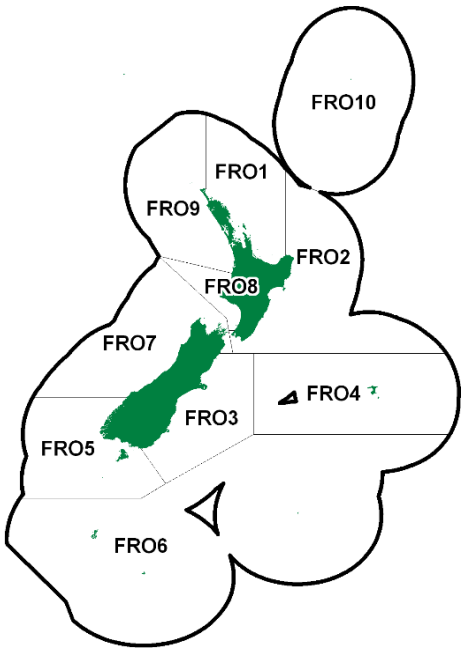
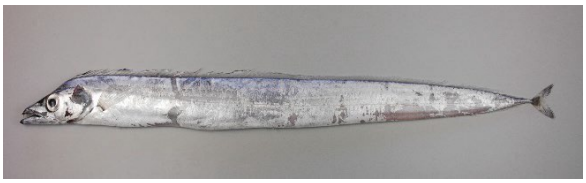
FROSTFISH (FRO)

(*Lepidopus caudatus)*
Para, Taharangi, Hikau





1. FISHERY SUMMARY

1.1 Commercial fisheries

Frostfish are predominantly taken as bycatch from target trawl fisheries on jack mackerel and hoki and to a lesser extent, arrow squid, barracouta, and gemfish. These fisheries are predominantly targeted by larger vessels owned or chartered by New Zealand fishing companies. Target fishing for frostfish is reported from off the west coast of both the South Island and North Island and at Puysegur Bank, with the best catches taken from the west coast of the South Island.

Frostfish catches are mainly reported to the west of New Zealand primarily in QMA 7 off the west coast of the South Island and to a lesser extent QMA 8 and 9 in the north and south Taranaki Bight. The highest annual catches are associated with hoki fishing during winter (since 1986–87) and jack mackerel fishing during late spring and early summer. The proportion of catch coming from these two main fisheries has varied over time. Sources of error in the catch figures include unreported catch and discarded catch. Compliance investigations have shown that damaged and small hoki were recorded as frostfish by some vessels.

Since the mid-2000s, most frostfish landings have come from the trawl fishery targeting jack mackerel (JMA) in the North and South Taranaki bights and off the west coast of the South Island (Statistical Areas 035 to 041; FRO 7, 8, 9). In 2009–10, over 80% of the national frostfish landings came from this fishery. Since 1999–2000, the fishery has been dominated by seven vessels which use midwater trawling exclusively and are relatively highly observed. Catches of frostfish have become more concentrated on two distinct periods, October to January and June to July, and in the north and south Taranaki Bight (Statistical Areas 037, 040, 041) rather than the west coast of the South Island (Statistical Areas 034, 035, 036).

No catch data from deepwater vessels for frostfish are available prior to the introduction of the EEZ in 1978 (Table 1). Frostfish were introduced into the QMS from 1 October 1998. The total reported landings and TACCs for each QMA are given in Table 2 and 3, while Figure 1 shows the historical landings and TACC values for the main FRO stocks. An allowance of 2 t was made for non-commercial catch in each of FRO 1, 2, 7, and 9. TACCs were increased from 1 October 2006 in FRO 2 to 110 t, in FRO 3 to 176 t, and in FRO 4 to 28 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%

(Table 3). Landings have since been well below the TACCs for FRO 2, FRO 3, and FRO 4, with the exception of FRO 4 in 2014–15, when the 28 t TACC was exceeded by just under 150% and in 2018–19, when the landings were over 250%. Highest landings of frostfish in most years are reported from FRO 7. Total landings have always been below the level of the TACC since its introduction. Landings in 2019–20 and 2020–21 were about 40% of the TACC but increased in 2021–22 to 64%. Landings frequently exceeded the TACCs for FRO 8 until 2015–16 but have declined since. In FRO 9, landings follow a similar pattern to FRO 8 until 2018–19 and 2019–20 when the TACC was exceeded. In 2020–21 there was a redistribution of TACCs of two groups of stocks: FRO 3 (from 176 to 80 t) and 4 (from 28 to 124 t); and FRO 7 (from 2623 to 2110 t), 8 (from 649 to 900 t), and 9 (from 138 to 400 t). The rationale was that the original QMAs for frostfish were based on FMAs and not aligned with the distribution of the biological stocks.

Table 1: Reported landings (t) of frostfish by fishing year and area, by foreign licensed and joint venture vessels, 1978– 79 to 1983–83. The EEZ areas (see figure 2 of Baird & McKoy 1988) correspond approximately to the QMAs as indicated. Fishing years are from 1 April to 31 March. The 1983–83 is a 6 month transitional period from1 April to 30 September. No data are available for the 1980–81 fishing year.

EEZ area	B	C(M)	C(-)	D	E	F	G	H	Total
QMA	1 & 2	3	3	4	6	5	7	8 & 9	
1978–79	5	1	6	0	1	0	1 283	226	1 522
1979–80	13	0	1	23	1	1	26	151	216
1980–81	–	–	–	–	–	–	–	–	–
1981–82	0	5	2	19	1	4	55	464	550
1982–83	0	1	0	9	3	1	56	1 545	1 615
1983–83	0	1	1	1	1	1	22	123	150

Table 2: Reported landings (t) for the main QMAs from 1978 to 1982. Landings reported pre-1978 were from FRO 2 (1 t in 1941–42), FRO 1 (3 t in 1947), FRO 9 (1 t in 1947), FRO 2 (5 t in 1966), FRO 8 (1 t each in 1969 and 1970).

Year	FRO 1	FRO 2	FRO 3	FRO 4	FRO 5	FRO 6	FRO 7	FRO 8	FRO 9
1978	1	4	2	0	0	0	782	30	16
1979	1	14	4	19	1	1	614	93	88
1980	0	0	2	20	7	1	41	54	10
1981	0	0	6	25	3	0	327	226	209
1982	4	0	0	8	13	0	132	385	546

Notes:
The 1931–1943 years are April–March but from 1944 onwards are calendar years. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be under-estimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings.

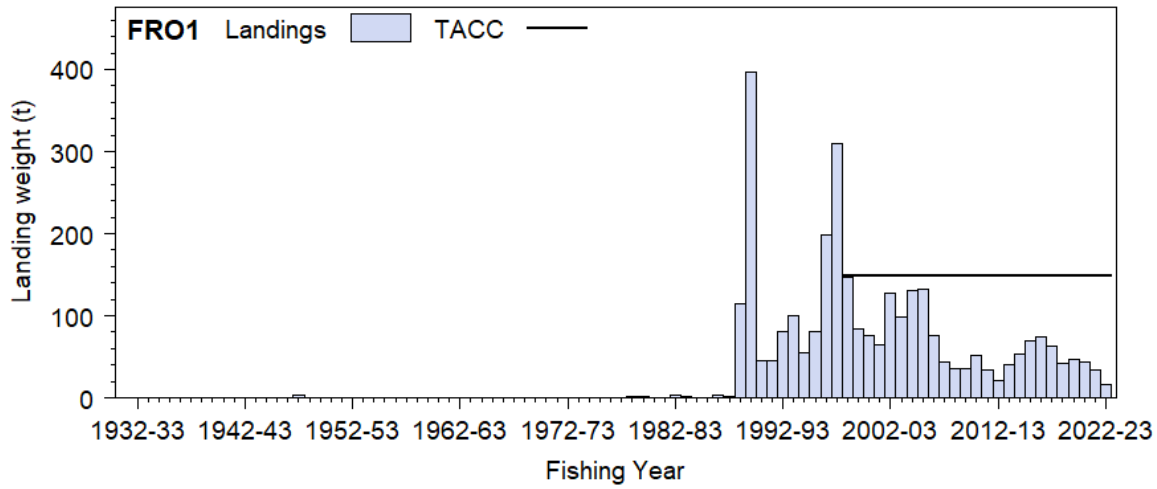
Table 3: Reported landings (t) of frostfish by QMA and fishing year, 1983–84 to present. The data in this table have been updated from data published in the 1998 Plenary Report by using the data up to 1996–97 in table 26 on p. 244 of the "Review of Sustainability Measures and Other Management Controls for the 1998–99 Fishing Year - Final Advice Paper" dated 6 August 1998. Data since 1997–98 are based on catch and effort returns (where area was not reported, catch was prorated across all QMAs). There are no landings reported from QMA 10. [Continued on next page]

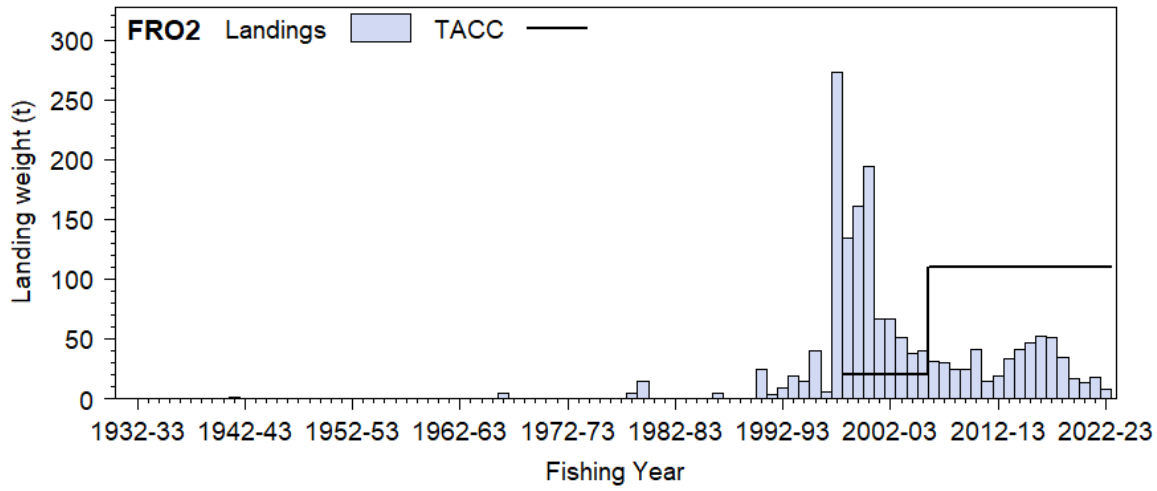
Fishstock	FRO 1		FRO 2		FRO 3		FRO 4		FRO 5	
FMA	1		2		3		4		5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84	2	–	0	–	0	–	10	–	28	–
1984–85	0	–	0	–	2	–	1	–	100	–
1985–86	0	–	0	–	9	–	2	–	258	–
1986–87	4	–	4	–	5	–	6	–	71	–
1987–88	2	–	0	–	3	–	1	–	20	–
1988–89	115	–	0	–	1	–	0	–	15	–
1989–90	397	–	0	–	58	–	0	–	146	–
1990–91	45	–	24	–	224	–	0	–	496	–
1991–92	46	–	3	–	143	–	0	–	337	–
1992–93	80	–	9	–	51	–	0	–	0	–
1993–94	100	–	19	–	168	–	0	–	0	–
1994–95	55	–	14	–	120	–	0	–	87	–
1665–96	80	–	40	–	72	–	29	–	0	–
1996–97	198	–	6	–	12	–	4	–	8	–
1997–98	309	–	273	–	35	–	< 1	–	9	–
1998–99	146	149	134	20	39	128	< 1	5	19	135
1999–00	84	149	161	20	97	128	< 1	5	57	135
2000–01	76	149	194	20	107	128	48	5	33	135
2001–02	64	149	67	20	176	128	81	5	59	135
2002–03	127	149	66	20	268	128	15	5	63	135
2003–04	98	149	52	20	19	128	7	5	14	135
2004–05	130	149	38	20	427	128	15	5	20	135
2005–06	132	149	40	20	45	128	31	5	17	135
2006–07	76	149	31	110	21	176	13	28	16	135

Table 3 [Continued]:

Fishstock	FRO 1		FRO 2		FRO 3		FRO 4		FRO 5	
FMA	1		2		3		4		5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2007–08	44	149	30	110	31	176	7	28	5	135
2008–09	36	149	24	110	6	176	10	28	2	135
2009–10	36	149	24	110	15	176	3	28	4	135
2010–11	52	149	41	110	< 1	176	4	28	14	135
2011–12	34	149	15	110	8	176	14	28	3	135
2012–13	21	149	18	110	32	176	2	28	4	135
2013–14	40	149	34	110	63	176	15	28	11	135
2014–15	54	149	41	110	13	176	69	28	14	135
2015–16	70	149	46	110	10	176	13	28	8	135
2016–17	75	149	52	110	9	176	9	28	27	135
2017–18	62	149	51	110	12	176	16	28	44	135
2018–19	42	149	34	110	12	176	100	28	4	135
2019–20	47	149	16	110	7	176	16	28	5	135
2020–21	43	149	13	110	19	80	12	124	75	135
2021–22	34	149	18	110	10	80	29	124	27	135
2022–23	16	149	8	110	18	80	32	124	62	135

Fishstock	FRO 6		FRO 7		FRO 8		FRO 9			
FMA	6		7		8		9		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84	7	–	432	–	539	–	457	–	1 475	–
1984–85	0	–	214	–	455	–	129	–	901	–
1985–86	0	–	344	–	574	–	226	–	1 415	–
1986–87	4	–	1 089	–	898	–	190	–	2 272	–
1987–88	0	–	3 466	–	875	–	22	–	4 391	–
1988–89	3	–	1 950	–	413	–	455	–	2 952	–
1989–90	29	–	1 370	–	132	–	0	–	2 132	–
1990–91	67	–	3 029	–	539	–	0	–	4 424	–
1991–92	7	–	2 295	–	750	–	1	–	3 582	–
1992–93	0	–	1 360	–	1 165	–	0	–	2 665	–
1993–94	0	–	1 998	–	696	–	12	–	2 993	–
1994–95	0	–	3 069	–	388	–	7	–	3 740	–
1995–96	0	–	1 536	–	22	–	9	–	1 788	–
1996–97	0	–	2 881	–	126	–	93	–	3 328	–
1997–98	0	–	2 590	–	143	–	205	–	3 564	–
1998–99	0	11	2 461	2 623	156	649	33	138	2 969	3 858
1999–00	< 1	11	917	2 623	28	649	48	138	1 392	3 858
2000–01	< 1	11	1 620	2 623	303	649	43	138	2 424	3 858
2001–02	< 1	11	2 303	2 623	138	649	25	138	2 913	3 858
2002–03	< 1	11	1 025	2 623	621	649	67	138	2 252	3 858
2003–04	< 1	11	959	2 623	293	649	367	138	1 809	3 858
2004–05	< 1	11	934	2 623	770	649	327	138	2 661	3 858
2005–06	< 1	11	888	2 623	787	649	181	138	2 119	3 858
2006–07	< 1	11	951	2 623	722	649	142	138	1 972	4 019
2007–08	< 1	11	906	2 623	678	649	136	138	1 837	4 019
2008–09	< 1	11	576	2 623	605	649	110	138	1 369	4 019
2009–10	< 1	11	382	2 623	686	649	238	138	1 389	4 019
2010–11	< 1	11	248	2 623	578	649	167	138	1 106	4 019
2011–12	< 1	11	500	2 623	893	649	198	138	1 665	4 019
2012–13	< 1	11	570	2 623	890	649	278	138	1 814	4 019
2013–14	< 1	11	880	2 623	814	649	261	138	2 120	4 019
2014–15	< 1	11	1 027	2 623	732	649	373	138	2 322	4 019
2015–16	< 1	11	1 063	2 623	692	649	310	138	2 212	4 019
2016–17	< 1	11	1 164	2 623	553	649	96	138	1 986	4 019
2017–18	< 1	11	2 062	2 623	380	649	65	138	2 693	4 019
2018–19	< 1	11	1 999	2 623	507	649	171	138	2 869	4 019
2019–20	< 1	11	931	2 623	434	649	247	138	1 702	4 019
2020–21	< 1	11	923	2 110	430	900	122	400	1 638	4 019
2021–22	< 1	11	1 860	2 110	494	900	110	400	2 582	4 019
2022–23	< 1	11	1 137	2 110	650	900	25	400	1 948	4 019





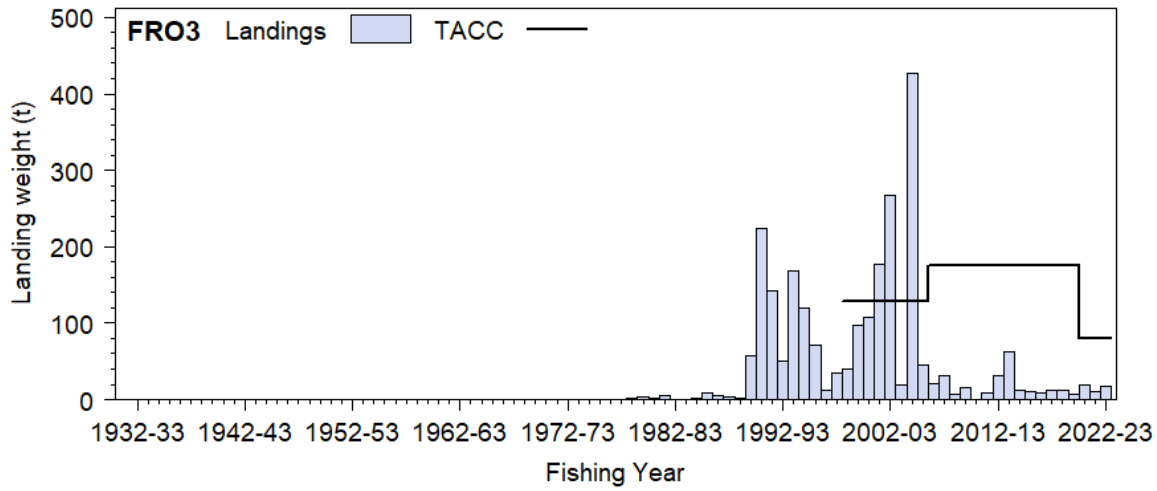
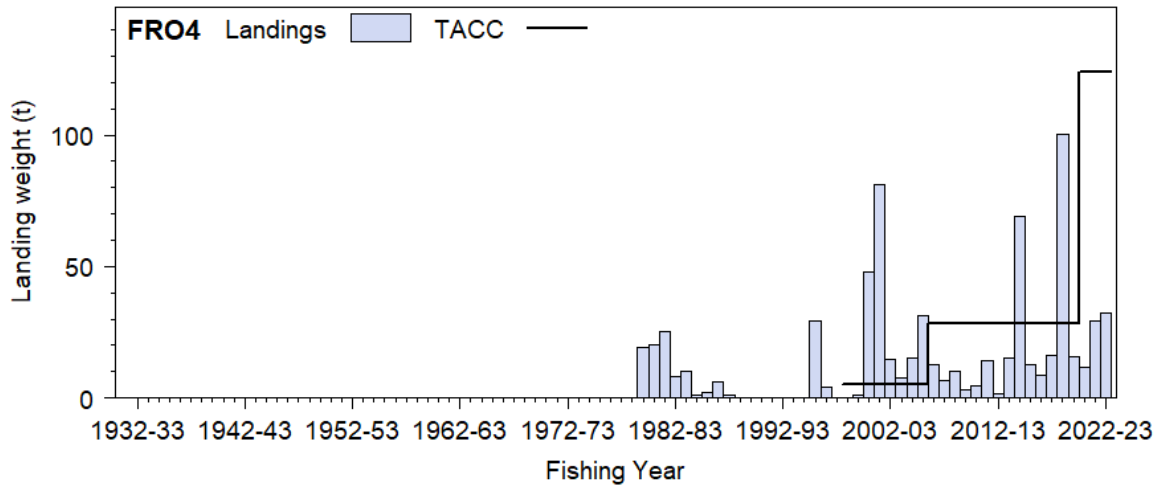
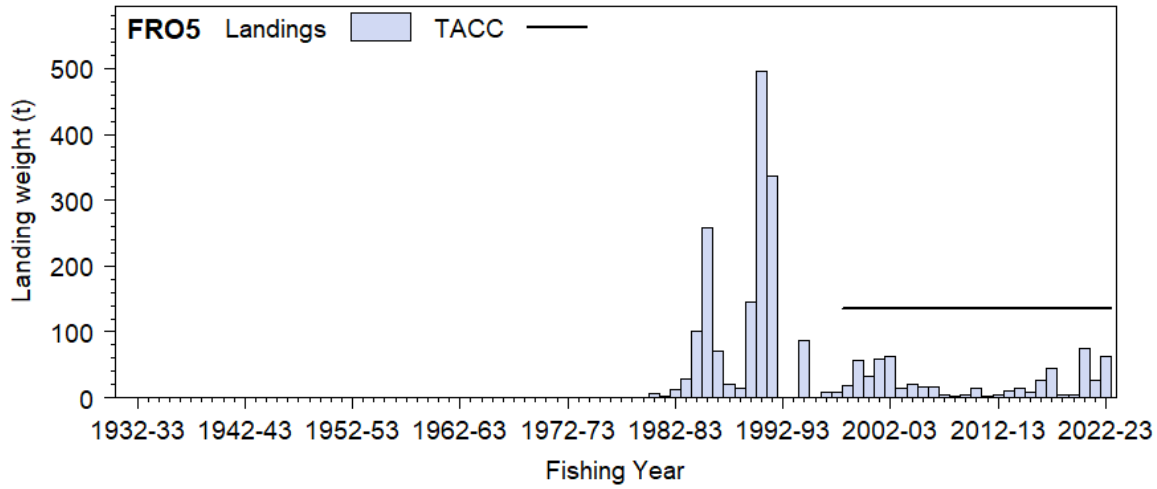


Figure 1: Reported commercial landings and TACC for the eight main FRO stocks. FRO 1 (Auckland East), FRO 2 (Central East), FRO 3 (South East Coast). Data before entry into the QMS are not shown. [Continued next page]





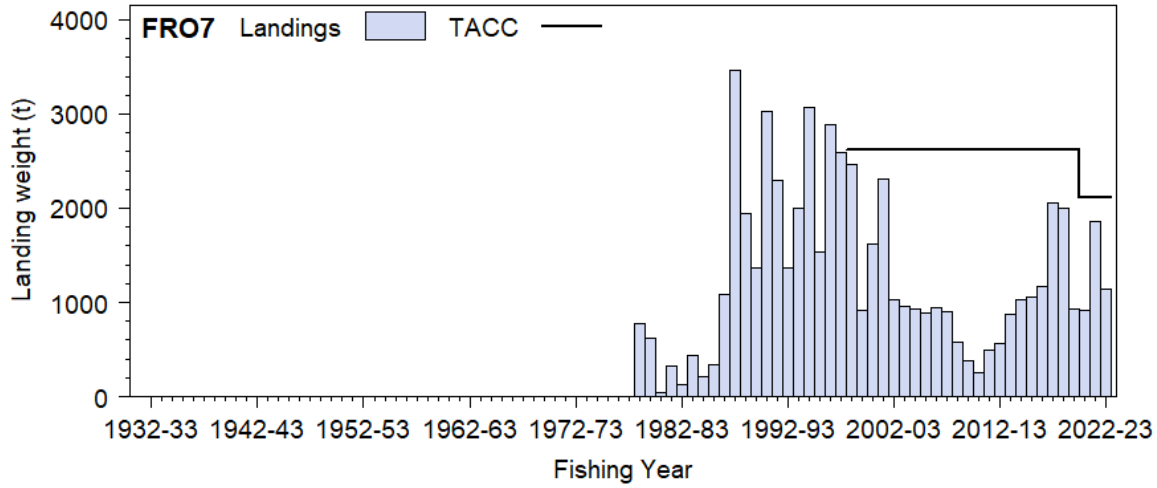


Figure 1 [Continued]: Reported commercial landings and TACC for the eight main FRO stocks. From top: FRO 4 (South East Chatham Rise), and FRO 5 (Southland), FRO 7 (Challenger). Data before entry to the QMS are not shown. [Continued on next page]

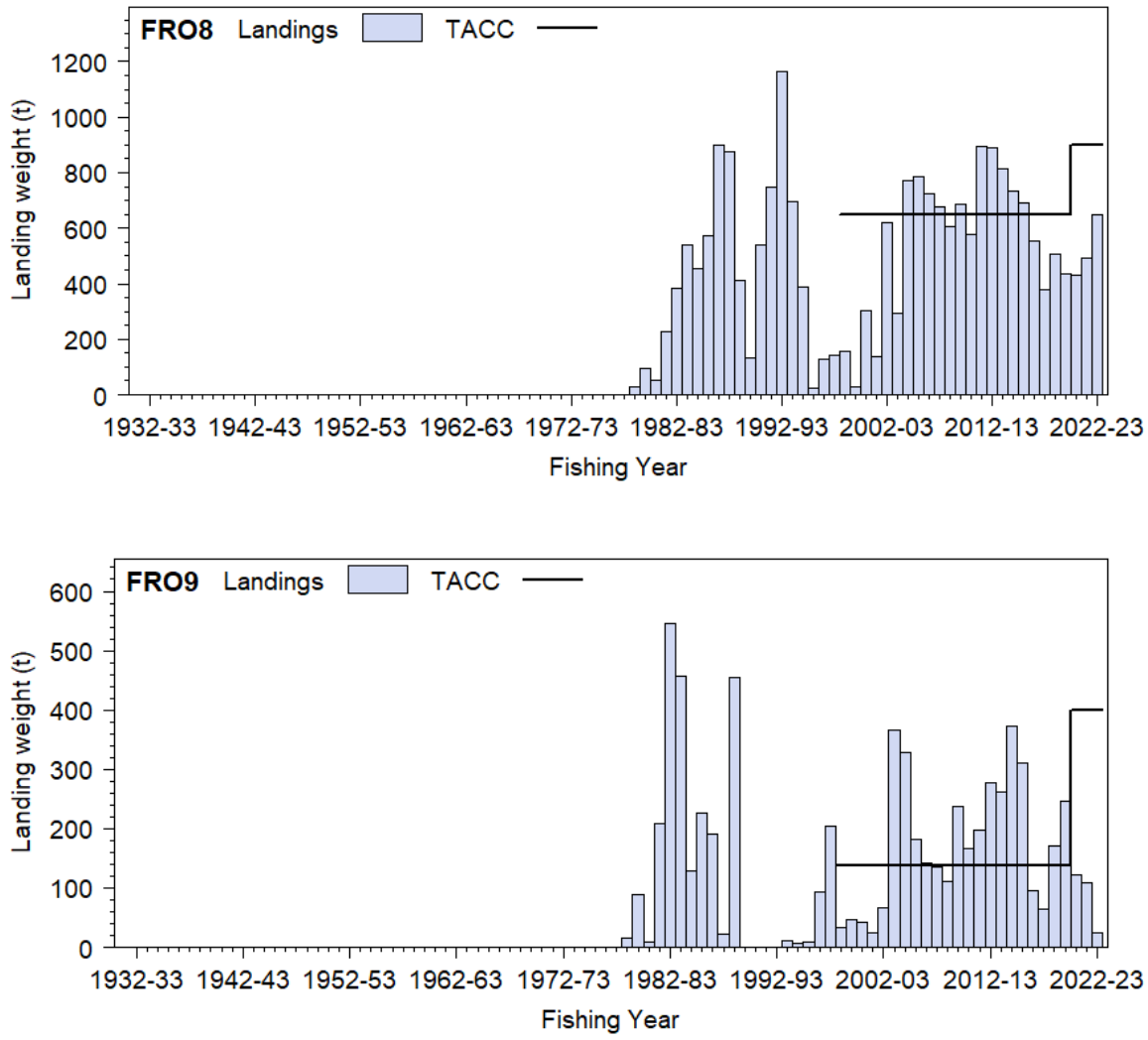


Figure 1 [Continued]: Reported commercial landings and TACC for the eight main FRO stocks. From top: FRO 8 (Central West), and FRO 9 (Auckland West). Data before entry into the QMS are not shown.

1.2 Recreational fisheries

Frostfish are occasionally taken by recreational fishers. Small numbers have been reported from recreational diary surveys, mainly in QMA 1 and rarely in QMA 2 and 9.

1.3 Customary non-commercial fisheries

No quantitative information is available on the current level of customary non-commercial take. Māori have collected beach cast frostfish in the past (Graham 1956).

1.4 Illegal catch

No information is available.

1.5 Other sources of mortality

No information is available on other sources of mortality.

2. BIOLOGY

Frostfish are widely distributed throughout the continental shelf and upper slopes of all oceans, except the North Pacific, and have a benthopelagic lifestyle. In New Zealand, frostfish are found from about 34° S to 49° S, but are most common between 36° S and 44° S. They occur mainly in depths of 50–600 m with the largest catches made at around 200 m bottom depth. Preferred bottom temperatures range

between 10 and 16 °C. There is one species of *Lepidopus* recorded from New Zealand waters. However, scabbardfishes (*Benthodesmus* species) and the false frostfish (*Paradiplospinosus gracilis*) may be confused with small *Lepidopus caudatus*.

Frostfish reach a maximum length of 165 cm (fork length) around New Zealand, although the same species may reach 205 cm and 8 kg weight in the eastern North Atlantic (Nakamura & Parin 1993). In the northwestern Mediterranean males reach sexual maturity at 97 cm and a maximum length of 176 cm, whilst females reach sexual maturity at 111 cm and a maximum length of 196 cm (Demestre et al 1993).

A 2013 study developed ageing methods and estimated growth rates for frostfish from the west coast of New Zealand (Horn 2013). This study confirmed that frostfish are fast growing and relatively short lived. Most fish reach 100 cm fork length (FL) by the end of their third year and the maximum estimated age for both sexes was 10.6 years. The von Bertalanffy parameters estimated for both sexes combined were: L_∞=137 cm, k=0.505 yr^{-1}, t_0=0.07 yr. The estimated growth curves were similar, for the first four years, to those estimated for northern hemisphere frostfish, although the asymptotic length is lower. Horn (2013) estimated the instantaneous rate of natural mortality to be 0.6 yr^{-1} based on 1% of the population reaching 7–8 years of age.

A length-weight relationship for New Zealand frostfish is available from the west coast South Island *Kaharoa* trawl surveys (Horn 2013).

Frostfish migrate into midwater at night and feed on crustaceans, small fish, and squid (Nakamura & Parin 1993). Euphausiids and *Pasiphaea* spp. (both crustaceans) are the most common prey of frostfish in the northwest Mediterranean (Demestre et al 1993). In Tasmanian waters, the diet of frostfish consists mainly of myctophids and euphausiids (Blaber & Bulman 1987).

Frostfish are distributed widely in temperate seas but are most commonly reported in the north-eastern Atlantic (including the Mediterranean), in the southern Atlantic off Namibia and South Africa, and in the south-west Pacific around Australia and New Zealand (Nakamura & Parin 1993, Froese & Pauly 2012). Morphometric studies have shown differences in dorsal-fin pigmentation and meristic characteristics between north-eastern Atlantic and southern Atlantic populations (Mikhailin 1977). Genome sequencing of frostfish showed strong genetic differentiation between the northern and southern hemisphere populations and suggests that there are two distinct biological species (Ward et al 2008).

Robertson (1980) examined the seasonality and location of frostfish spawning based on the occurrence of planktonic eggs. He concluded that spawning probably occurs around all New Zealand except for the south-east coast and adults probably congregate in the late spring months, and spawn during the summer and autumn over the mid to outer shelf. Fertilisation was calculated to take place between noon and sunset at depths greater than 50 m where the surface waters have a temperature of 17.5 to 22.0 °C. Analysis of data on female gonad stages from the scientific observer programme suggested that, for the west coast of both the North and South islands, frostfish have a protracted spawning period starting in mid-winter with a peak from summer to early autumn (Bentley et al 2014).

Biological parameters relevant to the stock assessment are shown in Table 4.

Table 4: Estimates of biological parameters for frostfish.

Fishstock							Estimate	Source
1. Natural mortality (M)								
All stocks							M = 0.6 y^{-1} considered best estimate for all areas for both sexes	Horn (2013)
2. Weight = a (length)^b (Weight in g, length in cm fork length)								
			a	b				
WCSI trawl surveys			0.000407	3.155				Horn (2013)
3. von Bertalanffy growth parameters								
			Male			Female		
	$L\infty$	k	$t0$	$L\infty$	k	$t0$		
WCSI	129.2	0.56	0.08	143.5	0.457	-0.04		Horn (2013)

2. STOCKS AND AREAS

Spawning areas identified from eggs taken in plankton tows include the outer shelf from the Bay of Islands to south of East Cape and an area off Fiordland (Robertson 1980). No eggs were recorded from the south-east coast of the South Island and no spawning has been recorded on Chatham Rise. Spawning is also known to take place off the west coast South Island in March.

Juvenile frostfish (less than 30 cm) have been reported from trawl surveys in the Bay of Plenty, the Hauraki Gulf, off Northland, the west coast of the North Island, and the west coast of the South Island.

The occurrence of spawning in three areas at similar times of year and the distribution of frostfish from catches suggest that there may be at least three separate stocks. A fourth stock is also possible based on known distribution of juveniles and adults and analogies with other species which often have a separate Chatham Rise stock. Bagley et al (1998) proposed the following Fishstock areas for management of frostfish: FRO 1 (FMA 1 and 2); FRO 3 (FMA 3 and 4); FRO 5 (FMA 5 and 6), and FRO 7 (FMA 7, 8, and 9). There have been no reported landings from QMA 10. TACs were set for each QMA (1–9) in 1998 and each FMA is managed separately.

3. STOCK ASSESSMENT

There are no stock assessments available for any stocks of frostfish and therefore estimates of biomass and yields are not available.

3.1 Estimates of fishery parameters and abundance

No estimates of fishery parameters are available for frostfish.

Biomass indices on frostfish are available from trawl surveys carried out by different vessels (Table 5). Few surveys cover the central west coast of New Zealand where the commercial catch records highest landings. The catchability of frostfish is not known but, because they are known to occur frequently well off the bottom, catchability is expected to be low and variable between surveys.

Table 5: Doorspread biomass indices (t) and CVs (%) of frostfish from random stratified trawl surveys 1981–2022. – means zero catch. [Continued on next two pages]

Vessel	Trip Code	Depth range (m)	Dates	Biomass index (t)	CV (%)
QMA 1					
Bay of Plenty	Re-stratified to be consistent with current survey				
Kaharoa	KAH9004	10–100	Feb–Mar 1990	24	47.5
Kaharoa	KAH9202	10–100	Feb 1992	8	56.7
Kaharoa	KAH9601	10–100	Feb 1996	127	81.1
Kaharoa	KAH9902	10–100	Feb 1999	73	36.2
Kaharoa	KAH2001	10–100	Feb 2020	19	55.7
Kaharoa	KAH2101	10–100	Jan–Feb 2021	–	–
QMA 3					
ECSI					
Kaharoa	KAH9105	30–400	May–Jun 1991	–	–
Kaharoa	KAH9205	30–400	May–Jun 1992	1	100
Kaharoa	KAH9306	30–400	May–Jun 1993	0	100
Kaharoa	KAH9406	30–400	May–Jun 1994	–	–
Kaharoa	KAH9606	30–400	May–Jun 1996	–	–
Kaharoa	KAH0705	10–400	May–Jun 2007	–	–
Kaharoa	KAH0806	10–400	May–Jun 2008	–	–
Kaharoa	KAH0905	10–400	May–Jun 2009	–	–
Kaharoa	KAH1207	10–400	Apr–Jun 2012	–	–
Kaharoa	KAH1402	10–400	Apr–Jun 2014	7	95.8
Kaharoa	KAH1605	10–400	Apr–Jun 2016	2	100
Kaharoa	KAH1803	10–400	Apr–Jun 2018	1	90.0
Kaharoa	KAH2104	10–400	Apr–Jun 2021	–	–
Chatham Rise		Core strata			
Tangaroa	TAN9106	200–800	Dec 1991–Feb 1992	17	48.6
Tangaroa	TAN9212	200–800	Dec 1992–Feb 1993	80	36.8
Tangaroa	TAN9401	200–800	Jan 1994	19	58.2

Table 5 [Continued]:

Vessel	Trip Code	Depth range (m)	Dates	Biomass index (t)	CV (%)
Tangaroa	TAN9501	200–800	Jan–Feb 1995	–	–
Tangaroa	TAN9601	200–800	Dec 1995–Jan 1996	76	75.0
Tangaroa	TAN9701	200–800	Jan 1997	–	–
Tangaroa	TAN9801	200–800	Jan 1998	1	100
Tangaroa	TAN9901	200–800	Jan 1999	16	100
Tangaroa	TAN0001	200–800	Dec 1999–Jan 2000	–	–
Tangaroa	TAN0101	200–800	Dec 2000–Jan 2001	135	79.7
Tangaroa	TAN0201	200–800	Dec 2001–Jan 2002	8	100
Tangaroa	TAN0301	200–800	Dec 2002–Jan 2003	10	63.8
Tangaroa	TAN0401	200–800	Dec 2003–Jan 2004	172	91.9
Tangaroa	TAN0501	200–800	Dec 2004–Jan 2005	160	80.4
Tangaroa	TAN0601	200–800	Dec 2005–Jan 2006	13	65.1
Tangaroa	TAN0701	200–800	Dec 2006–Jan 2007	–	–
Tangaroa	TAN0801	200–800	Dec 2007–Jan 2008	2	100
Tangaroa	TAN0901	200–800	Dec 2008–Jan 2009	9	100
Tangaroa	TAN1001	200–800	Jan 2010	–	–
Tangaroa	TAN1101	200–800	Jan 2011	8	100
Tangaroa	TAN1201	200–800	Jan 2012	29	100
Tangaroa	TAN1301	200–800	Jan 2013	72	39.6
Tangaroa	TAN1401	200–800	Jan 2014	10	94.0
Tangaroa	TAN1601	200–800	Jan 2016	8	100
Tangaroa	TAN1801	200–800	Jan 2018	296	96.2
Tangaroa	TAN2001	200–800	Jan 2020	1 255	56.1
Tangaroa	TAN2201	200–800	Jan 2022	98	60.7
Sub–Antarctic					
Tangaroa	TAN9105	300–1000	Nov–Dec 1991	–	–
Tangaroa	TAN9211	300–1000	Nov–Dec 1992	–	–
Tangaroa	TAN9310	300–1000	Nov–Dec 1993	–	–
Tangaroa	TAN0012	300–1000	Nov–Dec 2000	–	–
Tangaroa	TAN0118	300–1000	Nov–Dec 2001	–	–
Tangaroa	TAN0219	300–1000	Nov–Dec 2002	–	–
Tangaroa	TAN0317	300–1000	Nov–Dec 2003	–	–
Tangaroa	TAN0414	300–1000	Nov–Dec 2004	–	–
Tangaroa	TAN0515	300–1000	Nov–Dec 2005	–	–
Tangaroa	TAN0617	300–1000	Nov–Dec 2006	–	–
Tangaroa	TAN0714	300–1000	Nov–Dec 2007	–	–
Tangaroa	TAN0813	300–1000	Nov–Dec 2008	2	100
Tangaroa	TAN0911	300–1000	Nov–Dec 2009	–	–
Tangaroa	TAN1117	300–1000	Nov–Dec 2011	–	–
Tangaroa	TAN1215	300–1000	Nov–Dec 2012	15	100
Tangaroa	TAN1412	300–1000	Nov–Dec 2014	–	–
Tangaroa	TAN1614	300–1000	Nov–Dec 2016	–	–
Tangaroa	TAN1811	300–1000	Nov–Dec 2018	–	–
Tangaroa	TAN2014	300–1000	Nov–Dec 2020	–	–
QMA 7					
WCSI inshore					
Kaharoa	KAH9006	20–400	Mar–Apr 1990	121	27
Kaharoa	KAH9204	20–400	Mar–Apr 1992	25	32
Kaharoa	KAH9404	20–400	Mar–Apr 1994	27	23
Kaharoa	KAH9504	20–400	Mar–Apr 1995	89	31
Kaharoa	KAH9701	20–400	Mar–Apr 1997	259	32
Kaharoa	KAH0004	20–400	Mar–Apr 2000	316	16
Kaharoa	KAH0304	20–400	Mar–Apr 2003	494	22
Kaharoa	KAH0503	20–400	Mar–Apr 2005	423	45
Kaharoa	KAH0704	20–400	Mar–Apr 2007	529	39
Kaharoa	KAH0904	20–400	Mar–Apr 2009	835	35
Kaharoa	KAH1104	20–400	Mar–Apr 2011	251	29
Kaharoa	KAH1305	20–400	Mar–Apr 2013	424	24
Kaharoa	KAH1503	20–400	Mar–Apr 2015	341	34
Kaharoa	KAH1703	10–400	Mar–Apr 2017	518	23
Kaharoa	KAH1902	10–400	Mar–Apr 2019	520	22
Kaharoa	KAH2103	10–400	Mar–Apr 2021	338	43
WCSI offshore					
Tangaroa	TAN0007	300–650 ‘all’ strata	Jul–Aug 2000	31	27.3
Tangaroa	TAN1210	200–800	Jul–Aug 2012	38	46.1
Tangaroa	TAN1308	200–800	Jul–Aug 2013	26	35.3
Tangaroa	TAN1609	200–800	Aug 2016	729	80.7
Tangaroa	TAN1807	200–800	Jul–Aug 2018	70	30.1
Tangaroa	TAN2107	200–800 All+deep strata	Aug 2021	90	64.1
Tangaroa	TAN1609	200–1000	Aug 2016	729	80.7
Tangaroa	TAN1807	200–1000	Jul–Aug 2018	70	30.1
Tangaroa	TAN2107	200–1050	Aug 2021	90	64.1

Table 5 [Continued]:

Vessel	Trip Code	Depth range (m)	Dates	Biomass index (t)	CV (%)
Discontinued surveys					
QMA 1					
Bay of Plenty	Original strata (including deeper than modern survey)				
Kaharoa	KAH9004	10–150	Feb–Mar 1990	246	87
Kaharoa	KAH9202	10–150	Feb 1992	92	48
Kaharoa	KAH9601	10–250	Feb 1996	328	49
Kaharoa	KAH9902	10–250	Feb 1999	193	34
QMA 2					
ECNI					
Kaharoa	KAH9304	20–400	Mar–Apr 1993	573	38
Kaharoa	KAH9402	20–400	Feb–Mar 1994	1 079	40
Kaharoa	KAH9502	20–400	Feb–Mar 1995	493	22
Kaharoa	KAH9602	20–400	Feb–Mar 1996	693	17
QMA 7					
WCSI south of 41° 30’ S					
James Cook	JCO8311	25–450	Sep–Oct 1983	183	34
James Cook	JCO8415	25–450	Aug–Sep 1985	181	25
QMA 7 & 8					
Tomi Maru		30–300	Dec 1980–Jan 1981	2 173	22
Shinkai Maru	SHI8102	20–300	Oct–Nov 1981	6 638	12
Cordella	COR9001	25–300	Feb–Mar 1990	2 189	20

East coast North Island (FRO 1 & 2)

There are no stock monitoring indices available for FRO 1 & 2 (Table 5). The majority of the frostfish caught in the east coast North Island surveys in the 1990s were from strata deeper than the deepest included in the surveys started in 2020 (Stevenson & Hanchet 1999).

Chatham Rise and east coast South Island (FRO 3 & 4)

Frostfish are caught very rarely in the ECSI *Kaharoa* survey and catch rates are insufficient in the Chatham Rise survey to form an abundance index (Table 5).

Southland and Subantarctic (FRO 5 & 6)

Frostfish are caught very rarely in the Sub-Antarctic *Tangaroa* survey (Table 5). The only positive catch records have been north of 50° S.

West coast (FRO 7, 8, and 9)

The most consistent survey series for frostfish is the west coast South Island inshore *Kaharoa* survey. Biomass increased from the early1990s into the early 2000s. Biomass possibly continued to increase until 2009, although the size of the survey CVs makes this uncertain. Since 2011 biomass estimates have fluctuated between 250 t and just over 500 t (Table 5, Figure 2). Frostfish are caught in the west coast strata (there is one record only from the Tasman Bay and Golden Bay strata).

Length frequencies are available from the west coast South Island inshore *Kaharoa* survey from 2000 onward. Compared with the maximum lengths recorded from the Mediterranean by Demestre et al (1993) female frostfish rarely exceed 150 cm and male frostfish 125 cm (Figure 3). In some years more than one length mode is clearly visible for one or both sexes, and, if frostfish reach 100 cm at age three, it is possible cohorts can be distinguished up to age three.

Small amounts of frostfish have been caught consistently in the west coast South Island offshore *Tangaroa* survey. The exception was the 2016 survey when a ten-fold larger catch was taken than in other years. The CV in 2016 was very high (81%) and CVs from other years have also been high indicating the survey is not good at tracking frostfish biomass (Table 5).

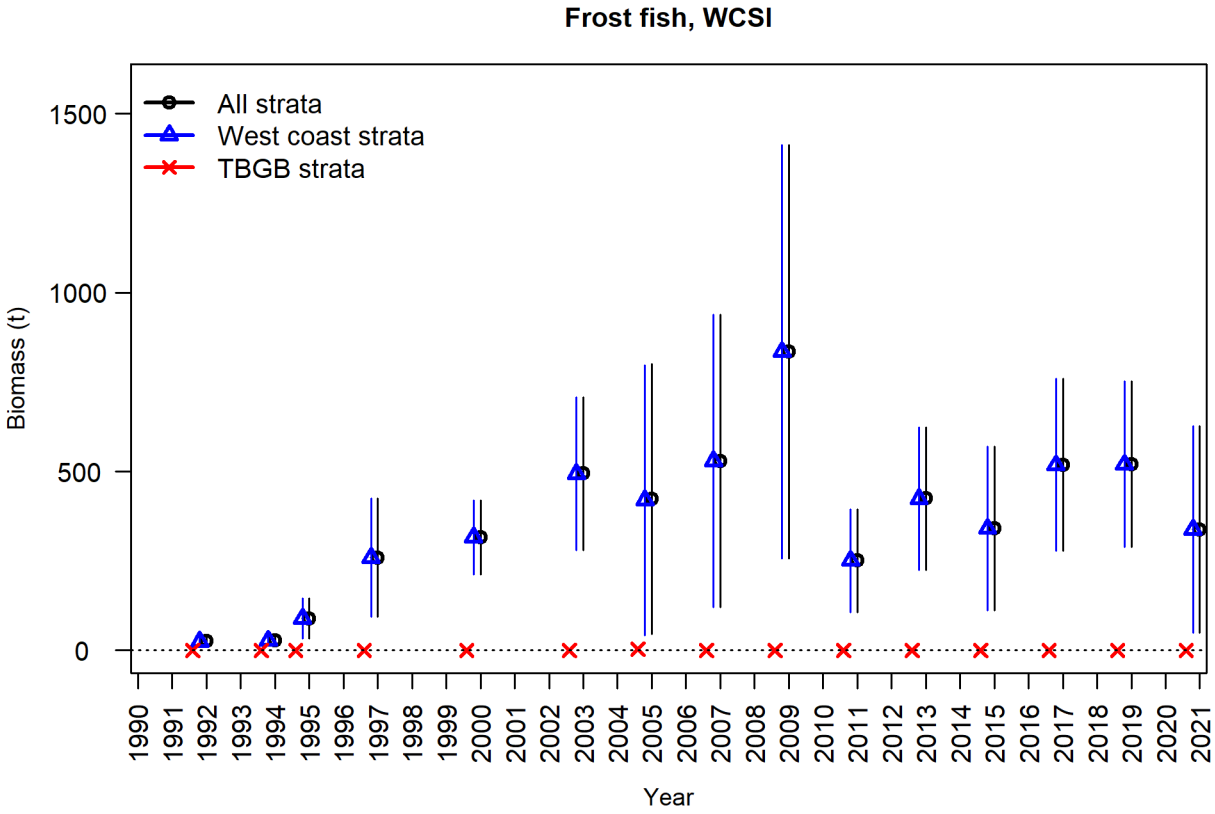


Figure 2: Doorspread biomass estimates for frostfish (error bars are ± two standard deviations) from the WCSI *Kaharoa* surveys 1992, 1994, 1995, 1997, 2000, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019, and 2021.

Since the mid-2000s, most frostfish landings have come from the trawl fishery targeting jack mackerel (JMA) in the North and South Taranaki bights and off the west coast South Island (Statistical Areas 035 to 041; FRO 7, 8, 9). In 2009–10, over 80% of the national frostfish landings came from this fishery (Bentley et al 2014). Catches of frostfish have become more concentrated in the North and South Taranaki bights (Statistical Areas 037, 040, 041) rather than the west coast South Island (Statistical Areas 034, 035, 036) (Dunn 2022). Commercial catches are therefore disjoint from the west coast South Island inshore *Kaharoa* survey spatially and in terms of gear type. A partial quantitative assessment using survey biomass index is not appropriate.

3.2 Biomass estimates

No biomass estimates are available for frostfish.

3.3 Yield estimates and projections

MCY cannot be determined because only a small percentage (less than 2%) of the reported catch in recent years is from target fishing. Annual catches are likely to vary according to effort targeting other species in areas of frostfish abundance. It is therefore not possible to choose a catch history which represents a period of stable and unrestricted effort in order to estimate yields. Other problems include under-reporting of frostfish catches and restrictions on targeting frostfish in QMAs 3, 4, 5, and 6.

There are no reliable data on current biomass; *CAY* was therefore not estimated.

3.4 Other factors

None available.

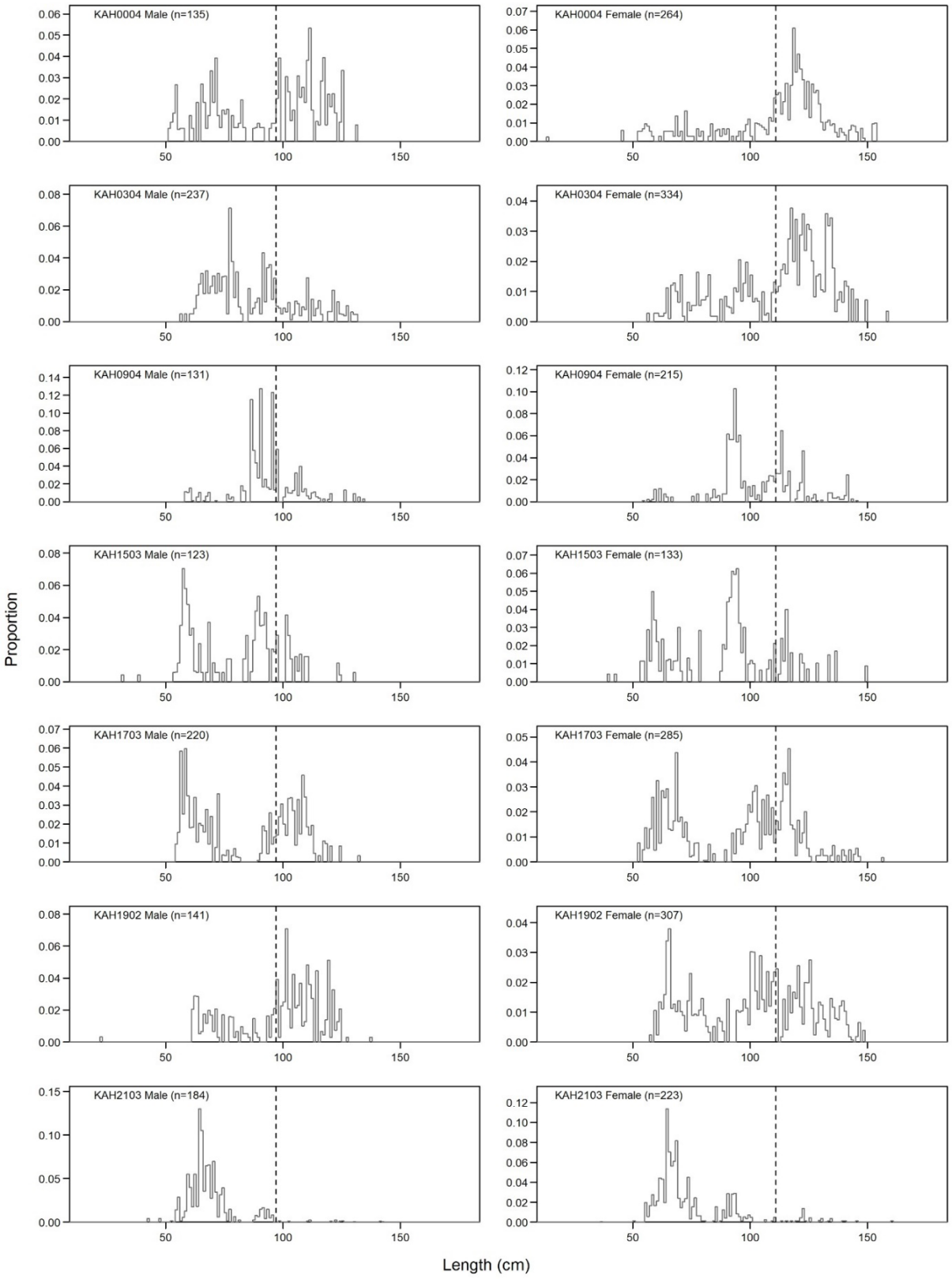


Figure 3: Frostfish length frequency distribution from west coast South Island *Kaharoa* surveys. Length frequencies are shown from years with the greatest number of length measurements by sex: 2000, 2003, 2009, 2015, 2017, 2019, and 2021. Vertical line is at 97 cm for males and 111 cm for females (length at maturity for frostfish in the Mediterranean, Demestre et al 1993).

3.5 Future research considerations

Bentley et al (2014) conducted separate catch per unit effort standardisations for frostfish using data from the hoki and jack mackerel fisheries west of the North Island and South Island. They concluded that the index based on the jack mackerel fishery provided the most promise as an index of biomass. At the time, the series was short because around 1999–2000 there was a sudden change in fleet composition

in the jack mackerel fishery, which resulted in a substantial shift in fishing methods towards shorter duration and higher tow speed midwater trawling. Assuming no further substantial shifts in fleet composition and methods, there would now be more than 20 years of data, much of it observed, to use for a CPUE analysis.

4. STATUS OF THE STOCKS

Estimates of current and reference biomass are not available. The stock structure is uncertain; the fishery is variable and almost entirely a bycatch of other target fisheries. No age data or estimates of abundance are available.

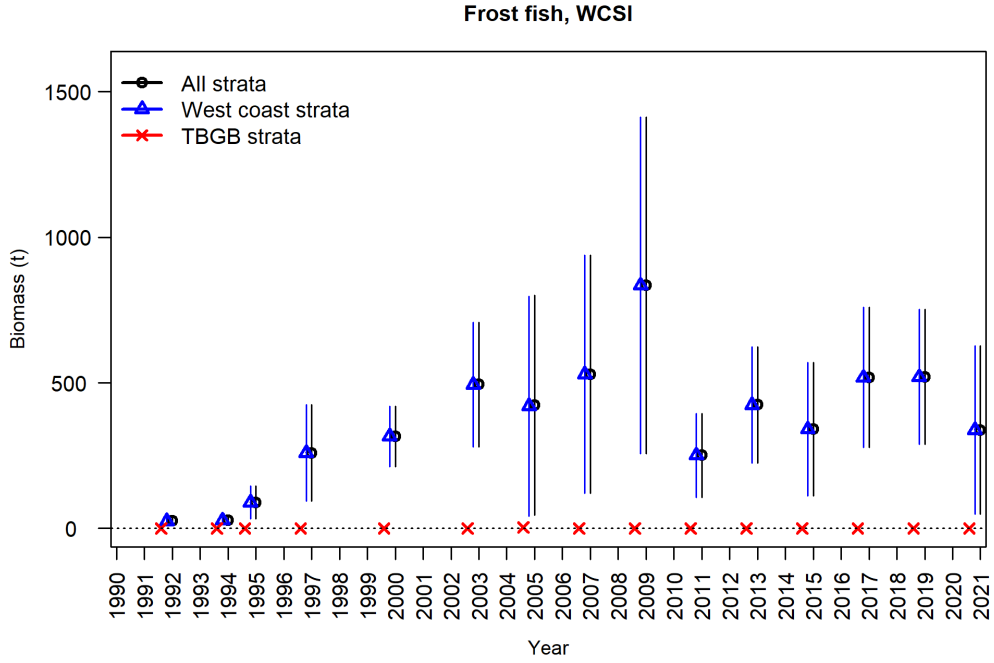
For all Fishstocks there is insufficient information to estimate current stock status.

FRO 7

- **FRO 7 (west coast South Island)**

Stock Status		
Most Recent Assessment Plenary Publication Year	2022	
Catch in most recent year of assessment	Year: 2020–21	Catch: 923 t
Assessment runs presented	-	
Reference Points	Target: Not established but 40% B_0 assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -	
Status in relation to Target	Unknown	
Status in relation to Limits	Unknown for Soft limit Unknown for hard limit	
Status in relation to Overfishing	-	

Historical Stock Status Trajectory and Current Status



Doorspread biomass estimates for frostfish (error bars are ± two standard deviations) from the WCSI *Kaharoa* surveys 1992, 1994, 1995, 1997, 2000, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019, and 2021.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass increased from the early1990s into the early 2000s. Biomass possibly continued to increase until 2009, although the size of the survey CVs makes this uncertain. Since 2011 biomass estimates have fluctuated without a clear trend.
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	Stock size is unlikely (< 40%) to change much at current catch levels in FMA 7.
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	-

Assessment Methodology		
Assessment Type	Level 2: Partial quantitative stock assessment	
Assessment Method	Survey indices	
Assessment dates	Latest assessment Plenary publication year: 2022	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

Fishery Interactions
Frostfish are predominantly taken as bycatch from target trawl fisheries on jack mackerel and hoki and to a lesser extent, arrow squid, barracouta, and gemfish.

5. FOR FURTHER INFORMATION

Bagley, N W; Schofield, K A; Colman, J A (1998) A summary of biological and commercial landings, and a stock assessment of the frostfish *Lepidopus caudatus* Euphrasen, 1788 (Pisces: Trichiuridae), in New Zealand waters. New Zealand Fisheries Assessment Research Document 1998/23. 28 p. (Unpublished document held by NIWA library.)

Baird, G G; McKoy, J.L. (Comps. and Eds.) (1988) Papers from the workshop to review fish stock assessments for the 1987–88 New Zealand fishing year. 300 p. (Preliminary discussion paper held by NIWA library, Wellington.)

Bentley, N; Kendrick, T H; MacGibbon, D J (2014) Fishery characterisation and catch-per-unit-effort analyses for frostfish (*Lepidopus caudatus*), 1989–90 to 2009–10. *New Zealand Fisheries Assessment Report 2014/25*. 131 p.

Blaber, S J M; Bulman, C M (1987) Diets of fishes of the upper continental slope of eastern Tasmania: Content, calorific values, dietary overlap and trophic relationships. *Marine Biology 95(3)*: 345–356.

Demestre, M; Moli, B; Recasens, P; Sanchez, P (1993) Life history and fishery of *Lepidopus caudatus* (Pisces: Trichiuridae) in the Catalan Sea (Northwestern Mediterranean). *Marine Biology 115*: 23–32.

Dunn, M R (2022) Climate change and the distribution of commercially caught marine fish species in New Zealand. Part 1: Spatio-temporal changes since 1989. *New Zealand Aquatic Environment and Biodiversity Report No. 286*. 405 p.

FAO (1993) Yearbook of Fishery Statistics, 1993. Catches and landings (Vol. 76). *FAO Statistics Series No. 123*.

Froese, R; Pauly, D (eds) (2012) FishBase. World Wide Web electronic publication. www.fishbase.org Graham, D.H. (1956) *A Treasury of New Zealand fishes*. A H & A W Reed Ltd. 424 p.

Graham, D H (1956) A treasury of New Zealand fishes. A H & A W Reed, Wellington. 424 p.

Horn, P L (2013) Age determination of frostfish (*Lepidopus caudatus*) off west coast South Island. *New Zealand Fisheries Assessment Report 2013/21*. 24 p.

Mikhailin, S V (1977) The intraspecific variability of the frostfish, *Lepidopus caudatus. Vopr Ikhtiol.17(2)*: 226–236.

Nakamura, I; Parin, N V (1993) FAO species catalogue vol. 15. Snake mackerels and cutlassfishes of the world. *FAO Fisheries Synopsis No. 125*. 136 p.

Robertson, D A (1980) Spawning of the frostfish, *Lepidopus caudatus* (Pisces: Trichiuridae), in New Zealand waters. *New Zealand Journalof Marine and Freshwater Research 14*: 129–136.

Schofield, K A; Bagley, N W; Colman, J A (1998) A summary of biology and commercial landings, and a stock assessment of the frostfish, *Lepidopus caudatus* Euphrasen, 1788 (Pisces: Trichiuridae) in New Zealand waters. New Zealand Fisheries Assessment Research Document 1998/23. 28 p. (Unpublished report held by NIWA library, Wellington.)

Stevenson, M; Hanchet, S (1999) Review of the inshore trawl survey series along the east coast North Island 1993–96. (Unpublished Final Research Report for Ministry of Fisheries Project INT9801 held by Fisheries New Zealand, Wellington.) 83 p.

Ward, R D; Costa F O; Holmes, B H; Steinke, D (2008) DNA barcoding of shared fish species from the North Atlantic and Australasia: minimal divergence for most taxa, but *Zeus faber* and *Lepidopus caudatus* each probably constitute two species. *Aquatic Biology 3*: 71–78.