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A summary of biology and commercial landings, and a stock assessment of the frostfish, *Lepidopus caudatus* Euphrasen, 1788 (Pisces: Trichiuridae), in New Zealand waters

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1. EXECUTIVE SUMMARY

Frostfish (*Lepidopus caudatus*) are predominantly taken as bycatch from target trawl fisheries on jack mackerel (*Trachurus* spp.) and hoki (*Macruronus novaezelandiae*) and, to a lesser extent, arrow squid (*Nototodarus* spp.), barracouta (*Thyrsites atun*), and gemfish (*Rexea solandri*). These fisheries are predominantly targeted by larger vessels owned or chartered by New Zealand fishing companies.

Biological data on frostfish in New Zealand waters are limited. No estimates of instantaneous natural mortality (*M*) are available for frostfish in New Zealand.

Annual catches have been variable, ranging from 900 t in the 1984–85 fishing year to over 4400 t in 1990–91. A suggested stock structure based on known spawning areas is presented. Catch histories based on two scenarios are given and are likely to be conservative as some catches of frostfish are not reported on fishing returns.

2. INTRODUCTION

2.1 Overview

Frostfish belong to the family Trichiuridae (cutlassfishes), which are found in tropical to temperate waters and are represented by 32 species in 9 genera worldwide. In New Zealand waters there are only three genera, *Lepidopus*, *Benthodesmus*, and *Aphanopus* (Paulin *et al.* 1989, A. Stewart, MONZ pers comm.). Worldwide, there are six species in the genus *Lepidopus*, but only *Lepidopus caudatus* is considered an important commercial fish species (Nakamura & Parin 1993). Of the two other genera found in New Zealand waters, *Benthodesmus* (slender scabbardfishes) is represented by *B. elongatus* and *B. tenuis*, and *Aphanopus* by one species, *A. mikhailini*, which is considered rare (Stewart 1996). These are of no commercial importance. *Benthodesmus* and some species of the related family Gempylidae, especially the false frostfish (*Paradiplospinosus gracilis*), are sometimes misidentified as frostfish.

Frostfish are widely distributed throughout the continental shelf and upper slopes of all oceans, except the North Pacific, and have a benthopelagic lifestyle. Countries reporting landings over 1000 t of *L. caudatus* in 1993 were South Africa (14435 t), Portugal (8719 t), Russian Federation (2352 t) and New Zealand (2295 t) (FAO 1993). Small quantities are landed in southern Australian waters, but most frostfish are discarded at sea because of poor market acceptance Kailola et al (1993). They are

found all around mainland New Zealand and the Chatham Islands in depths ranging from 50 to 600 m.

This document summarises the biological and fisheries data available for New Zealand's frostfish (*L. caudatus*). The biological data were extracted and summarised from the Ministry of Fisheries (MFish) research trawl survey database; commercial catch data were from the MFish catch and effort database. Maximum Constant Yield (MCY) could not be estimated as there is no estimate of natural mortality for New Zealand frostfish. Current Annual Yield (CAY) could not be estimated because there is no assessment of current biomass. The New Zealand 200 mile Exclusive Economic Zone (EEZ), Fishery and Quota Management Areas (QMA), and places mentioned in the text are given in Figure 1.

2.2. Literature review

Few publications have dealt with frostfish in any detail. Key references on the identification of the species are Paulin *et al.* (1989) and Nakamura & Parin (1993). The most comprehensive review of the biology of the species is by Demestre *et al.* (1993) for *L. caudatus* in the northwestern Mediterranean Sea. These authors included information on the distribution, population structure, growth, longevity, diet, and reproduction of frostfish in these waters. Blaber & Bulman (1987) presented data on the diet of frostfish and other species in Tasmanian waters. Spawning of the frostfish in New Zealand waters was described by Robertson (1980). Some theories on why frostfish cast themselves ashore were presented by Graham (1956). Stewart (1996) presented a short account, including a description of the species and of its distribution. Some catch and distribution summaries for frostfish around New Zealand were given by Kerstan & Sahrhage (1980). Various reports on trawl surveys around New Zealand give catch details on frostfish, and occasional distribution and length frequencies.

3. COMMERCIAL FISHERY

3.1 Data sources

Data on commercial catch landings were obtained from the Fisheries Statistics Unit (FSU) database and summaries for the years (1978–79 to 1988–89), and the MFish Catch and Effort Database (1988–89 to 1996–97). There are no reliable records of catch before to the introduction of the EEZ on 1 April 1978.

Individual tow data for deepwater vessels were available from the FSU database from 1982–83 to 1988–89 and from the MFish Catch and Effort Database from 1988–89 to 1993–1994. These data were used in the frostfish catch analysis. Catch data from inshore vessels were taken from summaries provided by MFish from FSU and quota management system (QMS) databases. Data were supplied by the Ministry of Fisheries and have not been checked for errors.

A variety of sources of information were used to derive the best estimate of annual landings for the fishing years 1983–84 to 1995–96. For the 1983–84 to 1988–89 fishing years, the best estimate of landings is the sum of the FSU inshore and

deepwater catch returns. For the transitional year from FSU to the QMS data, 1988–89, the best estimate is the sum of the FSU and Licensed Fish Receivers Return (LFRR) data. From the 1989–90 fishing year on, the best estimate is the greater of either the LFRR or the Catch Landing Return (CLR) data. The Trawl, Catch, Effort and Processing Returns ($TCEPR_{estimated}$) include only the five most abundant species in each trawl shot and, therefore, are not suitable for frostfish as it is not often one of the five. The $TCEPR_{processed}$ data record all fish processed on a particular day and should be more reliable, but were always less than the $TCEPR_{estimated}$ data. Catch histories presented by QMA have been pro-rated to equal the best estimate of catch for each fishing year.

Sources of error include unreported catch and discarded catch. The difference between the $TCEPR_{processed}$ and $TCEPR_{estimated}$ data suggests some frostfish may not be processed. Recent compliance investigations have suggested the probability of damaged and small hoki going to fish meal being recorded as frostfish. Landings reported from vessels filling out inshore Catch Effort Landing Returns (CELR) were very small and it is likely that most frostfish taken were discarded, as there has been a reluctance by local companies to take frostfish (Anon. 1979).

Subsequent to the preparation of this report and its presentation to the working group in March 1998, errors with the catch statistics provided were found. These related mainly to the recording of catches by QMA. Original data summaries by QMA, catch histories by proposed fishstock and estimated yields, as presented to the working group are included in this report. Revised figures as at June 1988 are also given.

The estimated primary value (i.e., port price) of New Zealand's frostfish fishery was about $1.2 million in 1993 (NZFIB 1994), $1.6 million in 1994, and $1.2 million in 1995 (NZFIB 1996).

3.2 Annual landings

Catch histories of frostfish by EEZ area for the fishing years 1978–79 to 1983–83 for foreign chartered and licensed vessels are given in Table 1. Reported catches from 1983–84 to 1996–97 and a best estimate of annual catch are given in Table 2. In Table 3a an estimate of annual catch from CLR data (pro-rated to match the best estimate of catch for each fishing year) for the years 1983–84 to 1995–96 (*see* Table 2) has been summarised by QMA. Table 3b gives a summary of catches by QMA using revised data supplied by MFish (*see* section 3.1). The main areas reporting frostfish catches are to the west of New Zealand, primarily in QMAs 7 and 8 on the west coast of the South Island and in the North and South Taranaki Bight. The highest annual catches are associated with hoki fishing during winter since 1986–87 and with jack mackerel fishing during late spring and early summer.

In QMAs 3, 4, 5, and 6, frostfish have been totally prohibited as a target species since October 1991, but they are allowed to be taken and landed as bycatch. Only small quantities were reported from these QMAs.

Target fisheries for frostfish (i.e., where frostfish is recorded as the target species in the tow by tow data by fishers) from 1982–83 to 1988–89 occurred on the west coasts

of both the South Island and North Island, from Abut Head in the south to Manukau Harbour in the north, and at Puysegur Bank, with the best catch rates recorded off the west coast of the South Island (Figure 2). In later years, the area where frostfish is targeted has narrowed to the west coast of the South Island (Figure 3). Target fishing on frostfish accounted for 8% of the frostfish catch for the period 1983–84 to 1988–89, with less than 2% reported from 1988–89 to 1993–94.

Most frostfish were caught as bycatch of middle depth species trawl fisheries. Over 99% of the total frostfish catch was reported taken by large deepwater trawlers. The main areas in which these fisheries operate are shown in Figures 4 to 8.

In the fishing years 1983–84 to 1988–89, 60% of the frostfish catch came from the jack mackerel fishery, 17% from hoki, 7% from squid, and 3% from each of the barracouta and gemfish target fisheries. The range of frostfish commercial catches in western areas extends from Manukau Harbour to Abut Head with target species predominantly jack mackerel, hoki, and squid, and at Puysegur with gemfish and barracouta as target species. In the fishing years 1989–90 to 1993–94, 64% of the frostfish catch came from hoki target fisheries, 22% from jack mackerel, 8% from squid, 3% from barracouta, and 1% from gemfish target fisheries. The most significant change from earlier years has been the increase in reported frostfish catches associated with hoki fishing in QMA 7 and a corresponding decrease reported from the jack mackerel fishery in QMAs 7 and 8.

Frostfish are mostly caught in depths of 50–600 m (from FSU deepwater data, 1982–83 to 1988–89). The average depth for all tows where frostfish were taken is 247 m (Figures 9 and 10) and 173 m for target fishing. The largest catches of frostfish were made at about 200 m bottom depth. Most of the commercial catch (81%) was reported taken by mid-water trawl for the fishing years 1989–90 to 1993–94.

Catches of frostfish reported by vessels filling out inshore CELR returns were very low with the highest reported being 5 t in the 1993–94 fishing year. Data from CELR forms show that no frostfish were reported landed from 1988–89 to 1993–94.

3.3 Non-commercial fisheries

There are no known Maori, recreational, or other non-commercial fisheries for frostfish. Frostfish are occasionally taken by recreational fishers. Small numbers have been reported from recreational diary surveys, mainly in QMA 1 and rarely in QMAs 2 and 9. Maori have collected beach-cast frostfish in the past (Graham 1956).

4. RESEARCH

4.1 Distribution

In New Zealand, frostfish are taken in research bottom trawl catches from 34° to 49°, but are most common between 36° and 44° (Figure 11). They occur mainly in depths of 50–600 m and at bottom temperatures between 10 and 16 °C. The distribution of frostfish from research data is similar to that suggested by commercial fishing (*see*

Figures 2 to 8), except that research occurrences extend around the whole of the North Island.

Most research frostfish catches were small, with less than 10 kg taken per nautical mile, but occasionally catches up to 800 kg per nautical mile were recorded. The larger catches (over 50 kg per nautical mile) have been taken from around most of the North Island, Cook Strait, and the west coast of the South Island. These larger catches occur from 50–600m depth (Figure 12), but are more frequent around 200 m depth. Bottom temperatures associated with research catches ranged from 6.2 to 19.5 °C (Figure 13), with larger catches spread through 10 to 16 °C. This is a wider range, and a considerably higher upper limit, than the preferred temperature range of 11.5 to 13 °C reported by Kerstan & Sahrhage (1980). The accuracy of the bottom temperatures recorded on the earlier research surveys is unknown.

4.2 Length frequency data

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

The few length frequencies on frostfish from the MFish trawl survey database were extracted and scaled by the percentage sampled, the area swept by the trawl (using doorspread values), and the area surveyed. There are no sexed length frequency data available. Scaled length frequencies from two Bay of Plenty *Kaharoa* surveys in 1996 are shown in Figure 14. Unscaled length frequencies from a *Kaharoa* survey on the west coast North Island in 1991 and a *Shinkai Maru* survey in 1981 off central western New Zealand are shown in Figure 14. The North Island surveys showed the presence of juveniles through to adults, whereas no fish less than 50 cm were present on any west coast South Island trawl surveys.

4.3 Length-weight relationships

No length-weight relationships can be calculated from the MFish trawl survey database as individual weights have not been recorded. However, length-weight relationship data are available for *Lepidopus caudatus* from the northwestern Mediterranean for males and females separately and for both sexes combined (Demestre *et al.* 1993). These data are summarised in Table 4.

4.4 Age, growth, and productivity

No information on age or growth rates is available from New Zealand specimens. Frostfish (*Lepidopus caudatus*) from the northwestern Mediterranean exhibit fast growth and attain a maximum age of 8 years. Von Bertalanffy growth parameters for the Mediterranean fish are given in Table 5.

Using the maximum age given by Demestre *et al* (1993) of 8 years, an estimate of natural mortality (M) can be derived from the equation:

$$M = \log_e(100)/A_{max}$$

where A_{max} is the age reached by 1% of the virgin population (Sparre *et al.* 1989). This gives an estimate of M of 0.58.

Demestre *et al* (1993) read otoliths whole after soaking them in seawater for 24 h. Two readers were used and the analysis included only data where there was complete agreement between readers. Frostfish in the Mediterranean appear to reach a greater size than members of the same species in New Zealand, i.e., up to 196 cm CFL compared with 165 cm CFL recorded in New Zealand.

4.5 Spawning areas and stock structure

Robertson (1980) identified spawning areas from eggs taken in plankton tows around New Zealand. Spawning areas included the outer shelf from the Bay of Islands to south of East Cape and an area off Fiordland. No eggs were recorded from the south-east coast of the South Island (Robertson 1980) 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 (authors' unpublished data). The 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 – 22.0 °C (Robertson 1980).

Juvenile frostfish (less than 30 cm) have been reported from trawl surveys in the Bay of Plenty, Hauraki Gulf, off Northland, the west coast of the North Island, and the west coast of the South Island. Juvenile frostfish were trapped in the meshes of the trawl during *W. J. Scott* surveys (1981–1983) in inshore waters of the west coast of the South Island from May through to September, with fish at 15 cm recorded in June (authors' unpublished data).

The following proposed stock structure is based on the observation of spawning occurring in three areas at similar times of year as well as known distribution of juveniles and adults (*see* Figures 2–8, 11). Suggested fishstock areas (Figure 15) for frostfish are as follows.

FRO 1: (QMAs 1 and 2). Known spawning areas, Bay of Islands to East Cape.;

FRO 3: (QMAs 3 and 4). No known spawning in this area. Small quantities of commercial catch reported.

FRO 5: (QMAs 5 and 6). Known spawning off Fiordland, commercial catch on Puysegur Bank and Stewart/Snares shelf.

FRO 7: (QMAs 7, 8, and 9). Known spawning off the west coast South Island. Main area for the commercial catch.

FRO 10: QMA 10. There have been no reported landings, and this could be retained as a separate Fishstock.

A catch history based on the suggested Fishstocks is given in Table 6a and 6b.

4.6 Feeding

Frostfish are benthopelagic, migrating into midwater at night. They feed on crustaceans, small fish, and squid (Nakamura & Parin 1993). Euphausids 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 is mainly myctophids and euphausids (Blaber & Bulman 1987).

5. BIOMASS ESTIMATES

5.1 Trawl surveys

Biomass indices for frostfish are available from trawl surveys carried out by different vessels (Table 7). 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, it is expected to be low. Biomass indices given in Table 7 are considered to be conservative.

5.2 Catch-per-unit-effort

An analysis of catch-per-unit-effort (cpue) data as an indicator of relative biomass was not attempted because frostfish are landed almost exclusively as a bycatch of numerous target trawl fisheries.

6. YIELD ESTIMATION

A stock assessment of frostfish is not possible. The proposed stock structure is uncertain, the fishery is variable and almost entirely a bycatch of other target fisheries, and there are no age data or estimates of abundance. It is therefore not possible to estimate yields and it is unknown if recent catches are sustainable or are at levels that will allow the stock to move towards a size that will support the maximum sustainable yield.

There are no estimates of absolute biomass or reference fishing mortalities for frostfish. The estimates of natural mortality based on aging data from frostfish in Mediterranean waters has not been used to provide any yields because of probable differences in growth between the two areas. Mediterranean sampling would have been conducted on an already exploited stock. Also, using whole otoliths to determine age (as done by Demestre *et al* (1993) for frostfish) may result in underestimates of age of larger fish (e.g. Horn & Sutton 1996).

Relative biomass estimates from trawl surveys are commonly used in population models to determine biomass of fish stocks. This may be possible for QMA 2 but the time series has been discontinued. This time series used a high opening bottom trawl with a headline height of about 8 m and was therefore probably more suited to catching frostfish than other time series surveys conducted from *Kaharoa* around New Zealand, where a net with a much lower headline height is used and biomass estimates of frostfish are low.

6.1 Estimation of MCY and catch history

No estimates of MCY are given. As less that 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. An averaged catch history, rounded to the nearest 5 t, based on two scenarios is presented.

The range of years chosen for the catch history should ideally represent a period of stable and unrestricted effort, but this is not feasible in this predominantly bycatch fishery. Also, regulations prohibiting target fishing in QMAs 3, 4, 5, and 6 were introduced from 1 October 1991. For these reasons two approaches for the catch histories are given.

a) The use of the fishing years 1983–84 to 1995–96.

b) The use of two catch histories, 1983–84 to 1990–91 for FRO 3 (QMAs 3 and 4) and FRO 5 QMAs (5 and 6), when there were no restrictions on effort and target fishing for frostfish, and from 1991–92 to 1995–96 for FRO 1 (QMAs 1 and 2) and FRO 7 (QMAs 7, 8 and 9) during a recent period of stable effort.

Thus:

Scenario a:		Data as supplied by MFish (April 1997)	Revised data from MFish (June 1998)
FRO 1	QMAs 1 + 2	110 t	80 t
FRO 3	QMAs 3 + 4	90 t	70 t
FRO 5	QMAs 5 + 6	190 t	130 t
FRO 7	QMAs 7, 8, + 9	2 340 t	2 390 t
Scenario b:			
FRO 1	QMAs 1 + 2	65 t	90 t
FRO 3	QMAs 3 + 4	40 t	40 t
FRO 5	QMAs 5 + 6	155 t	155 t
FRO 7	QMAs 7,8, + 9	2 530 t	2 260 t

Problems associated with these years include non-reporting and possible mis-reporting of frostfish catches. Also, the amount of effort and catch history on frostfish relates very closely to effort on other target species such as hoki and jack mackerel. Changing fishing patterns, such as a decline in the target fishing for jack mackerel in JMA 7 in

recent years and a change of hoki target fishing outside the spawning season in the last 4–5 years, may have affected landings of frostfish.

6.2 Estimation of CAY

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

7. MANAGEMENT IMPLICATIONS

As less than 2% of the reported catch in recent years is from target fishing, most quota allocated under the QMS system, if frostfish is introduced to it will be required to cover bycatch of other middle depth fishing activities. Annual catches are likely to vary according to effort targeting other species in areas of frostfish abundance.

Due to discarding or mis-reporting the catch histories presented here may be lower than the actual catches in these years. If quota allocation for frostfish is based on reported landings this may restrict target fishing activities on other quota species.

Similarities between juvenile frostfish and the scabbardfishes (*Benthodesmus* species) and the false frostfish (*Paradiplospinosus gracilis*) may cause problems with the correct identification of *Lepidopus caudatus*.

8. ACKNOWLEDGMENTS

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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 and McKoy (1988)) correspond approximately to the QMA 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 area	1&2	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) of frostfish by fishing year, 1983–84 to 1995–96. Data sources were: Fisheries Statistics Unit (FSU); catch, effort and landing return (CELR); trawl, catch, effort and processing return (TCEPR); catch landing return (CLR); licensed fish receivers return (LFRR). Fishing years are from 1 October to 30 September

Year	FSU Inshore	FSU Deepwater	FSU Total	CELR Estimated	TCEPR Estimated	TCEPR Processed	CLR	LFRR	Best Estimate
1983–84	0	1 475	1 475						1 475
1984–85	0	901	901						901
1985–86	2	1 413	1 415						1 415
1986–87	11	2 261	2 272					1 485	2 272
1987–88	3	4 388	4 391					2 783	4 391
1988–89	7	1 117	1 124	0	1 107	130	918	1 828	2 952
1989–90				2	1 576	476	2 037	2 536	2 538
1990–91				1	2 764	834	4 436	3 976	4 437
1991–92				1	2 081	722	3 563	3 298	3 564
1992–93				3	1 657	563	2 700	2 800	2 803
1993–94				5	2 281	715	2 202	2 964	2 969
1994–95				1	2 679	1 023	3 920	3 315	3 921
1995–96				NA	1 344	930	1 769	1 602	1 769
1996–97				NA	NA	NA	NA	NA	2 006

Table 3: Reported landings (t) of frostfish by QMA and fishing year, 1983–84 to 1995–96. Total landings for each fishing year are prorated to the best estimate given in Table 2 from FSU data (1983–84 to 1988–89) and QMS data from 1988–89 to 1996–97. There are no landings reported from QMA 10. Fishing year from 1 October to 30 September

	QMA 1	QMA 2	QMA 3	QMA 4	QMA 5	QMA 6	QMA 7	QMA 8	QMA 9	Total
1983–84	2	0	0	10	28	7	432	539	457	1 475
1984–85	0	0	2	1	100	0	214	455	129	901
1985–86	0	0	9	2	258	0	344	574	226	1 413
1986–87	4	4	5	6	71	4	1 089	898	190	2 271
1987–88	2	0	3	1	20	0	3 466	875	22	4 389
1988–89	115	0	1	0	15	3	1 950	413	455	2 952
1989–90	804	0	58	0	146	29	1 370	132	0	2 538
1990–91	133	0	228	0	496	67	2 939	576	0	4 437
1991–92	26	7	142	0	336	7	2 302	742	0	3 564
1992–93	44	9	77	92	604	54	575	1 345	0	2 803
1993–94	40	13	214	0	63	20	2 011	590	16	2 969
1994–95	55	14	120	157	87	24	3 069	388	7	3 921
1995–96	79	40	20	29	0	3	1 567	22	9	1 769
1996–97	196	6	11	4	3	0	1 575	118	93	2 006

Table 3b: Ministry of Fisheries revised catches of frostfish by QMA (22 July 1998). Data complied for quota allocation catch histories (pers com Marianne Vignaux).

	QMA 1	QMA 2	QMA 3	QMA 4	QMA 5	QMA 6	QMA 7	QMA 8	QMA 9	Total
1983–84	2	0	0	10	28	7	432	539	457	1 475
1984–85	0	0	2	1	100	0	214	455	129	901
1985–86	0	0	9	2	258	0	344	574	226	1 413
1986–87	4	4	5	6	71	4	1 089	898	190	2 271
1987–88	2	0	3	1	20	0	3 466	875	22	4 389
1988–89	115	0	1	0	15	3	1 950	413	455	2 952
1989–90	397	0	58	0	146	29	1 370	132	0	2 132
1990–91	45	24	224	0	496	67	3 029	539	0	4 424
1991–92	46	3	143	0	337	7	2 295	750	1	3 582
1992–93	80	9	51	0	0	0	1 360	1 165	0	2 665
1993–94	100	19	168	0	0	0	1 998	696	12	2 993
1994–95	55	14	120	0	87	0	3 069	388	7	3 740
1995–96	80	40	72	29	0	0	1 536	22	9	1 788
1996–97	198	6	12	4	8	0	2 881	126	93	3 328
1997–98*	121	148	11	0	7	0	676	149	256	1 368

* incomplete year.

Table 4: Length-weight relationship data for frostfish (*Lepidopus caudatus*) from the northwestern Mediterranean for males and females separately and for both sexes combined (after Demestre *et al.* 1993). Using the equation $W = aL^b$ where W is the total weight (g) and L is the total length (cm).

Population	*n*	*a*	*b*	r^2
Males	310	0.000291	3.1851	0.97
Females	234	0.000322	3.2196	0.98
Immature	167	0.000322	3.2183	0.99
Total sample	590	0.000323	3.2280	0.99

Table 5: Parameters of von Bertalanffy growth equations for frostfish (*Lepidopus caudatus*) from the northwest Mediterranean, estimated from an age-length key (after Demestre *et al* 1993).

Sex	L_{inf} (cm)	k	t_0 (years)
Males	201.8	0.226	-0.919
Females	243.9	0.142	-1.632
All fish	200.0	0.238	-0.759

Note: The values for t_0 for males and females in the referenced text are given as positive but it is clear from the plots of the growth curves in that paper that the values are negative and they have been corrected here.

Table 6a: Reported landings (t) of frostfish by proposed Fishstock area and fishing year 1983–84 to 1996–97. Total landings for each fishing year are prorated to the best estimate of catch (*see* Table 3) from FSU data (1983–84 to 1988–89) and QMS data from 1988–89 to 1996–97. There are no landings reported from QMA 10. Fishing year from 1 October to 30 September

	Proposed fishstock and equivalent QMAs				
	FRO 1 1 and 2	FRO 3 3 and 4	FRO 5 5 and 6	FRO 7 7, 8 and 9	Total
1983–84	2	10	35	1 428	1 475
1984–85	0	3	100	798	901
1985–86	0	11	258	1 144	1 415
1986–87	8	11	75	2 177	2 272
1987–88	2	4	20	4 363	4 391
1988–89	115	1	18	2 818	2 952
1989–90	804	58	175	1 502	2 538
1990–91	133	228	563	3 515	4 437
1991–92	33	142	343	3 044	3 564
1992–93	53	169	658	1 920	2 803
1993–94	53	214	83	2 617	2 969
1994–95	69	277	111	3 464	3 921
1995–96	119	49	3	1 598	1 769
1996–97	202	15	3	1 786	2 006

Table 6b: Ministry of Fisheries revised catches of frostfish, as of June 22 1998, totaled to represent proposed fish stocks (*see* Table 3b).

	Proposed fishstock and QMA				
	FRO 1 1 and 2	FRO 3 3 and 4	FRO 5 5 and 6	FRO 7 7, 8 and 9	Total
1983–84	2	10	35	1 428	1 475
1984–85	0	3	100	798	901
1985–86	0	11	258	1 144	1 413
1986–87	8	11	75	2 177	2 271
1987–88	2	4	20	4 363	4 389
1988–89	115	1	18	2 818	2 952
1989–90	397	58	175	1 502	2 132
1990–91	69	224	563	3 568	4 424
1991–92	49	143	344	3 046	3 582
1992–93	89	51	0	2 525	2 665
1993–94	119	168	0	2 706	2 993
1994–95	69	120	87	3 464	3 740
1995–96	120	101	0	1 567	1 788
1996–97	204	16	8	3 100	3 328
1997–98*	269	11	7	1 081	1 368

* incomplete year.

Table 7: Doorspread biomass estimates (t) and *c.v.*s (%) of frostfish from random stratified trawl surveys, 1981 to 1997

Vessel	Voyage	Depth range (m)	Biomass (t)	*c.v.* (%)	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
QMA 2					
Kaharoa	KAH9304	20–400	573	38	March/April 1993
Kaharoa	KAH9402	20–400	1079	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	2173	22	December 1980 – January 1981
Shinkai Maru	SHI8102	20–300	6638	12	October/November 1981
Cordella	COR9001	25–300	2189	20	February/March 1990
QMA 7					
West coast South Island					
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
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

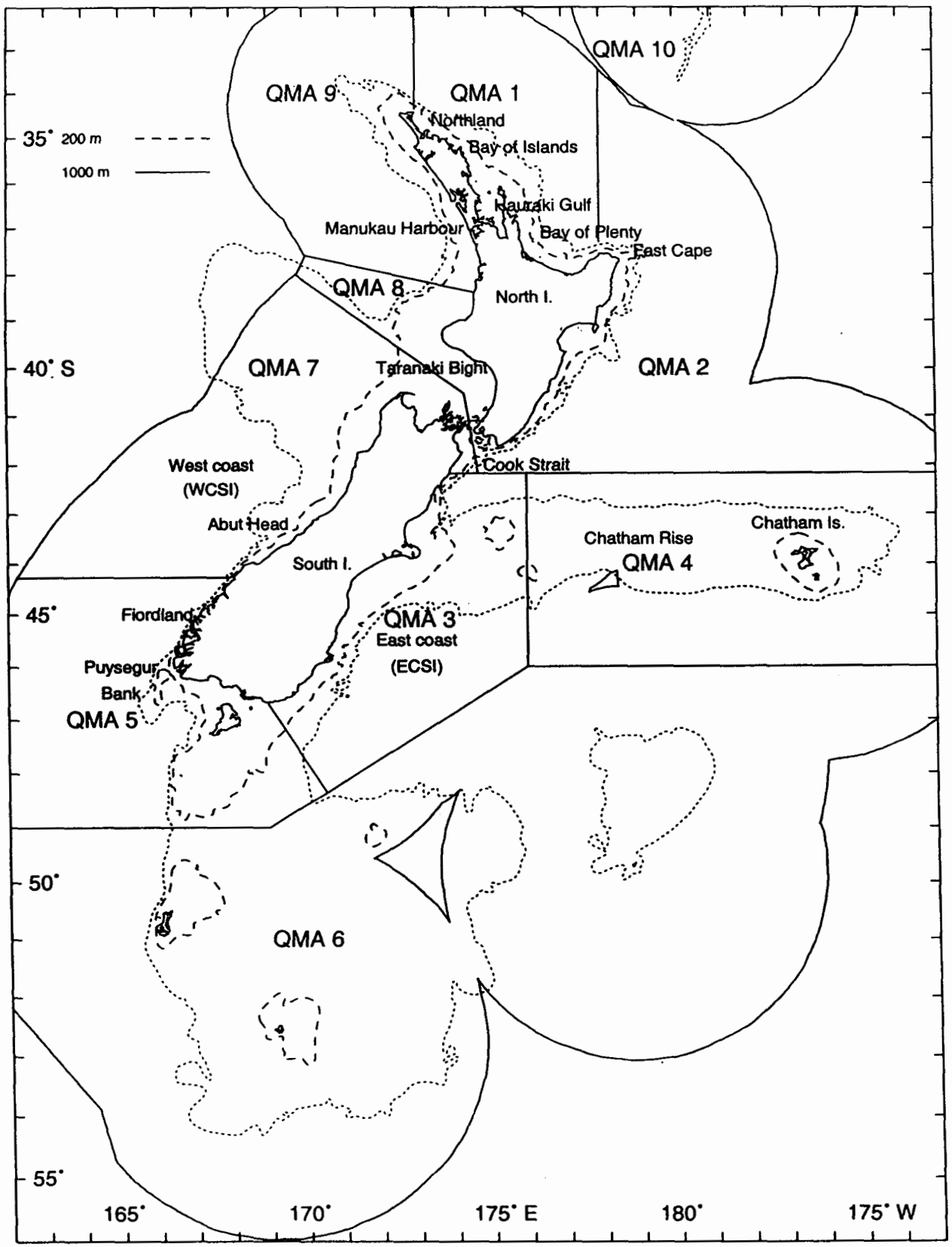


Figure 1: Map of the 200 mile Exclusive Economic Zone (EEZ), Fishery Management Areas QMAs and places named in the text.

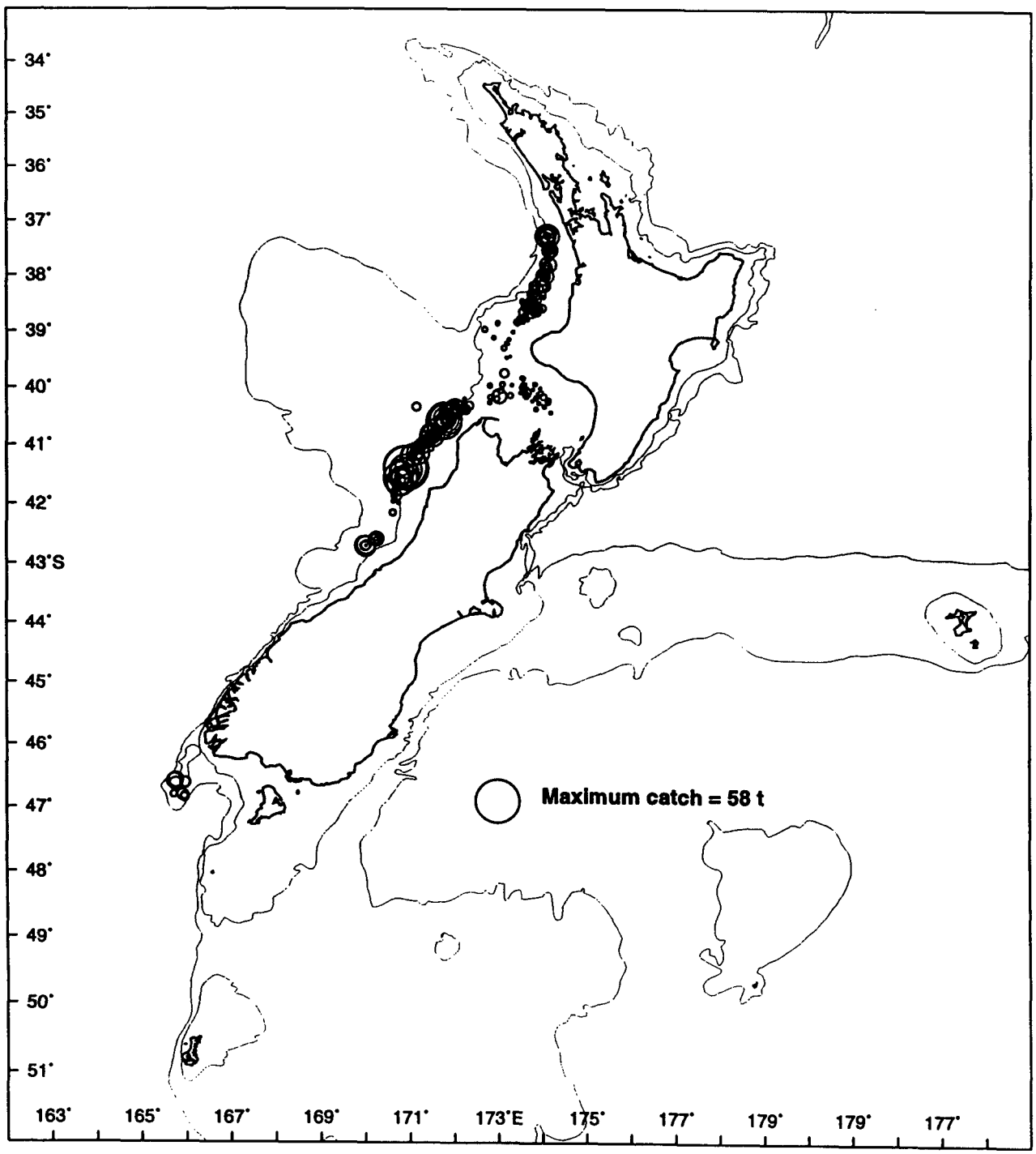


Figure 2: Frostfish target catches for fishing years 1982–83 to 1987–88. Circle size is proportional to the maximum catch.

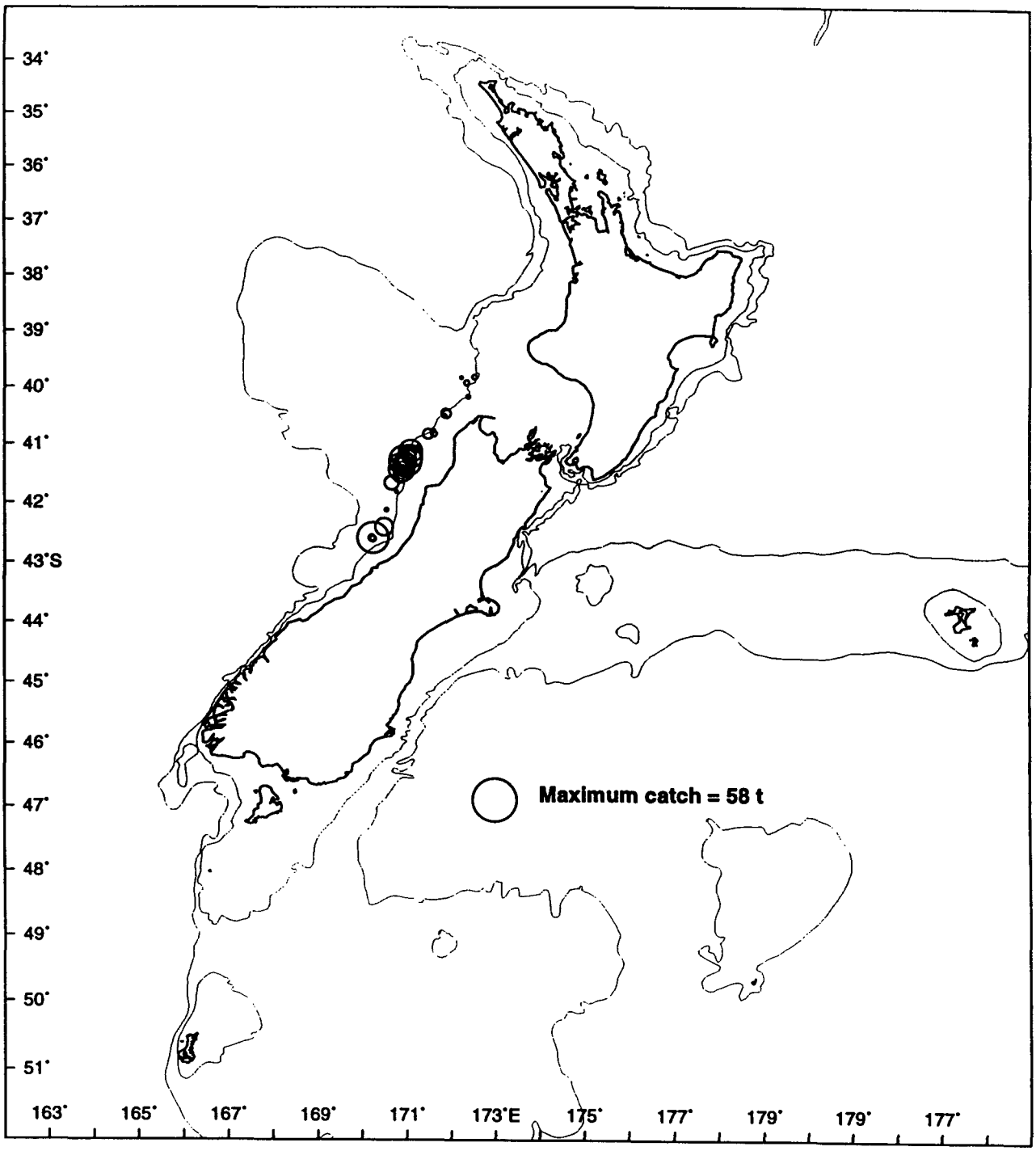


Figure 3: Frostfish target catches for fishing years 1988–89 to 1993–94. Circle size is proportional to the maximum catch.

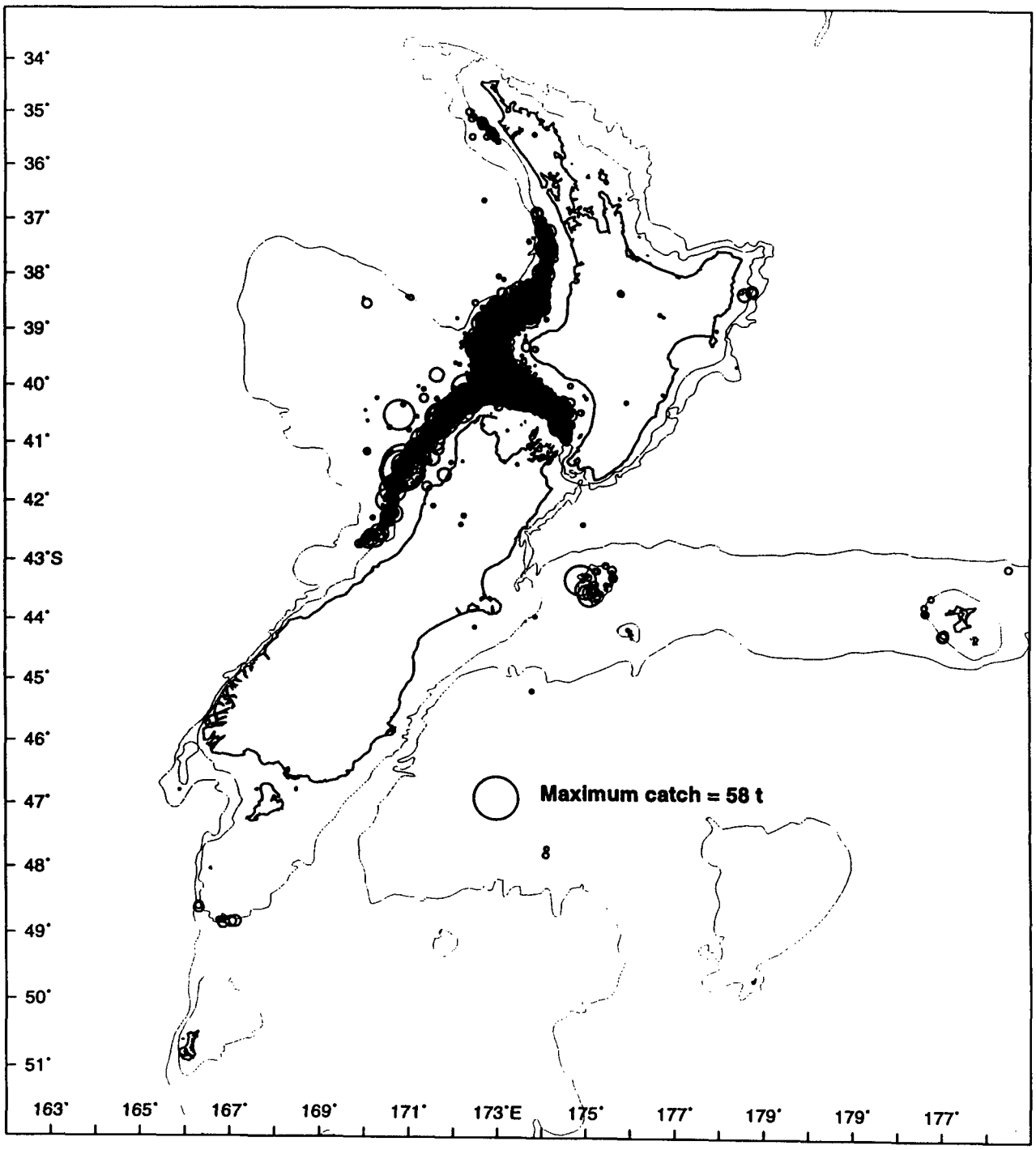


Figure 4: Frostfish bycatch from jack mackerel target fishing 1982–83 to 1993–94. Circle size is proportional to the maximum catch.

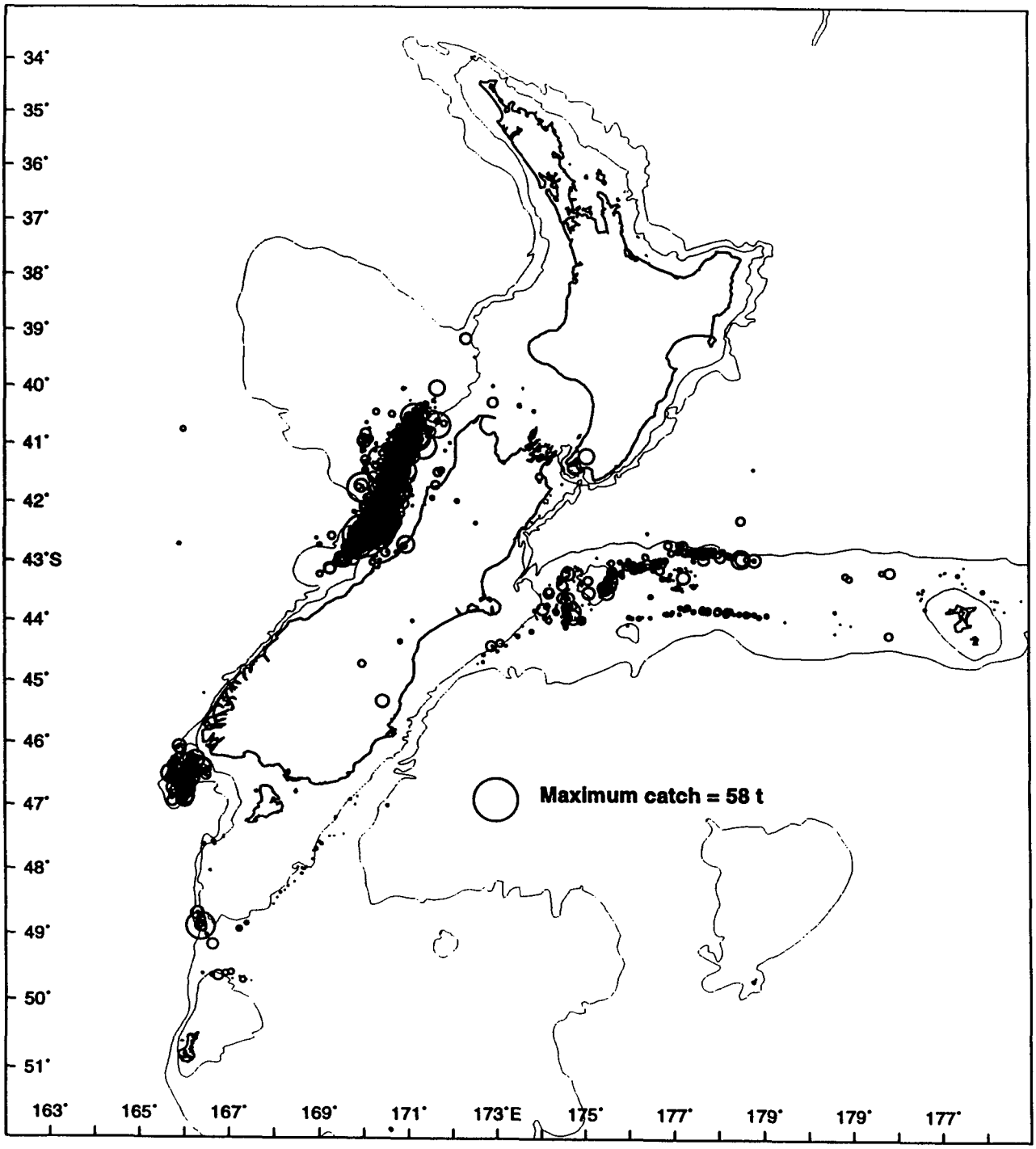


Figure 5: Frostfish bycatch from hoki target fishing 1982–83 to 1993–94. Circle size is proportional to the maximum catch.

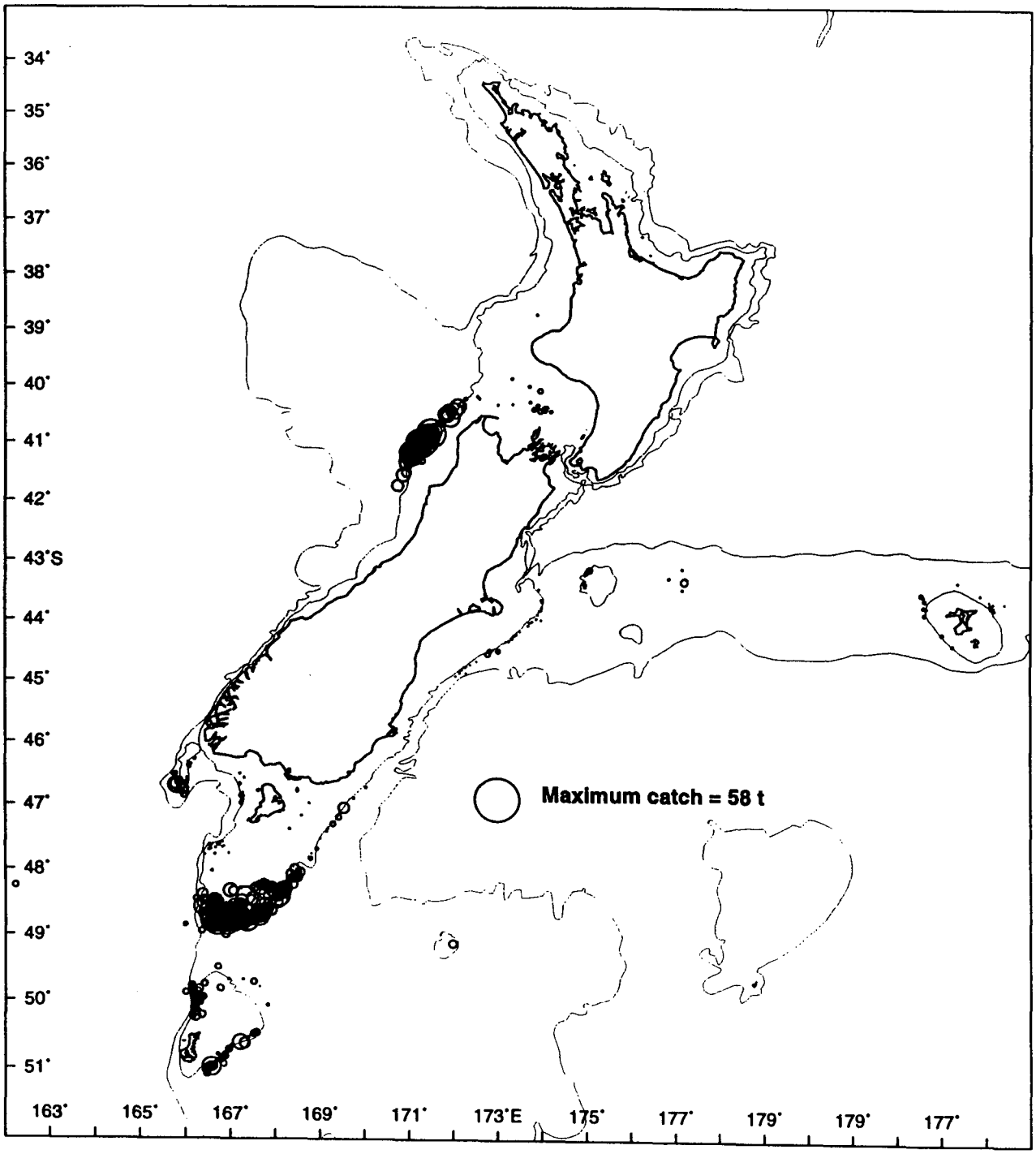


Figure 6: Frostfish bycatch from arrow squid target fishing 1982–83 to 1993–94. Circle size is proportional to the maximum catch.

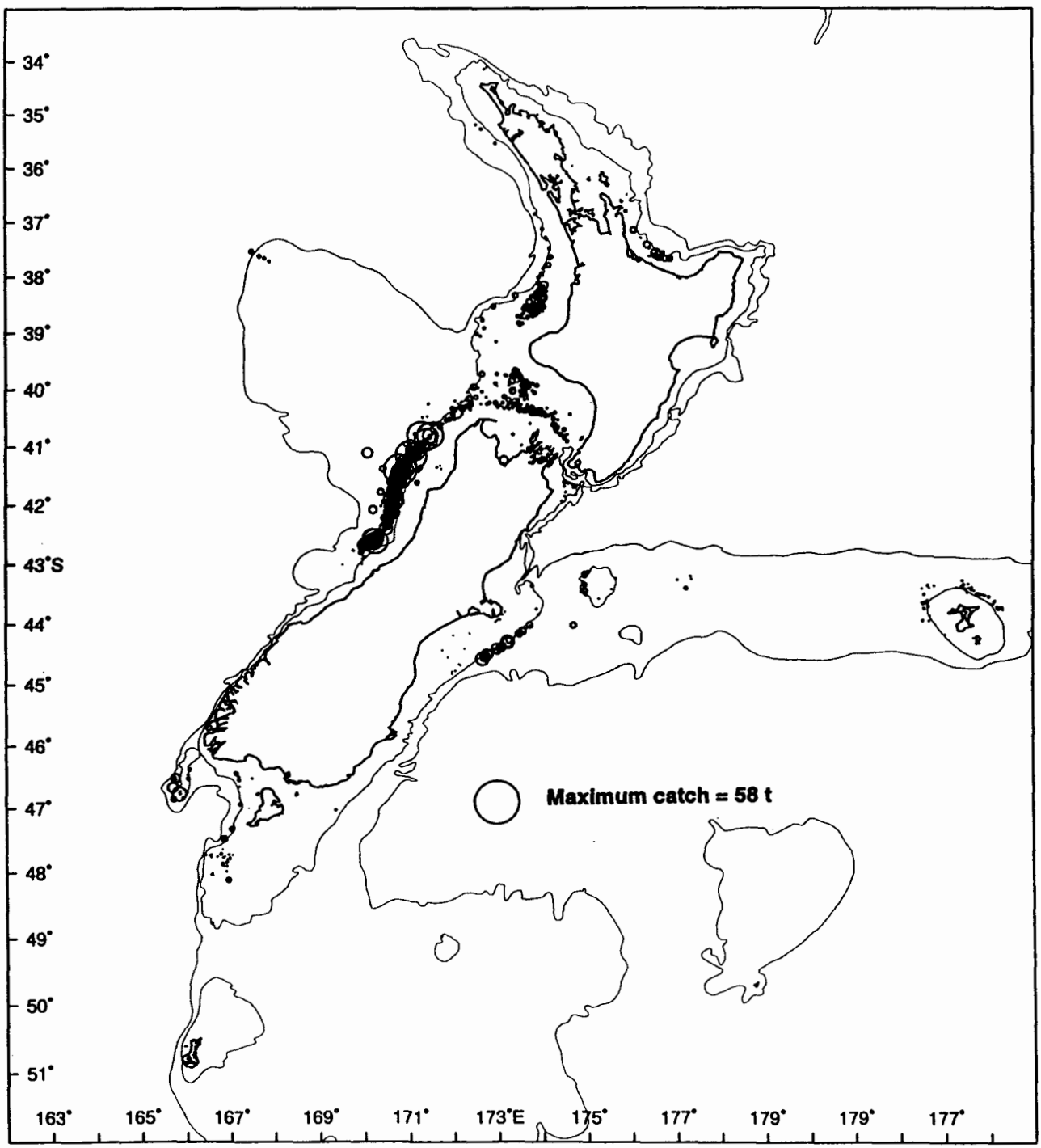


Figure 7: Frostfish bycatch from barracouta target fishing 1982–83 to 1993–94. Circle size is proportional to the maximum catch.

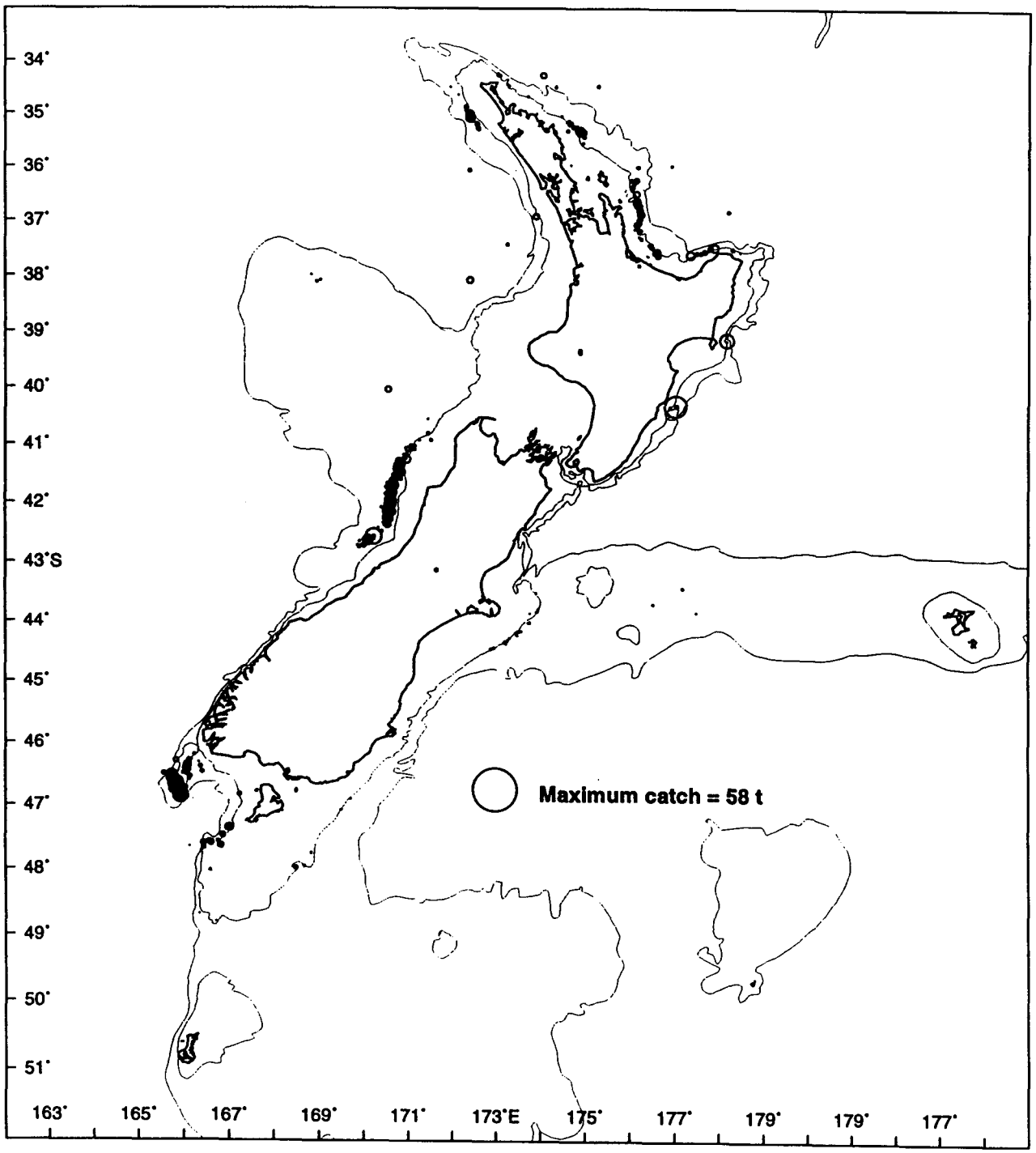
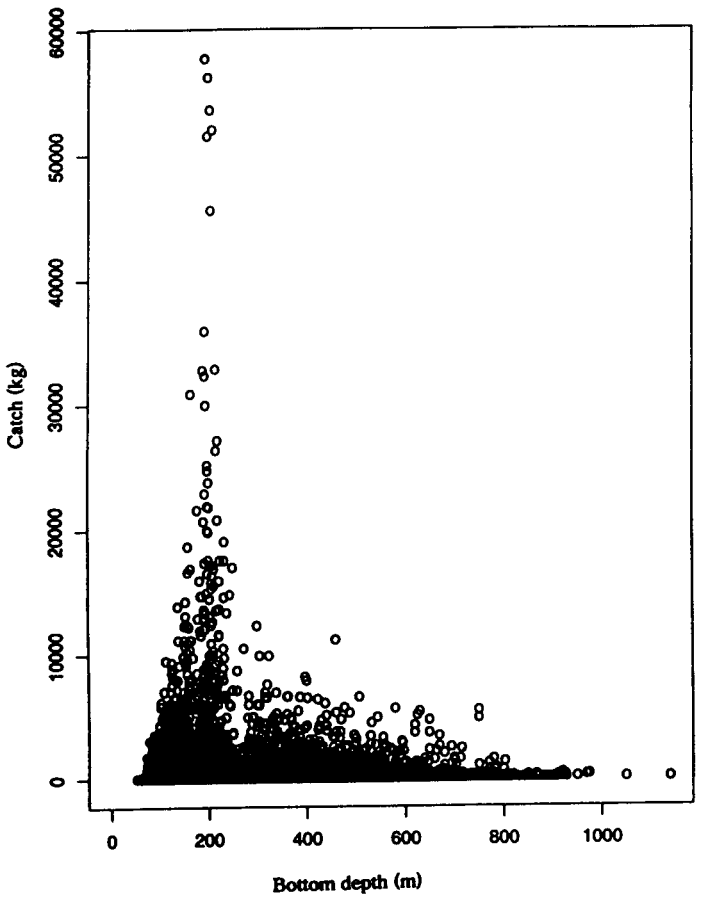


Figure 8: Frostfish bycatch from gemfish target fishing 1982–83 to 1993–94. Circle size is proportional to the maximum catch.



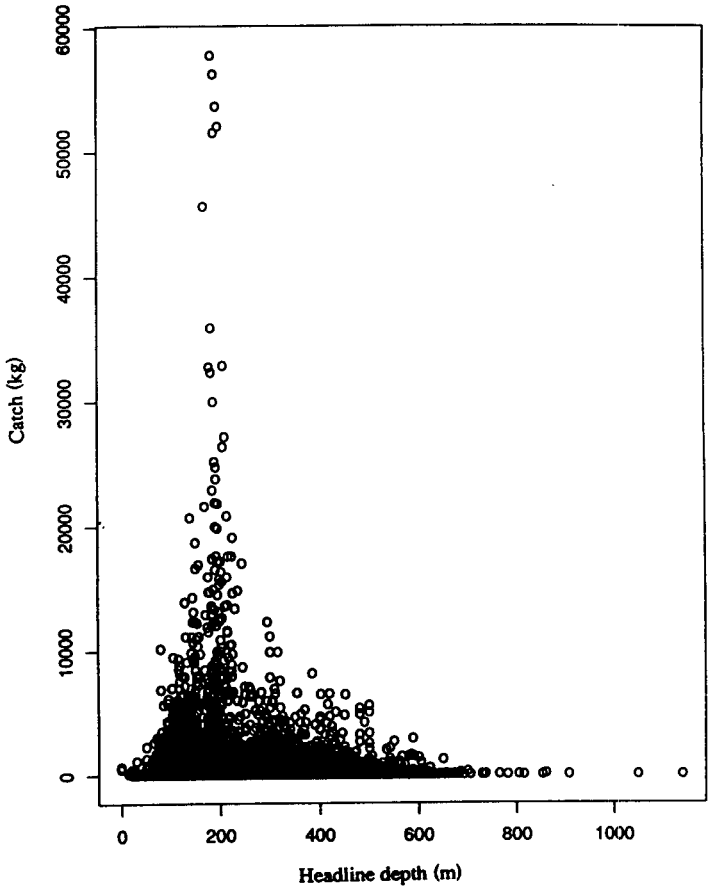


Figure 9: (left) Frostfish catch (kg) by bottom depth from FSU deepwater data from 1982–83 to 1988–89.

Figure 10: (right) Frostfish catch (kg) by net depth from FSU data from 1982–83 to 1988–89.

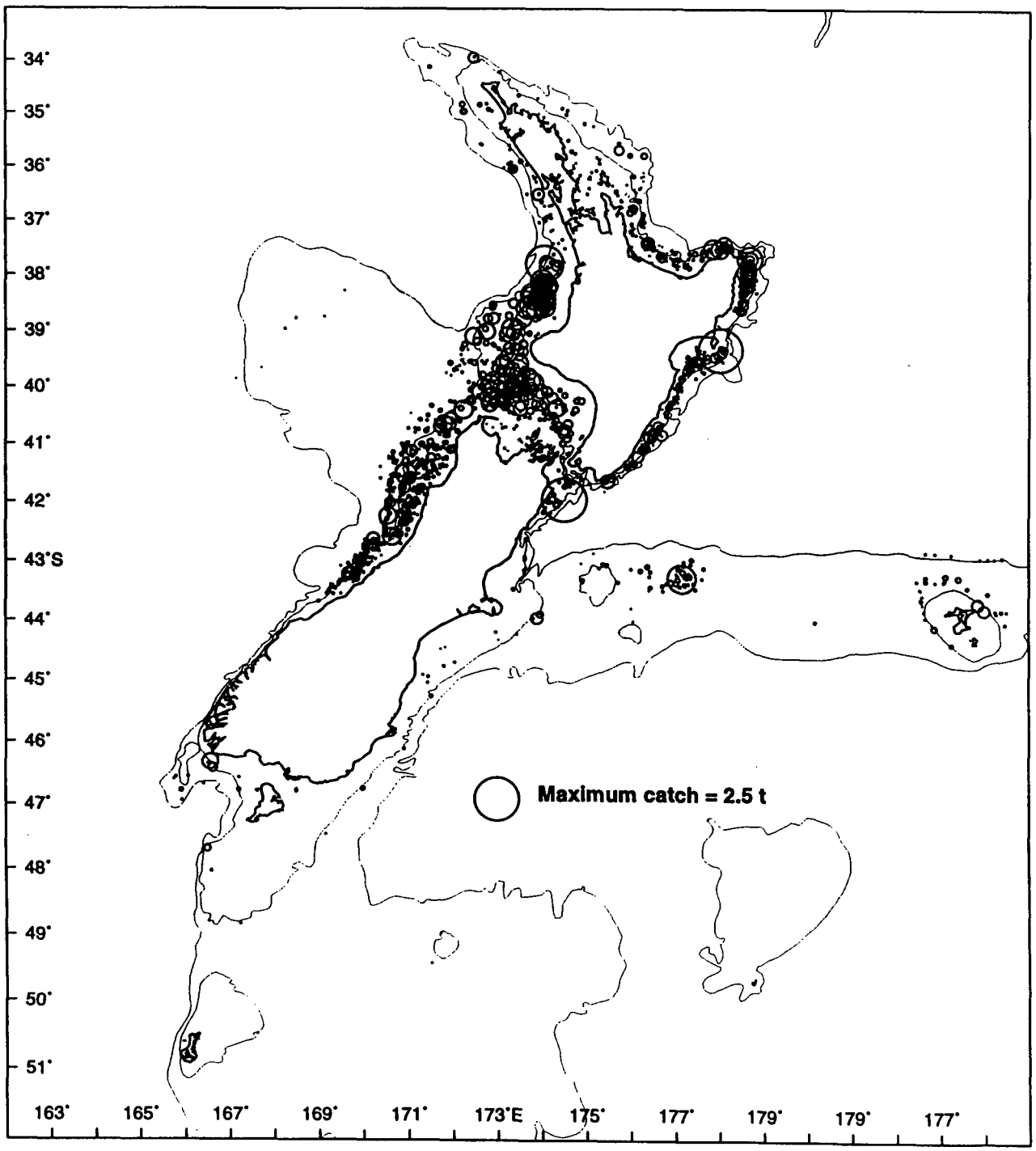
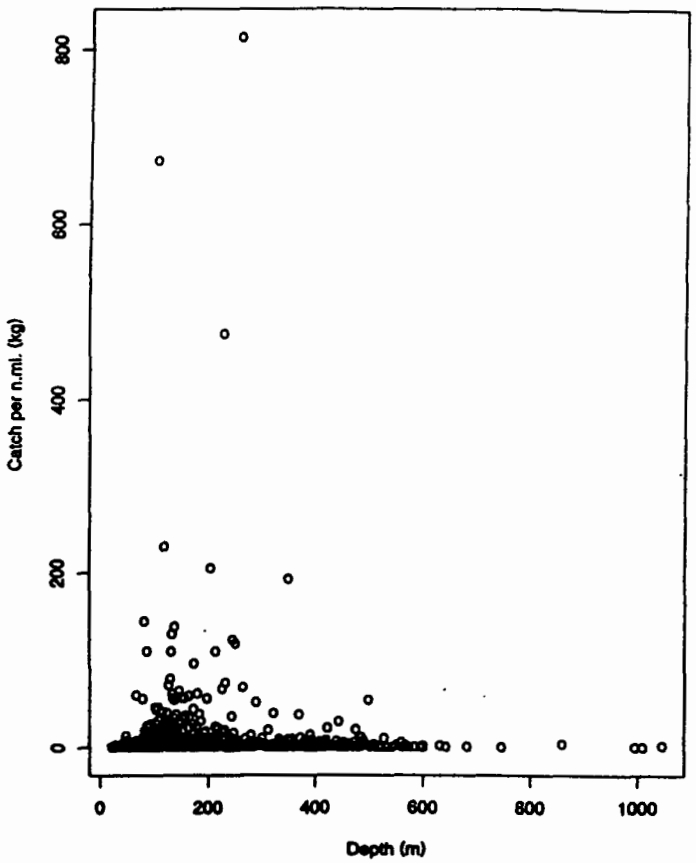


Figure 11: Frostfish catch rates from research surveys (kg per n mile).



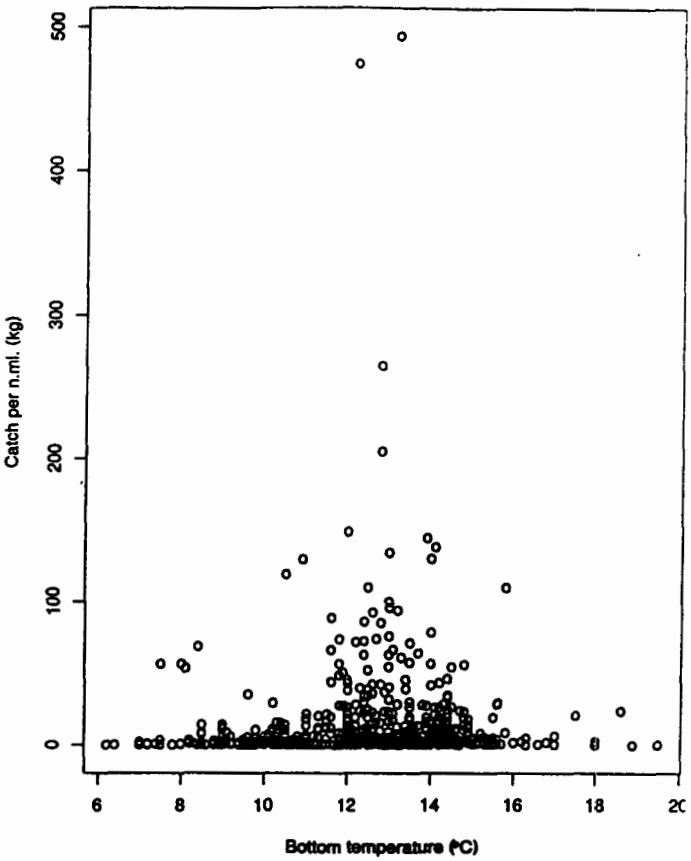


Figure 12: (left) Frostfish catch rate by depth from research surveys.

Figure 13: (right) Frostfish catch rate by bottom temperature from research surveys.

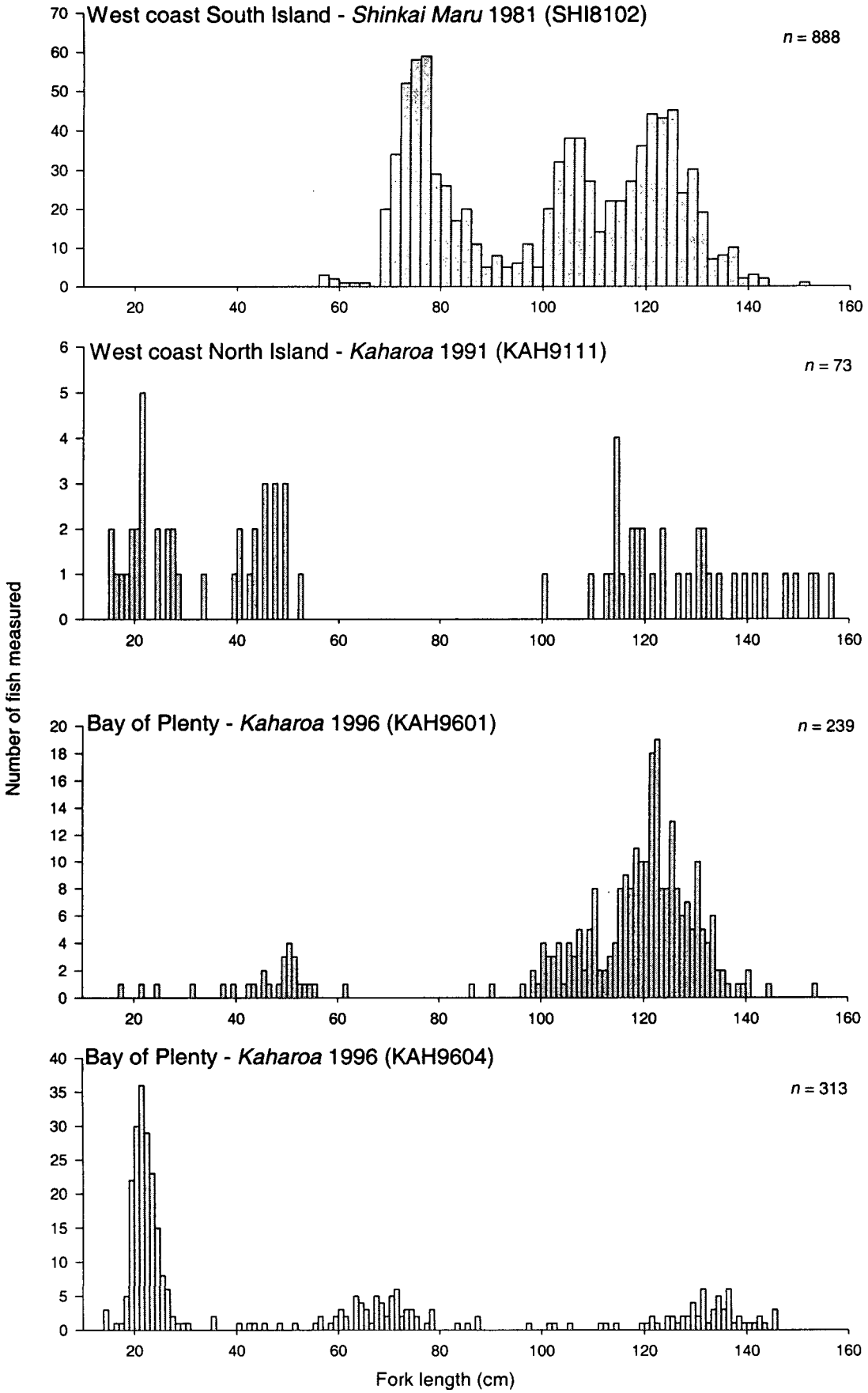


Figure 14: Length-frequeny distributions of frostfish from various trawl surveys (n, number of fish measured.)

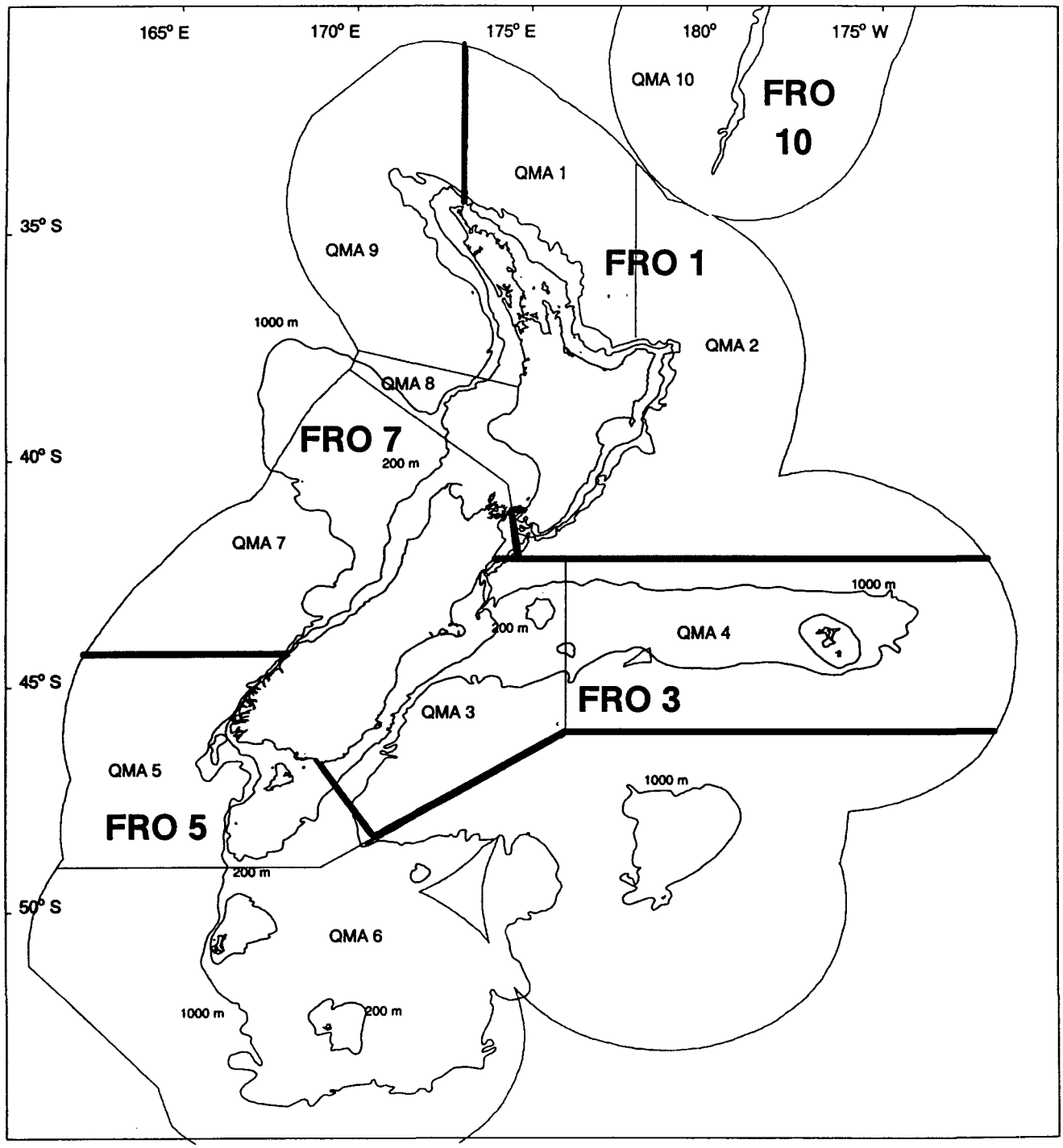


Figure 15: Proposed Quota Management Areas for frostfish.