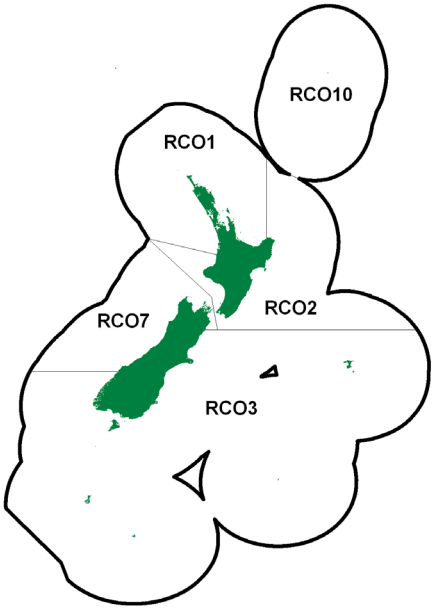
RED COD (RCO)

(*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. Red cod 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.

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 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.

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

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) and TACCs (t) for red cod by Fishstock. Source: QMR/MHR from 1986–present. [Continued on next page]

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	42	46	364	3 300	13 018	619	3 125
1987–88	8	42	81	364	2 880	13 018	1 609	3 125
1988–89	9	42	85	364	7 840	13 018	1 357	3 125
1989–90	8	42	105	364	6 589	13 018	800	3 125
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
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

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
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	1 822	4 600	1 014	3 126
2019–20	5	42	30	500	1 557	4 600	758	3 126
2020–21	11	42	30	500	1 963	4 600	911	3 126
2021–22	13	42	30	500	2 435	4 600	253	3 126
2022–23	2	42	25	500	1 145	4 600	72	3 126

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	2 912	8 278
2019–20	0	10	2 349	8 278
2020–21	0	10	2 915	8 278
2021–22	0	10	2 730	8 278
2022–23	0	10	1 244	8 278

[1] Commercial catch allowance increased through application of in-season MP with additional ACE provided under S68 of Fisheries Act 1996.
[2] Recommended commercial catch allowance increase to 6289 t consulted but not implemented.
*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 management resources would be better allocated elswhere. RCO 3 landings were below 2000 t in 2018–19, 2019–20, and 2020–21.

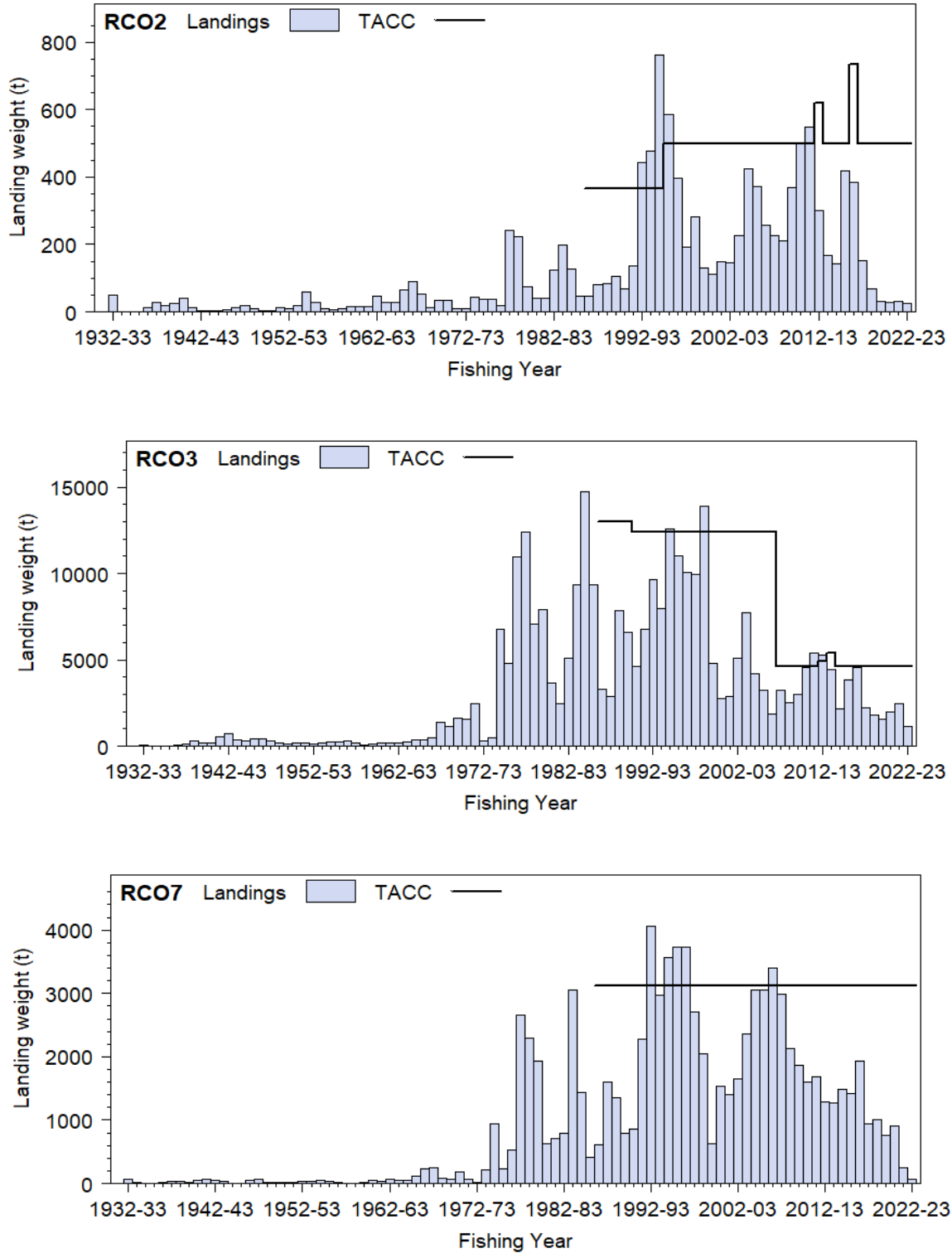


Figure 1: Reported commercial landings and TACC for the three main RCO stocks. Top to bottom: RCO 2 (Central East), RCO 3 (South East Coast), and RCO 7 (Challenger). RCO 2 and RCO 3 show in-season adjustments to the commercial limit.

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 2004). 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 in standardised phone interviews. The national panel survey was repeated during the 2017–18 and 2022–23 fishing years using very similar methods to produce directly comparable results (Wynne-Jones et al 2019; Heinemann & Gray, in prep). Recreational catch estimates from the three national panel surveys are given in Table 4b. Note that national panel survey estimates do not include recreational harvest taken on charter vessel trips or under s111 general approvals.

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

Stock	Year	Method	Number of fish	Total weight (t)	CV
RCO 1	2011–12	Panel survey	2 511	2.7	0.36
	2017–18	Panel survey	2 148	2.3	0.36
	2022–23	Panel survey	443	0.4	0.79
RCO 2	2011–12	Panel survey	20 286	24.3	0.18
	2017–18	Panel survey	18 330	19.3	0.29
	2022–23	Panel survey	369	0.4	0.53
RCO 3	2011–12	Panel survey	7 369	8.0	0.25
	2017–18	Panel survey	6 411	6.8	0.27
	2022–23	Panel survey	860	0.8	0.58
RCO 7	2011–12	Panel survey	2 184	2.3	0.46
	2017–18	Panel survey	3 049	3.2	0.31
	2022–23	Panel survey	830	0.8	0.72

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 and 3).

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 WG 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 elephantfish and red gurnard which were officially included in the list of target species in 2012. The 2007 survey and all surveys from 2012 onwards provide full coverage of the 10–30 m depth range. The winter surveys are currently conducted on a biennial cycle.

Following the resumption of the winter surveys in 2007, red cod core strata biomass was low relative to the period in the 1990s, except for large estimates in the 2012 and 2021 surveys, which were a result of a few large catches associated with inflated CVs (Figure 2, Table 6) (Beentjes et al 2023). The biomass in 2021 increased by 10-fold and was the highest in the time series following the lowest in 2018, although the associated CVs were very high for both of these surveys (2018 = 83%; 2021 = 69%). The 2022 biomass was of similar magnitude to the surveys from 2007 onward, excluding the two extreme values in 2012 and 2021 (Table 6, Figure 2) (Beentjes et al 2023). 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 6% to 59% of the total biomass and in 2022 it was 11%. The proportion of juvenile biomass (based on the length-at-50% maturity) also varied greatly among surveys, with corresponding peaks in 1994 and 2012 of about 70% juvenile; in 2022, juvenile biomass was relatively low at 11%.

The additional red cod biomass captured in the 10–30 m depth range accounted for 5% or less of the biomass in five of the seven core plus shallow strata (10–400 m) surveys. However, in 2014 and 2022, it accounted for substantially more (44% and 34%, respectively) of the total biomass—indicative of the sporadic importance of shallow strata for red cod and the variable nature of red cod catches (Table 6, Figure 2) (Beentjes et al 2023). The addition of the 10–30 m depth range had little effect on the shape of the length frequency distributions in any of the six surveys, except 2014 when the largest fish (over 60 cm) were in 10–30 m.

The spatial distribution of red cod aggregations (large catches) varied geographically among surveys and was in contrast to more frequent zero or very small catches. Overall, however, this species was consistently well represented over the entire survey area, most commonly from 30 m to about 300 m.

West coast South Island inshore trawl survey
Total biomass estimates were relatively high and stable for the first four surveys, varying from 2546 t to 3370 t. There was a sharp decline in 2000 to 414 t, but biomass gradually increased to pre-decline levels by 2009. Since 2009, biomass has declined, and the last three surveys were particularly low; the 2019 and 2021 estimates were the third and fourth lowest, respectively, and the 2023 estimate of just 69 t was the lowest in the time series (Table 6, Figure 3).

Throughout the time series, most of the red cod biomass has come from the west coast. While estimates from Tasman Bay and Golden Bay have always been substantially lower than the west coast, estimates have been particularly low since 2011, ranging between 0.3 t (2023) and 64.8 t, compared with the Tasman Bay and Golden Bay time series mean of 188 t. The estimate of 0.3 t in

2023 was based on three individual fish, one caught from each of the core strata in Tasman Bay and Golden Bay (MacGibbon et al 2024).

Juvenile (under 50 cm) biomass has consistently been greater than adult biomass throughout the time series (MacGibbon et al 2024). Both declined in 2023. The biomass of adult red cod declined to 6 t or 9% of the total biomass in 2023. This followed a large decrease in 2021; adult biomass declined from 36% of the total biomass in 2019 to 16% of the total in 2021 (MacGibbon at al 2022).

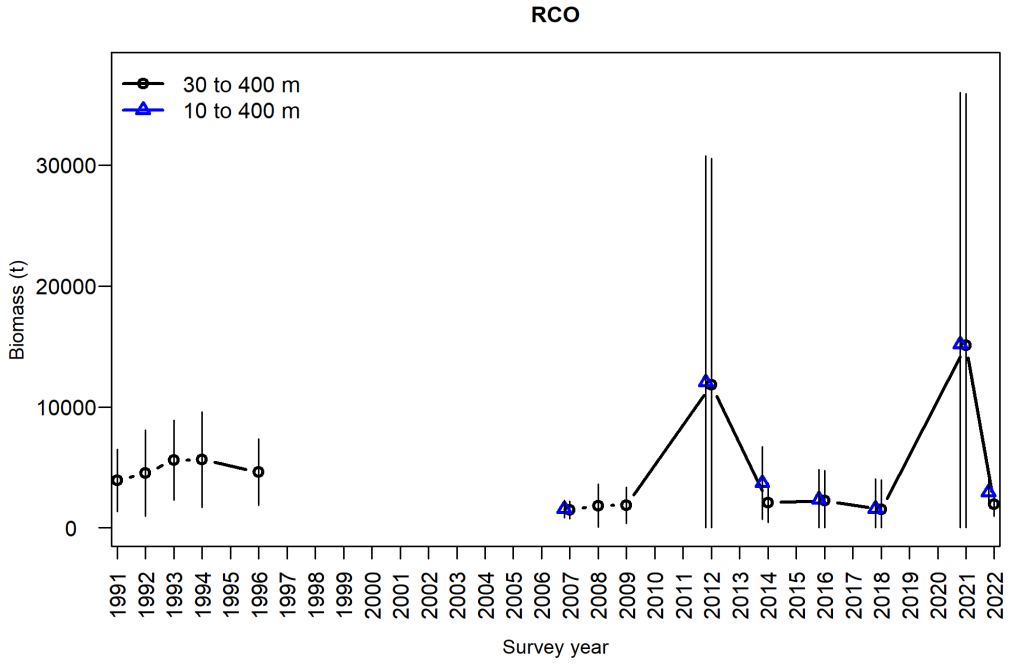


Figure 2: Red cod total biomass for east coast South Island winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m). Error bars are ± two standard deviations.

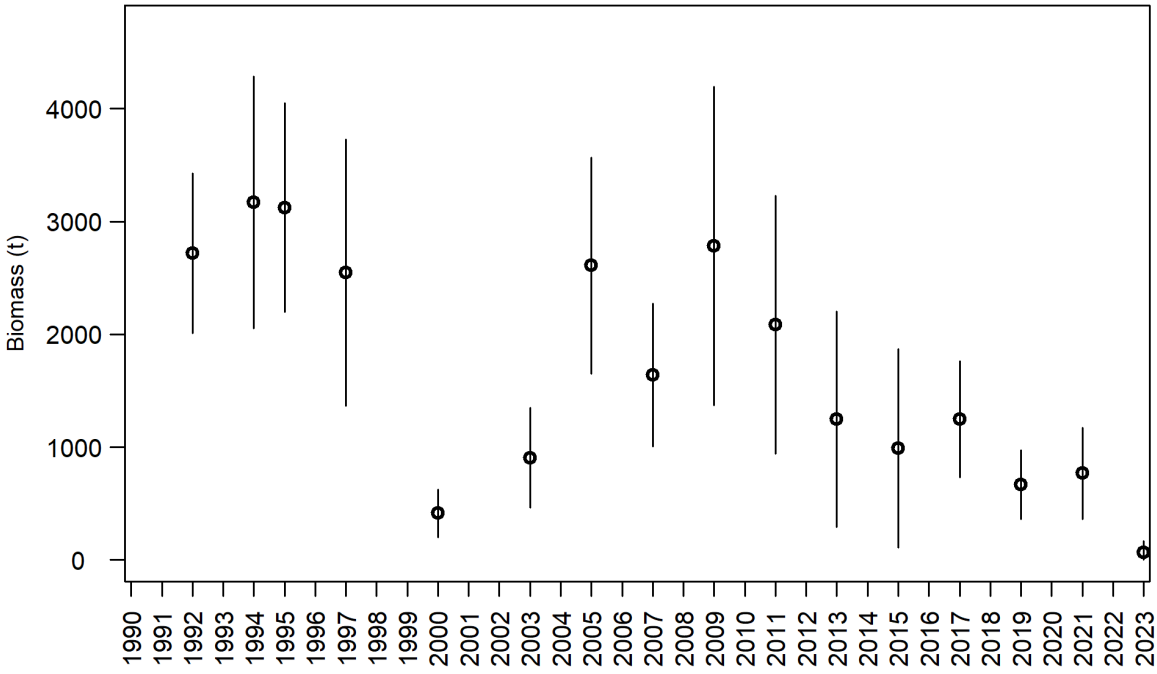


Figure 3: Biomass estimates from the west coast South Island inshore trawl survey. Error bars are ± two standard deviations.

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 (%)
ECSI(winter)	RCO 3				30–400m		10–400m		30–400m		30–400m
		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	1 824	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
		2021	KAH2104	15 096	69	15 177	69	896	56	14 200	73
		2022	KAH2204	1 943	25	2 951	19	212	29	1 731	27
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	2 610	18	–	–		–	–	–
		2007	KAH0704	1 638	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						
		2021	KAH2103	768	26						
		2023	KAH2302	69	71						
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		

4.2 Length frequency distributions

East coast South Island inshore trawl survey
The size distributions of red cod in each of the fourteen 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 2023). The 1996 to 2009 surveys showed poor recruitment of 1+ fish compared with earlier surveys, followed by the strongest 1+ cohort of all surveys in 2012, and then by weak recruitment in 2014 to 2018. In 2021, the 1+ cohort was the strongest since 2012 but less distinct, merging into the older cohorts. In the 2022 survey, all cohorts were relatively weak. Red cod off 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 except in 2014, when the largest female fish (over 60 cm) were in less than 30 m (Beentjes et al 2023).

West coast South Island inshore trawl survey
In a number of years, 0+, 1+, and occasionally 2+ fish have been discernible in the length frequency distribution (MacGibbon et al 2024). Strong cohorts of 1+ fish (approximately 24–35 cm) were particularly apparent in all surveys from 2005 to 2013 but either have not been seen since, or, when visible, such as in 2015 and 2017, were substantially weaker than those seen from 2005 to 2013. The red cod length frequency distribution in 2023 showed two weak modes, a 0+ mode under 24 cm and a 1+ mode from around 24–34 cm.

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 4 and 5, 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 4 and 5) 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 4 and Figure 5 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 the following changes made:

a) all years were included in the predictive regression (Figures 4 and 5), 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 4 and 5). 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 6 and 7 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).

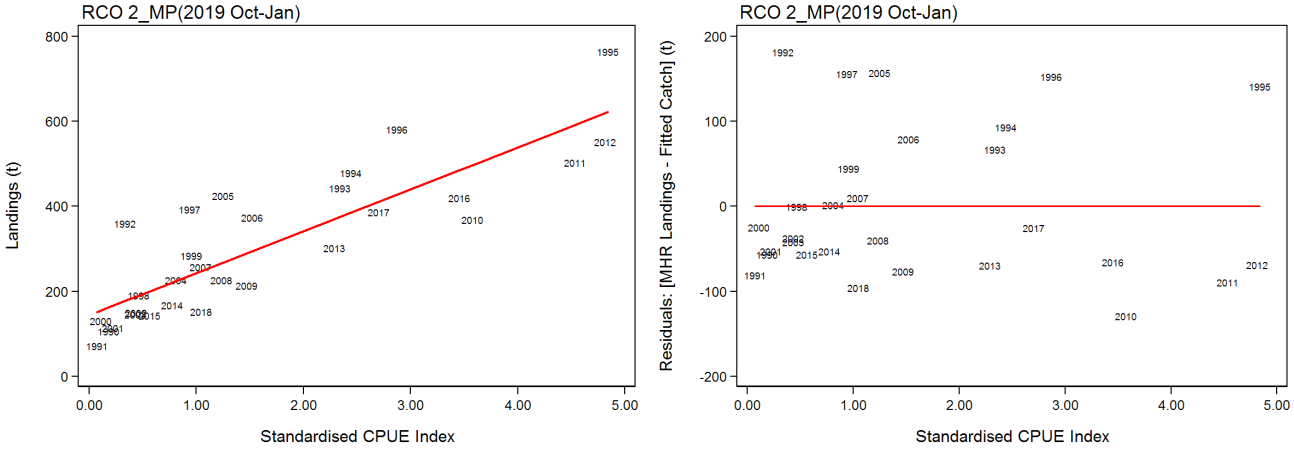


Figure 4: Relationship between annual RCO 2 CPUE and total annual RCO 2 QMR/MHR landings from 1989–90 to 2017–18; [left panel]: regression based on TACC and declared landings for all years; [right panel]: residuals from the left panel regression.

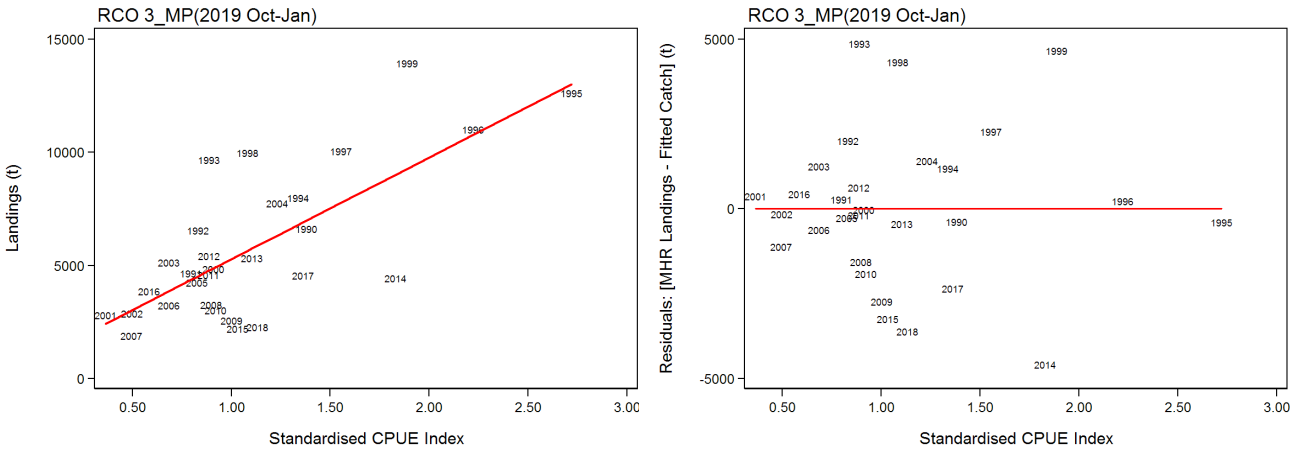


Figure 5: Relationship between annual RCO 3 CPUE and total annual RCO 3 QMR/MHR landings from 1989–90 to 2017–18; [left panel]: regression based on TACC and declared landings for all years; [right panel]: residuals from the left panel regression.

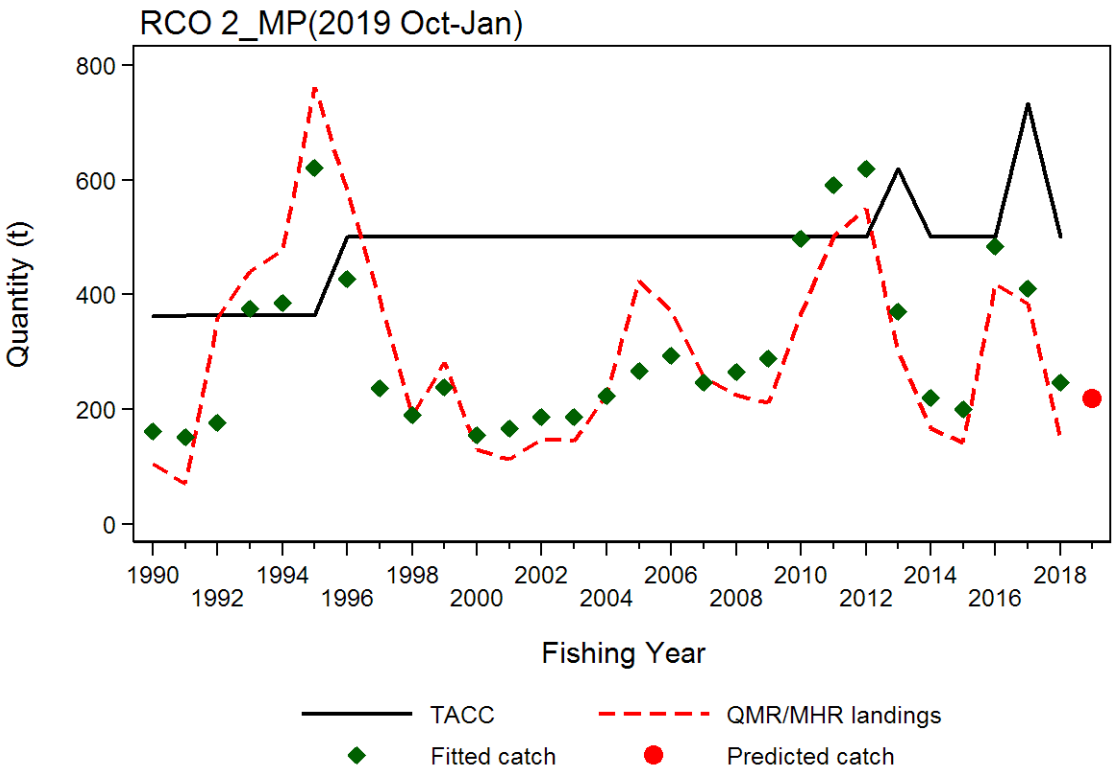


Figure 6: Operation of the 2019 MP for RCO 2, showing the relationship of the fitted catch estimates to the observed MHR/QMR landings and the annual recommended catches for all years to 2017–18 based on the estimated standardised CPUE up to the end of January. The TACC line includes approved additional ACE for the year, if present.

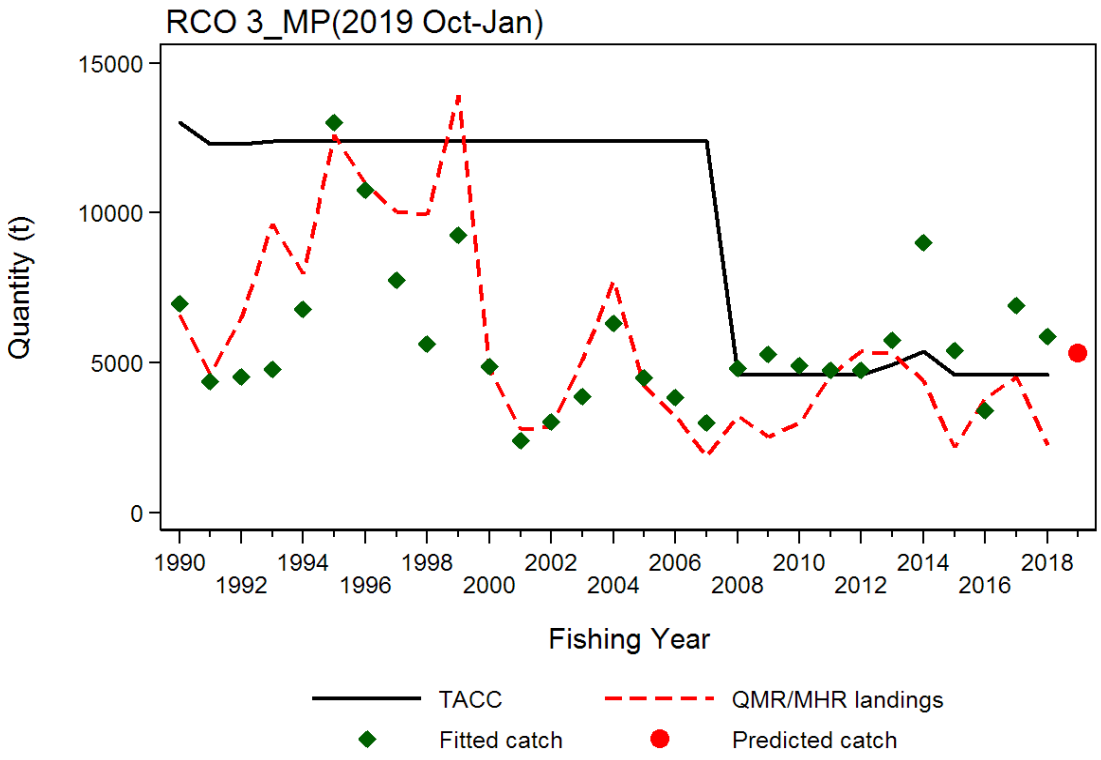


Figure 7: Operation of the 2019 MP for RCO 3, showing the relationship of the fitted catch estimates to the observed MHR/QMR landings and the annual recommended catches for all years to 2017–18 based on the estimated standardised CPUE up to the end of January. The TACC line includes approved additional ACE for the year, if present.

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 4 and 5, 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.

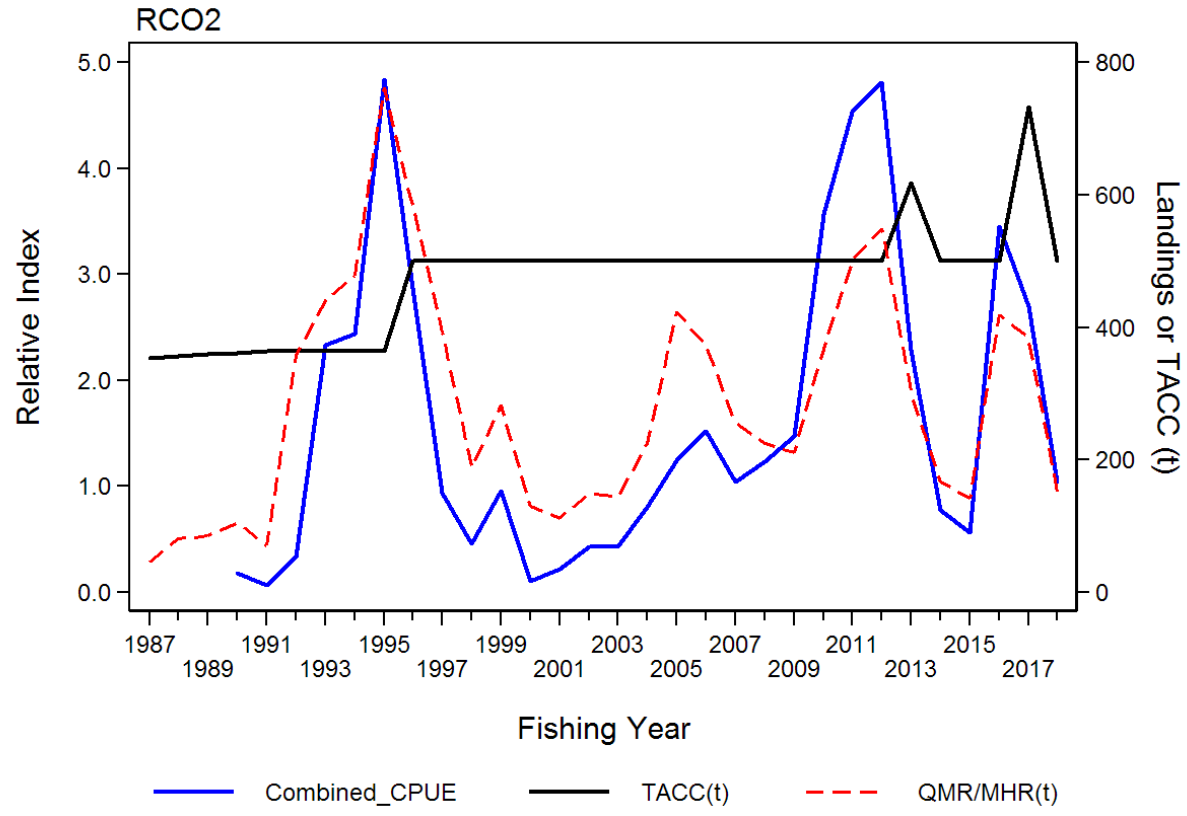
5. STATUS OF THE STOCKS

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.

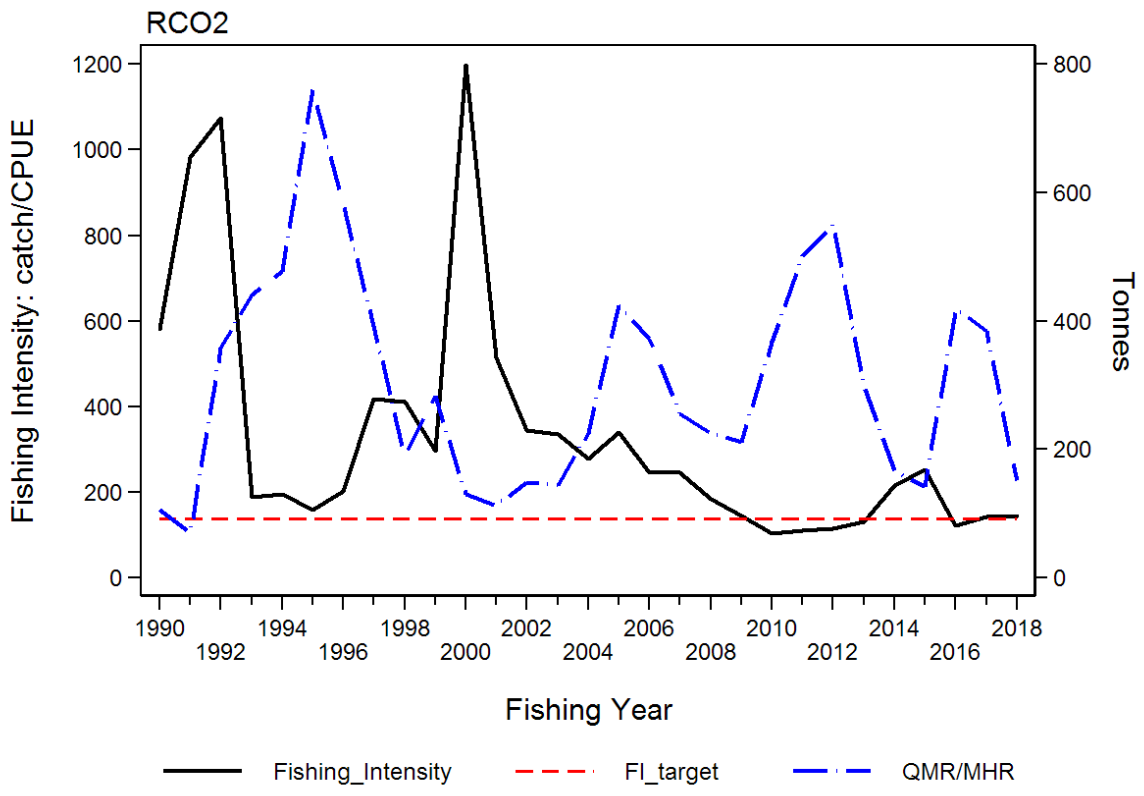
- **RCO 2**

Stock Status		
Most Recent Assessment Plenary Publication Year	2018	
Catch in most recent year of assessment	Year: 2016–2017	Catch: 385 t
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: Unknown Hard Limit: Unknown	
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 of Figure 4). 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 Plenary publication year: 2018	Next assessment: Unknown
	MP: latest assessment: 2019	MP: next assessment:

		Unknown
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	-	

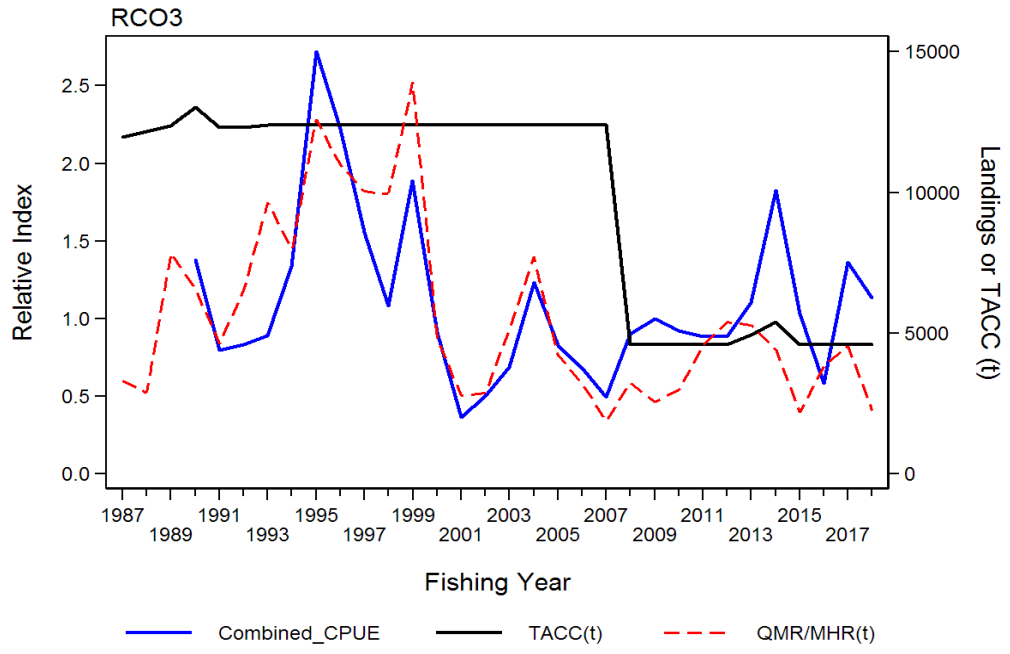
Qualifying Comments
-

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 set net fisheries. Incidental captures of seabirds occur.

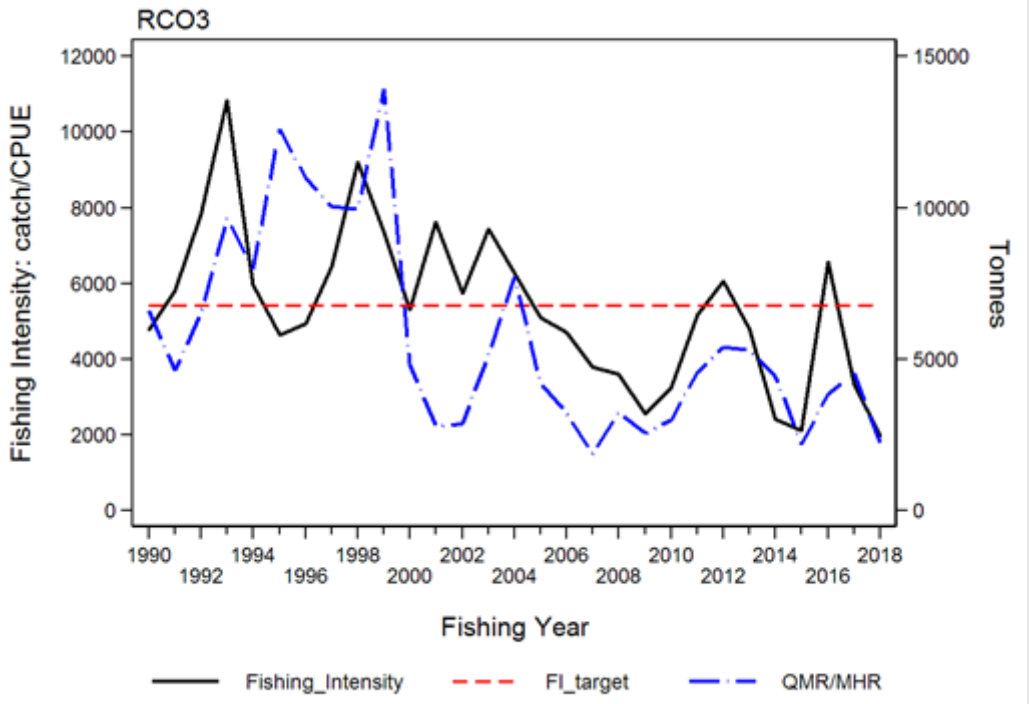
- **RCO 3**

Stock Status		
Most Recent Assessment Plenary Publication	2018	
Catch in most recent year of assessment	Year: 2016–17	Catch: 4 543 t
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 of Figure 5). 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 Plenary publication year: 2018	Next assessment: Unknown
	MP: latest assessment: 2019	MP: next assessment:

		Unknown
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
-

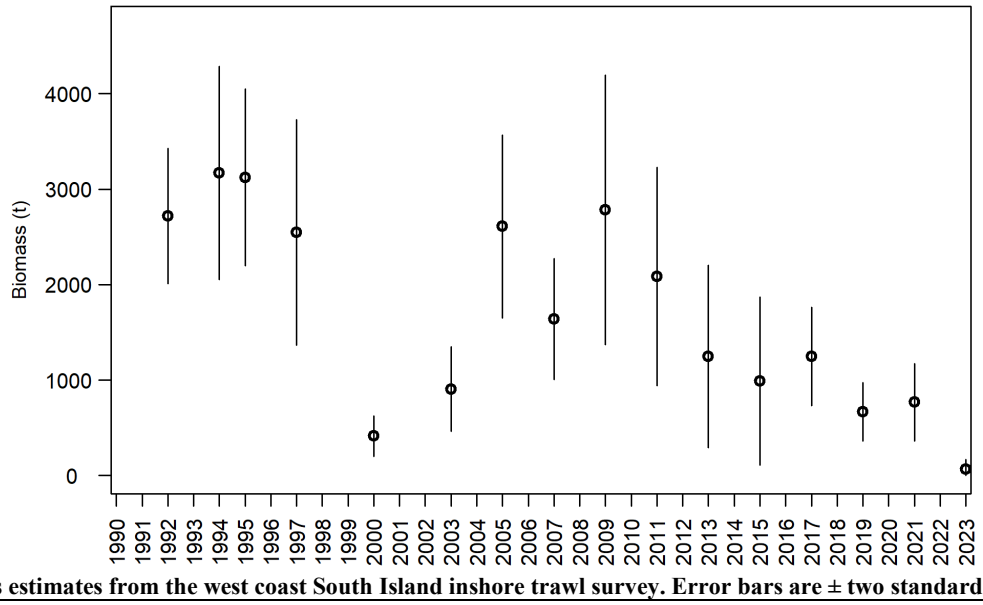
Fishery Interactions
Red cod are landed as bycatch in barracouta, flatfish, squid, and tarakihi bottom trawl fisheries and ling, school shark, spiny dogfish, rig, tarakihi, and moki setnet fisheries. Incidental captures of seabirds occur.

- **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		
Most Recent Assessment Plenary Publication Year	2023	
Catch in most recent year of assessment	Year: 2021–22	Catch: 253 t
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 2023 biomass estimate is the lowest estimate in the time series. There is an overall declining trend since 2009. The vast majority of the biomass is made up of juvenile fish.
Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	Continued low numbers of 1+ fish, low numbers of 0+ fish in 2023. Almost all of the biomass is juvenile fish. Biomass has declined throughout the survey ground but is especially low in Tasman Bay and Golden Bay.

Projections and Prognosis	
Stock Projections or Prognosis	The continued lack of 0+ and 1+ fish is a concern in a recruitment-driven fishery. There has been an overall declining trend in biomass since 2009 and the 2023 estimate is less than 10% of the previous estimate in 2021.
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 Plenary publication year: 2023	Next assessment: Unknown
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)	N/A
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: giant 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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