New Zealand Fisheries Assessment Research Document 98/3

A summary of biology and commercial landings, and a stock assessment of southern (SKI 3 and SKI 7) gemfish *Rexea solandri* (Gempylidae) in New Zealand waters

R. J. Hurst and N. W. Bagley
National Institute of Water & Atmospheric Research Ltd
PO Box 14–901
Kilbirnie
Wellington

February 1998

Ministry of Fisheries, Wellington

This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

A summary of biology and commercial landings, and a stock assessment of southern (SKI 3 and SKI 7) gemfish *Rexea solandri* (Gempylidae) in New Zealand waters

R. J. Hurst and N. W. Bagley

N.Z. Fisheries Assessment Research Document 98/3. 51 p.

1. EXECUTIVE SUMMARY

Southern (SKI 3 and SKI 7) gemfish (*Rexea solandri*) catches peaked at 6914 t in 1985–86, with a significant proportion target fished. Catches in both areas have since undergone a significant decline, to about 280 t in 1994–95, and are now predominantly bycatch of the seasonal target fisheries on hoki (*Macruronus novaezelandiae*) and arrow squid (*Nototodarus sloanii*). These fisheries are predominantly targeted by larger vessels owned or chartered by New Zealand fishing companies.

Available biological data on length-weight, length at age, spawning locations, size structure of populations, size at recruitment and length at maturity are summarised. Relative biomass estimates for gemfish from trawl surveys since 1981 in the Southland area are presented and show a significant (50%) decline in the 1993–1996 time series and suggest a possibly significant (up to 87%) decline since the early 1980s to 1996.

Age frequency data confirm the pattern of recruitment apparent from the length frequency time series from both the west coast South Island and Southland fisheries, i.e., that the only strong year classes present between 1982 and 1994 are 1982, 1984, 1985, and 1989. All the others are relatively weak or absent. This pattern of recruitment is strongly correlated with environmental factors.

All relevant commercial catch data, biological parameters and abundance indices were incorporated into a population model. MIAEL estimates of virgin biomass, current biomass, and yields were obtained, but all had low or zero information indices and are therefore not well estimated within the range of values estimated by the least squares method. Least squares estimates of current biomass fell within the range 0–63% B_0. The model requires further development, particularly of year class strength estimation, before more meaningful estimates of biomass and yields can be obtained.

2. INTRODUCTION

2.1 Overview

Gemfish belong to the family Gempylidae (snake mackerels), represented worldwide by 16 genera and 23 species (Nakamura & Parin 1993). In New Zealand waters there are seven genera (Paulin *et al.* 1989), of which five (*Lepidocybium, Neolatus, Nesiarchus*

Paradiplospinus, and *Ruvettus*) are represented by species not occurring in commercial quantities and of little or no commercial importance. The genus *Thyrsites* is represented by barracouta, *T. atun*, of which 20 000 – 30 000 t is caught by trawling each year (Annala & Sullivan 1996). Six species of the genus *Rexea* (Waite, 1911) are recognised (Nakamura & Parin 1993), but only two species have been recorded in New Zealand waters: *R. solandri* (Cuvier, 1832) and *R. antefurcata* (Parin, 1989).

The genus *Rexea* occurs in tropical and temperate waters of the Indian and west to southern East Pacific Oceans (Nakamura and Parin 1993). They are benthopelagic, dwelling from lower shelves to middle slopes, around islands and seamounts, at 100–800 m depth. *R. Solandri*, the common gemfish (also called southern kingfish in New Zealand) is restricted to southern Australian, Tasmanian, and New Zealand waters. Important target trawl fisheries exist in both countries.

This document summarises the biological and fishery data available for gemfish in the southern areas of New Zealand. A preliminary stock assessment is also presented. The New Zealand 200 n.mile Exclusive Economic Zone (EEZ), and Fishery and Quota Management Areas (FMA and QMA) are shown in Figure 1, and places mentioned in the text are shown in Figure 2.

2.2. Literature review

Gemfish has been an important fishery in Australian waters and there are numerous published reports on the biology and fishery. Rowling (1994) reviewed the South East fishery for gemfish, including data from unpublished reports. Key published references are: Paxton & Colgan (1993) on stock structure; Lyle & Ford (1993), on reproductive biology; Withell & Wankowski (1989), Rowling (1990), & Rowling & Reid (1992) on age and growth; Rowling (1994) and Tilzey *et al.* (1990) on the fishery.

In New Zealand, specific publications on gemfish are limited; they include a background paper to the early stock assessments (Hurst 1988) and the catch-per-unit-effort (cpue) analyses of the northern fishery (Langley 1995, Ingerson and Colman, in press). Holton (1987) reviewed some of the early development of the domestic fishery.

A number of trawl survey reports since 1980 have included biomass and length frequency data on gemfish. Kerstan & Sahrhage (1980) included mention of gemfish distribution and one length frequency from *Wesermunde* surveys of New Zealand waters in 1979. Key published surveys of relevance to southern gemfish stock assessment are the southern *Shinkai Maru* series in February 1981 (Kawahara & Tokusa 1981), March-April 1982, (van den Broek *et al.* 1984), April 1983 (Uozumi *et al.* 1987), October-November 1983 (Hatanaka *et al.*, 1989), and June 1986 (Hurst *et al.*, 1990); a Southland *Akebono Maru No. 3* survey in November 1986 (Hurst & Bagley 1997a); and a Southland *Tangaroa* time series from 1993–1996 (Hurst & Bagley 1994, Bagley & Hurst 1995, 1996 a, 1996 b). The *Tangaroa* time series was summarised and compared with *Shinkai Maru* results by Hurst & Bagley (1997b).

Research carried out in conjunction with this stock assessment project of southern gemfish (Ministry of Fisheries project MSK701) which will be published in detail elsewhere includes age validation and stock structure of New Zealand gemfish (Horn & Hurst, unpublished results) and climate influences on southern gemfish recruitment (Renwick *et al.*, submitted).

3. COMMERCIAL FISHERY

3.1 Data sources

Data presented here are from Hurst (1988) or were extracted from the MFish commercial catch and effort database. These include annual catches and individual tow records from the Fisheries Statistic Unit (FSU) database up to the 1987–88 fishing year; annual catches recorded by the Quota Management System (QMS) from 1986–87; inshore domestic vessel catch from Catch, Effort and Landing return (CELR) forms since 1988–89 (which record the top six species per day and statistical area); and individual tow records from the Trawl, Catch, Effort and Processing Returns (TCEPR) since 1988–89 (which record the five most abundant species in each trawl shot). No attempt has been made to error check any of the commercial data provided by MFish, and summaries and plots of data probably contain some errors. This is most apparent in some of the catch location maps where some tows are probably in error by several degrees of latitude or longitude.

3.2 Annual catch landings

Hurst (1988) summarised the development of the early gemfish fishery, up to the fishing year 1986–87. Reported New Zealand domestic gemfish landings did not exceed 200 t per annum until 1967. They then fluctuated between 200 and 700 t, peaking in 1971. Foreign licensed vessels operating in New Zealand waters during this period also probably caught gemfish but it was largely unreported during the early and mid 1970s. On 1 March 1978, the EEZ was established and annual catches increased significantly, mainly due to reported catches by foreign nations (Table 1). Larger "deepwater" foreign trawlers were also chartered by New Zealand companies and fished in more offshore areas not previously fished by smaller domestic trawlers, e.g., the outer shelf areas of Southland. For the fishing years 1978–79 to 1985–1986, catches were unrestrained and averaged 4500 t per year, of which 72% was taken by deepwater vessels and 69% came from southern areas (old EEZ areas C, D, E, F, and G, now SKI 3 and SKI 7). Main southern fishing grounds were off Southland and the west coast of the South Island (WCSI) (Tables 2, 3). Catches peaked at 8253 t in 1985–86, of which 5446 t was caught in SKI 3 and 1468 t in SKI 7.

On 1 October 1986, Individual Transferable Quota (ITQ) controls were introduced under the Quota Management System (QMS). The quotas for gemfish were initially based on 1983 catch levels (1984 for SKI 1), which were the highest levels of catch recorded up to that time (Hurst 1988). For SKI 3, another yield estimate was also obtained by using the highest ever trawl survey biomass estimate (*Shinkai Maru* 1983 survey) as an estimate of absolute biomass, using the average of the doorspread and wingspread biomass estimates. The underlying assumption was that the fisheries were still developing in all areas.

Since the quotas were introduced in SKI 3 and SKI 7, they have never been caught (Table 3). Catches have steadily declined from the peak combined catch of 6914 t in 1985–86 to 279 t in 1994–95. This represents a 96% reduction in catch and the TACC is 94% under-caught. On 1 October 1996, the TACC was reduced to 1500 t in SKI 3 and 900 t in SKI 7, as an interim measure until the stock assessment presented here was carried out. The estimated primary value (i.e., port price) of New Zealand's gemfish fishery was about $3.4 million in 1995 (NZFIB 1996).

3.3 Fishing areas and depths

In order to determine the main fishing areas within SKI 3 and SKI 7, the fishing years 1983–84 to 1987–88 were used as they represented the peak period of catches and almost all of the catch was recorded by area (Table 4). Catches during later years were often so small that they did not feature in the top five species listed. During the selected period, most (90%) of the SKI 3 catch came from the Southland area (EEZ areas F and E(A), QMA 5). Most of the remainder came from the east coast of the South Island (ECSI)(EEZ area C⁻, QMA 3) with less than 1% of the total from the Chatham Rise (EEZ areas C(M) and D, QMA 4). In SKI 7, the main fishing area was on the WCSI (EEZ area G), with 90% of the catch from this area. The remainder was from further north (EEZ area H).

Main bottom trawl target fisheries for gemfish in SKI 3 and SKI 7, from 1983–84 to 1994–95, occurred off the northern WCSI and on Puysegur Bank with secondary areas on the Southland shelf and ECSI (Figure 2). Midwater targeting in SKI 3 and SKI 7 is also recorded off the WCSI (Figure 3). During the peak years in the mid 1980s, the main target areas were similar to those from more recent years, but much more extensive on the southern and eastern edges of the Southland shelf (Figure 4). The proportion of the gemfish catch recorded as targeted on the WCSI and in Southland has decreased from 36% during 1983–84 to 1987–88 to an estimated 14% from 1988–89 to 1994–95. Most of this target catch would have come from the start of this second period.

Most gemfish bycatch in SKI 3 and SKI 7 is taken as a result of hoki (*Macruronus novaezelandiae*) target fishing on the WCSI, and squid (*Nototodarus sloanii*) and barracouta (*Thyrsites atun*) target fishing on the edge of the Southland shelf (Table 5, Figures 5 a–c). Before1988–89, 47% of the gemfish catch was recorded as bycatch in these fisheries. After 1988–89, this increased to 55%, with increased catches in the barracouta and hoki fisheries. Smaller amounts of gemfish are recorded as bycatch from jack mackerel (*Trachurus* spp.), and silver warehou (*Seriolella punctata*) target fisheries (Figures 5 d, e). Most of the gemfish bycatch positions include gemfish target positions, but extend the distribution into deeper or more offshore areas. These include extensions across the northwestern Chatham Rise (with hoki and jack mackerel), around the Auckland Islands (with hoki and squid), and into Taranaki Bight (with jack mackerel).

The depth of gemfish target catches in SKI 3 and SKI 7 was mostly 200 – 500 m off the WCSI and Southland (Figure 6). Most target catches shallower than 200 m occurred in localised areas in the Canterbury Bight and around the Snares Islands. The average depth of tows where gemfish were recorded as target-fished was 230 m, which is similar to the average depth of 250 m for all gemfish catches.

3.4 Seasonal and diurnal fishing patterns

The recorded catch by month within each QMA has continued to show the same patterns between the peak period, 1983–85 and the recent period, 1991–93 (Figure 7). The main difference over time has been the large reduction in the recorded catch, which is due to a real reduction in overall catch and not the catch recording method. On the WCSI (QMA 7) most gemfish are caught in August/September, in association with the hoki fleet activities, but also at the time that gemfish spawn. In Southland (QMA 5), the season is mainly late summer/autumn, in association with squid fleet activities. The catch during October-December decreased in the 1991–93 period, probably partly due to the closure of the Solander corridor on 1 October 1985, which restricted gemfish target fishing in the Puysegur Bank area (Figure 8). On the ECSI (QMA 3) the fishery is also in late summer/autumn when squid is also an important target species.

The seasonal pattern in the northern gemfish fisheries is also shown in Figure 8 to demonstrate that the same seasonality occurs in these fisheries, i.e., a summer/autumn ground to the south of the area (SKI 2) with a spawning season in winter to the north (SKI 1). These data are consistent with the data presented and the stock hypothesis suggested by Hurst (1988), but include significantly more catch from the SKI 1 fishery.

There is a strong diurnal pattern in catch rates. Bottom trawl catches peak between dawn and dusk (Figure 9), suggesting that fish move off the bottom at night. This is supported by midwater trawl data which show the reverse trend of lowest catch rates at midday.

3.5 Catch-per-unit-effort

An analysis of catch-per-unit-effort (cpue) data as an indicator of relative biomass was not attempted because gemfish are landed mainly as a bycatch of other fisheries, in particular hoki and arrow squid, and the gemfish bycatch has declined to such an extent that any analysis would not be meaningful.

3.6 Non commercial fisheries

There are no known Maori, recreational, or other non-commercial fisheries for gemfish.

4. RESEARCH

4.1 Data sources

Data presented here have either been published in individual research survey reports or were re-extracted from the MFish research trawl survey database to ensure consistency of presentation (e.g., particularly with length frequencies). Biological data collected by the MFish Scientific Observer Programme (SOP) have also been summarised. Note that the research catch rates are used to determine general patterns only as they not strictly comparable with each other because of the different vessels and gear used.

4.2 Distribution

In New Zealand, gemfish are recorded from research bottom trawl catches from 34° S to 49° 30' S, but appear to be more common around the South Island, mainly because of the greater frequency of sampling in the gemfish depth range in this area (Figure 10). They occur mainly towards the outer edge of the continental shelf edge around the main islands. They are caught occasionally on the Challenger Plateau and on the western edge of the Chatham Rise and rarely at the Chatham Islands. The distribution of zero tows (Figure 11) confirms that catches in inshore areas, on the eastern Chatham Rise, most of the Challenger Plateau, and around the Sub-Antarctic Islands are rare. It also suggests that at least some of the commercial catch positions in more offshore areas (*see* Figure 2) may be mis-recorded on the catch and effort database.

Most research gemfish catches are less than 100 kg per nautical mile (*see* Figure 11). The larger catches are all from southern surveys on the WCSI, ECSI, and in Southland, but these are also areas where the larger research trawlers have tended to operate. Most gemfish in research catches were taken in 50–500 m depth (Figure 12) and in 8–14 °C (Figure 13), with no clear differences between areas.

4.3 Length, weight, and sex ratio data

Length-weight relationships were calculated for each sex and all fish (including unsexed), for all South Island areas combined and for the Chatham Rise and Southland areas separately (Table 6). Data used were from all research surveys where gemfish were individually weighed. Gemfish caught in bottom research trawls, with a minimum codend mesh of 60 mm, range from about 20–110 cm fork length and reach a maximum weight of about 13 kg (Figure 14).

Length frequencies (Figures 15–17) from random stratified trawl surveys, from 1981 to 1996, were extracted and scaled by the percentage sampled, the area swept by the trawl (using doorspread values), and the area surveyed. No adjustment for different catching efficiency of vessels or different areas surveyed has been attempted. Note that for some surveys, scaling was required for some tows where gemfish were caught but not measured. This is more of a problem with the earlier *Shinkai Maru* and *Amaltal Explorer* data. Few fish were caught or measured on the Chatham Rise and ECSI surveys and these data are therefore not presented.

Overall, modal peaks appear similar in younger fish but the maximum length of females is slightly greater than that of males. Using 1 August as the birthdate, fish appear to be about 30 cm at age 1, 40 cm at age 2, 52 cm at age 3 and 60 cm at age 4 (Figures 15 and 17). Older ages cannot be determined easily from the length frequencies, except in Figure 16, where age 3+ fish at 60 cm in 1993 can be followed through to age 6+ at about 80 cm in 1996. The size range of adult fish in all surveys is similar with a general spread from 60 to100 cm length, except for the June 1986 survey in Southland (*see* Figure 15) in which adult fish greater than about 65 cm are absent, presumably having migrated out of the area to spawn. The variation in the relative importance of younger fish modes in the surveys may reflect changes in year class strengths. The *Tangaroa* data are the best example of this, where the 3+ (1989 year class) fish in 1993 are the only recruiting year class apparent in the 4 year time series.

Length frequency data collected by the SOP from 1987–1996 are presented for Southland (Figure 18) and from 1986–1995 for the WSCI (Figure 19). Data from both areas show annual variations in the relative importance of recruiting year classes. The stronger year classes, 1982, 1984 and 1985, first recruit at age 4, except for the 1989 year class which recruited at age 2. As with the Southland *Tangaroa* series, there is little evidence of recruitment since the 1989 year class. The main difference between the WCSI and Southland SOP time series is in the relative strength of the adult modes, with the 1982, 1984, and 1985 year classes appearing much reduced and the 1989 year class appearing more prominent in the WCSI series in later years. The reason for this is unknown. There is little suggestion of any temporal variation in fishing or sampling strategies from the location of WCSI catches sampled (Figure 20). Possible explanations could include variation in how the fish distribute themselves within the areas or changes in the proportion of fish which may migrate to the WCSI spawn. The SOP Southland length frequency data for 1993–95 closely match the *Tangaroa* data from the wider area. The SOP data are therefore probably a fair representation of the size structure, at least for fish 3+ and older.

The SOP length frequency data from SKI 3 and SKI 7 were scaled to commercial catch, by sex (Figures 21 and 22). The proportion of the annual catch measured was low (often less than 1%) and not all fish were sexed, especially in the early years. Hence, the totals in these figures are generally less than those for Figures 18 and 19. There are also a few records outside the Southland area which are included in the SKI 3 data. Nevertheless, the modal patterns in both scaled and unscaled data are similar, although the scaled numbers better illustrate the decline in numbers of adult fish during the series.

The ratio of males to females, derived from research surveys scaled length frequencies from Southland (Table 7), is mostly 1:1 (range 0.8–1.5:1). Ratios were not calculated for other areas because samples sizes were low or fish were not sexed. There are insufficient data to enable detection of any changes in sex ratio by season.

4.4 Age, growth and age at maturity

Rowling (1994) reviewed age, growth, and mortality of Australian gemfish. Maximum ages from New South Wales gemfish were 16 years for females and 11 years for males (Rowling 1990). He also calculated instantaneous total mortality rates between 1980 and 1984 of 1.22 for males and 0.59 for females, but noted that no direct estimates of fishing mortality had been made.

Horn & Hurst (1997, unpublished results) developed an ageing technique for New Zealand gemfish and validated ages up to 14 years by correlating progressions in length modes and appearance of hyaline zones of juvenile fish up to age 4 and following the progression of strong and weak year classes in two stocks (SKI 1(east) and SKI 3) up to age 14. Maximum ages for Southland gemfish were 15 years for females and 17 years for males, with most fish in the 7–14 age groups (Figure 23). Estimated von Bertalanffy parameters from this recent work are given in Table 7. The earlier estimate from SKI 1 (east) gemfish by Langley *et al.* (1993) is also given and was the only estimate available at the time of the population modelling. It was therefore used in the assessment.

A range of estimates 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), and by assuming that A_{max} was 20 in the virgin population. This gives an estimate of M of 0.23. If
A_{max} in the virgin population was nearer 15, as in the current population, M would be closer to 0.3.

Determination of the length (and age) at which 50% of males and females reach sexual maturity was made difficult by the possible inconsistency of identification of sexually mature fish and the relatively few records of reproductively active fish on the research and SOP databases. For some surveys on the research database a staging scale which separates resting from immature gonads was used. These data suggest that all fish over 45 cm had reached maturity. There were few records of smaller fish. If the gonad stages which include maturing (eggs and milt visible) to spent fish only are considered, the smallest sizes at maturity are 46 cm (females) and 48 cm (males) on the research database and 47 cm (females) on the SOP database. This suggests that gemfish may spawn as young as 2 years old, but provides no information on the proportion which may spawn at this age. The SOP length frequencies from the WCSI spawning fishery suggest that most gemfish recruit to this fishery at about 60 cm, or 4 years old, except for the 1989 year class which appears to have recruited earlier, at 40 cm or age 2. The 1986 winter trawl survey observation of fish mostly less than 65 cm remaining in the Southland area during the spawning season suggests that most fish probably reach sexual maturity by age 5.

4.5 Trawl survey biomass estimates

Biomass estimates from the MFish research database are given for southern New Zealand (Table 8). These are the only biomass data which can be used for stock assessment of gemfish in the SKI 1 and SKI 3 fisheries. Other surveys on the east and west coasts of the South Island did not sample the full depth range of the species and were carried out in inappropriate seasons to monitor recruited biomass (i.e., jack mackerel surveys by *Shinkai Maru*, 1981 and *Cordella*, 1990; barracouta surveys by *James Cook* in 1983 and 1984; and inshore surveys by *Kaharoa* in 1992, 1994, and 1995). In general, the biomass estimates from these surveys were less than 200 t, with coefficients of variation (*c.v.*) mostly over 25%. On the Chatham Rise surveys, less than 10 fish were caught on each survey was, indicating extremely low abundance in this area.

The Southland survey data have been previously analysed by Hurst & Bagley (1997b) who compared the summer/autumn surveys by *Shinkai Maru* surveys in 1981, 1982, 1983 and 1986 with annual surveys by *Tangaroa* from 1993 to 1996. They developed a set of indices which were as comparable as possible in the absence of data on relative catching efficiency of the two vessels. These surveys generally covered the distribution of gemfish in these areas, except that *Shinkai Maru* surveys had few stations in the western part of the area and none at Puysegur Bank. No correction was made for this as the distribution of fish within the *Tangaroa* surveys was found to vary annually even though the surveys were at the same time of year. In all surveys the total biomass is used as an estimate of recruited biomass as the minimum codend mesh size used in the surveys, 60 mm, is the same as that used by vessels operating in the Southland squid fishery.

There was a statistically significant (50%) decline in gemfish biomass during the *Tangaroa* 1993–96 time series. If it is assumed that the catchability of gemfish was equal for the *Shinkai Maru* and *Tangaroa* time series (summer/autumn survey 1981–83 and 1993–96), the average biomass declined by 86%. Even if it is assumed that the *Shinkai Maru* had twice the catching efficiency of the *Tangaroa*, the decline is still statistically significant. The smaller area surveyed by the *Shinkai Maru* suggests that the relative biomass on these surveys may have been underestimated and that the real decline may have been even greater. The proportion of gemfish in the total species biomass also declined between the two time series, from an average of 5% to 0.6%, an 88% decline.

The biomass estimates for Southland surveys in early spring 1983 (Hatanaka *et al.*) and 1986 (Hurst & Bagley, 1997b) and the winter 1986 (Hurst *et al.* 1990) are also presented in Table 8, but are not comparable with the summer/autumn surveys because some adult fish may have been out of the area for spawning at these times, or more abundant in parts of the survey area not sampled.

4.5 Feeding

All records of gemfish feeding on the research database are from the Southland area. The main prey items were fish (59%), mostly jack mackerels and hoki, and squid (40%), mostly arrow squid.

4.6 Spawning areas and stock structure

Hurst (1988) suggested that there are two stocks of gemfish.

1. A northern/east coast stock, caught mainly on the east coast of the North Island (south of East Cape, SKI 2) in spring through to autumn, which is thought to migrate to the Bay of Plenty and North Cape (SKI 1) to spawn in winter.

2. A southern/west coast stock, caught in the southern area (SKI 3) from spring through to autumn, which is thought to migrate to the WCSI (SKI 7) to spawn and is caught there mainly in August-September.

Hurst (1988) considered that it would be unwise to amalgamate the four existing Fishstock areas into the two proposed biological stock areas (SKI 1+2, SKI 3+7) until there was more supporting evidence for the hypothesis.

Since the 1988 assessment, five sources of information have supported the existence of more than one gemfish stock in New Zealand waters:

1. Seasonal migrations

Seasonality of commercial fishing patterns on the east coast of the North Island and to the south and west of the South Island have are similar to those found before 1988 (*see* Figures 7 and 8). In the northeastern fisheries these seasonal patterns provide strong evidence for spawning migration, as gemfish is of moderately high value and most of the catch is targeted. For southern gemfish, the evidence is less strong as gemfish catches have become increasingly less targeted and are now mainly bycatch of the winter hoki fishery on the WCSI and summer/autumn squid fishery off Southland.

However, seasonal trawl surveys in the Southland area in 1986 showed the absence of adult fish in June and their subsequent reappearance in November (*see* Figure 17), suggesting a migration out of the Southland area to spawn. Since 1988, a new winter fishery has developed on the western side of North Cape, also presumably on fish migrating to spawn, but the origin of these fish is not clear from fishing patterns.

2. Spawning areas

Commercial (SOP) and research sampling have recorded most of the ripe and running ripe female gemfish in the two known areas of spawning activity off the WCSI and the northeast coast of the North Island, from May to October (Figure 24). There are also a few sporadic records of ripe females in Southland and on the east coast of the South Island. Unfortunately, the northern gemfish market sampling data from the spawning fishery do not record fish by exact locality. The distribution of young fish (15–30 cm, 6–12 months old) also suggests a WCSI spawning area as well as a northern North Island area (Figure 25).

3. Recruitment patterns

There is a strong correlation between the pattern of strong and weak year classes in the WCSI and Southland SOP and research survey length frequency data which suggests fish in these areas are either the same stock, or have the same environmental factors affecting year class strength. Strong year classes are 1982, 1984, 1985, and 1989 (*see* Figure 23). This pattern is different to that observed in the SKI 1 (east) and SKI 2 fisheries, where 1980, 1982, 1984 and 1991 appear to be strongest (Horn & Hurst, unpublished results). These data provide strong evidence for the separation of the northeastern and southwestern gemfish stocks.

The 1996 data from the SKI 1(west) fishery show some similarity to the SKI 1(east) data, in that 1982, 1984, and 1991 year classes appear to be relatively strong. However, year classes for 1988 and 1989 also appear to be relatively strong in the SKI 1(west) female samples. There is therefore a possibility that some of the southern stock (particularly the 1989 year class) could migrate further north than the WCSI to spawn. Unfortunately, there are no comparable age frequency data from the SKI 1(east) fishery since 1994 and the apparent differences between SKI 1(east) and SKI 1(west) could also be caused by incomplete recruitment of age 5 and 6 fish to the SKI 1(east) fishery in 1994. The affinities of the SKI 1(west) fish are therefore unclear from recruitment patterns at this stage.

4. Age and growth patterns

Von Bertalanffy growth parameters for gemfish from Australia (Rowling & Reid 1992), SKI 1 (east) (Langley *et al.* 1993) and SKI 3 (Southland) (Horn & Hurst, unpublished results) are given shown in Table 7. In a preliminary analysis, Horn & Hurst (unpublished results) also calculated von Bertalanffy growth parameters for gemfish from SKI 1 (east), SKI 1 (west), and SKI. They found no significant difference in growth parameters for females. For males, there were significant differences between SKI 3 (Southland) and SKI 1 (west) values of L_∞ and SKI 3 (Southland), and SKI 1(west)/ SKI 2 values of k. If it is assumed that the three northern fisheries are one stock, there were no significant differences between northern groups and the Southland group. The question of northern stock structure will be addressed further when the second year of age data from SKI 1(west) and SKI 2 are included in the final analysis.

5. Genetics

Paxton & Colgan (1993) carried out biochemical analyses of Australian and New Zealand gemfish and concluded that there may be a low level of mixing between the two countries, but not enough to regard them as a single stock. They also found an indication of a difference between New Zealand northeastern and southern gemfish which required further investigation.

These data strongly support the existence of at least two separate stocks: a northeastern stock including gemfish in QMA 1 and 2 (i.e., SKI 1(east) and SKI 2); and a southwestern stock including QMAs 5, 6 (SKI 3), and QMA 7 (SKI 7). The stock affiliations of gemfish in QMAs 3, 4, 8, and 9 are uncertain and the data from these fisheries are minimal. The only fishery of any size is in QMA 9 (SKI 1(west)) and this is now being sampled (from 1996). At present, QMAs 3, 4, and 8 are included in the "southern stock"; QMAs 3 and 4 in SKI 3; and QMA 8 in SKI 7. Gemfish in QMA 9 are included in the "northern" stock, SKI 1. The stock assessment presented here treats the southern stock as SKI 3 combined with SKI 7 and therefore includes the relatively small amount of catch from fisheries in QMAs 3 and 8.

5. STOCK ASSESSMENT

In the 1996 assessment, there were no yield estimates available for gemfish. For SKI 3 the previous method of estimating MCY based on trawl survey results was removed.

In 1997 a stock reduction analysis was carried out on both the northern and southern gemfish stocks for the first time. Estimates of virgin biomass (B_0), biomass in mid 1997 as a percentage of virgin biomass (B_{mid97}), biomass at the start of 1998 (B_{beg98}), maximum Constant Yield (MCY), and Current Annual Yield (CAY) are presented below, using the MIAEL estimation technique of Cordue (1993). The bounds on virgin biomass used by the MIAEL technique were derived using the model based approach of Cordue (1996).

5.1 Estimation of fishery parameters and abundance

The model developed was an age-structured, two-sex population model using the biological input parameters given in Table 9. Steepness was set at 0.75, as recommended by Francis (1992) when there is no other information, with a sensitivity test at 0.9. Recruitment variability was set at 1.0, as used in the hoki assessment, on the basis that it is equal to, if not more extreme than, the recruitment variability found for hoki stocks. The proportion spawning (95%) was determined from comparison of the 1986 winter and late spring trawl survey length frequency data. *M* was set at 0.23, as described above. Estimates of the maximum exploitation rate (r_{max}) of 0.6 on the Southland fishery and 0.8 on the spawning fishery were considered to be the maximum proportion of the beginning of season biomass that could have been caught by the fleet. The minimum level of exploitation when the catch was the largest (r_{mmx}) was set at 0.1. The maturity ogive was determined from Southland and WCSI commercial and research length frequency data, which suggest that fish can recruit as early as 2 years old (*see* Figures 15, 18, and 19) and that most fish may recruit by age 4 (*see* Figure 15, 1986 trawl surveys). None of the originally planned sensitivity tests to these inputs were carried out because of problems with the modelling which are described below.

The catch history for the SKI 3 and SKI 7 fisheries from 1978–79 to the present used data from Tables 1–3. The division of domestic catch from 1972–1983 (*see* Table 1) into areas covered by SKI 3 and SKI 7 was done from port of landing statistics (Holton 1987). Nelson landings were divided equally between SKI 3 and SKI 7. Table 2 was used to assign EEZ area catch before 1983–84 into equivalent FMA areas. The foreign catch history then had to be extended back beyond 1978–79 as gemfish were caught by foreign licensed vessels operating around the South Island before to the declaration of the EEZ. Unfortunately, gemfish do not appear in the available data summaries, except in the 1975 Japanese records. These data were used to estimate missing catches by calculating gemfish catch as percentage of the reported barracouta catch by area (i.e., 20% on WCSI, 25% Southland). It was not possible to use this method for the Soviet fishing fleet and no catch was estimated or assumed. The catch for 1980–81 also had to be estimated as final foreign (licensed and chartered) vessel figures for this year were never produced. This was done by taking the average of the two closest years (1979 and 1981) for the foreign vessel catch and adding the inshore domestic vessel catch. The resulting catch history used for modelling is given in Table 10, divided into pre-spawning (SKI 3) and spawning (SKI 7) season catch. The 1997 catch is assumed to be equal to the 1996 catch.

The relative year class strengths were estimated in the model, using the proportion at age data given in Table 11 and abundance indices. The model did not cope well with the zero year classes present in the proportion at age data and had to be given a nominal low value. The size of this value had a significant effect on the estimation of all other year classes. For the base case run, a value of 0.001 was assigned to the missing year classes and all other values from 1979 to1990 were estimated by the model (Table 12). Values before 1979 and from 1995 on were assumed to be 1. Year classes from 1991 to 1994 were assigned low values based on the correlation between low sea surface temperature and missing year classes (Renwick *et al.*, draft ms.). Industry representatives at the working group meetings requested a more simplified form, with year classes assigned 0.001, or 1 if they were weak or strong. These simplified year class strengths were used as sensitivity analyses for the working group but were rejected by the Plenary and are not included here. A sensitivity test with the age data removed was also carried out, but was rejected as the biomass trajectories were unrealistic.

Relative abundance indices of recruited gemfish from two series of trawl surveys, in the same season (February to May) were used in the model (*see* Table 8). No attempt was made to relate the two time series by putting bounds on catchability, although it could be attempted in any further development of the model.

5.2 Biomass estimates

Estimates of mid-season virgin biomass (B_0) and current biomass (B_{mid97}), and estimates of 1998 beginning of year biomass (B_{beg98}) were obtained using the least squares and MIAEL estimation techniques (Table 13). All MIAEL estimates had information indices of less than 1%. The MIAEL estimates were: B_0 of 40 923 t, $B_{mid\ 97}$ at 28.64% of B_0, and $B_{beg\ 98}$ of 24 641 t. A mean square error loss function was used to estimate B_{mid97}, and $B_{beg\ 98}$, rather than the usual proportional mean square error function, because of zeros in the range. Trajectories for minimum (B_{min}) and maximum (B_{max}) estimates of biomass are shown in Figure 26.

The model fit to the two trawl survey time series is shown in Figure 27. The model did not fit the age data well and requires further development.

5.3 Estimation of Maximum Constant Yield (MCY)

The use of commercial catch data to estimate MCY was not considered valid as the effort and catch increased significantly after the introduction of the deepwater policy in 1983 and before the introduction of the QMS in 1986. Catches recorded from these areas have declined significantly since 1985–86.

MCY was estimated from MCY = pB_0, where p is determined for each stock using the method of Francis (1992) such that the biomass does not go below 20% of B_0 more than 10% of the time. B_0 is estimated by the MIAEL method, with associated information indices indicating how well MCY is estimated within the given range of values. Results are given in Table 14.

The range of MCY estimates was 990–2770 t. The MIAEL estimate of MCY for SKI 3 + SKI 7 is 1563 t, with a low information index of 0.3%. None of these estimates may be appropriate at this time if the current stock size is at the lower end of the B_0 range.

5.4 Estimation of Current Annual Yield (CAY)

The method of Francis (1992) was used to estimate CAY from the MIAEL estimates of current biomass ($B_{beg\ 98}$). Results are given in Table 14. The range of CAY estimates is 20–5930 t. The MIAEL estimate of CAY is 2792t, with an information index of 0%.

5.5 Other factors

Other species (e.g., barracouta, hake) may have been mis-reported as gemfish, and this may have inflated some of the reported catches before 1986. There is also considerable uncertainty in estimated foreign catches before 1978.

Declining catches in SKI 3 and SKI 7 since the mid 1980s appear to be caused mainly by declining abundance resulting from low recruitment in at least 9 of the last 15 years. There is a significant correlation of the occurrence of strong and weak year classes with environmental factors in the spawning area and season (i.e., sea surface temperature and southwesterly air flow, *see* Renwick *et al.* draft ms.). The last successful year class appeared in 1989 and environmental factors since then suggest poor year classes till at least 1996. Future recruitment to the fishery may therefore be minimal until the year 2000.

6. STATUS OF THE STOCKS

Estimates of virgin and current biomass are available for SKI 3 + SKI 7. The assessments for these stocks are the first carried out using stock assessment modelling techniques and are very uncertain. The model needs further development in terms of optimal estimation of year class strength and maturity/selectivity ogives. The model may also be improved by bounding the trawl catchabilities for the two time series of trawl surveys.

The stock assessment for this stock is very uncertain because of problems with estimation of year class strength and possibly catches before 1978, when catches could have been at their maximum. Reported catches in SKI 3 and SKI 7 have continued to decline steadily since 1985–86, and are well below the TACCs. Recruitment also appears to be minimal into these two Fishstocks since 1986, with the most recent successful year class appearing in 1989 and environmental factors since then suggesting poor recruitment till at least 2000. Model results suggest this stock could be below the level that would produce the MSY ($B_{MAY} = 35\%B_0$), but information indices for all estimates are zero or very low. It is not known if the current catches are sustainable or will allow the stock to move towards the size that will support the MSY. The 1996–97 TACC for both fisheries (2400 t) is near the upper bound of the MCY range and is therefore unlikely to be sustainable.

7. CONCLUSIONS

Conclusions from the stock assessment part of the project are summarised in the status of the stocks section above. Additional conclusions, relevant to stock assessment, from the commercial and research data summary part of the project are as follows:

1. There are no apparent differences in the location and timing of target fishing off the WCSI and Southland between the peak fishing years in the mid 1980s and more recent years. However, the proportion of gemfish recorded as target fished has declined substantially over the last decade.
2. Over the last decade, the traditional gemfish target areas have continued to be fished during target fishing for other species (mainly hoki and squid) and the proportion of gemfish taken as bycatch has increased. However, the tonnage of gemfish bycatch has declined substantially over this period.
3. The Southland trawl survey time series 1993–96 provided a valuable time series of data which enabled the trends of strong and weak year classes to be confirmed and significantly improved our understanding of the dynamics of this fishery and why it

has declined over the last decade.

4. Strong support for the hypothesis of one southern stock (SKI 3 + SKI 7) comes from seasonal fishing patterns, seasonal estimates of recruited abundance from trawl surveys and recruitment patterns. These data also strongly support the separation of the southern stock from gemfish in the SKI 1 (east) and SKI 2 fisheries. Further work is required on age and growth, recruitment patterns, and genetics to fully determine the relationship between the southern stock and gemfish in SKI 1 (west) fishery.

8. ACKNOWLEDGMENTS

We thank NIWA staff who collaborated on this project, including Patrick Cordue (supervision of population modelling), John Kidson and Jim Renwick (climate factors correlations), Peter Horn (ageing) and Sira Ballara (scaling of the SOP length frequencies to catch), and Adrian Colman for his helpful review of the manuscript. This work was funded as part of the Ministry of Fisheries research contract MSK701.

9. REFERENCES

Annala, J. H. & Sullivan, K. J. (Comps.) 1996: Report from the Fishery Assessment Plenary, April-May 1996: stock assessments and yield estimates. 308 p. (Unpublished report held in NIWA library, Wellington.)

Bagley, N.W. & Hurst, R.J. 1995: Trawl survey of middle depth and inshore bottom species off Southland, February-March 1994(TAN9402). *N.Z. Fisheries Data Report No. 57.* 50 p.

Bagley, N.W. & Hurst, R.J. 1996a: Trawl survey of middle depth and inshore bottom species off Southland, February-March 1995(TAN9502). *N.Z. Fisheries Data Report No. 73.* 47 p.

Bagley, N.W. & Hurst, R.J. 1996b: Trawl survey of middle depth and inshore bottom species off Southland, February-March 1996(TAN9604). *N.Z. Fisheries Data Report No. 77.* 51 p.

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

Cordue, P.L. 1993: A Minimised Integrated Average Expected Loss approach to biomass and risk estimation. *In* McAleer, M. & Jakeman, A.J. (Eds.): Proceedings of the International congress on modelling and simulation, 6–10 Dec., 1993, University of Western Australia. pp. 1665–1670.

Cordue, P.L. 1996: A model based method for bounding virgin biomass using a catch history, relative biomass indices, and ancillary information. N.Z. Fisheries Assessment Research Document 96/8. 48 p.

Francis, R.I.C.C. 1992: recommendations concerning the calculation of Maximum Constant Yield (MCY) and Current Annual Yield (CAY). N.Z. Fisheries Assessment Research Document 92/8. 23 p.

Hatanaka, H., Uozumi, Y., Fukui, J., Aizawa, M., & Hurst, R.J. 1989: Japan-New Zealand trawl survey off southern New Zealand, October-November 1983. *N.Z. Fisheries Technical Report No. 9.* 52 p.

Holton, A.L. 1987: Project proposal and literature review of the biology of gemfish and history of the New Zealand fishery (Unpublished Fisheries Management Division report held by the authors).

Hurst, R.J. 1988: Gemfish. N.Z. Fisheries Assessment Research Document 88/14.

Hurst, R.J. & Bagley, N.W. 1994: Trawl survey of middle depth and inshore bottom species off Southland, February-March 1993(TAN9301). *N.Z. Fisheries Data Report No. 52.* 58 p.

Hurst, R.J. & Bagley, N.W. 1997a: Results of a trawl survey of barracouta and associated shelf and upper slope species off southern New Zealand, November, 1986. *N.Z. Fisheries Technical Report No. 47.* 38 p.

Hurst, R.J. & Bagley, N.W. 1997b: Trends in Southland trawl surveys of inshore and middle depth species , 1993–96. *N.Z. Fisheries Technical Report No. 50.* 67 p.

Hurst, R.J., Bagley, N.W., & Uozumi, Y. 1990: New Zealand - Japan trawl survey of shelf and upper slope species off southern New Zealand, June 1986. *N.Z. Fisheries Technical Report No. 18.* 50 p.

Ingerson, J.K.V. & Colman, J.A. 1997: Analysis of commercial catch and effort data from the northern gemfish (SKI 1 and SKI 2) trawl fishery, 1988–89 to 1994–95. N.Z. Fisheries Assessment Research Document 97/18. 16 p.

Kawahara, S. & Tokusa, K. 1981: Report on Japan/New Zealand joint squid survey in areas E and F by *Shinkai Maru*. (Unpublished manuscript held in NIWA library, Wellington.)

Kerstan, M. & Sahrhage, D. 1980: Biological investigation on fish stocks in the waters off New Zealand. *Mitteilungen aus dem Institut fur Seefischerei der Bundesforschungsanstalt fur Fischerei, Hamburg, No. 29.* 168 p.

Langley, A.D. 1995: Analysis of commercial catch and effort from the gemfish (SKI 1) trawl fishery from 1988–89 to 1993–94. New Zealand Fisheries Assessment Research Document 95/16.

Langley, A., Hartill, B., & Walshe, C. 1993: Summary of the northern gemfish (SKI 1) trawl fishery, 1989–92. Northern Fisheries Region Internal Report No. 14. 39 p. (Draft report held by Ministry of Fisheries North Region, Auckland.)

Lyle, J.M. & Ford, W.B. 1993: Review of trawl research 1979–1987, with summaries of biological information for the major species. *Tasmanian Department of Primary Industries Division Sea Fisheries Technical Report No. 46.*

Nakamura, I. & Parin, N.V. 1993: FAO species catalogue vol. 15. Snake mackerels and cutlassfishes of the world (Families Gempylidae and Trichiuridae). *FAO Fisheries Synopsis No. 125, Vol 15.* Food and Agriculture Organisation of the United Nations, Rome.

NZFIB 1996: The New Zealand seafood industry economic review 1994–1996. New Zealand FIB, Wellington. 65 p.

Paxton, J.R. & Colgan, D.J. 1993: Biochemical genetics and stock assessment of common gemfish and ocean perch. Final report, FRDC Project 91/35. Australian Museum, Sydney.

Paulin, C., Stewart, A., Roberts, C., & McMillan, P. 1989: New Zealand fish: A Complete Guide. *National Museum of New Zealand Miscellaneous Series No. 19.* 279 p.

Renwick, J.A., Hurst, R.J. & Kidson, J.W.: Climatic influences on the recruitment of southern gemfish (*Rexea solandri*, Gempylidae) in New Zealand waters. Unpublished manuscript submitted to *International Journal of Climatology.*

Rowling, K.R. 1990: Changes in the stock composition and abundance of spawning gemfish *Rexea solandri* (Cuvier) Gempylidae, in south eastern Australian waters. *Australian Journal of Marine and Freshwater Research 41(1)*: 145–163.

Rowling, K.R. 1994: Gemfish *Rexea solandri*, *In* Tilzey, R.D.J. (ed.) The South East Fishery. A scientific review with particular reference to quota management. Bureau of Resource Sciences. Australian Government Publishing service, pp. 115–123.

Rowling, K.R. & Reid, D.D. 1992: Effect of temporal changes in size composition on estimates of von Bertalanffy growth parameters for gemfish, *Rexea solandri* (Cuvier) Gempylidae. *Australian Journal of Marine and Freshwater Research 43*: 1229–1239.

Sparre, P., Ursin, E., & Venema, S.C. 1989: Introduction to tropical fish stock assessment. Part 1. Manual. *FAO Fisheries Technical Paper 306.* 337 p.

Tilzey, R.D.J., Zann-Schuster, M., Klaer, N.L., & Williams, M.E. 1990: The South East Trawl Fishery: Biological synopses and catch distributions for seven major commercial fish species. *BRR Bulletin No. 6* Australian Government Print Service, Canberra.

Uozumi, Y., Yatsu, A., & Robertson, D.A. 1987: Japan-New Zealand trawl survey off southern New Zealand, April 1983. *N.Z. Fisheries Technical Report No. 4.* 52 p.

Van den Broek, W.L.F., Tokusa, K., & Kono, H. 1984: A survey of demersal fish stocks in waters south of New Zealand, March-May 1982. *Fisheries Research Division Occasional Publication No. 44.* 51 p.

Withell, A.F. & Wankowski, J.W. 1989: Age and growth estimates for pink ling *Genypterus blacodes* (Schneider) and gemfish *Rexea solandri* (Cuvier) from eastern Bass Strait, Australia. *Australian Journal of Marine and Freshwater Research 40*: 215–226.

Table 1: Reported landings (t) of gemfish, by nation, 1978–79 to 1985–86. Fishing years to 1982–83 are from 1 April to 31 March. 1983–83 is a 6 month transitional period from 1 April to 30 September. Subsequent years are 1 October to 30 September. Data other than domestic catches are not available (N/A) for the 1980–81 fishing year

	New Zealand		Foreign licensed				
Year	Domestic	Chartered	Japan	Korea	USSR	Total	Total
1978–79	352	53	1 509	1 079	0	2 588	2 993
1979–80	423	1 174	1 036	78	60	1 174	2 771
1980–81	1 050	N/A	N/A	N/A	N/A	N/A	>1 050
1981–82	1 223	1 845	391	16	0	407	3 475
1982–83	822	1 368	274	567	0	841	3 031
1983–83	1 617	1 799	57	37	0	94	3 510
1983–84	1 982	3 532	819	305	0	1 124	6 638
1984–85	1 360	2 993	470	223	0	693	5 046
1985–86	1 696	4 056	2 059	442	0	2 501	8 253

Table 2: Reported landings (t) of gemfish by fishing year and area, by foreign licensed and joint venture vessels, 1978–79 to 1985–86. The EEZ areas (*see* Figure 2 of Baird & McKoy 1988) correspond approximately to the QMA as indicated. Fishing years are as in Table 1. No data are available (N/A) for the 1980–81 fishing year

EEZ area	B	C	D	E - E(A)	E(A)	F(E)	F(W)	G	H	Total
QMA area	1 & 2	3	4	6			5	7	8 & 9	
1978–79	87	638	0	0	342	263	65	1 093	154	2 642
1979–80	284	369	29	18	944	352	214	303	34	2 347
1980–81	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1981–82	0	112	5	0	321	223	361	1 063	167	2 252
1982–83	0	13	3	0	883	135	310	458	408	2 209
1983–83	0	92	2	0	44	100	16	1 125	11	1 391
1983–84	0	59	2	0	298	582	2 234	1 395	86	4 657
1984–85	0	29	1	3	262	758	1 204	1 317	37	3 686
1985–86	0	293	7	32	403	2 213	2 315	1 268	28	6 558

Notes:

Catches in EEZ area E(A) were mostly from the part of FMA 5 south of 48°30' S.

Totals do not match Table 1 as some catch was undefined by area.

Table 3: Reported landings (t) of gemfish by Fishstock from 1983–84 to 1994–95 and actual TAC's for 1986–87 to 1994–95.

	SKI 1		SKI 2		SKI 3		SKI 7		Fishstock SKI 10		Total	
Year	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1983–84	588	-	632	-	3 481	-	1 741	-	0	-	6 442	-
1984–85	388	-	381	-	2 533	-	1 491	-	0	-	4 793	-
1985–86	716	-	381	-	5 446	-	1 468	-	0	-	8 011	-
1986–87	773	550	896	860	2 045	2 840	1 069	1 490	0	10	4 783	5 750
1987–88	696	632	1 095	954	1 664	2 852	1 073	1 543	0	10	4 528	5 991
1988–89	1 023	1 139	1 011	1 179	1 126	2 922	1 083	1 577	0	10	4 243	6 827
1989–90	1 230	1 152	1 043	1 188	1 164	3 259	932	1 609	0	10	4 369	7 218
1990–91	1 058	1 152	949	1 188	616	3 339	325	1 653	0	10	2 948	7 342
1991–92	1 017	1 152	1 208	1 197	287	3 339	584	1 653	0	10	3 096	7 350
1992–93	1 292	1 152	1 020	1 230	371	3 345	469	1 663	0	10	3 152	7 401
1993–94	1 156	1 152	1 058	1 300	75	3 345	321	1 663	0	10	2 616	7 470
1994–95	1 031	1 152	905	1 300	160	3 355	119	1 663	0	10	2 215	7 480

Table 4: Reported landings (t) of gemfish by QMA and fishing year, 1982–83 to 1994–95.

		QMA (EEZ area)		Total	%	QMA (EEZ area)		Total	%
				SKI 3	Southland			SKI 7	WCSI
Year	3 (C)	4 (D)	5 (EA+F)			7 (G)	8+9 (H)		
1983–84	225	2	3123	3350	93	1589	115	1704	93
1984–85	234	1	2236	2471	90	1480	37	1517	98
1985–86	407	7	4965	5379	92	1390	73	1463	95
1986–87	174	2	1571	1747	90	906	71	977	93
1987–88	284	66	1293	1643	79	990	23	1013	98

Table 5: Main fisheries in which gemfish was recorded as bycatch in the WCSI and Southland areas, 1983–84 to 1994–95

Target species	1983–4 to 1987–88 % of total gemfish recorded by tow (21 986 t)	1988–89 to 1994–95 % of total gemfish recorded by tow (4 169 t)
Arrow squid	21.8	10.1
Barracouta	13.0	26.5
Hoki	12.6	18.0
Jack mackerel	1.4	12.1
Ling	1.8	1.8
Red cod	0.6	1.4
Silver warehou	5.2	5.2

Table 6: Length-weight relationships for gemfish from Southland trawl surveys. The parameters describe the equation in the form $W=a.L^b$, where W is weight (g) and L is fork length (cm). Range, range of lengths, to the nearest attained centimetre used to calculate the equation. Relationships for all fish include fish not sexed

Sex	*n*	Length range (cm)	*a*	*b*	R^2
All	1026	26-108.5	0.0012	3.43	0.94
Males	528	48- 98.1	0.0095	3.47	0.91
Females	498	26-108.5	0.0012	3.41	0.96

Table 7: Von Bertalanffy growth parameters for SKI 1(east) (Langley *et al.* 1993), SKI 3 (Horn & Hurst, draft ms) and Australian (Rowling & Reid 1992) gemfish

Area	Sex	L_∞ (cm)	k	t_0 (yr)
Australia	male	97.5	0.21	-0.52
	female	109.4	0.18	-0.61
SKI 1(east)	male	90.7	0.204	-0.493
	female	122.7	0.114	-1.012
Southland	male	88.5	0.242	-0.66
	female	104.2	0.178	-0.88

Table 8: Biomass estimates (t), coefficients of variation, *c.v.* (%), and sex ratios of gemfish from random stratified trawl surveys off southern New Zealand, FMA 5, 1981 to 1996

Vessel	Voyage	Stations per km^2	Biomass (t)	*c.v.* (%)	Sex ratio M:F	Date
Shinkai Maru *	SHI8101	1:579	3 900	17	-	February 1981
Shinkai Maru *	SHI8201	1:574	3 100	31	-	March/April 1982
Shinkai Maru *	SHI8302	1:508	5 500	33	-	April 1983
Shinkai Maru *	SHI8303	1:1480	1 100	43	-	October/November 1983
Shinkai Maru	SHI8601	1:952	2 553	26	0.8:1	June 1986
Akebono Maru No. 3 *	AKE8601	1:386	3 100	15	1.1:1	November 1986
Tangaroa	TAN9301	1:446	1 066	17	1.0:1	February/March 1993
Tangaroa	TAN9402	1:384	406	18	1.1:1	February/March 1994
Tangaroa	TAN9502	1:331	539	25	1.5:1	February/March 1995
Tangaroa	TAN9604	1:401	529	23	1.1:1	February/March 1996

* Estimate reduced by 10% to correct for net width measurement method (*see* Hurst & Bagley 1997b)

Table 9: Biological input parameters for the SKI 3 + SKI 7 assessment

Parameter	Estimate
Steepness	0.75
Recruitment variability	1.0
Proportion spawning	0.95
M	0.23
Maximum exploitation (r_{max}) pre-spawning, spawning	0.6, 0.8
Minimum exploitation when largest catch (r_{mmx})	0.1
Maturity ogive	0.1, 0.4, 0.8, 1.0 for ages 2, 3, 4, 5

Table 10: Catch history (t) for the period 1972 to 1997 for the SKI 3 + SKI 7 assessment (*, estimated as described in section 5.1)

Year	SKI 3 pre-spawning	SKI 7 spawning
1972*	1 000	200
1973*	1 000	400
1974*	1 000	600
1975*	1 220	900
1976*	2 350	850
1977*	2 500	6 000
1978	1 360	1 300
1979	2 000	460
1980*	1 650	910
1981	1 300	1 450
1982	1 540	1 070
1983	1 060	1 420
1984	3 480	1 740
1985	2 350	1 490
1986	5 450	1 470
1987	2 045	1 070
1988	1 660	1 070
1989	1 130	1 080
1990	1 160	930
1991	620	325
1992	290	580
1993	370	470
1994	75	320
1995	160	103
1996	50	80
1997*	50	80

Table 11: Proportion at age from Southland trawl surveys used in the SKI 3 + SKI 7 assessment

		Age												
Year		3	4	5	6	7	8	9	10	11	12	13	14	15
1993	Male	0.001	0.093	0.008	0.001	0.024	0.261	0.268	0.051	0.200	0.025	0.007	0.036	0.017
	Female	0.001-	0.247	0.001	0.001	0.048	0.142	0.293	0.020	0.186	0.018	0.029	0.017	0.001
1994	Male	0.001	0.001	0.128	0.001	0.001	0.037	0.246	0.370	0.042	0.130	0.018	0.013	0.017
	Female	0.001	0.001	0.198	0.015	0.001	0.061	0.201	0.151	0.066	0.173	0.012	0.107	0.016
1995	Male	0.001	0.001	0.007	0.081	0.001	0.010	0.083	0.303	0.281	0.030	0.160	0.018	0.018
	Female	0.001	0.015	0.001	0.386	0.001	0.014	0.012	0.111	0.212	0.056	0.173	0.009	0.012
1996	Male	0.001	0.001	0.001	0.001	0.248	0.001	0.018	0.060	0.318	0.223	0.024	0.081	0.001
	Female	0.001	0.001	0.001	0.069	0.430	0.017	0.001	0.040	0.191	0.190	0.001	0.062	0.001

Table 12: Estimated or assumed (*) year class strengths (YCS) from the SKI 3 + SKI 7 base case assessment

Year class	YCS
1977	1.000*
1978	1.000*
1979	3.310
1980	1.940
1981	0.001
1982	5.690
1983	0.070
1984	4.250
1985	2.250
1986	0.300
1987	0.001
1988	0.010
1989	0.240
1990	0.010
1991	0.001*
1992	0.001*
1993	0.010*
1994	0.010*

Table 13: Least squares (LSQ) estimates of biomass and MIAEL estimates of biomass and information indices from the SKI 3 + SKI 7 base case assessment. Biomass and bounds are presented either as tonnes or percentage of B_0

Estimate	Bmin - Bmax	LSQ	p	k	MIAEL	Info. Index (%)
B_0	25938–72563	26393	0.04	41528	40923	0
$B_{mid\ 97}$	0–63%	5%	0.10	31.5	29%	0
$B_{beg\ 98}$	155–51447	1627	0.05	25801	24641	0

Table 14: Estimates of MCY , MAY and CAY from the SKI 3 + 7 base case assessment

	$B_{MCY/MAY}$ (% of B_0)	(% of B_0)	Range (t)	MIAEL estimate (t)	Info. Index (%)
MCY	59.4	3.82	990–2770	1563	0.3
MAY	35.5	5.59			
CAY			20–5930	2792	0

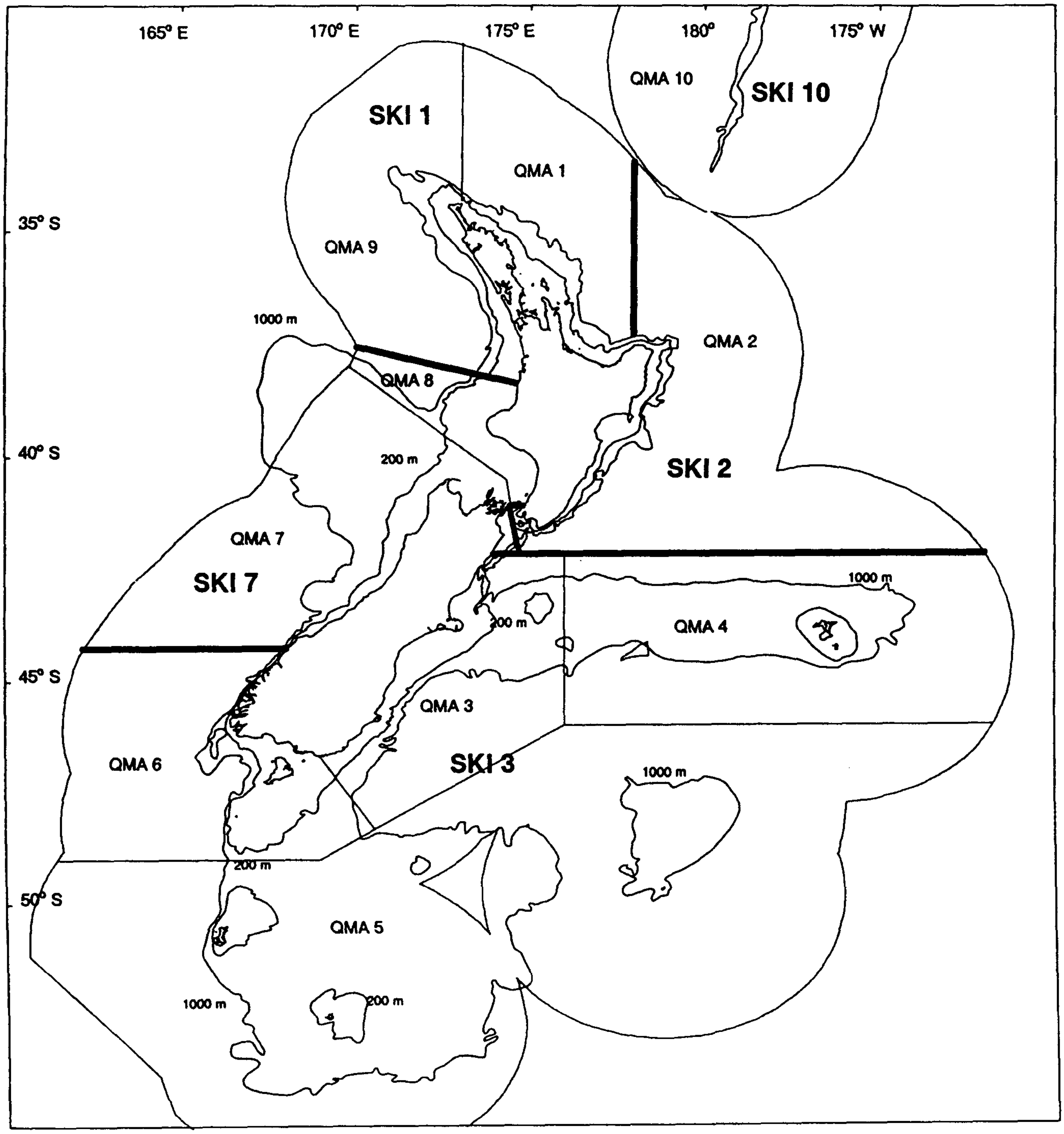


Figure 1: Map of the 200 mile Exclusive Economic Zone (EEZ), Quota Management Areas (QMA), and gemfish Fishstock areas (SKI).

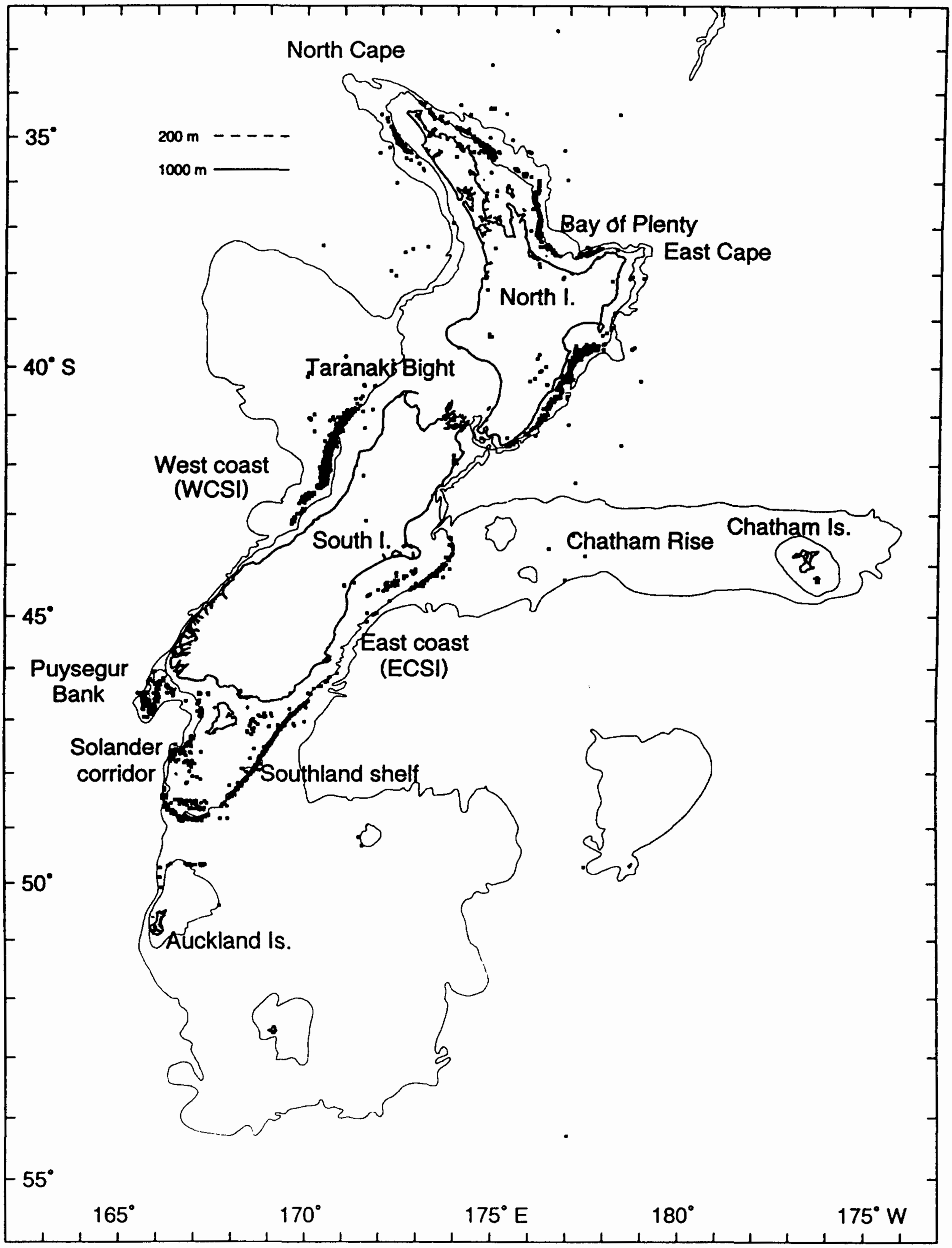


Figure 2: Gemfish target bottom trawl positions, 1983–84 to 1994–95, and places mentioned in the text.

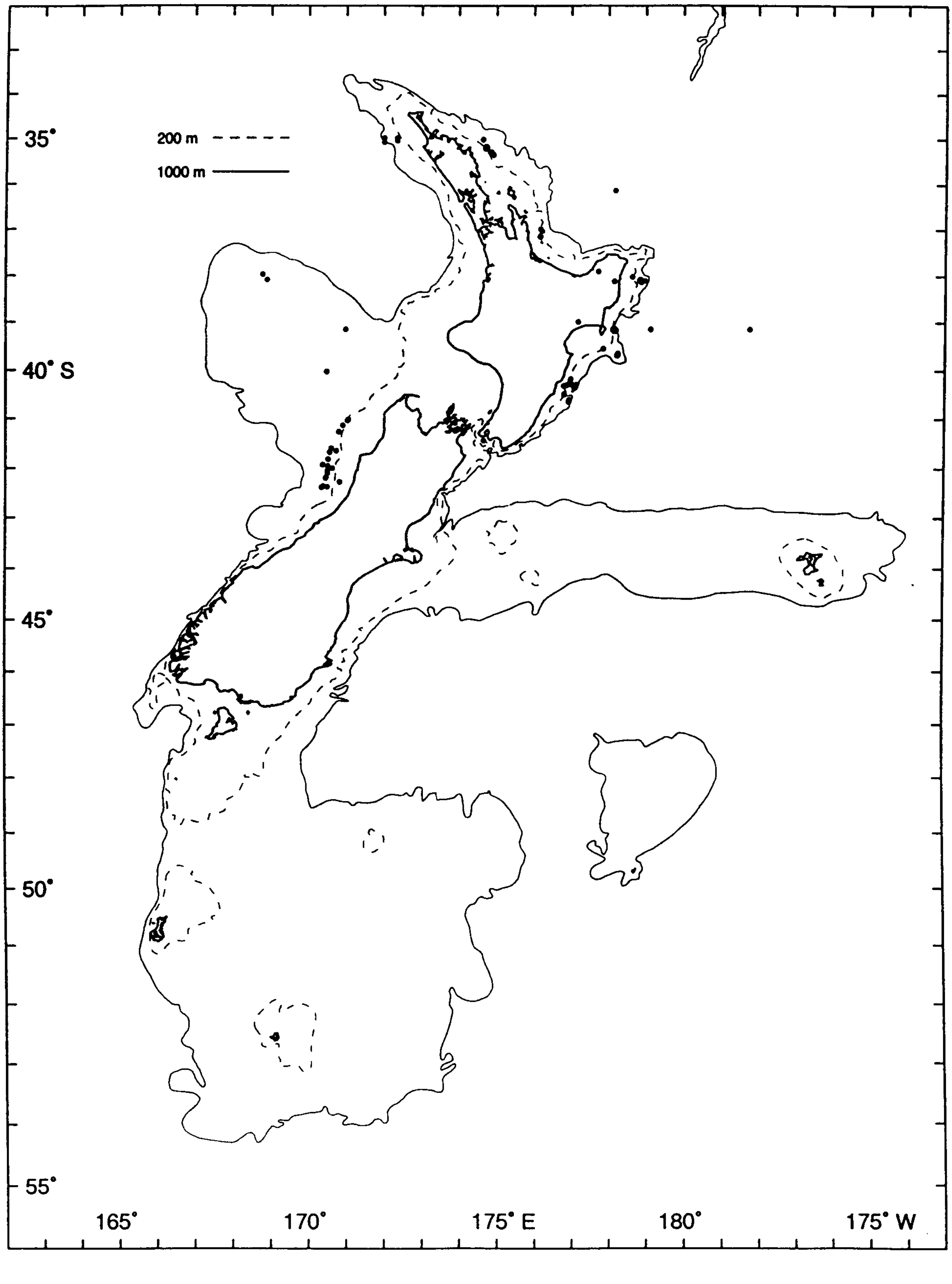


Figure 3: Gemfish target midwater trawl positions, 1983–84 to 1994–95.

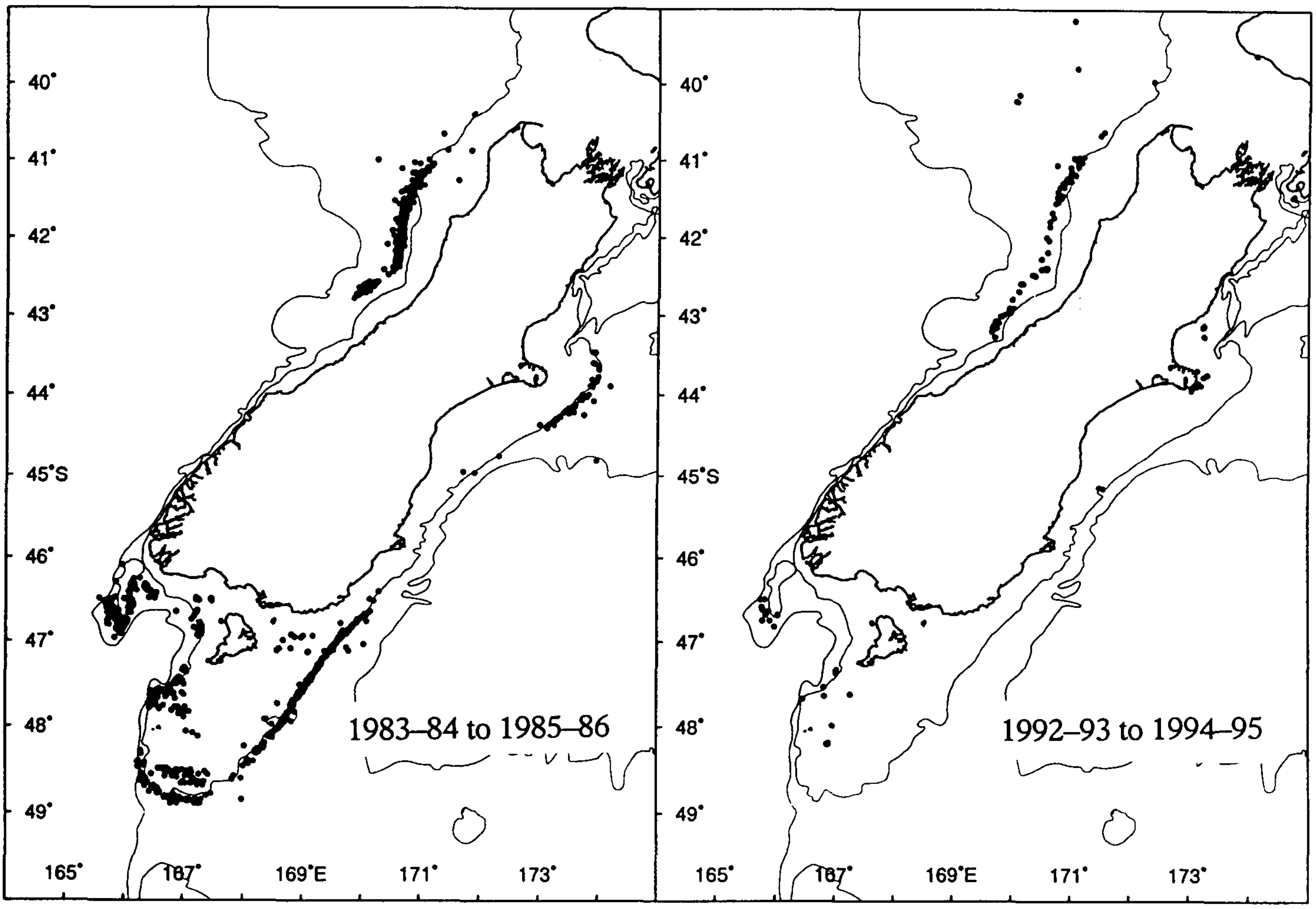


Figure 4: Gemfish target positions for 1983–84 to 1985–86 and 1992–93 to 1994–95.

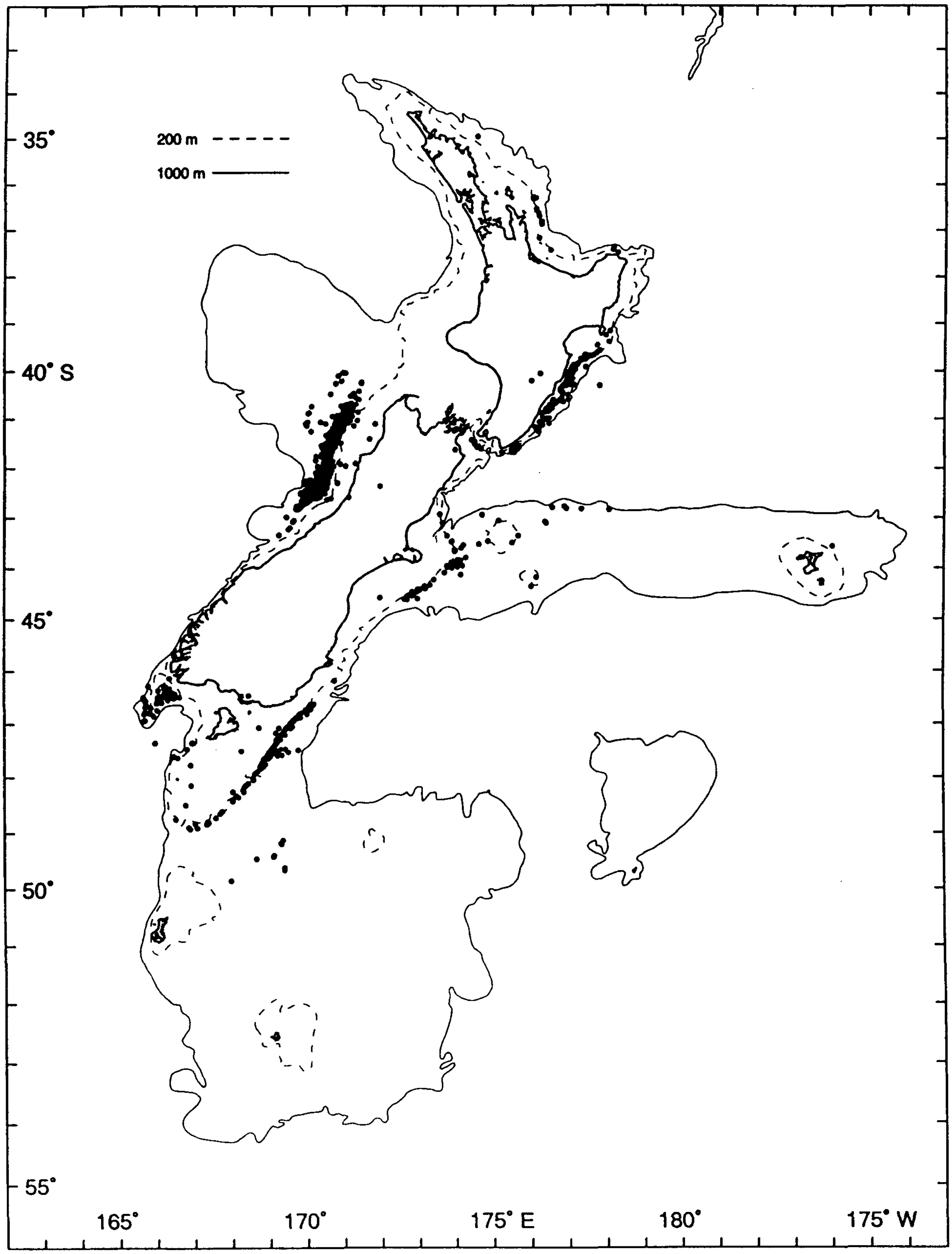


Figure 5a: Gemfish bycatch positions from hoki target fishing, 1988–89 to 1994–95.

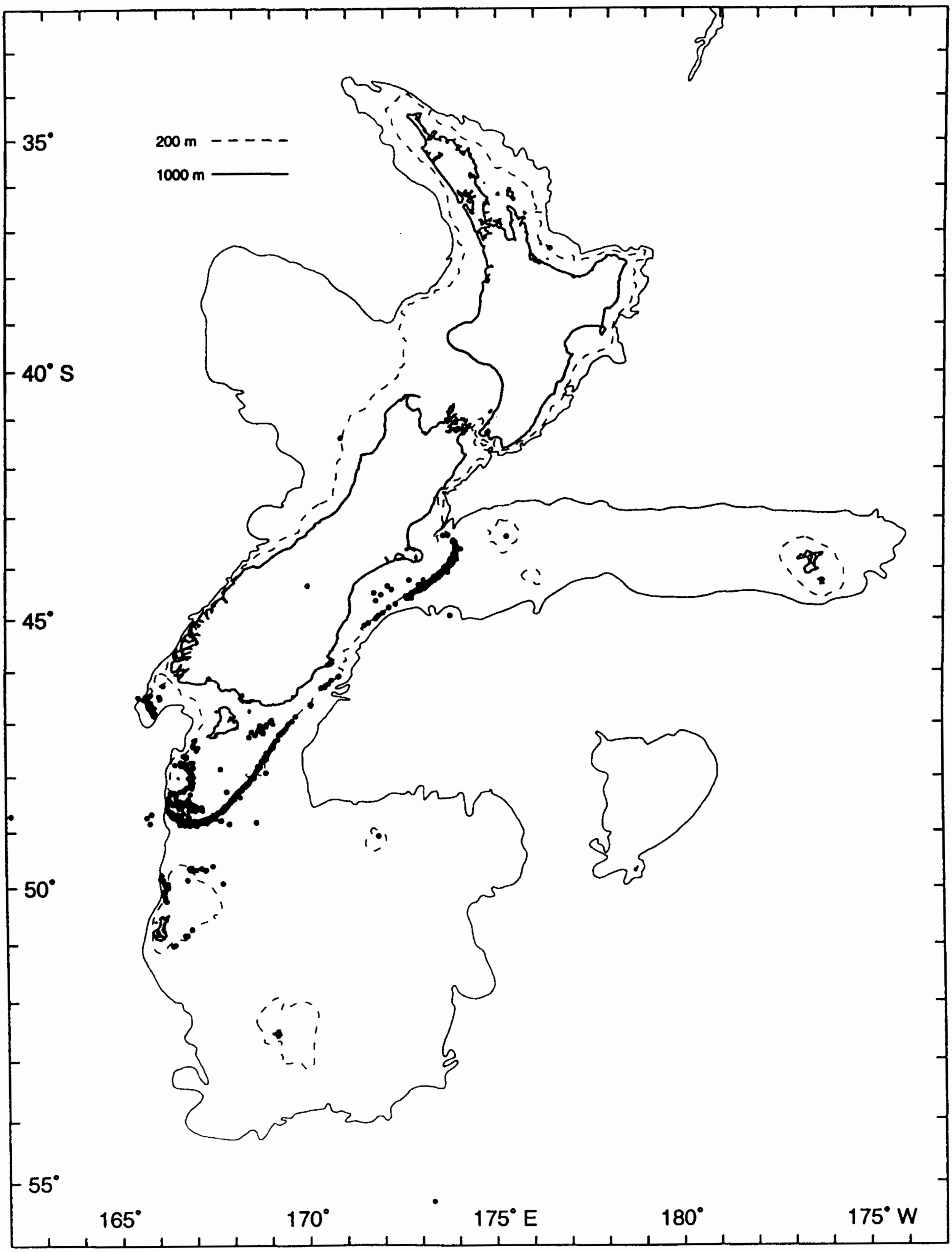


Figure 5b: Gemfish bycatch positions from arrow squid target fishing, 1988–1989 to 1994–95.

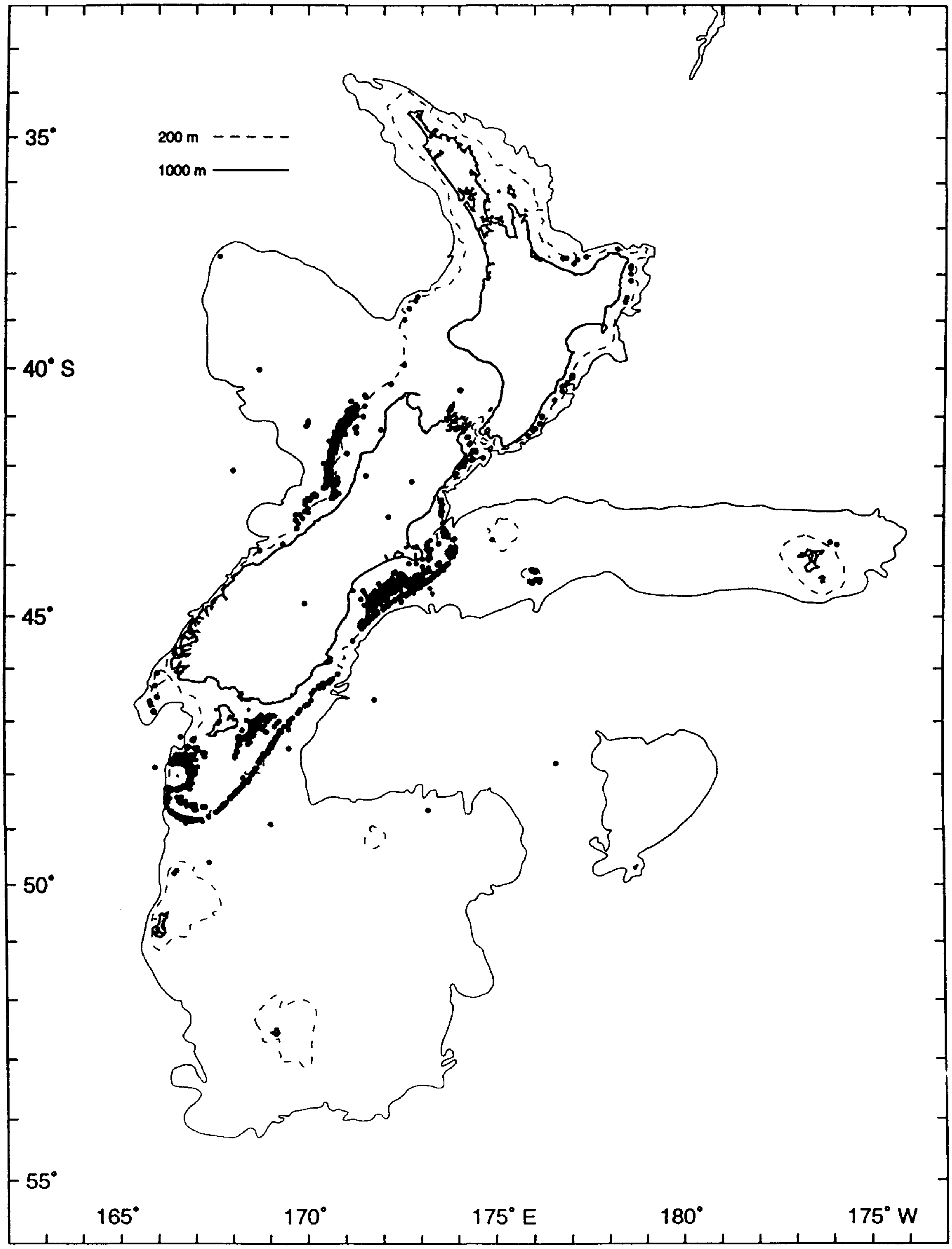


Figure 5c: Gemfish bycatch positions from barracouta target fishing, 1988–89 to 1994–95.

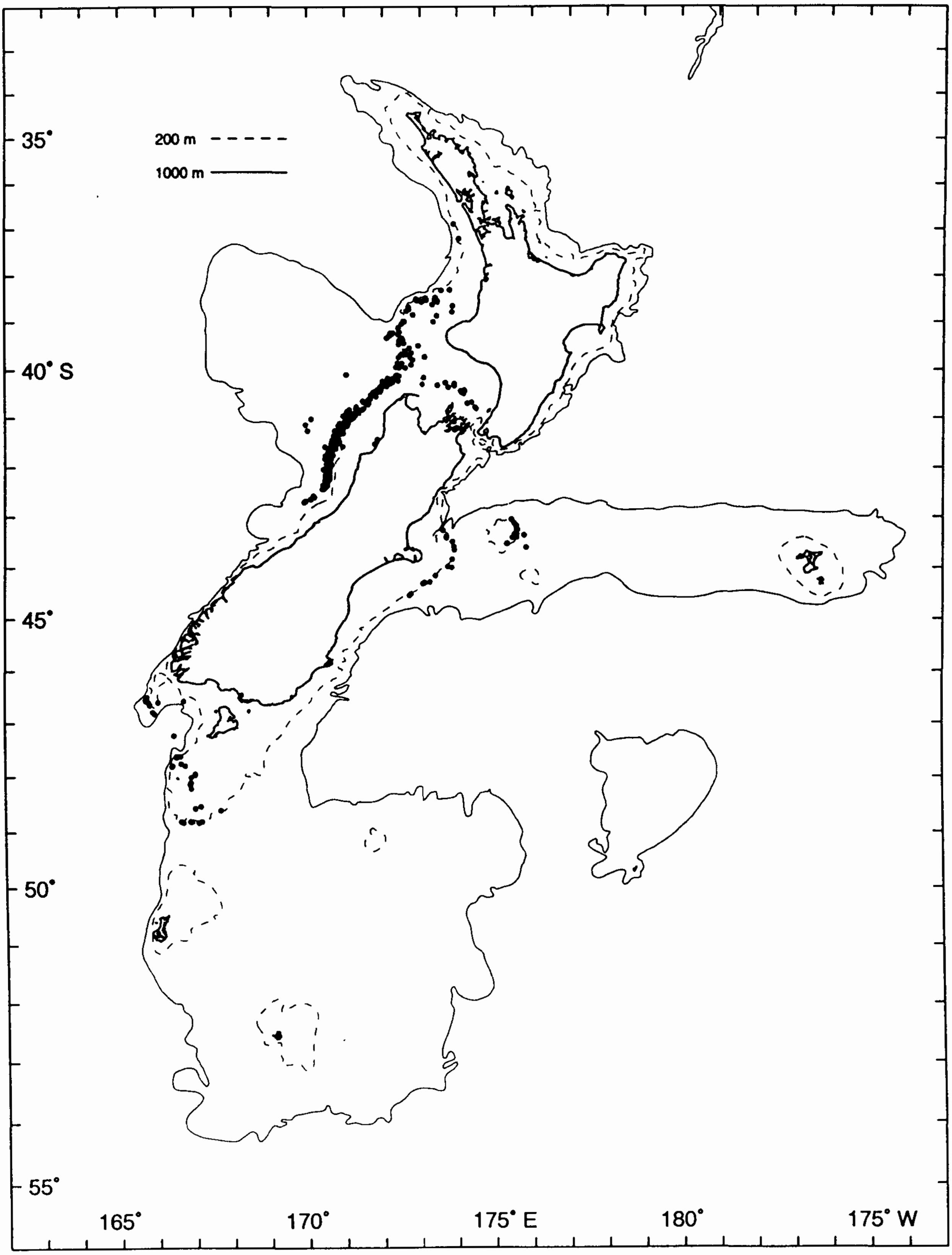


Figure 5d: Gemfish bycatch positions from jack mackerel target fishing, 1988–1989 to 1994–95.

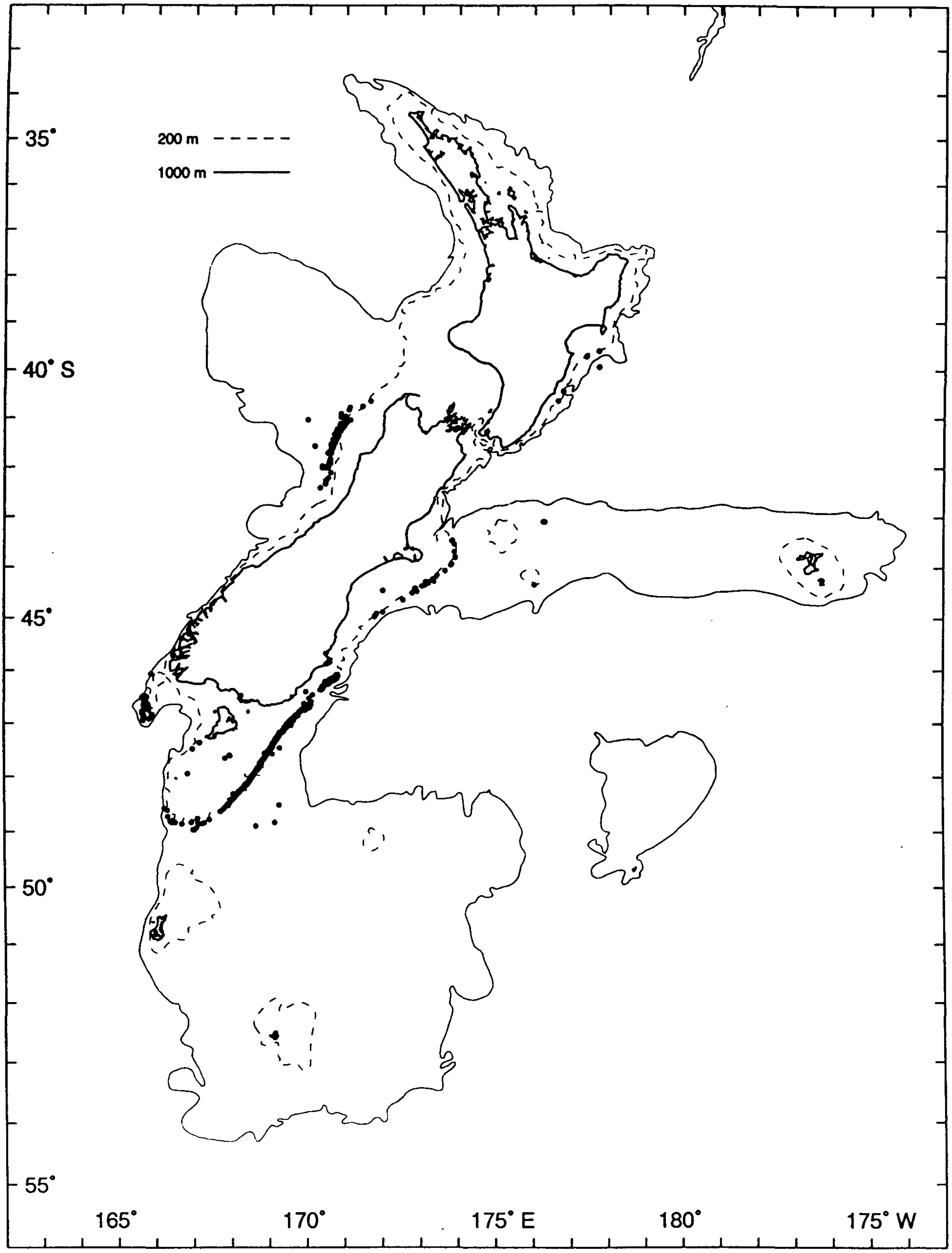


Figure 5e: Gemfish bycatch positions from silver warehou target fishing, 1988–89 to 1994–95.

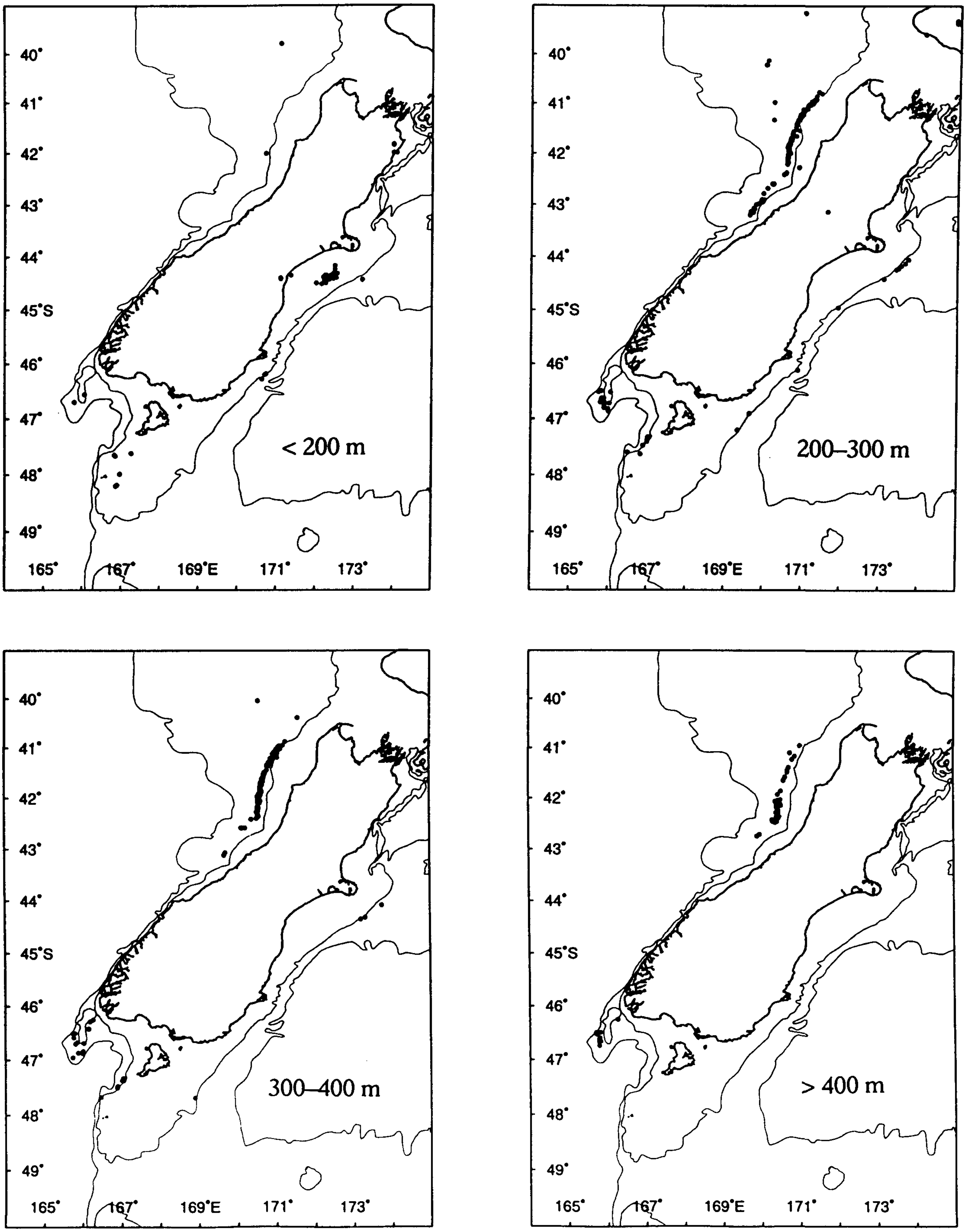


Figure 6: Gemfish target trawl positions, by depth, 1988–89 to 1994–95.

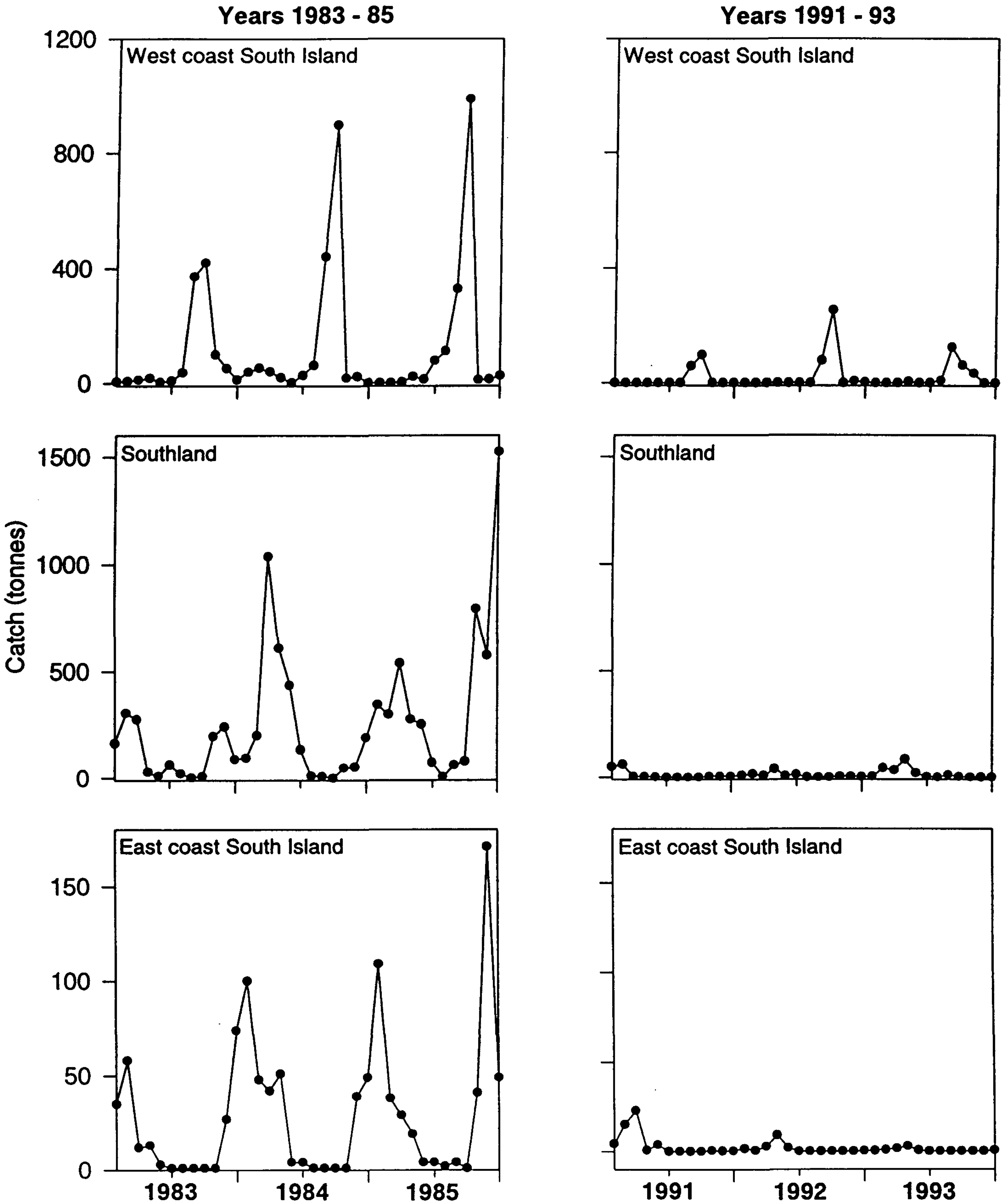


Figure 7: Gemfish catch by month for 1983 to 1985 and 1991 to 1993.

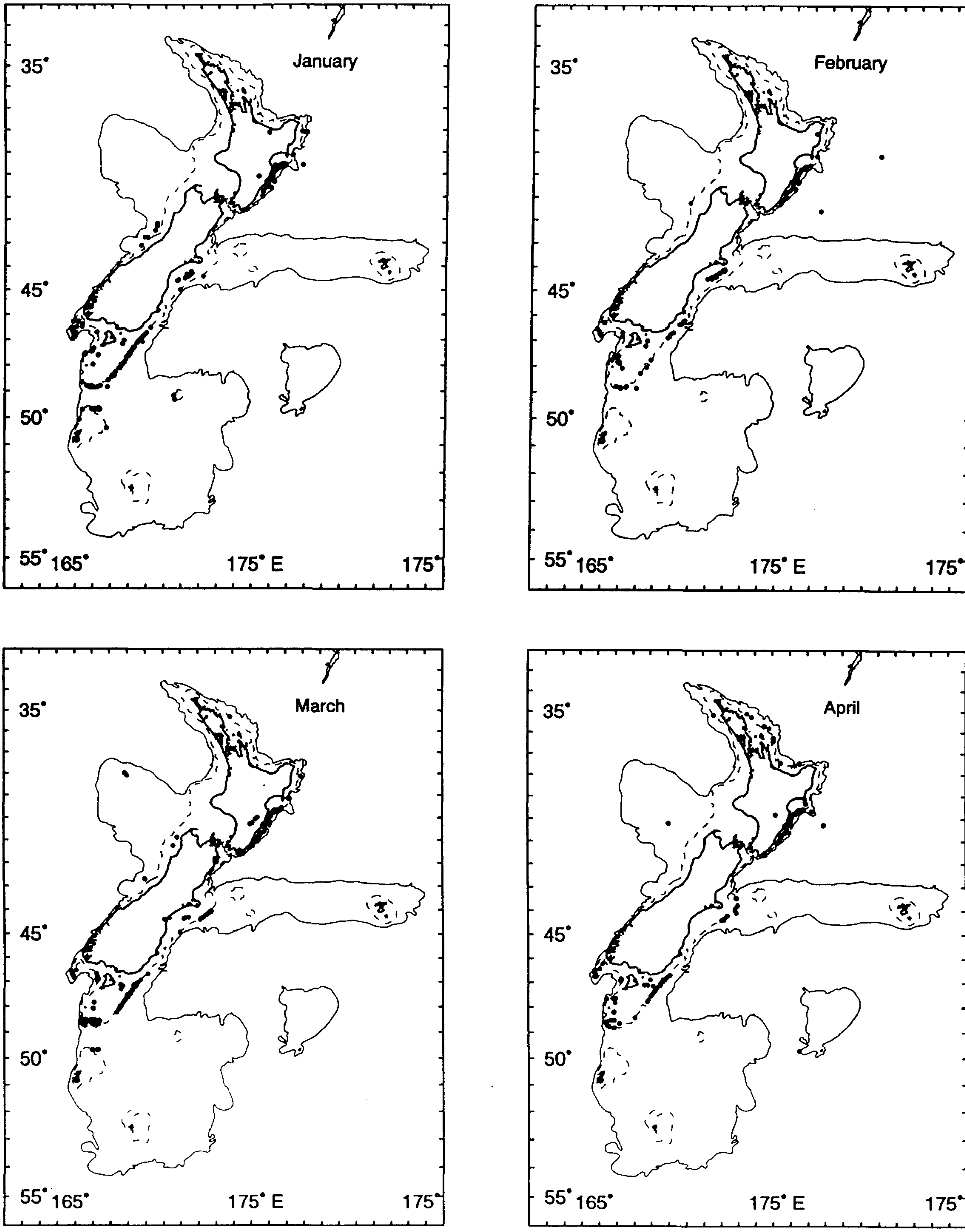
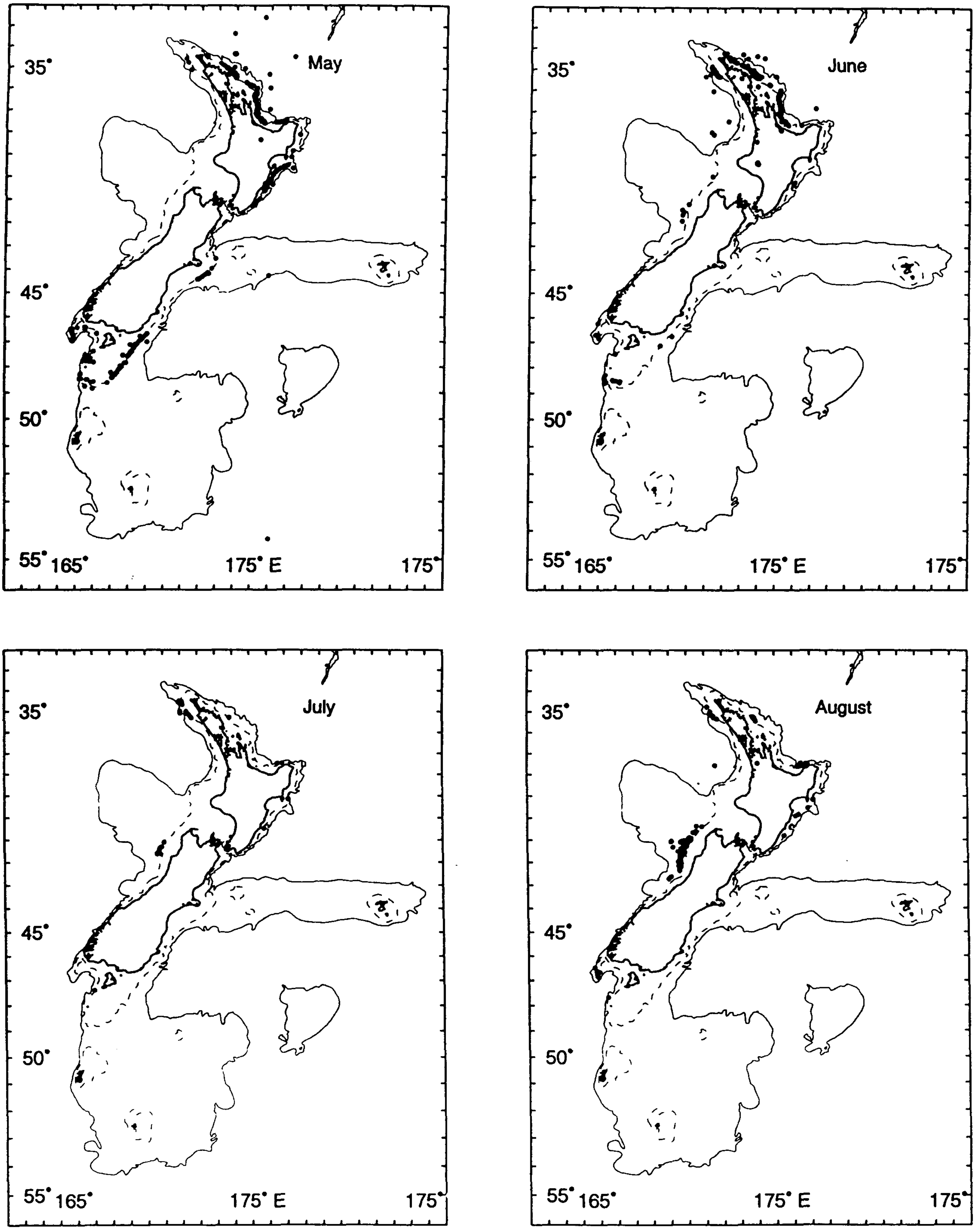
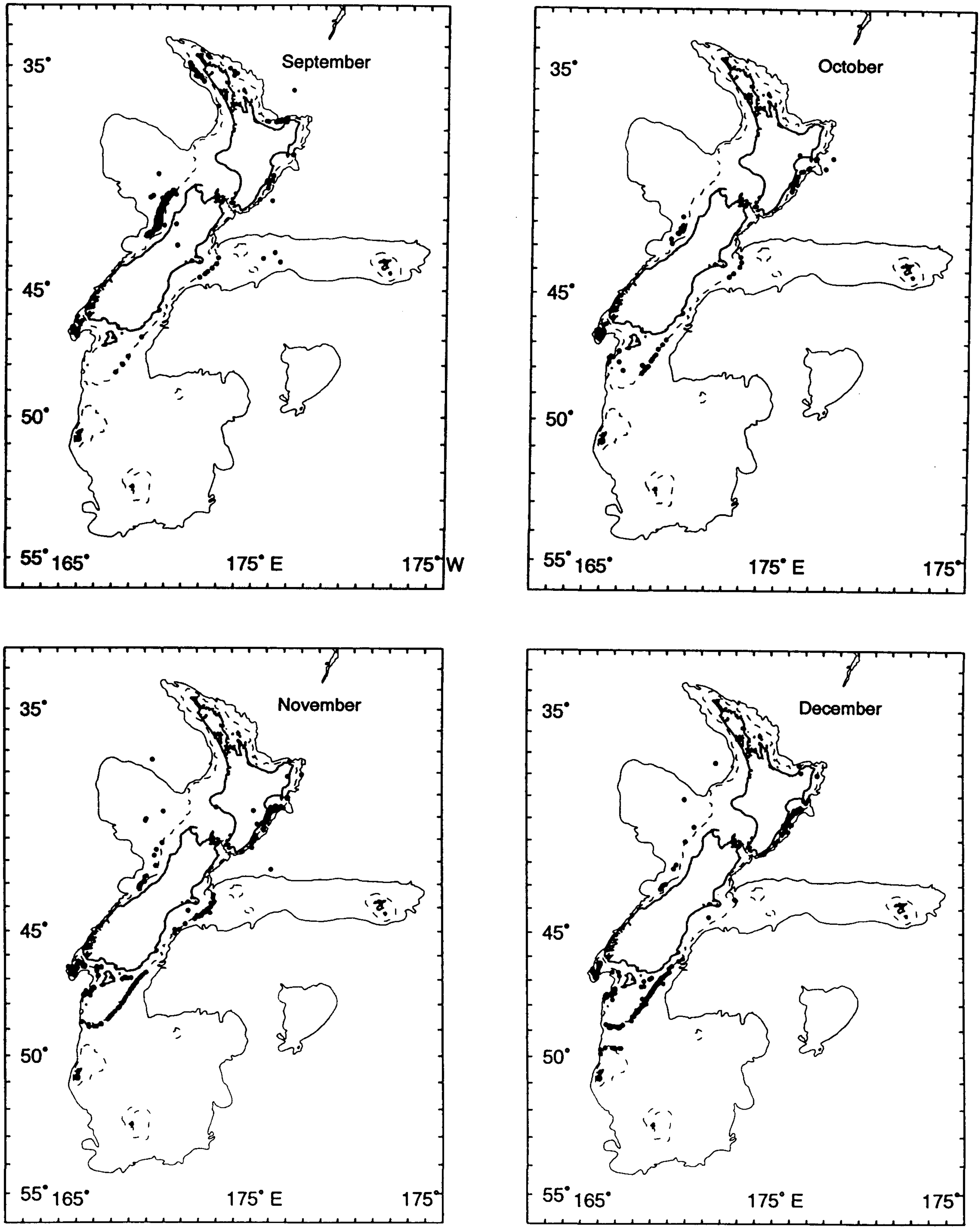


Figure 8: Gemfish target trawl positions, by month, 1983–84 to 1994–95.


May
June
July
August
35°
45°
50°
55°
165°
175° E
175°


September
October
November
December
35°
45°
50°
55°
165°
175° E
175° W

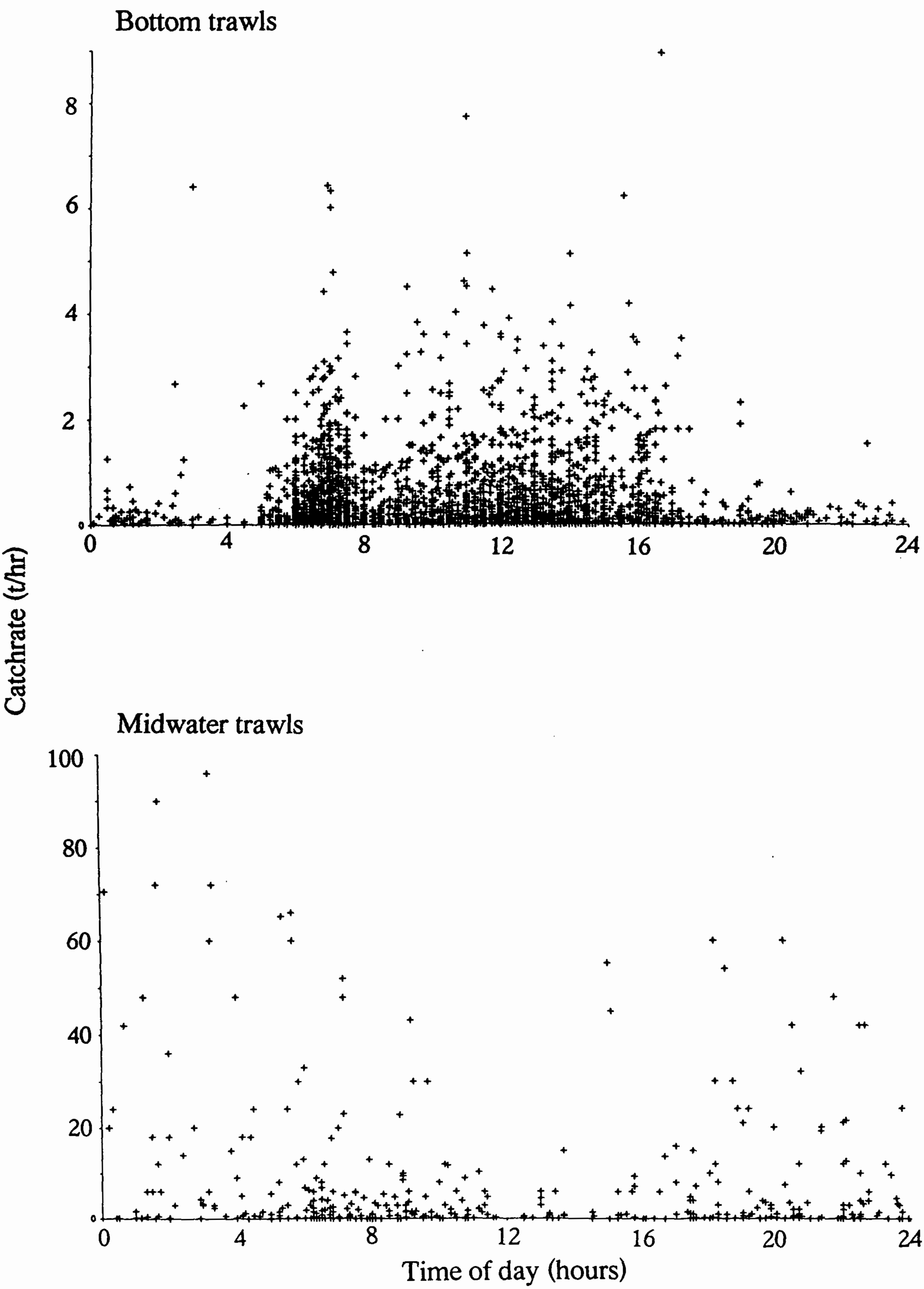


Figure 9: Gemfish target bottom and midwater trawl catch rates, by time of day, 1988–89 to 1994–95.

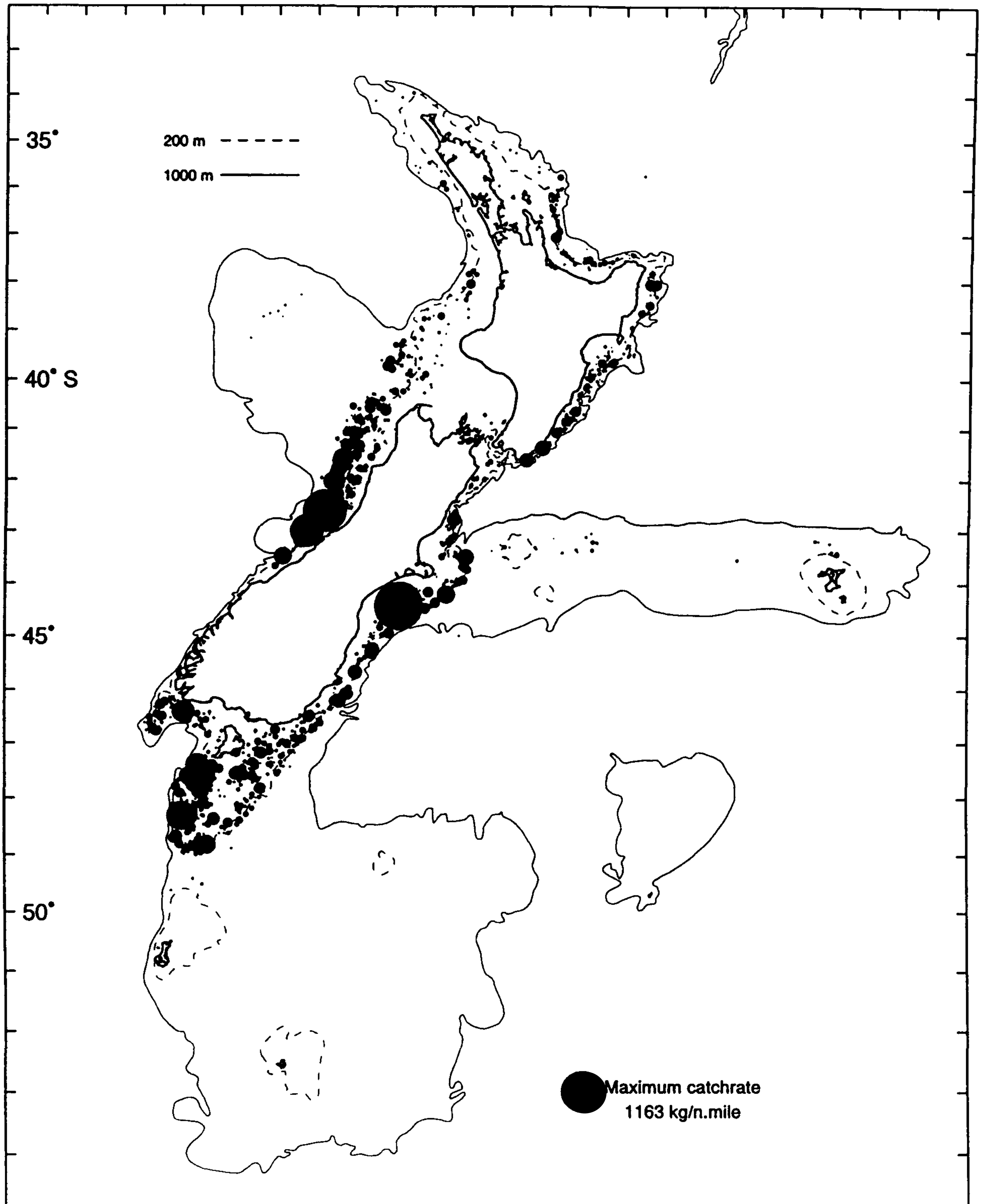


Figure 10: Gemfish catch rate (kg/n.mile) from research surveys.

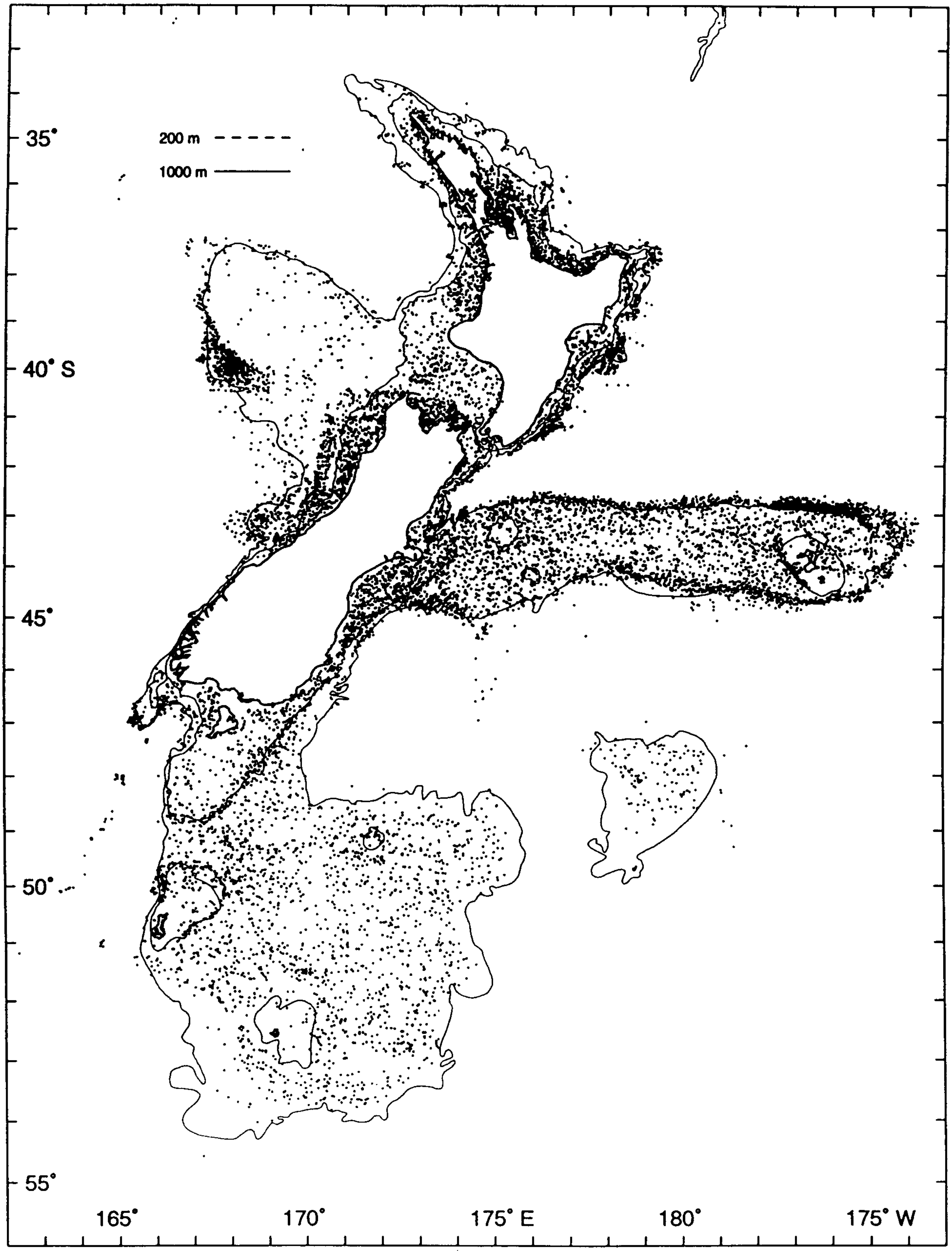
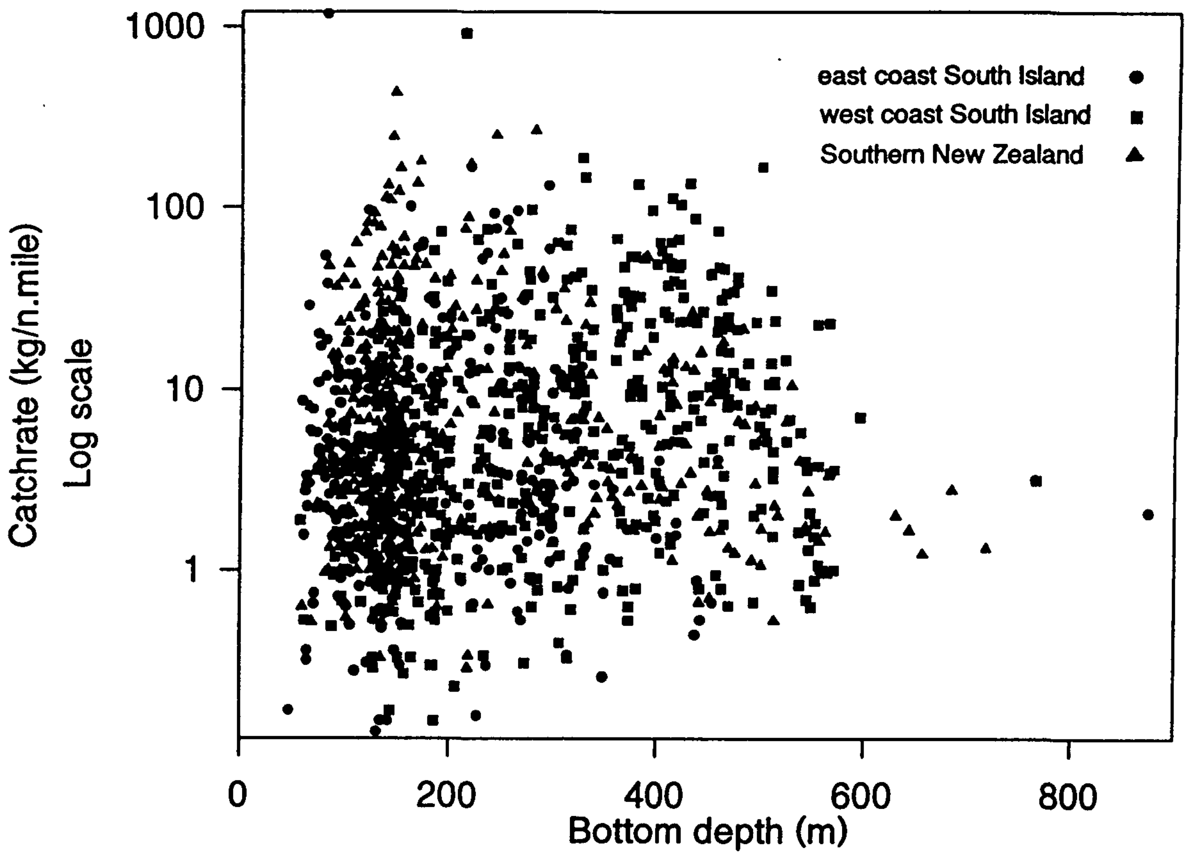


Figure 11: Stations from research surveys where gemfish were not caught.



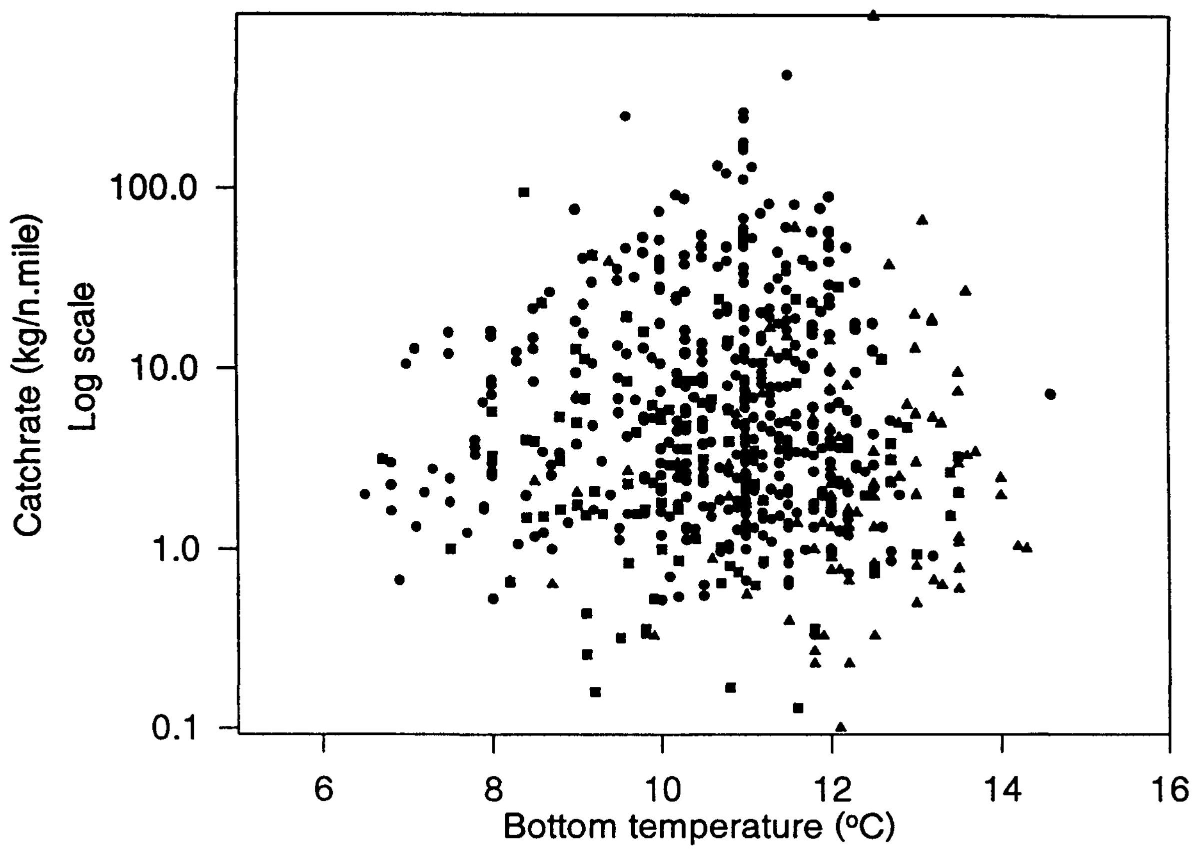


Figure 12 (Above): Gemfish catch rate by depth and area, from research surveys.

Figure 13 (Below): Gemfish catch rate by bottom temperature and area, from research surveys.

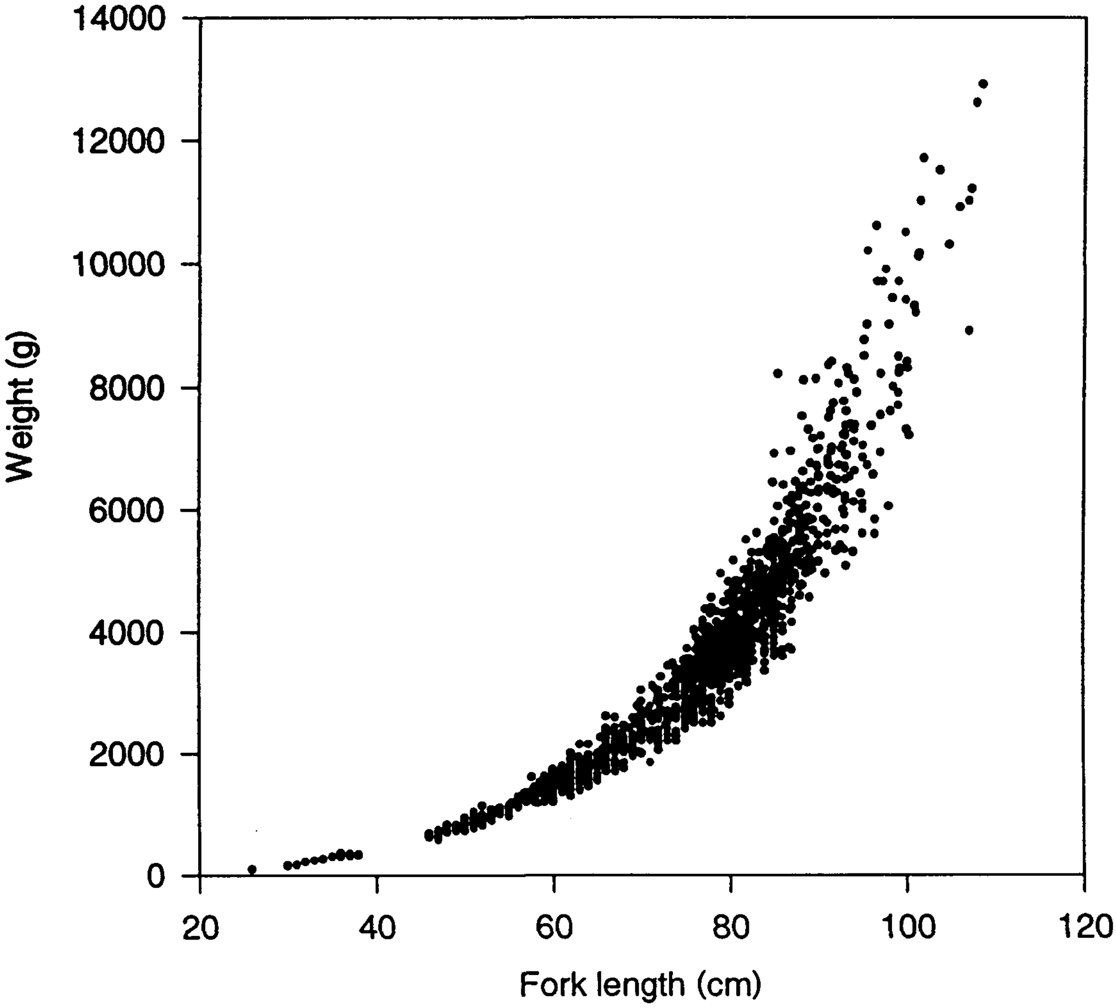


Figure 14: Gemfish length–weight relationship.

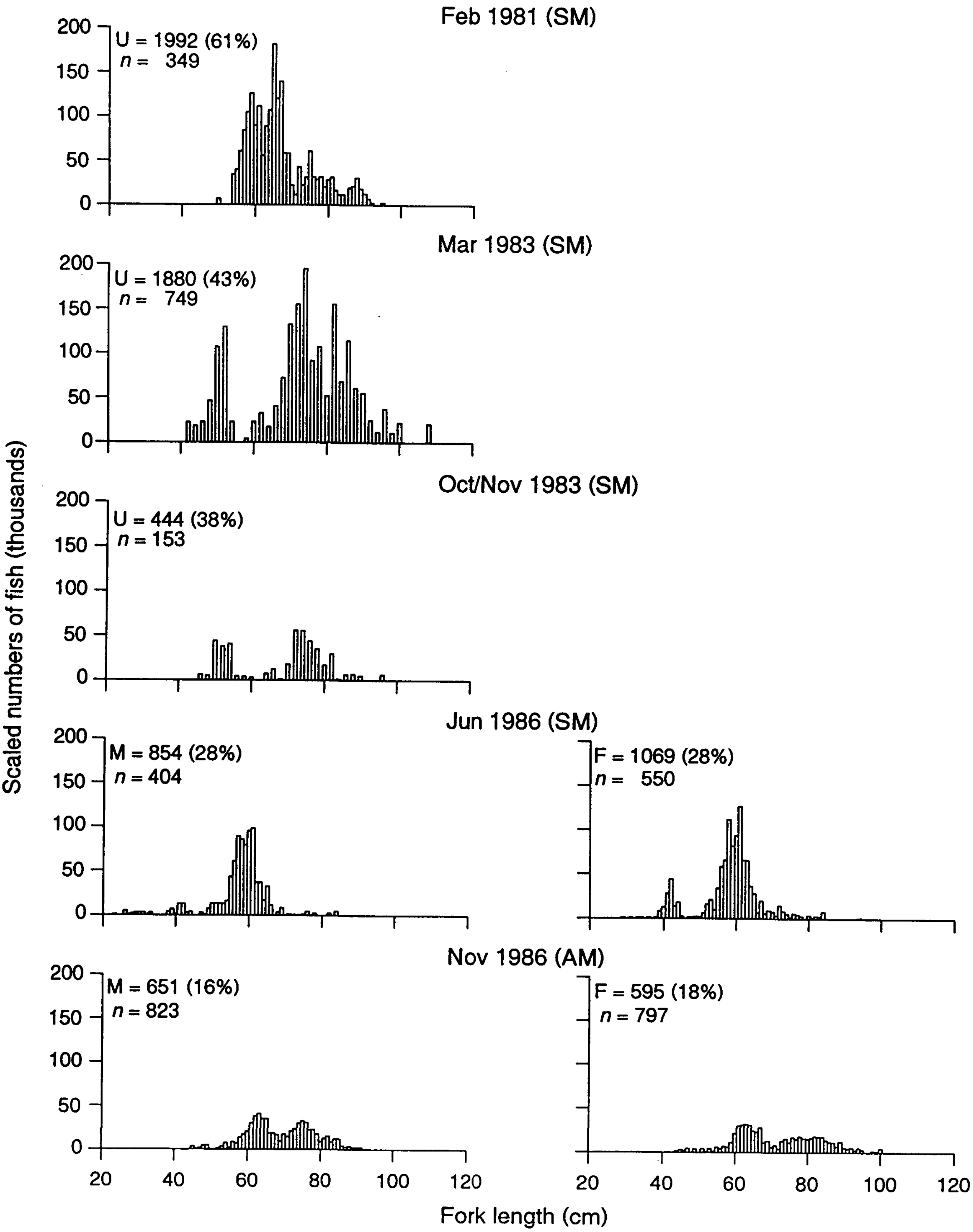


Figure 15: Scaled length-frequency distributions of gemfish from Southland trawl surveys by *Shinkai Maru* (SM) and *Akebono Maru No. 3* (AM) (M, number of males; F, number of females; U, number unsexed; (%), coefficent of variation; n, number of fish measured.

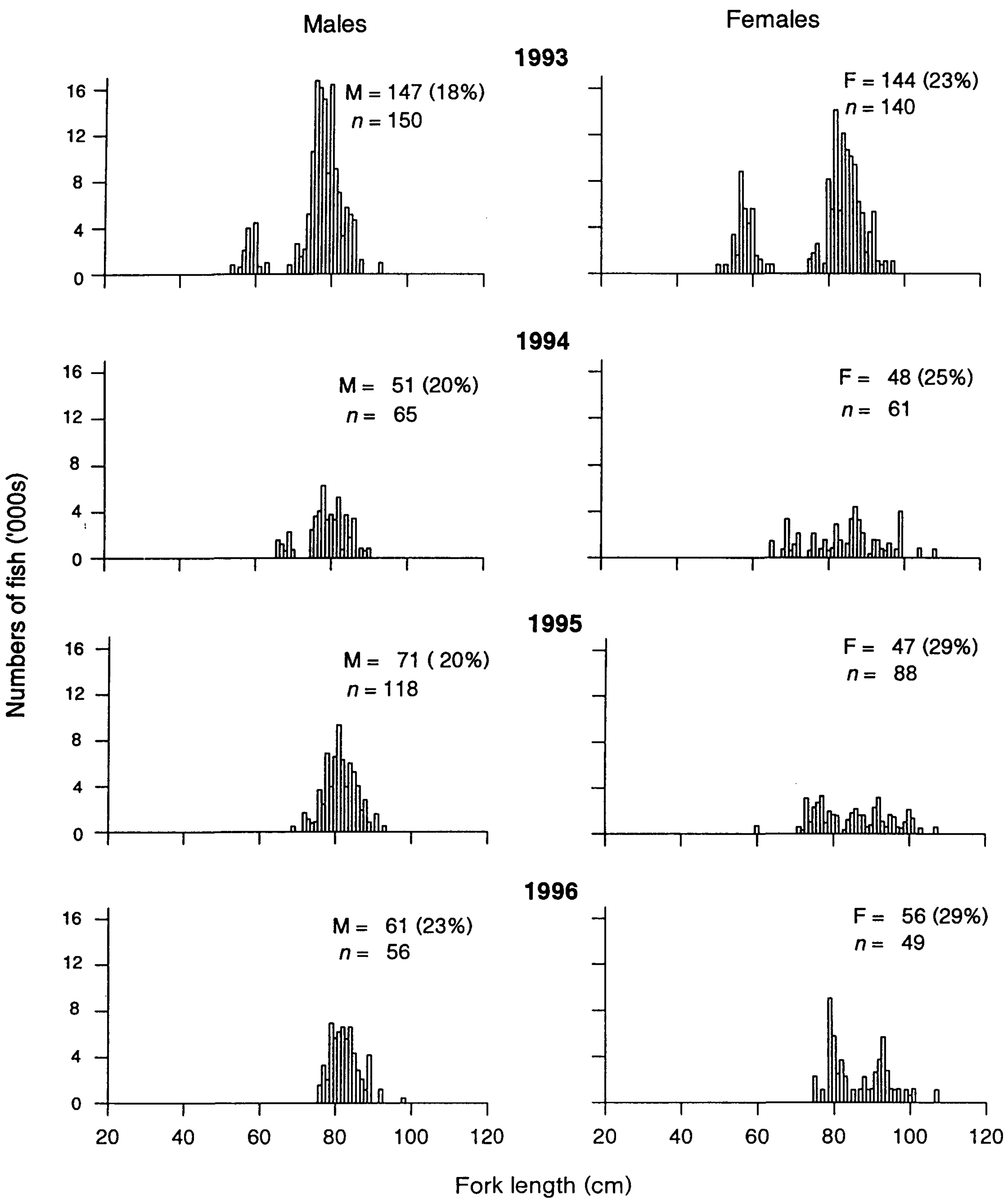


Figure 16: Scaled length–frequency distributions of gemfish from Southland trawl surveys by *Tangaroa*, 1993–1996 (M, number of males; F, number of females; U, number of unsexed fish; (%), coefficient of variation ; *n*, number of fish measured).

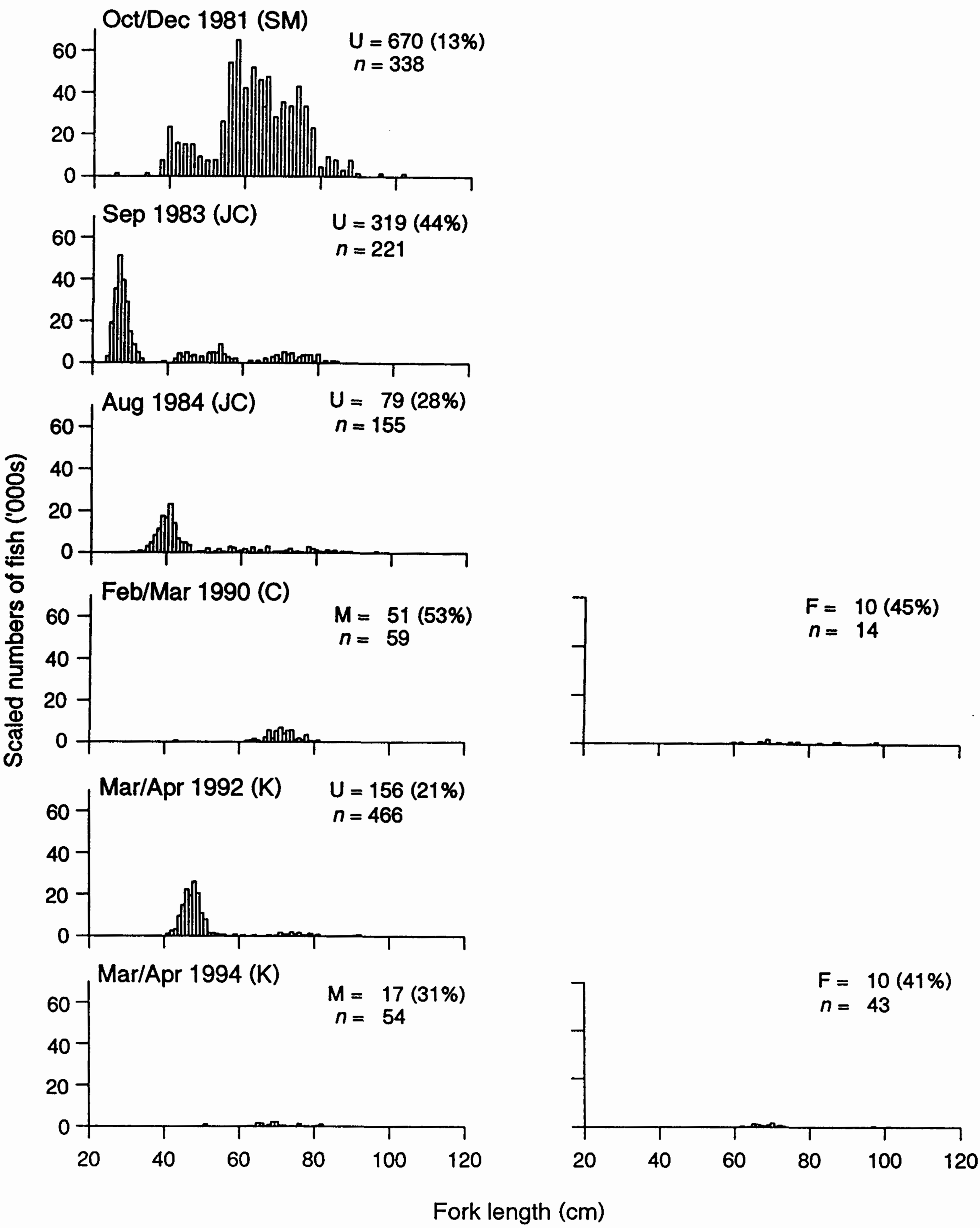


Figure 17: Scaled length–frequency distributions of gemfish from the WCSI by *James Cook* (JC), and *Kaharoa* (K), and central west New Zealand by *Shinkai Maru* (SM), and *Cordella* (C) (M, number of males; F, number of females; (%), coefficient of variation ; *n*, number of fish measured).

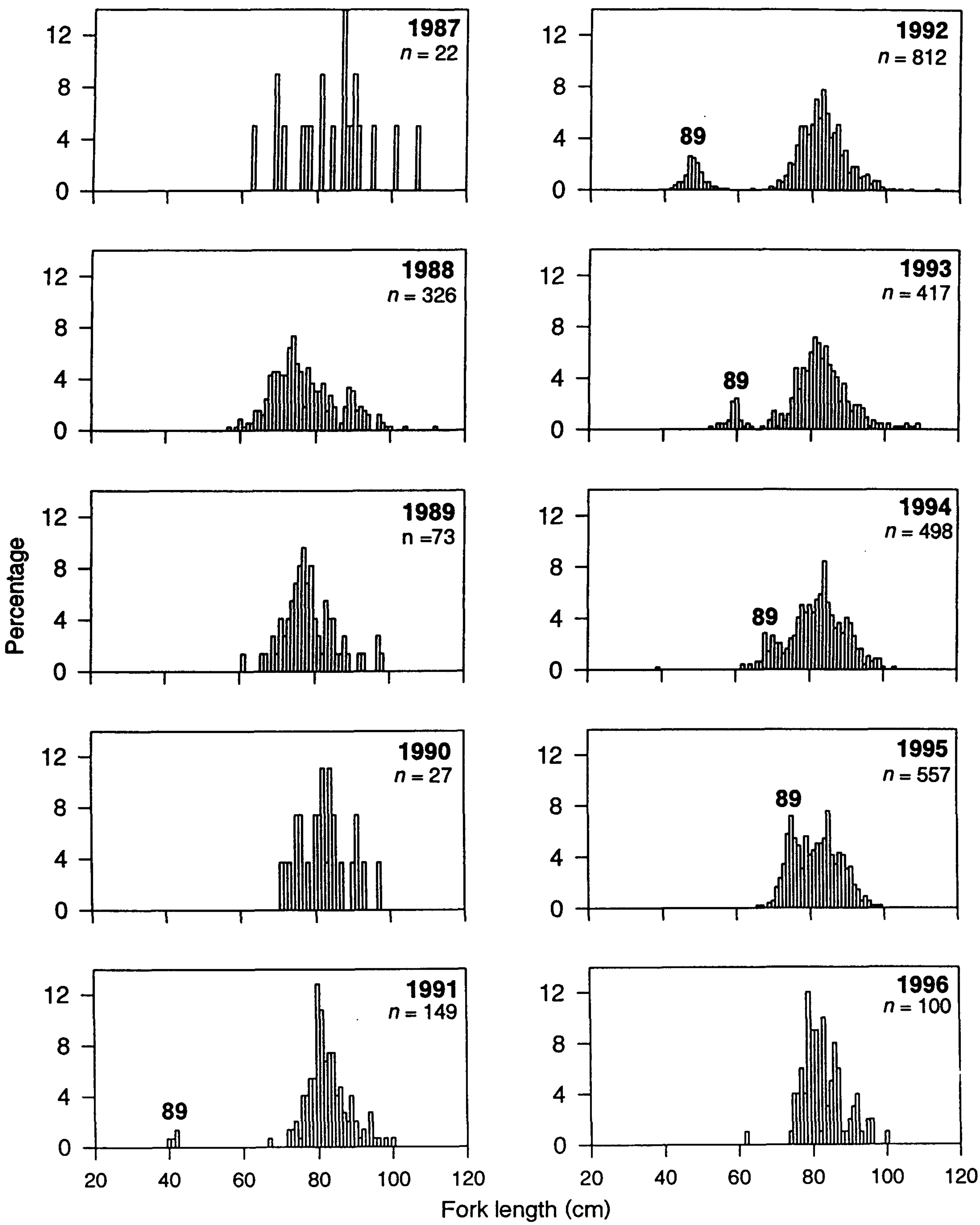


Figure 18: Length frequencies from the commercial fleet in Southland, summer/autumn, 1987 to 1996 (*n*, number of fish measured).

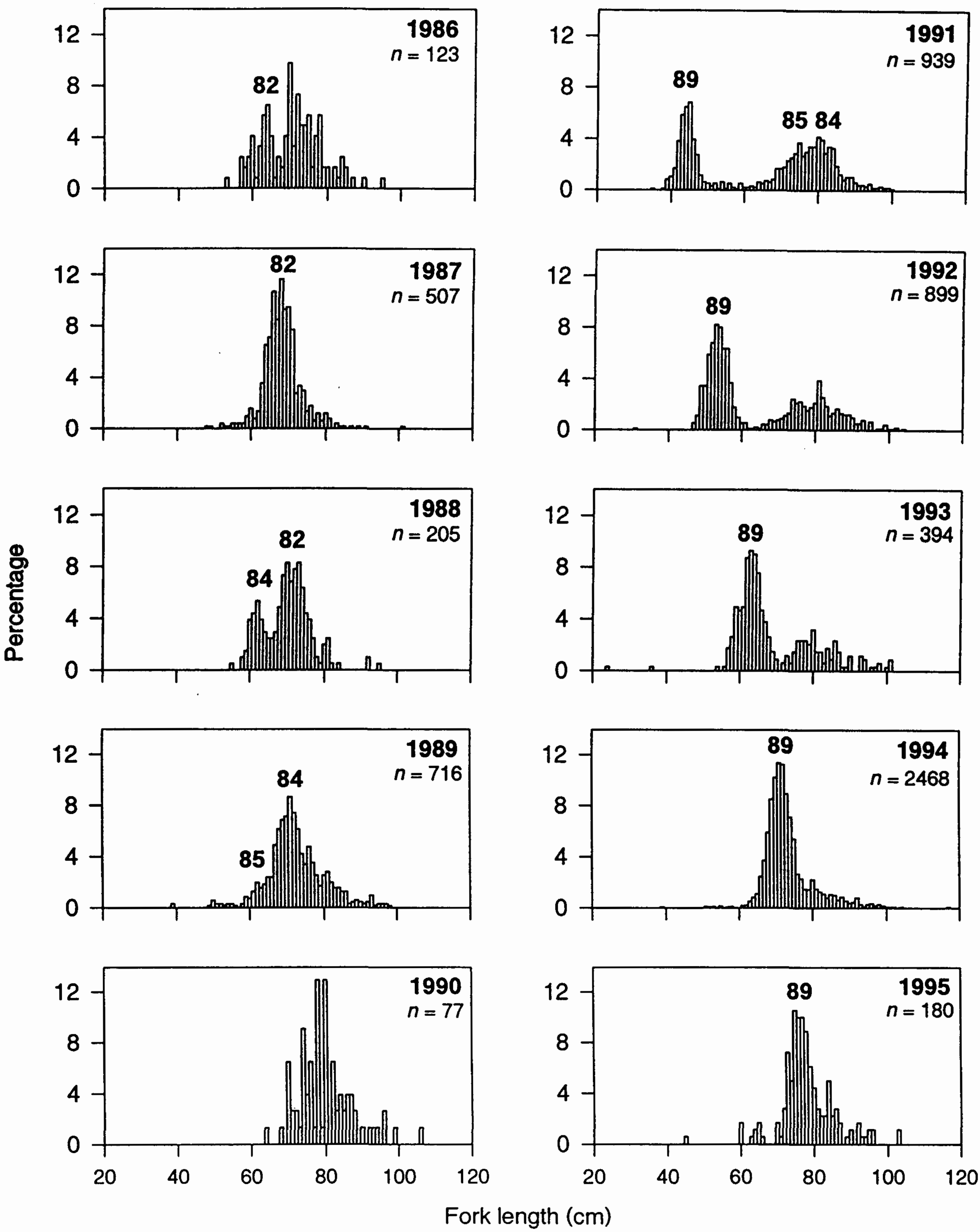


Figure 19: Length frequencies from the commercial fleet on the WCSI, winter/early spring, 1986 to 1995 (*n*, number of fish measured).

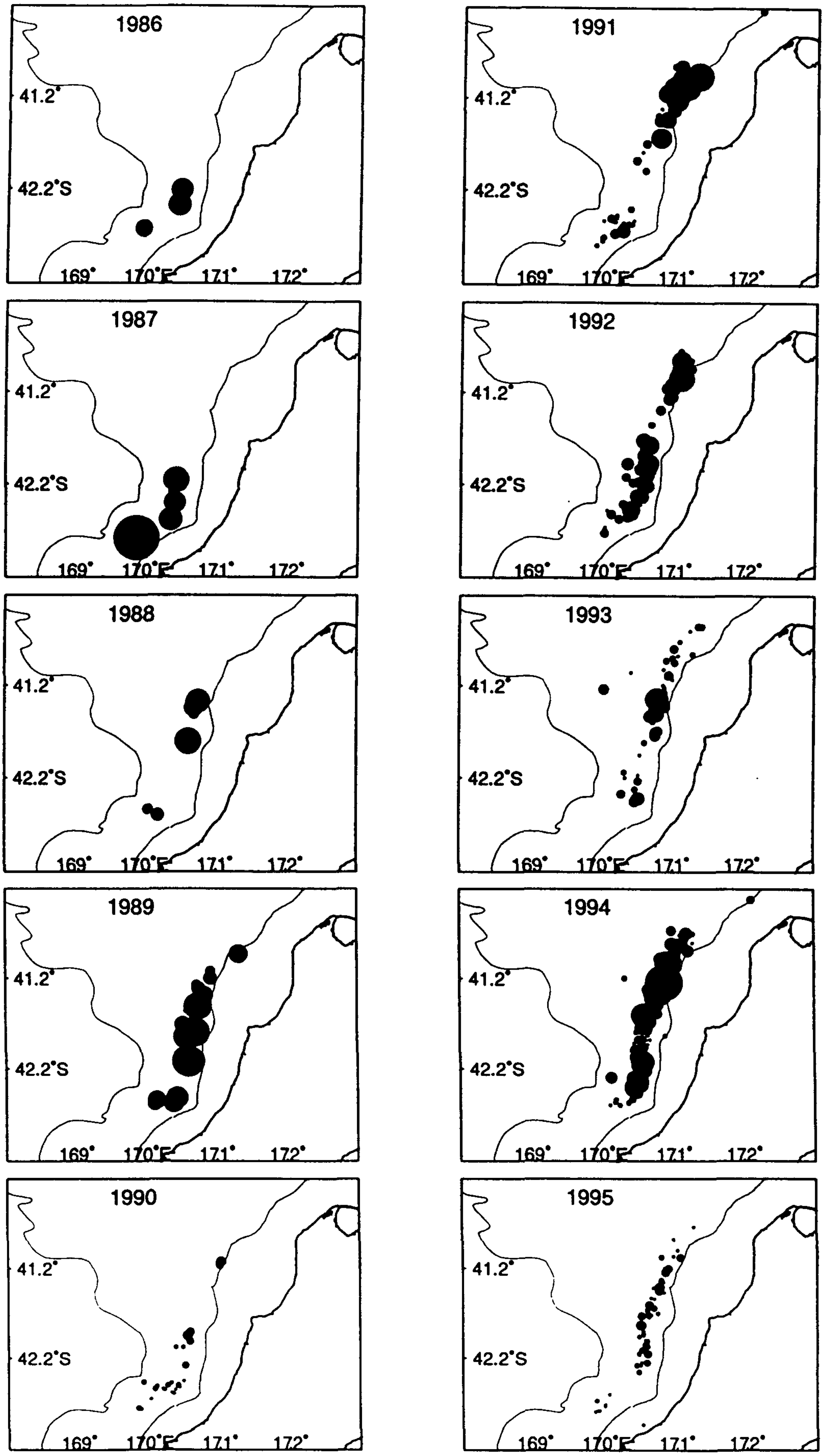


Figure 20: Location of commercial gemfish length frequencies samples given in Figures 18 to 21 (maximum circle size = 197 fish in 1987).

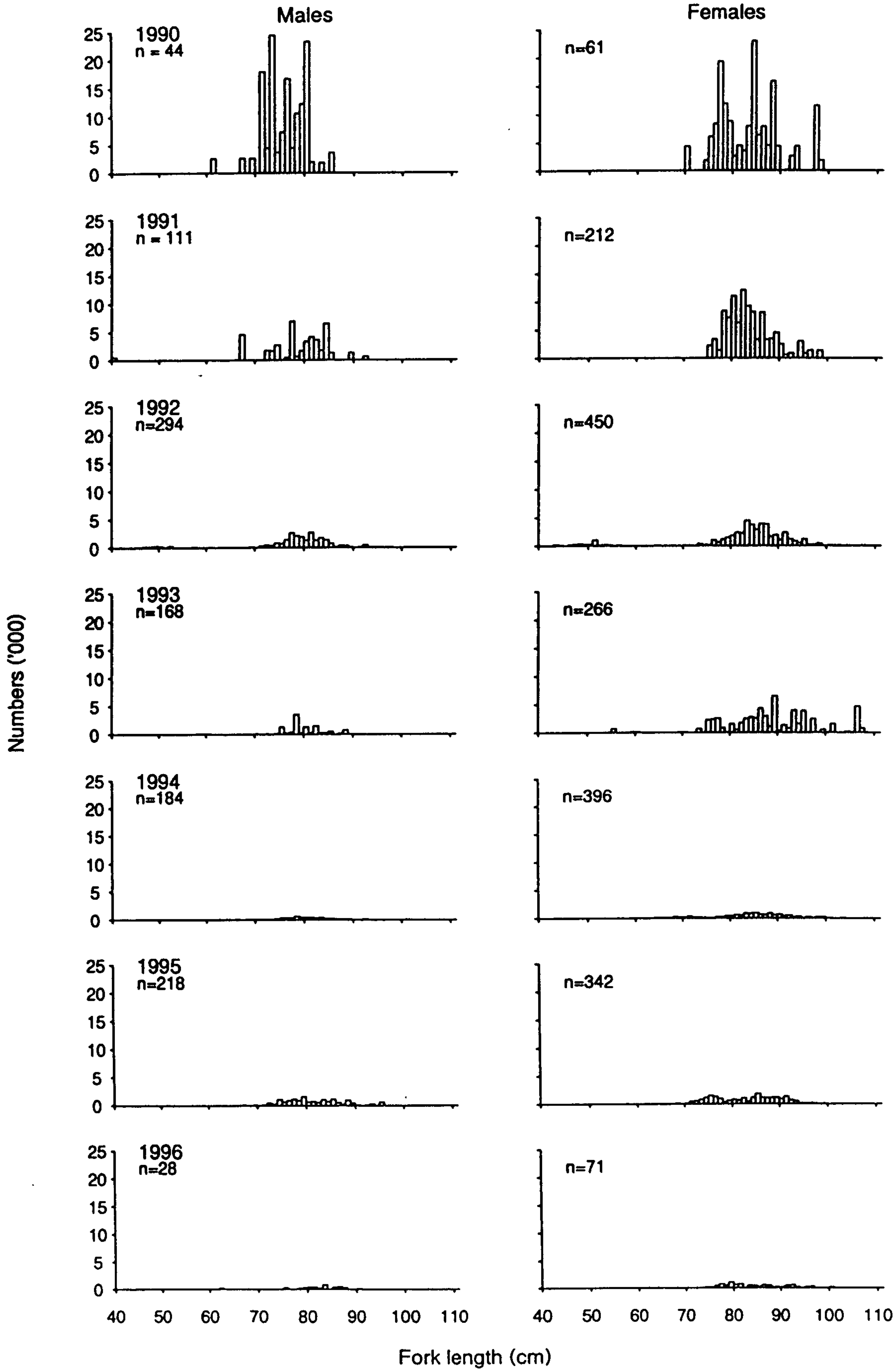


Figure 21: Scaled length frequencies, by sex, from the commercial fleet in SKI 3, 1990 to 1996 (*n*, number of fish measured).

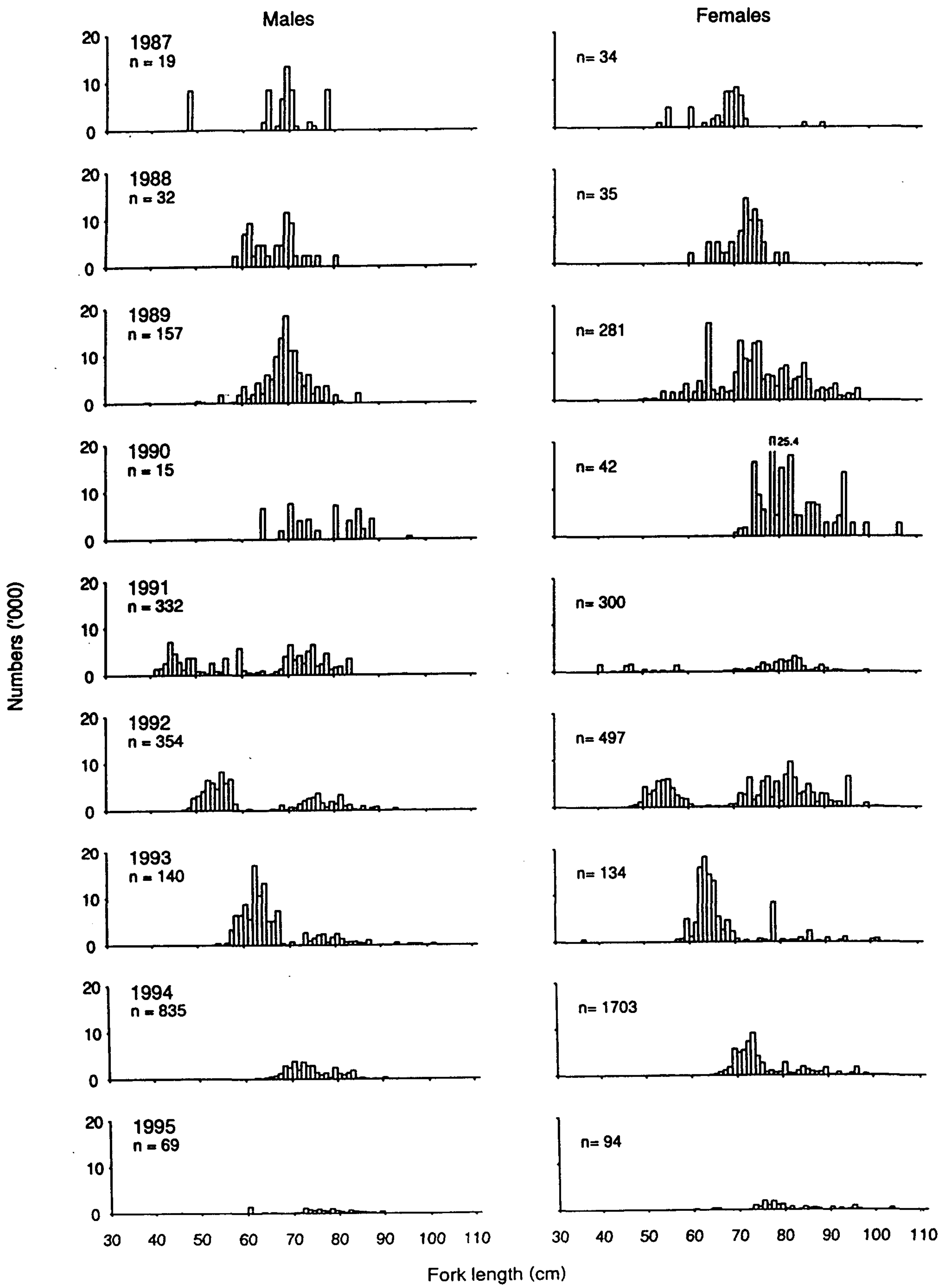


Figure 22: Scaled length frequencies, by sex, from the commercial fleet in SKI 7, 1987 to 1995.

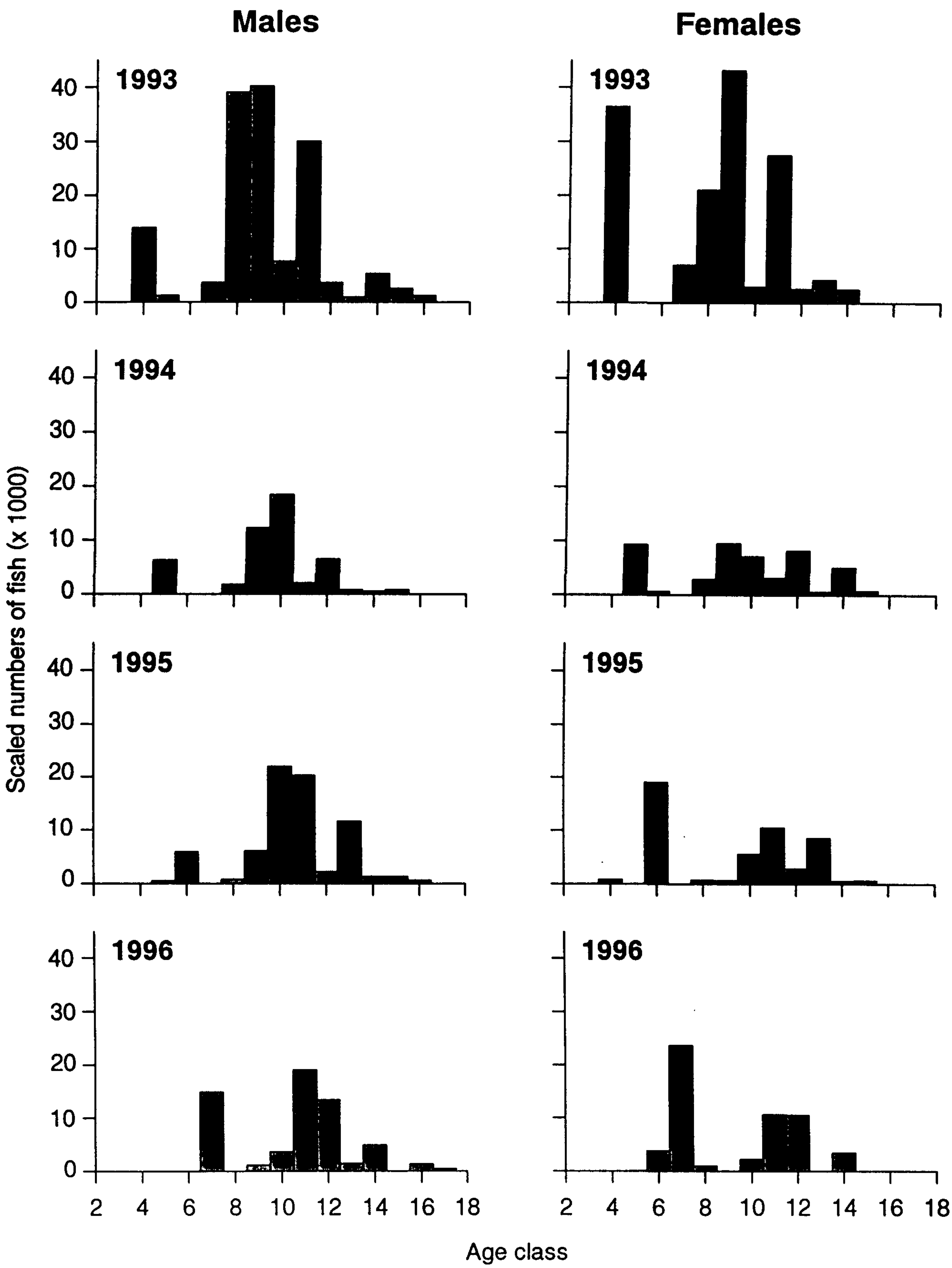


Figure 23: Gemfish scaled age frequency from Southland trawl surveys by *Tangaroa*, 1993 to 1996.

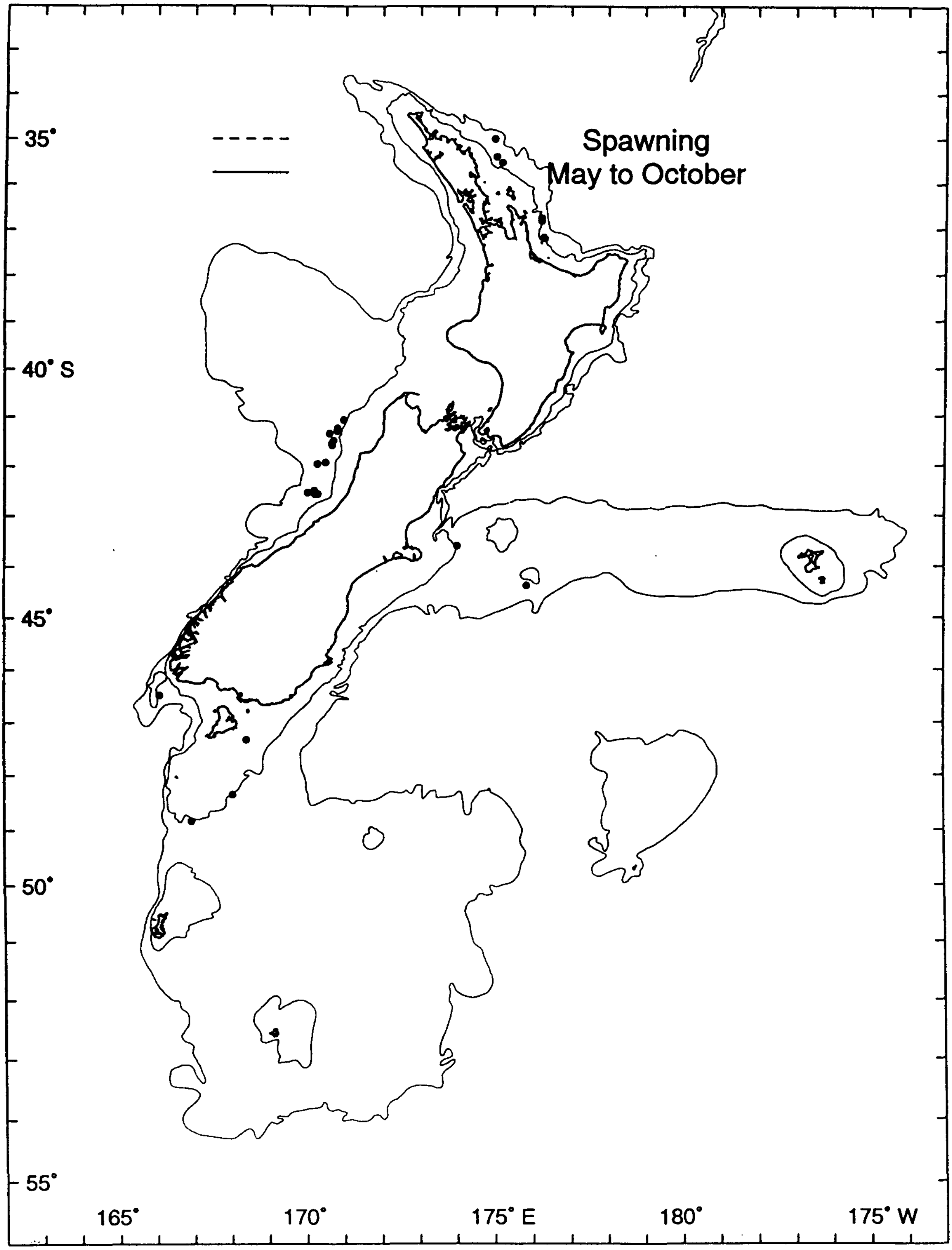


Figure 24: Records of running ripe female gemfish from research and scientific observer databases.

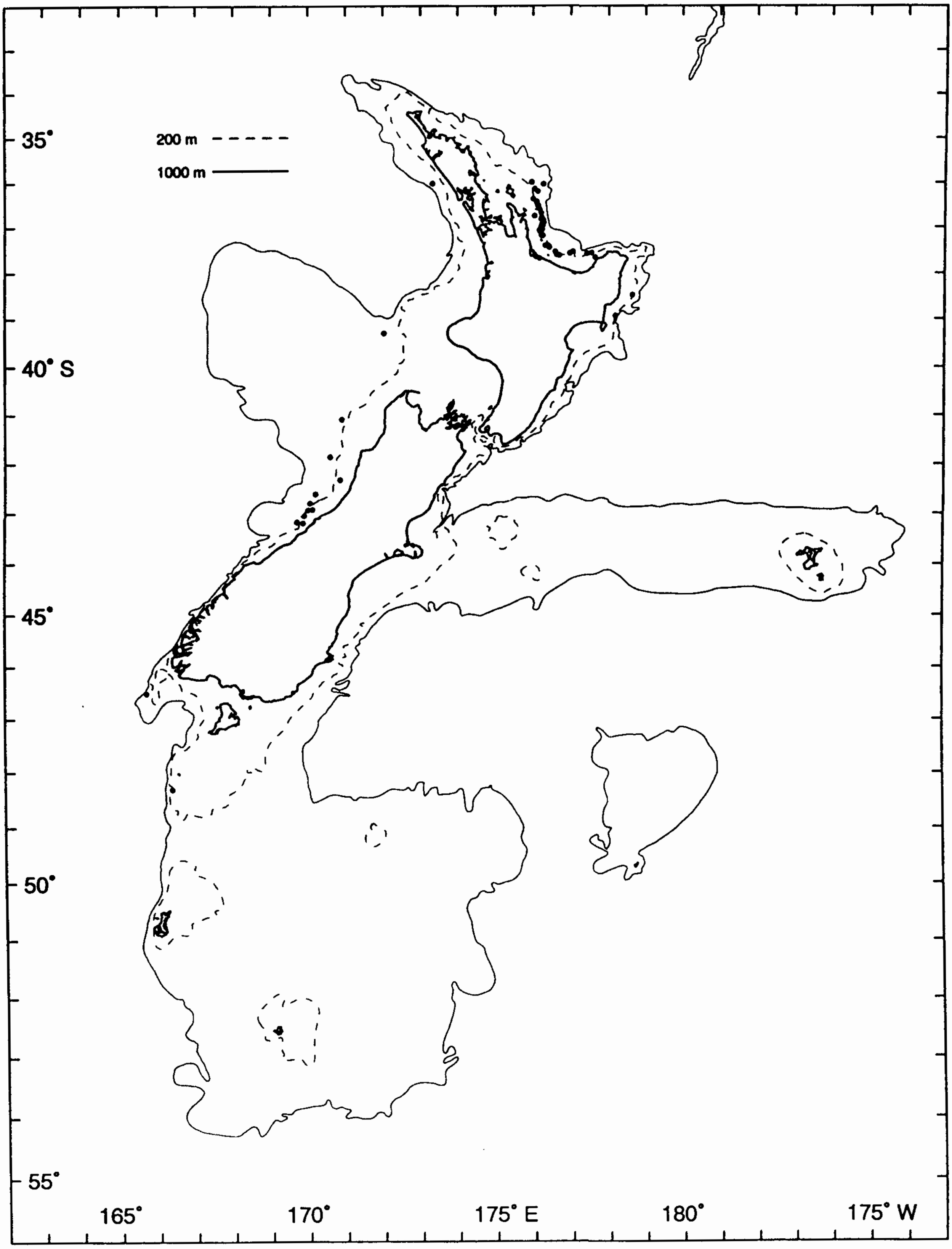
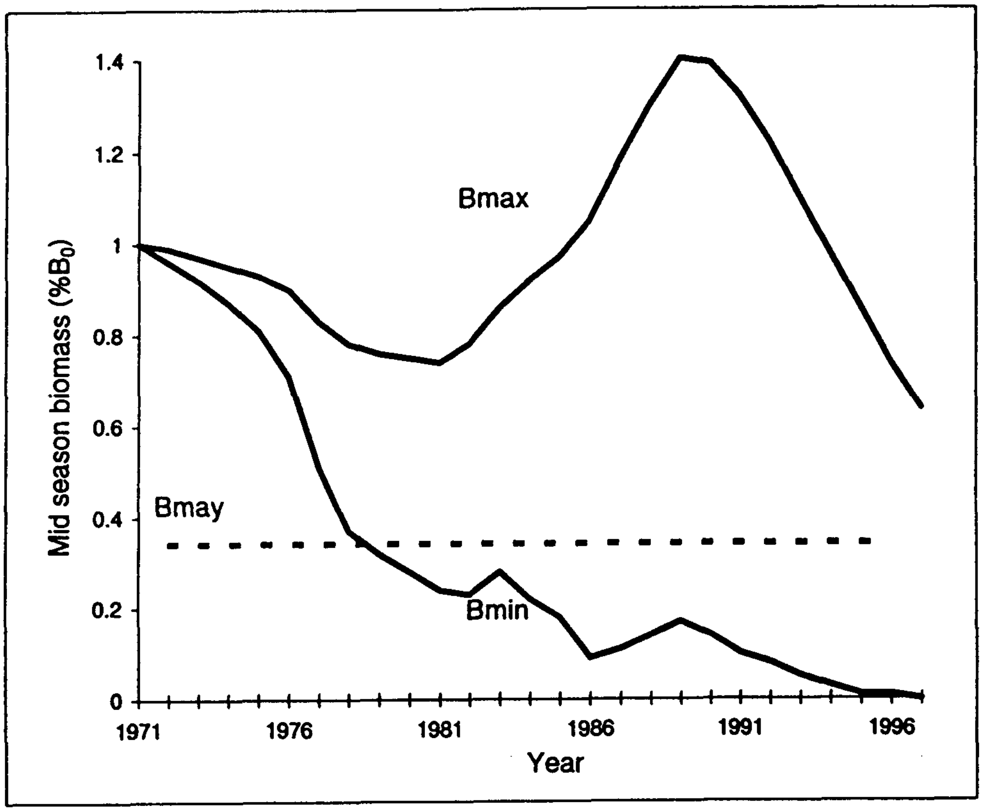


Figure 25: Distribution of juvenile gemfish less than 30 cm long.



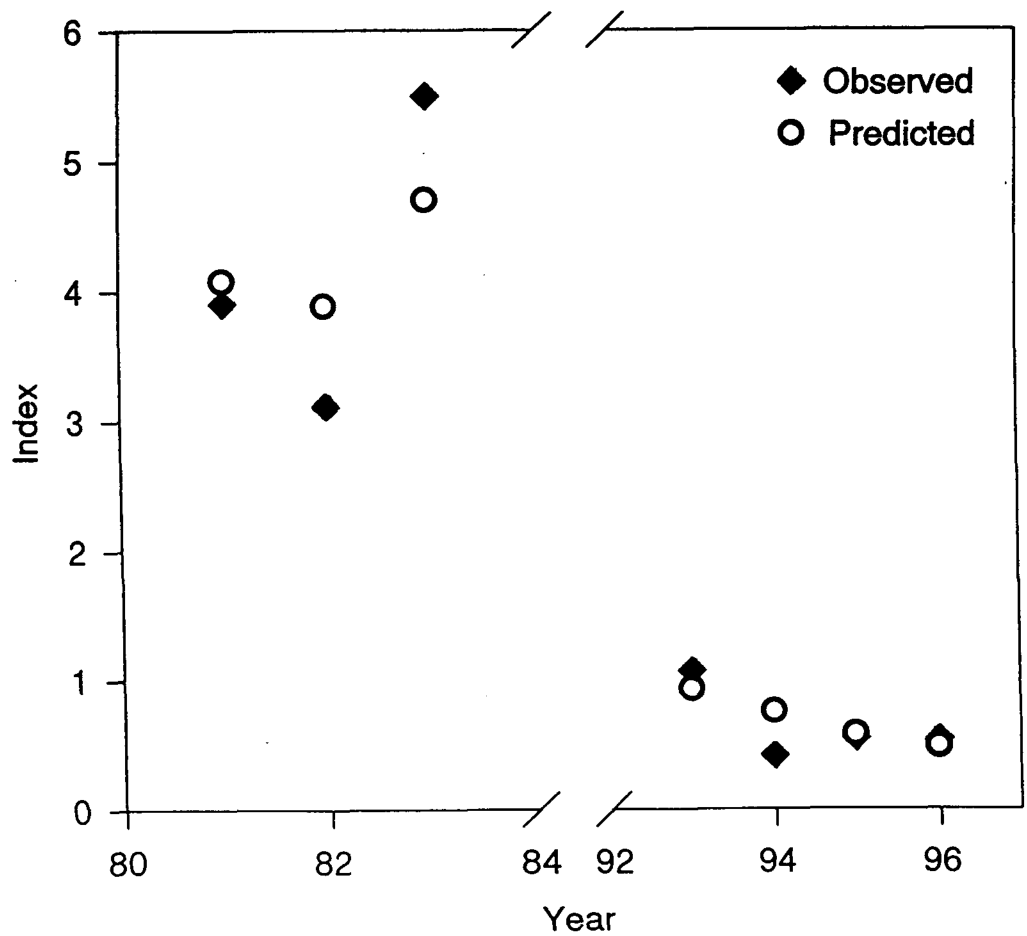


Figure 26 (Above): Trajectories for minimum (B^{min}) and maximum (B^{max}) estimates of biomass for the base case stock assessments for SKI 3+7.

Figure 27 (Below): Model fit of the predicted to the observed trawl survey abundance indices.