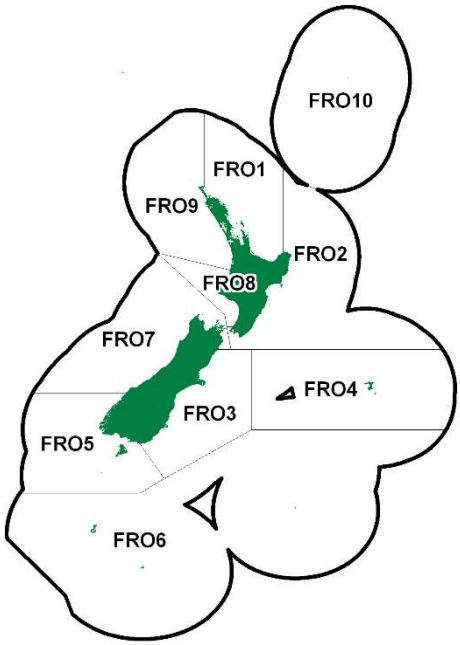
FROSTFISH (FRO)

(*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 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 on 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. 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%. Landings frequently exceeded the TACCs for FRO 8 until 2016–17, but has declined slightly 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 from 1 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 1931 to 1982 [Continued on next page].

Year	FRO 1	FRO 2	FRO 3	FRO 4	FRO 5	Year	FRO 1	FRO 2	FRO 3	FRO 4	FRO5
1931–32	0	0	0	0	0	1957	0	0	0	0	0
1932–33	0	0	0	0	0	1958	0	0	0	0	0
1933–34	0	0	0	0	0	1959	0	0	0	0	0
1934–35	0	0	0	0	0	1960	0	0	0	0	0
1935–36	0	0	0	0	0	1961	0	0	0	0	0
1936–37	0	0	0	0	0	1962	0	0	0	0	0
1937–38	0	0	0	0	0	1963	0	0	0	0	0
1938–39	0	0	0	0	0	1964	0	0	0	0	0
1939–40	0	0	0	0	0	1965	0	0	0	0	0
1940–41	0	0	0	0	0	1966	0	5	0	0	0
1941–42	0	1	0	0	0	1967	0	0	0	0	0
1942–43	0	0	0	0	0	1968	0	0	0	0	0
1943–44	0	0	0	0	0	1969	0	0	0	0	0
1944	0	0	0	0	0	1970	0	0	0	0	0
1945	0	0	0	0	0	1971	0	0	0	0	0
1946	0	0	0	0	0	1972	0	0	0	0	0
1947	3	0	0	0	0	1973	0	0	0	0	0
1948	0	0	0	0	0	1974	0	0	0	0	0
1949	0	0	0	0	0	1975	0	0	0	0	0
1950	0	0	0	0	0	1976	0	0	0	0	0
1951	0	0	0	0	0	1977	0	0	0	0	0
1952	0	0	0	0	0	1978	1	4	2	0	0
1953	0	0	0	0	0	1979	1	14	4	19	1
1954	0	0	0	0	0	1980	0	0	2	20	7
1955	0	0	0	0	0	1981	0	0	6	25	3
1956	0	0	0	0	0	1982	4	0	0	8	13

Year	FRO 6	FRO 7	FRO 8	FRO 9	Year	FRO 6	FRO 7	FRO 8	FRO 9
1931–32	0	0	0	0	1957	0	0	0	0
1932–33	0	0	0	0	1958	0	0	0	0
1933–34	0	0	0	0	1959	0	0	0	0
1934–35	0	0	0	0	1960	0	0	0	0
1935–36	0	0	0	0	1961	0	0	0	0
1936–37	0	0	0	0	1962	0	0	0	0
1937–38	0	0	0	0	1963	0	0	0	0
1938–39	0	0	0	0	1964	0	0	0	0
1939–40	0	0	0	0	1965	0	0	0	0
1940–41	0	0	0	0	1966	0	0	0	0
1941–42	0	0	0	0	1967	0	0	0	0
1942–43	0	0	0	0	1968	0	0	0	0
1943–44	0	0	0	0	1969	0	0	1	0
1944	0	0	0	0	1970	0	0	1	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	1	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

Table 2 [Continued]

Year	FRO 6	FRO 7	FRO 8	FRO 9	Year	FRO 6	FRO 7	FRO 8	FRO 9
1951	0	0	0	0	1977	0	0	0	0
1952	0	0	0	0	1978	0	782	30	16
1953	0	0	0	0	1979	1	614	93	88
1954	0	0	0	0	1980	1	41	54	10
1955	0	0	0	0	1981	0	327	226	209
1956	0	0	0	0	1982	0	132	385	546

Notes:
The 1931–1943 years are April–March but from 1944 onwards are calendar years, Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports, 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 frostfish by QMA and fishing year, 1983–84 to present. The data in this table has been updated from that 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 based on catch and effort returns (where area was not reported catch was pro-rated 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
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

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

Table 3 [Continued]

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
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

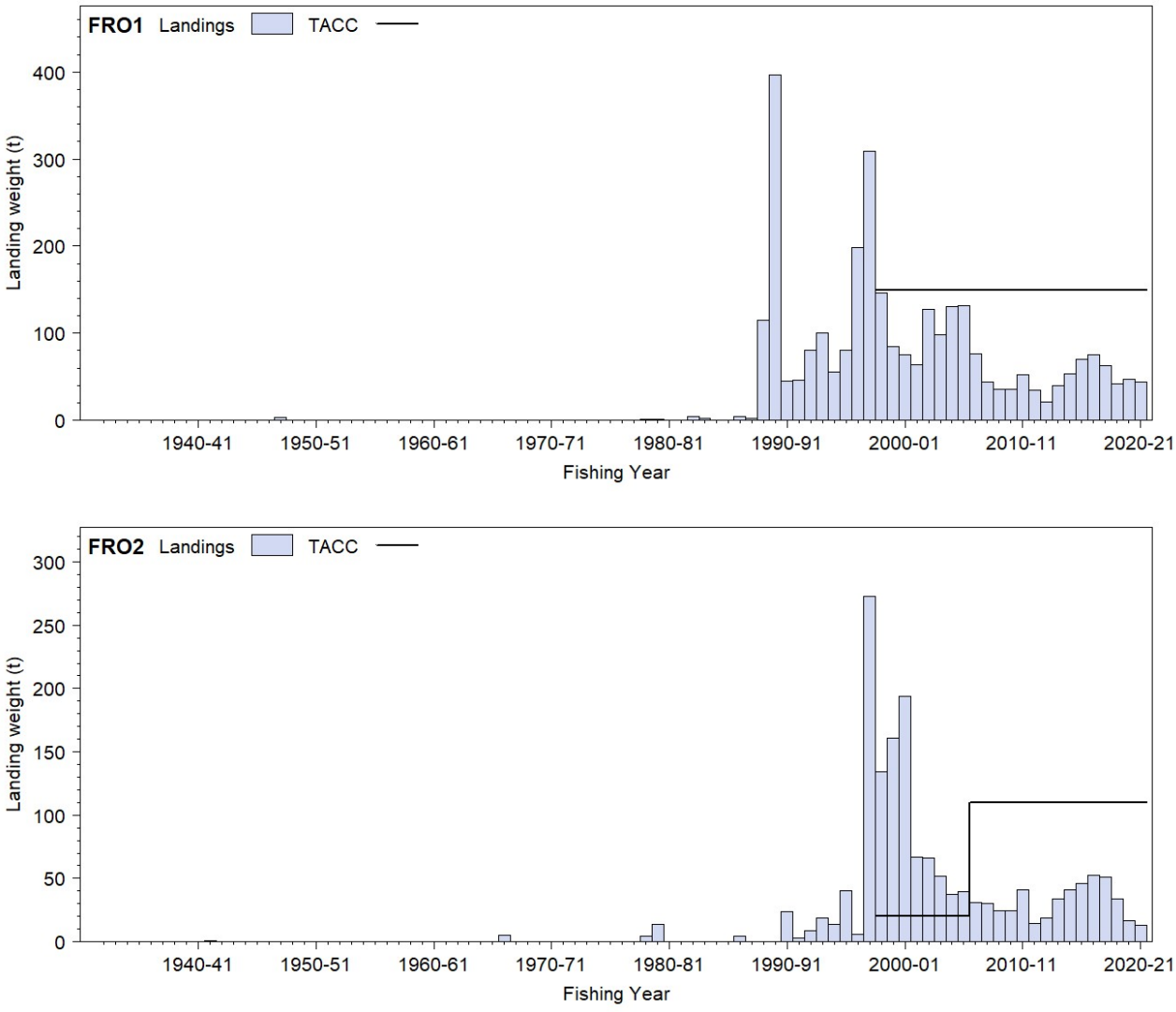
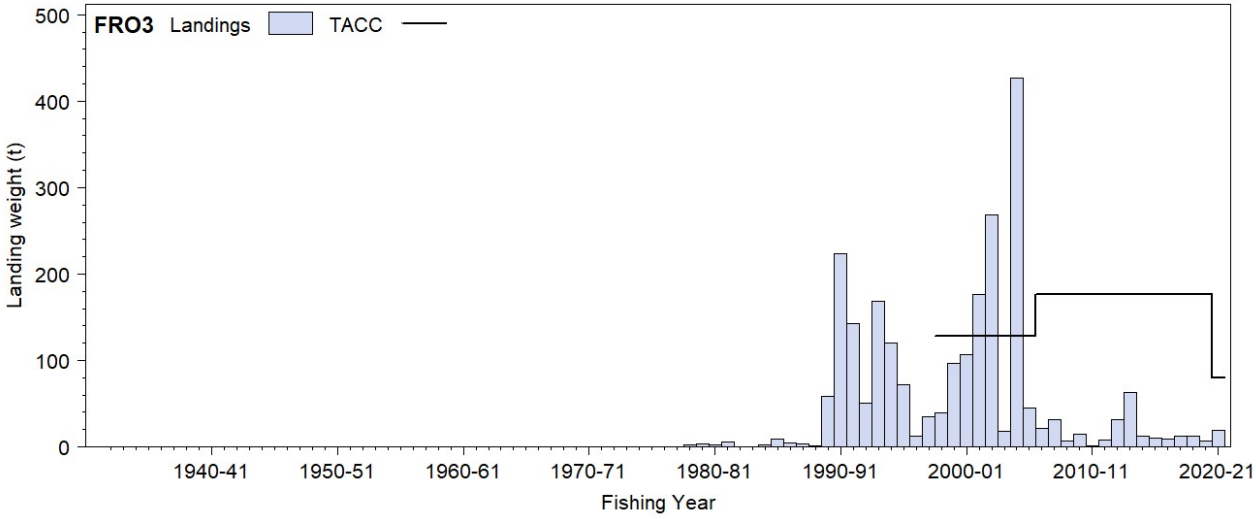
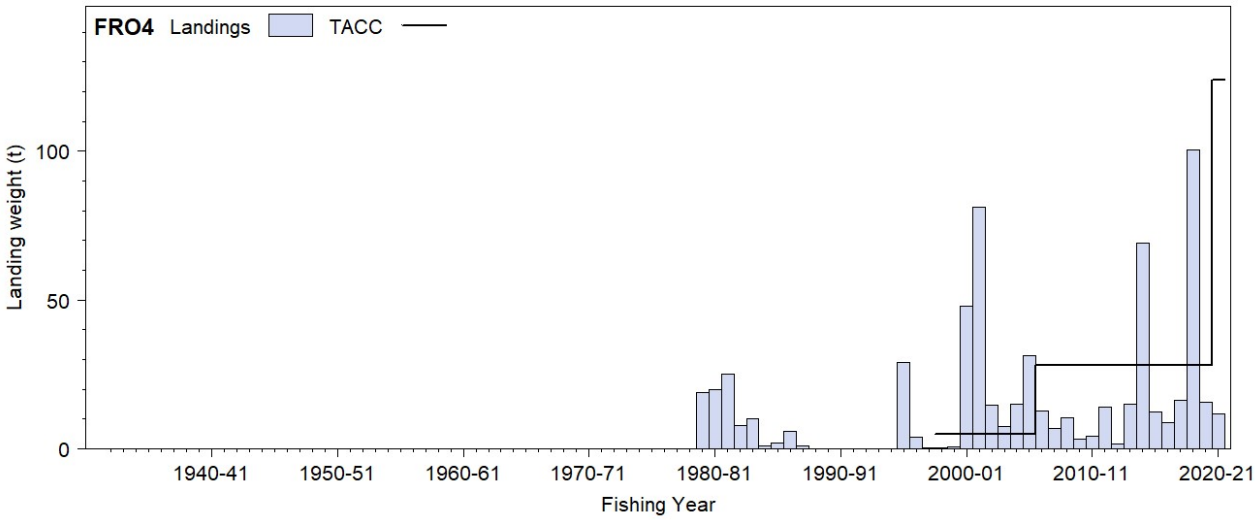


Figure 1: Reported commercial landings and TACC for the eight main FRO stocks. From top: FRO 1 (Auckland East) and FRO 2 (Central East). [Continued on next page]





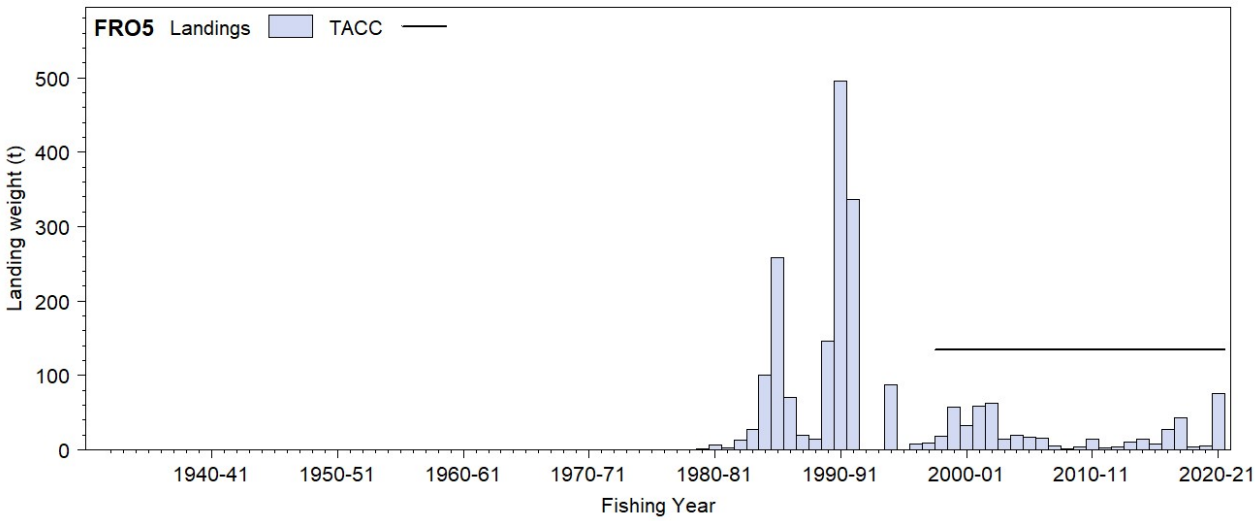
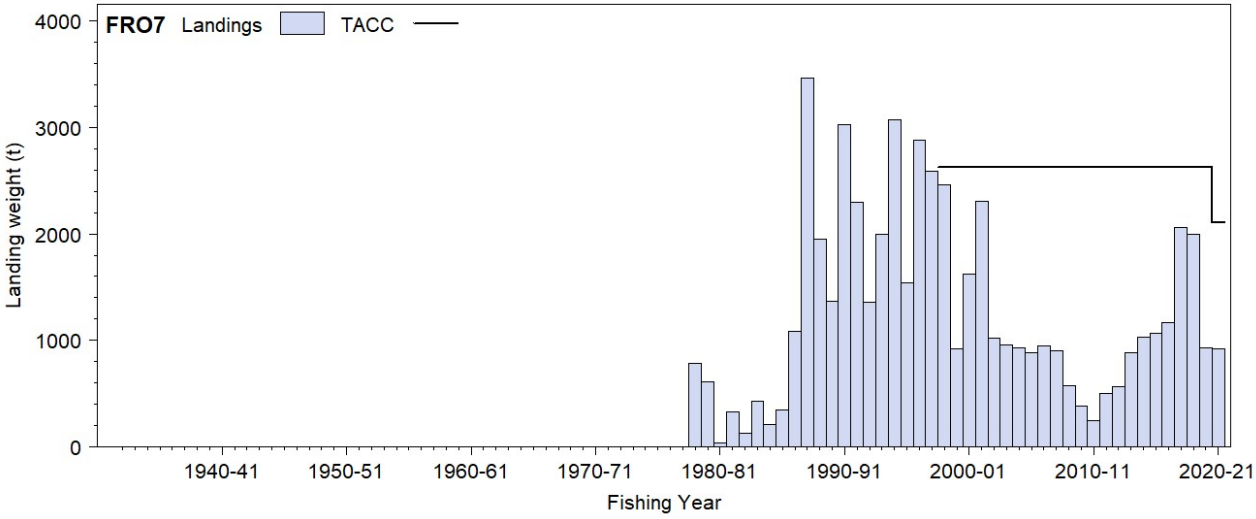
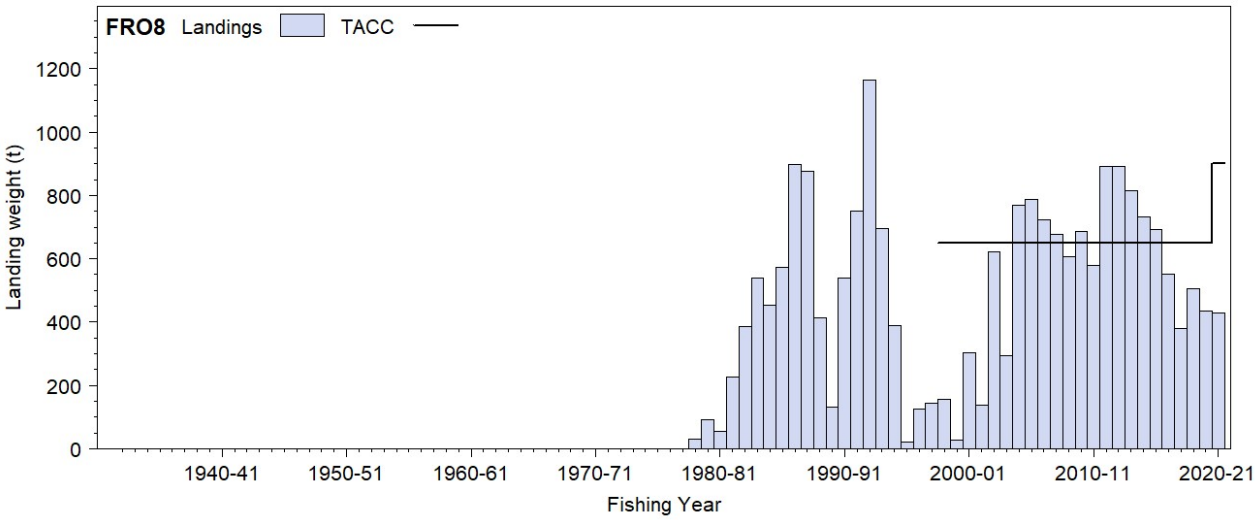


Figure 1 [Continued]: Reported commercial landings and TACC for the eight main FRO stocks. From top: FRO 3 (South East Coast), FRO 4 (South East Chatham Rise) and FRO 5 (Southland). [Continued on next page]





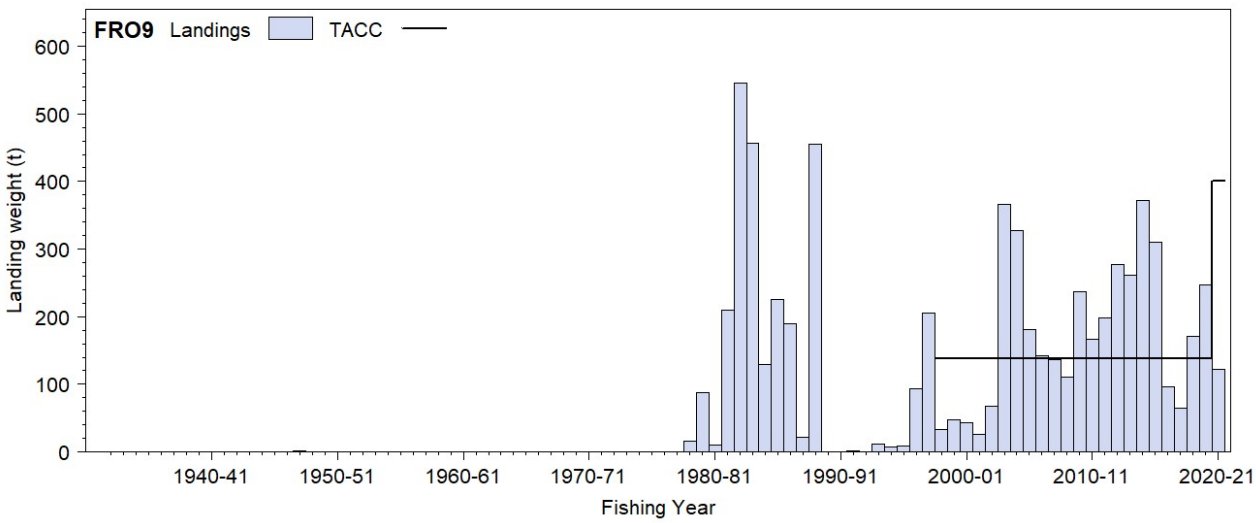


Figure 1 [Continued]: Reported commercial landings and TACC for the eight main FRO stocks. From top: FRO 7 (Challenger), FRO 8 (Central West) and FRO 9 (Auckland West). Note that these figures do not show data prior to entry into the QMS.

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. Maori 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 34ºS to 49ºS, but are most common between 36ºS and 44ºS. 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 16ºC. 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).

The adults probably congregate in the late spring months, and spawn during the summer and autumn over the mid to outer shelf. Fertilisation has been 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 22.0ºC (Robertson 1980).

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 FL (fork length) 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 *Kaharoa* trawl surveys (Horn 2013).

Frostfish migrate into mid-water 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 of 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 (see Section 6.1) suggests 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.

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_∞	k	t_0	L_∞	k	t_0	
WCSI	129.2	0.56	0.08	143.5	0.457	-0.04	Horn (2013

3. 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 the Chatham Rise. Spawning is also known to take place on the west coast of the 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.

4. STOCK ASSESSMENT

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

4.1 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 1981–2013.

Vessel	Trip Code	Depth Range (m)	Biomass index (t)	CV (%)	Date
QMA 1					
Bay of Plenty					
Kaharoa	KAH9004	10–150	246	87	February/March 1990
Kaharoa	KAH9202	10–150	92	48	February 1992
Kaharoa	KAH9601	10–250	328	49	February 1996
Kaharoa	KAH9902		193	34	February 1999
QMA 2					
Kaharoa	KAH9304	20–400	573	38	March/April 1993
Kaharoa	KAH9402	20–400	1 079	40	February/March 1994
Kaharoa	KAH9502	20–400	493	22	February/March 1995
Kaharoa	KAH9602	20–400	693	17	February/March 1996
QMA 7 & 8					
Tomi Maru		30–300	2 173	22	December 1980 - January 1981
Shinkai Maru	SHI8102	20–300	6 638	12	October/November 1981
Cordella	COR9001	25–300	2 189	20	February/March 1990
QMA 7 (WCSI)					
Kaharoa	KAH9006	20–400	121	27	March/April 1990
Kaharoa	KAH9204	20–400	24	29	March/April 1992
Kaharoa	KAH9404	20–400	53	37	March/April 1994
Kaharoa	KAH9504	20–400	89	31	March/April 1995
Kaharoa	KAH9701	20–400	259	32	March/April 1997
Kaharoa	KAH0004	20–400	316	16	March/April 2000
Kaharoa	KAH0304	20–400	494	22	March/April 2003
Kaharoa	KAH0504	20–400	423	45	March/April 2005
Kaharoa	KAH0704	20–400	529	38	March/April 2007
Kaharoa	KAH0904	20–400	835	34	March/April 2009
Kaharoa	KAH1104	20–400	251	28	March/April 2011
Kaharoa	KAH1305	20–400	424	24	March/April 2013
WCSI south of 41° 30’					
James Cook	JCO8311	25–450	183	34	September/October 1983
James Cook	JCO8415	25–450	181	25	August/September 1985

4.2 Biomass estimates

No biomass estimates are available for frostfish.

4.3 Yield estimates and projections

MCY cannot be determined as 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.

4.4 Other factors

None available.

5. 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.

It is therefore not possible to estimate yields. It is not known if recent catches are sustainable or whether they are at levels that will allow the stock to move towards a size that will support the maximum sustainable yield.

6. FOR FURTHER INFORMATION

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