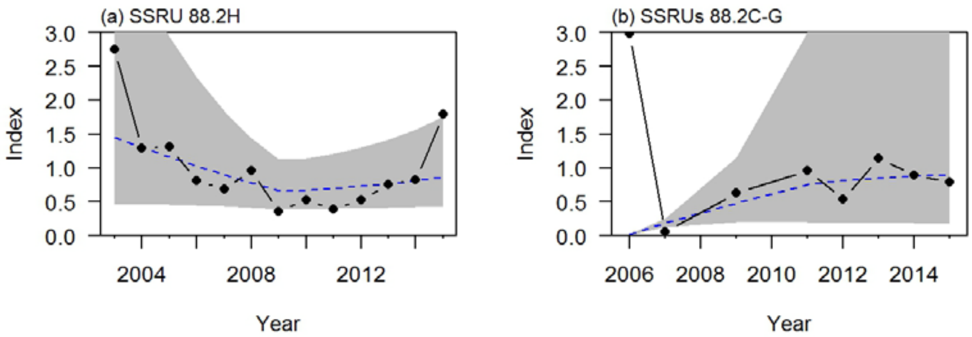


Figure 5: Relative CPUE indices (scaled to have mean of one) for (a) the SSRU 88.2H fishery, and (b) the SSRU 88.2C–G fishery, 2003-2015. Blue dashed lines show smoothed fit with 95% confidence intervals (grey area).

Mark-recapture data

The tagging program for *Dissostichus* spp. in the Ross Sea was first initiated in the 2000–01 season in Statistical Subarea 88.1 by New Zealand vessels participating in the fishery (Parker & Mormede 2017a). Since then, the toothfish tagging programme has been made a requirement for all vessels participating in the fishery in both the Ross Sea region and Amundsen Sea region.

An index of vessel-specific tag detection performance for the Ross Sea fishery using a case-control methodology was developed by Mormede & Dunn (2013) and further refined into the calculation of effective tag release survival rate and effective tag detection rate of recaptured fish (Mormede 2014e).

The method controls for the inter-annual spatial and temporal variability of commercial fishing operations from which tagged fish are released and recaptured. The values used for each vessel are recalculated for each new assessment and summarised by Devine et al (2019) for the most recent assessment.

Between 2001 and 2019, more than 60 000 *Dissostichus* spp. have been tagged in Statistical Subareas 88.1 and 88.2, with just over 50 000 and more than 10 000 *D. mawsoni* in the Ross Sea and SSRUs 88.2C–H respectively (Devine et al 2019). Recaptured fish at liberty for more than six years, and within-season recaptures, were not used in the assessment. Although more than 2 500 tags had been released on the shelf and slope of Statistical Subarea 88.2 (SSRUs 88.2C–G) by 2014, few fish had been recaptured, likely reflecting the inconsistent pattern of fishing in these areas. The Scientific Committee recognised the need to develop an estimate of abundance for the South, and recommended a two-year research plan to collect the necessary information (SC-CAMLR-XXXIII 2014, paragraph 3.168).

As part of the approved research plan, fishing effort in the South was restricted to four fishing blocks for the 2014–15 and 2015–16 fishing seasons to increase the likelihood of tagged fish being recaptured. This approach has led to an increase in the tag recapture rate. The Scientific Committee considered that the research plan was providing the information necessary to develop the stock assessment and recommended that it be extended with increased tagging rate in the north to 3 fish per tonne, consistent with the rate in the south (CCAMLR 2016c, SC paragraphs 3.215 and 3.216). At its 2018 meeting, the CCAMLR Scientific Committee recommended that the research plan in place for SSRUs 882C–H continues through the 2018/19 season following Scientific Committee advice (SC-CAMLR-XXXVII, paragraphs 3.183-3.188).

Catch-at-age data

Strata for the Antarctic toothfish length and age frequency data were determined using tree-based regression (a post-stratification method) (Hanchet et al 2013). The analysis used the median length of fish in each longline set, and the explanatory variables SSRU and depth. On average, about 500 Antarctic toothfish otoliths collected by observers were selected for ageing each year, and used to construct annual area-specific age-length keys (ALKs) for the Ross Sea region. In the Ross Sea, ALKs for each sex were applied to the shelf/slope fisheries and the north fishery separately. The ALKs were applied to the scaled length-frequency distributions for each year to produce annual catch-at-age distributions (Devine et al 2019). In the Amundsen Sea region (SSRU 88.2C–H) fishery, otoliths were only available from the New Zealand fleet, which did not fish there every year. Therefore, for this fishery a single ALK for each sex using otolith ages from all available years was used to construct annual age frequencies for SSRU 88.2H, and SSRU 88.2C–G fisheries separately.

Recruitment surveys

Eight years of an annual research longline survey of sub-adult (70–110 cm long) toothfish have now been carried out in the southern Ross Sea (Hanchet et al 2012, Parker et al 2013b, Mormede et al 2014c, Hanchet et al 2015, Dunn et al 2016, Large et al 2017, Stevens et al. 2018, Parker et al. 2019). Catches and size structure were similar among the surveys but consistently show year class progression in the age distributions. The survey age structure and local biomass estimations were incorporated into the 2019 assessment and were shown to stabilise the index of year class strength; on this basis, continuation of the survey has been recommended.

Parameter estimates

A list of parameter values used for the assessments is given in Table 8.

Table 8: Parameter values for *D. mawsoni* in Statistical Subareas 88.1 and 88.2. [Continued on next page]

Component	Parameter	Value			Units
		Male	Female	All	
Natural mortality	M	0.13	0.13		y^{-1}
VBGF	K	0.093	0.090		y^{-1}
VBGF	t_0	-0.256	0.021		y
VBGF	L_∞	169.07	180.20		cm
Length to mass	‘a’	0.00001387	0.00000715		cm, kg
Length to mass	‘b’	2.965	3.108		
Length to mass variability (CV)				0.1	
Maturity	A_{m50}	12.8	16.6		y

Table 8 [Continued]

Component	Parameter	Value			Units
		Male	Female	All	
Range: 5% to 95% maturity		9.3–16.3	9.3–23.9		y
Recruitment variability	σ_R			0.6	
Stock recruit steepness (Beverton-Holt)	h			0.75	
Ageing error (CV)				0.1	
Initial tagging mortality				10%	
Instantaneous tag loss rate (single tagged)				0.062	y^{-1}
Instantaneous tag loss rate (double tagged)				0.0084	y^{-1}
Tag detection rate				98.7%	
Tagging related growth retardation (TRGR)				0.5	y

5.2 Biomass estimates

(i) The Ross Sea fishery (Statistical Subarea 88.1 and SSRUs 88.2A and 88.2B)

The stock assessment model

The model was sex- and age-structured, with ages from 1–50, where the last age group was a plus group (Dunn 2019). The annual cycle was broken into three discrete time steps, nominally summer (November–April), winter (May–October), and end-winter (age-incrementation) (Table 9).

Table 9: Annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

Step	Period	Processes	M^1	Age[2]	Observations	
					Description	M^3
1	Nov–April	Recruitment and fishing mortality	0.5	0.0	Tag-recapture	0.5
					Catch-at-age proportions	0.5
2	May–November	Spawning	0.5	0.0		
3	-	Increment age	0.0	1.0		

1. M is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length at age, which was assumed to occur in that time step.
3. M is the proportion of the natural mortality in each time step that was assumed to have taken place at the time each observation was made.

The model was run from 1995 to 2019, and was initialised assuming an equilibrium age structure at an unfished equilibrium biomass, i.e. a constant recruitment assumption. Recruitment was assumed to occur at the beginning of the first (summer) time step. Recruitment sex ratio was assumed to be 50:50 and was parameterised as a year class strength multiplier (assumed to have mean equal to one over a defined range of years), multiplied by an average (unfished) recruitment (R_0) and a spawning stock-recruitment relationship. In this model, the year class strength multipliers were assumed fixed, and set equal to 1.

The base-case model was implemented as a single-area, three-fishery model. A single area was defined with the catch removed using three concurrent fisheries (N70, S70, SRZ). Selectivity for each fishery was parameterised by a sex-based double-normal ogive (i.e. domed selectivity). In the 2013 assessment, the selectivity allowed for annual selectivity shifts that shifted the ogive left or right (shelf fishery) with changes in the mean depth of the fishery (slope and north fisheries in the Ross Sea) but this was removed in 2015 following CCAMLR recommendation. The double-normal selectivity was parameterised using four estimable parameters and allowed for differences in maximum selectivity by sex – the maximum selectivity was fixed at one for males, but estimated for females. The double-normal selectivity ogive was employed as it allowed the estimation of a declining right-hand limb in the selectivity curve.

Fishing mortality was applied only in the first (summer) time step. The process was to remove half of the natural mortality occurring in that time step, then apply the mortality from the fisheries instantaneously, then to remove the remaining half of the natural mortality.

The population model structure includes tag–release and tag–recapture events. Each tagged fish was assigned an age-sex based on its length and the modelled population structure of fish at that age and sex. Tagging from each year was applied as a single tagging event. The usual population processes (natural mortality, fishing mortality etc.) were then applied over the tagged and untagged components of the model simultaneously. Tagged fish were assumed to suffer a retardation of growth from the effect of tagging (TRGR), equal to 0.5 of a year for the year immediately following release.

Model estimation
The model parameters were estimated using Bayesian analysis, first by maximising an objective function (MPD), which is the combination of the likelihoods from the data, prior expectations of the values of the those parameters, and penalties that constrain the parameterisations; and second, by estimating the Bayesian posterior distributions using Monte Carlo Markov Chains (MCMCs). Initial model fits were evaluated at the MPD, by investigating model fits and residuals. Parameter uncertainty was estimated using MCMCs. These were estimated using a burn-in length of 5×10^5 iterations; with every 1000th sample taken from the next 1×10^6 iterations (i.e. a final sample of length 1000 was taken).

Observation assumptions
The catch proportions-at-age data for 1998–2018 were fitted to the modelled proportions-at-age composition using a multinomial likelihood. Following previous recommendations of WG-SAM that CPUE indices were not indexing changes in abundance, the CPUE indices were not used. Tag–release events were defined for the 2001–2018 years, weighted by the vessel-specific tag survival rate. Within-season recaptures were ignored. Tag–release events were assumed to have occurred at the end of the first (summer) time step, following all (summer) natural and fishing mortality.

The estimated number of scanned fish (i.e. those fish that were caught and inspected for a possible tag) was derived from the sum of the scaled length frequencies from the vessel observer records multiplied by the vessel-specific tag detection rate, plus the numbers of fish tagged and released. Tag recapture events were assumed to occur at the end of the first (summer) time step, and were assumed to have a detection probability of 85% to account for unlinked tags.

For each year, the recovered tags at length for each release event were fitted, in 10 cm length classes (range 40–230 cm), using a binomial likelihood.

Process error and data weighting
Additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance for all observations, following the methods of Francis (2011). Adding such additional errors to each observation type has two main effects, (i) it alters the relative weighting of each of the data sets (observations) used in the model, and (ii) it typically increases the overall uncertainty of the model, leading to wider credible bounds on the estimated and derived parameters. The additional variance, termed process error, was estimated for each MPD run, and the total error assumed for each observation was calculated by adding process error and observation error. A single process error was estimated for each of the observation types (i.e. one for the catch-at-age data and one for the tag-recapture data).

Penalties
Two types of penalties were included within the model. First, the penalty on the catch constrained the model from returning parameter estimates where the population biomass was such that the catch from an individual year would exceed the maximum exploitation rate. Second, a tagging penalty discouraged population estimates that were too low to allow the correct number of fish to be tagged. These penalties had no effect on the model outcome.

Priors
The parameters estimated by the models, their priors, the starting values for the minimisation, and their bounds are given in Table 10. In models presented here, priors were chosen to be relatively non-informative and that also encouraged conservative estimates of B_0.

Table 10: Number (N), start values, priors, and bounds for the free parameters (when estimated) for the Ross Sea base-case.

Parameter		*N*	Start value	Prior	Bounds	
					Lower	Upper
B_0		1	80 000	Uniform-log	1×10^4	1×10^6
Male fishing selectivities	a_1		8.0	Uniform	1.0	50.0
	s_L		4.0	Uniform	1.0	50.0
	s_R	9	10.0	Uniform	1.0	500.0
Female fishing selectivities	a_{max}		1.0	Uniform	0.01	10.0
	a_1		8.0	Uniform	1.0	50.0
	s_L		4.0	Uniform	1.0	50.0
	s_R	12	10.0	Uniform	1.0	500.0
YCS	*YCS*	7	1.0	Lognormal	0.001	100.0
Survey biomass	*cv*	1	0.001	Uniform	0	10.0

Base case and sensitivity models

The model runs conducted for the base case (R1) and sensitivity tests (R2 to R5) as well as the steps taken since the 2015 assessment (R0.1 to R0.2) are described in Table 11. The base-case model excluded quarantined mark-recapture and length data (but included catch removals from quarantined trips). A sensitivity model was carried out which included all the quarantined data.

Model estimates

MCMC samples from the posterior were estimated. MCMC diagnostics suggested no evidence of poor convergence in the key biomass parameters and between-sample autocorrelations were low.

Table 11: Median MCMC estimates (and 95% credible intervals) of B_0, B_{2019}, and B_{2019} as $\%B_0$ for the 2017 base case model, the 2019 base case model (R1.3) and models R1.1– R1.2.

Model	B_0	B_{2019}	B_{2019} ($\%B_0$)
2017	72 620 (65 040–81 050)	–	–
R1.1	72 060 (65 780–79 150)	47 760 (41 730–54 280)	66.3 (63.1–69.1)
R1.2	71 710 (65 530–79 080)	47 760 (41 720–54 730)	66.4 (63.3–69.5)
R1.3	71 730 (65 890–78 730)	47 300 (41 630–53 840)	66.0 (63.0–69.0)

Key output parameters for the base case (R1.3) and sensitivities are summarised in Table 12. Biomass was estimated as 66% B_0 (95% CIs 63–69%). Table 12 shows the estimated yields following the CCAMLR decision rules. The catch limit based on R1.3 was 3,140 t for the 2019–20 and 2020–21 seasons. The current stock status trajectory and uncertainty relative to the CCAMLR decision rules are shown in Figure 6.

Table 12: Estimated risks of the 2017 catch limit (3157) using the CCAMLR decision rules for the 2019 base case (R1.3), the base case model run (R1.3), models R1.1–R1.2, and the estimated precautionary yield for the base case model run (R1.3).

Model	Pr(SSB < 50% B_0)	Pr(SSB < 20% B_0)	Catch limit (t)*
2017	0.50	<0.01	3 258
R1.1	0.52	<0.01	3 157
R1.2	0.53	<0.01	3 157
R1.3 (average of 2018–19 catch split)	0.52	<0.01	3 157
R1.3 (with CM 91-05 catch split)	0.52	<0.01	3 157
R1.3 estimated yield	0.50	<0.01	3 140

* While the precautionary yield was estimated as 3258 t in 2017, CM 91-05 para 28(i) restricted the catch limit to be between 2583 and 3157 t for the 2018–2020 seasons.

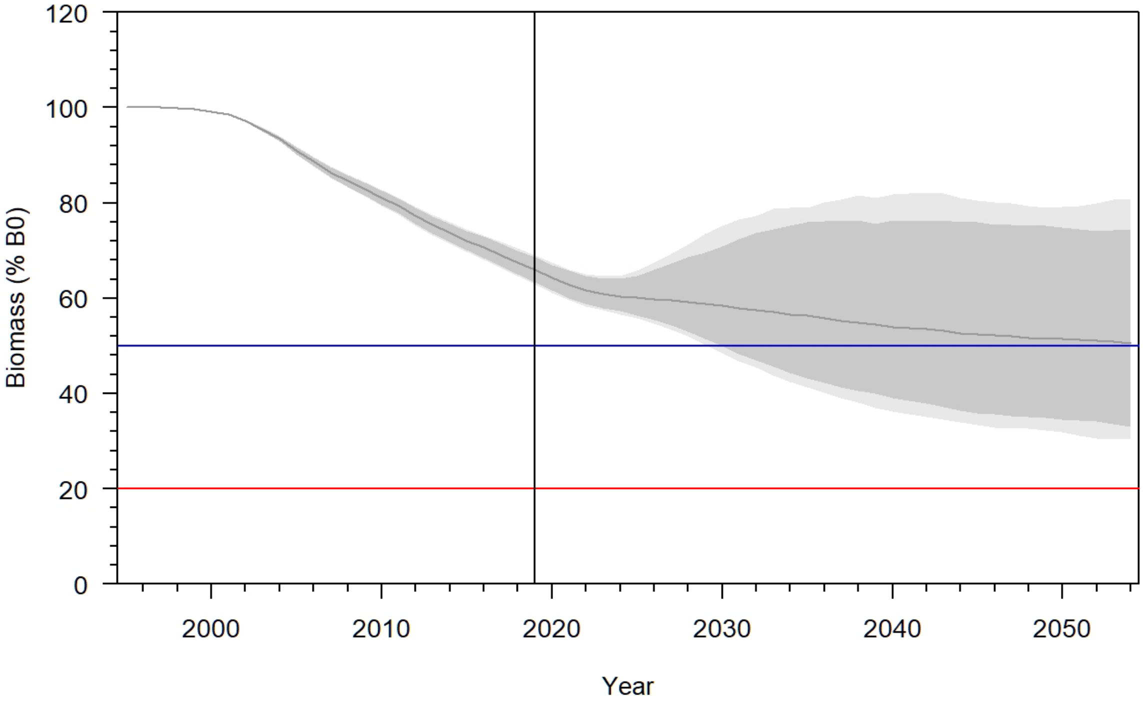


Figure 6: MCMC estimates of the spawning stock biomass trajectory as a percentage of initial biomass (black line) with the 90% and 95% (dark and light grey shading respectively), projected out to 2054 for the base case model run (R1.3). Horizontal lines correspond to 50% B0 and 20% B0.

Diagnostic plots of the observed proportions-at-age of the catch versus expected values show little evidence of inadequate model fit. Estimated selectivity curves appeared reasonable, although the right-hand limb parameters lacked convergence. Post-MCMC analyses of the non-convergence in these parameters showed no evidence that the estimates of initial biomass were unduly influenced. The tag-recapture data are well fitted, and provide most of the information on abundance in the model.

Year class strengths were estimated for the years 2003 to 2013. Estimates showed that there was stronger than average recruitment in 2005 and 2014, and weaker than average recruitment in 2003 and 2008. Fits to the survey biomass indices were within the confidence interval of the survey, although the trend in the survey is not represented well. This is likely a function of a number of factors including recent YCS not currently estimated, fewer older fish caught in the 2015 survey than previously (Hanchet et al 2015), and the amount of commercial fishing prior to the survey. Future data will be used to investigate this further.

(ii) The Amundsen Sea region fishery (Statistical Subarea 88.2 SSRUs 88.2C–H)

There is no current stock assessment of the Amundsen Sea region fishery. A single area stock assessment model of the Amundsen Sea region was unable to fit the trends in the tag-recapture data, which came almost entirely from SSRU 88.2H (Mormede et al 2014a). Fits to the tag data from a two-area developmental model (SSRUs C-G versus SSRU H) were more encouraging, but identified the need for additional recaptures of tagged fish from the southern SSRUs 88.2C–G (Mormede et al 2014b).

Fishing in the Amundsen Sea region (SSRUs 882C–H) has been managed through a research plan since the 2015 fishing season. The aim of the research plan is to collect sufficient information to carry out a reliable stock assessment of the toothfish stock in that area. The key feature of the initial two-year research plan was to restrict fishing effort to grounds in SSRUs 88.2C–G which had been fished previously to facilitate the recapture of previously tagged toothfish during year 1.

Four fishing grounds were identified where fishing should take place based on an analysis by Hanchet

& Parker (2014). The tagging rate was also increased from 1 tag per tonne to 3 tags per tonne so that more tagged fish would be available for recapture in year 2 and subsequent years. Analysis of ice conditions by Hanchet & Parker (2014) demonstrated that in most years one or more of the grounds were inaccessible or unfishable due to ice, and so some flexibility was necessary in prescribing areas where fishing would be allowed.

Catch limits for the research plan were derived from Petersen biomass estimates based on recaptures of tagged fish from SSRU 88.2H. Parker & Mormede (2014) demonstrated that estimates of biomass for SSRU 88.2H were biased upwards for each successive year that the tagged fish had been at liberty, probably as a result of immigration of untagged fish from a source population (Parker 2014). Therefore, CCAMLR agreed that a catch limit for SSRU 88.2H should be based on the number of recaptures of tagged fish which had been at liberty for a single year. The resulting biomass estimate of 5000 tonnes was multiplied by an exploitation rate of 4% to give a catch limit of 200 tonnes for 88.2H.

CCAMLR also agreed that an estimate of biomass based on the number of recaptures of tagged fish from SSRU 88.2H which had been at liberty for all years could apply to the entire stock in SSRUs 88.2C–H. The resulting estimate of biomass of 20 649 tonnes (Goncharov & Petrov 2014) was multiplied by an exploitation rate of 3% to give a catch limit of 619 tonnes for the entire stock. It should be noted that this latter estimate of biomass and yield did not include any tag recapture data (i.e., number of tagged fish released, tagged fish recaptured or scanned fish) from the south, and was based on the assumption that all fish tagged in the north would have been available for recapture in the south. By subtraction, the catch limit for 88.2C-G (constrained to 4 research blocks) was 419 t which had the added effect of releasing many more tagged fish in the south given the increase in TAC. This was considered a good mechanism to release many tagged fish in the southern areas in just two years to more quickly obtain a mark-recapture biomass estimate.

The final research plan was approved for two years and had the following components:
(i) the catch limits were adopted for 2014/15 and 2015/16
(ii) the catch limit for SSRU 88.2H was 200 tonnes
(iii) the fishing in SSRUs 88.2C–G was restricted to four fishing areas (research blocks)
(iv) the combined catch limit for SSRUs 88.2C–G was 419 tonnes, with no more than 200 tonnes to be taken from any one of the fishing grounds in (iii)
(v) toothfish to be tagged at the rate of 3 fish per tonne in SSRUs 88.2C–G and 1 fish per tonne in SSRU 88.2H

Some preliminary model runs using a two-area model were carried out to assess the utility of the results of the experiment (Mormede et al 2016) and FSA recommended further work be undertaken on the model structure (CCAMLR 2016, FSA paragraph 3.127). The Scientific Committee considered that the research plan was providing the information necessary to develop the stock assessment and recommended it be extended by a further two years with increased tagging rate in the North to 3 fish per tonne, consistent with the rate in the South (CCAMLR 2016, SC paragraphs 3.215 and 3.216).

In the 2016 and 2017 seasons, a total of 19 tagged fish (excluding within season recaptures) were recaptured in the research blocks in the South Amundsen Sea region, confirming the utility of the research plan to recapture tagged fish, and providing key information on the size of the population in the South. Although only four tagged fish were recaptured (excluding within season recaptures) in the North (SSRU 882H) in 2017, the increase in tagging rate to 3 fish per tonne in the 2017 season has increased the number of tagged fish at liberty and therefore the number of recaptures of tagged fish is likely to continue to increase in the 2019 season. Estimates of local biomass based on mark-recapture data were updated in 2019 which followed the trend analysis rules (CAMLR-XXXVI 2017, Annex 7 paragraph 4.33) to set catch limits for individual fishing areas. The resulting catch limits were 192 t in research block 1, 232 t in research block 2, 182 t in research block 3, and 128 t in research block 4 , and 160 t in SSRU88.2H(SC-CAMLR XXXVII 2019 Table 1).

No validated age data are currently available since 2014 for the North, and for 2014, 2015, and 2017 from the South to support the development of a stock assessment (Parker & Mormede 2017c).

5.3 Yield estimates and projections

Yields were estimated for the Ross Sea stock using the methods described in Mormede et al (2015a). For each sample from the posterior distribution estimated for each model, the stock status was projected forward 35 years under a scenario of a constant annual catch (i.e. for the period 2020–2055). Recruitment from 2003–2009 was as estimated in the model, and from 2010–2050 was assumed to be lognormally distributed with a standard deviation of 0.6 with a Beverton-Holt stock-recruitment steepness h = 0.75. Future catch was assumed to follow the same split between fisheries as that in the years 2011–2019 (i.e. 11%, 75% and 14% of the total future catch was allocated to the N70, S70, and SRZ fisheries respectively).

The decision rules are $rule_1 = \max(Pr[\text{SSB}_i < 0.2 \times B_0]) \leq 0.10$, where i is any year in the projection period, and $rule_2 = Pr[SSB_{+35} < 0.5 \times B_0] \leq 0.50$. They were evaluated by calculating the maximum future catch that meets both decision rule criteria.

The constant catch for which there was median escapement of 50% of the median pre-exploitation spawning biomass level at the end of the 35-year projection period was 3 140 tonnes (Table 12). At this yield there is a less than 10% chance of spawning biomass dropping to less than 20% of the initial biomass. The allocation method used to set previous catch limits for SSRUs in Statistical Subarea 88.1 was continued for 2015–16 and 2016-17. A research catch limit of 100 tonnes was set aside for a winter survey in 2019 from the overall catch limit. The remaining catch was split among the three areas using the agreed proportions. This resulted in 597 tonnes in the N70 area (SSRUs 88.1A, B, C, part of G), 2072 tonnes on the slope (SSRUs 88.1G, H, I, K) and 426 tonnes in the SRZ, and an additional 45 tonnes was set aside from the SRZ catch limit for a directed research survey for sub-adult toothfish on the shelf in 2019.

6. STATUS OF THE STOCKS

Stock structure assumptions

Uncertainty remains with respect to spawning dynamics and early life history of Antarctic toothfish. The present hypothesis is that Antarctic toothfish in Statistical Subareas 88.1 and 88.2 spawn to the north of the Antarctic continental slope, mainly on the ridges and banks of the Pacific-Antarctic Ridge. It has been recommended that for stock assessment purposes Statistical Subarea 88.1 and SSRUs 88.2A and 88.2B be treated as a 'Ross Sea' stock, while Statistical Subarea 88.2 SSRU 88.2C–H be treated as a separate 'Amundsen Sea' stock.

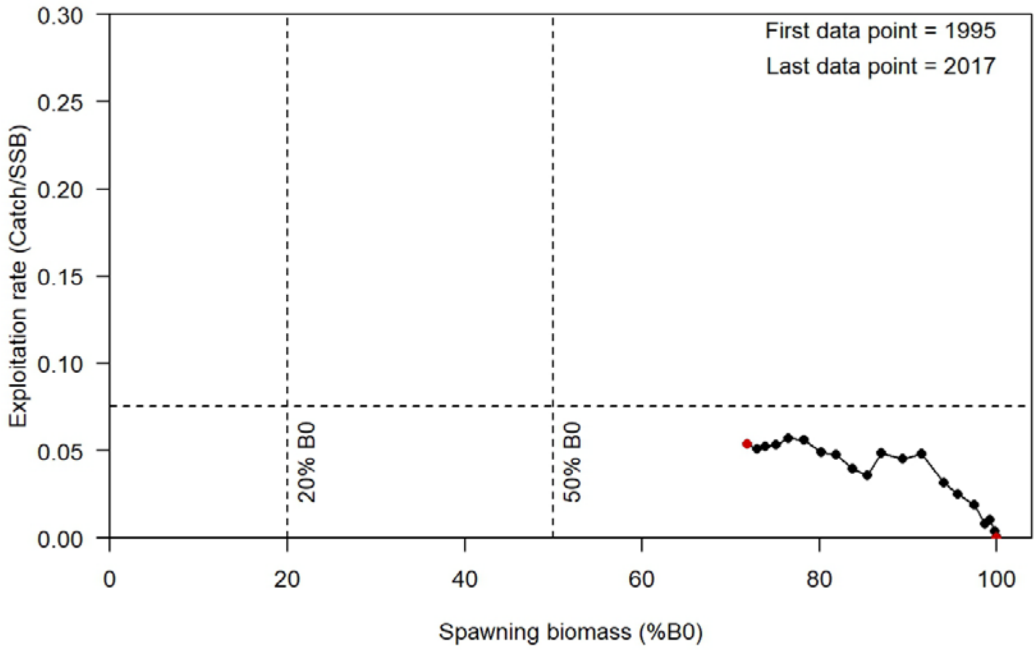
In 2014, the Commission of CAMLR recognised that while there had been a large number of tagged fish recaptured in SSRU 882H, very few tags had been recaptured in 882C–G and a change in management was required to address this issue. It is also noted that the stock affinity of the toothfish in Statistical Subareas 88.1 and 88.2 with toothfish in surrounding areas is not well understood; however the current stock structure used in the stock assessments should be continued.

- **Ross Sea stock**

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	A single base case model (R1.3) was accepted by CCAMLR.
Reference Points	Target: CCAMLR decision rule 2[4]: 50% B_0 after 35 years with Pr(SSB > 20% B_0) ≥ 0.9 for a constant catch harvest strategy (Soft) Limit: CCAMLR decision rule 1: 20% B_0 with Pr(SSB > 20% B_0) ≥ 0.9 Hard Limit: 10% B_0 Overfishing threshold: Not defined
Status in relation to Target	B_{2019} was estimated to be 66% B_0. Virtually Certain (> 99%) to be above the long term target (50% B_0)
Status in relation to Limits	B_{2017} is Exceptionally Unlikely (< 1%) to be below both soft

	and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Trends in spawning biomass and exploitation rate over time.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Estimates of biomass have never been below 50% B_0, and the fishery is still in a fish-down phase.
Recent Trend in Fishing Intensity or Proxy	Fishing pressure increased early in the fishery and has stabilised at about target levels.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	The CPUE indices are not deemed to be an index of abundance. The catch-at-age data, although a relatively short time series, is showing indication of truncation of the right-hand limb, which is captured in the stock assessment. For assessments, the tag-recapture data provide the best information on stock size, but the total number of fish recaptured is small and may introduce bias into the model. Spatial population operating models have indicated that the stock assessment is likely to be negatively biased (precautionary). Although the absolute stock size is uncertain, the available evidence (tag recapture data, catch rates, age frequency data) suggests that the stock has been lightly exploited to date.

Projections and Prognosis		
Stock Projections or Prognosis	The biomass of the stock is expected to decline slowly over the 35 year projection period to the target level under constant catch.	
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Exceptionally Unlikely (< 1%)	
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%)	
Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2019	Next assessment: 2021
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Multi-year tag-recapture data - Commercial catch-at-age proportions - Sub-adult survey series (2012 onwards) to estimate annual year class strength	1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	Commercial CPUE	3 – Low Quality: not believed to be indexing abundance
Changes to Model Structure and Assumptions	-	
Major sources of Uncertainty	The model assumes homogenous mixing of tags within the population, which is unlikely to be true in the short term. Bias was estimated to be about 30% conservative (Mormede et al 2014f). Other major sources of uncertainty include estimates of initial mortality of tagged fish, detection rates of tagged fish, natural mortality rate, stock structure and migration patterns, stock-recruit steepness and natal fidelity assumptions with respect to other areas.	

Qualifying Comments
For the base case and sensitivity models, current biomass is estimated to be between 63% and 69% B_0. The precautionary yield, using the CCAMLR decision rules[5] consistent with previous fishing activities and with the Ross Sea region MPA, was 3 104 t. At its 2019 meeting CCAMLR agreed to set the catch limit to 3 140 t for the Ross Sea for the 2019-20 and the 2020-21 seasons (CCAMLR 2019c).

Fishery Interactions
Main bycatch species are macrourids and rajids for which there are catch limits and move-on rules. Rajids can be released alive.

- **Amundsen Sea stock (Statistical Subarea 88.2 SSRUs 88.2C-H)**

[5] Yield estimates are calculated by projecting the estimated current status under a constant catch assumption, using the decision rules:

1. Choose a yield, γ_1, so that the probability of the spawning biomass dropping below 20% of its median pre-exploitation level over a 35-year harvesting period is 10% (the depletion probability);
2. Choose a yield, γ_2, so that the median escapement in the SSB at the end of a 35 year period is 50% of the median pre-exploitation level (the level of escapement); and
3. Select the lower of γ_1 and γ_2 as the yield.

In the models, the depletion probability was calculated as the proportion of samples from the Bayesian posterior where the predicted future spawning stock biomass (SSB) was below 20% of B_0 in that respective sample in any one year, for each year over a 35-year projected period. The level of escapement was calculated as the proportion of samples from the Bayesian posterior where the predicted future status of the SSB was below 50% of B_0 in that respective sample at the end of a 35-year projected period.

Stock Status	
Year of Most Recent Assessment	2019
Assessment Runs Presented	An estimate of biomass for the north area (SSRU 88.2H) was available from tag recapture data. An estimate of biomass which could be applied to the total area (SSRUs 88.2C–H) was made from tag recapture data.
Reference Points	No reference points were used for the assessment. Each of the estimates of biomass were multiplied by an exploitation rate based on a general yield model.
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	N/A (no defined reference level)

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass in the northern hills based on tag recapture data has been trending down. No data are available for the southern area.
Recent Trend in Fishing Intensity or Proxy	Fishing pressure in the northern hills has been increasing as seen by an increased number of tags recovered. No data are available for the southern area.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	The CPUE indices for the northern area have been declining to 2009 and increasing slightly since, but are not deemed to be an index of abundance. The catch-at-age data, when age length keys are applied annually, is showing an indication of truncation of the right-hand limb. The paucity of otoliths each year makes annual age length keys uncertain, and is seen as a priority work to improve upon. There has been no change in the sex ratio in this fishery.

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	N/A (no defined reference level)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial quantitative stock assessment	
Assessment Method	Tag based biomass estimate multiplied by exploitation rate	
Assessment Dates	Latest assessment: 2019	Next assessment: 2021
Overall assessment quality rank	2 – Medium or Mixed Quality for the north and Low Quality for the south	
Main data inputs (rank)	- Multi-year tag-recapture data (north) - Multi-year tag-recapture data (south) - Commercial catch-at-age proportions (north) - Commercial catch-at-age proportions (south)	1 – High Quality 3 – Low Quality 1 – High Quality 3 – Low Quality

	- Catch at age from annual age length keys where possible (north) - Catch at age from annual age length keys where possible (south)	1 – High Quality 3 – Low Quality
Data not used (rank)	Commercial CPUE	3 – Low Quality
Changes to Model Structure and Assumptions	A two-area model has been developed and requires further data to index the South area biomass. A research plan was set in place in the south to increase knowledge about the biomass in this area.	
Major Sources of Uncertainty	The estimate of biomass for SSRUs 88.2C–H is extremely uncertain because it assumes homogenous mixing of tags within the population (i.e. fish which leave the north are available for recapture in the South). No separate assessment or estimate of abundance is currently available for the southern area (SSRUs 88.2C–G) and this is the priority for further work. Other sources of uncertainty include estimates of initial mortality of tagged fish, detection rates of tagged fish, natural mortality rate, stock structure and migration patterns, stock-recruit steepness and natal fidelity assumptions with respect to other areas	

Qualifying Comments
At its 2019 meeting, the CCAMLR Scientific Committee recommended that the research plan in place for SSRUs 882C–H continue for the 2019/20 season following Scientific Committee advice, although catch limits were set using CCAMLRs trend analysis rule algorithm and either a mark-recapture biomass estimate or a CPUE by seabed area analogy (SC-CAMLR-38, Paragraphs 3.141–3.143).

Fishery Interactions
Main bycatch species are macrourids and rajids for which there are catch limits and move-on rules. Rajids can be released alive.

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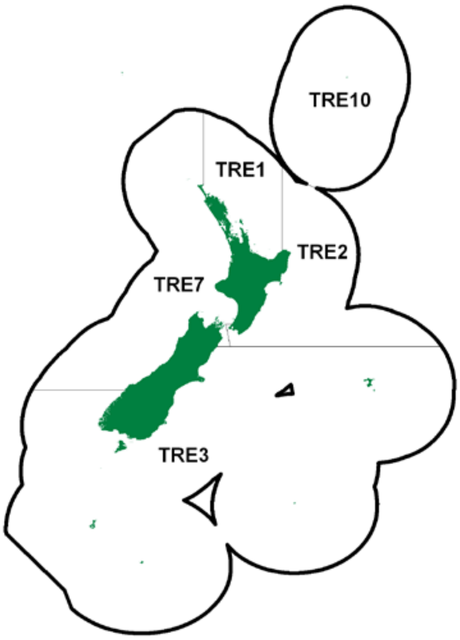
TREVALLY (TRE)

(*Pseudocaranx dentex*)
Arara



1. FISHERY SUMMARY

Trevally was introduced into the QMS in 1986 with five QMAs. A Total Allowable Catch (TAC) was set under the provisions of the 1983 Fisheries Act initially at 3220 t. Since the introduction into the QMS there have been no recreational or customary allocations in TRE 1, 3, 7, or 10; therefore the total allowable commercial catch (TACC) is the same as the TAC. In 2010 TRE 2 was allocated a 100 t recreational catch, 1 t customary catch, and 7 t for other mortality, combining to make a 350 t TAC.

1.1 Commercial fisheries

Trevally is caught around the North Island and the north of the South Island, with the main catches from the northern coasts of the North Island. Trevally is taken in the northern coastal mixed trawl fishery, mostly with snapper. Since the mid-1970s trevally has been taken by purse seine, mainly in the Bay of Plenty (BoP), in variable but often substantial quantities. Set net fishermen take modest quantities.

Historical estimated and recent reported trevally landings and TACCs are shown in Tables 1 and 2, and Figure 1 shows the historical and recent landings and TACC values for the main trevally stocks.

Trevally landings peaked during the 1970s, with total landings exceeding 6000 t in 1977 and 1978, before declining for all three main trevally stocks: TRE 1, TRE 2, and TRE 7. TRE 1 landings have ranged from 790 t to 1718 t since the introduction of the TACC in 1986–87, with landings in recent years amongst the highest in the time series. TRE 2 landings have fluctuated around the TACC of 241 t since it was introduced and have exceeded the TACC in several recent fishing years including 2018–19 when just under 270 t of landings were recorded. Landings from TRE 7 have been under the TACC since 2003–04; 2018–19 had the lowest landings since 1991–92, with just 1427 t recorded.

Table 1: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	TRE 1	TRE 2	TRE 3	TRE 7	Year	TRE 1	TRE 2	TRE 3	TRE 7
1931–32	9	0	0	0	1957	788	235	0	374
1932–33	6	0	0	0	1958	856	197	1	409
1933–34	30	0	0	3	1959	980	175	0	433
1934–35	27	0	0	3	1960	1141	191	1	686
1935–36	0	0	0	0	1961	1144	368	0	567
1936–37	0	0	0	0	1962	1415	431	0	658
1937–38	20	4	0	4	1963	1284	348	0	769
1938–39	53	10	2	8	1964	1329	395	2	639
1939–40	17	9	0	6	1965	1581	344	2	673
1940–41	12	13	0	7	1966	1568	382	0	1151
1941–42	17	6	0	4	1967	1121	472	1	1512
1942–43	90	1	0	1	1968	1425	504	0	1547
1943–44	190	2	0	1	1969	1428	474	0	1378
1944	401	2	0	19	1970	2010	490	0	1740
1945	307	9	0	23	1971	3060	779	1	2109
1946	316	12	2	19	1972	2738	946	0	2309
1947	317	8	1	28	1973	1950	616	0	2381
1948	432	7	0	34	1974	2365	687	0	2077
1949	291	9	0	39	1975	1470	361	0	1679
1950	402	39	0	60	1976	2659	1026	0	1994
1951	470	57	0	82	1977	3749	558	0	2176
1952	310	73	0	63	1978	3627	518	1	2381
1953	376	90	0	136	1979	2566	449	1	2658
1954	471	132	0	116	1980	1471	330	0	2545
1955	609	120	0	193	1981	1524	229	0	2957
1956	556	124	0	179	1982	2102	135	0	2548

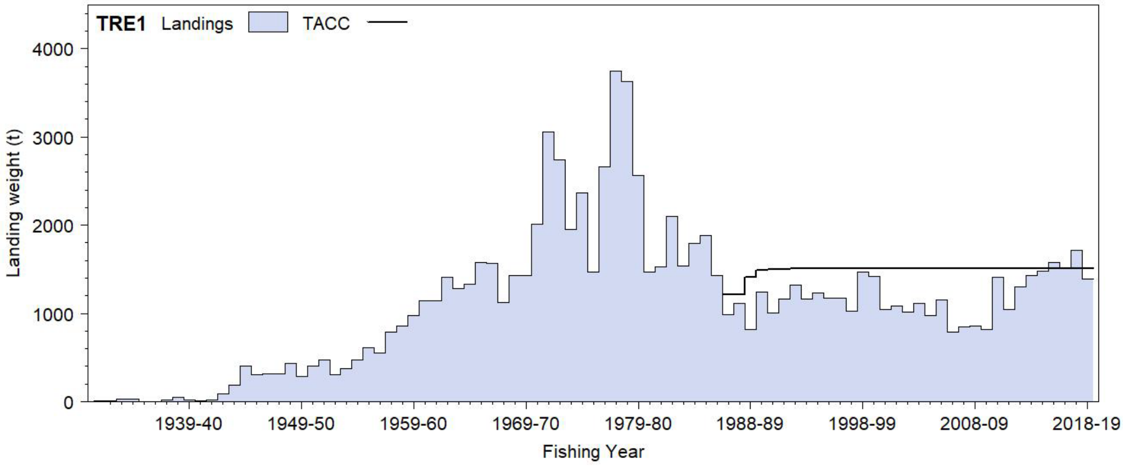
Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns. Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 2: Reported landings (t) of trevally by Fishstock from 1983 to 2018–19 and TACCs (t) from 1986–87 to 2018–19. QMS data from 1986 to 2018–19. [Continued on next page]

Fishstock	TRE 1		TRE 2		TRE 3		TRE 7		TRE 10	
FMA (s)	1		2		3, 4, 5, 6		7, 8, 9		10	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983*	1 534	-	77	–	3	–	2 165	–	0	–
1984*	1 798	-	335	–	1	–	1 707	–	0	–
1985*	1 887	-	162	–	1	–	1 843	–	0	–
1986*	1 431	-	161	–	3	–	1 830	–	0	–
1986–87	982	1 210	237	190	< 1	20	1 626	1 800	0	10
1987–88	1 111	1 210	267	219	< 1	20	1 752	1 800	0	10
1988–89	818	1 413	177	235	< 1	20	1 665	2 010	0	10
1989–90	1 240	1 493	275	237	18	20	1 589	2 146	0	10
1990–91	1 011	1 495	273	238	8	22	2 016	2 153	0	10
1991–92	1 169	1 498	197	238	< 1	22	1 367	2 153	< 1	10
1992–93	1 328	1 505	247	241	< 1	22	1 796	2 153	< 1	10
1993–94	1 162	1 506	230	241	< 1	22	2 231	2 153	0	10
1994–95	1 242	1 506	179	241	< 1	22	2 138	2 153	0	10
1995–96	1 175	1 506	211	241	< 1	22	2 019	2 153	0	10
1996–97	1 174	1 506	317	241	< 1	22	1 843	2 153	0	10
1997–98	1 027	1 506	223	241	3	22	2 102	2 153	0	10
1998–99	1 469	1 506	284	241	24	22	2 148	2 153	0	10
1999–00	1 424	1 506	309	241	3	22	2 254	2 153	0	10
2000–01	1 049	1 506	211	241	< 1	22	1 888	2 153	0	10
2001–02	1 085	1 506	243	241	< 1	22	1 856	2 153	0	10
2002–03	1 014	1 507	270	241	< 1	22	2 029	2 153	0	10
2003–04	1 111	1 507	251	241	< 1	22	2 186	2 153	0	10
2004–05	977	1 507	319	241	< 1	22	1 945	2 153	0	10
2005–06	1 149	1 507	417	241	< 1	22	1 957	2 153	0	10
2006–07	790	1 507	368	241	< 1	22	1 739	2 153	0	10
2007–08	847	1 507	230	241	< 1	22	1 797	2 153	0	10
2008–09	855	1 507	302	241	< 1	22	2 018	2 153	0	10
2009–10	814	1 507	261	241	< 1	22	1 966	2 153	0	10
2010–11	1 408	1 507	245	241	< 1	22	1 922	2 153	0	10
2011–12	1 050	1 507	186	241	< 1	22	1 895	2 153	0	10
2012–13	1 301	1 507	197	241	<1	22	1 842	2 153	0	10
2013–14	1 431	1 507	303	241	<1	22	1 610	2 153	0	10
2014–15	1 447	1 507	220	241	<1	22	1 824	2 153	0	10
2015–16	1 576	1 507	285	241	<1	22	1 949	2 153	0	10
2016–17	1 506	1 507	304	241	<1	22	1 728	2 153	0	10
2017–18	1 718	1 507	273	241	<1	22	1 768	2 153	0	10
2018–19	1 394	1 507	269	241	<1	22	1 427	2 153	0	10

Table 2 [Continued]

FMA (s)	Total	
	Landings	TACC
1983*	3 779	–
1984*	3 841	–
1985*	3 893	–
1986*	3 425	–
1986–87	2 845	2 230
1987–88	3 131	3 259
1988–89	2 651	3 688
1989–90	3 122	3 906
1990–91	3 308	3 918
1991–92	2 733	3 921
1992–93	3 371	3 931
1993–94	3 624	3 932
1994–95	3 559	3 932
1995–96	3 405	3 932
1996–97	3 333	3 932
1997–98	3 355	3 932
1998–99	3 925	3 932
1999–00	3 989	3 932
2000–01	3 148	3 932
2001–02	3 185	3 933
2002–03	3 313	3 933
2003–04	3 548	3 933
2004–05	3 241	3 933
2005–06	3 524	3 933
2006–07	2 897	3 933
2007–08	2 875	3 933
2008–09	3 175	3 933
2009–10	3 042	3 933
2010–11	3 575	3 933
2011–12	3 131	3 933
2012–13	3 340	3 933
2013–14	3 344	3 933
2014–15	3 521	3 933
2015–16	3 810	3 933
2016–17	3 538	3 933
2017–18	3 759	3 933
2018–19	3 090	3 933



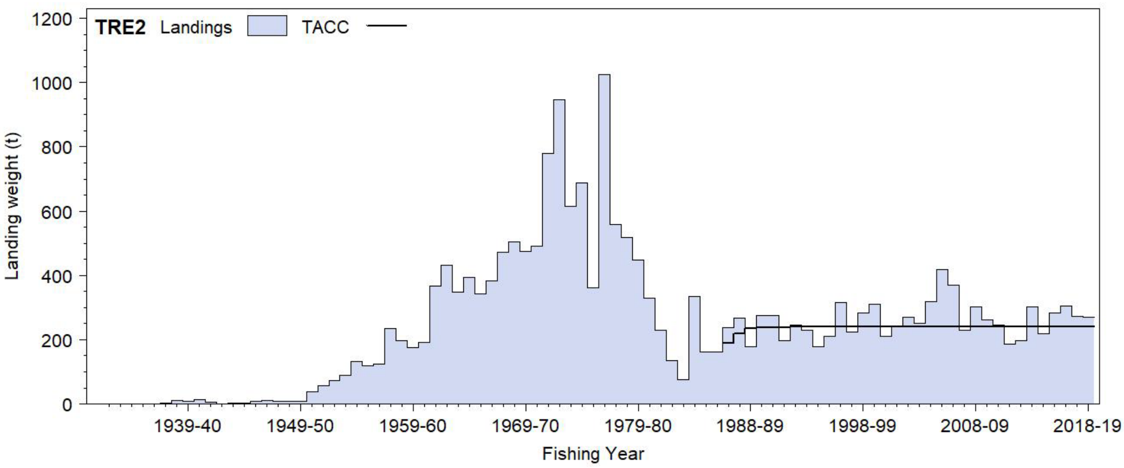


Figure 1: Historical landings and TACCs (t) for the three main TRE stocks. TRE 1 (Auckland) and TRE 2 (Central East). [Continued on next page]

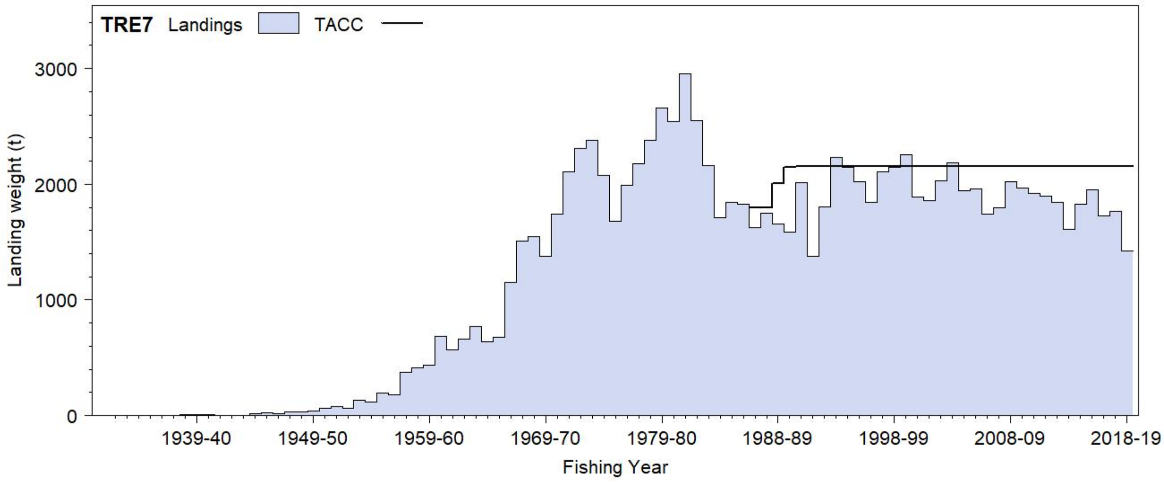


Figure 1 [Continued]: Historical landings and TACCs (t) for the three main TRE stocks. TRE 7 (Challenger).

1.2 Recreational fisheries

Recreational fishers catch trevally by line and set net methods. Although highly regarded as a table fish, some trevally may be used as bait.

1.2.1 Management controls

The main methods used to manage recreational harvests of trevally are minimum legal size limits (MLS), method restrictions, and daily bag limits. Fishers can take up to 20 trevally as part of their combined daily bag limit (except in the South-East and Southland fisheries management areas including the Fiordland Marine Recreational Fishing Area where the limit is 30 (within a combined daily bag limit of 30 finfish) and the MLS is 25 cm in all areas.

1.2.2 Estimates of recreational harvest

Recreational catch estimates are given in Table 3. 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 for trevally were calculated using offsite telephone-diary surveys in 1996 (Bradford 1998), 2000 (Boyd & Reilly 2002), and 2001 (Boyd et al 2004).

The harvest estimates provided by these telephone diary surveys are no longer considered reliable for various reasons. With the early telephone/diary method, fishers were recruited to fill in diaries by way of a telephone survey that also estimates the proportion of the population that is eligible (likely to fish). A “soft refusal” bias in the eligibility proportion arises if interviewees who do not wish to co-operate falsely state that they never fish. The proportion of eligible fishers in the population (and, hence, the harvest) is thereby underestimated. 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; therefore an alternative maximum count aerial-access onsite method was developed to provide 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 and optimised to estimate snapper harvests in the Hauraki Gulf in 2003–04. It was then extended to survey the wider FMA 1 fishery in 2004–05 and to provide estimates for other species, including trevally (Hartill et al 2007). This survey was repeated in 2011–12 (Hartill et al 2013) and 2017–18 (Hartill et al 2019).

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 development and implementation of a national panel survey for the 2011–12 fishing year (Wynne-Jones et al 2014), repeated for the 2017–18 fishing year (Wynne-Jones et al 2019). The panel surveys used face-to-face interviews of a random sample of about 30 000 New Zealand households to recruit a panel of fishers and non-fishers for a full year. Panel members were contacted regularly about their fishing activities and catch information collected in standardised phone interviews.

Aerial-access surveys conducted in FMA 1 in 2011–12 (Hartill et al 2013) and 2017–18 (Hartill et al 2019) provide independent harvest estimates for comparison with those generated from the concurrent national panel survey. Both survey types appear to provide plausible results that corroborate each other in TRE 1 and are therefore considered to be broadly reliable (Hartill et al 2013).

Table 3: Recreational harvest estimates for trevally stocks (Bradford 1998, Boyd & Reilly 2002, Boyd et al 2004, Hartill et al 2007, 2013, 2019, Wynne-Jones et al 2014, 2019). The telephone/diary surveys and earlier aerial-access survey ran from December to November but are denoted by the January calendar year. The surveys since 2010 have run through the October to September fishing year but are denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey harvest estimates).

Stock	Year	Method	Number of fish	Total weight (t)	CV
TRE 1	1996	Telephone/diary	194 000	234	0.07
	2000	Telephone/diary	701 000	677	0.13
	2001	Telephone/diary	449 000	434	0.19
	2005	Aerial-access *	–	105	0.18
	2012	Aerial-access *	–	124	0.12
	2012	Panel survey	139 473	165	0.11
	2018	Aerial-access *	–	145	0.09
	2018	Panel survey	95 097	125	0.09
TRE 2	1996	Telephone/diary	9 000	13	0.19
	2000	Telephone/diary	153 000	160	0.60
	2001	Telephone/diary	32 000	339	0.23
	2012	Panel survey	10 308	11	0.24
	2018	Panel survey	10 988	17	0.24
TRE 3	1996	Telephone/diary	2 000	3#	-
	2000	Telephone/diary	10 000	10	0.45
	2001	Telephone/diary	2 000	12	0.46
	2012	Panel survey	859	1	0.73
	2018	Panel survey	221	<1	0.59
TRE 7	1996	Telephone/diary	67 000	70	0.11
	2000	Telephone/diary	69 000	81	0.27
	2001	Telephone/diary	107 000	124	0.21
	2012	Panel survey	23 123	32	0.16
	2018	Panel survey	31 879	68	0.17

* Aerial-access surveys did not include catches from charter vessels, whereas these are included in the panel survey estimates. The estimates for FMA 1 in this table are not, therefore, directly comparable. See Edwards & Hartill (2015) for details.

No harvest estimate available in the survey report; the estimate presented is calculated as average fish weight for all years and areas multiplied by the number of fish estimated caught.

1.3 Customary non-commercial fisheries

Trevally is an important traditional and customary food fish for Maori. No quantitative information is available on the current level of customary non-commercial take.

1.4 Illegal catch
No quantitative information is available on the level of illegal trevally catch. An estimate of historical illegal catch is incorporated in the TRE 7 stock assessment model catch history (see Section 4.3.2).

1.5 Other sources of mortality
No quantitative estimates are available regarding the impact of other sources of mortality on trevally stocks. Trevally are known to occur in sheltered harbour and estuarine ecosystems particularly as juveniles. Some of these habitats are known to have suffered substantial environmental degradation

2. BIOLOGY

Trevally are both pelagic and demersal in behaviour. Juvenile fish up to 2 years old are found in shallow inshore areas including estuaries and harbours. Young fish enter a demersal phase from about 1 year old until they reach sexual maturity. At this stage adult fish move between demersal and pelagic phases. Schools occur at the surface, in midwater and on the bottom, and are often associated with reefs and rough substrate. Schools are sometimes mixed with other species such as koheru and kahawai. The occurrence of trevally schools at the surface appears to correlate with settled weather conditions rather than with a specific time of year.

Surface schooling trevally feed on planktonic organisms, particularly euphausids. On the bottom, trevally feed on a wide range of invertebrates.

Trevally are known to reach in excess of 40 years of age. The growth rate is moderate during the first few years, but after sexual maturity at 32 to 37 cm fork length (FL), the growth rate becomes very slow. The largest fish are typically around 60 cm FL and weigh about 4.5 kg, however much larger fish of 6–8 kg are occasionally recorded.

Fecundity is relatively low until females reach about 40 cm FL. They appear to be batch spawners, releasing small batches of eggs over periods of several weeks or months during the summer. Biological parameters relevant to stock assessment are shown in Table 4.

Table 4: Estimates of biological parameters.

Fishstock			Estimate	Source
1. Natural mortality (M)			See Section 4.1.4	
2. Weight = a(length)^b (Weight in g, length in cm fork length).				
			Both sexes	
		a	b	James (1984)
TRE 1		0.016	3.064	
3. von Bertalanffy growth parameters				
			Both sexes	
	L_∞	k	t_0	
TRE 1	47.55	0.29	-0.13	Walsh et al 1999
TRE 7	46.21	0.28	-0.25	

3. STOCKS AND AREAS

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

4. STOCK ASSESSMENT

4.1 TRE 1
The TRE 1 QMA is believed to contain two biological stocks: East Northland (EN) to Hauraki Gulf (HG), and Bay of Plenty. Stock assessments for each of these stocks were rejected by the Northern Inshore Working Group in 2015 and 2016. The Bay of Plenty assessment was rejected on account of strong conflict between abundance indices (standardised bottom trawl CPUE and Aerial Sightings). The East Northland to Hauraki Gulf assessment was not initially attempted because the abundance index,

based on standardised bottom trawl CPUE (there are insufficient aerial sightings data for the East Northland area), showed conflicting trends in the positive-catch and proportion-of-zero-catch models. This conflict was due to a trend of increasing reporting of low catches in a tow. CPUE analysis was therefore conducted on data that had been amalgamated to the trip level, which successfully eliminated conflict between the positive-catch and proportion-of-zero-catch models. The resulting standardised bottom trawl CPUE index was accepted by the working group as an index of abundance (Figure 2), but an assessment was not attempted due to the lack of contrast within the index.

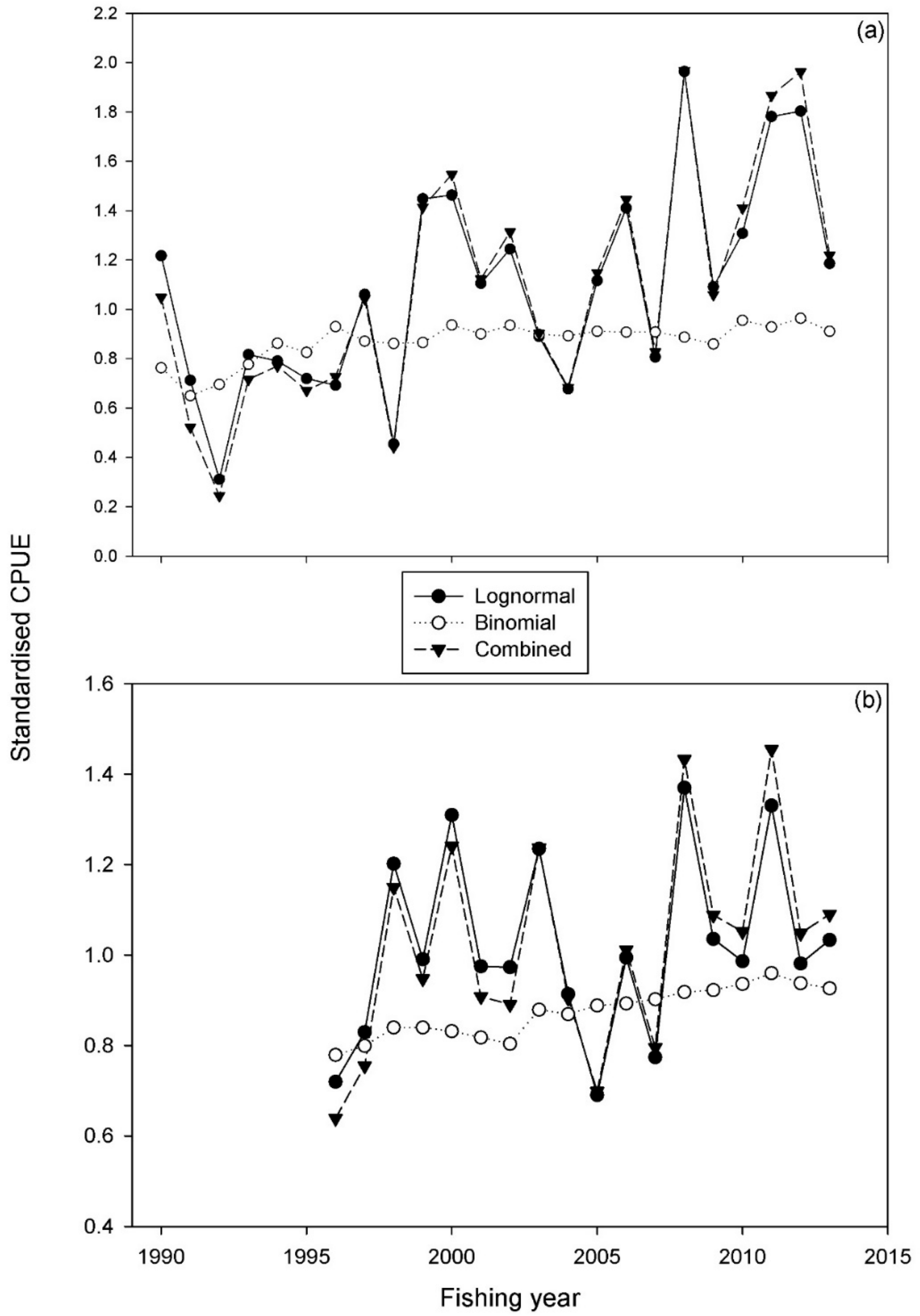


Figure 2: Indices of abundance accepted for the two TRE 1 stocks. (a) Bay of Plenty standardised bottom trawl CPUE produced from CELR, TCEPR, and TCER data forms rolled–up to the trip level, (b) East Northland to Hauraki Gulf standardised bottom trawl CPUE produced from TCEPR/TCER data forms rolled-up to the trip level. Note that for each stock it is the combined index which is accepted as an index of abundance.

Patterns seen in the time-series of catch at-age data from TRE 1 suggest that the Bay of Plenty and East Northland regions are likely to constitute two biological sub-stocks (McKenzie et al 2015). An age-based total catch-history assessment model for the Bay of Plenty trevally sub-stock was unable to achieve plausible assessment results when both the aerial sightings and bottom trawl CPUE abundance indices were fitted or when the model was fitted to the aerial sightings index on its own (McKenzie et al 2015). The model was, however, able to achieve plausible estimates for B_0 when the aerial index was excluded, achieving acceptable fits to both the bottom trawl CPUE and the bottom trawl age-composition data (McKenzie et al 2015). The working group accepted that the bottom-trawl-index-only model provided a basis for a future assessment of the Bay of Plenty sub-stock; and also recommended that the aerial sightings index should be dropped from future Bay of Plenty assessments due to inconsistency with the other observational data in the model, i.e., catch history, catch at-age, and bottom trawl CPUE. The working group recommended that assessments for the TRE 1 east Northland and Bay of Plenty sub-stocks should be undertaken, after completion of the next catch-at-age study for TRE 1.

4.2 TRE 2

High annual variability in standardised CPUE indices, and narrow confidence intervals (Bentley 2014), led the Northern Inshore Working Group to conclude that trevally in TRE 2 are probably part of the TRE 1 biological stock in the Bay of Plenty, with abundance in TRE 2 fluctuating markedly according to the movement of fish into and out of this QMA. Stock assessments for TRE 2 will in future be done in conjunction with TRE 1.

A new CPUE analysis for TRE 2 was conducted in 2018 (Schofield et al 2018). Combined (binomial/Weibull) indices were produced for 1989–90 to 2016–17 using data aggregated to vessel-day resolution, and from 2006–07 to 2016–17 using tow resolution data. There was good correspondence between the two indices for the overlapping period.

Comparison of CPUE trends between the TRE 2 combined series and the TRE 1 BoP index (Figure 3) showed good correspondence between 1989–90 and 2006–07, but a poor relationship thereafter.

For TRE 2, the working group considered that the large variations in the early part of the series, over relatively short time periods, suggests that factors in addition to changes in abundance may be influencing the index.

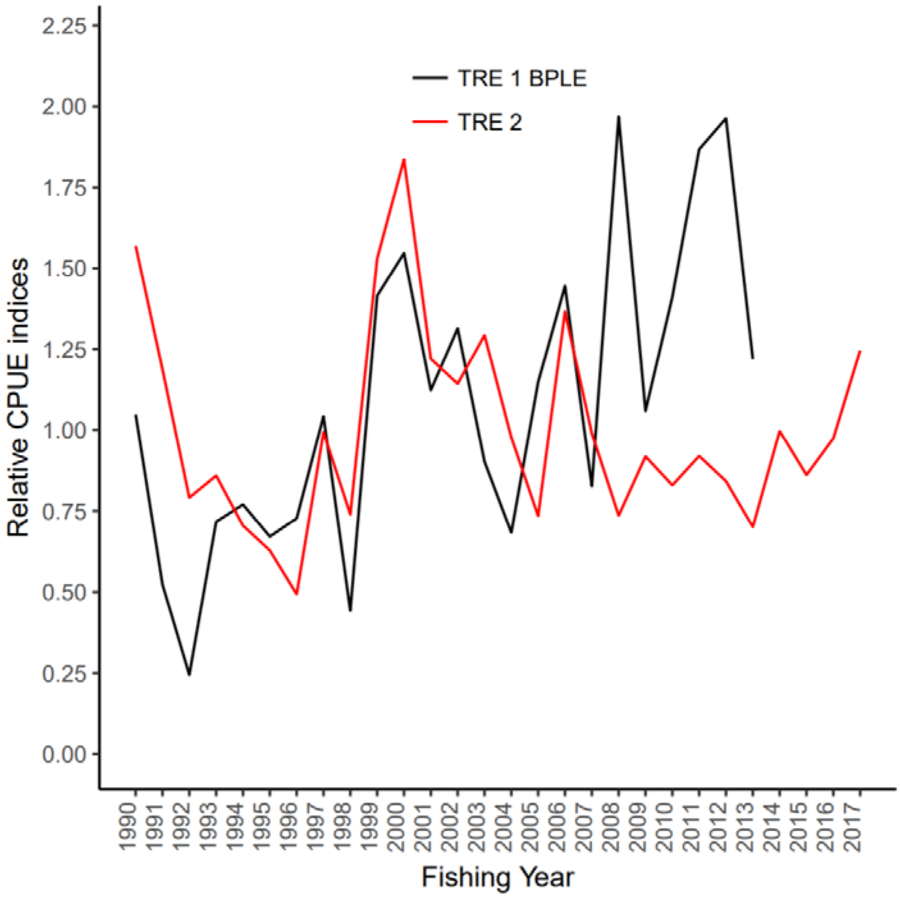


Figure 3: Standardised CPUE for TRE 2 (Schofield et al 2018) and TRE 1 Bay of Plenty (BPLE, McKenzie et al 2016).

4.3 TRE 7

The TRE 7 stock assessment was revised and updated in 2015 (Langley 2015). Recent analyses have revealed considerable differences in TRE 7 age composition data and trends in CPUE indices among the three main fishing areas within the TRE 7 Fishstock; i.e. Ninety Mile Beach (NMB), South Taranaki Bight (STB), and the core area of the fishery between North Taranaki Bight and Tauroa Point (KMNTB). The apparent spatial heterogeneity within TRE 7 indicated that assuming a single stock was not appropriate. Attempts to incorporate spatial structure within the TRE 7 assessment model were not successful due to inadequate historical catch-at-age data from the STB and NMB areas (Langley 2015). The final 2015 stock assessment was limited to the core area of the fishery (KMNTB) only. This area accounted for 60% of the total TRE 7 commercial catch from 1944 to 2012–13 and 70% of the catch from recent years (2010–2011 to 2012–13).

4.3.1 CPUE

A standardised CPUE index of abundance was used in the 2015 assessment (Table 5). The CPUE data set comprised catch and effort records from the single bottom trawl fishery targeting trevally or snapper within the core area of the fishery (KMNTB area) during 1990–91 to 2012–13. Fishing effort records were aggregated by vessel fishing day in a format consistent with the CELR reporting format. The final data set excluded one of the vessels that dominated the fishery in recent years. The trend in catch rate of trevally for this vessel differed considerably from the remainder of the fleet and there were also marked differences in the overall age composition of the trevally catches taken by this vessel (Langley 2015).

The standardised CPUE analysis included two components: a positive trevally catch component modelled assuming a Weibull error structure and a binomial model of the presence/absence of trevally in the vessel daily catch. The CPUE final index multiplied the annual indices from the separate models to derive a combined index.

The CPUE indices increase markedly after 2007–08. There were considerable changes in the operation of the fishery during that period related to an increased degree of targeting trevally following the reduction in the TACC for snapper in 2005–06. The CPUE standardisation accounts for a component of the change in the operation of the fishery, although it is unknown whether the shift in targeting is fully accounted for in the final CPUE indices.

Table 5: Standardised single trawl CPUE indices (relative year effects) from 1990–90 to 2012–13 (Langley 2015).

Fishing year	CPUE index	Fishing year	CPUE index
1989–90	–	2004–05	0.620
1990–91	1.291	2005–06	0.855
1991–92	1.202	2006–07	0.685
1992–93	0.862	2007–08	0.920
1993–94	1.181	2008–09	0.819
1994–95	0.980	2009–10	0.828
1995–96	0.888	2010–11	1.209
1996–97	0.830	2011–12	1.055
1997–98	0.782	2012–13	1.023
1998–99	0.992		
1999–00	0.764		
2000–01	0.678		
2001–02	0.805		
2002–03	0.882		
2003–04	0.783		

4.3.2 Catch history

Commercial catch records for TRE 7 date back to 1944. Before that time the stock is assumed to have been lightly exploited and close to its unexploited state. It is likely that reported catches prior to 1970 are underestimates of the true catch due to large-scale discarding of fish (James 1984). Total annual TRE 7 catches were apportioned by fishery area and fishing method (single and pair bottom trawl) (Figure 4). The base assessment model included annual catches from the KMNTB area only. A separate fishery was configured to account for the catch by the single dominant vessel operating in the bottom trawl fishery in recent years.

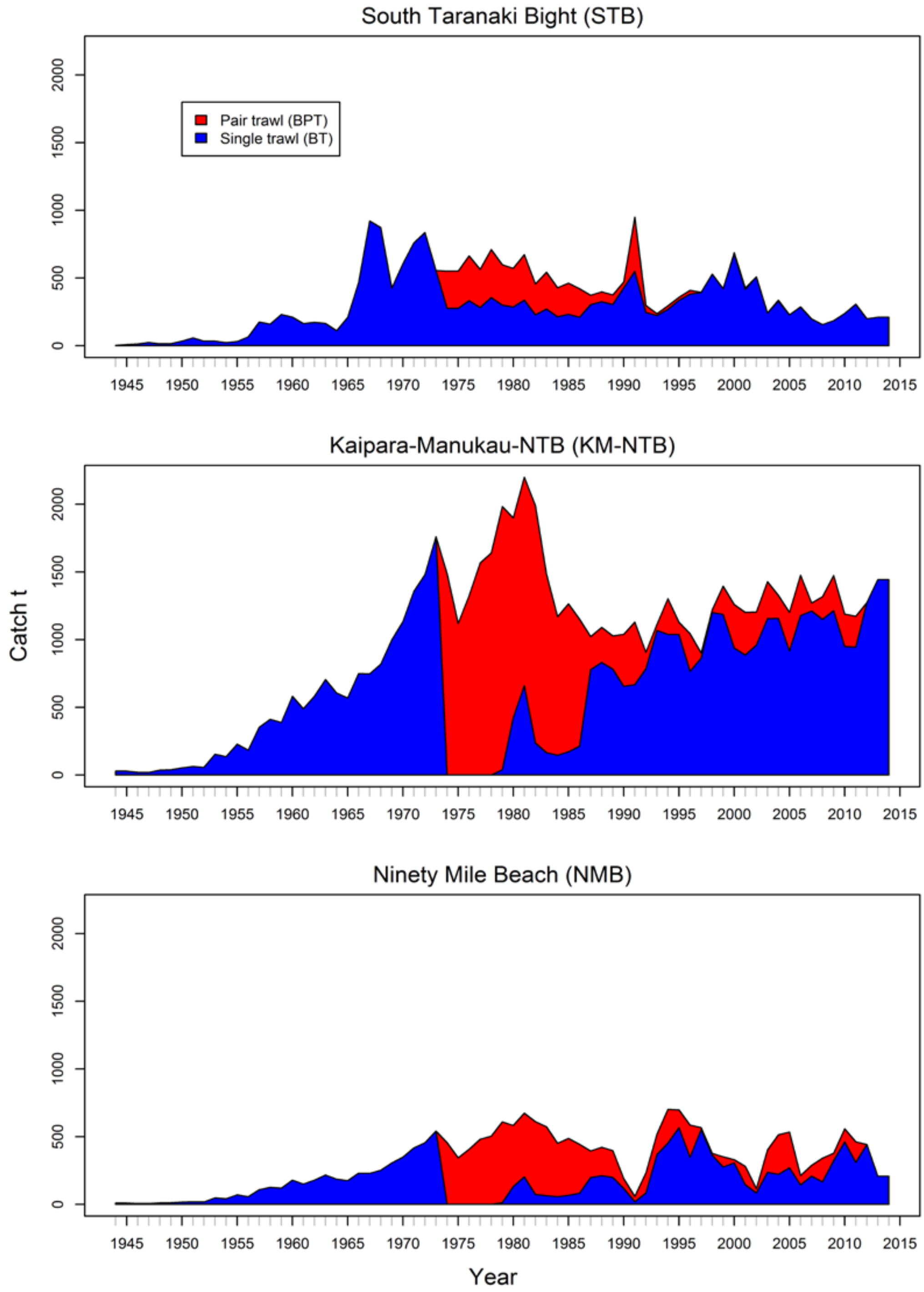


Figure 4: Total TRE 7 commercial catch history formulated for the stock assessment, apportioned by fishing method and sub-area of TRE 7.

Since 1944, there has also been a recreational and customary catch as well as an illegal or non-reported catch. For the purposes of modelling the KMNTB component of the TRE 7 stock, it is necessary to make allowance for mortality due to discarded fish, recreational catch, customary catch, and non-reported catch. The final catch history included in the assessment model is presented in Table 6.

Table 6: Catch history (t) for the KMNTB area of the TRE 7 fishery including total annual reported commercial catch, estimated discarded (D) commercial catch, estimated non-reported commercial catch, recreational catch, and customary catch. (The year denotes the year at the end of the fishing year).

Year	Reported landings	D	Under-reported catch	Rec. catch	Cust. catch	Total	Year	Reported landings	D	Under-reported catch	Rec. catch	Cust. catch	Total
1944	14	9	5	14	15	57	1980	1 582	0	317	70	12	1 981
1945	15	10	5	16	15	60	1981	1 833	0	367	70	12	2 282
1946	10	7	3	18	15	53	1982	1 659	0	331	70	12	2 072
1947	11	5	2	20	15	53	1983	1 237	0	247	70	12	1 566
1948	21	10	5	23	15	74	1984	975	0	195	70	12	1 252
1949	23	13	3	25	15	79	1985	1 053	0	211	70	12	1 346
1950	31	16	6	27	15	95	1986	959	0	192	70	12	1 233
1951	37	19	7	29	15	107	1987	929	0	93	70	12	1 104
1952	33	17	6	31	15	102	1988	1 001	0	90	70	12	1 173
1953	90	45	18	33	15	201	1989	951	0	76	70	12	1 109
1954	79	40	16	36	15	186	1990	971	0	68	70	12	1 121
1955	134	67	27	38	15	281	1991	1 065	0	64	70	12	1 211
1956	108	54	22	40	15	238	1992	863	0	43	70	12	988
1957	207		41	42	15	409	1993	1 070	0	43	70	12	1 195
1958	241		49	44	15	470	1994	1 264	0	38	70	12	1 384
1959	228		45	46	15	449	1995	1 106	0	22	70	12	1 210
1960	411	88	82	48	10	639	1996	1 034	0	10	70	12	1 126
1961	346	74	69	51	10	550	1997	892	0	9	70	12	983
1962	411	88	82	53	10	644	1998	1 208	0	12	70	12	1 302
1963	499		99	55	10	770	1999	1 382	0	14	70	12	1 478
1964	429	92	86	57	10	673	2000	1 246	0	13	70	12	1 341
1965	402	86	81	59	10	638	2001	1 189	0	12	70	12	1 283
1966	597	33	119	61	10	820	2002	1 192	0	12	70	12	1 286
1967	595	33	119	64	10	821	2003	1 414	0	14	70	12	1 510
1968	652	36	130	66	10	894	2004	1 314	0	13	70	12	1 409
1969	795	44	159	68	10	1 076	2005	1 190	0	12	70	12	1 284
1970	945	0	189	70	10	1 214	2006	1 461	0	15	70	12	1 558
1971	1 130	0	226	70	10	1 436	2007	1 259	0	12	70	12	1 353
1972	1 233	0	247	70	10	1 560	2008	1 305	0	12	70	12	1 399
1973	1 468	0	294	70	10	1 841	2009	1 460	0	14	70	12	1 556
1974	1 239	0	248	70	10	1 567	2010	1 177	0	12	70	12	1 271
1975	933	0	187	70	10	1 200	2011	1 161	0	11	70	12	1 254
1976	1 102	0	221	70	10	1 403	2012	1 260	0	13	70	12	1 355
1977	1 306	0	261	70	10	1 647	2013	1 429	0	14	70	12	1 525
1978	1 367	0	273	70	10	1 720	2014	1 429	0	14	70	12	1 525
1979	1 653	0	331	70	10	2 064							

4.3.3 Catch at age

A time series of age frequency distributions is available from the target TRE 7 single trawl fishery within KMNTB from 1997–98 to 2012–13 (9 observations). The age sampling data from the dominant single trawl vessel were excluded from the age frequency samples for 2009–10 and 2012–13. There are also some age frequency samples for the pair trawl method from the late 1990s and early 2000s (three observations). Previous comparisons found no significant difference between the age composition of catches made by pair and single trawl methods (Hanchet 1999).

In addition, two sources of age frequency data are available from the 1970s: (1) a series covering the years 1971–74 derived from research sampling carried out by the vessel *James Cook*, and (2) a series derived from market sampling carried out in the 1974–76 and 1978–79 fishing years (five observations). There is considerable variability amongst the latter series with the result that these data were relatively uninformative in the assessment modelling and, hence, were down-weighted in the final model options.

4.3.4 Estimate of natural mortality (*M*)

Following previous assessments, natural mortality was assumed to be 0.10 based on an observed maximum age of about 40 years (using the regression method of Hoenig 1983). Estimates of stock status were sensitive to the value of natural mortality and the final model runs included a sensitivity run using a lower value of 0.083, corresponding to an assumed maximum age of 50 years.

4.3.5 Model structure

The age structured population model encompasses the 1944–2014 period. The model structure includes two sexes and 1–40 year age classes, including an accumulating age class for older fish (40+ years). The age structure of the population at the start of the model is assumed to be in an unexploited, equilibrium state. The biological parameters are those used in previous assessments and equivalent for the two sexes (see Table 4). For the base model, natural mortality was invariant with age at a value of

0.1. A Beverton-Holt spawning stock recruitment relationship (SRR) was assumed with steepness (*h*) fixed at 0.85 and the standard deviation of the natural logarithm of recruitment (σ_R) was fixed at 0.6. Recruitment deviates were estimated for the 1970–2008 years.

Separate fishery selectivities were estimated for the main bottom trawl fishery (double normal parameterisation) and the pair trawl fishery (logistic), and a double normal selectivity was estimated for the *James Cook* research trawl age samples. The CPUE indices were linked to the vulnerable biomass of the main bottom trawl fishery.

The model was fitted to: (a) a combined (either trevally or snapper targeted) bottom trawl CPUE index for the years 1990 to 2013, (b) a research sampling proportions-at-age series for 1971 to 1974, (c) a market sampling proportions-at-age series covering 1974 to 1976 and 1978 to 1979, (d) a commercial proportions-at-age series for 1997 to 2013. The weighting of the individual data sets followed the approach of Francis (2011). The final assessment model adopted a CV of 16% for the time series of CPUE indices. The recent bottom trawl age composition data were assigned a moderately high weighting in the likelihood (ESS of about 50).

During model development, a range of options was investigated to examine the key structural assumptions of the model. The most influential assumption was the value of natural mortality, and a lower value of natural mortality (0.083) was used as a key model sensitivity. An additional sensitivity run was conducted assuming a lower value of steepness for the SRR (0.7 compared with 0.85), and with *M*=0.1).

The base model estimates a low selectivity of older fish for the bottom trawl (BT) fishery. The age composition data appear to be uninformative regarding the selectivity of the oldest age classes and, hence, the selectivity was sensitive to the prior for the associated parameters. An additional selectivity was conducted that assumed a prior value which corresponded to a high selectivity of the older age classes (0.8 for the oldest age class) (*BTselect*).

The base model encompassed the KMNTB area only. The spatial stratification of the TRE 7 Fishstock was primarily based on differences in the age composition of trevally amongst sub-areas of TRE 7. However, limited sampling has been conducted in the other areas and, although some differences in age structure of the catch are apparent among areas, there are some similarities in the age structures from the three areas. Spatial differences in age composition could be attributable to differences in fishery selectivity and/or variability in the sampled component of the catch. On that basis, an alternative model was formulated based on a single stock hypothesis, including the entire catch from TRE 7 within the framework of the KMNTB model (*AllCatch*). The *AllCatch* model provides estimates of yield that are consistent with the total TRE 7 catch and the TACC.

Further model runs were undertaken to explore the influence of two key data sets in the assessment: the recent (2007–2013) CPUE indices and the 1998–2001 bottom pair trawl (BPT) age composition data.

Model projections for a five year period (2015–19) were conducted using the *AllCatch* model. These projections were conducted with annual commercial catch assumed to be either at the level of the TACC or equivalent to the annual catch from the 2012–13 fishing year and included additional allowances for customary and recreational catch. In the projection period, recruitment variation was incorporated in the model with the recruitment deviates simply constrained by the assumed variation in the deviates (σ_R = 0.60). Parameter uncertainty was determined using a Markov chain Monte Carlo (MCMC) approach.

4.3.6 Results

The assessment models indicate that the spawning biomass gradually declined during the 1940s and 1950s. The rate of decline increased in the 1960s and 1970s consistent with the increase in the total annual catch. The extent of the reduction in the spawning biomass during the 1970s was informed by the 1998–2001 age composition data from the BPT fishery. The proportion of older fish included in the age composition provide information regarding the level of fishing mortality in the preceding period. Thus, the estimation of the level of depletion will also be influenced by the assumed value of *M* (i.e., higher depletion with lower *M*). The spawning biomass remained relatively stable during the late 1990s and 2000s.

The stock status of the KMNTB component of TRE 7 has been assessed relative to a default target biomass level of 40% SB_0 and associated soft limit and hard limits of 20% and 10% SB_0 (Ministry of Fisheries 2008). Stock status conclusions are specific to the area encompassed by the base assessment model (i.e., KMNTB). For the base model, spawning biomass was maintained at about 50% SB_0 during the late 1990s and 2000s and there is a very low probability that the biomass declined below the target biomass during that period (Figure 5). The spawning biomass is estimated to have increased from 2010 to 2014 and the base model estimates that current biomass (SB_{2014}) is above the target biomass level (Tables 7 and 8).

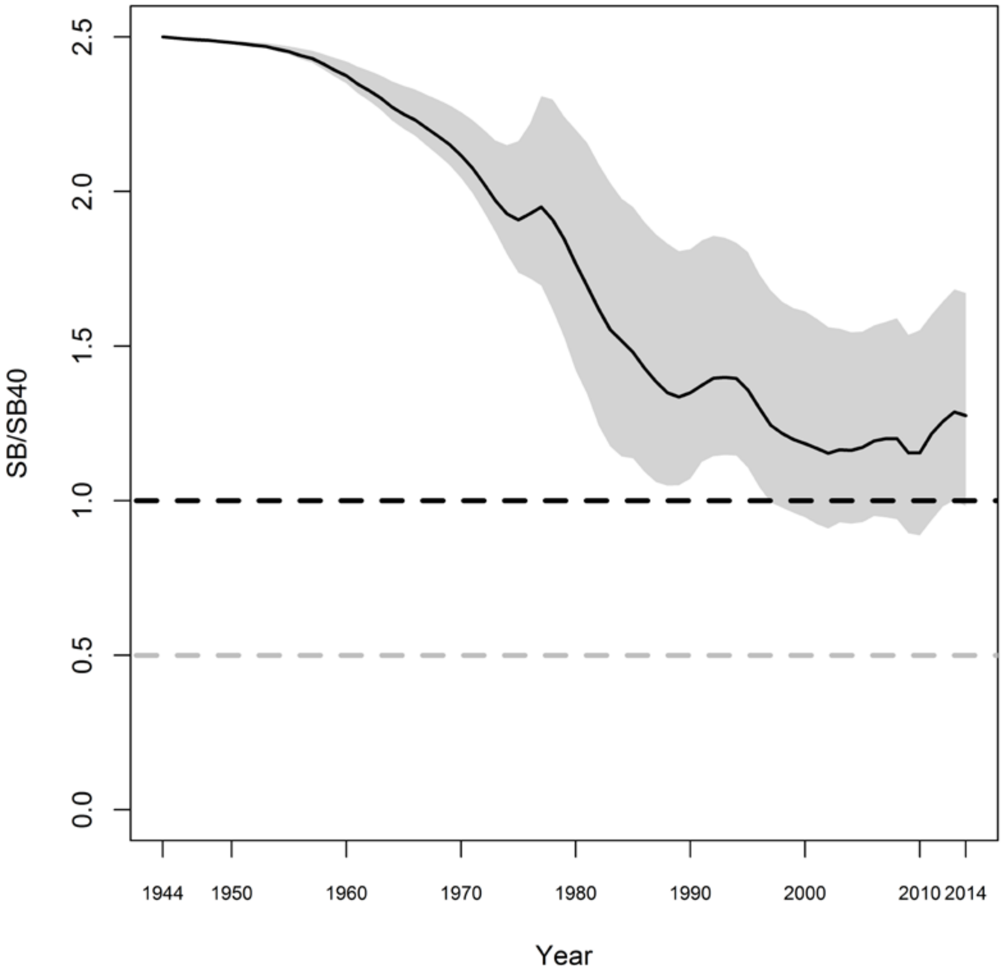


Figure 5: Spawning biomass (female only) trajectory from MCMC model fits for the base model, with 95% credible intervals.

Table 7: Biomass and yield estimates (medians, with 95% confidence intervals in parentheses) for the base model and sensitivities. Estimates are derived from MCMC analysis. Model results are limited to the KMNTB area of TRE 7, except for the *AllCatch* sensitivity which represents the entire TRE 7 area.

Model option	SB_0	SB_{2014}	$SB_{40\%}$	SB_{2014}/SB_0	$SB_{2014}/SB_{40\%}$
Base	22 339	11 526	8 935	0.510	1.275
	(18 493–36 213)	(73 84–23 808)	(7 397–14 485)	(0.393–0.669)	(0.982–1.672)
M low	21 026	8 399	8 410	0.399	0.998
	(18 692–26 268)	(5 774–13 446)	(7 477–10 507)	(0.305–0.525)	(0.762–1.313)
Steep70	23 557	11 483	9 423	0.489	1.224
	(19 723–39 933)	(7 384–26 688)	(7 889–15 973)	(0.368–0.682)	(0.92–1.704)
BTselect	20 436	9 698	8 174	0.474	1.184
	(17 787–27 121)	(6 708–16 116)	(7 115–10 848)	(0.371–0.619)	(0.927–1.549)
AllCatch	34 363	16 873	13 745	0.49	1.226
	(29 348–50 375)	(11 247–32 361)	(11 739–20 150)	(0.381–0.66)	(0.951–1.649)

Table 8: Estimates of target fishing mortality ($F_{SB40\%}$) and current fishing mortality (F_{2014}) relative to the target level (medians, with 95% confidence intervals in parentheses) for the base model and sensitivities. Estimates are derived from MCMC analysis. Model results are limited to the KMNTB area of TRE 7, except for the *AllCatch* sensitivity which represents the entire TRE 7 area.

Model option	$F_{SB40\%}$	$F_{2014}/F_{SB40\%}$	Pr (F_{2014}<$F_{SB40\%}$)
Base	0.0877 (0.0844-0.0904)	0.678 (0.338-1.024)	0.969
M low	0.0768 (0.0742-0.079)	1.067 (0.69-1.517)	0.365
Steep70	0.077 (0.0741-0.0795)	0.776 (0.351-1.183)	0.851
BTselect	0.0885 (0.0855-0.0908)	0.796 (0.49-1.12)	0.902
AllCatch	0.0872 (0.0843-0.0896)	0.591 (0.319-0.862)	0.999

Current levels of fishing mortality are estimated to be below the $F_{SB40\%}$ level for all model options with the base level of natural mortality (*M*=0.1). The model sensitivity with the lower *M* estimated current fishing mortality to be at about the $F_{SB40\%}$ level (Table 8 and Figure 6).

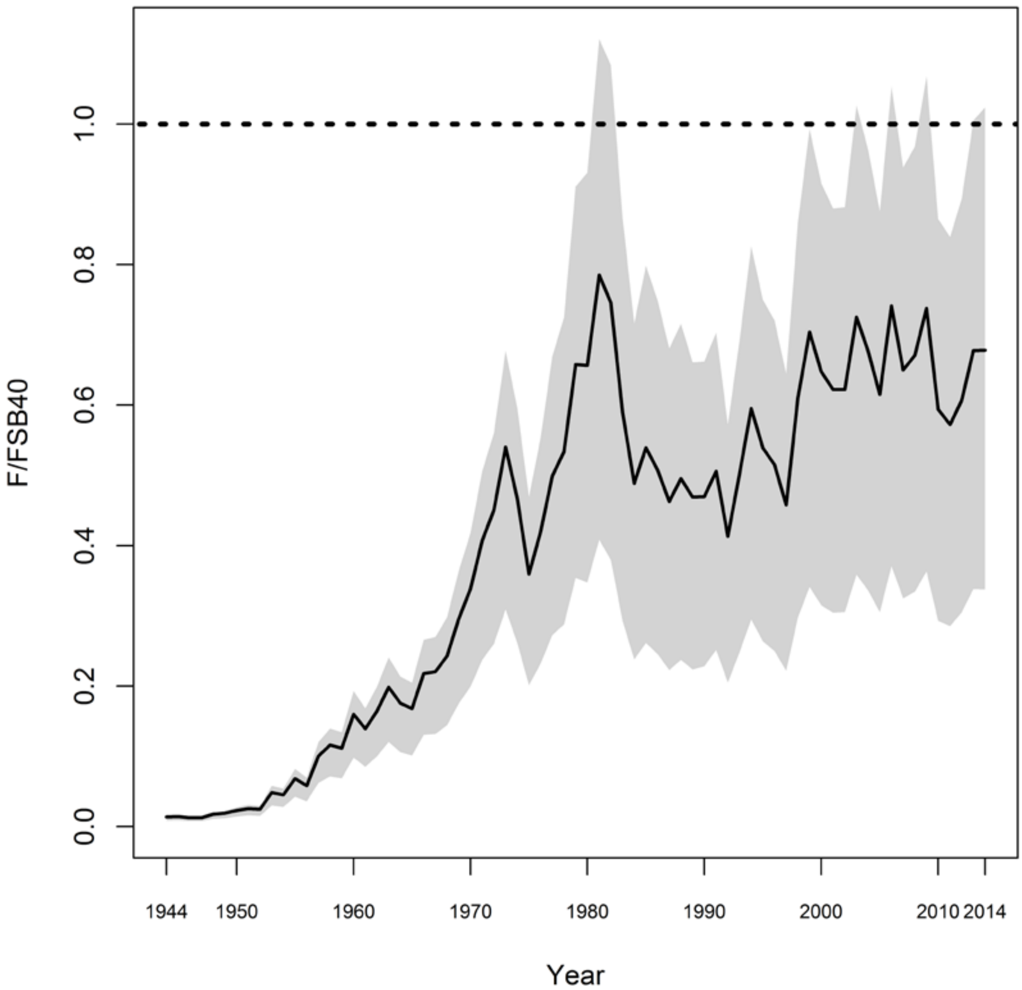


Figure 6: Fishing mortality (female only) relative to the overfishing threshold ($F_{SB40\%}$) (median of MCMCs) for the base model run. 95% credible intervals were derived from MCMC. The dashed, black horizontal line represents the default overfishing threshold.

Stock status from the model sensitivities is comparable to the base model, although the status is less optimistic for the *Low M* sensitivity (Tables 7–9 and Figure 7). For the *Low M* sensitivity, current biomass was estimated to be at about the target biomass level with no associated risk that the stock biomass has approached the biomass limit reference points. The stock status from the *AllCatch* model, that includes all the TRE 7 catch, is very similar to the base model, although the estimate of equilibrium yield is considerably higher, which is consistent with the magnitude of catch included in the *AllCatch* model.

Table 9: Probability (*Pr*) of the KMNTB component of the TRE 7 stock being above key reference points in 2014. Estimates are derived from MCMC analysis.

	$Pr\ (B_{2014}>0.1B_0)$	$Pr\ (B_{2014}>0.2B_0)$	$Pr\ (B_{2014}>0.4B_0)$
Base	1.000	1.000	0.961
M low	1.000	1.000	0.492
Steep70	1.000	1.000	0.899
BTselect	1.000	1.000	0.909
AllCatch	1.000	1.000	0.931

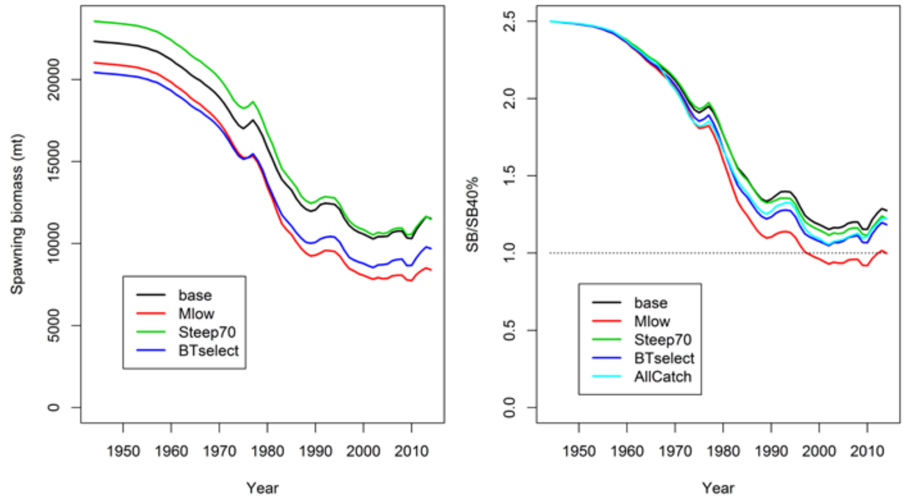


Figure 7: Median spawning biomass (female only) trajectories from MCMC model fits for the base model and sensitivities. The horizontal line in the right panel represents the target biomass level.

Further model runs were undertaken to explore the influence of two key data sets in the assessment. There is some concern regarding the reliability of the recent (2007–2013) CPUE indices due to changes in the targeting behaviour of the trawl fleet. A model trial was conducted that down-weighted the later indices (by increasing the CV to 30%). The BPT age composition data from 1998–2001 are influential in determining the extent of the stock depletion during the preceding period. A model trial was conducted that assigned a high weight (ESS 200) to these BPT age data to ensure that the estimated levels of fishing mortality were entirely consistent with the age composition data (i.e., to ensure a good fit to the "plus group" in the age composition). Both model trials resulted in a reduction in the current stock status relative to SB_0 compared with the base model (by approximately 10%), although in both the current stock status was estimated to be above the target biomass level. On that basis, it was concluded that the overall conclusions of the assessment were not overly sensitive to either set of data.

4.3.7 Yield estimates and projections

Stock projections, for a five-year period, were conducted for the *AllCatch* model. The projections used either the TACC or a constant catch equivalent to the 2013 catch level; i.e., 2153 t for the TACC projection and 1952 t for the 2013 catch projection. For the TACC projection, the spawning biomass is projected to decline slightly (by 3%) during the projection period, although there is a low probability that the biomass will decline below the target biomass level (Table 10). For the constant catch projection, projected biomass is maintained at the current (2014) level. The $F_{40\%B0}$ yield at the 2014 biomass level is 2949 t (1987–5557 t) for the *AllCatch* model that includes the entire TRE 7 catch. The current TACC is 2153 t.

Table 10: Stock status in the terminal year (2019) of the five year forecast period for the *AllCatch* model using either the current TACC or the 2013 catch in the projections.

Model option	SB_{2019}/SB_0	$Pr(SB_{2019} > X\%SB_0)$		
		10%	20%	40%
AllCatch (with TACC projection)	0.478 (0.355–0.659)	1.000	1.000	0.863
AllCatch (with 2013 catch projection)	0.494 (0.374–0.671)	1.000	1.000	0.924

5. STATUS OF THE STOCKS

- **TRE 1**

Preliminary assessments were undertaken for the BoP and EN/HG, using abundance indices derived from standardised CPUE analyses, bottom trawl catch-at-age, and catch history. These assessments have not been finalised and will be updated once the new catch-at-age data become available. Relative abundance series were increasing for both BoP and EN/HG.

- **TRE 2**

There is no accepted stock assessment for TRE 2. Trevally in TRE 2 are thought to be part of the biological stock located in the Bay of Plenty (TRE 1); therefore future assessments for TRE 2 will be undertaken in conjunction with TRE 1.

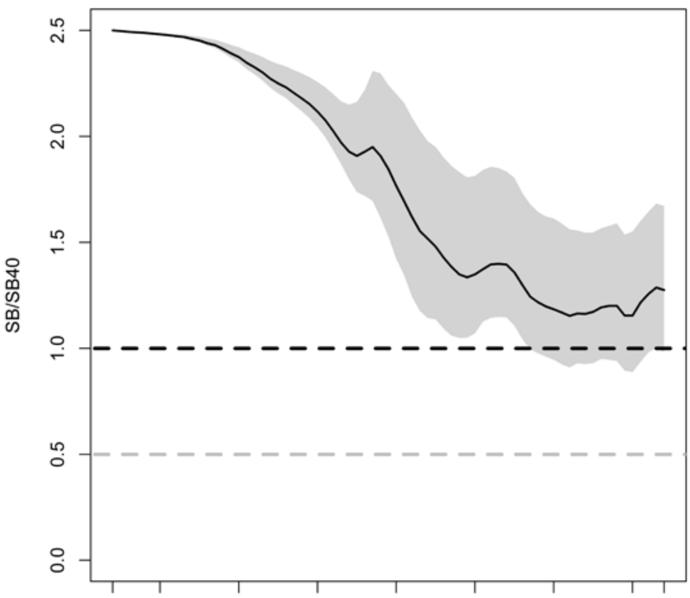
- **TRE 7**

Stock Structure Assumptions

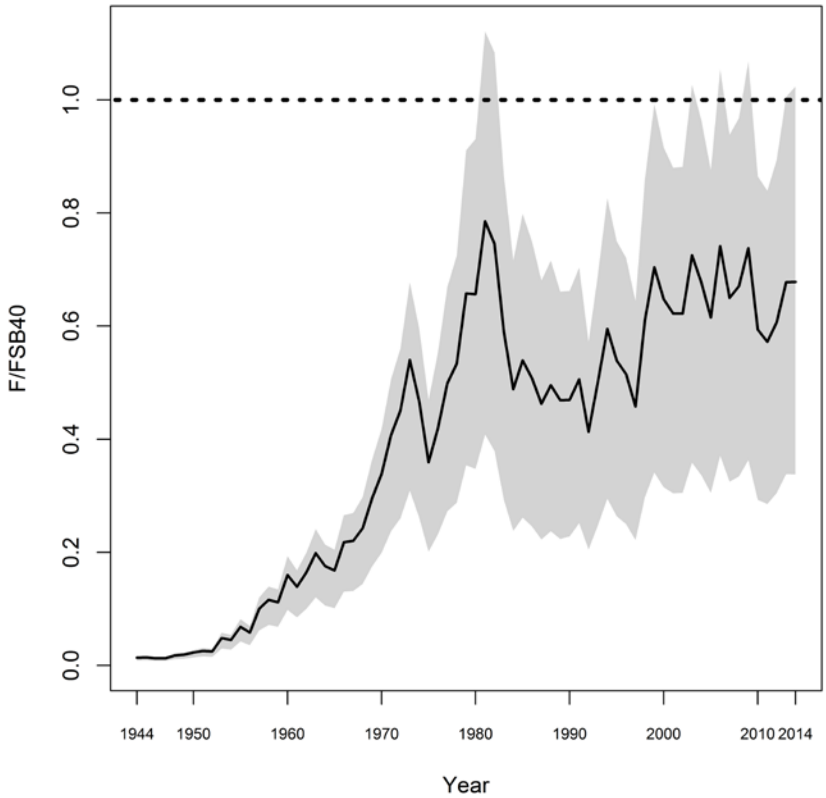
Trevally occurring along the west coast of the North Island are believed to comprise a single stock.

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	A base case model based on the main fishery area only (Kaipara-Manukau-Northern Taranaki Bight; KMNTB); this represents about 70% of recent (2010–11 to 2012–13) TRE 7 catches
Reference Points	Interim Target: 40% SB_0 Soft Limit: 20% SB_0 Hard Limit: 10% SB_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Very Likely (> 90%) 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	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Spawning biomass (female only) relative to the interim target biomass ($SB_{40\%}$) (median of MCMCs) for the base model run. 95% credible intervals were derived from MCMC. The dashed, black horizontal line represents the default target biomass level and the grey line represents the default soft limit (20% SB_0).

<table>
<tr><th colspan="2">Fishery and Stock Trends</th></tr>
<tr><td>Recent Trend in Biomass or Proxy</td><td>Spawning biomass is estimated to have declined gradually during the 1940s and 1950s. The rate of decline increased from the 1960s to the mid-1980s consistent with the increase in the total annual catch. Since the mid-1990s spawning biomass has remained relatively stable.</td></tr>
<tr><td>Recent Trend in Fishing Intensity or Proxy</td><td>Fishing mortality rates are estimated to have been relatively stable since the late 1990s, at a level below $F_{SB40\%}$.


Annual fishing mortality relative to the level of fishing mortality that corresponds to the default target spawning biomass from the KMNTB base assessment model. The solid line represents the median of the MCMC samples and the shaded area represents the 95% credible interval.</td></tr>
</table>

Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Model projections indicate that the biomass of TRE 7 is About as Likely as Not (40–60%) to decline over the next 5 years (to 2019), but with low probability of dropping below 40% SB_0 by 2019.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits (5 years)	Exceptionally Unlikely (< 1%) to decline below Soft and Hard Limits
Probability of Current Catch or TACC 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 Bayesian estimation of posterior distributions

Assessment Dates	Latest assessment: 2015	Next assessment: 2020
Overall assessment quality rank	1 – High Quality	

Main data inputs (rank)	- Standardised CPUE index of abundance - Proportions at age data from the commercial fisheries and trawl surveys	1 – High Quality 1 – High Quality
Data not used (rank)	- Bottom pair trawl CPUE, 1973–74 to 1984–85	3 – Low Quality: does not index abundance
Changes to Model Structure and Assumptions	The stock assessment was based on data from KMNTB only. The fishery catch, CPUE and age composition data sets were reconfigured accordingly. The model was re-run with the total TRE 7 catch to calculate the total expected yield at $F_{SB40\%}$. Projections were based on the model for the entire area, using both the 2014 catch and the 2014 TACC.	
Major Sources of Uncertainty	- Reliability of CPUE as an index of stock abundance as a result of recent increases in the degree of targeting of trevally - Whether results for the KMNTB sub-area reflect changes in biomass in the other two sub-areas within TRE 7 - Reliability of the pair trawl age composition data (1998–2001), which strongly influence estimates of B_0 and exploitation rates during the period of peak catch	

Qualifying Comments
- The stock assessment was based on the KMNTB sub-area only, and the extent to which it is reflective of the other two (smaller) sub-areas is unknown.

Fishery Interactions
Main QMS bycatch species are snapper, red gurnard, John dory and tarakihi. Interactions with other species are currently being characterised.

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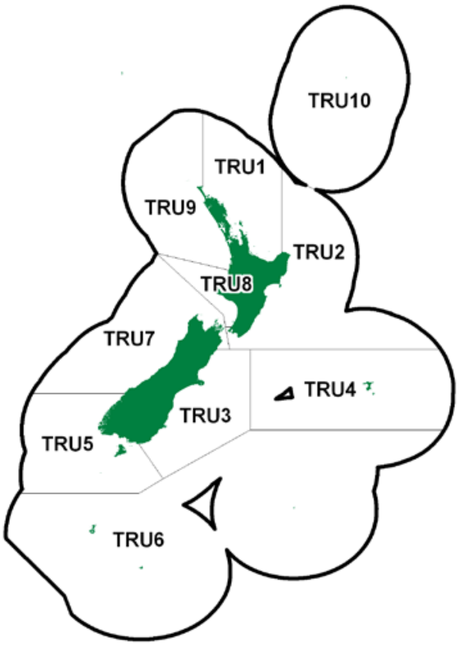
TRUMPETER (TRU)

(*Latris lineata*)
Kohikohi



1. FISHERY SUMMARY

1.1 Commercial fisheries

Historical estimated landings are shown in Table 1 for the main trumpeter stocks. Total reported landings of trumpeter ranged between 3 t and 44 t until the fishing year 1990-91, after which landings increased steadily to reach 162 t in 1995–96 (Tables 2 and 3). Total landings subsequently decreased to a minimum of 25 t in 2000–01 and 2001–02, before once again increasing to over 100 t in the 2007-08, 2010-11 and 2011–2012 fishing years. In 2013-14 to 2018-19 total annual landings averaging just over 60 t were recorded. Historic under-reporting is probable (Paul 1999).

Most landings of trumpeter have come from the east coast between the eastern Bay of Plenty and Southland. There have been changes over time in contributions from different parts of the east coast, but the reason for this is not known. Until the early 1950s most landings were made in QMA 3. From the mid 1950s until the mid 1980s most landings were in QMA 2 (Table 1). The rapid increase in landings after the mid 1980s has come predominantly from QMAs 3 and 4 (Table 3), reportedly from an increase in line fishing on the outer shelf and in the Mernoo Bank region. Figure 1 shows the historical landings for TRU from 1936.

Most trumpeter is taken as bycatch in line-fisheries; a small amount is trawled, and from the 1970s it has also been taken by setnet. Only a small proportion of trumpeter is targeted. Catches are irregular with no seasonal trend and are likely to be driven by fishing activities for other species. No information on changes in fishing effort is available.

Trumpeter have been managed under the Quota Management System in New Zealand since 1 October 1988, at which time an original TACC of 100 t was set. The TACC was increased to 144 t in October 2001 following a period of declining landings. This TACC has never been reached; the 110 t landed in 2010–11 was the highest since 1996–97. In recent years (2006–07 to 2018–19), significant landings have come from TRU 3 east coast South Island and TRU 4 on the Chatham Rise (Table 3), with small landings also coming from TRU 2, 5, and 7 (south-eastern North Island and South Island). Trumpeter are also taken by recreational fishers in southern New Zealand, and although good estimates of recreational catch are not available, they may be around one-third to one-half of the commercial catch.

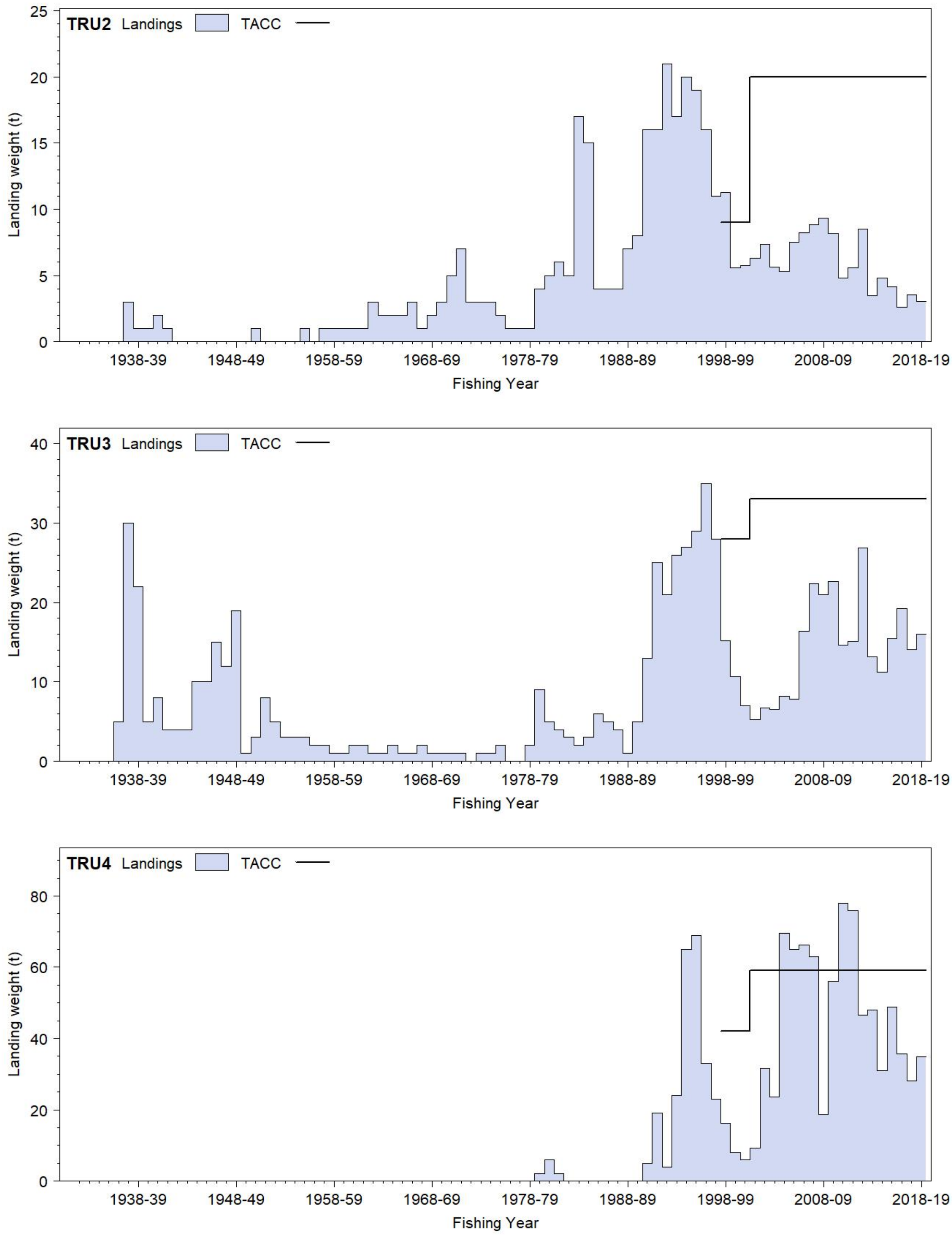


Figure 1: Reported commercial landings and TACCs for the four main TRU stocks. Top to bottom: TRU 2 (Central East), TRU 3 (South East Coast), TRU 4 (South East Chatham Rise), **[Continued on next page]**

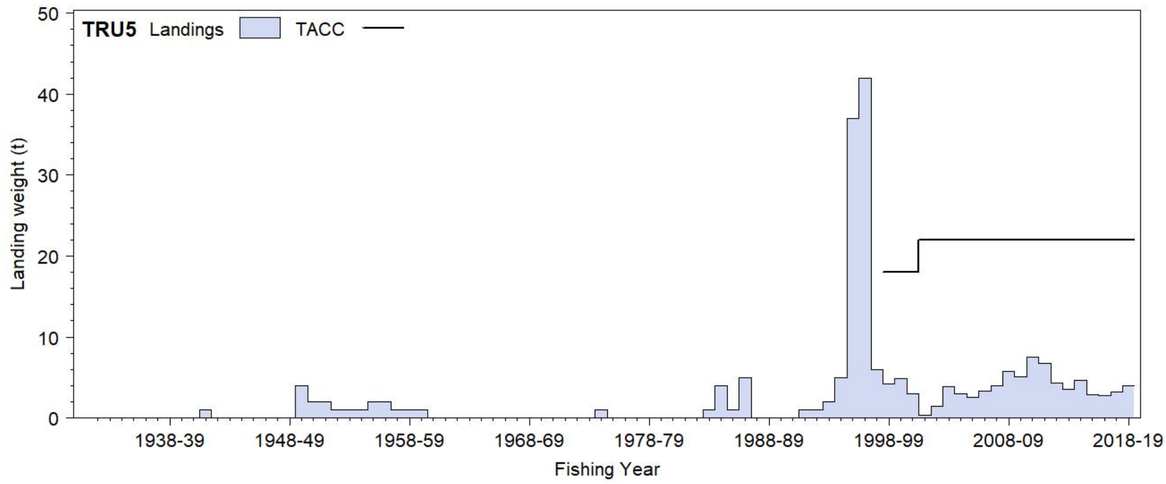


Figure 1: [Continued] Reported commercial landings and TACCs for the four main TRU stocks. TRU 5 (Southland).

Table 1: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	TRU 1	TRU 2	TRU 3	TRU 4	Year	TRU 1	TRU 2	TRU 3	TRU 4
1931–32	0	0	0	0	1957	0	1	2	0
1932–33	0	0	0	0	1958	0	1	1	0
1933–34	0	0	0	0	1959	0	1	1	0
1934–35	0	0	0	0	1960	0	1	2	0
1935–36	0	0	0	0	1961	0	1	2	0
1936–37	0	0	5	0	1962	0	3	1	0
1937–38	0	3	30	0	1963	0	2	1	0
1938–39	0	1	22	0	1964	0	2	2	0
1939–40	0	1	5	0	1965	0	2	1	0
1940–41	0	2	8	0	1966	0	3	1	0
1941–42	0	1	4	0	1967	0	1	2	0
1942–43	0	0	4	0	1968	0	2	1	0
1943–44	0	0	4	0	1969	0	3	1	0
1944	0	0	10	0	1970	0	5	1	0
1945	0	0	10	0	1971	0	7	1	0
1946	0	0	15	0	1972	0	3	0	0
1947	0	0	12	0	1973	0	3	1	0
1948	0	0	19	0	1974	0	3	1	0
1949	0	0	1	0	1975	0	2	2	0
1950	0	1	3	0	1976	0	1	0	0
1951	0	0	8	0	1977	0	1	0	0
1952	0	0	5	0	1978	0	1	2	0
1953	0	0	3	0	1979	0	4	9	2
1954	0	0	3	0	1980	0	5	5	6
1955	0	1	3	0	1981	0	6	4	2
1956	0	0	2	0	1982	2	21	6	0

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. 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 includes both foreign and domestic landings.

Table 2: Reported total landings (t) of trumpeter from 1931 to 1982. Values for 1931 to 1944 are April–March years, listed against the April year. Fisheries Annual Report (1931 to 1974) or FSU data (Paul 1999).

Year	Landing	Year	Landings	Year	Landings	Year	Landings	Year	Landings
1936	20	1946	16	1956	5	1965	4	1974	5
1937	41	1947	13	1957	5	1966	5	1975	4
1938	30	1948	19	1958	3	1967	7	1976	3
1939	37	1949	6	1959	3	1968	5	1977	3
1940	17	1950	6	1960	3	1969	5	1978	6
1941	11	1951	11	1961	3	1970	7	1979	17
1942	5	1952	11	1962	4	1971	10	1980	10
1943	5	1953	5	1963	3	1972	4	1981	12
1944	11	1954	5	1964	3	1973	5	1982	37
1945	11	1955	6						

Table 3: Reported landings (t) of trumpeter by QMA and fishing year, 1983–84 to 2018–19*.

Fishstock	TRU 1		TRU 2		TRU 3		TRU 4		TRU 5	
FMA	1		2		3		4		5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1982–83	0	-	5	-	3	-	0	-	0	-
1983–84	1	-	17	-	2	-	0	-	1	-
1984–85	0	-	15	-	3	-	0	-	4	-
1985–86	0	-	4	-	6	-	0	-	1	-
1986–87	0	-	4	-	5	-	0	-	5	-
1987–88	0	-	4	-	4	-	0	-	0	-
1988–89	0	-	7	-	1	-	0	-	0	-
1989–90	0	-	8	-	5	-	0	-	0	-
1990–91	3	-	16	-	13	-	5	-	0	-
1991–92	1	-	16	-	25	-	19	-	1	-
1992–93	3	-	21	-	21	-	4	-	1	-
1993–94	3	-	17	-	26	-	24	-	2	-
1994–95	2	-	20	-	27	-	65	-	5	-
1995–96	2	-	19	-	29	-	69	-	37	-
1996–97	2	-	16	-	35	-	33	-	42	-
1997–98	1	-	11	-	28	-	23	-	6	-
1998–99	< 1	1	11	9	15	28	16	42	4	18
1999–00	< 1	1	6	9	11	28	8	42	5	18
2000–01	< 1	1	6	9	7	28	6	42	3	18
2001–02	< 1	3	6	20	5	33	9	59	< 1	22
2002–03	< 1	3	7	20	7	33	32	59	1	22
2003–04	1	3	6	20	7	33	24	59	4	22
2004–05	< 1	3	5	20	8	33	70	59	3	22
2005–06	< 1	3	7	20	8	33	65	59	3	22
2006–07	< 1	3	8	20	16	33	66	59	3	22
2007–08	1	3	9	20	22	33	63	59	4	22
2008–09	< 1	3	9	20	21	33	19	59	6	22
2009–10	< 1	3	8	20	22	33	56	59	5	22
2010–11	< 1	3	5	20	15	33	78	59	8	22
2011–12	< 1	3	6	20	15	33	76	59	7	22
2012–13	<1	3	8	20	27	33	47	59	4	22
2013–14	<1	3	3	20	13	33	48	59	4	22
2014–15	0	3	5	20	11	33	31	59	4	22
2015–16	<1	3	4	20	15	33	49	59	3	22
2016–17	<1	3	3	20	19	33	36	59	3	22
2017–18	<1	3	4	20	14	33	28	59	3	22
2018–19	<1	3	3	20	16	33	35	59	4	22

Fishstock	TRU 6		TRU 7		TRU 8		TRU 9			
FMA	6		7		8		9		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1982–83	0	-	0	-	0	-	0	-	8	-
1983–84	0	-	0	-	0	-	0	-	21	-
1984–85	0	-	0	-	0	-	0	-	22	-
1985–86	0	-	0	-	0	-	0	-	11	-
1986–87	0	-	2	-	0	-	0	-	16	-
1987–88	0	-	0	-	0	-	0	-	8	-
1988–89	0	-	1	-	0	-	0	-	9	-
1989–90	0	-	0	-	1	-	0	-	14	-
1990–91	0	-	7	-	0	-	0	-	44	-
1991–92	0	-	4	-	0	-	0	-	69	-
1992–93	0	-	4	-	2	-	0	-	56	-
1993–94	0	-	6	-	0	-	0	-	78	-
1994–95	0	-	4	-	0	-	0	-	123	-
1995–96	0	-	6	-	0	-	0	-	162	-
1996–97	2	-	3	-	< 1	-	< 1	-	133	-
1997–98	< 1	-	3	-	< 1	-	0	-	72	-
1998–99	0	0	3	2	< 1	0	0	0	50	100
1999–00	0	0	2	2	< 1	0	0	0	33	100
2000–01	0	0	3	2	< 1	0	< 1	0	25	100
2001–02	0	0	5	6	< 1	1	0	0	25	144
2002–03	0	0	3	6	< 1	1	< 1	0	51	144
2003–04	0	0	2	6	< 1	1	< 1	0	44	144
2004–05	0	0	4	6	< 1	1	0	0	90	144
2005–06	0	0	4	6	< 1	1	0	0	88	144
2006–07	0	0	4	6	< 1	1	0	0	99	144
2007–08	< 1	0	2	6	< 1	1	< 1	0	101	144
2008–09	0	0	2	6	< 1	1	< 1	0	63	144
2009–10	0	0	3	6	< 1	1	0	0	95	144
2010–11	< 1	0	4	6	< 1	1	< 1	0	110	144
2011–12	< 1	0	4	6	< 1	1	< 1	0	108	144
2012–13	<1	0	6	6	<1	1	<1	1	93	144
2013–14	0	0	5	6	<1	1	<1	0	74	144
2014–15	0	0	4	6	1	1	0	0	56	144
2015–16	0	0	4	6	1	1	<1	0	76	144
2016–17	0	0	3	6	1	1	<1	0	65	144
2017–18	0	0	3	6	<1	1	<1	0	52	144
2018–19	0	0	4	6	<1	1	<1	0	63	144

*The data in this table have been updated from those published in previous Plenary Reports by using the data through 1996–97 in table 41 on p. 288 of the "Review of Sustainability Measures and Other Management Controls for the 1998–99 Fishing Year - Final Advice Paper" dated 6 August 1998. There are no landings reported from TRU 10, which has a TAC of 0

1.2 Recreational fisheries

Results from four separate recreational fishing surveys undertaken in the 1990s are shown in Table 4. Most of the estimated recreational catch in these surveys was taken in FMAs 3, 5 and 7.

Table 4: Estimated number of trumpeter caught by recreational fishers by FMA using telephone-diary surveys. Surveys were carried out in different years in MAF Fisheries regions: South in 1991–92, Central in 1992–93, North in 1993–94 and National in 1996 (Bradford 1998).

FMA	Survey	Number	CV (%)
1991–92			
FMA 3	South	6 000	29
FMA 5	South	6 000	33
FMA 7	South	8 000	-
1992–93			
FMA 2	Central	1 000	-
FMA 3	Central	3 000	-
FMA 5	Central	1 000	-
FMA 7	Central	0	-
FMA 8	Central	0	-
1993–94			
FMA 1+9	North	0	-
FMA 2	North	1 000	-
FMA 8	North	0	-
1996			
FMA 1	National	< 500	-
FMA 2	National	1 000	-
FMA 3	National	13 000	19
FMA 5	National	21 000	19
FMA 7	National	3 000	-

The harvest estimates provided by telephone-diary surveys are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout the 2011–12 fishing year. 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 harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 5. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 5: Recreational harvest estimates for trumpeter stocks (Wynne-Jones et al 2014, 2019). Mean fish weights were obtained from boat ramp surveys (Hartill & Davey 2015, Davey et al 2019).

Stock	Year	Method	Number of fish	Total weight (t)	CV
TRU 1	2011/12	Panel survey	898	1.3	0.83
	2017/18	Panel survey	0	0	-
TRU 2	2011/12	Panel survey	787	1.1	0.82
	2017/18	Panel survey	32	<1	1.01
TRU 3	2011/12	Panel survey	2 870	4.0	0.41
	2017/18	Panel survey	8 070	21.0	0.34
TRU 5	2011/12	Panel survey	1 505	2.1	0.42
	2017/18	Panel survey	0	0	-
TRU 7	2011/12	Panel survey	215	0.3	0.83
	2017/18	Panel survey	142	<1	1.00
TRU 8	2011/12	Panel survey	273	0.4	1.03
	2017/18	Panel survey	0	0	-

1.3 Customary non-commercial fisheries

The customary non-commercial take has not been quantified.

1.4 Illegal catch
There is no quantitative information on illegal fishing activity or catch.

1.5 Other sources of mortality
No quantitative estimates are available regarding the impact of other sources of mortality on trumpeter stocks. Trumpeter principally occur on deep coastal reefs, where they are taken in net and line fisheries targeted at other species.

2. BIOLOGY

Trumpeter have a Southern Hemisphere distribution in cool temperate waters. They occur in New Zealand, Australia, the Sub-Antarctic islands of the southern Indian and Atlantic oceans, the Foundation Seamount in the central South Pacific, and possibly off Chile (Roberts 2003, Tracey & Lyle 2005). In New Zealand, trumpeter occur from the Three Kings Islands through all of mainland New Zealand to the Auckland Islands; however they are rare north of East Cape and Cape Egmont (Kingsford et al 1989, Francis 1996, 2001). The greatest concentrations of trumpeter apparently occur on the Chatham Rise and around the southern South Island and Stewart Island.

Trumpeter have an extended larval and post-larval duration of up to 9 months in surface waters (Tracey & Lyle 2005), resulting in extensive drift of young fish among geographic regions. Juveniles are largely sedentary, but some adults are highly migratory with tagged fish travelling 650 km from Tasmania to southern New South Wales, and 5800 km from Tasmania to St Paul Island in the southern Indian Ocean (Lyle & Murphy 2002). This suggests that there is one circum-global genetic stock in the Southern Hemisphere, although analysis of otolith morphometrics from Tasmania and St Paul and Amsterdam Islands showed regional variation (Tracey et al 2006) suggesting that migration and inter-breeding may be limited.

Trumpeter occur mainly over rocky reefs ranging from shallow inshore waters to deep reefs on the central continental shelf. In New Zealand, they apparently range from a depth of a few metres down to about 200 m. In Australia some reports indicate they may go as deep as 300 m (reviewed by Paul 1999). Fish inhabiting inshore reefs tend to be smaller, whereas fish from deep reefs tend to be much larger. Trumpeter initially settle on to inshore reefs at the end of their long postlarval period, where they remain for several years, before migrating into deeper areas as they reach maturity (Tracey & Lyle 2005).

Some biological traits differ between New Zealand and Tasmanian populations. Notably, trumpeter are thought to spawn in winter (July) in New Zealand (Graham 1939b), and late winter to spring in Australia (peaking around September in Tasmania) (Ruwald et al 1991, Furlani & Last 1993, Morehead 1998, Morehead et al 1998, 2000, Furlani & Ruwald 1999). However, the New Zealand data seem to be based on limited sampling, and it is uncertain whether the apparent regional difference is real.

Trumpeter grow to about 110–120 cm fork length (FL) and 25–27 kg weight in New Zealand and Australia (Gomon et al 1994, Paul 1999, Francis 2001). Nothing is known about growth, longevity or maturity in New Zealand waters. However, because of their importance for aquaculture in Australia, a comprehensive study has recently been completed on their age and growth in Tasmania (Tracey & Lyle 2005, Tracey et al 2006). Partial validation of age estimates was completed there by comparison of otolith growth in known-age reared fish and wild fish (enabling validation of the time of formation of the first growth band), and tracking a strong wild cohort over seven years (ages 1+ to 7+). Although full validation was not achieved, the authors considered their ages validated up to and beyond the size and age of habitat transition.

In Australia, trumpeter grow rapidly during the first 4–5 years, reaching about 45 cm FL at that stage, and moving offshore to deeper water (Tracey & Lyle 2005, Tracey et al 2006). At that time, there is a reduction in growth rate. They reach a maximum age of about 43 years (though the largest fish in the samples was 95 cm FL, which is well below the reported maximum length of 120 cm), and there are no clear differences between males and females (although small sample sizes of fish older than 10 years meant that the power to detect differences was low). Similarly, no differences were found in growth rates between fish from Tasmania and St Paul and Amsterdam Islands. Growth rates are seasonally variable, at least for the first few years, with maximum growth in late summer-autumn. It is thought that maturation coincides with the offshore movement to deep habitat.

In New Zealand, the only population information available for trumpeter comes from a 6-year survey (1994–1999) in Paterson Inlet, Stewart Island. Chadderton & Davidson (2003) carried out underwater visual counts, and obtained comprehensive length-frequency distributions from 1065 fish caught by rod at 12–15 different sites. Their length-frequency data show two or three clear juvenile cohorts which progress through time (a strong cohort was also found in Tasmania by Tracey & Lyle (2005)). Chadderton & Davidson (2003) interpreted this as evidence of variable annual recruitment pulses. Their largest fish was 46.9 cm FL with few fish over 40 cm in most years. This is consistent with evidence from Australia of offshore migration at about 45 cm, though the migration may occur at a slightly smaller size in the New Zealand population.

3. STOCKS AND AREAS

There are no data relevant to stock boundaries in New Zealand. Trumpeter are potentially wide-ranging, and there is one circum-global genetic stock in the Southern Hemisphere, although analysis of otolith morphometrics from Tasmania and St Paul and Amsterdam Islands showed regional variation (Tracey et al 2006) suggesting that migration and inter-breeding may be limited. Therefore there may be localised populations in areas of suitable habitat as they seem to be restricted to rocky reef habitat.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance
No estimates are available.

4.2 Biomass estimates
No estimates are available.

4.3 Yield estimates and projections
No estimate of *MCY* is available.

The level of risk to the stock by harvesting trumpeter at recent catch levels cannot be determined.

No estimates of current biomass, fishing mortality, or other information are available which would permit the estimation of *CAY*.

4.4 Other factors
There is anecdotal information from Australia and New Zealand that localised populations of trumpeter can be quickly depleted.

5. STATUS OF THE STOCKS

No estimates of current and reference biomass are available. It is not known if recent catch levels are sustainable.

TACCs and reported landings of trumpeter for the 2017–18 fishing year are summarised in Table 6.

Table 6: Recreational and customary non-commercial allowances (t), Total Allowable Commercial Catches (TACC, t) and Total Allowable Catch (TAC, t), along with reported landings (t) of trumpeter for the most recent fishing year.

Fishstock	FMA	TAC	TACC	Customary	Recreational	2018–19 Reported

							Landings
TRU 1	Auckland (East)	1	5	3	1	1	< 1
TRU 2	Central (East)	2	22	20	1	1	3
TRU 3	South-east (Coast)	3	53	33	7	13	16
TRU 4	South-east (Chatham)	4	59	59	0	0	35
TRU 5	Southland	5	54	22	11	21	4
TRU 6	Sub-Antarctic	6	0	0	0	0	0
TRU 7	Challenger	7	11	6	2	3	4
TRU 8	Central (West)	8	1	1	0	0	<1
TRU 9	Auckland (West)	9	0	0	0	0	<1
TRU 10	Kermadec	10	0	0	0	0	0
Total			205	144	22	39	63

6. FOR FURTHER INFORMATION

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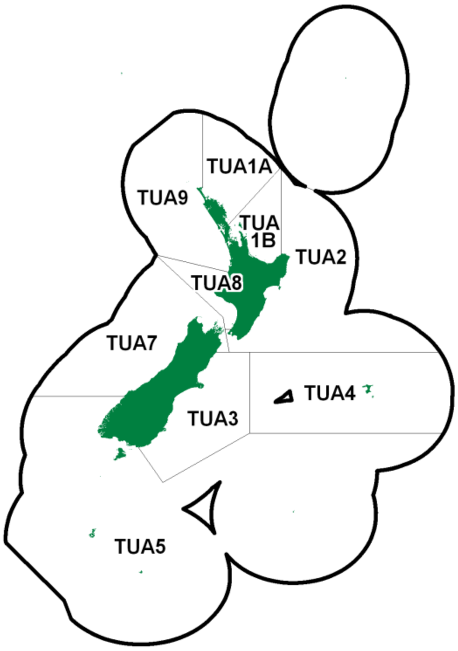
TUATUA (TUA)

(*Paphies subtriangulata*)
Tuatua



1. FISHERY SUMMARY

Tuatua (*Paphies subtriangulata*) were introduced into the QMS on 1 October 2005. The fishing year runs from 1 October to 30 September, and commercial catches are measured in greenweight. In October 2005 all TUA QMAs were allocated customary, recreational, and other sources of mortality allowances; and a TACC was introduced for TUA 9. A breakdown of each QMA TAC is listed in Table 1.

1.1 Commercial fisheries

QMA boundaries for tuatua were set the same as those established for FMAs, except for FMA 1 (the area between North Cape and Cape Runaway), which was divided into two QMAs, TUA 1A and TUA 1B, on either side of Te Arai Point (Pakiri Beach). The formerly specified historic commercial areas within TUA 1B (Papamoa domain to Maketu Beach, Bay of Plenty) and TUA 9 (i.e., Ninety Mile Beach, Hokianga Harbour to Maunganui Bluff, and specific areas between Maunganui Bluff to the North Head of the Kaipara Harbour) were revoked, and regulations were amended to remove the commercial daily catch limits for tuatua, which were no longer applicable. Commercial fishing was allowed to continue only in TUA 9 in the specified commercial area of the Kaipara Harbour entrance. A TACC of 43 t, which reflected the average of the reported landings taken from the Kaipara fishery between 1990–91 and 2003–04, was allocated to the TUA 9 stock in recognition that commercial tuatua fishing was constrained to the Kaipara Harbour entrance.

There is no minimum legal size (MLS) for tuatua, although fishers probably favour large individuals. Tuatua are available for harvest year-round, so there is no apparent seasonality in the fishery. Significant landings since 1989–90 have been reported from TUA 9 only (Table 2), and there have been no reported landings from TUA 5, TUA 6, and TUA 8. Landings from TUA 9 reached a peak of 192 t in 1997–98, and subsequently decreased, ranging from 4 to 76 t (average 32 t) between 1998–99 and 2003–04. This decline in commercial catches from the Kaipara bed is probably related to historic participants retiring from the fishery. The commercial effort had greatly reduced by 1992, post moratorium implementation, and catches were then influenced by the fact that commercial fishing is intermittent with only one or two fishers involved. No landings were reported from TUA 9 for 2004–05 to 2010–11. Since 2011-12 landings have fluctuated, exceeding 5 t in 2012-13 and 2015-16, but dropping to 0.6 t in 2016-17. There were no landings reported in 2017–18 and 2018-19.

Table 1: Current Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) for tuatua.

Fishstock	TAC	Customary	Recreational	Other Mortality	TACC
TUA 1A	84	40	40	4	0
TUA 1B	126	60	60	6	0
TUA 2	7	3	3	1	0
TUA 3	7	3	3	1	0
TUA 4	3	1	1	1	0
TUA 5	3	1	1	1	0
TUA 7	3	1	1	1	0
TUA 8	5	1	1	1	0
TUA 9	102	26	26	7	43

Table 2: Reported landings (t) of tuatua (*Paphies subtriangulata*) by Fishstock from 1989–90 to the present day. Data up to 2003–04 taken from page 163 of MFish's Initial Position Paper (IPP), dated 31 March 2005, data since from CELR and CLR (early CELR and CLR data erroneously record commercial landings from FMA 9 as FMA 1 because permit holders were not filling in the forms correctly). There have been no reported landings of tuatua in TUA 5, TUA 6, and TUA 8. There were no landings reported from 2004–05 to 2010–11. Tuatua were introduced into the QMS on 1 October 2005; a TACC of 43 t was allocated (to TUA 9 only), and FMA 1 was divided into TUA 1A and TUA 1B.

Year	TUA 1	TUA 2	TUA 3	TUA 4	TUA 7	TUA 9	Total	TACC
1989–90	0	0	0	0	0	69.015	69.015	-
1990–91	0	0	0	0	0.176	68.245	68.421	-
1991–92	0	0	0	0	1.667	82.002	83.669	-
1992–93	0	0	0	0	0.891	109.280	110.171	-
1993–94	0	0	0.042	0	0	177.165	177.207	-
1994–95	0	0	0	0	0	182.262	182.262	-
1995–96	0	0	0	0	0	100.016	100.016	-
1996–97	0	0	0.125	0	0.005	68.575	68.705	-
1997–98	0	0	0.184	0	0	192.262	192.446	-
1998–99	0	0	0	0	0	76.205	76.205	-
1999–00	0	0	0	0	0	44.450	44.450	-
2000–01	0	0	0	0	0	16.150	16.150	-
2001–02	0	0	0	0	0	4.900	4.900	-
2002–03	0	0	0	0	0	36.160	36.160	-
2003–04	0	0	0.054	0	0	34.336	34.390	-
2004–05	0	0	0	0	0	0	0	-
2005–06	0	0	0	0	0	0	0	43
2006–07	0	0	0	0	0	0	0	43
2007–08	0	0	0	0	0	0	0	43
2008–09	0	0	0	0	0	0	0	43
2009–10	0	0	0	0	0	0	0	43
2010–11	0	0	0	0	0	0	0	43
2011–12	0	0	0	0	0	4.881	4.881	43
2012–13	0	0	0	0	0	5.294	5.294	43
2013–14	0	0	0	0.02	0	0	0.02	43
2014–15	0	0	0	0	0	1.801	1.801	43
2015–16	0	0	0	0	0	5.939	5.939	43
2016–17	0	0	0	0	0	0.58	0.58	43
2017–18	0	0	0	0	0	0	0	43
2018-19	0	0	0.004	0	0	0	0.004	43

1.2 Recreational fisheries

Tuatua support an extensive recreational fishery, with harvesting occurring in all stocks wherever there are accessible beds, particularly in the upper North Island. Tuatua are harvested entirely by hand gathering, and there is no MLS (although large tuatua are preferred). There is a recreational daily catch limit of 150 tuatua per person, except in the Auckland - Coromandel region where the limit has been 50 per day per person since November 1999.

The harvest estimates provided by telephone-diary surveys between 1993 and 2001 are no longer considered reliable for various reasons but a more reliable National Panel Survey was conducted for the first time throughout the 2011–12 fishing year. 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 harvest information collected in standardised phone interviews. The panel survey was repeated in 2017-18 (Wynne-Jones et al. 2019). Harvest estimates (in numbers of tuatua) are given in Table 3 (from Wynne-Jones et al 2014 and Wynne-Jones et al. 2019).

Table 3: Recreational harvest estimates for paua stocks from the national panel survey in 2011–12 (Wynne-Jones et al. 2014) and 2017–18 (Wynne-Jones et al. 2019). Mean weights were not available from boat ramp surveys to convert these estimates to weights.

Stock	Number of tuatua	CV
2011–12 (national panel survey)		
TUA 1A	297 826	0.45
TUA 1B	267 380	0.52
TUA 2	14 222	0.84
TUA 3	2 102	0.77
TUA 7	14 503	0.88
TUA 8	42 608	0.47
TUA 9	231 109	0.49
TUA total	869 751	0.26
2017–18 (national panel survey)		
TUA 1A	31 059	0.72
TUA 1B	249 308	0.57
TUA 2	9 205	0.78
TUA 3	11 439	0.71
TUA 5	10 629	1.00
TUA 7	3 020	1.01
TUA 8	29 998	0.72
TUA 9	219 744	0.40
TUA total	564 401	

1.3 Customary non-commercial fisheries

In common with many other intertidal shellfish, tuatua are an important customary species taken as kaimoana. Both oral tradition and the numerous middens of *P. triangulata* shells around the coastline clearly show that this fishery has been an important one to Maori for at least several hundred years. Very limited quantitative information on the level of customary take is available from Fisheries New Zealand (Table 4). These numbers are likely to be an underestimate of customary harvest as only the catch in kilograms and numbers are reported in the table.

Table 4: Fisheries New Zealand records of customary harvest of tuatua (reported as weight (kg) and numbers), since 2001–02. – no data.

	TUA 1A				TUA 1B			
	Weight (kg)		Numbers		Weight (kg)		Numbers	
Fishing year	Approved	Harvested	Approved	Harvested	Approved	Harvested	Approved	Harvested
2001–02	–	–	–	–	–	–	–	–
2002–03	–	–	–	–	–	–	–	–
2003–04	–	–	–	–	–	–	–	–
2004–05	–	–	–	–	–	–	–	–
2005–06	–	–	–	–	–	–	–	–
2006–07	–	–	–	–	–	–	–	–
2007–08	–	–	–	–	75	25	–	–
2008–09	–	–	–	–	346	285	–	–
2009–10	75	75	–	–	215	180	2 000	2 000
2010–11	100	100	–	–	50	30	–	–
2011–12	–	–	–	–	–	–	–	–
2012–13	–	–	–	–	–	–	–	–
2013–14	–	–	–	–	–	–	–	–
2014–15	–	–	–	–	–	–	–	–
2015–16	–	–	–	–	–	–	–	–
2016–17	–	–	–	–	35	35	–	–
2017–18	–	–	–	–	–	–	400	400
2018-19	–	–	–	–	–	–	–	–

	TUA 2				TUA 3			
	Weight (kg)		Numbers		Weight (kg)		Numbers	
Fishing year	Approved	Harvested	Approved	Harvested	Approved	Harvested	Approved	Harvested
2001–02	–	–	–	–	–	–	60	60
2002–03	–	–	–	–	–	–	–	–
2003–04	–	–	300	265	–	–	–	–
2004–05	–	–	–	–	–	–	–	–
2005–06	–	–	–	–	–	–	–	–
2006–07	–	–	–	–	–	–	–	–
2007–08	–	–	–	–	–	–	–	–
2008–09	–	–	–	–	–	–	–	–

Table 4 [Continued]:

	TUA 2				TUA 3			
	Weight (kg)		Numbers		Weight (kg)		Numbers	
Fishing year	Approved	Harvested	Approved	Harvested	Approved	Harvested	Approved	Harvested
2009–10	–	–	–	–	–	–	–	–
2010–11	–	–	–	–	–	–	150	150
2011–12	–	–	–	–	–	–	–	–
2012–13	–	–	–	–	–	–	–	–
2013–14	–	–	–	–	–	–	–	–
2014–15	–	–	–	–	–	–	–	–
2015–16	–	–	–	–	–	–	–	–
2016–17	–	–	–	–	–	–	–	–
2017–18	–	–	–	–	–	–	–	–
2018-19	–	–	–	–	–	–	–	–

	TUA 4				TUA 9			
	Weight (kg)		Numbers		Weight (kg)		Numbers	
Fishing year	Approved	Harvested	Approved	Harvested	Approved	Harvested	Approved	Harvested
2001–02	–	–	–	–	–	–	60	60
2002–03	–	–	–	–	–	–	–	–
2003–04	–	–	–	–	–	–	–	–
2004–05	–	–	–	–	–	–	–	–
2005–06	–	–	–	–	–	–	–	–
2006–07	–	–	–	–	–	–	–	–
2007–08	–	–	–	–	–	–	–	–
2008-09					–	–	–	–
2009–10	–	–	300	300	–	–	–	–
2010–11	–	–	–	–	100	100		
2011–12	–	–	–	–	–	–	–	–
2012–13	–	–	–	–	–	–	–	–
2013–14	–	–	–	–	–	–	–	–
2014–15	–	–	100	100	–	–	–	–
2015–16	–	–	–	–	–	–	–	–
2016–17	–	–	100	100	–	–	–	–
2017–18	2	2	–	–	–	–	–	–
2018-19	–	–	–	–	–	–	–	–

1.4 Illegal catch

The illegal catch of tuatua is probably significant in some areas, with some recreational fishers exceeding their bag limit, but no quantitative information on the level of illegal catch is available.

1.5 Other sources of fishing-related mortality

No quantitative information on the level of other sources of mortality is available. Tuatua are generally sedentary and beds are susceptible to localised depletion, not only by harvesting pressure, but also by habitat disturbance and degradation. Incidental mortality of tuatua is likely in the Kaipara Harbour dredge fishery if tuatua are damaged during encounters with the dredge. Changes in bank stability could arise from dredging operations and might cause additional incidental mortality. However, the level of dredge-related mortality is unknown. As suspension feeders, tuatua may also be adversely affected by high sedimentation loads in the water column. In some areas, such as Ninety Mile Beach, Dargaville and Muriwai, vehicles driven along the beach pass directly over tuatua beds, increasing mortality either directly by damaging tuatua or indirectly by adversely modifying surface sand conditions leading to desiccation of tuatua.

2. BIOLOGY

Tuatua (*Paphies subtriangulata*) belong to the family Mesodesmatidae, a group of moderate to large wedge-shaped surf clams that include toheroa (*Paphies ventricosum*), deepwater tuatua (*Paphies donacina*), and pipi (*Paphies australis*). *P. subtriangulata* is extensively distributed around New Zealand in localised abundant populations, but mainly occurs around the North Island, and at more scattered locations in the northern South Island, Stewart Island, and the Chatham Islands.

Tuatua are ecological markers of fine, clean, fluid sands on ocean beaches with moderate wave exposure The densest beds are found in the zone from the low intertidal to the shallow subtidal (down to about 4 m depth). The tuatua is a suspension feeder with short siphons. It is usually wedged only a few centimetres into the sand, with the straight siphonal end often characteristically exposed and discoloured by a green or brown algal film. Individuals are often dragged about the surface and redistributed by swash and backwash before actively burrowing back into the sand.

Tuatua have separate sexes (1:1 sex ratio) and reproduce by broadcast spawning, synchronously releasing eggs and sperm into the water column for external fertilisation. In north-eastern New Zealand, two main spawning periods have been documented, one between September and November, the other between February and April. Spawning events have been observed *in situ* at high water on a number of occasions, with only a small proportion of the population participating in each event. These spawning events were synchronous with pipi spawning in the same area.

Planktonic larval development takes about two to three weeks, so larvae have the potential to disperse widely if conditions allow. Larval settlement is thought to occur high in the intertidal, but spat and juveniles are highly mobile, moving around with the tidal flow before reburying themselves rapidly. Tuatua appear to migrate down the beach to occupy the lower intertidal and shallow subtidal as they grow larger. Growth appears to be rapid but variable, with tuatua reaching 40–70 mm shell length in about 3 years. Maximal length is variable among areas, ranging from about 50 to 80 mm, and the maximum age is probably about 5 or more years. Highly variable recruitment has been observed on the northwest coast of the North Island, and this is likely to occur in other areas. As in other surf clams, natural mortality is likely to be high.

A length-weight relationship has been estimated for tuatua sampled from East Auckland, and a southern population (probably Dunedin) where weight (in g) = a (length (in mm))^b, where a = 0.2×10^{-3} and b = 2.927. Data source: D. Allen unpublished data. Because the samples were from one northern and one southern population, the estimated relationship may not be representative of other populations.

3. STOCKS AND AREAS

Little is known of the stock structure of tuatua. There have been no biological studies directly relevant to the identification of separate stocks of *P. subtriangulata* around New Zealand, although “stocks” are likely to be linked by larval dispersal. For management purposes stock boundaries are based on FMAs, with the exception of TUA 1, which was divided into TUA 1A and TUA 1B on either side of Te Arai Point because there are likely to be significant differences in the state and use of the tuatua beds between the Northland and Hauraki Gulf / Bay of Plenty areas, and the respective alignment of recreational and customary fishing interests to those management areas. The circulation patterns that maintain the separation of the surf zone habitat to form a self-contained ecosystem also retain planktonic larvae of surf clams probably isolating surf clams genetically as well as ecologically.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any tuatua fishstock.

4.2 Biomass estimates

There is no time series of biomass surveys for tuatua either in the bed in the Kaipara Harbour entrance where commercial harvesting by dredge occurs now, or anywhere else that would indicate whether tuatua populations are changing in response to past and current levels of harvesting.

4.3 Yield estimates and projections

MCY has not been estimated for *P. subtriangulata*.

CAY has not been estimated for *P. subtriangulata*.

5. STATUS OF THE STOCKS

There are no estimates of biomass or sustainable yields of tuatua for any tuatua stock and the status of all stocks is unknown. Because natural mortality is high and recruitment is variable, the biomass of tuatua is likely to be highly variable.

- **TUA -** *Paphies subtriangulata*

Stock Status	
Year of Most Recent Assessment	No formal assessment conducted for any of the stocks
Assessment Runs Presented	Recruited biomass (shells ≥ 50mm)
Reference Points	Target: Undefined Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold:
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	-

Historical Stock Status Trajectory and Current Status -

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Landings are less than a quarter of the TACC and have generally been declining since 2002–03.

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	-

Assessment Methodology and Evaluation		
Assessment Type	-	
Assessment Method	-	
Assessment Dates	-	Next assessment: Unknown
Overall assessment quality rank		
Main data inputs (rank)		
Data not used (rank)		
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Landings are thought to have been declining in recent times because of economic rather than biological reasons.

Fishery Interactions
Interactions with other species are currently being characterised.

6. FOR FURTHER INFORMATION

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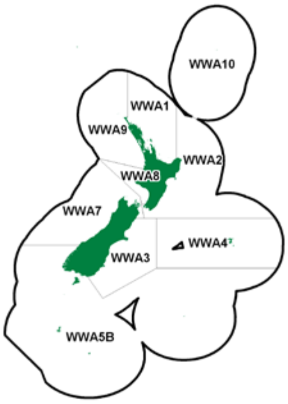
WHITE WAREHOU (WWA)

(Seriolella caerulea)
Warehou



1. FISHERY SUMMARY

1.1 Commercial fisheries

White warehou are predominantly taken as bycatch from target trawl fisheries on hoki and silver warehou, and to a lesser extent, hake, ling and scampi. White warehou are mostly caught in 150 to 800 m depth by larger vessels owned or chartered by New Zealand fishing companies.

Prior to the establishment of the EEZ on 1 March 1978, white warehou landings were combined with both silver and blue (or common) warehou as 'warehous'. An estimate of total white warehou catches for 1970 to 1977 calendar years has been made (Table 1). From 1978–79 to 1982–83 annual catches of up to 900 t during the fishing year were reported, mainly from Southland and the Chatham Rise (Table 2).

Annual catches of white warehou have been variable, ranging from 315 t in the 1978–79 fishing year to 3 694 t in 1996–97 (Tables 2 and 3). White warehou entered the Quota Management System on 1 October 1998, with an initial Total Allowable Commercial Catch (TACC) of 3 374 t. The TACCs for each QMA are given in Table 3. A nominal allowance of 1 t was made for both recreational and customary catch in each of WWA 2–7. TACCs were increased from 1 October 2006 in WWA 3 to 583 t, in WWA 4 to 330 t, and in WWA 7 to 127 t. In these stocks, landings had previously been above the TACC for a number of years; the TACCs were increased to the average of the previous 7 years plus an additional 10%. Despite this change the catch in WWA 3 in 2006–07 was well above the new TACC, but has been under the TACC since 2007–08. From 1 October 2007, WWA 5 was merged with WWA 6 to create WWA 5B, with a TACC of 2 617 t. TACCs have been under-caught in WWA 3, 4 and 5B in recent years. In WWA 7 landings have fluctuated, approaching the available quota in the fishing years 2012-13 and 2013-14, and exceeding it in 2017-18. By contrast only 44 t and 40 t of landings were recorded in 2015-16 and 2018-19 respectively, with 40 t being the lowest reported annual catch since the mid-1980s. Figure 1 shows the historical landings and TACC values for the main white warehou stocks.

White warehou are almost entirely caught from 300–700 m bottom trawls targeted on hoki, squid, ling and silver warehou (Ballara & Baird 2012), with a smaller amount caught by midwater trawl Until the introduction of electronic reporting by the >28m trawl fleet on 1 October 2017, most catch was recorded on Trawl Catch Effort and Processing Returns. In 2013 and 2014, about 20% of the west coast South Island (WCSI) white warehou catch was reported on the TCER form (Ballara 2015). From 1990 to 2014, 52 238 t of white warehou catch was reported: 70% from the Sub-Antarctic area, 24% from off the east coast South Island (ECSI) and across the Chatham Rise, and 4% from the WCSI (Ballara 2015).

Target fishing on white warehou has been reported from around Mernoo Bank, the Stewart-Snares shelf, Puysegur Bank and on the west coast of the South Island, with the best catch rates recorded in the southern areas. Target fisheries accounted for only 8% of the total white warehou catch for the years from 1988–89 to 1994–95. In the Sub-Antarctic, 36% of catches are from target fishing, although since 2003 this has been over 50% in most years; the remainder was primarily from tows targeting ling, hoki, and silver warehou (Ballara 2015). The greatest catches in this area are from waters off the Stewart-Snares shelf, near the Puysegur Bank, and off the Auckland Islands Shelf. About 63% of the catch from off the ECSI and the Chatham Rise was from hoki target tows, with only 1% from white warehou targeted tows (Ballara 2015). The highest catches were from the east coast statistical areas. There appeared to be no definite season for white warehou catches in those areas. Catches off the WCSI were from bottom and mid-water hoki and hake tows, and were restricted to the months in which those target fisheries operated (June–September).

Table 1: Estimated catch (t) of white warehou for years 1970 to 1977.

Vessel nationality	1970*	1971*	1972	1973	1974	1975	1976	1977
Japanese	17	25	222	447	234	1 453	1 558	334
Russian	NA	NA	1 300	1 200	1 480	40	440	1 260
Korean	-	-	-	-	-	-	-	400
Total	17	25	1 522	1 647	1 714	1 493	1 998	1 994

* Japanese data only.

Table 2: Reported landings (t) of white warehou by fishing year and area, by foreign licensed and joint venture vessels, 1978–79 to 1983–83. The EEZ areas correspond approximately to the QMAs as indicated. Fishing years are from 1 April to 31 March. The 1983–83 is a six month transitional period from 1 April to 30 September. No data are available for the 1980–81 fishing year.

EEZ area	B	C(M)	C(1)	D	E(B)	E(P)	E(C)	E(A)	F(E)	F(W)	G	H	
QMA area	1& 2		3	4				6		5	7	8 & 9	Total
1978–79	1	20	10	1	0	5	0	141	86	26	20	6	315
1979–80	2	8	5	230	57	5	4	312	34	97	42	0	795
1980–81	-	-	-	-	-	-	-	-	-	-	-	-	-
1981–82	0	41	2	53	0	2	5	153	27	248	10	1	542
1982–83	0	375	1	88	0	11	0	198	39	137	33	0	882
1983–84	0	167	5	49	0	0	0	12	9	34	24	0	300

Note: The EEZ area E(A) also included part of QMA 5, south of 48º30' S.

Table 3: Reported landings (t) of white warehou by fishstock and fishing year, 1982–83 to 2018–19. The data in this table has been updated from that published in previous Plenary Reports by using the data through 1996–97 in table 44 on p. 296 of the "Review of Sustainability Measures and Other Management Controls for the 1998–99 Fishing Year - Final Advice Paper" dated 6 August 1998. Data since 1997–98 are based on catch and effort returns. There are no landings reported from QMA 10. [Continued on next page]

Fishstock	WWA 1		WWA 2		WWA 3		WWA 4		WWA 5(5B)*	
FMA		1		2		3		4		5 (&6)*
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1982–83	0	-	35	-	179	-	69	-	248	-
1983–84	0	-	28	-	111	-	33	-	282	-
1984–85	0	-	2	-	123	-	39	-	150	-
1985–86	0	-	5	-	589	-	61	-	277	-
1986–87	0	-	10	-	239	-	29	-	167	-
1987–88	<1	-	9	-	431	-	26	-	113	-
1988–89	6	-	1	-	118	-	43	-	843	-
1989–90	1	-	9	-	484	-	16	-	555	-
1990–91	2	-	12	-	695	-	88	-	568	-
1991–92	6	-	22	-	589	-	113	-	833	-
1992–93	2	-	13	-	281	-	106	-	560	-
1993–94	6	-	34	-	197	-	23	-	1 235	-
1994–95	4	-	41	-	327	-	243	-	1 936	-
1995–96	2	-	68	-	566	-	137	-	1 555	-
1996–97	3	-	89	-	508	-	220	-	2 309	-
1997–98	2	-	31	-	516	-	153	-	1 217	-
1998–99	<1	4	34	73	398	399	120	220	1 269	2 127
1999–00	<1	4	48	73	559	399	277	220	1 112	2 127
2000–01	<1	4	21	73	661	399	303	220	703	2 127
2001–02	0	4	8	73	446	399	262	220	921	2 127
2002–03	<1	4	20	73	852	399	397	220	1 462	2 127
2003–04	<1	4	47	73	458	399	365	220	1 141	2 127
2004–05	<1	4	24	73	347	399	365	220	1 568	2 127
2005–06	<1	4	35	73	589	399	312	220	1 176	2 127
2006–07	<1	4	10	73	733	583	304	330	1 484	2 127
2007–08	<1	4	43	73	345	583	207	330	*1 431	*2 617

Table 3 [Continued]

Fishstock	WWA 1		WWA 2		WWA 3		WWA 4		WWA 5(5B)*	
FMA	1		2		3		4		5 (&6)*	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2008–09	<1	4	22	73	302	583	85	330	1 644	2 617
2009–10	<1	4	7	73	355	583	179	330	1 106	2 617
2010–11	<1	4	12	73	391	583	81	330	787	2 617
2011–12	<1	4	3	73	204	583	112	330	978	2 617
2012–13	<1	4	6	73	174	583	117	330	1 037	2 617
2013–14	<1	4	8	73	302	583	110	330	1 373	2 617
2014–15	<1	4	7	73	225	583	69	330	447	2 617
2015–16	<1	4	5	73	269	583	51	330	699	2 617
2016–17	<1	4	5	73	288	583	52	330	637	2 617
2017–18	<1	4	6	73	282	583	57	330	649	2 617
2018–19	<1	4	5	73	212	583	91	330	681	2 617

Fishstock	WWA 6		WWA 7		WWA 8		WWA 9			
FMA	6		7		8		9		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1982–83	7	-	24	-	<1	-	0	-	562	-
1983–84	24	-	29	-	<1	-	0	-	510	-
1984–85	12	-	15	-	<1	-	0	-	342	-
1985–86	43	-	81	-	<1	-	0	-	1 058	-
1986–87	144	-	15	-	<1	-	0	-	573	-
1987–88	20	-	28	-	<1	-	0	-	629	-
1988–89	16	-	10	-	0	-	0	-	1 040	-
1989–90	291	-	83	-	0	-	0	-	1 438	-
1990–91	278	-	69	-	1	-	0	-	1 713	-
1991–92	1 028	-	45	-	0	-	0	-	2 636	-
1992–93	645	-	125	-	2	-	0	-	1 734	-
1993–94	592	-	69	-	0	-	0	-	2 156	-
1994–95	185	-	80	-	0	-	0	-	2 816	-
1995–96	50	-	62	-	0	-	0	-	2 440	-
1996–97	494	-	71	-	0	-	0	-	3 694	-
1997–98	126	-	98	-	<1	-	<1	-	2 155	-
1998–99	412	490	73	60	<1	1	0	0	2 306	3 374
1999–00	211	490	153	60	<1	1	0	0	2 351	3 374
2000–01	119	490	90	60	<1	1	0	0	1 897	3 374
2001–02	219	490	85	60	<1	1	<1	0	1 941	3 374
2002–03	457	490	158	60	0	1	0	1	3 346	3 374
2003–04	211	490	135	60	0	1	0	1	2 357	3 374
2004–05	436	490	123	60	<1	1	0	1	2 863	3 374
2005–06	250	490	133	60	0	1	0	1	2 495	3 374
2006–07	563	490	121	127	0	1	0	0	3 215	3 735
2007–08	N/A	N/A	90	127	0	1	<1	0	2 116	3 735
2008–09	N/A	N/A	110	127	<1	1	<1	0	2 164	3 735
2009–10	N/A	N/A	44	127	<1	1	0	0	1 691	3 735
2010–11	N/A	N/A	52	127	<1	1	0	0	1 324	3 735
2011–12	N/A	N/A	77	127	<1	1	<1	0	1 375	3 735
2012–13	N/A	N/A	118	127	<1	1	0	0	1 452	3 735
2013–14	N/A	N/A	115	127	<1	1	<1	0	1 908	3 735
2014–15	N/A	N/A	98	127	0	1	0	0	846	3 735
2015–16	N/A	N/A	44	127	0	1	<1	0	817	3 735
2016–17	N/A	N/A	87	127	0	1	0	0	1 069	3 735
2017–18	N/A	N/A	139	127	0	1	0	0	1 134	3 735
2018–19	N/A	N/A	40	127	<1	1	<1	0	1 029	3 735

* In 2007–08 WWA 5 was merged with WWA 6 to create WWA 5B. The landings and TACC for WWA 5B are presented after 2007–08 in the WWA 5(5B)* column.

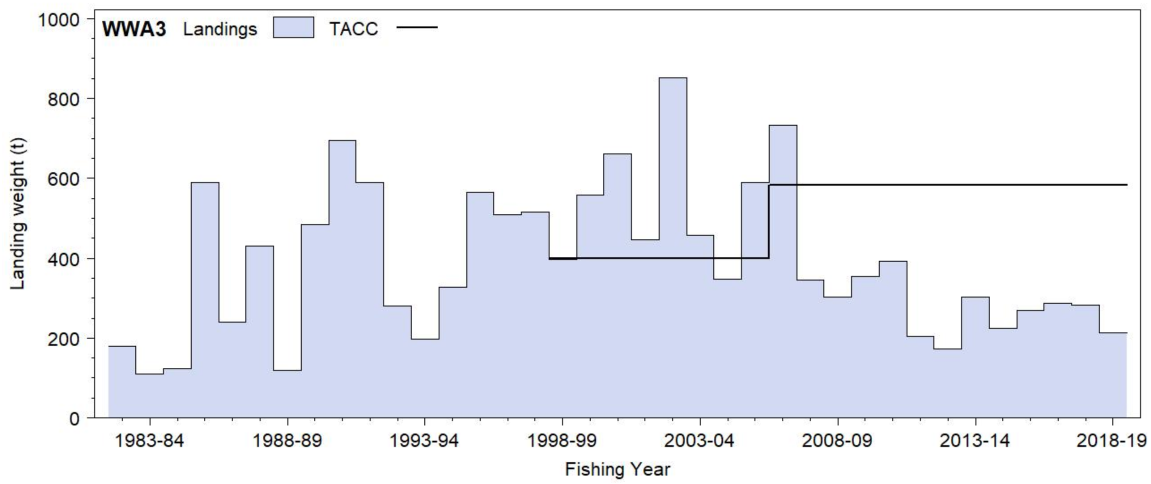
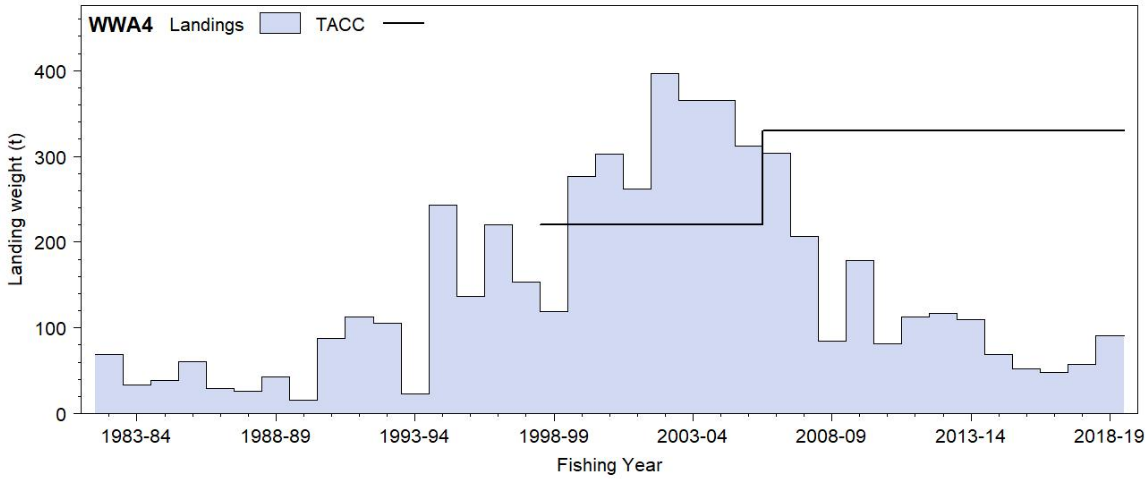
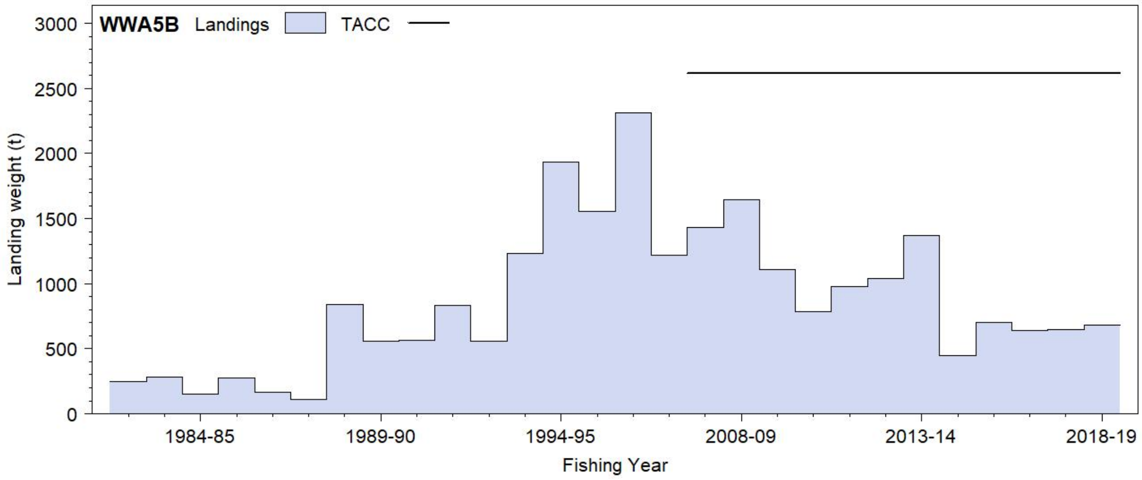


Figure 1: Reported commercial landings and TACC for the four main WWA stocks. WWA 3 (South East Coast). [Continued on next page]





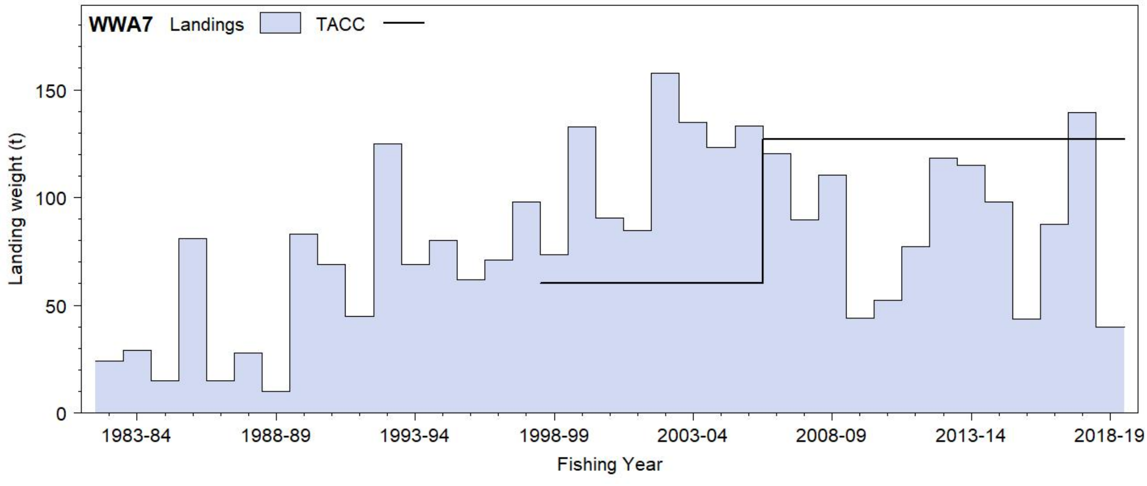


Figure 1 [Continued]: Reported commercial landings and TACC for the four main WWA stocks. WWA 4 (South East Chatham Rise) and WWA 5B* (Southland, Sub-Antarctic) and WWA 7 (Challenger).

1.2 Recreational fisheries

The recreational take of white warehou is likely to be very small given its distribution and depth preferences.

1.3 Customary non-commercial fisheries

No quantitative information is available on the current level of customary non-commercial take.

1.4 Illegal catch

Silver warehou were reported as white warehou when the latter was a non QMS species. Compliance investigations in 1988 successfully proved that substantial quantities of silver warehou were reported as white warehou, but catch statistics were not altered as a result. The true extent of misreporting is unknown and thus the accuracy of annual catch records cannot be determined.

1.5 Other sources of mortality

No information is available on other sources of mortality.

2. BIOLOGY

Adult white warehou range between 40 and 60 cm fork length (FL) and reach a maximum length and weight of 67 cm and 5.7 kg respectively. White warehou were aged by Gavrilov (1979) who gives the maximum age as 12 years, but this was likely to be an underestimate because he read whole otoliths and scales (Horn & Sutton 1996). Ageing of white warehou was partially validated by Horn (1999, 2001), based on a dataset of otoliths, covering all months of the year, collected during 1992–98 from the Chatham Rise and Sub-Antarctic. Growth of females is significantly faster than that of males and thus females are significantly larger at age than males (Horn 2001). Females also attain larger maximum size than males. Fish grow rapidly until they spawn (at about 3 or 4 years), and growth is much slower after 6–8 years (Horn 2001).

Table 4: Estimates of biological parameters of white warehou.

Fishstock							Estimate	Source
	1. Weight = a(length)^b (Weight in g, length in cm, total length).							
	Female		Male		Both sexes			
	a	b	a	b	a	b		
Chatham Rise	0.0177	3.069	0.0247	2.981	0.0200	3.037		Horn (1999)
Sub-Antarctic	0.0106	3.197	0.0138	3.132	0.0111	3.188		Horn (1999)

	2. von Bertalanffy growth parameters (4-parameter curve)								
	Female				Males				
	L_∞	k	t_0	P	L_∞	k	t_0	P	
Chatham Rise	61.0	0.131	0.14	0.350	57.1	0.153	0.19	0.328	Horn (2001)
Sub-Antarctic	70.2	.058	0.22	0.281	62.4	0.098	0.14	0.297	Horn (2001)

Instantaneous natural mortality (M) was estimated (sing several methods) to be between 0.20 and 0.28, and to be higher for males relative to females (Horn 1999). The Working Group considered the data inadequate for establishing a difference in M by sex and recommended the use 0.25 for both sexes in any stock assessment modelling with sensitivity tests of plus or minus 0.05.

Ripe and running ripe fish have been recorded from the ECNI, Chatham Rise, WCSI, off Puysegur, and in the Sub-Antarctic, especially off the Stewart-Snares shelf. Most ripe and running ripe females were seen in waters off the WCSI in July–October, in the Sub-Antarctic (off Puysegur and between the Stewart-Snares shelf and the Auckland Islands Shelf) in March–December, and the western Chatham Rise from May–October) (Ballara 2015). These data suggest that the spawning season may extend from winter to late spring, or that there are multiple stocks with differences in the timing of their spawning seasons.

Sex ratio data derived from scaled length frequencies appear to show a slight bias towards males. On the Chatham Rise sex ratios vary from 1.0:1 to 1.4:1 (males to females). In the southern area, ratios vary from 0.7:1 to 4.2:1, but sample sizes at either extreme of the range are very small. There are insufficient data to enable detection of any changes in sex ratio with season.

Feeding records from the Fisheries New Zealand research database *trawl* show salps as the predominant prey item observed in white warehou stomachs. Gavrilov & Markina (1979) noted salps (*Iasis*) and the tunicate *Pyrosoma* as major food items. Horn et al (2011) found that the diet on the Chatham Rise was dominated by pelagic tunicates (mainly *Iasis* and *Salpa* species), with the remainder comprising mostly small crustaceans (amphipods, copepods, and euphausiids). An unknown but small component of the crustacean prey was ingested unintentionally owing to a common commensal relationship between some crustaceans (primarily amphipods) and tunicates.

3. STOCKS AND AREAS

The existence of three possible spawning areas for white warehou (Mernoo Bank, Puysegur Bank and the west coast of the South Island) at the same time of year, suggests the possibility of three separate stocks. Bagley & Hurst (1997) proposed the following Fishstock areas: WWA 1 (QMAs 1, 2, 3 and 4), WWA 5 (QMAs 5 and 6) and WWA 7 (QMAs 7, 8 and 9) for white warehou. However, TACs were set for each QMA (1–9) in 1998 and each Fishstock is managed separately (note WWA 5 and WWA 6 were merged to form Fishstock WWA 5B in 2007–08).

4. STOCK ASSESSMENT

No assessments are available for any stocks for white warehou, therefore estimates of biomass and yield are not available.

4.1 Estimates of fishery parameters and abundance

CPUE analyses were carried out for Chatham Rise and Sub-Antarctic fisheries (Ballara 2015). The Chatham Rise stock showed increased CPUE from 1994 to 2006, but flatter since then (Table 5). The pattern did not match the trawl survey but neither series indicates a problem with WWA abundance in this area. The Sub-Antarctic fishery showed an initial decline to 1997 but was very flat since then (Table 5). There is little data available for the WCSI fishery with low catches and many years with less than 100 records. There are quite strong impacts of varying vessels and target species and the WG queried the reliability of the CPUE as abundance indicators.

Table 5: Chatham Rise and Sub-Antarctic TCEPR tow-by-tow lognormal CPUE indices by fishing year, where 1993–94 is 1994.

Year	Chatham Rise	Sub-Antarctic	Year	Chatham	Sub-Antarctic
1992	-	1.73	2004	1.34	0.75
1993	-	1.26	2005	1.14	0.82
1994	0.67	2.00	2006	1.45	0.87
1995	0.79	2.57	2007	1.39	0.94
1996	0.71	2.69	2008	1.10	0.93
1997	0.75	1.03	2009	1.04	0.78
1998	0.75	0.80	2010	1.22	0.79
1999	0.73	1.24	2011	1.11	0.71
2000	0.82	0.93	2012	1.16	0.63
2001	0.95	0.79	2013	1.15	0.80
2002	0.87	0.67	2014	1.20	0.83
2003	1.23	0.75			

4.2 Biomass estimates

Several time series of relative abundance estimates are available from trawl surveys, but these estimates may not be reliable indicators of relative abundance because of large fluctuations between years and moderate to high CVs. The larger biomass estimates are generally associated with moderate to high CVs (i.e., over 40%), having resulted from one or two large catches. Smaller biomass estimates have lower CVs, but this could be because the survey missed the main white warehou schools.

The Chatham Rise trawl surveys show an increase in biomass up until 2004, then a decrease to 2010 and flat since then (Table 6, Figure 2). Although the CVs are quite high, the period of increased abundance coincided with stronger recruitment of small fish to the shallow strata in 2001 and 2002 and to the deeper strata in 2004. The length data from the surveys showed the progression of a mode from 30 cm in 2001 to 45 cm in 2004. The survey time series may be an adequate monitoring tool, despite the high CVs.

Table 6: Biomass indices (t) for white warehou from *Tangaroa* trawl surveys.

Year	Sub-Antarctic Summer (Nov–Dec)	Sub-Antarctic Autumn	Sub-Antarctic Spring	Southland	Chatham Rise Summer (Jan)	WCSI Winter
1991	1 605	-	-	-	-	-
1992	243	256	350	-	2 227	-
1993	293	907	-	18	2 939	-
1994	-	-	-	46	1 606	-
1995	-	-	-	2	734	-
1996	-	239	-	102	533	-
1997	-	-	-	-	2 287	-
1998	-	2 887	-	-	1 009	-
1999	-	-	-	-	3 136	-
2000	266	-	-	-	2 385	-
2001	2 433	-	-	-	4 262	12
2002	853	-	-	-	6 881	-
2003	709	-	-	-	3 685	-
2004	1 061	-	-	-	7 932	-
2005	538	-	-	-	4 542	-
2006	646	-	-	-	2 929	-
2007	1 707	-	-	-	2 853	-
2008	2 283	-	-	-	1 899	-
2009	2 093	-	-	-	3 667	-
2010	-	-	-	-	983	-
2011	390	-	-	-	1 861	-
2012	1 259	-	-	-	1 925	65
2013	-	-	-	-	2 030	26
2014	211	-	-	-	1 299	-

The Sub-Antarctic summer time series does not appear useful to monitor abundance. Length modes do not follow the series and CVs are high from occasional large catches. More stations in the area of white warehou abundance could possibly increase the utility of the survey. Autumn, spring, and the Southland surveys also do not appear to be useful, and the fish appear to remain in the southern area all year. Biomass estimates from the Chatham Rise survey are much higher than for the Sub-Antarctic survey, although catches are much lower.

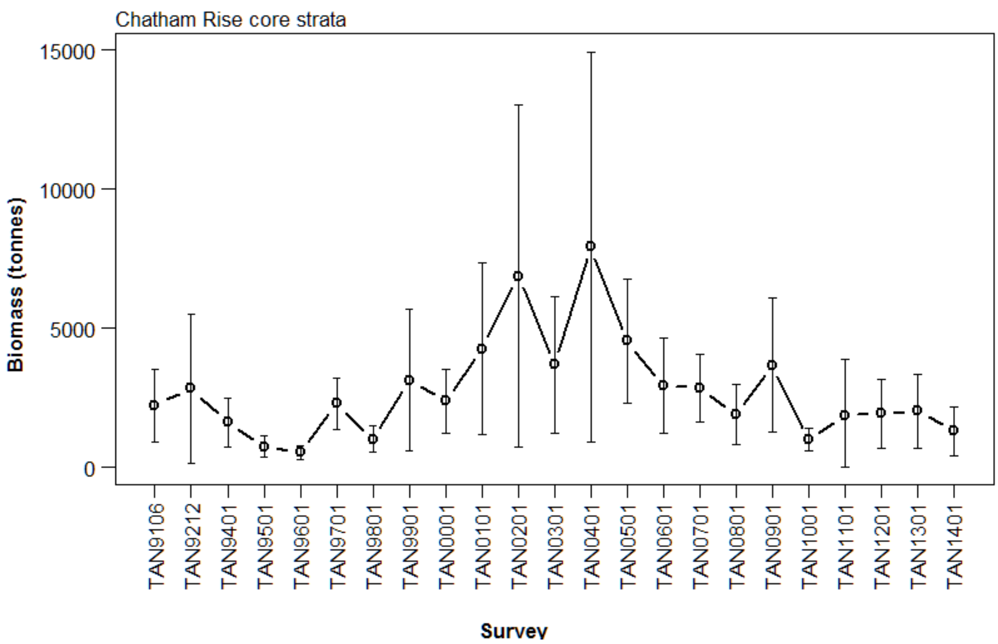


Figure 2: Doorspread biomass estimates, for all white warehou (± CV) from the Chatham Rise *Tangaroa* surveys from 1991 to 2014.

There were two recent surveys on the WCSI but these covered only the northern area. It appears that much of the WWA biomass is further down the WCSI so these surveys may not be able to monitor the stock abundance in WWA 7.

4.3 Yield estimates and projections

MCY cannot be determined. Problems with mis-reporting of silver warehou as white warehou and the lack of consistent catch histories make *MCY* estimates based on catch data alone unreliable. Also the amount of effort on white warehou relates very closely to effort on other target species such as hoki and silver warehou. Large fluctuations in the availability of white warehou to the trawl, as indicated by trawl surveys, are also likely to apply to commercial fishing operations. Estimates of *M* need to be determined.

CAY cannot be estimated because of the lack of current biomass estimates.

4.4 Other factors

None

5. STATUS OF THE STOCKS

It is not known whether recent catches are sustainable or if they are at levels that will allow the stock to move towards a size that will support the maximum sustainable yield.

TACCs were increased from 1 October 2006 in WWA 3 to 583 t, in WWA 4 to 330 t, and in WWA 7 to 127 t. In these stocks landings were above the TACC for a number of years and the TACCs have been increased to the average of the previous 7 years plus an additional 10%.

TACCs and reported landings for the 2017–18 fishing year are summarised in Table 7.

Table 7: Summary of TACCs (t), and reported landings (t) of white warehou for the most recent fishing year.

Fishstock		FMA	2017–18 Actual TACC	2017–18 Reported landings
WWA 1	Auckland (East)	1	4	< 1
WWA 2	Central (East)	2	73	6
WWA 3	South-east (Coast)	3	583	282
WWA 4	South-east (Chatham)	4	330	57
WWA 5B	Southland, Sub-Antarctic	5 & 6	2 617	649
WWA 7	Challenger	7	127	139
WWA 8	Central (West)	8	1	0
WWA 9	Auckland (West)	9	0	<1
WWA 10	Kermadec	10	0	0
Total			3 735	1 134

6. FOR FURTHER INFORMATION

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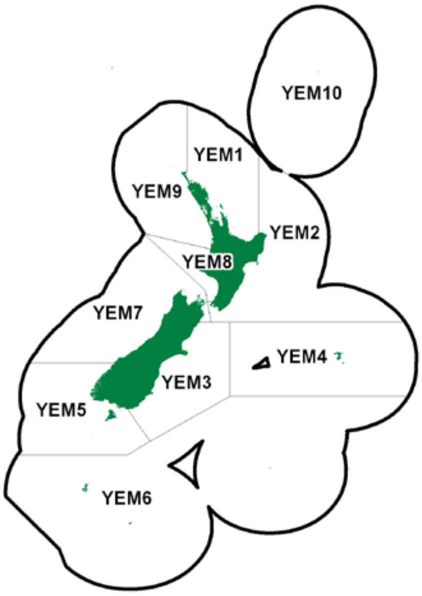
YELLOW-EYED MULLET (YEM)

(*Aldrichetta forsteri*)
Aua



1. FISHERY SUMMARY

1.1 Commercial fisheries

Yellow-eyed mullet entered the Quota Management System (QMS) on 1 October 1998. There is very little published information on the commercial fishery for yellow-eyed mullet apart from brief comments about its use as bait. From 1934 to 1972 information from catch records indicate that yellow-eyed mullet was taken by "other nets", meaning nets other than trawl or Danish seine. Catch by gear-type data from the Fisheries Statistics Unit (FSU) records between 1982–83 and 1988–89 show a predominant use of setnets and gillnets (about 95.5% of total catch) over beach seine and drag net (about 4.5% of total catch).

There is the potential for incorrect assignment of yellow-eyed mullet in landings records because of similarity in the common names of grey mullet and yellow-eyed mullet and the possibility that some fishers refer to both as *mullet*. A second possible classification error may arise from erroneous use of the names *herring* or *sprat*. The level of error in the landings data due to misidentification is not known.

Before 1960 the majority of the recorded landings of yellow-eyed mullet was taken in Northland. Between 1960 and 1968, there was a marked increase in landings from Lake Ellesmere. Regular records are also available for Napier beginning in 1941, and Manukau Harbour. Apart from Lake Ellesmere, records for the South Island are generally incomplete.

Pre-1980, landings of yellow-eyed mullet by QMA were low, perhaps as a result of under-reporting. Landings increased in the early 1980s due to an increase in landings in QMA 9, and to a lesser extent in QMA 1. In the 1990s landings in QMA 1 equaled and often exceeded landings in QMA 9. Landings have remained below 20 t in QMA 9 since the fishing year 1993-94 with the exception of the 1999–00 landings, which was almost triple that of the previous year and more than double the landings recorded in QMA 1. Most recently, in 2010-11 to 2018-19, an average of 14 t of annual landings were recorded in QMA 1, compared to 10 t in QMA 9.

Yellow-eyed mullet landings have fluctuated over time, with a peak of 68 t being recorded in 1986–87. The high landings recorded since the mid 1980s most likely reflect increased fishing in the Auckland area in response to an increase in market demand for yellow-eyed mullet. An annual average of 37 t of total landings were recorded between 1996–97 and 1999–2000, and an average of 27 t between 2000-01 and 2018-19. Strong seasonal trends are evident in the landings data for each QMA with annual peaks mostly in July–August, indicating a winter fishery.

A breakdown of the current Total Allowable Catch (TAC) is shown in Table 1. Historical estimated and recent reported yellow-eyed mullet landings and TACCs are shown in Tables 2 and 3, while Figure 1 shows the historical landings and TACC values for the main YEM stocks.

Commercial landings of yellow-eyed mullet have been generally been below the TACC in each QMA since this species was introduced into the QMS on 1 October 1998. YEM 8 and YEM 3 landings however exceeded the TACCs slightly in 2005-06 and 2014-15 respectively.

Table 1: Recreational and customary non-commercial allowances (t), Total Allowable Commercial Catches (TACC, t) and Total Allowable Catches (TAC, t) declared for YEM.

Fishstock		FMA	TAC	TACC	Customary	Recreational
YEM 1	Auckland (East)	1	50	20	15	15
YEM 2	Central (East)	2	14	2	4	8
YEM 3	South-east (Coast)	3	14	8	2	4
YEM 4	South-east (Chatham)	4	0	0	0	0
YEM 5	Southland	5	2	0	1	1
YEM 6	Sub-Antarctic	6	0	0	0	0
YEM 7	Challenger	7	20	5	5	10
YEM 8	Central (West)	8	18	3	5	10
YEM 9	Auckland (West)	9	38	30	4	4
Total			156	68	36	52

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	YEM 1	YEM 9	Year	YEM 1	YEM 9
1931-32	0	0	1957	19	0
1932-33	0	0	1958	22	0
1933-34	0	0	1959	20	0
1934-35	0	0	1960	9	0
1935-36	0	0	1961	20	0
1936-37	0	0	1962	19	1
1937-38	0	0	1963	8	1
1938-39	1	0	1964	9	0
1939-40	0	0	1965	6	3
1940-41	0	0	1966	4	5
1941-42	0	0	1967	23	4
1942-43	0	0	1968	19	2
1943-44	1	0	1969	17	2
1944	0	0	1970	17	1
1945	9	0	1971	14	1
1946	52	0	1972	7	1
1947	65	0	1973	0	0
1948	71	0	1974	0	0
1949	81	0	1975	11	0
1950	31	0	1976	11	0
1951	36	0	1977	2	0
1952	13	0	1978	1	0
1953	13	0	1979	1	0
1954	15	0	1980	2	1
1955	28	0	1981	5	4
1956	28	0	1982	4	2

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. 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 includes both foreign and domestic landings.

Table 3: Reported landings (t) of yellow-eyed mullet by fishstock and fishing year, 1983–84 to 2018–19. The data in this table has been updated from that published in previous Plenary Reports using the data through to 1996–97 in table 47 on p. 304 of the "Review of Sustainability Measures and Other Management Controls for the 1999–2000 Fishing Year - Final Advice Paper" dated 6 August 1998. There are no landings from FMA 10, which has a TACC of 0 [Continued next page].

Fishstock	YEM 1		YEM 2		YEM 3		YEM 4		YEM 5	
FMA	1		2		3		4		5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1982–83	2	-	35	-	3	-	0	-	0	-
1983–84	2	-	28	-	5	-	0	-	0	-
1984–85	12	-	2	-	1	-	0	-	0	-
1985–86	24	-	5	-	7	-	0	-	0	-
1986–87	14	-	10	-	4	-	0	-	0	-
1987–88	11	-	9	-	9	-	0	-	0	-
1988–89	3	-	1	-	4	-	0	-	0	-
1989–90	1	-	9	-	17	-	0	-	0	-
1990–91	21	-	12	-	13	-	0	-	0	-
1991–92	15	-	22	-	23	-	0	-	0	-
1992–93	32	-	13	-	1	-	1	-	0	-
1993–94	53	-	34	-	2	-	0	-	0	-
1994–95	32	-	41	-	1	-	0	-	0	-
1995–96	19	-	68	-	2	-	0	-	0	-
1996–97	32	-	89	-	7	-	< 1	-	0	-
1997–98	10	-	31	-	< 1	-	0	-	0	-
1998–99	16	10	34	1	7	6	0	0	0	0
1999–00	10	10	48	1	7	6	0	0	0	0
2000–01	9	10	21	1	5	6	0	0	0	0
2001–02	6	20	8	2	< 1	8	0	0	0	0
2002–03	9	20	< 1	2	4	8	0	0	0	0
2003–04	4	20	< 1	2	6	8	0	0	0	0
2004–05	4	20	< 1	2	1	8	0	0	< 1	0
2005–06	3	20	1	2	3	8	0	0	0	0
2006–07	5	20	< 1	2	5	8	0	0	< 1	0
2007–08	3	20	< 1	2	3	8	0	0	0	0
2008–09	6	20	< 1	2	< 1	8	0	0	0	0
2009–10	15	20	< 1	2	4	8	0	0	0	0
2010–11	10	20	< 1	2	7	8	0	0	0	0
2011–12	9	20	< 1	2	5	8	0	0	0	0
2012–13	14	20	<1	2	3	8	0	0	0	0
2013–14	15	20	<1	2	4	8	0	0	<1	0
2014–15	19	20	<1	2	9	8	0	0	<1	0
2015–16	16	20	<1	2	6	8	0	0	<1	0
2016–17	15	20	0	2	3	8	0	0	<1	0
2017–18	13	20	<1	2	4	8	0	0	<1	0
2018–19	16	20	<1	2	4	8	0	0	<1	0

Fishstock	YEM 6		YEM 7		YEM 8		YEM 9			
FMA	6		7		8		9		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1982–83	0	-	0	-	5	-	5	-	17	-
1983–84	0	-	0	-	5	-	26	-	26	-
1984–85	0	-	3	-	3	-	33	-	33	-
1985–86	0	-	4	-	2	-	61	-	61	-
1986–87	0	-	6	-	0	-	68	-	68	-
1987–88	0	-	4	-	0	-	43	-	43	-
1988–89	0	-	5	-	0	-	21	-	21	-
1989–90	0	-	0	-	3	-	11	-	11	-
1990–91	0	-	10	-	0	-	21	-	21	-
1991–92	0	-	14	-	1	-	25	-	25	-
1992–93	0	-	2	-	5	-	31	-	31	-
1993–94	0	-	3	-	4	-	20	-	20	-
1994–95	0	-	8	-	2	-	18	-	18	-
1995–96	0	-	4	-	0	-	10	-	10	-
1996–97	0	-	5	-	2	-	11	-	58	-
1997–98	0	-	0	-	0	-	2	-	12	-
1998–99	0	0	2	4	< 1	2	9	33	34	56
1999–00	0	0	1	4	< 1	2	26	33	44	56
2000–01	0	0	< 1	4	< 1	2	12	33	28	56
2001–02	0	0	3	5	0	3	15	30	24	68
2002–03	0	0	< 1	5	< 1	3	19	30	34	68
2003–04	0	0	1	5	0	3	11	30	22	68
2004–05	0	0	0	5	< 1	3	7	30	13	68
2005–06	0	0	0	5	4	3	4	30	14	68
2006–07	0	0	< 1	5	3	3	9	30	23	68
2007–08	0	0	< 1	5	2	3	9	30	17	68
2008–09	0	0	2	5	2	3	10	30	20	68
2009–10	0	0	2	5	3	3	5	30	30	68
2010–11	0	0	2	5	2	3	17	30	38	68
2011–12	0	0	< 1	5	2	3	13	30	29	68
2012–13	0	0	<1	5	2	3	5	30	25	68
2013–14	0	0	<1	5	<1	3	11	30	31	68

Table 3 [Continued]

Fishstock		YEM 6		YEM 7		YEM 8		YEM 9		
FMA		6		7		8		9		Total
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2014–15	0	0	<1	5	1	3	15	30	45	68
2015–16	0	0	<1	5	2	3	9	30	39	68
2016–17	0	0	<1	5	<1	3	5	30	24	68
2017–18	0	0	<1	5	<1	3	7	30	25	68
2018–19	0	0	<1	5	0	3	13	30	33	68

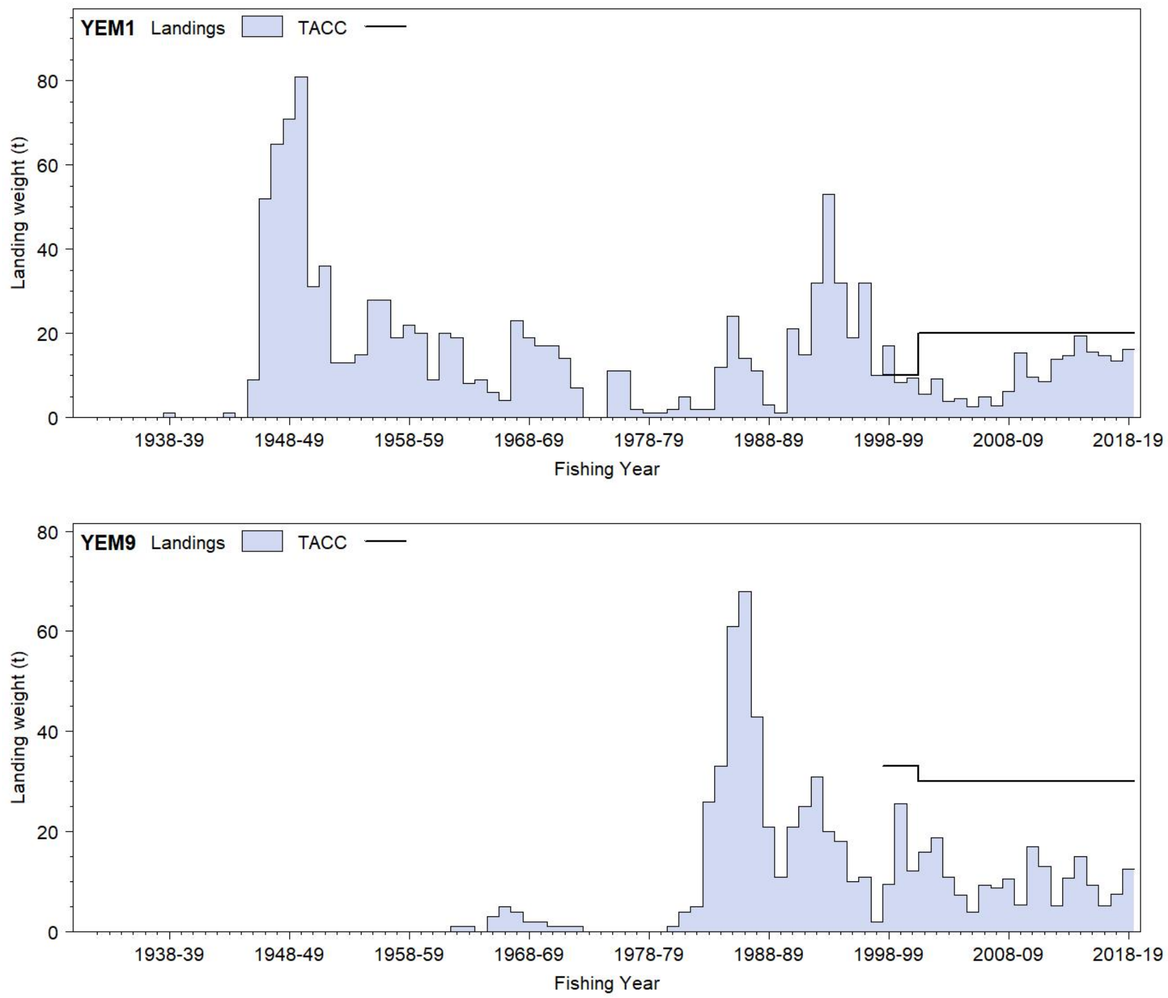


Figure 1: Reported commercial landings and TACCs for the two main YEM stocks. YEM 1 (Auckland East) and YEM 9 (Auckland West).

1.2 Recreational fisheries

Yellow-eyed mullet are a popular recreational species throughout New Zealand, particularly in YEM 1. Numbers of fish and harvest tonnages for yellow-eyed mullet taken by recreational fishers estimated using telephone-diary surveys are presented in Table 4. The harvest estimates provided by these telephone-diary surveys are no longer considered reliable for various reasons. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In addition, some confusion probably arises between grey and yellow-eyed mullet during surveys, and the incorrect use of names like herring and sprat adds further uncertainty.

In response to these problems and the cost and scale challenges associated with onsite methods, a National Panel Survey was conducted for the first time throughout 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 harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). Recreational catch estimates from the two national panel surveys are given in Table 5. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

Table 4: Estimated number of yellow-eyed mullet and unassigned mullet (MUU) harvested by recreational fishers by Fishstock and survey. Surveys were carried out in different years in MAF Fisheries regions: South in 1991–92, Central in 1992–93, and North in 1993–94 (Bradford 1996) and National in 1996 (Bradford 1998) and 1999–00 (Boyd & Reilly 2005). Estimates of CV and harvest tonnages are not presented where sample sizes are considered too small. The mean weight (100 g) used to convert numbers to catch weight is from Manikiam (1963) and considered the best available estimate. Survey tonnages are presented as a range to reflect the uncertainty in the estimate. It is assumed that some proportion of unassigned mullet are yellow-eyed mullet.

Fishstock	Survey	Total Number	CV (%)	Estimated Harvest Range (t)	Point Estimate (t)
1991–92					
QMA 1	South	1 000			
QMA 3	South	29 000	34	1–5	
QMA 7	South	3 000			
QMA 9	South	2 000			
1992–93					
QMA 1	Central	14 000			
QMA 2	Central	57 000			
1993–94					
QMA 1	North	289 000	15	25–33	
QMA 2	North	7 000			
QMA 8	North	1 000			
QMA 9	North	52 000	33	2–8	
1996					
Yellow-eyed mullet					
QMA 1	National	91 000	14	5–15	9
QMA 2	National	80 000	-	-	-
QMA 3	National	38 000	-	-	-
QMA 5	National	2 000	-	-	-
QMA 7	National	66 000	19	5–10	7
QMA 8	National	74 000	21	5–10	7
QMA 9	National	31 000	-	-	-
Unassigned mullet					
QMA 1	National	43 000	23	3–5	4
QMA 2	National	1 000	-	-	-
QMA 3	National	6 000	-	-	-
QMA 7	National	16 000	-	-	-
QMA 8	National	5 000	-	-	-
QMA 9	National	1 000	-	_	-
1999–00					
YEM 1	National	342 000	28	12–21	-
YEM 2	National	432 000	72	6–36	-
YEM 3	National	168 000	29	6–11	-
YEM 5	National	7 000	88	0–1	-
YEM 7	National	86 000	37	3–6	-
YEM 8	National	89 000	33	3–6	-
YEM 9	National	127 000	53	3–10	-

1.3 Customary non-commercial fisheries
No quantitative information is available on the current level of customary non-commercial take.

1.4 Illegal catch
No quantitative information is available on the level of illegal catch.

1.5 Other sources of mortality

No quantitative estimates are available about the impact of other sources of mortality on yellow-eyed mullet stocks. Yellow-eyed mullet principally occur in sheltered harbour and estuarine ecosystems. Some of these habitats are known to have suffered environmental degradation.

Table 5: Recreational harvest estimates for yellow-eyed mullet stocks from national panel surveys (Wynne-Jones et al 2014, 2019). Mean fish weights were obtained from boat ramp surveys (Hartill & Davey 2015 and Davey et al 2019).

Stock	Year	Method	Number of fish	Total weight (t)	CV
YEM 1	2011/12	Panel survey	57 504	11.5	0.26
	2017/18	Panel survey	39 584	11.5	0.30
YEM 2	2011/12	Panel survey	12 053	2.4	0.38
	2017/18	Panel survey	10 629	3.1	0.60
YEM 3	2011/12	Panel survey	8 326	1.7	0.36
	2017/18	Panel survey	12 576	3.7	0.58
YEM 5	2011/12	Panel survey	0	0	-
	2017/18	Panel survey	251	0.1	1.00
YEM 7	2011/12	Panel survey	15 792	3.2	0.33
	2017/18	Panel survey	10 804	3.2	0.33
YEM 8	2011/12	Panel survey	11 762	2.4	0.36
	2017/18	Panel survey	19 818	5.8	0.34
YEM 9	2011/12	Panel survey	20 535	4.1	0.34
	2017/18	Panel survey	14 830	4.3	0.49

2. BIOLOGY

The yellow-eyed mullet, *Aldrichetta forsteri* (Cuvier & Valenciennes 1836), is a member of the Mugilidae family (mullets). It is found in New Zealand, Norfolk Island and Australia. Its range extends from North Cape to Stewart Island in New Zealand and from the Murchison River in Western Australia, across South Australia and around Tasmania, to the Hawkesbury River in New South Wales. It is typically a schooling species that occurs commonly along coasts, in estuaries and in lower river systems, with juveniles sometimes observed in freshwater where they have been observed feeding on algae. In New Zealand, the species is widely but erroneously known as herring.

Yellow-eyed mullet are omnivorous and feed on a wide range of food types including algae, crustaceans, diatoms, molluscs, insect larvae, fish, polychaetes, coelenterates, fish eggs and detritus.

Egg development begins in July and maturity occurs by late December. Generally, spawning is during summer from late December to mid-March although there is some evidence in females from Canterbury to suggest biennial spawning, with peaks in winter and summer. Yellow-eyed mullet appear to leave their estuarine habitat to spawn in coastal waters, with eggs and larvae being found in surface waters up to 33 km offshore. There is no information available on the age of recruitment into estuarine systems of New Zealand waters.

Within estuaries and river systems, yellow-eyed mullet are separated to some extent by age, with older fish preferring more saline water and juveniles sometimes found in freshwater. The larger fish also prefer deeper water than juveniles.

M was estimated from the equation $M = \log_e 100/\text{maximum age}$, where maximum age is the age to which 1% of the population survives in an unexploited stock. Using 7 years for the maximum age results in an estimate of M = 0.66. The maximum age used here is for a yellow-eyed mullet taken in Wellington Harbour in 1963.

Biological parameters relevant to stock assessment are shown in Table 6.

Table 6: Estimates of biological parameters of yellow-eyed mullet.

Fishstock		**Estimate**	**Source**
1. Natural mortality (*M*)			
		Both Sexes	NIWA (unpub. Data)
Wellington Harbour		0.66	
2. Weight = a(length)^b (Weight in g, length in cm fork length).			
		Both Sexes	
	a	b	
Lake Ellesmere	0.0068	3.2	Gorman (1962)

3. STOCKS AND AREAS

No information is available to determine the stock structure of yellow-eyed mullet in New Zealand waters. Because catches are generally taken locally within harbours and estuarine systems that are relatively easy to identify, boundaries for Fishstocks take this natural division into account.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance
No estimates of fishery parameters or stock abundance are available for yellow-eyed mullet.

4.2 Biomass estimates
Biomass estimates are not available for any stocks.

4.3 Yield estimates and projections
Estimates of *MCY* are not available.

No estimates of current biomass, fishing mortality, or other information are available which would permit the estimation of *CAY*.

4.4 Other factors
Because of the highly localised nature of the fishery and the relatively high landings taken recently, particularly in the Manukau Harbour, yellow-eyed mullet may be susceptible to localised depletion.

Concern has been expressed by the Working Group about the effects of the small-meshed nets used to fish yellow-eyed mullet on other species within estuarine systems. For example, species such as grey mullet may suffer increased pressure as a consequence of increased target fishing for yellow-eyed mullet.

5. STATUS OF THE STOCKS

Estimates of current and reference biomass are not available. It is not known if recent catch levels are sustainable.

TACCs and reported landings for the 2017–18 fishing year are summarised in Table 7.

Table 7: Summary of TACs (t), and reported landings (t) of yellow-eyed mullet for the most recent fishing year.

Fishstock		FMA	2018–19 Actual TACC	2018–19 Reported landings
YEM 1	Auckland (East)	1	20	16
YEM 2	Central (East)	2	2	<1
YEM 3	South-east (Coast)	3	8	4
YEM 4	South-east (Chatham)	4	0	0
YEM 5	Southland	5	0	<1
YEM 6	Sub-Antarctic	6	0	0
YEM 7	Challenger	7	5	<1
YEM 8	Central (West)	8	3	0
YEM 9	Auckland (West)	9	30	13
Total			68	33

6. FOR FURTHER INFORMATION

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