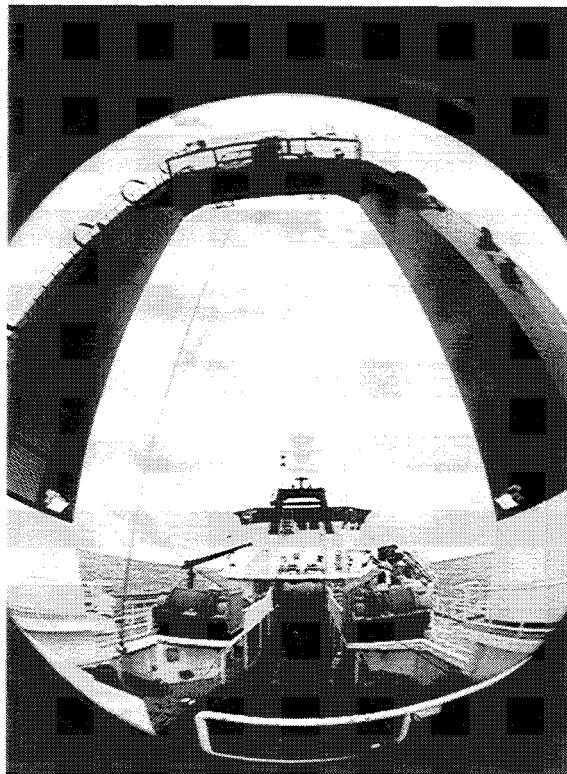


# **A review of hoki and middle depth trawl surveys of the Chatham Rise, January 1992–2001**

**M. E. Livingston  
B. Bull  
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## Abstract

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Changes in the abundance, length, and catch distribution of the 31 most abundant species caught in bottom trawl surveys of the Chatham Rise were analysed. Within the 10 annual surveys carried out in January 1992 to 2001, survey design and gear deployment remained consistent, but the estimated relative abundance of several species changed significantly. Species that declined in abundance included hoki, hake, and giant stargazer. Those that increased in abundance included lookdown dory, sea perch, spiny dogfish, javelinfish, lemon sole, and dark ghost shark. There was no obvious link between changes in relative abundance and changes in environmental variables, although sea temperatures were slightly higher in more recent surveys. Increased fishing activity on the Chatham Rise, targeting hoki in particular, may have contributed to the decline in abundance of some species caught as bycatch. There was a 3-fold drop in hoki abundance (relative abundance estimate) from a peak of 185 000 t in 1993 to 60 000 t in 2001 and a drop in the proportion of hoki from about 60% of the total fish abundance 1992–97, to less than 30% in 2001. This reduction may have provided the opportunity for other species to move into niches previously occupied by hoki, or to capitalise on increased food availability. However, the increase in relative abundance of some species has not fully compensated for the decline in hoki abundance, because the total abundance of fish dropped within the time series.

The catch distribution of most species within the survey area remained similar over time, except spiny dogfish which increased its depth range and geographical range. Plots of sea surface and bottom temperatures showed that temperatures in the survey area varied as much as 5 °C from year to year, and the location of the Sub-Tropical Front (STF, defined as the zone of greatest longitudinal thermal gradient) was centred nearer to the crest of the Chatham Rise in some years, while in others it lay along the southern slope. Although the catch distributions of some species such as oreo and alfonsino are associated with particular water masses either side of the STF, changes in catch distribution relative to yearly changes in location of the STF along the Chatham Rise were not evident.

The mean length of many species, particularly those with variable recruitment, such as hoki, varied from year to year. However, only ling showed a clear trend, declining in mean length within the time series. Hake, ribaldo, giant stargazer, and silver warehou were the only species actively spawning during the January surveys.

An analysis of hoki catch rate with time of day showed a substantial effect: catch rates were lowest at the beginning and end of the day. Catchability remained low for about 4 hours after sunrise then rose to a peak before noon. This was followed by a dip in early afternoon and a second peak in the late afternoon before declining towards sunset. This effect was most pronounced for 1+ hoki. The diurnal changes in catchability were found to have little effect on the trends in hoki biomass. We recommend that sampling times remain unchanged for consistency in the time series.

## Introduction

The Chatham Rise is a prominent ridge lying east of Banks Peninsula, rising up from depths of 3000 m to about 50 m at its western end and above sea level at the Chatham Islands near the eastern end (Figure 1). Because of its physical prominence, and the convergence of southward and northward currents along the east coast of New Zealand, the Chatham Rise bounds Sub-Tropical and Sub-Antarctic water masses. The Sub-Tropical Front (STF), a zone of mixing between the two water masses, is permanently located more or less along the crest

of the ridge, dipping south of the Chatham Islands shelf at the eastern end (Heath 1985, Bradford-Grieve et al. 1991, Carter et al. 1998). The Chatham Rise is an area of relatively high productivity (Sullivan 1993), with hotspots of high chlorophyll density which relate to localised upwelling, turbulence, and mixing along the STF, as well as enhanced geostrophic flow (Bradford & Roberts 1978, Bradford-Grieve et al. 1991, McClatchie et al. 1997). A wide range of commercial and other fish species are found on the Chatham Rise, and it is the principal nursery ground for hoki, which are currently the basis of New Zealand's largest commercial fishery (Ballara et al. 2000). Fishing on hoki and several other species in the depth range surveyed has been sustained in the area for some years, and catches have increased within the time frame of the surveys (Table 1) due to a move towards year-round fishing by the hoki fleet.

The Chatham Rise has supported several important upper slope (200–800 m) fisheries, including hoki, hake, ling, and silver warehou, since offshore exploration of New Zealand waters was initiated by foreign fleets in the mid 1970s. After declaration of New Zealand's 200 mile Exclusive Economic Zone (EEZ) in 1978, a series of trawl surveys to investigate the biomass of these species on the Chatham Rise was carried out in 1979 (Kerstan & Sahrhage 1980), 1983 (Fenaughty & Uozumi 1989, Hatanaka et al. 1989), 1986 (Livingston et al. 1991), and 1989 (Livingston & Schofield 1995). As exploratory surveys, the data collected were invaluable, but their use for monitoring fish stocks was relatively limited because of the wide range of vessels and gear used. With the acquisition of a large, purpose-built research vessel, R.V. *Tangaroa*, in 1991, time series of trawl surveys using the same vessel and gear became possible. Beginning in January 1992, trawl surveys of the Chatham Rise have been carried out annually with *Tangaroa* to determine the relative biomass of hoki and other upper slope fish species that are found at depths of 200 to 800 m. As well as the publication of survey results for each year, the relative abundance of a range of species was compared for the first five surveys in the series (Livingston & Schofield 1996). A comprehensive study to describe the community structure of the Chatham Rise using data from surveys between 1992 and 1999 has also been completed (Bull et al. 2001). Other work on the Chatham Rise *Tangaroa* time series includes a preliminary analysis of acoustic signals and the variation in hoki catch rate with time of trawling (Bull 2000).

In the present report, we update the trends in relative biomass described by Bull et al. (2001) to include a wider range of species as well as data collected in January 2000 and 2001. We also present the catch distribution and size structure of the populations of important species in surveys from 1992 to 2000. Age class data for hoki, hake, and ling are presented, and variations in hoki catchability with time of day is analysed.

## Objectives

The Ministry of Fisheries research programme to monitor the relative abundance of hoki and other middle depth species on the Chatham Rise using trawl surveys has been underway since 1992, and has resulted in a range of reports documenting the results of individual trawl surveys (Table 2). In 1999, the Ministry requested a review of survey results within the time series with the specific objective "To review trends in the relative abundance, distribution, and size frequency of hoki and other middle depth species on the Chatham Rise, January 1992–2000.

Since the project was initiated, a tenth survey in January 2001 has been completed. Our analyses therefore included the tenth survey in all data sets except length and catch rate distributions. Variation in hoki catch with time of day was also investigated as a variation to the original proposal.

## Methods

### Survey design, vessel, and gear

Trawl surveys have been carried out annually during January from 1992 to 2001 using RV *Tangaroa* (Table 2). The survey area covered depths of 200–800 m on the Chatham Rise, with the exception of the survey in 2000 which included a new stratum to investigate hake distribution in depths of 800–1000 m on the northeast side of the Chatham Rise. Tows were allocated randomly in each survey according to a stratified random design (Francis 1989), with strata divided by 200 m depth intervals and longitude boundaries (Figure 2). The total number of stations and stratification within the survey area have undergone several changes within the time series. The surveys have been optimised in recent years to obtain a target coefficient of variation for 2 year-old hoki of 20%. Weight has also been given to strata where hake are caught, and in some years hake strata have been substratified to improve sampling of the population. Rationalisation of survey resources resulted in a drop in station numbers in 1996, which has since risen again slightly (Table 3). The area of the 200–800 m depth range is the same throughout the series, apart from minor adjustments as the accuracy of the depth contours improved.

The gear and trawling methods in each survey followed the specifications of Hurst et al. (1992). Tows were nominally 3 nautical miles (n. mile) long at 3.5 knots. All tows were carried out in daylight hours. An eight-panel, winged otter-trawl with a 58.8 m groundrope and 45 m headrope was used in all surveys (see Chatterton & Hanchet 1994). The codend mesh size was 60 mm. Distance between the doors was recorded every 5 min using Scanmar sensors and averaged for the tow. Tow positions were recorded by GPS and depths by the vessel's depth sounder.

### Abundance estimation

The data used covers only 200–800 m depths, and excludes the deeper stratum surveyed in 2000 (Stevens et al. 2001). Catch rates were calculated by the swept-area method of Francis (1989), using doorspread  $\times$  distance towed as the effective area swept. Biomass was estimated by the standard stratified random survey estimator:

$$\text{abundance} = \sum_{\text{strata}} (\text{mean catch rate} \times \text{stratum area}).$$

Coefficients of variation (c.v.) were calculated:

$$\text{c.v. (\%)} = S_B / B \times 100$$

where  $S_B$  is the standard error of the biomass,  $B$ .

Analyses were restricted to the 31 most abundant species which together made up 98% of the mean total catch.

Hoki 1+, 2+, and 3++ age groups were included separately in the analyses in this paper because their distributions are known to differ with depth (e.g., Bagley & Livingston 2000) and there were sufficient length frequency data collected to distinguish them. The 1+ and 2+ age classes usually form clear, separable length modes (e.g., Bagley & Livingston 2000). Fish in older age classes overlap in length and cannot be easily separated, so these were grouped

into a third plus group (3++). Appropriate length mode cutoffs were assessed for surveys individually and are given below to the nearest centimetre:

Cohort	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1+	27–47	27–46	31–46	31–44	31–44	31–43	31–45	31–47	31–46	31–46
2+	48–55	47–56	47–57	45–57	45–54	44–56	46–53	48–52	47–61	47–61
3++	56+	57+	58+	58+	55+	57+	54+	53+	62+	62+

## Trends in abundance

Trends in the abundance of individual species and hoki age classes were assessed from the survey biomass estimates 1992–2001, using the methodology developed by Bull et al. (2001). The slope of each biomass series was calculated by least squares linear regression. The statistical significance of the estimated slope was tested against the null hypothesis of no change in abundance using a parametric bootstrap hypothesis test. For each species, the estimated slope was compared with the distribution of slopes under the null hypothesis, as estimated by randomising biomass estimates 3000 times with independent lognormal distributions and c.v.s as given in the survey reports and recalculating slopes for each randomisation. Trends were considered significant if  $p < 0.01$  and borderline significant if  $0.01 < p < 0.05$ . Only species for which biomass was consistently estimated in the survey reports were included.

## Catch rate and length frequency distributions

Catch rate plots show the localised distribution of individual species and any changes in geographic distribution and, to some extent, the relative abundance of the fish within the survey area. The catch rate distributions for the 21 most abundant species standardised as  $\text{kg.km}^{-2}$  per tow were plotted scaled to the largest catch for each species within the time series. Hoki catch rates were plotted as 1+, 2+, and 3++ (the plus group including all fish 3 years or older) for each survey from 1992 to 2000. Hake and ling catch rates were presented as immature and mature catches.

Length frequency histograms from each survey are presented to show changes in the length structure of 15 species caught and measured during surveys from 1992 to 2000. The population numbers of fish for each 1 cm length interval were calculated with the Trawlsurvey Analysis Program, version 3.2 (Vignaux 1994). Within the program, length data from each station are multiplied by the proportion of the catch sampled to obtain station length frequencies which are then multiplied by the ratio of the area swept to the stratum area to obtain stratum length frequencies. These are then summed across strata to obtain a total survey length frequency. As a check, biomass estimates calculated from catch rate data are compared with the biomass calculated from the length frequency data using a length–weight relationship. Slight differences arising from the two methods were eliminated by adjusting the length frequency biomass to match the catch rate biomass.

We also present summaries of the gonad stages of females observed during surveys, and the sex ratios where possible. Hoki, hake, and ling otoliths collected during the trawl survey time series have been routinely aged using the break and burn method of Horn & Sullivan (1996). Population estimates of numbers of fish at age were calculated by applying proportions at age in each 1 cm length class to the length frequency.

## Environmental conditions

During the surveys, swell height, cloud cover, and wind speed and direction are recorded at every station. These data were summarised for indications of variability in conditions that may have affected fish catchability within the time series. Also presented is the approximate location of the STF, estimated by superimposing satellite sea surface temperature data from NIWA's climate database on to plots of sea surface and bottom temperature obtained at trawl stations during the surveys. A plot of deviations from the mean Southern Oscillation Index for summer (December, January, February) is also given.

## Commercial catch

The commercial effort within the depth and area covered by the trawl survey was summarised from Total Catch Effort Processing Returns (TCEPRs, Ministry of Fisheries Database).

## Diurnal variation in hoki catchability

Sunset and sunrise times were calculated for each day of each survey from the date, latitude, and longitude. Each day was divided into eight time periods of equal length (about 2 hours) extending from sunrise to sunset. Each tow was allocated to the time period containing its midpoint. Four tows had pre-sunrise midpoints and were allocated to time period 1 (the first post-dawn period). One tow had a post-sunset midpoint and was allocated to time period 8. For a typical day, sunrise was at about 0440, sunset about 1950, and the eight time periods, and the numbers of stations by time period were approximately as given in Table 4.

The effects of time periods on catchability were assessed as follows:

- for all hoki
- for age groups: 1+, 2+, 3++ separately
- by 200 m depth zones (200–400, 400–600, 600–800 m) for 3++ fish only.

Generalised linear modelling (GLM, McCullagh & Nelder 1989) was used to assess diurnal variation in catchability. Time effects on catchability were included by using 'time period' as a categorical variable. Stratum and survey effects were incorporated using a categorical variable 'survey/stratum' that took a different value for each stratum of each survey. This method estimates time effects within each stratum of each survey, and pools the results across strata and surveys: direct comparisons were not made between distinct strata or between years. The same stratification – that of the 1998–99 survey – was used for every survey. Strata with no non-zero catches were excluded. The numbers of stations by time period and survey are given in Table 4: there were 1168 stations.

The GLM model was hence:

catch rate  $\sim$  independent random (mean =  $\exp(\beta_{\text{survey/stratum}} + \beta_{\text{time period}})$ , c.v. constant)

Time period effects were expressed on the linear scale, relative to time period 1, with 95% confidence intervals. Survey/stratum effects were discarded. To assess the effect of outliers on the results, each analysis was repeated excluding stations with catch rates over 5000 kg.km<sup>-2</sup> (37 stations).

The effects of low catch rates at the start and end of the day on hoki biomass estimates were investigated. Biomasses of 1+, 2+, 3++, and all hoki were recalculated excluding stations in time periods 1, 2, and 8. Coefficients of variation were not calculated because some strata had only one station in time periods 3–7 and a few strata in the more recent surveys had no stations in time periods 3–7. For these surveys, both biomass estimates were calculated excluding these strata, and scaled up to the entire survey area by multiplying by the ratio of biomass in all strata: biomass excluding these strata with all stations included. In the 2000 survey, some strata were subdivided and marked as "hake strata". For this analysis, these strata were not subdivided.

## Results

### Survey comparability

The surveys have used the same vessel, gear, and gear deployment procedure throughout the time series. Further, randomised tows within the same depth strata have always been allocated, and all surveys have followed a two-phase design.

Although the number of stations has changed from a maximum of 194 in 1993 to a minimum of 96 in 1996, the proportion of stations allocated to each depth zone has altered little (Table 5). The station allocation to deeper strata has been consistently less than in shallow strata, and does not reflect the relative area of the depth zones (Table 5). The optimisation process towards 2+ hoki reflects the shallower distribution of young hoki, and the higher c.v.s associated with younger cohorts.

There is little evidence of change in gear parameters within the survey time series (Table 6). Mean doorspread in each depth zone was lower in 2000 (Table 6).

### Trends in abundance

The relative abundance of each species by survey and the mean proportional abundance are given in Table 7. Hoki were far more abundant than any other species (mean 52% of total), although within the time series abundance has dropped from about 60% of the total relative abundance to 30% in 2001 (Table 8). The results of the trend analysis of individual species in the survey area are shown in Table 9 and Figures 3–5. Estimated abundance of all hoki (all ages combined) and 3++ hoki (hoki age 3 years and over) declined significantly within the survey period ( $p < 0.0001$ ). The 1+ and 2+ cohorts were highly variable, because they represented single age classes (see below), although 2+ hoki showed a slight but statistically significant increase. Hake, giant stargazer, slender mackerel, and arrow squid also declined in abundance, and spiny dogfish, sea perch, lookdown dory, javelinfish, lemon sole, school shark, and dark ghostshark all increased significantly in abundance (Table 9). Although changes in abundance for the remaining species were not significant, the power of the regression analysis would have been low for highly variable species, such as some rattail species, and species that are surveyed only at the margins of their normal depth range, such as tarakihi, alfonsino, barracouta, and oreo species (see mean c.v.s in Table 7). Biomass estimates for many of the species shown were low in the 1995 survey (Figures 3–5), suggesting a change in catchability of these species in that year.

The relative decline in abundance of hoki has contributed to a decline in total abundance, but the combined relative abundance of other species has changed little within the time series (Figure 6).

## **Trends in catch rate, length frequency and age distributions**

The catch rate distributions (Figures 7a–7y) and length frequency plots (Figures 8–22) are summarised by species in alphabetical order below. The numbers at age for hoki, hake, and ling are described in Figures 23–25. Mean lengths are tabulated in Appendix 1, and length weight relationships determined during surveys are given in Appendix 2.

### **Alfonsino**

Catches of alfonsino were patchy, which is to be expected for a schooling, semi-pelagic species (Figure 7a). The largest catches were usually taken east of 180°. Catches to the west occurred only on the northern slopes of the Rise. Length distributions for males and females closely overlapped (Figures 8a, 8b), and there was a tendency for the larger fish to be caught in deeper water than the smaller fish. The surveys mostly caught juvenile alfonsino, although larger fish were caught in 1992 and 1993.

### **Black oreo**

Black oreo catches were consistently associated with deep water on the south side of the Rise. Most of the catches have been west of 180°, but they are occasionally caught as far to the east as the Chatham Islands (Figure 7b). The size of fish caught has remained relatively similar within the time series, peaking around 27–28 cm total length most of the time (Figures 9a, 9b). Little difference between male and female size distributions was evident.

### **Big-eye rattail**

Big-eye rattail were widely distributed in the western and southern middle depth (400–600 m) zone of the Rise (Figure 7c). Catch rates during 1995 to 1998 were considerably less than in 1992–94, but increased again in recent surveys. There are no size distribution data for this species.

### **Dark ghost shark**

Dark ghost shark were distributed mainly across the shallow crest of the Rise, with some larger catches around Veryan Bank on the south side (Figure 7d). Like big-eye rattail, catches were lowest in 1995–98. Females were considerably larger than males (Figures 10a, 10b). There appears to have been a slight decrease in the length of the dominant modal peak of males over time.

### **Giant stargazer**

Giant stargazer were distributed in two parts of the Rise. The largest catches were centred around Mernoo Bank at the western end, and the smallest were centered around the Chatham Islands (Figure 7e). Catches of giant stargazer were lowest 1995–98, increasing only slightly in 1999 and 2000. Males are considerably smaller than females (Figures 11a, 11b). The bimodal distribution among females became less obvious within the time series, with fewer fish of 45–55 cm being caught. The size distributions of males did not alter much.

## Hake

Small hake (less than 76 cm total length) were generally distributed further west than larger hake (76 cm or more total length) that were mostly caught near or on a spawning area located northwest of the Chatham Islands (Figures 7f, 7g). The overall distribution of hake appears to be towards the northern rather than the southern slopes of the Rise. The catch rate of mature size hake shows a decline within the time series (Figure 7g). Male and female hake have different size distributions, and there is evidence of some recruitment during 1993 that can be tracked through to 1998 as these fish increased in size (Figures 12a, 12b).

Hake have undergone variations in recruitment within the time series, with a pulse of new recruits aged 2 in 1993 that can be tracked right through the time series (Figures 25a, 25b).

## Hoki

The decline in abundance of the hoki 3++ group (fish aged 3 years and over) is evident in the catch rate distribution. Although the larger number of stations in 1992 and 1993 emphasises the apparent decline, the size of the circles is clearly smaller as time progressed (Figure 7h). The greatest decline initially occurred at the western end of the Rise, and then in the central part of the Rise from 1997 on, until by 2000, the largest catches were at the eastern end of the Rise (Figure 7h). Zero catches of the 3++ hoki occurred consistently on the crest of the Rise just east of Mernoo Bank (around 177° E). When abundant, hoki were widespread, but the highest catches tended to be in the western half of the Rise (Figure 7h). The decline in the number of hoki over about 60 cm in the length frequency histograms reflects the trends in catch rates observed for the plus group (Figures 13a, 13b).

The catch rates of 2+ hoki were greatest in 1994, 1995, 1997, 1999, and 2000, with the catch rate in other years extremely low (Figure 7i). This is a result of different year class strengths among juvenile hoki, and can be seen clearly in the length frequency histograms for both sexes (Figures 13a, 13b). The catch distributions of 2+ hoki suggest two centres of distribution: one around Mernoo Bank at the western end, and the other around the Chatham Islands at the eastern end (Figure 7i). The distribution of 1+ hoki, however, shows only western strata as important (Figure 7j). High catch rates for 1+ hoki did not always precede the years of high catch rates for 2+ hoki. Further, the catch rates for 1+ hoki were considerably lower than for 2+ hoki (Figures 7i, 7j). This is because 1+ hoki are largely pelagic, are less vulnerable to the trawl because of their size, and may not have yet arrived on the Chatham Rise nursery grounds from their natal spawning sites.

The length frequency histograms show that male hoki do not grow as large as females (Figures 13a, 13b) and indicate that growth rate varied considerably between year classes. For example, the 1994 year class at 1+ in 1996 (modal peak 32–44 cm) had achieved the least growth within the time series, with a mean length of about 36 cm at age 1+, and 50 cm by age 2+ (Figures 13a, 13b). The following year class spawned in 1995 at age 1+ in 1997 had already achieved 31 cm of growth, and by 1998 had almost caught up to the slow growing 1994 year class, showing as a small bump on the left slope of the 50–60 cm modal peak. The mean length of hoki by survey has declined slightly within the time series due to the lower numbers of larger fish (Appendix 1).

Recruitment of both males and females has been variable (Figures 23a, 23b). When the series began in 1992, hoki 3 and 4 years old (1987 and 1988 year classes) dominated the population. These two year classes remain evident in the plots until they reach the plus group of hoki 10 years or older (Figures 23a, 23b). Other year classes that were abundant as 1 year olds (e.g., 1991 year class in 1993 survey, 1994 year class in the 1996 survey) seem to disappear from the plots at an earlier age.

## **Javelinfish**

The distribution and catch rate of javelinfish has altered considerably within the time series. From 1992 to 1994, quite high catch rates were taken along the western Rise, just south of Mernoo Bank, in the deeper strata north of Mernoo Bank, and in a stratum to the east, just north of the Chatham Islands (Figure 7k). From 1995 to 1998, catch rates were considerably lower, but increased again slightly in 1999 and 2000. There are no length data available for this species.

## **Ling**

Ling catch rates were generally even and widespread throughout the survey area (Figures 7l, 7m). Among fish over 68 cm total length, one catch near the Chatham Islands in 1999 was more than four times that of any other station catch within the time series. The denser number of black circles towards the western end of the Rise in 1992 to 1994 surveys reflects the higher number of stations rather than any real change in distribution. Large catches of juvenile ling (under 68 cm total length) were typically associated with the Mernoo and Veryan Banks (Figure 7l). Although large male fish were evident in length frequencies from all years, the abundance of smaller males was greatest in the early and later part of the series (Figure 14a). The pattern was less clear for female ling, although more young fish were present in 1999 and 2000 (Figure 14b).

It seems that the Chatham Rise surveys do not catch many ling less than 3 years old (Figures 24a, 24b). A pulse of strong recruitment spawned in 1995 and 1996 is evident in surveys 1999 to 2001, and has contributed to a decline in mean length of ling within the time frame of the survey series (Appendix 1).

## **Lookdown dory**

Lookdown dory were widely and evenly distributed across the Rise throughout most of the surveys (Figure 7n). The catch rate of lookdown dory is quite low compared with other species in the survey, but there appears to be an eastward movement of the higher catches within the time series (Figure 7n). Length frequency distributions show that females grow larger than males, and that the adult modes of both sexes dominate throughout the time series. Modal peaks of young fish can be tracked entering the fishery (e.g., 1998 to 2000) in some years (Figures 15a, 15b).

## **Orange perch**

Orange perch appeared to have two main centres of distribution, one associated with the Reserve Bank to the east of Mernoo Bank, and the other to the west, and occasionally east, of the Chatham Islands (Figure 7o). This distribution reflects the shallow depth range of this species. The largest catch was taken in 1997, and catch rates were higher in 1999. There are no length data for this species.

## **Pale ghost shark**

Pale ghost sharks were widespread throughout the deeper strata of the survey area, although the highest catch rates were consistently on the south side of the Rise (Figure 7p). Length frequency distributions have changed little within the time series (Figures 16a, 16b). Females grow larger than males.

## **Ribaldo**

Ribaldo were mostly caught in deeper strata, particularly on the northwest slopes of the Rise (Figure 7q). Catch rates have remained reasonably stable, although the higher number of deep stations in early surveys emphasises the catch rates in surveys from 1992 to 1994. Nevertheless, there has been a drop in the maximum catch rate over time. Length data show that, again, females grow larger than males (Figures 17a, 17b). There is no evidence of change in the mean size of ribaldo over time.

## **Sea perch**

Catch rates of sea perch were relatively high in 1992–94, dropped during 1995–96, and have risen again in more recent surveys (Figure 7r). Their distribution has remained consistent however, in strata that lie just east of Mernoo Bank (178° E). Length data suggest that the age specific catchability of this species may have contributed to the drop in 1995–96, as the year class evident at 17–18 cm in 1994 is absent for 2 years and then reappears in 1997 (Figures 18a, 18b). Further, the numbers of sea perch caught have been increasing steadily since 1995.

## **Shovelnose dogfish**

Shovelnose dogfish are a deepwater species found only in the deeper strata of the survey area. Most of the fish have consistently occurred on the northern slopes of the Rise (Figure 7s). There are no length data for this species.

## **Silver dory**

Catches of silver dory occurred in shallow depths (under 400 m), mostly around the Chatham Islands, and in the early surveys in small quantities at Mernoo Bank (Figure 7t). There are no length data for this species.

## **Silver warehou**

The catch distribution of silver warehou was mostly associated with Mernoo Bank, Veryan Bank, Matheson Bank, and the Chatham Islands (Figure 7u). Particularly poor catch rates occurred in 1995–97. The length data suggest that this may have been partly due to a lack of new recruits in the survey area (Figures 19a, 19b). Silver warehou are semi-pelagic and feed on salps in the water column. It is likely that their distribution is linked to salp distribution.

## **Smooth oreo**

Smooth oreo were caught only in deep strata (600–800 m) of the Rise (Figure 7v). The largest catches in the series were taken southwest of the Chatham Islands in 1997 and 1998. These catches were mostly smaller smooth oreo of 24–31 cm (Figures 20a, 20b).

## **Spiky oreo**

Spiky oreo is also a deepwater species with a northern slope distribution (Figure 7w). There are no length data for this species.

## **Spiny dogfish**

In the early surveys, the catch distribution of spiny dogfish was largely restricted to shallow stations (under 200 m) on Mernoo Bank, the ridge that extends eastwards along the Reserve Bank, and Matheson Bank (Figure 7x). Very few fish were caught at the Chatham Islands in 1992 and 1993. However, from 1994, catches were increasingly taken at the Chatham Islands; catch rates increased, and spiny dogfish were also caught in deeper stations (down to 400 m). Length data show that male spiny dogfish caught are not only smaller than the females, but are present in far lower numbers. Numbers of both sexes appear to have increased in all length classes within the time series (Figures 21a, 21b).

## **White warehou**

The catch rates of white warehou were lower than those of silver warehou, but their distribution across the Rise was slightly wider (Figure 7y). Like silver warehou, they are a semi-pelagic species, with high c.v.s. The length data suggest some variation in recruitment within the time series, with some years catching fish up to 65 cm, but in other years most of the fish are less than 40 cm (Figures 22a, 22b).

## **Gonad development and sex ratios**

Most species examined were either immature or resting (Table 10). Alfonsino, hake, ribaldo, giant stargazer, and silver warehou were the only fish with actively spawning females. Barracouta, lookdown dory, and ling showed some indication of ripening (Table 10). Overall, the proportions of males were slightly less than 50% for dark ghost shark, giant stargazer, hake, hoki, and lookdown dory (Table 11). Alfonsino, black oreo, and ling were about even, and pale ghost shark, ribaldo, sea perch, silver warehou, smooth oreo, and white warehou males tended to be just over 50% of the population. The most extreme was spiny dogfish, which was almost entirely dominated by females (Table 11). No obvious trends within the time series were seen.

## **Environmental variability**

Areas of rapid isotherm change from 7 to 10 °C on the seabed are mostly associated with the south side of Mernoo Bank and the southwest side of the Chatham Islands shelf (hatched areas in Figure 26). In 1999, the Mernoo Bank gradient was further south over deeper water just south of the Veryan Bank (Figure 26). The surface isotherms obtained from individual tow data during each survey suggest a particularly cold year in 1994, and a particularly warm

year in 1999 (Figure 26). Surface and bottom minima and maxima (see Table 6) show the same pattern. Mean sea surface temperatures obtained by satellite also suggest that 1999 was a particularly warm year, but indicate that 1993 was slightly cooler than 1994 (Figure 27). SSTs appear to trend upwards within the time series (Figure 26). The mean Southern Oscillation Index (SOI) broadly correlates with the SST data in that negative SOIs occurred mostly in years that had lower SSTs, and it can be seen that the SOI has become more positive in recent years (Figure 27). The discrepancy between surface temperatures recorded by *Tangaroa* and satellite SSTs is probably due to non-calibration of the temperature sensors on *Tangaroa* in the early part of the time series. Cloud cover can lead to misleading results on satellite SSTs if the ocean is obscured for extensive periods. There appears to have been a higher occurrence of extensive cloud cover during the 1993 survey than in 1994 (Figure 28), but during the 1996 survey cloud cover was even greater, yet SSTs were second highest in 1996 (Figure 27), so this explanation for the discrepancy is unlikely.

Sea conditions, as represented by swell height, were rougher in 1997 and 1998 (Figure 29) with higher wind speeds also evident in those years (Figure 30). Wind directions in 1993 and 1998 were predominantly from the west (southwest and northwest), whereas in other years they were noticeably more frequently from the east (north and south), particularly in 1996 and 1999 (Figure 31). 1996 and 1999 were both surveys with relatively warm SSTs (Figure 27), and 1993 and 1998 were cooler (Figure 27). The winds that occurred during the survey would have strongly influenced the SSTs recorded, and may account for the slight discrepancies between survey observations and satellite SSTs averaged from December to February.

## **Commercial catch**

The commercial catch effort during the time series has risen considerably, largely as a result of increased targeting of hoki on the Chatham Rise. The catch of hoki as a proportion of the total catch from the main target fisheries (200–800) m on the Chatham Rise is disproportionately high at 88% (Table 12) when compared with its proportional abundance in the trawl survey time series. The number of commercial tows on the shallow fisheries has varied little within the period examined (Table 13), but in middle depth fisheries, the number of tows has increased seven-fold (Table 14). The distribution of commercial tows in the 1999–2000 fishing year (Figure 32) is typical of the distribution of fishing effort that has occurred in recent years. On the Chatham Rise, most of the effort occurs in the western portion of the area, with almost no hoki target fishing north or east of the Chatham Islands. As the fishery developed on the Chatham Rise in the early 1990s, the commercial catch comprised mostly fish over 60 cm total length, but since 1994, a significant component of the catch has been smaller hoki, mostly less than 4 years old (Figures 33a, 33b).

## **Diurnal variation in the catchability of hoki**

The time of day was found to have a substantial effect on hoki catchability (Figure 34). Catchability was lowest in time periods 1, 2, and 8, i.e., at the start and end of daylight. Catchability remained low for about 4 hours after sunrise, then rose throughout the morning to a peak before noon, followed by a dip in the afternoon, a smaller peak in the late afternoon, and a decline towards sunset. Estimated catchability was 1.6 times higher during the noon peak than in the 2 hours following sunrise.

The results for individual age groups were similar (Figure 35). The results for the 2+ and 3++ age groups were almost indistinguishable, and very similar to the results for all hoki combined. However, the 1+ age group showed a much stronger time effect. The estimated catchability of 1+ hoki at the mid-morning peak time was about four times the catchability at

the start of the day. The overall shape of the time effect was similar to those of older fish, but the morning and afternoon peaks and the midday trough were each about 2 hours earlier for 1+ fish. (Of the total 1+ catch, 45% was taken in the morning peak time periods 3 and 4, which included only 22% of the total number of tows.)

Time effects were significance-tested using the standard GLM chi-squared test on residual deviance (McCullagh & Nelder 1989) and were found to be highly significant ( $p < 0.0001$ ), for the 1+, 2+, and 3++ age groups and for all ages combined.

There were 37 tows with hoki catch rates over  $5000 \text{ kg.km}^{-2}$ , of which 9, 5, and 13 had catch rates over  $5000 \text{ kg.km}^{-2}$  for the 1+, 2+, and 3++ age groups respectively. The exclusion of these tows had very little effect on the results, as shown by the similarity of the dotted and continuous lines in Figures 34 and 35. We conclude that the apparent time effects are produced by consistent changes in catchability rather than occasional outliers. This result is further strengthened by very similar results for non-overlapping subsets of the data, i.e.. age groups and depth ranges, which indicates a consistent trend over the entire dataset.

The GLM results for each depth range are shown in Figure 36. The results were very similar over time periods 4–8, especially considering the amount of variability involved, which is relatively high since the data were divided between the three subsets. The results for the morning time periods 1–3 differed between depth ranges, but no clear trend was visible.

The hoki biomass trajectories including and excluding time periods 1, 2, and 8 are shown in Figure 37. The effect of removing time periods 1, 2, and 8 from biomass estimation was to increase the estimated hoki biomasses for seven out of nine surveys. Increases ranged up to 22%, with an average change of +10%. The overall shape of the biomass trajectory changed very little, which is perhaps surprising considering over 40% of the stations were removed.

The increases in estimated biomass after excluding time periods 1, 2, and 8, were driven by the 3++ age group, which represented the largest proportion of the population (except in the 2000 survey) and showed the most consistent effect. The biomass trajectories for the 1+, 2+, and 3++ age groups are shown in Figure 38. The 3++ age group showed an increase in eight out of nine surveys, with increases ranging up to 28% and an average change of +14%. The results for the 2+ group were similar, with an increase in six out of nine surveys, increases ranging up to 40% and an average change of +10%. The 1+ group shows less clear results, with an increase in only five surveys and an average change of +4%. This result is surprising considering the strong effect of time on catchability shown for 1+ fish. The apparent cause is that 1+ biomass estimates are determined largely by a few tows with high catch rates, and hence their high variability obscures the time effect.

## **Discussion**

### **Trends in relative abundance**

The comparison of trawl surveys on the Chatham Rise carried out in January 1992–2000 has shown that although there is variability in the data, statistically significant trends are evident within the time series. Some species, in particular hoki, hake, and giant stargazer, decreased in relative abundance while others, in particular lookdown dory, sea perch, spiny dogfish, javelinfish, lemon sole, and dark ghost shark, increased in abundance. Apart from hoki, which had the highest biomass (mean proportion 52%), not all species showing a change were necessarily in the highest biomass bracket. For example, lemon sole formed a very low proportion of the overall biomass but showed a dramatic change within the time series.

Similarly, sea perch, Peruvian jack mackerel, and school shark form low proportions of the overall biomass (see Table 7).

A study using the trawl survey data from 1992 to 1999 to characterise the fish community structure of the Chatham Rise found little change in overall fish density (mean total catch rate) and diversity over the survey period (Bull et al. 2001). The same study found that the preferred bottom depth of most of the common species did not change between the first and second halves of the survey series. The extra data points from the surveys in 2000 and 2001 used in the study presented here improved the statistical significance of the trends presented by Bull et al. (2001) for hoki, hake, giant stargazer (declining abundance), and spiny dogfish, lookdown dory, and sea perch (increasing abundance).

The mean length of most species changed little within the time series – the exceptions being ling and to a lesser extent, hoki, which both decreased. Sex ratios appeared to be relatively stable. Changes in the catch distribution were evident among some species showing significant trends in biomass. The decline in hoki, hake, and giant stargazer abundance was most marked in the western and southern strata of the survey area, and mostly among larger fish. Among species with increased abundance, the spread was not always even. For example, lookdown dory catches increased in the central and eastern part of the Rise in recent surveys, but catch rates in strata west and immediately south of Mernoo Bank appeared to be lower. Sea perch distribution has remained fairly constant, while that of spiny dogfish has increased throughout the survey area, and spread into deeper strata.

The effectiveness of time series in measuring changes in the relative abundance of different species depends on minimising sampling error between and within surveys and maximising comparability between surveys. The Chatham Rise trawl survey time series has undergone some changes in the number of stations, particularly in the 600–800 m strata, and some changes in species optimisation, but the total area surveyed, the gear used, and the deployment method have all been constant. Maximum comparability and minimum error between surveys has therefore been achieved. The observed changes in relative abundance are therefore likely to be real. We must consider, however, whether or not the observed changes reflect changes in absolute abundance of a given species. Changes in environment (e.g., temperature) affect the catchability of fish and the decline in abundance of one species may result in the spread of another into the area, but not necessarily an increase in its absolute abundance.

In a study to evaluate catchability assumptions in New Zealand stock assessments, Francis et al. (2001) explored relative biomass estimates from a selected number of species within the Chatham Rise trawl survey series, and showed that the survey catchability in 1995 was significantly below average. However, no link to trends in environmental variables was established.

An increase in spiny dogfish abundance has been observed in some New Zealand waters, as well as on the Chatham Rise (Hanchet & Ingerson 1997). Dogfish and other elasmobranch abundance have been found to increase as the abundance of commercial species declines elsewhere, for example, in Australian waters (Hobday et al. 1996, Graham et al. in press) and Georges Bank off New England (Gabriel 1992). The increases observed on the Chatham Rise may therefore reflect a New Zealand-wide increase in spiny dogfish abundance, possibly in response to increased fishing activity throughout the zone.

Within the time series, the biggest change in relative abundance was that of hoki. The estimated abundance of 3++ hoki declined four-fold from its peak at 186 000 t in 1993 to its lowest at about 60 000 t in 2000. Recruitment has been variable with relatively strong year classes apparent as 1+ fish in 1993, 1996, and 1999 (corresponding to 1991, 1994, and 1997 year classes). The 1+ fish were not always a good indicator of abundance as 2+ fish (see

Figures 23a, 23b), although a plot of hoki 2+ against 1+ abundance shows that it is a good indicator of year class abundance. Further, some year classes declined in abundance far more rapidly than others for example, the 1994 year class which appeared to be very strong as 1+ and 2+ fish declined rapidly in subsequent surveys. There was also a decline in the relative proportion of hoki biomass out of the total biomass of fish from about 60% in the early part of the series, to 30% in surveys in 2000 and 2001. Within the time series, target fishing for hoki increased almost seven-fold (see Table 1), and it is clear from commercial length data that smaller hoki (2+ and 3+) were frequently targeted as well as larger fish (Ballara et al. 2000). Although there is evidence that sea temperatures were warmer in the more recent surveys possibly influencing hoki catchability, it seems likely that the observed change in hoki abundance on the Chatham Rise is related to both removals due to fishing effort and lower recruitment in recent years.

The cause of changes in abundance of other species is more difficult to assess. Many of the species commonly caught in the trawl surveys are also caught as bycatch in the commercial fisheries for hoki in the area (Annala et al. 2001). One might therefore expect the biomass for many of these species to decline in response to the increased targeting of hoki, as occurs with hake and giant stargazer. However, increases in relative abundance were observed for several species, in particular lookdown dory, spiny dogfish, sea perch, and javelinfish. It is unclear whether there has been a change in the catchability of these species (e.g., movement into areas previously occupied by hoki; changes in distribution due to increased sea temperatures) or a real change in abundance (e.g., more favourable environmental conditions, higher food availability in the absence of hoki). For fast growing species, such as lemon sole, a real increase in biomass may have occurred within the time frame of the surveys and commercial exploitation, but for slow growing species, such as sea perch, the observed trends are more likely to be a consequence of changes in catchability. There is evidence of higher recruitment of lookdown dory and sea perch since 1998 and of spiny dogfish since 1997. It has been hypothesised that the removal of cod as a dominant predator species through fishing on Georges Bank resulted in a change in the fish community structure (Hall 1998), and if fishing remains at a high level on the Chatham Rise, changes to community structure and biomass will continue. However, environmental change will also affect recruitment, and separation of the two effects will not be straightforward.

At present, the Chatham Rise trawl surveys provide the only consistent way to monitor changes in the relative abundance of a wide range of fish species that are caught commercially in the area. Although the mechanisms driving changes in relative abundance of different species are unproven, it is clear that changes are occurring, and it is important to monitor them. An increase in the information collected during each survey may also improve understanding of how and why such changes are occurring and enable us to develop clear hypotheses regarding the ecosystem on the Chatham Rise, and the effects of changes on fisheries in the area.

### **Diurnal catchability of hoki**

The diurnal variation in hoki catchability observed in the Chatham Rise data does not appear to have biased the estimation of abundance. Similar trends in abundance would have been observed, even if the surveys were restricted to the times of day when hoki catchability is high. To prevent bias from occurring in the future, it is important that consistency be maintained in the times of day at which trawling is carried out.

## Conclusions

- Hoki dominated the catch, forming about 50–60% of the total biomass from 1992 to 1997, thereafter dropping to 30% by 2001.
- Relative abundance indices of hoki, hake, and giant stargazer showed a significant downward trend within the time series of trawl surveys explored.
- Relative abundance indices of lookdown dory, javelinfish, sea perch, and spiny dogfish showed a significant upward trend within the time series of trawl surveys explored.
- The abundance of several species was particularly low in 1995.
- The highest sea temperature observed within the time series was in 1999, and the lowest was in 1994.
- The Southern Oscillation Index was generally negative in the first part of the time series, and has been average or positive in more recent years.
- Mean sea surface temperatures have risen within the time series.
- Annual changes in fish distribution did not alter in relation to annual changes in the location of the Sub-Tropical Front.
- The mean length of most species did not show a trend. Ling, showed a marked decrease in mean size, and to a lesser extent, hoki also showed a decline.
- Fish exploitation on the Chatham Rise, in particular the hoki catch, has increased seven-fold within the period of the study.
- The cause of trends in relative abundance is unclear.
- The catchability of hoki was lower at the start and at the end of the day, but this had little effect on biomass trends.

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**Table 1: Catch histories (t) of important fisheries on the Chatham Rise.  
(Data source: Annala et al. 2001.)**

Fishing Year	Hoki	Hake*	Orange roughy	Oreo
1989–90	13 000	977	31 400	16 100
1990–91	12 500	991	20 600	16 700
1991–92	46 000	2 454	16 400	17 500
1992–93	43 000	2 775	14 000	17 100
1993–94	24 000	2 898	13 500	17 400
1994–95	39 000	4 094	8 000	14 200
1995–96	50 000	4 760	7 500	14 500
1996–97	58 000	4 761	7 400	13 800
1997–98	74 000	4 763	8 000	13 300
1998–99	74 000	4 524	7 400	12 500
1999–00	57 000	4 700	7 800	12 900

\* Hake catches here may have been less, due to misreporting of catch from the west coast of the South Island.

**Table 2: Dates and documentation of *Tangaroa* trawl surveys on the Chatham Rise, January 1992–2001.**

Survey dates	Reference
28 Dec 1991–1 Feb 1992	Horn 1994a
30 Dec 1992–6 Feb 1993	Horn 1994b
2–31 Jan 1994	Schofield & Horn 1994
4–27 Jan 1995	Schofield & Livingston 1995
27 Dec 1995–14 Jan 1996	Schofield & Livingston 1996
2–24 Jan 1997	Schofield & Livingston 1997
2–24 Jan 1998	Bagley & Hurst 1998
3–26 Jan 1999	Bagley & Livingston 2000
27 Dec 1999–22 Jan 2000	Stevens et al. 2001
28 Dec 2000–25 Jan 2001	Stevens et al. 2001

**Table 3: Number of stations by stratum for trawl surveys of the Chatham Rise, January 1992–2001.**

Present stratum labels	Depth m	Area km <sup>2</sup>	Number of stations						Number of stations				
			2001	2000	1999	1998	1997	1996	Pre-96 stratum labels	1995	1994	1993	1992
1	600–800	2439	3	3	3	3	3	3	1	3	3	3	3
2a	600–800	3253	3	3	4	3	4	3	2	3	3	6	6
2b	600–800	8503	5	6					3	6	4	4	6
3	200–400	3499	3	3	4	3	3	3	21	3	6	6	3
4	600–800	11315	4	3	4	4	5	4	4 & 5	7	8	10	13
5	200–400	4078	6	5	5	4	6	5	22	10	4	4	3
6	600–800	8266	3	3	4	4	4	4	6	3	6	7	7
7	400–600	5233	8	8	9	7	7	8	7	12	11	7	9
8a	400–600	3286	3	3	6	7	7	5	8	3	5	5	7
8b	400–600	5722	5	9					9	4	4	9	7
9	200–400	5136	5	8	6	3	4	3	23	3	4	3	4
10a	400–600	2958	3	4	4	3	6	3	10	6	5	7	10
10b	400–600	3363	4	4									
11a	400–600	2966	6	6	4	4*	5	5	11	9	5	5	9
11b	400–600	2072	3	2									
11c	400–600	3342	3	7		3			25	4	5	7	0
11d	400–600	3368	6	3									
12	400–600	6578	3	3	3	3	5	4	12	7	4	6	9
13	400–600	6681	4	4	4	4	6	4	13	6	4	6	7
14	400–600	5928	3	4	3	3	5	4	14	6	5	6	8
15	400–600	5842	5	5	6	5	4	4	15	3	12	12	12
16	400–600	11522	9	8	7	9	8	7	16 & 17	7	21	24	25
17	200–400	865	3	3	3	3	3	3	24	3	3	3	3
18	200–400	4687	6	8	4	5	4	5	18	3	23	17	9
19	200–400	9012	5	5	10	4	4	8	19	3	10	25	16
20	200–400	9584	8	8	7	7	10	4	20	8	7	12	8
Total	200–800	139498	119	128	100	91	103	89		122	162	194	184

\* Strata 11a combined with 11b were labelled stratum 21 in 1998

**Table 4: Numbers of tows per time period**

Time period	Times	1992	1993	1994	1995	1996	1997	1998	1999	2000	Total
1	0440 – 0635	30	30	28	22	17	18	15	18	22	200
2	0635 – 0830	25	22	25	18	9	13	9	14	14	149
3	0830 – 1020	20	25	21	10	9	10	10	6	16	127
4	1020 – 1215	18	20	19	13	11	13	13	12	16	135
5	1215 – 1410	25	21	16	15	7	12	13	10	18	137
6	1410 – 1600	22	26	17	13	13	15	9	13	15	143
7	1600 – 1755	16	21	18	15	9	7	9	9	15	119
8	1755 – 1950	28	27	21	16	14	15	13	13	11	158
Total		184	192	165	122	89	103	91	95	127	1168

**Table 5: Summary of station distribution within 200 m depth intervals during trawl surveys of the Chatham Rise, January 1992–2001.**

Depth (m)	Area km <sup>2</sup>	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992
200–400	36 861	36	40	39	29	34	31	33	57	70	46
400–600	68 861	65	70	46	48	53	44	67	81	94	103
600–800	33 776	18	18	15	14	16	14	22	24	30	35
total	139 498	119	128	100	91	103	89	122	162	194	184
Percentage											
200–400	26	30	31	39	32	33	35	27	35	36	25
400–600	49	55	55	46	53	51	49	55	50	48	56
600–800	24	15	14	15	15	16	16	18	15	15	19

**Table 6: Minimum and maximum sea temperatures (°C), tow speed (knots), tow length (nautical miles), head-line height (HLH in m), and mean doorspread (m) in different depth zones during surveys of the Chatham Rise, January 1992–2000. (s.d. standard deviation).**

	1992	1993	1994	1995	1996	1997	1998	1999	2000
Surface temp. min	13.6	11.6	10.7	12.1	13.4	12.7	10.5	13.8	14.0
Surface temp. max	17.9	16.3	16.0	16.5	17.1	16.0	16.2	19.2	17.5
Bottom temp. min	6.6	5.4	5.2	6.0	5.6	6.6	5.4	5.7	7.2
Bottom temp. max	11.5	10.5	11.3	10.5	11.2	9.9	10.4	10.5	10.4
Mean tow speed	3.5	3.52	3.6	3.5	3.5	3.5	3.5	3.5	3.5
s.d.	0.05	0.12	0.12	0.04	0.09	0.08	0.11	0.07	0.07
Mean tow length	3.0	3.0	2.96	2.98	2.91	2.98	2.96	2.91	3.0
s.d.	nil	nil	0.2	0.19	0.26	0.15	0.2	0.26	0.22
Mean HLH 200–400	6.6	6.4	6.5	6.9	7.2	6.8	6.9	6.2	7.0
s.d.	0.4	0.5	0.5	0.5	0.4	0.3	0.3	0.25	0.3
Mean HLH 400–600	6.6	6.5	6.5	6.8	6.8	6.8	6.9	6.3	6.9
s.d.	0.4	0.3	0.4	0.5	0.4	0.3	0.3	0.3	0.3
Mean HLH 600–800	6.7	6.7	6.5	7.0	7.1	6.8	6.8	6.4	7.1
s.d.	0.4	0.39	0.3	0.4	0.3	0.4	0.3	0.31	0.3
Doorspread 200–400	116.6	121.4	114.0	114.3	114.3	118.8	115.2	114.5	111.6
s.d.	6.7	7.7	5.8	5.6	0.4	6.4	6.6	6.01	6.5
Doorspread 400–600	121.8	122.5	118.5	117.5	117.5	122.4	118.8	117.9	115.8
s.d.	5.9	7.9	4.1	5.3	0.4	5.6	7.9	4.17	5.6
Doorspread 600–800	120.7	121.7	120.5	119.3	119.3	120.8	122.5	120.4	114.1
s.d.	6.4	9.6	4.9	6.1	0.3	3.3	6.3	5.83	5.8

**Table 7: Relative abundance estimates (t in thousands) and proportion (p) of total abundance for 31 species (see Appendix 3 for scientific names) caught during trawl surveys of the Chatham Rise, January 1992–2001. (c.v. % coefficient of variation, hoki 1+, 2+ and 3++ hoki aged 1 year, 2 years and 3 years and older, p proportion of total mean biomass.)**

Species	Mean c.v.	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Mean biomass	Mean p
Hoki	9.8	120.2	185.6	145.6	120.4	152.8	157.9	86.7	109.3	71.7	60.3	121.1	0.5263
Black oreo	33.5	12.7	17.4	7.0	5.3	18.6	12.5	19.0	16.9	17.7	25.6	15.3	0.0664
Big-eyed rattail	11.6	10.8	11.6	16.8	5.1	8.8	6.9	9.4	13.6	12.1	14.0	10.9	0.0474
Ling	9.3	8.9	9.4	10.1	7.4	8.4	8.5	7.3	12.1	8.3	9.4	9.0	0.0390
Javelinfish	12.1	9.0	8.6	6.7	4.8	9.6	5.2	8.0	10.8	11.0	15.5	8.9	0.0388
Dark ghost shark	14.5	6.7	6.0	10.4	3.5	6.2	6.2	6.7	12.1	9.2	10.4	7.7	0.0337
Lookdown dory	6.8	4.8	6.4	7.7	4.5	7.5	6.6	7.0	7.4	7.7	7.7	6.7	0.0293
Spiny dogfish	13.0	2.4	2.2	3.4	2.8	5.0	9.6	5.7	8.6	8.9	9.6	5.8	0.0253
Spiky oreo	44.2	4.7	7.2	0.2	4.9	11.4	6.8	4.3	3.7	4.2	7.3	5.5	0.0238
Alfonsino	56.4	6.6	7.2	25.9	1.3	1.8	4.2	2.3	0.0	1.2	4.9	5.5	0.0241
Pale ghost shark	8.8	6.1	3.6	5.9	2.7	7.9	2.9	4.1	5.3	4.9	7.1	5.1	0.0220
Silver warehou	39.1	4.5	2.7	11.6	3.7	1.7	2.1	4.7	6.8	5.4	2.7	4.6	0.0200
Sea perch	10.4	3.1	3.1	3.9	1.5	3.0	2.8	3.4	4.8	4.8	6.3	3.7	0.0160
Shovelnose dogfish	24.5	5.1	3.8	1.9	4.2	3.8	3.7	2.8	4.1	4.4	4.2	3.8	0.0165
Hake	14.7	4.2	3.0	3.4	3.3	2.5	2.8	2.9	2.3	2.1	1.6	2.8	0.0122
Giant stargazer	13.5	2.6	2.6	2.9	1.4	3.0	2.3	1.7	1.9	2.1	1.8	2.2	0.0097
White warehou	29.4	2.2	2.9	1.6	0.7	0.5	2.3	1.0	3.1	2.4	4.3	2.1	0.0091
Oliver's rattail	24.5			2.8	0.6	1.1	1.2	1.8	1.2	1.4	3.4	1.7	0.0073
Barracouta	54.2	1.2	0.7	1.4	0.1	0.7	0.2	0.2	0.6	1.0	3.7	1.0	0.0043
Orange perch	57.1		0.8	0.3	0.3	0.5	3.9	0.5	2.7	0.8	1.2	1.2	0.0053
Oblique banded rattail	22.6		1.5	0.5	0.5	0.8	1.5	1.5	1.7	1.7	1.2	1.2	0.0053
Smooth oreo	66.7	0.5	1.0	0.8	0.1	1.1	1.5	1.9	0.4	0.0	0.9	0.8	0.0036
Arrow squid	29.0	1.2	1.0	1.0	1.3	0.9	0.9	0.2	0.8	0.3	0.5	0.8	0.0035
Red cod	40.4	0.3	0.5	0.6	0.2	0.3	0.3	0.2	1.2	3.9	0.4	0.8	0.0034
Red bait						3.5	1.6		2.1	0.8	0.1	1.6	0.0070
Peruvian mackerel	47.9	0.5	1.1	0.8	0.1	0.5	0.3	0.7	0.3	0.1	0.1	0.5	0.0020
School shark	38.4	0.1	0.2	0.2		0.4	0.2	0.2	0.3	0.9	0.3	0.3	0.0014
Tarakihi	50.9	0.3	0.2	0.2	0.1	0.4	0.2	0.1	0.1	0.2	0.2	0.2	0.0009
Ribaldo	17.0	0.5	0.4	0.7	0.4	0.5	0.3	0.5	0.4	0.4	0.8	0.5	0.0021
Lemon sole		0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0002
Hapuku	49.5	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.2	0.1	0.0004
Total		219.3	290.8	274.5	181.2	263.3	255.5	184.9	234.8	189.8	205.8	230.0	1.0000
Hoki 1+	32.8	2.8	32.9	14.6	6.6	27.6	3.2	4.5	25.6	14.4	0.4	13.3	0.0577
Hoki 2+	17.3	1.2	2.6	44.7	44.9	15.0	62.7	6.9	16.5	28.2	24.2	24.7	0.1074
Hoki 3++	9.2	93.5	143.8	86.2	69.0	106.6	92.1	75.6	67.0	29.1	35.7	79.9	0.3472

**Table 8: Proportion of relative biomass out of survey total for 31 species (see Appendix 3 for scientific names) estimated from trawl surveys of the Chatham Rise, January 1992–2001.**

Species	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Hoki	0.548	0.638	0.530	0.664	0.580	0.616	0.469	0.465	0.378	0.293
Black oreo	0.058	0.060	0.025	0.029	0.071	0.049	0.103	0.072	0.093	0.124
Ling	0.041	0.032	0.037	0.041	0.032	0.033	0.040	0.052	0.044	0.045
Silver warehou	0.020	0.009	0.042	0.021	0.006	0.008	0.025	0.029	0.029	0.013
Spiky oreo	0.021	0.025	0.001	0.027	0.043	0.026	0.023	0.016	0.022	0.035
Hake	0.019	0.010	0.012	0.018	0.009	0.011	0.016	0.010	0.011	0.008
Alfonsino	0.030	0.025	0.094	0.007	0.007	0.016	0.012	0.000	0.006	0.024
Smooth oreo	0.002	0.003	0.003	0.001	0.004	0.006	0.010	0.002	0.000	0.004
Giant stargazer	0.012	0.009	0.010	0.008	0.012	0.009	0.009	0.008	0.011	0.009
Peruvian mackerel	0.002	0.004	0.003	0.000	0.002	0.001	0.004	0.001	0.001	0.001
Arrow squid	0.006	0.004	0.004	0.007	0.003	0.004	0.001	0.003	0.002	0.002
School shark	0.000	0.001	0.001	nil	0.001	0.001	0.001	0.001	0.005	0.001
Barracouta	0.005	0.002	0.005	0.000	0.003	0.001	0.001	0.003	0.005	0.018
Red cod	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.005	0.020	0.002
Lemon sole	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000
Tarakihi	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001
Hapuku	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Dark ghost shark	0.031	0.020	0.038	0.019	0.023	0.024	0.036	0.052	0.048	0.050
Pale ghost shark	0.028	0.012	0.021	0.015	0.030	0.011	0.022	0.022	0.026	0.034
Lookdown dory	0.022	0.022	0.028	0.025	0.029	0.026	0.038	0.032	0.040	0.037
Sea perch	0.014	0.011	0.014	0.008	0.011	0.011	0.019	0.021	0.025	0.031
Spiny dogfish	0.011	0.008	0.013	0.016	0.019	0.037	0.031	0.036	0.047	0.047
Orange perch	nil	0.003	0.001	0.001	0.002	0.015	0.002	0.011	0.004	0.006
White warehou	0.010	0.010	0.006	0.004	0.002	0.009	0.005	0.013	0.013	0.021
Ribaldo	0.002	0.001	0.002	0.002	0.002	0.001	0.003	0.002	0.002	0.004
Red bait	nil	nil	nil	nil	0.013	0.006	nil	0.009	0.004	0.000
Big-eyed rattail	0.049	0.040	0.061	0.028	0.033	0.027	0.051	0.058	0.064	0.068
Javelinfish	0.041	0.030	0.024	0.027	0.037	0.020	0.043	0.046	0.058	0.075
Oliver's rattail	nil	nil	0.010	0.003	0.004	0.005	0.010	0.005	0.007	0.016
Shovelnose dogfish	0.023	0.013	0.007	0.023	0.014	0.015	0.015	0.018	0.023	0.020
Oblique banded rattail	nil	0.005	0.002	0.003	0.003	0.006	0.008	0.007	0.009	0.006

**Table 9: Trends in abundance and results of analysis of key species (see Appendix 3 for scientific names) from trawl surveys of the Chatham Rise, January 1992–2001.**

Species	a (intercept)	b (slope)	R squared	p	Significance
All hoki	174.838	-9.777	0.541	<0.0001	***
Hake	3.975	-0.215	0.793	<0.0001	***
Lookdown dory	5.387	0.244	0.379	<0.0001	***
Sea perch	1.962	0.311	0.487	<0.0001	***
Spiny dogfish	0.810	0.911	0.804	<0.0001	***
Javelin fish	5.546	0.613	0.351	<0.0001	***
Hoki 3++	126.987	-8.568	0.605	<0.0001	***
Lemon sole	0.023	0.006	0.41	0.004	**
Giant stargazer	2.721	-0.089	0.260	0.005	**
School shark	0.064	0.043	0.297	0.006	**
Dark ghost shark	5.262	0.448	0.263	0.007	**
Murphy's mackerel	0.809	-0.066	0.359	0.009	**
Arrow squid	1.344	-0.097	0.622	0.010	*
Hoki 2+	18.727	1.084	0.026	0.013	*
Orange perch	0.403	0.132	0.084	0.068	nil
Pale ghost shark	4.559	0.087	0.023	0.081	nil
Black oreo	8.485	1.231	0.382	0.085	nil
Oblique banded rattail	0.627	0.097	0.292	0.152	nil
Alfonsino	11.574	-1.099	0.195	0.157	nil
Oliver's rattail	0.959	0.109	0.082	0.170	nil
Hoki 1+	17.487	-0.768	0.039	0.172	nil
White warehou	1.258	0.154	0.158	0.203	nil
Red cod	-0.131	0.167	0.203	0.213	nil
Big-eyed rattail	10.009	0.167	0.021	0.241	nil
Barracouta	0.278	0.125	0.130	0.370	nil
Tarakihi	0.252	-0.009	0.083	0.393	nil
Ribaldo	0.445	0.006	0.015	0.580	nil
Silver warehou	5.189	-0.108	0.012	0.677	nil
Ling	8.769	0.040	0.007	0.714	nil
Spiky oreo	5.002	0.086	0.008	0.817	nil
Shovelnose dogfish	3.699	0.018	0.004	0.822	nil
Hapuku	0.098	-0.001	0.005	0.881	nil
Smooth oreo	0.824	-0.001	0.000	0.994	nil

\*\*\* highly significant, \*\* significant, \* borderline significance

**Table 10: Numbers of female fish at each gonad stage for all Chatham Rise surveys combined (January 1992-2001). Data source: biological records and staged length frequency records. (1 immature, 2 resting, 3 maturing, 4 ripening, 5 running ripe, 6 partially spent, 7 spent).**

	Stage							Total
	1	2	3	4	5	6	7	
Alfonsino	11	109	70	11	4	37	15	257
Banded stargazer	0	0	0	0	0	0	4	4
Barracouta	0	1	29	6	0	0	1	37
Dark ghost shark	10	0	0	2	0	0	0	12
Giant stargazer	26	72	46	8	0	28	63	243
Hake	380	814	453	45	12	72	119	1 895
Hapuku	0	3	0	0	0	0	0	3
Hoki	1 906	6 525	10	0	1	0	21	8 463
Jack mackerel	1	9	1	0	1	0	0	12
Ling	1 602	2 691	149	15	1	14	12	4 484
Lookdown dory	40	16	48	1	0	0	7	112
Orange roughy	0	1	0	0	0	0	0	1
Pale ghost shark	1	0	0	12	0	0	0	13
Red cod	10	5	0	0	0	0	3	18
Ribaldo	6	63	0	0	0	0	29	98
Sea perch	1	3	0	0	0	0	6	10
Silver warehou	72	470	16	0	0	4	113	675
Smooth oreo	8	16	0	0	0	0	0	24
Spiky oreo	0	0	1	0	0	2	1	4
White warehou	114	107	24	0	0	0	10	255

**Table 11: Sex ratios from trawl surveys of the Chatham Rise, January 1992–2000: population numbers (in millions) of male and female fish and % males by species (see Figures 7a to 21b) .**

Year	Males	Females	% male	Males	Females	% male	Males	Females	% male
	<b>Alfonsino</b>			<b>Black oreo</b>			<b>Dark ghost shark</b>		
1992	5.162	5.380	49.0	11.651	13.527	46.3	-	-	-
1993	4.930	3.272	60.1	16.577	16.929	49.5	2.450	2.565	48.9
1994	55.002	20.434	72.9	7.572	7.372	50.7	3.510	4.944	41.5
1995	2.086	1.348	60.7	5.661	4.508	55.7	1.375	1.485	48.1
1996	1.820	1.694	51.8	19.219	18.158	51.4	2.485	2.413	50.7
1997	5.000	4.464	52.8	13.125	11.507	53.3	2.524	2.631	49.0
1998	3.524	2.316	60.3	20.652	18.392	52.9	2.664	3.072	46.4
1999	5.908	4.557	56.5	16.940	16.676	50.4	4.648	5.917	44.0
2000	0.606	0.635	48.8	18.850	17.790	51.4	3.714	4.115	47.4
	<b>Giant stargazer</b>			<b>Hake</b>			<b>Hoki</b>		
1992	0.363	0.478	43.2	0.420	0.355	54.2	76.9	88.8	46.4
1993	0.339	0.430	44.1	0.293	0.344	46.0	164.1	178.6	47.9
1994	0.358	0.513	41.2	0.405	0.441	47.9	132.8	144.2	47.9
1995	0.144	0.298	32.7	0.329	0.346	48.7	103.6	114.6	47.5
1996	0.371	0.475	43.8	0.270	0.434	38.3	176.1	191.8	47.9
1997	0.283	0.335	45.7	0.351	0.365	49.1	131.9	145.5	47.5
1998	0.165	0.299	35.5	0.332	0.350	48.7	66.9	77.7	46.3
1999	0.258	0.309	45.5	0.227	0.317	41.8	107.5	115.4	48.2
2000	0.372	0.362	50.7	0.265	0.268	49.8	78.4	85.4	47.9
	<b>Ling</b>			<b>Lookdown dory</b>			<b>Pale ghost shark</b>		
1992	1.300	1.230	51.4	2.847	3.223	46.9	-	-	-
1993	1.499	1.241	54.7	4.125	5.048	45.0	1.068	1.018	51.2
1994	1.898	1.489	56.0	5.302	7.080	42.8	1.561	1.709	47.7
1995	1.058	1.063	49.9	2.814	4.400	39.0	0.736	0.616	54.4
1996	1.356	1.310	50.9	4.854	6.929	41.2	2.113	1.930	52.3
1997	1.583	1.107	58.9	4.408	5.205	45.9	0.767	0.651	54.1
1998	1.526	1.057	59.1	5.149	5.163	49.9	1.141	1.068	51.7
1999	2.179	1.718	55.9	6.042	6.474	48.3	1.498	1.240	54.7
2000	2.142	1.713	55.6	7.175	7.285	49.6	1.208	1.234	49.5
	<b>Ribaldo</b>			<b>Sea perch</b>			<b>Silver warehou</b>		
1992	0.166	0.120	58.1				1.550	1.318	54.0
1993	0.108	0.085	56.0	3.855	3.393	53.2	1.047	0.800	56.7
1994	0.179	0.205	46.5	4.173	4.193	49.9	2.657	3.859	40.8
1995	0.058	0.133	30.2	1.253	1.098	53.3	0.937	0.864	52.0
1996	0.076	0.134	36.2	3.171	2.931	52.0	0.611	0.426	58.9
1997	0.111	0.078	58.9	3.310	1.974	62.6	0.549	0.504	52.1
1998	0.084	0.161	34.2	3.525	2.553	58.0	1.390	0.960	59.1
1999	0.135	0.084	61.6	4.403	4.016	52.3	2.281	1.562	59.4
2000	0.067	0.096	41.3	5.540	5.791	48.9	1.562	1.738	47.3

**Table 11: Continued.**

Year	Smooth oreo			Spiny dogfish			White warehou		
	Males	Females	% male	Males	Females	% male	Males	Females	% male
1992	0.373	0.294	56.0	-	-	-	0.695	0.579	54.5
1993	0.560	0.397	58.5	0.166	1.097	13.2	0.723	0.554	56.6
1994	0.694	0.372	65.1	0.172	1.453	10.6	0.557	0.391	58.7
1995	0.107	0.095	52.9	0.372	1.100	25.3	0.207	0.203	50.6
1996	1.198	0.768	60.9	0.374	1.893	16.5	0.178	0.145	55.1
1997	1.522	1.414	51.8	1.394	4.683	22.9	0.788	0.820	49.0
1998	2.607	1.630	61.5	0.562	2.594	17.8	0.358	0.320	52.8
1999	0.039	0.034	53.4	0.600	3.681	14.0	1.135	0.728	60.9
2000	0.194	0.143	57.7	0.390	4.279	8.4	1.573	1.421	52.5

**Table 12: The total observed catch of finfish and arrow squid species within the main target fisheries (200–800 m depths) on the Chatham Rise. (Data source: Scientific Observer Database, fishing years 1985–86 to 1998–99.)**

Target Fishery	Catch (kg)	Proportion of total catch
Hoki	64 458 652	0.888
Barracouta	2 291 516	0.032
Silver warehou	2 116 751	0.029
Hake	1 395 311	0.019
Arrow squid	955 728	0.013
Ling	823 059	0.011
White warehou	126 545	0.002
Spiny dogfish	119 124	0.002
Alfonsino	95 656	0.001
Red cod	80 234	0.001
Slender mackerel	76 310	0.001
Tarakihi	16 715	0.000
Total target catch	72 555 601	

**Table 13: Total number of tows (TCEPRs) by vessels targeting shallow species (alfonsino, arrow squid barracouta, gemfish, slender mackerel\*, tarakihi) 200–800 m on the Chatham Rise by month in fishing years 1989–90 to 1998–99 (Data source: Ministry of Fisheries Database).**

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1989–90	16	12	16	9	194	341	96	260	223	7	14	60	1 248
1990–91	63	74	105	98	27	58	4	170	234	93		5	931
1991–92	2	7	5	31	6	110	387	387	281	12	9	11	1 248
1992–93	7	5	4	21	27	155	196	201	137		6	11	770
1993–94	10	11	12	52	6	29	287	555	216	4	8	26	1 216
1994–95	27	13	55	47	36	128	196	385	215	27	19	121	1 269
1995–96	39	10	19	47	115	377	315	380	246		2	33	1 583
1996–97	31	109	52	42	97	246	337	363	257	40		1	1 575
1997–98	70	18	108	74	54	162	152	367	277	4	5	1	1 292
1998–99	25	64	165	85	83	218	159	228	46	1	6	55	1 135
Total	290	323	541	506	645	1 824	2 129	3 296	2 132	188	69	324	12 267

\* Peruvian mackerel

**Table 14: Total number of tows (TCEPRs) by vessels targeting middle depth species (hake, hoki, ling, silver warehou, white warehou) 200–800 m on the Chatham Rise by month in fishing years 1989–90 to 1998–99 (Data source: Ministry of Fisheries Database).**

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1989–90	214	122	222	25	32	131	760	497	80	16	54	409	2 562
1990–91	405	269	642	635	387	813	169	119	185	38	76	309	4 047
1991–92	453	464	604	803	960	1 058	590	329	161	117	58	330	5 927
1992–93	460	430	527	770	687	832	599	462	560	87	121	349	5 884
1993–94	467	427	569	535	436	316	165	167	328	29	6	297	3 742
1994–95	868	753	882	493	506	718	488	468	475	303	100	551	6 605
1995–96	728	707	1 056	1 115	804	692	529	732	928	260	65	702	8 318
1996–97	1 106	1 053	846	1 016	880	1 210	878	826	610	420	27	721	9 593
1997–98	1 655	1 089	1 163	1 133	955	1 082	1 095	901	1 096	553	21	950	11 693
1998–99	1 118	1 402	1 330	1 468	1 311	1 355	909	953	958	150	13	536	11 503
Total	7 474	6 716	7 841	7 993	6 958	8 207	6 182	5 454	5 381	1 973	541	5 154	69 874

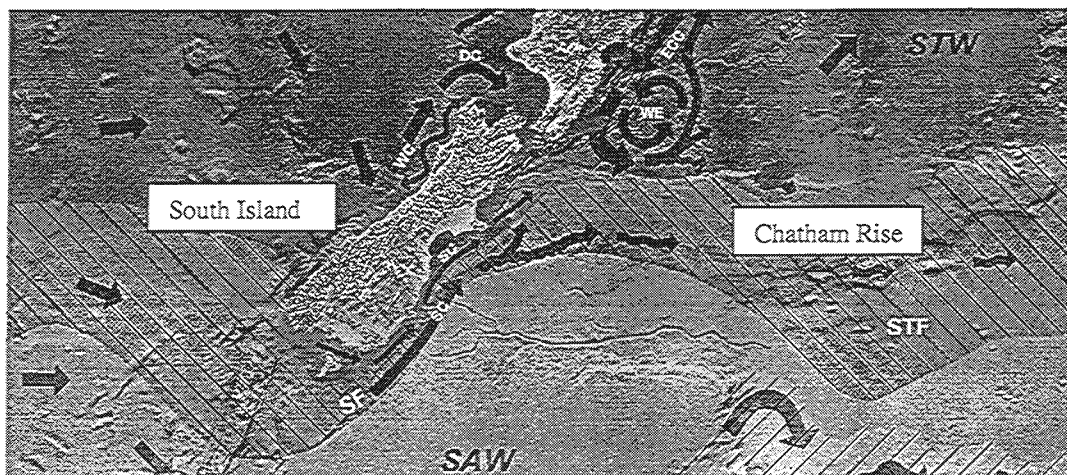


Figure 1: Circulation and water masses around the South Island and Chatham Rise of New Zealand (after Carter et al. 1998). SAW Sub-Antarctic Water, SC Southland Current, SF Southland Front, STF Sub-Tropical Front (delineated by white dash lines), STW Sub-Tropical Water.

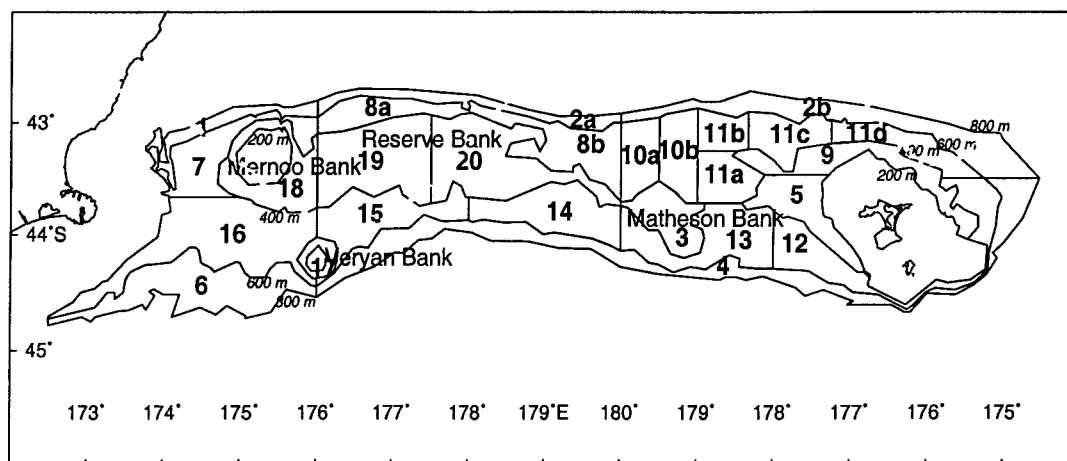
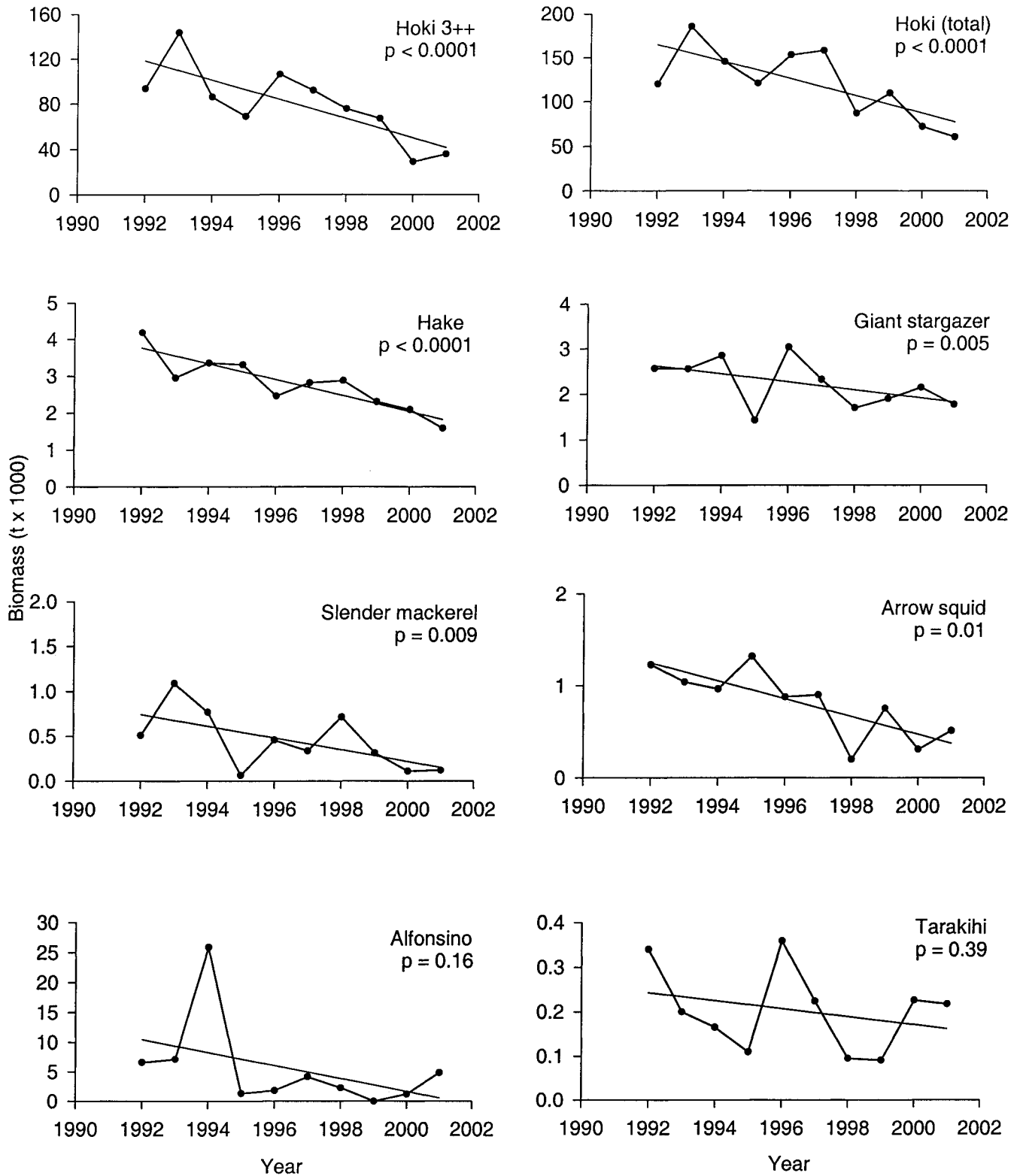
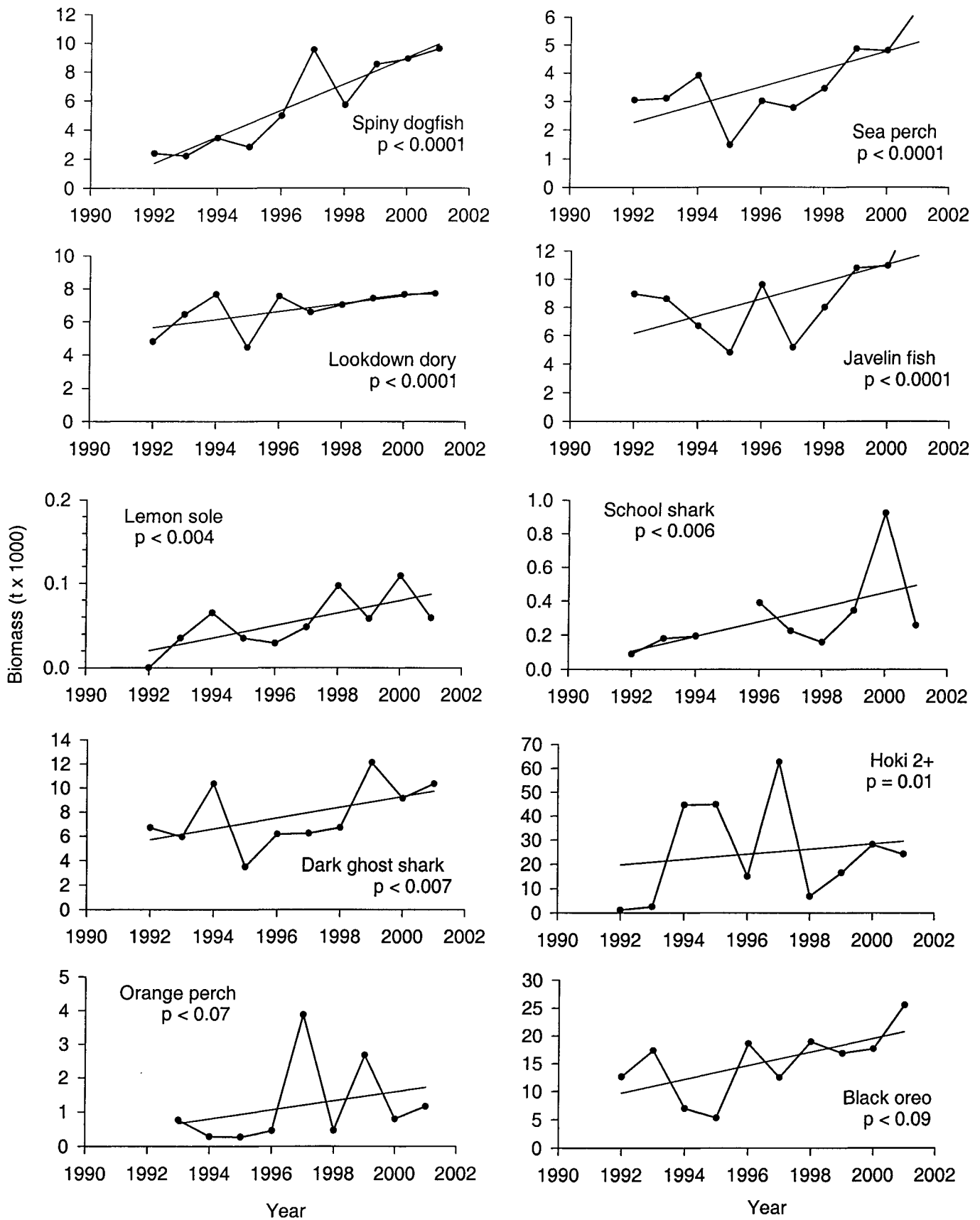


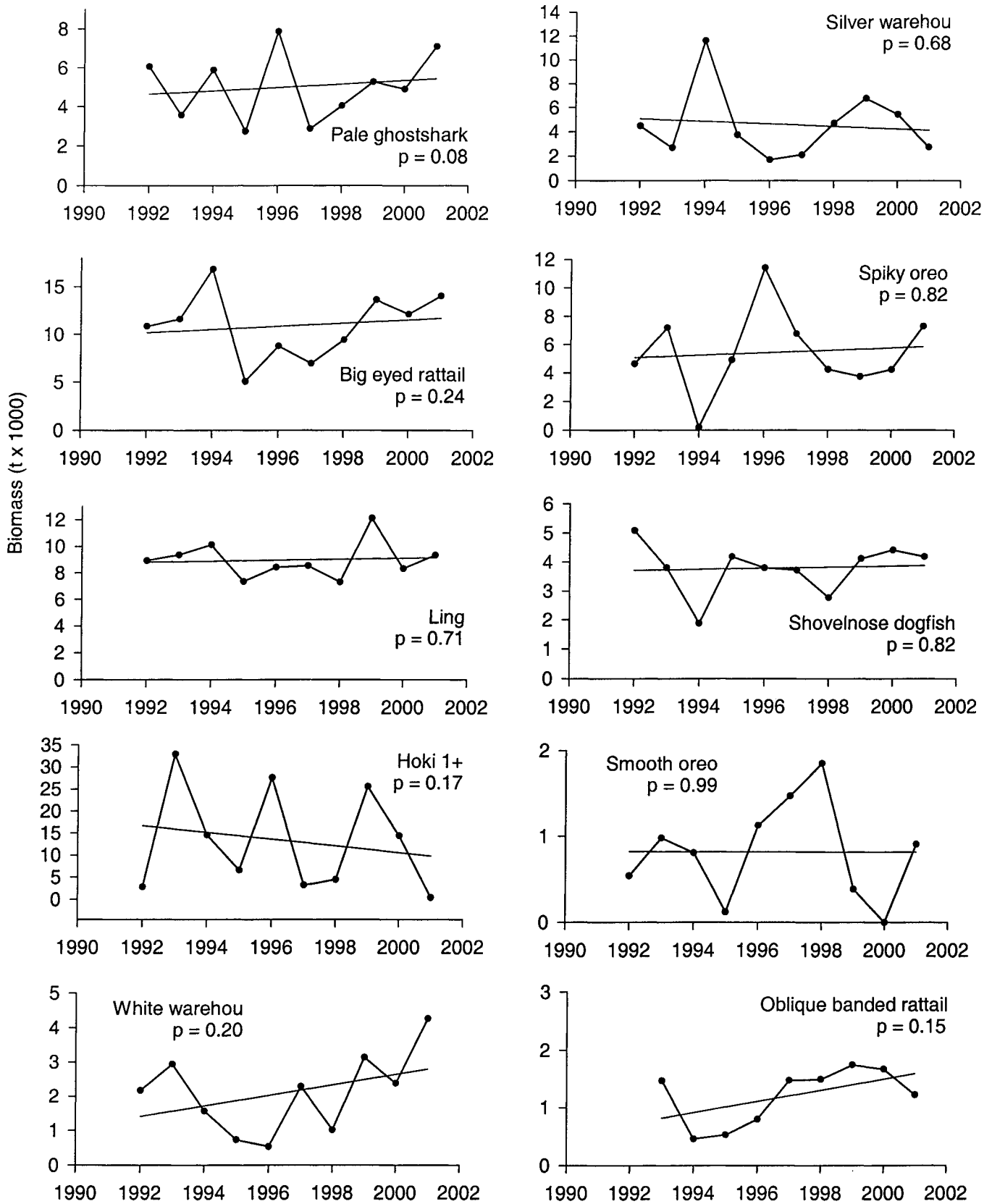
Figure 2: Stratification used for Chatham Rise trawl survey series in 2000.



**Figure 3: Downward trends in biomass estimates (thousands of tonnes) of species from research trawl surveys of the Chatham Rise January 1992-2001. p values represent the significance of the trend from a bootstrap analysis (see Table 9).**



**Figure 4: Upward trends in biomass estimates (thousands of tonnes) of species from research trawl surveys of the Chatham Rise January 1992-2001. p values represent the significance of the trend from a bootstrap analysis (see Table 9).**



**Figure 5: No significant unidirectional trends in biomass estimates (thousands of tonnes) of species from research trawl surveys of the Chatham Rise January 1992-2001. p values represent the significance of the trend from a bootstrap analysis (see Table 9).**

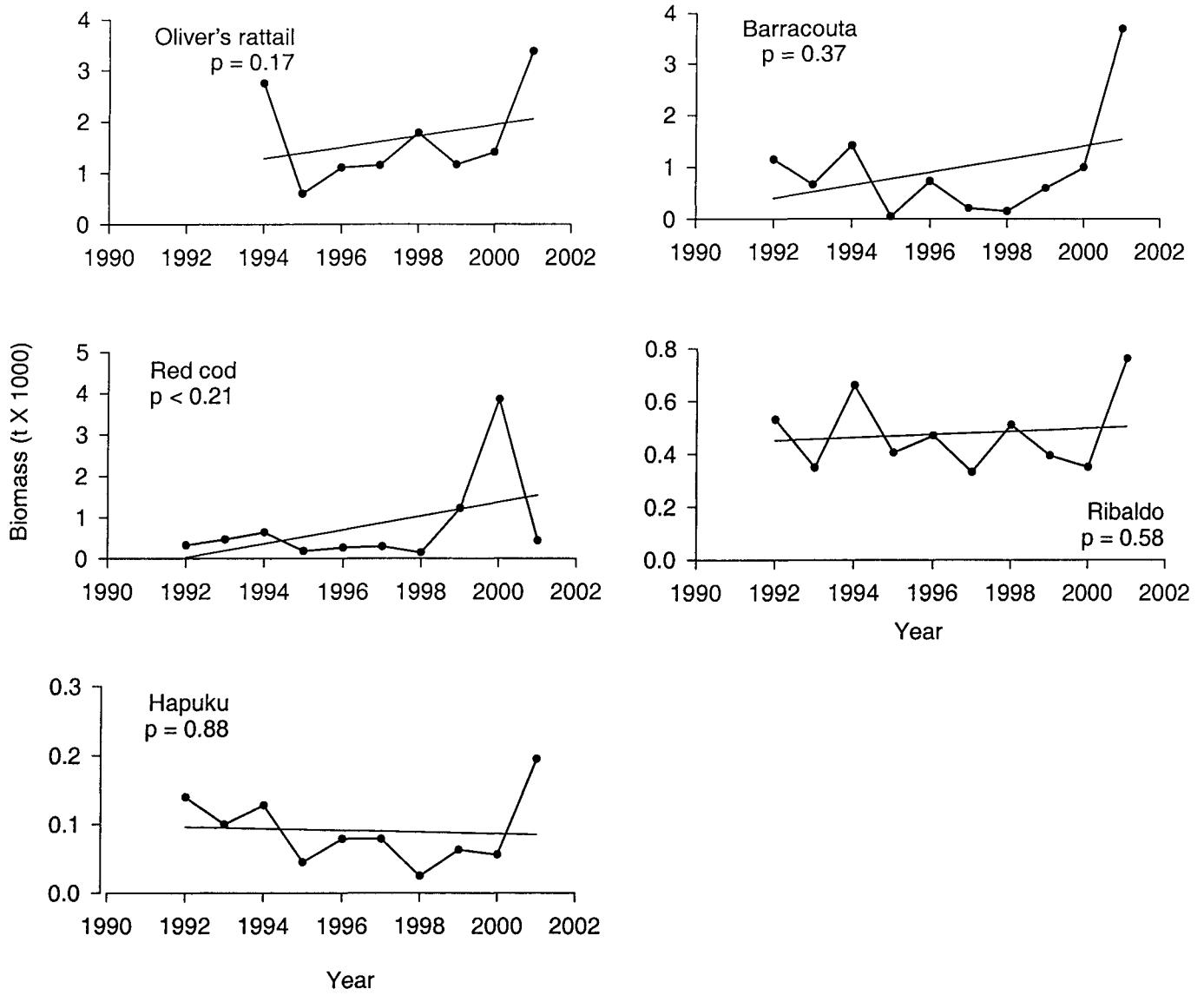
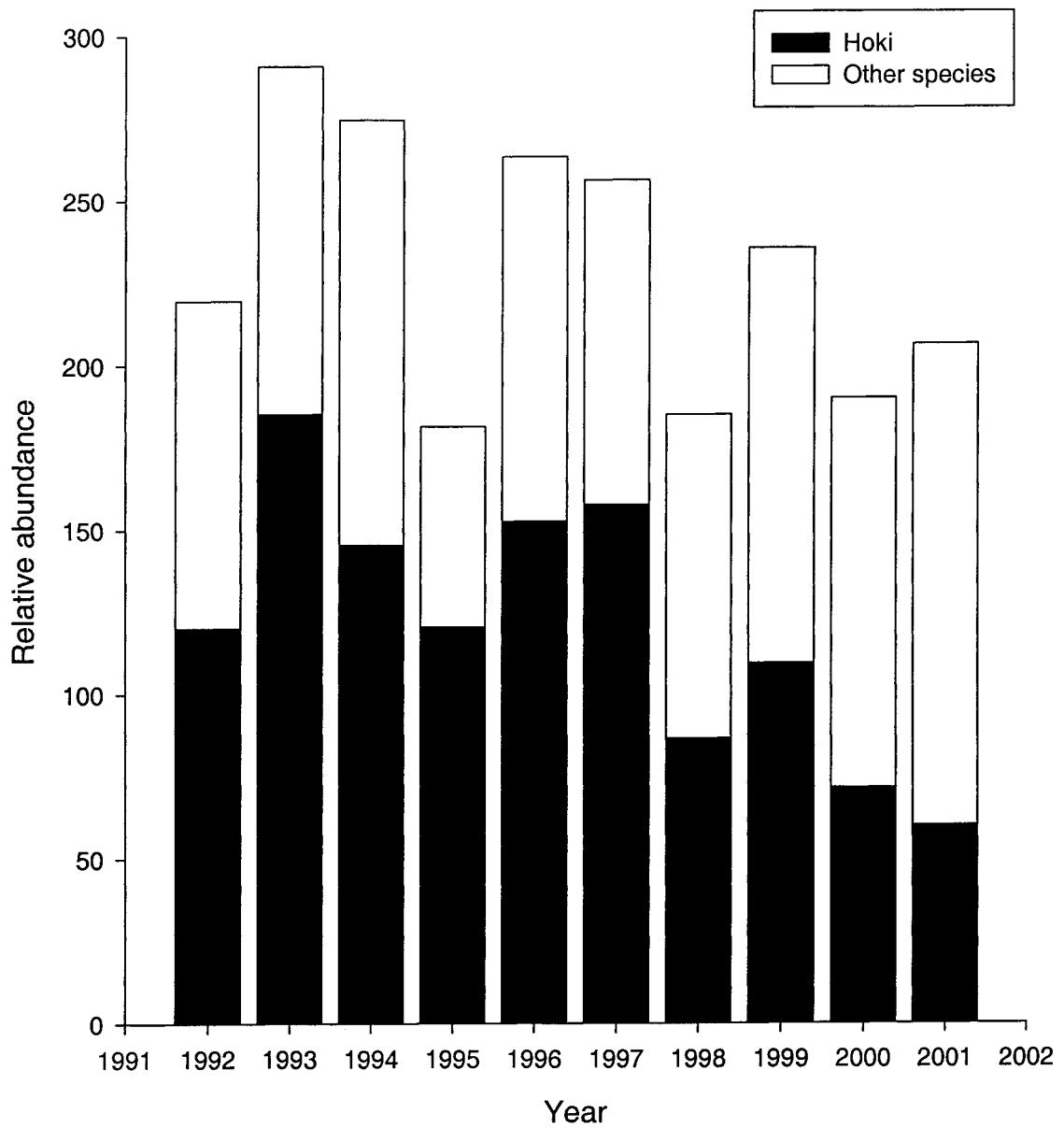


Figure 5: continued.



**Figure 6: The relative abundance (t in thousands) of hoki and all other species (as listed in Table 7) from trawl surveys of the Chatham Rise, January 1992 to 2001.**

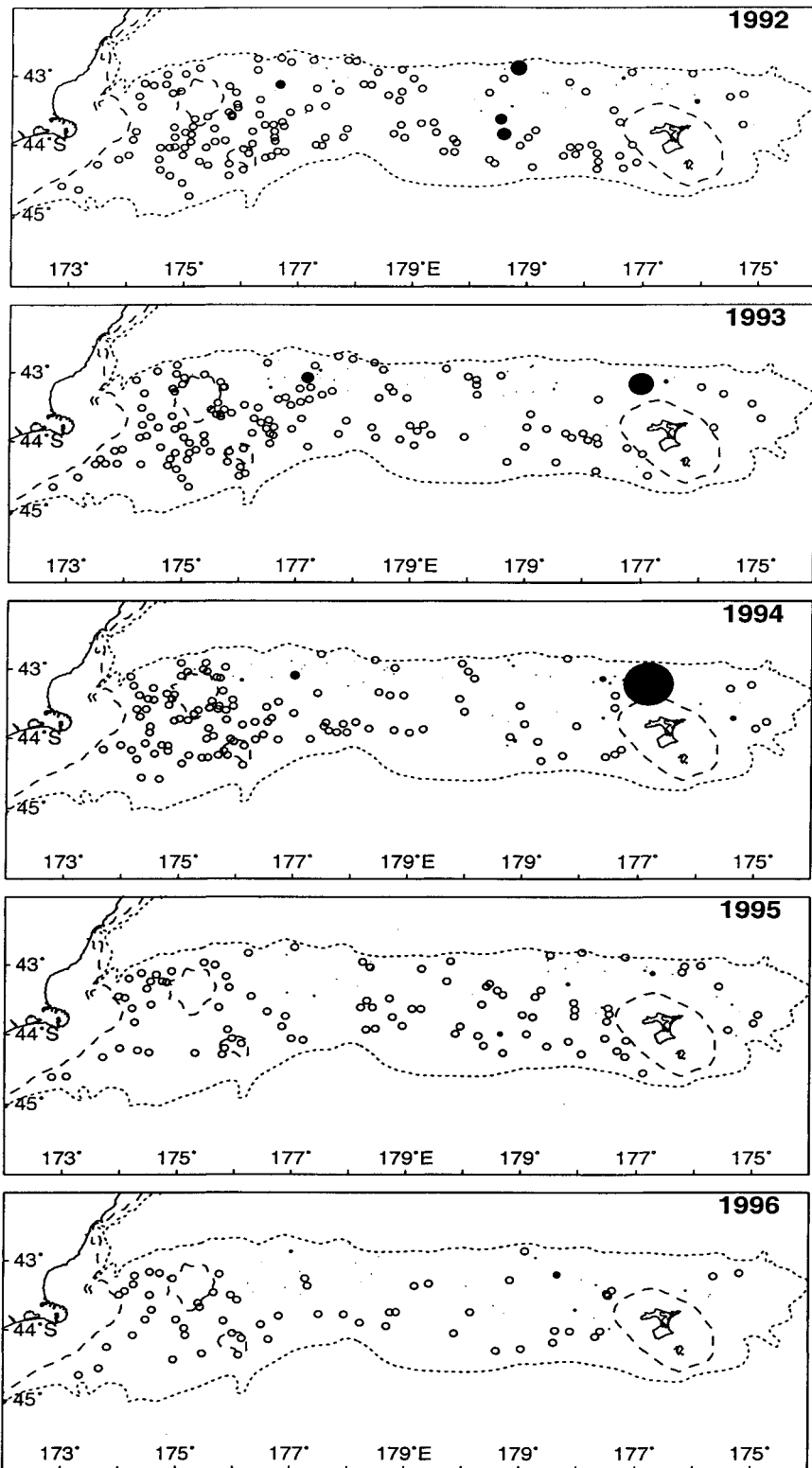


Figure 7a: Catch rates ( $\text{kg.km}^{-2}$ ) of alfonsino. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate 18 101  $\text{kg.km}^{-2}$ . (See Table 3 for station numbers).

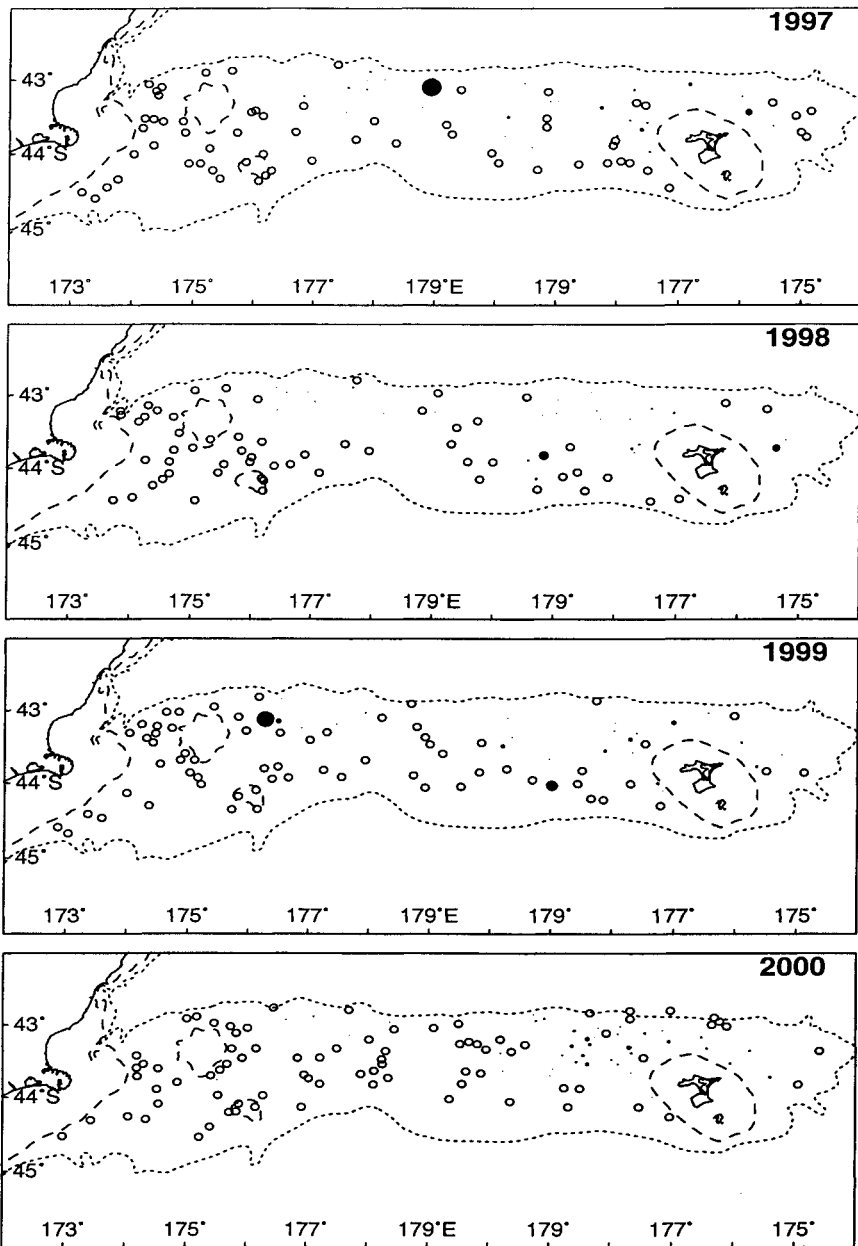


Figure 7a: *continued.*

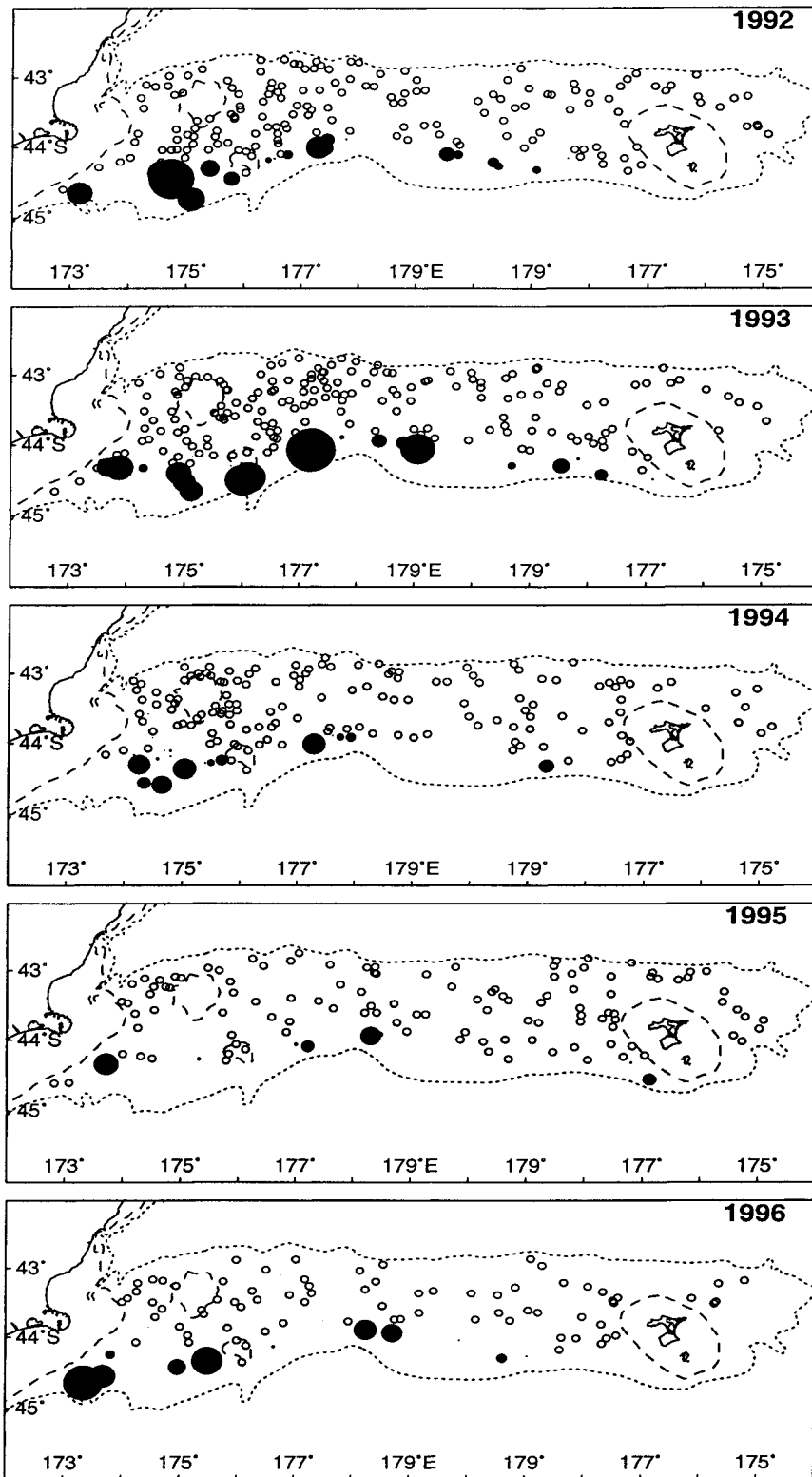


Figure 7b: Catch rates ( $\text{kg.km}^{-2}$ ) of black oreo. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $4\,379\text{ kg.km}^{-2}$ . (See Table 3 for station numbers).

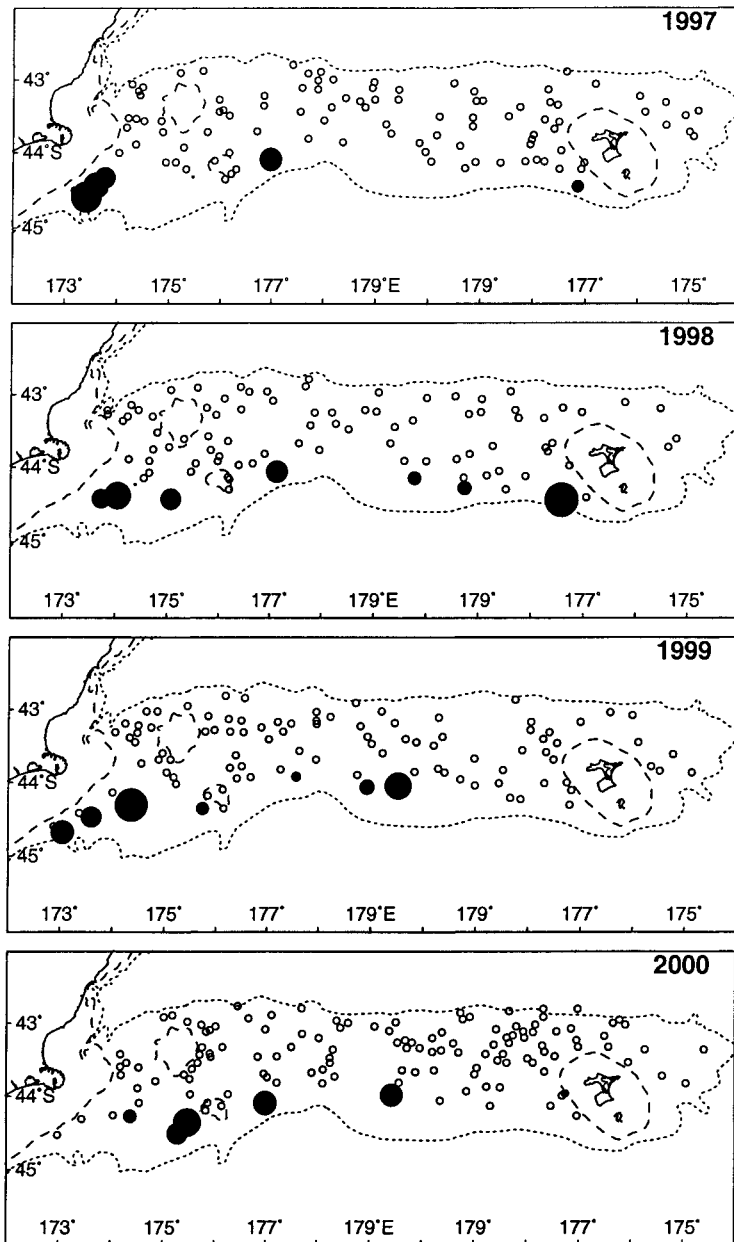


Figure 7b: *continued.*

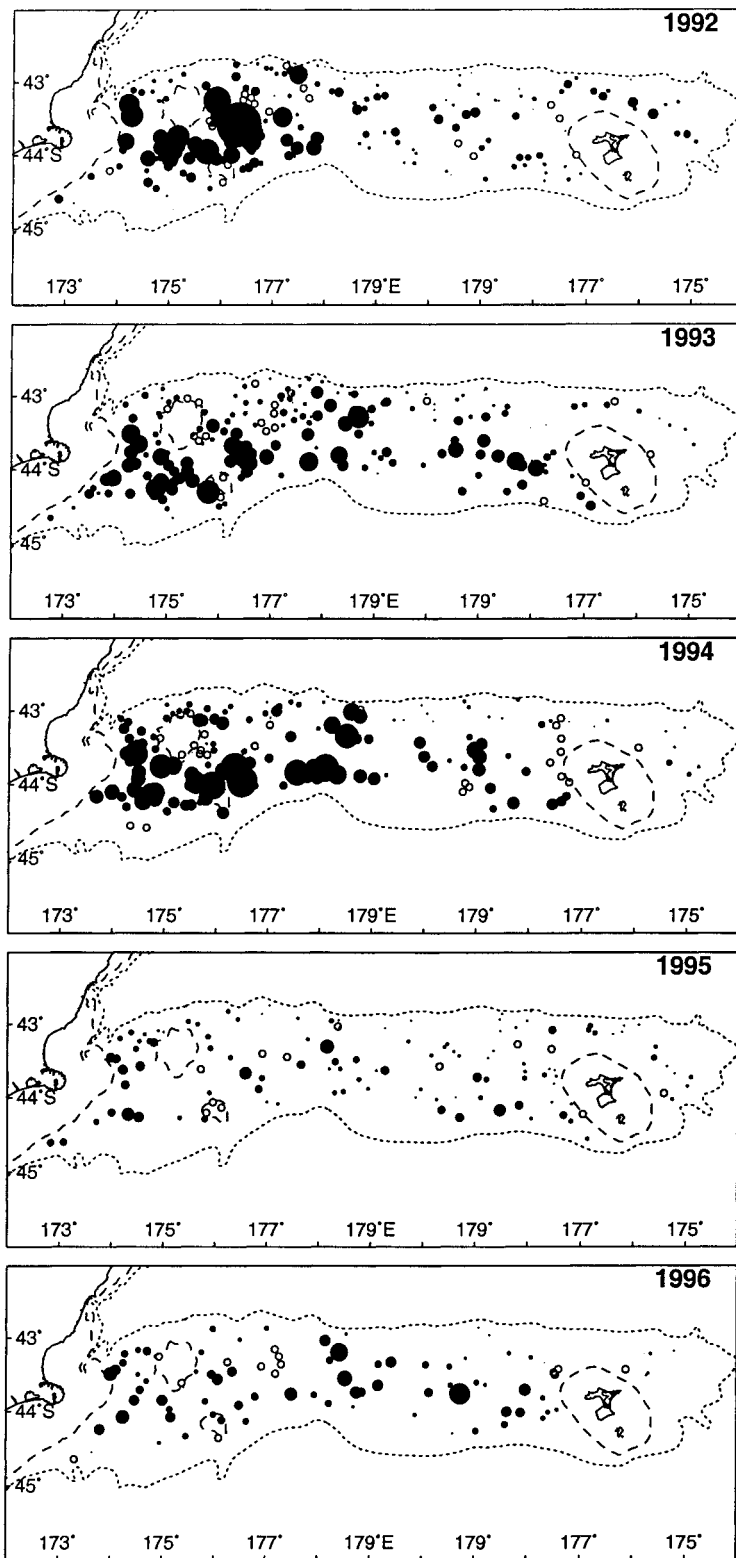


Figure 7c: Catch rates ( $\text{kg}\cdot\text{km}^{-2}$ ) of big-eye rattail. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $2\,316\text{ kg}\cdot\text{km}^{-2}$ . (See Table 3 for station numbers).

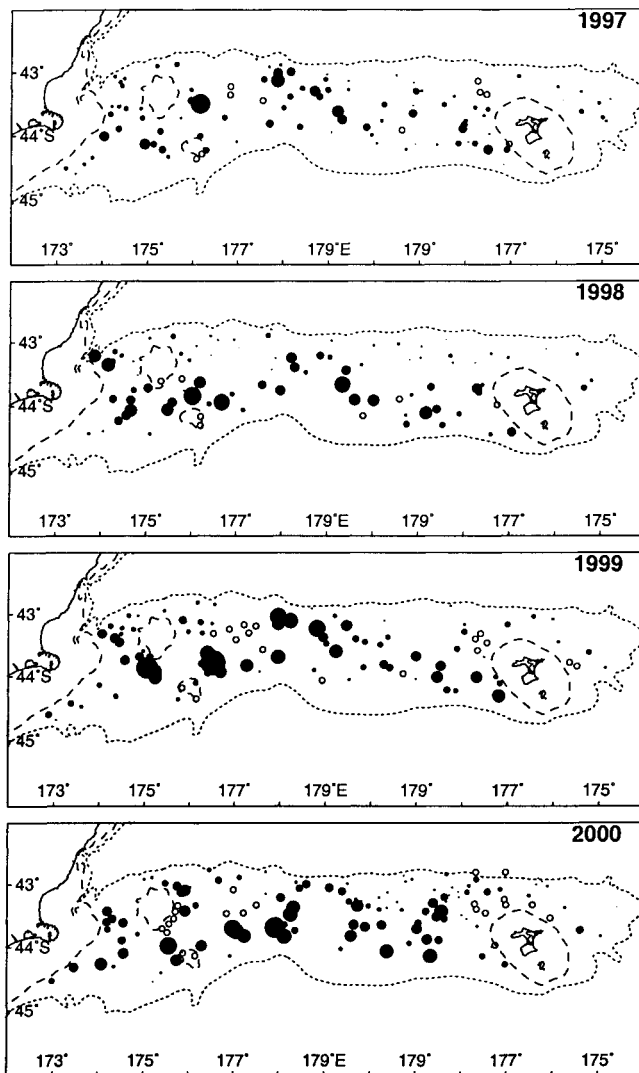


Figure 7c: *continued.*

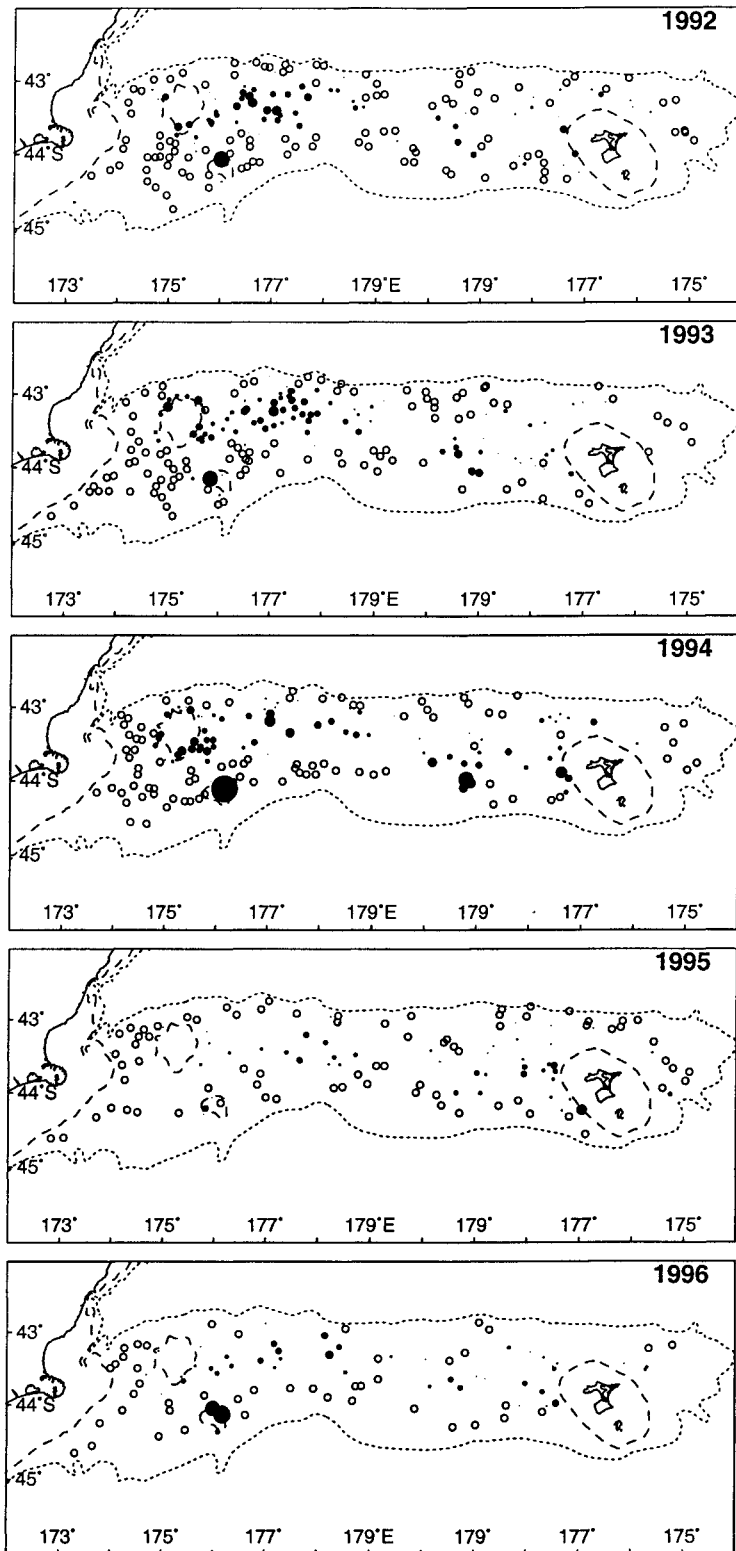


Figure 7d: Catch rates ( $\text{kg.km}^{-2}$ ) of dark ghost shark. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate 10 691  $\text{kg.km}^{-2}$ . (See Table 3 for station numbers).

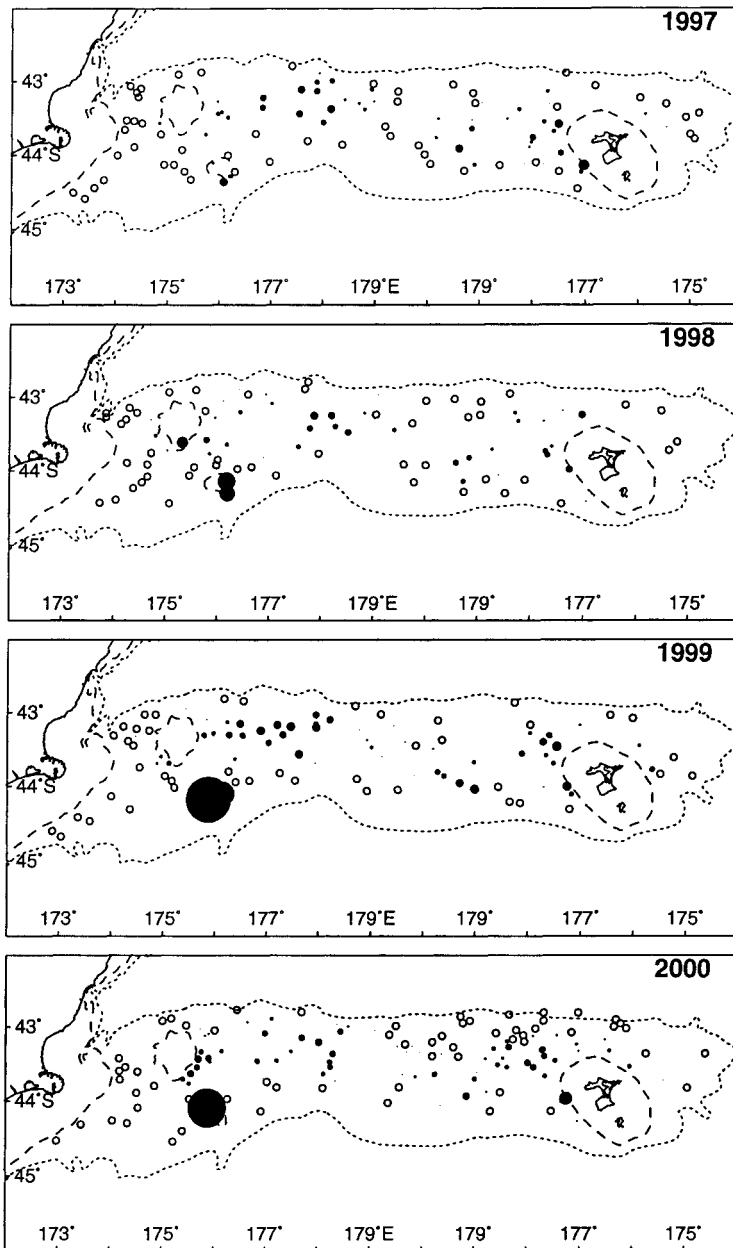
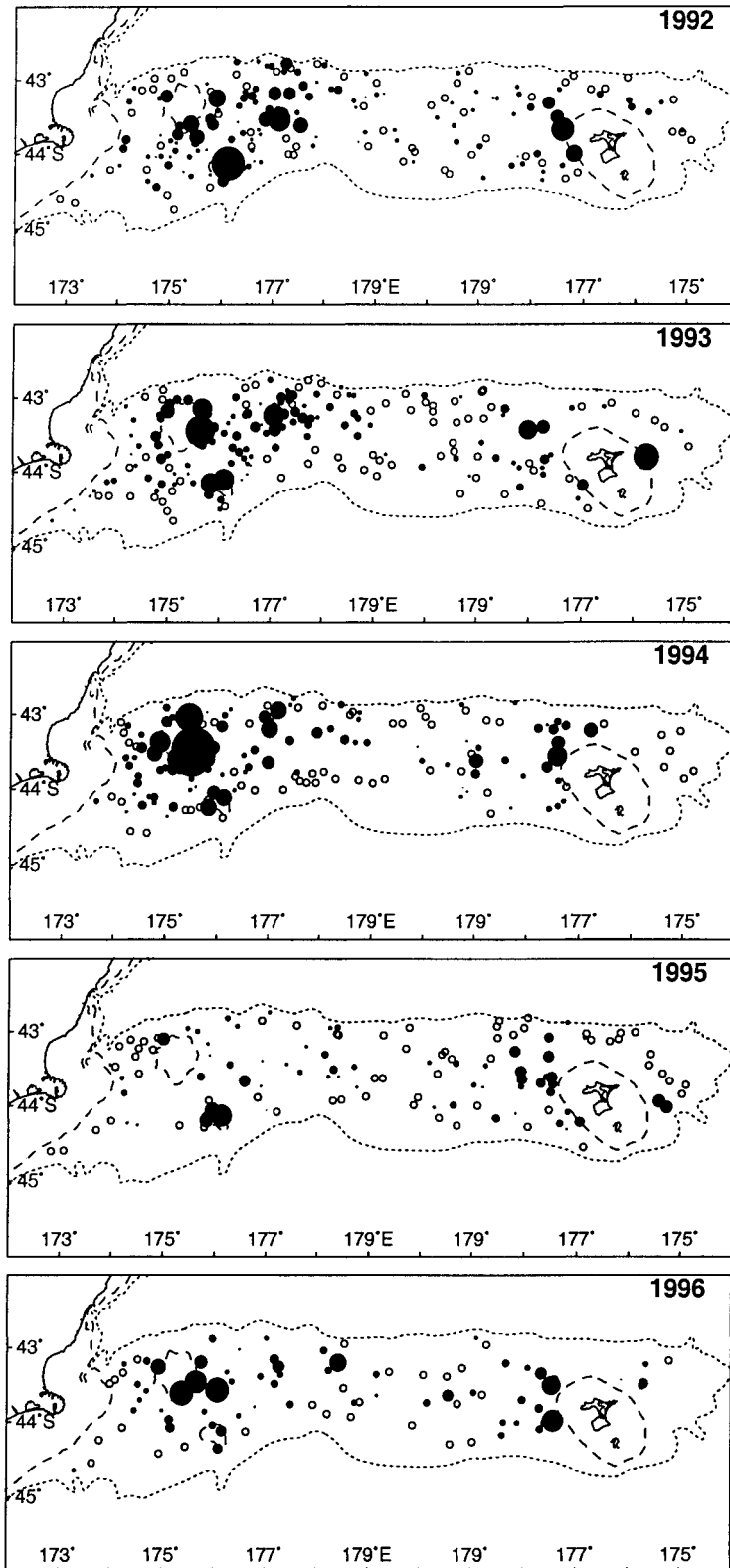


Figure 7d: *continued.*



**Figure 7e: Catch rates ( $\text{kg}\cdot\text{km}^{-2}$ ) of giant stargazer. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $859 \text{ kg}\cdot\text{km}^{-2}$ . (See Table 3 for station numbers).**

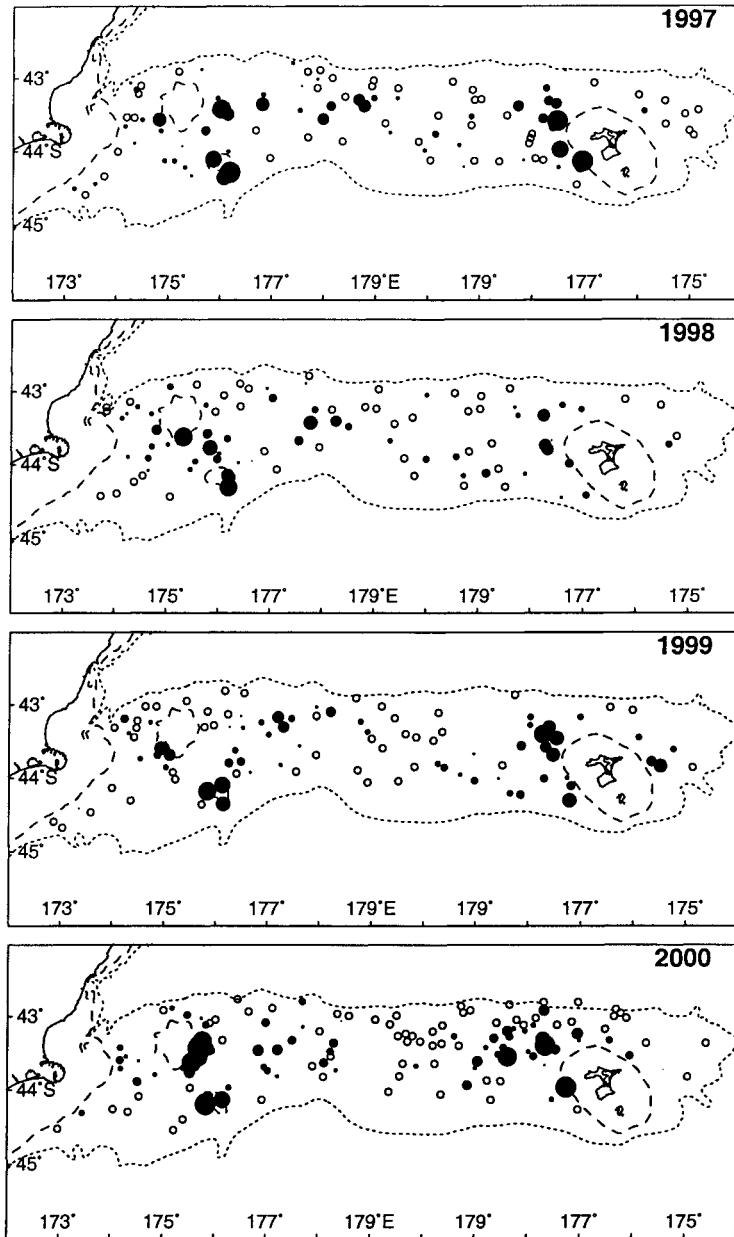


Figure 7e: *continued.*

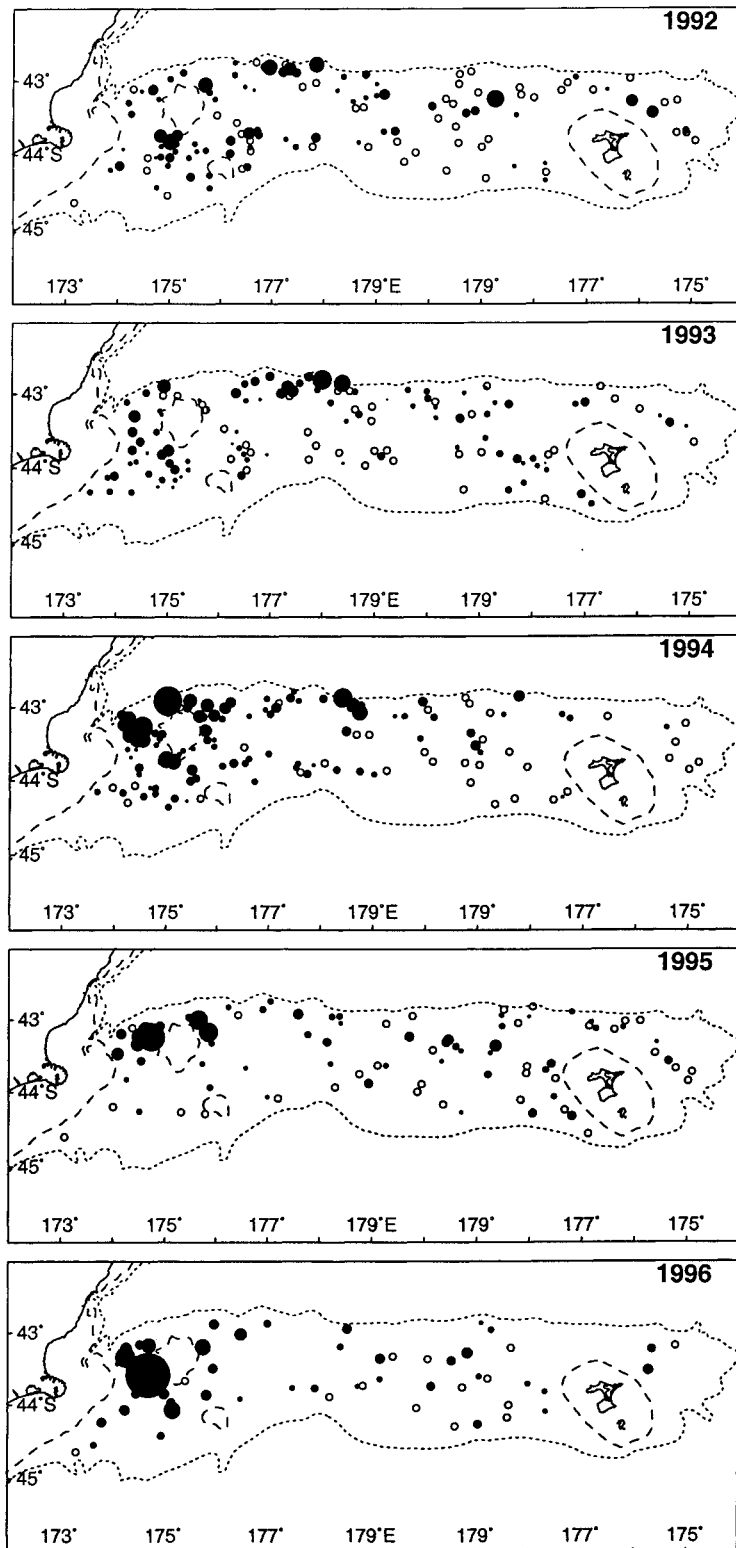


Figure 7f: Catch rates (kg.km<sup>-2</sup>) of hake less than 76 cm total length). Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate 194 kg.km<sup>-2</sup>. (See Table 3 for station numbers).

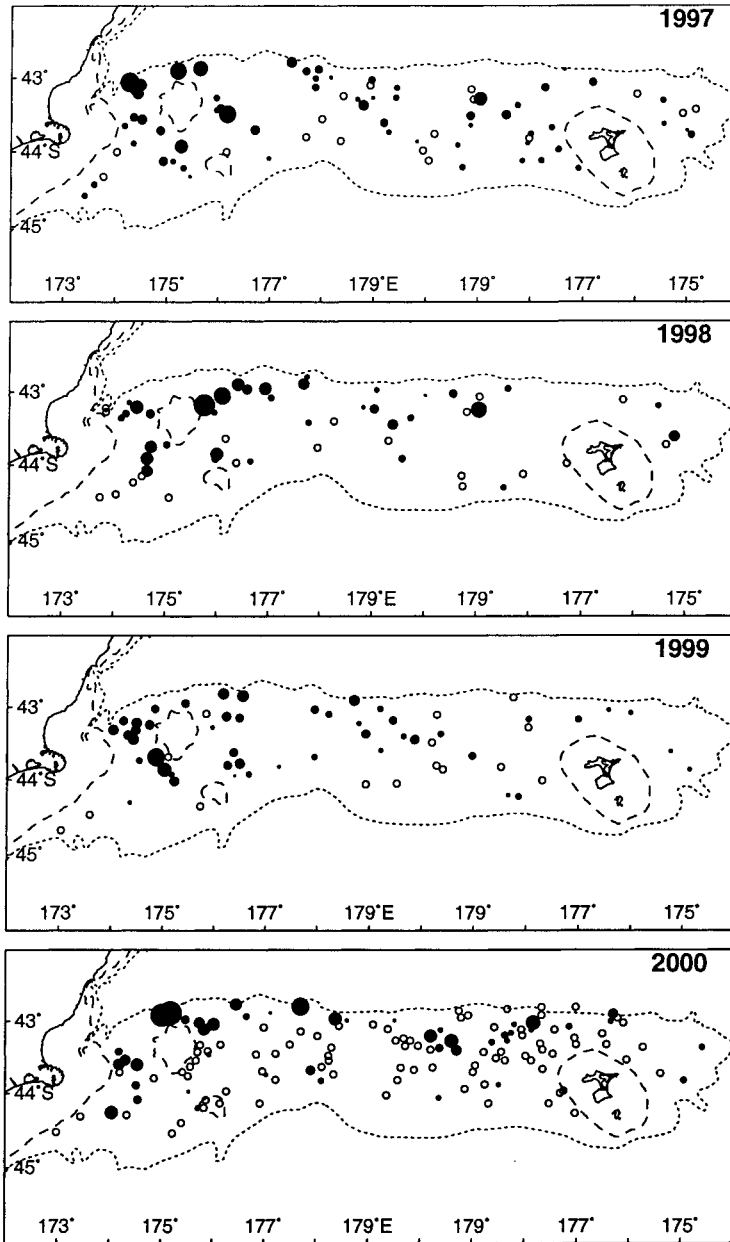


Figure 7f: *continued.*

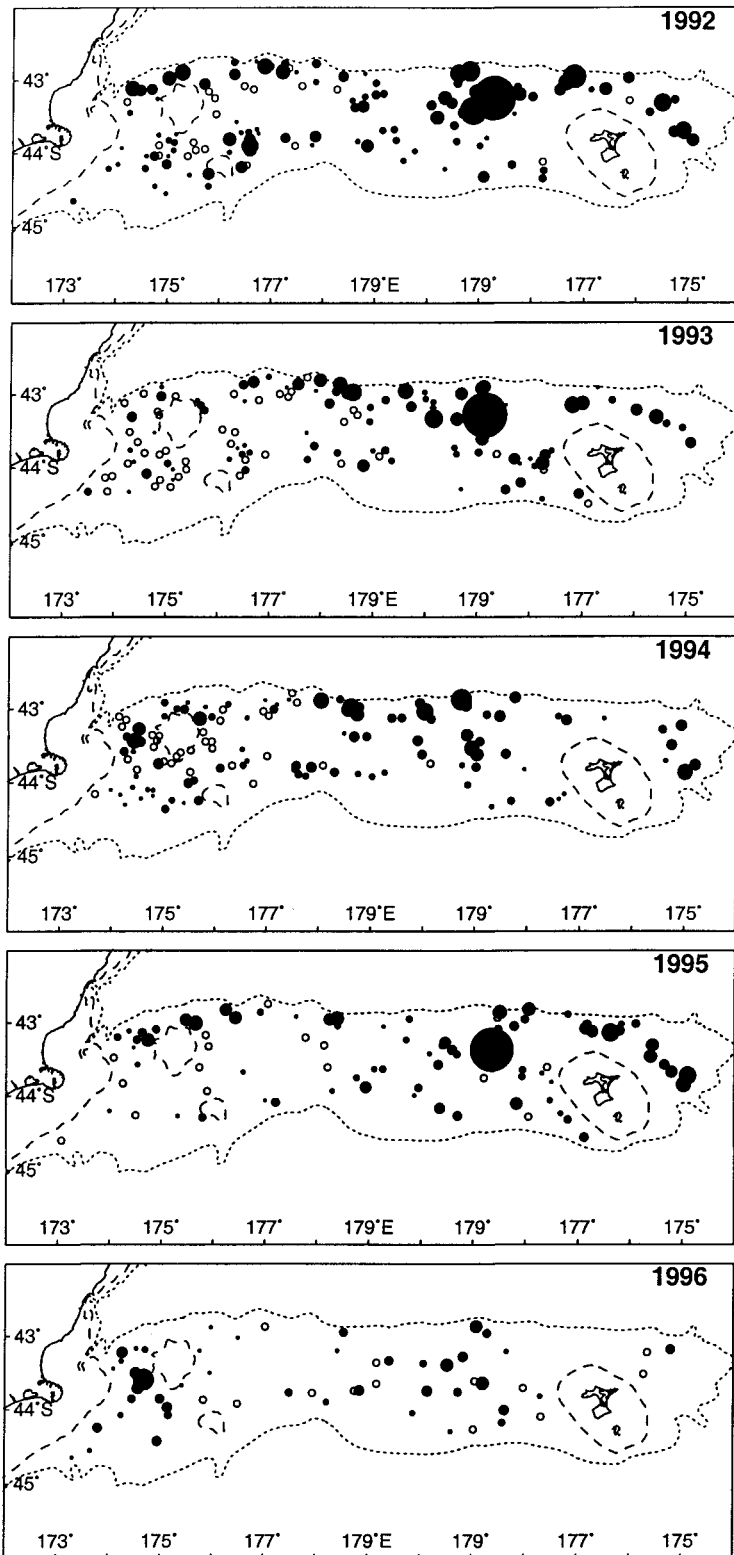


Figure 7g: Catch rates ( $\text{kg.km}^{-2}$ ) of hake greater than or equal to 76 cm total length). Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate 613  $\text{kg.km}^{-2}$ . (See Table 3 for station numbers).

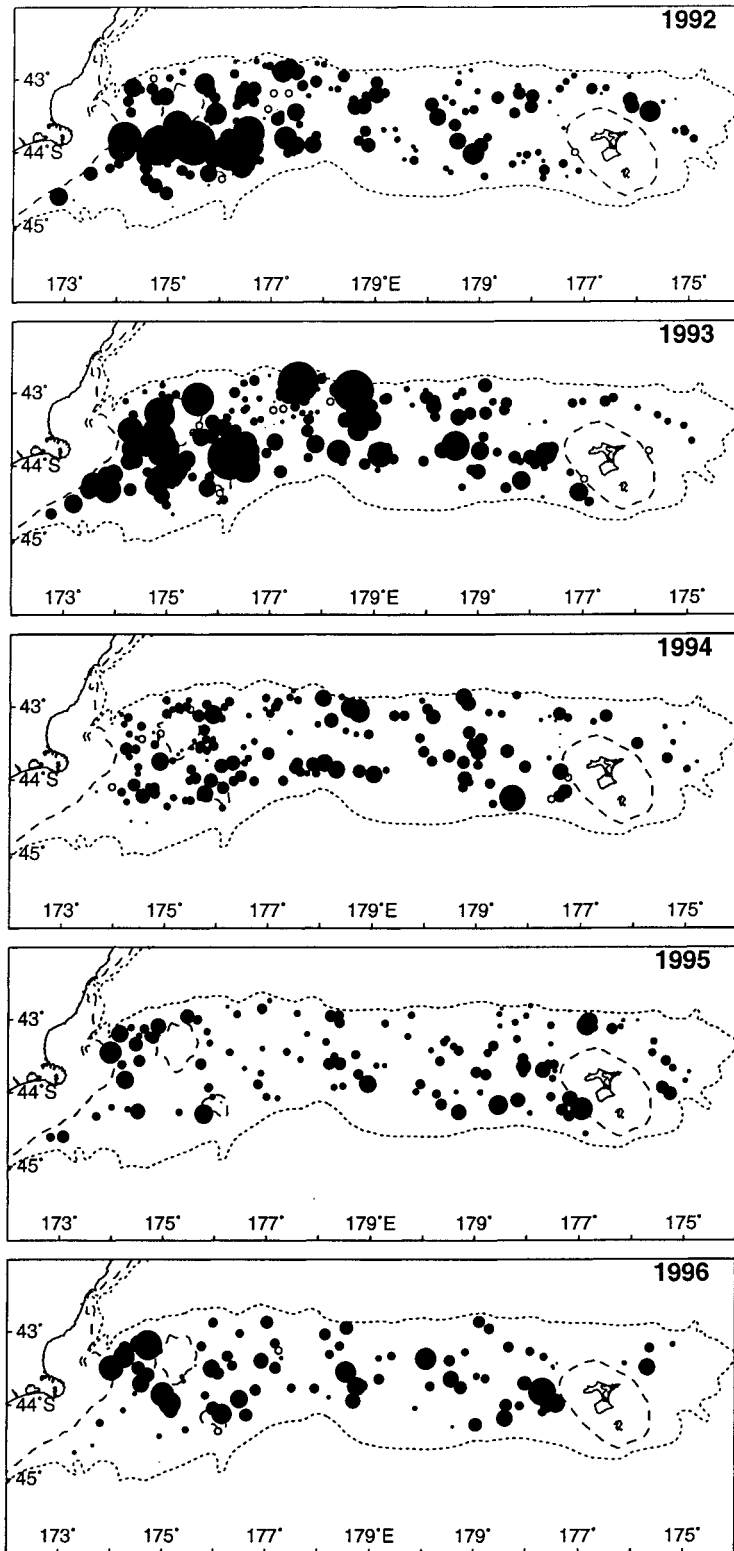


Figure 7h: Catch rates ( $\text{kg.km}^{-2}$ ) of 3++ hoki. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate 11 177  $\text{kg.km}^{-2}$ . (See Table 3 for station numbers).

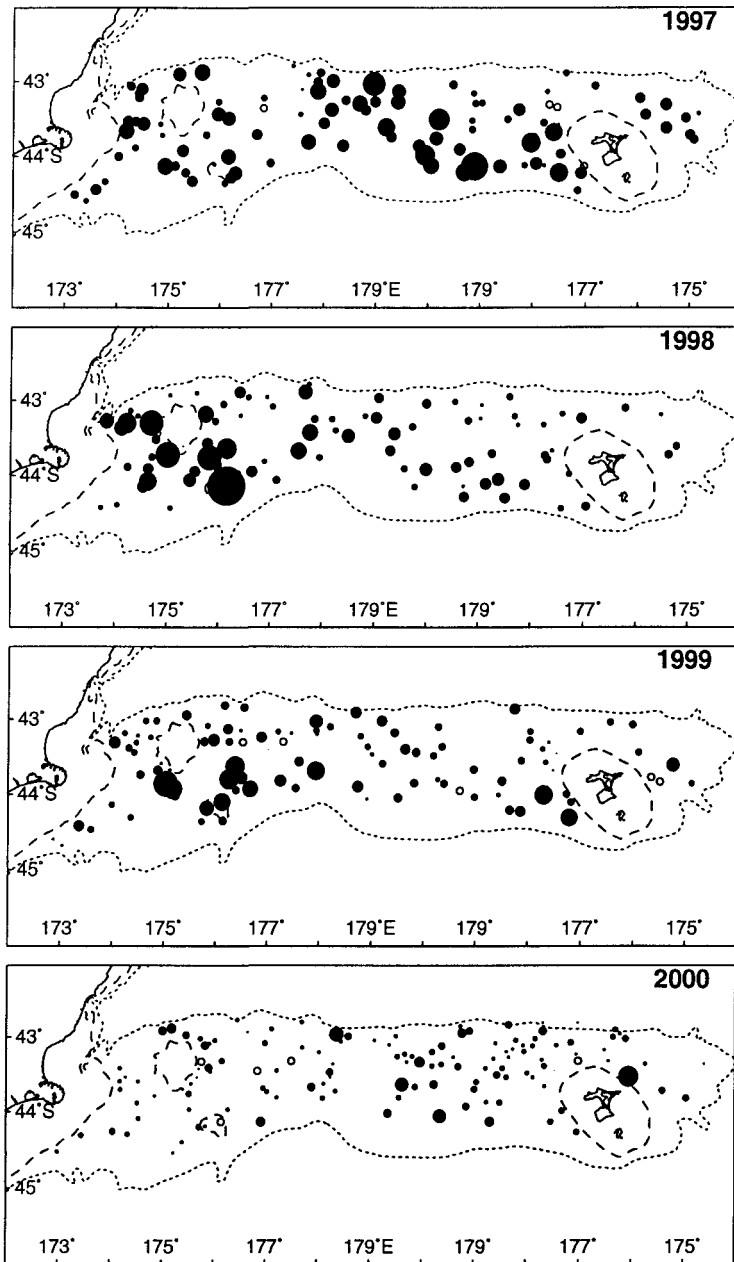


Figure 7h: *continued.*

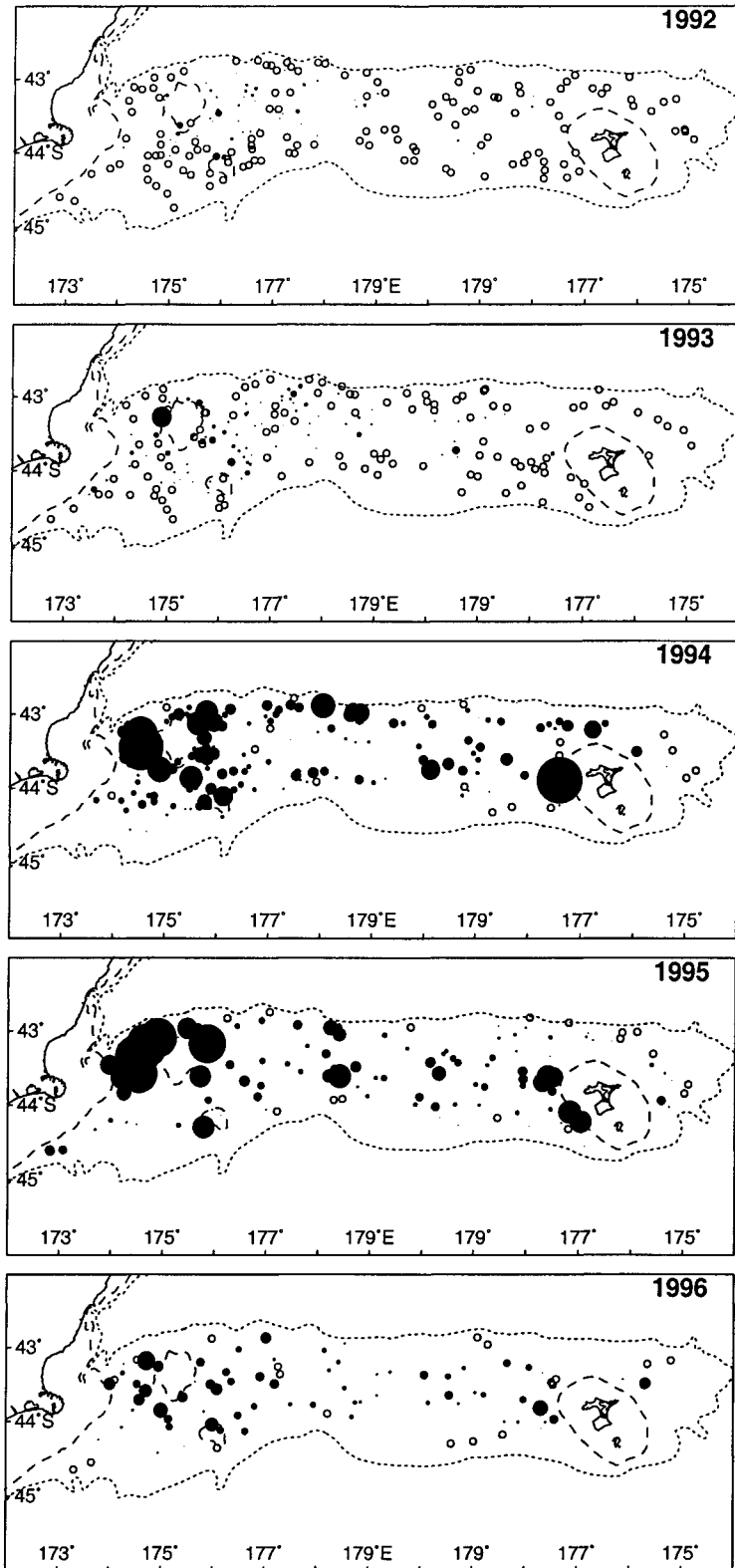


Figure 7i: Catch rates ( $\text{kg}\cdot\text{km}^{-2}$ ) of 2+ hoki. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $6\,791\text{ kg}\cdot\text{km}^{-2}$ . (See Table 3 for station numbers).

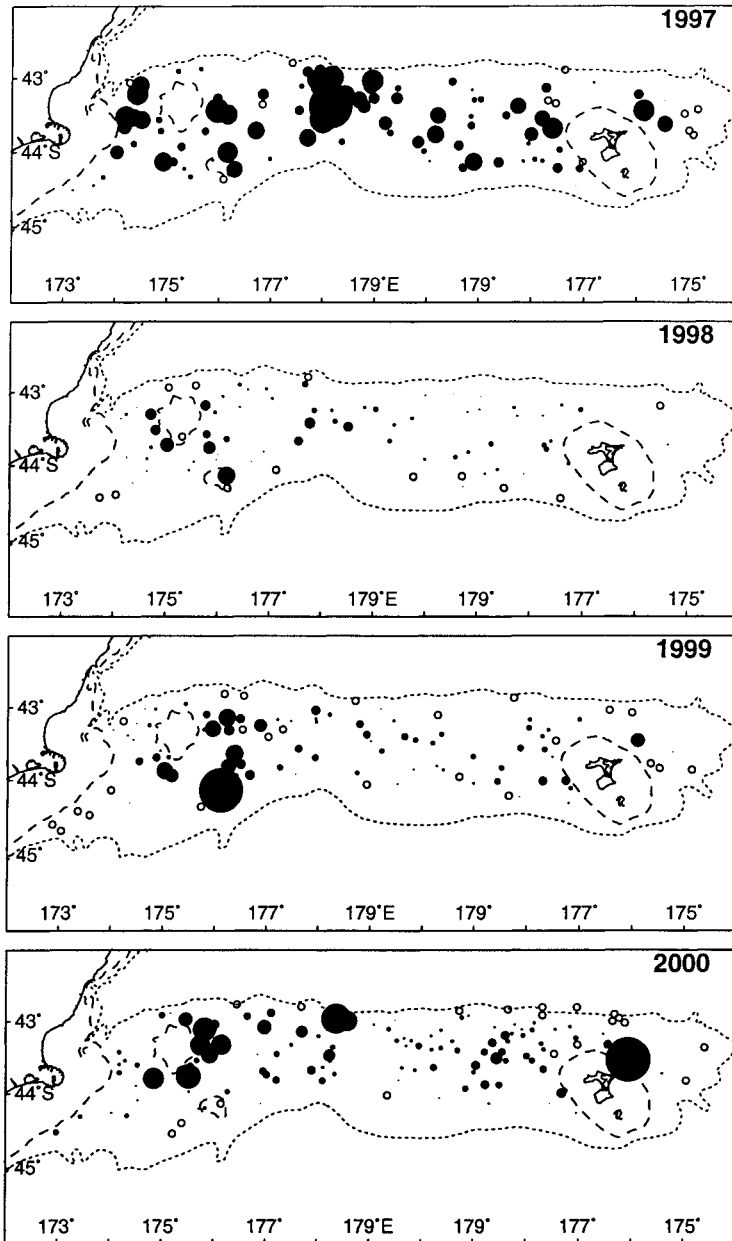
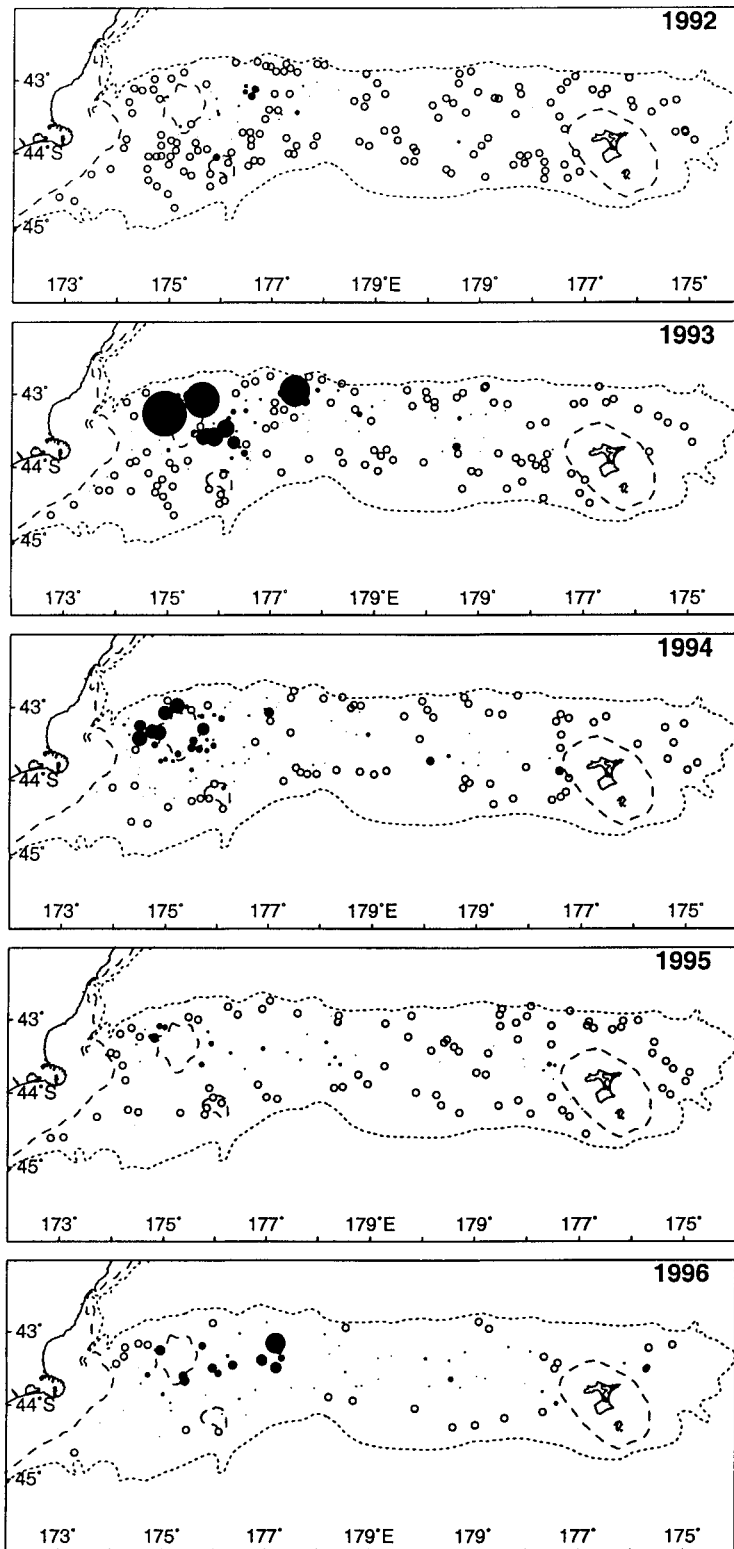


Figure 7i: *continued.*



**Figure 7j:** Catch rates ( $\text{kg}\cdot\text{km}^{-2}$ ) of 1+ hoki. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $30\,850\text{ kg}\cdot\text{km}^{-2}$ . (See Table 3 for station numbers).

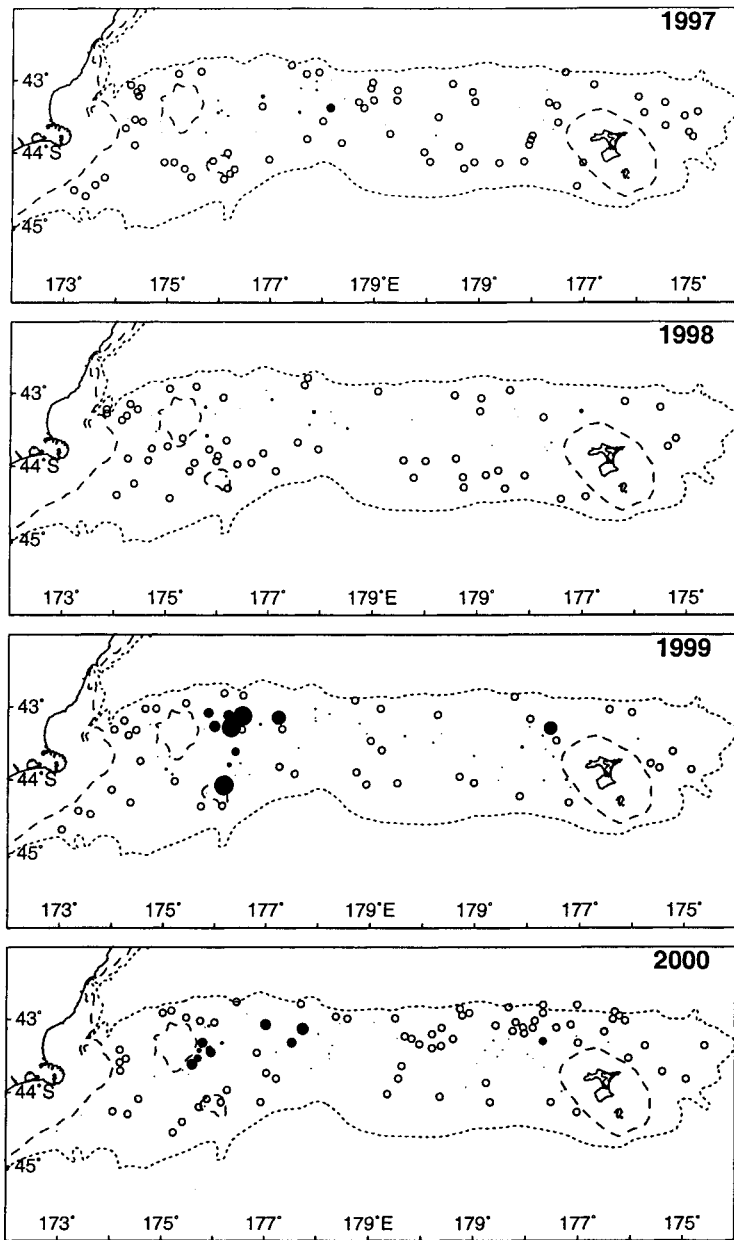


Figure 7j: *continued.*

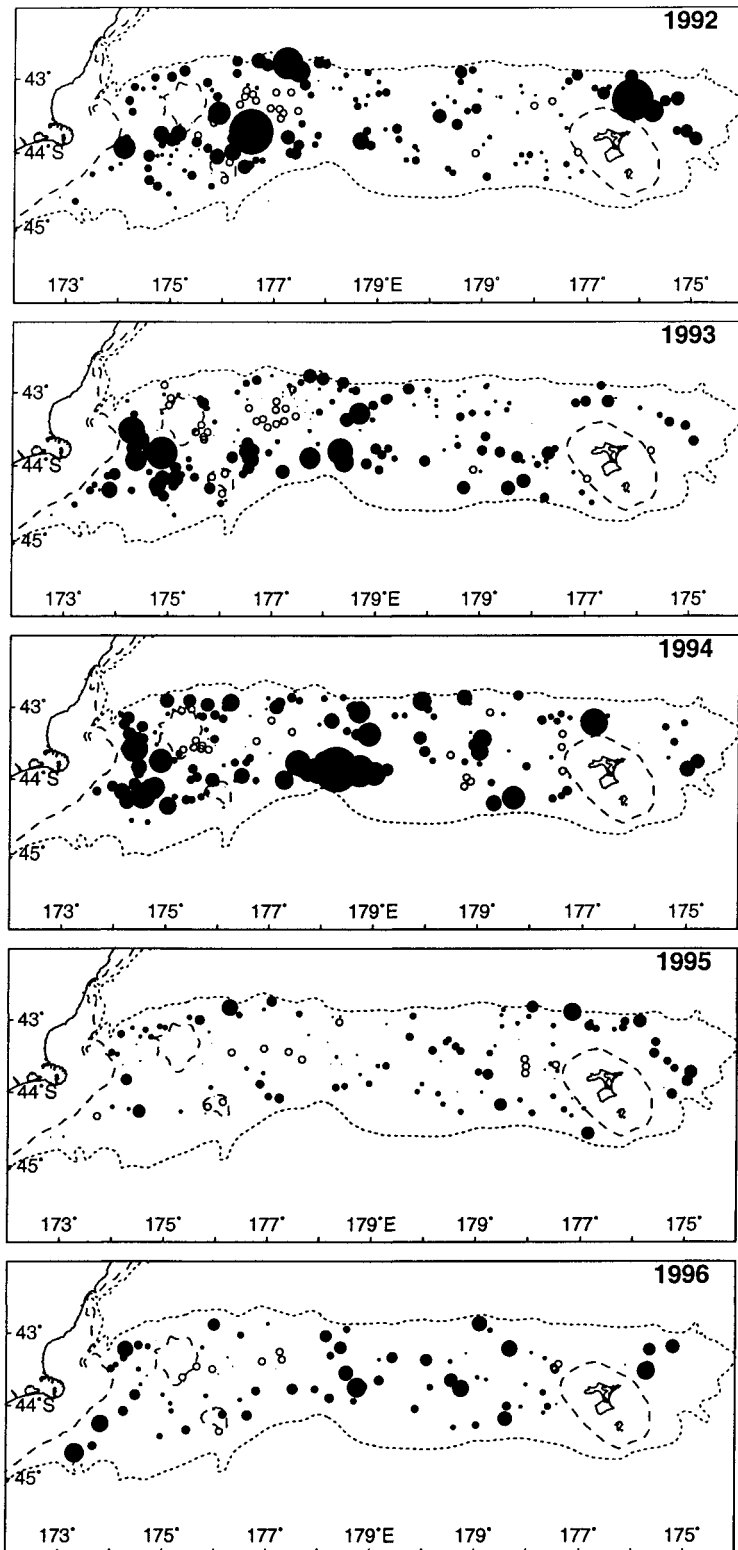


Figure 7k: Catch rates ( $\text{kg.km}^{-2}$ ) of javelinfish. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $1\,541\text{ kg.km}^{-2}$ . (See Table 3 for station numbers).

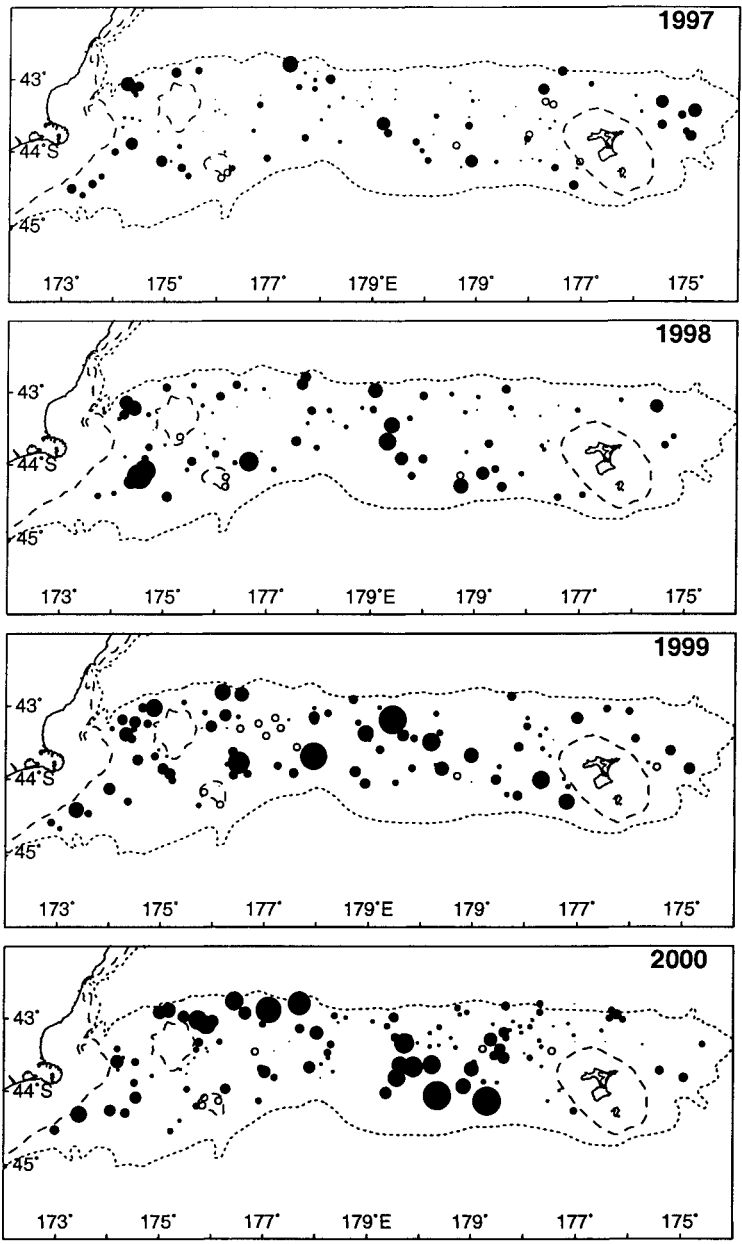
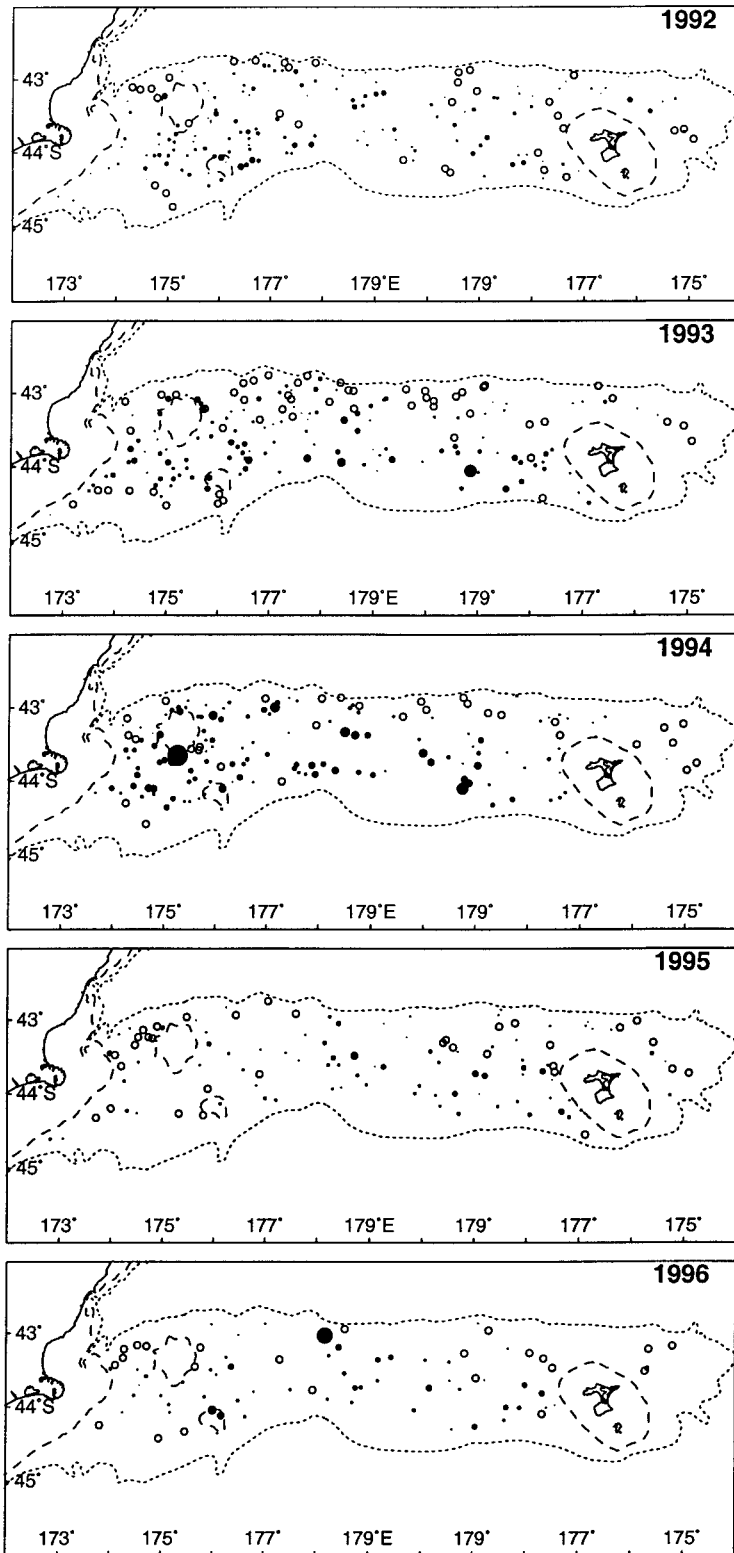


Figure 7k: *continued.*



**Figure 71: Catch rates (kg.km<sup>-2</sup>) of ling less than 68 cm total length). Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate 823 kg.km<sup>-2</sup>. (See Table 3 for station numbers).**

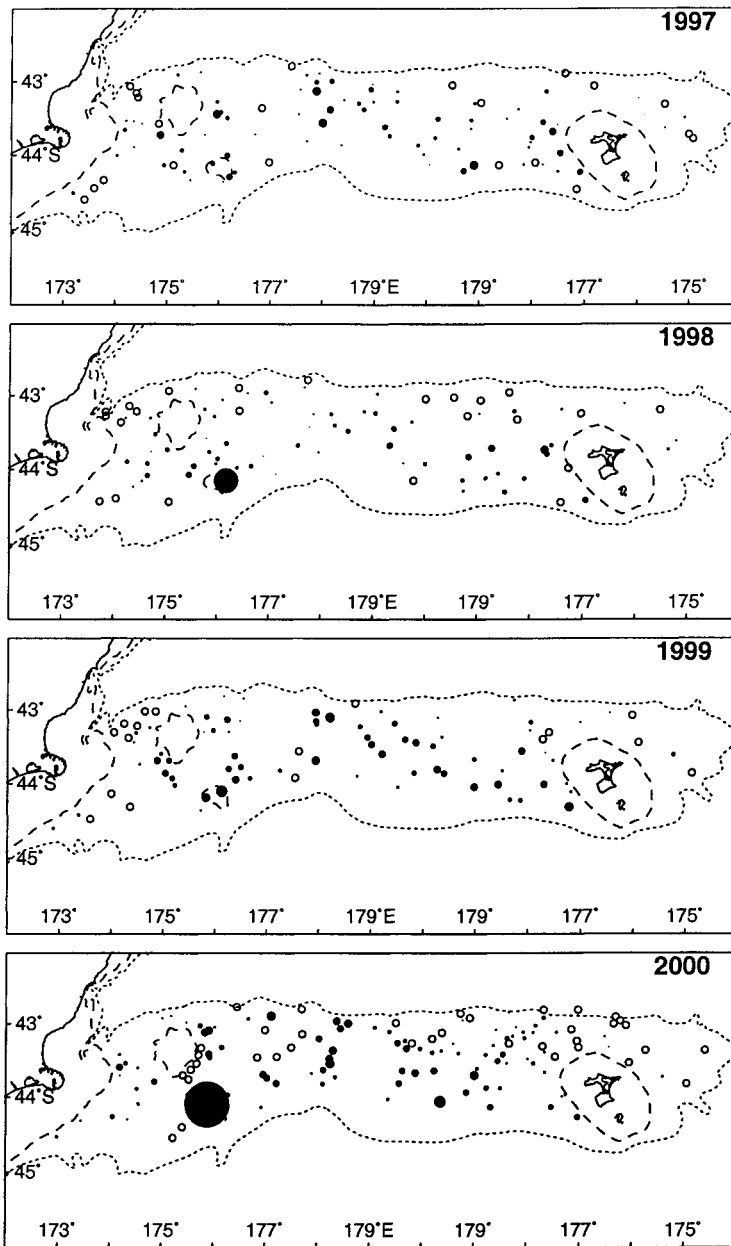


Figure 71: *continued.*

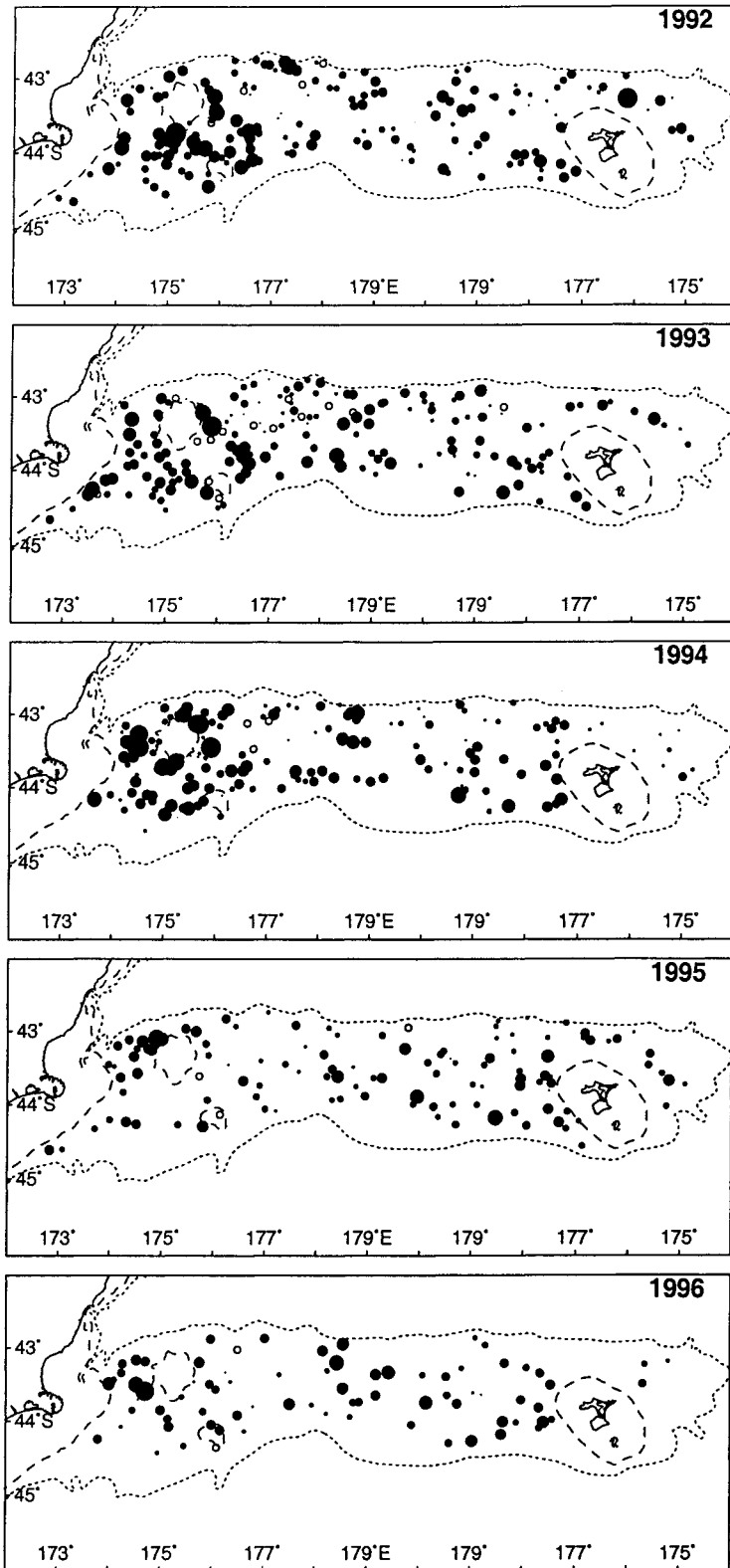


Figure 7m: Catch rates ( $\text{kg.km}^{-2}$ ) of ling greater than or equal to 68 cm total length. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate 1 796  $\text{kg.km}^{-2}$ . (See Table 3 for station numbers).

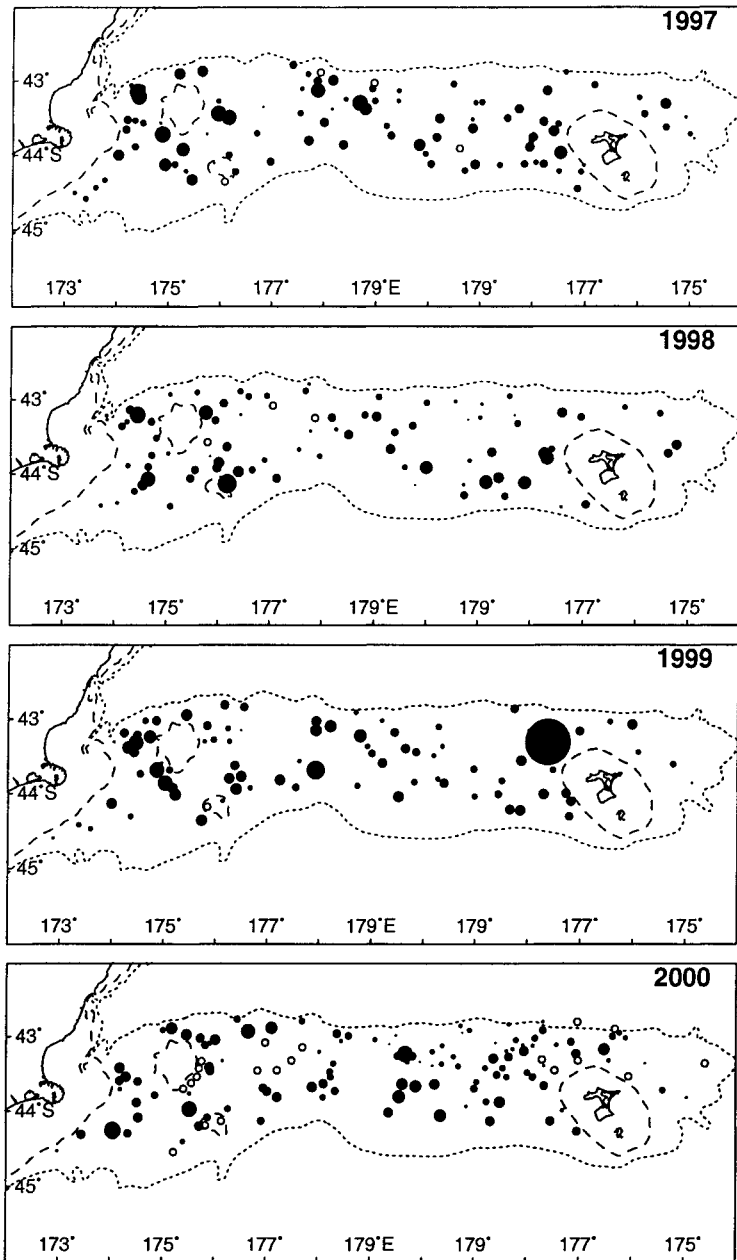


Figure 7m: *continued.*

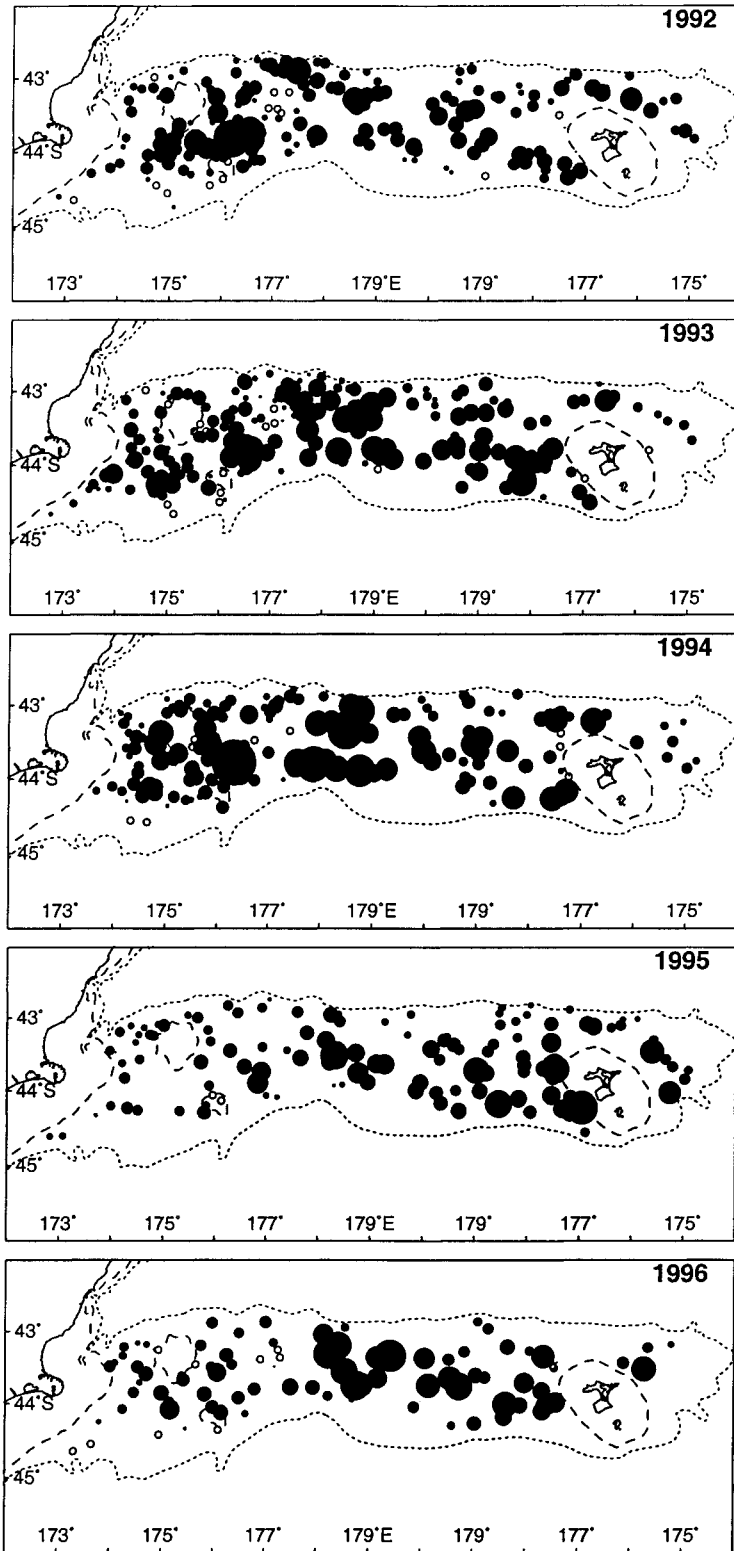


Figure 7n: Catch rates (kg.km<sup>-2</sup>) of lockdown dory. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate 455 kg.km<sup>-2</sup>. (See Table 3 for station numbers).

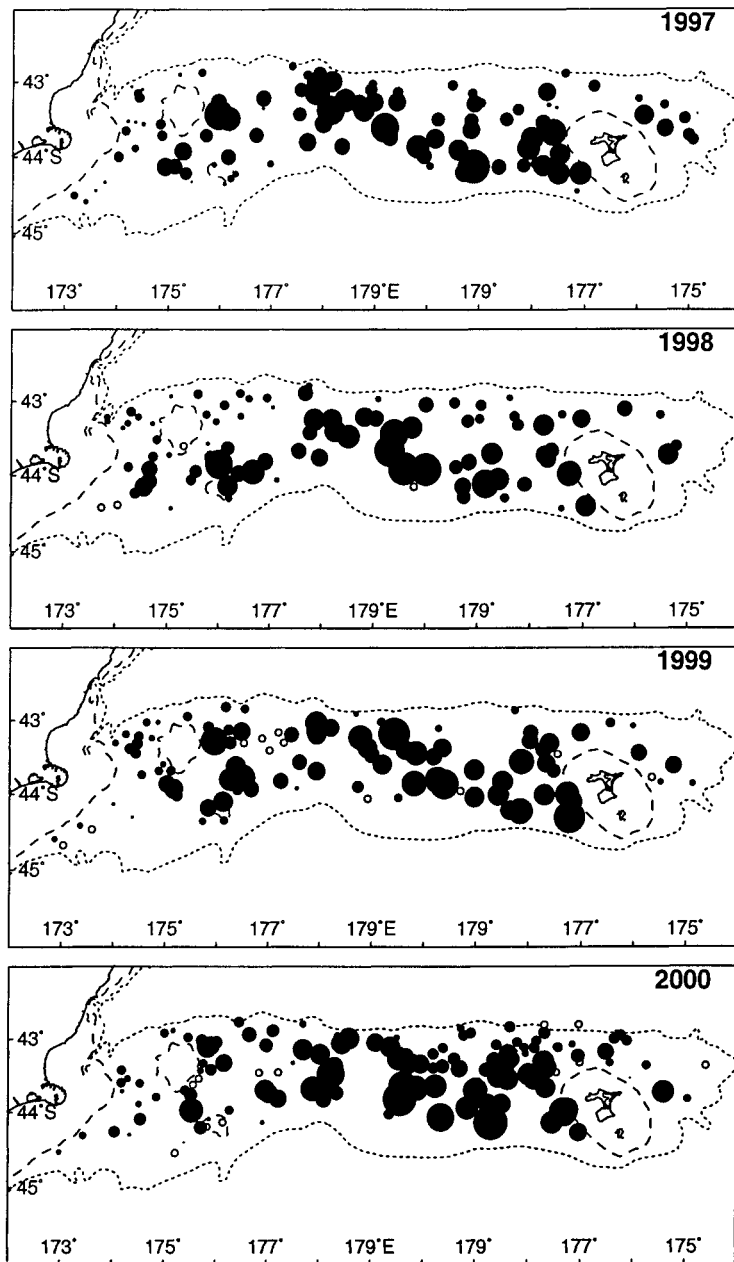


Figure 7n: *continued.*

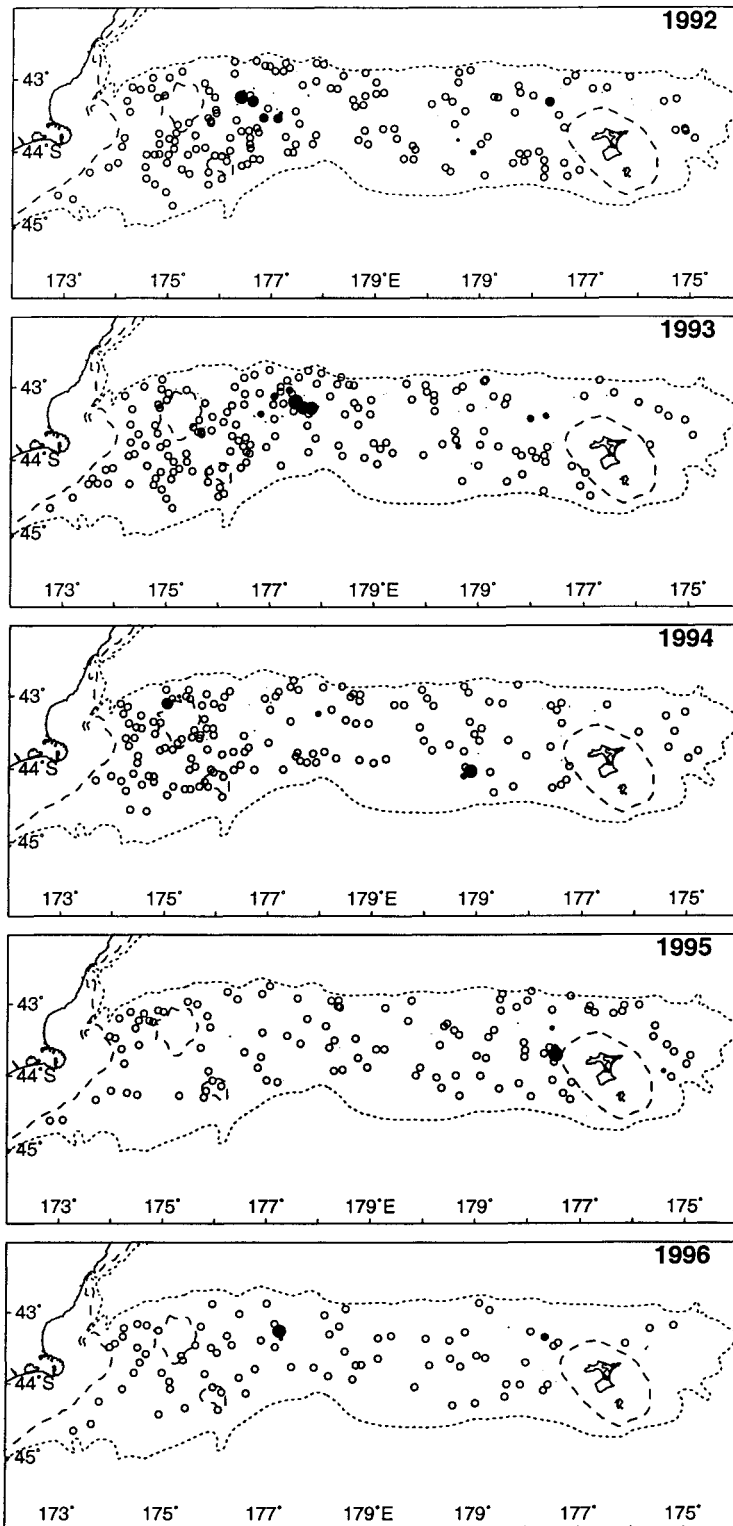


Figure 7o: Catch rates ( $\text{kg}\cdot\text{km}^{-2}$ ) of orange perch. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $2\,481\text{ kg}\cdot\text{km}^{-2}$ . (See Table 3 for station numbers).

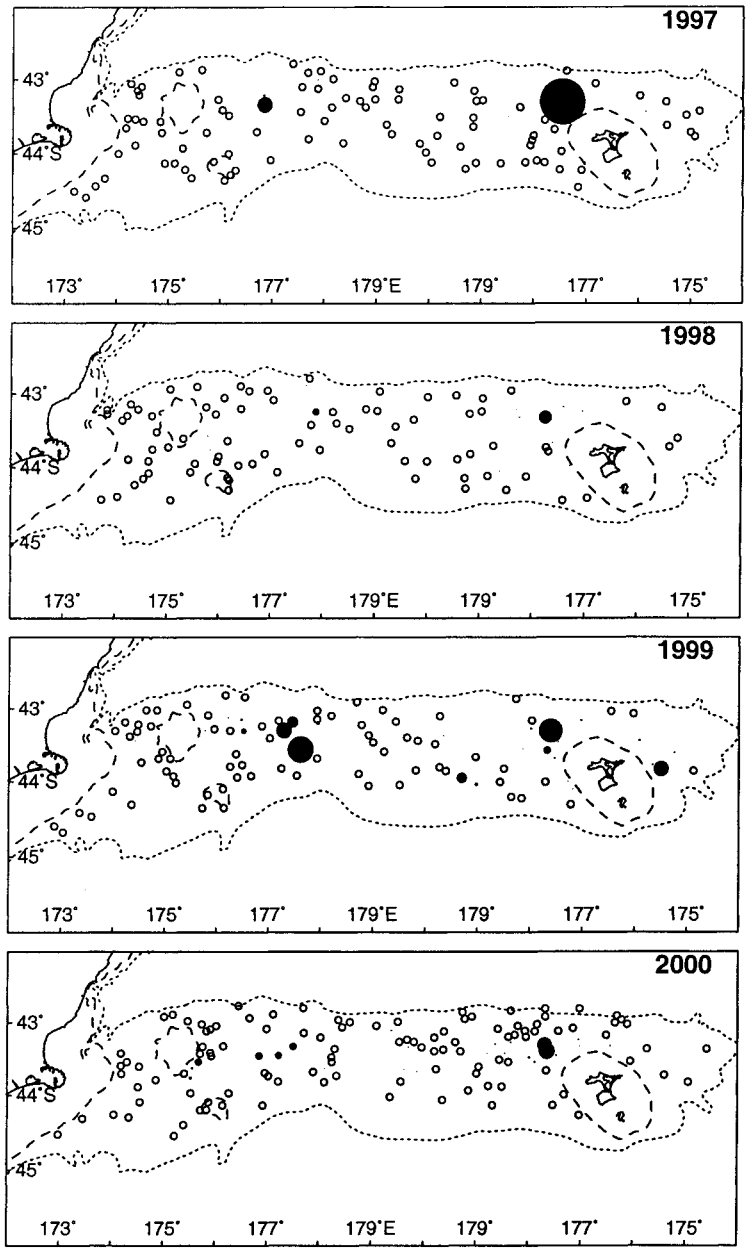


Figure 7o: *continued.*

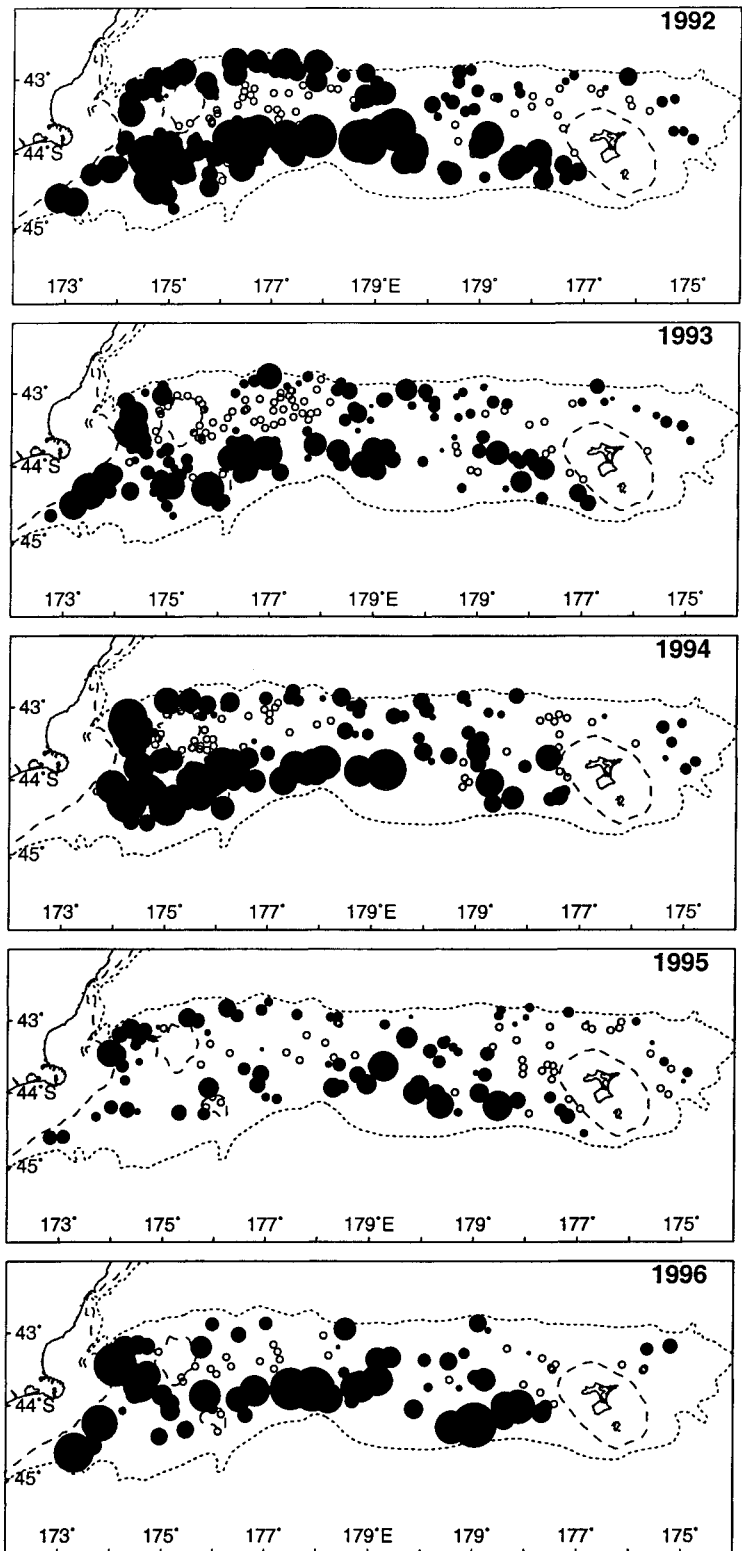


Figure 7p: Catch rates ( $\text{kg.km}^{-2}$ ) of pale ghost shark. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $279 \text{ kg.km}^{-2}$ . (See Table 3 for station numbers).

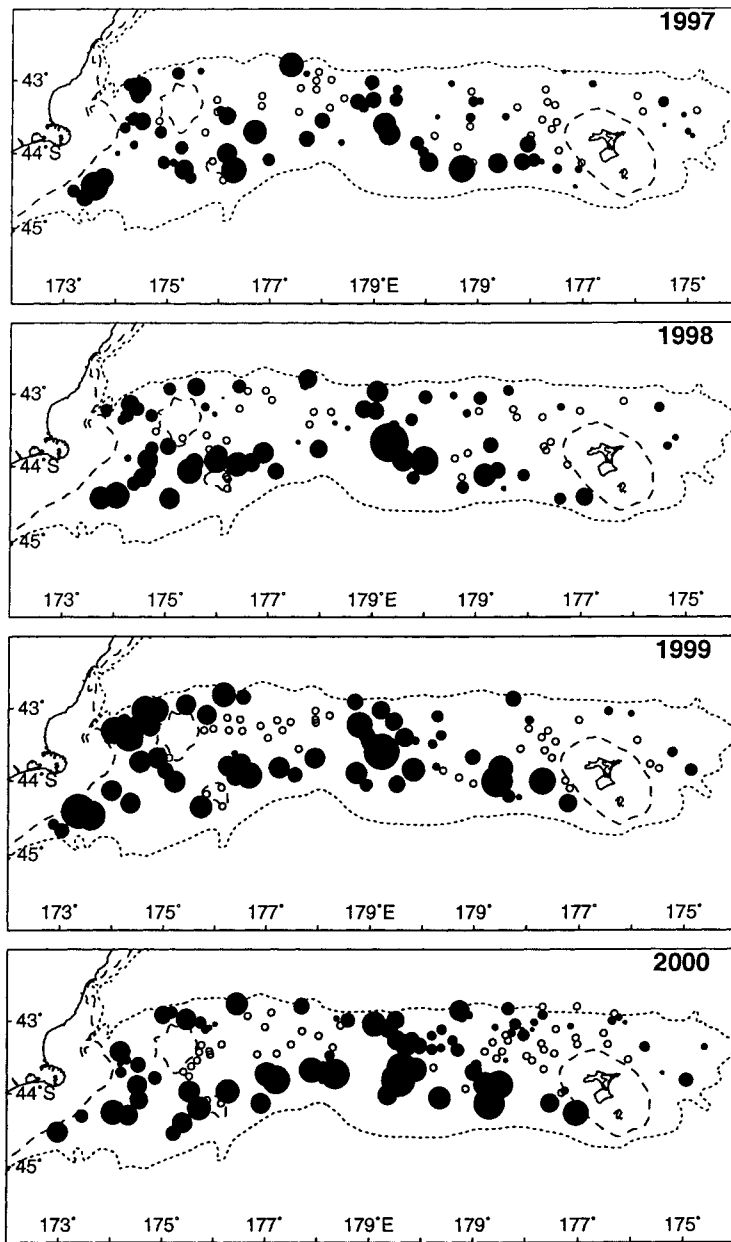


Figure 7p: *continued.*

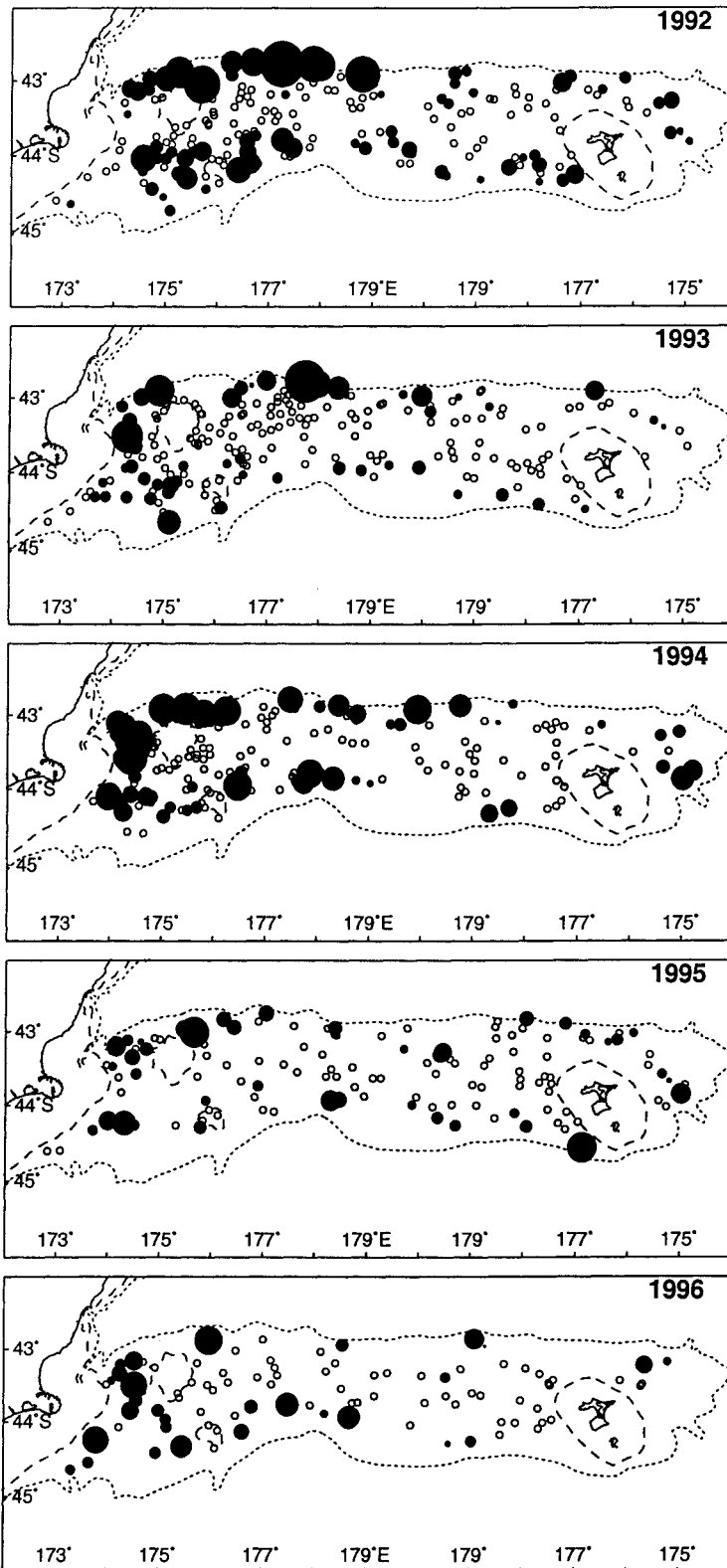


Figure 7q: Catch rates ( $\text{kg.km}^{-2}$ ) of ribaldo. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $70 \text{ kg.km}^{-2}$ . (See Table 3 for station numbers).

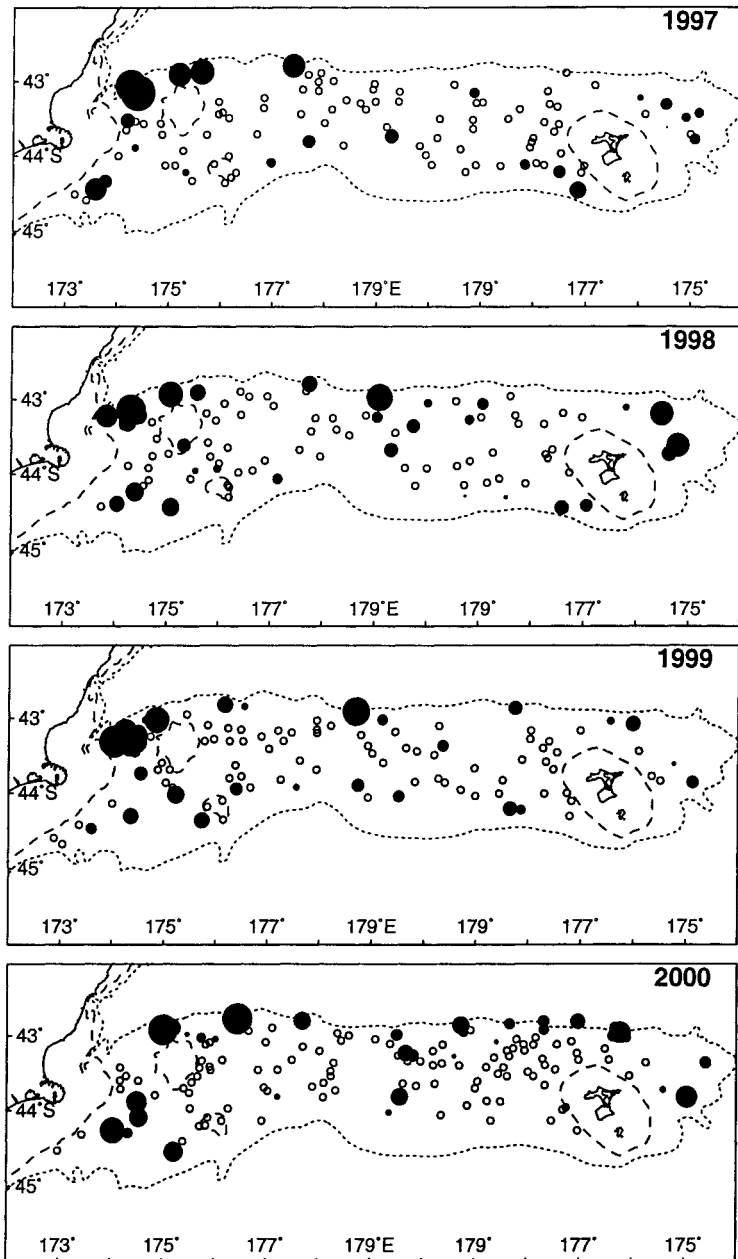


Figure 7q: *continued.*

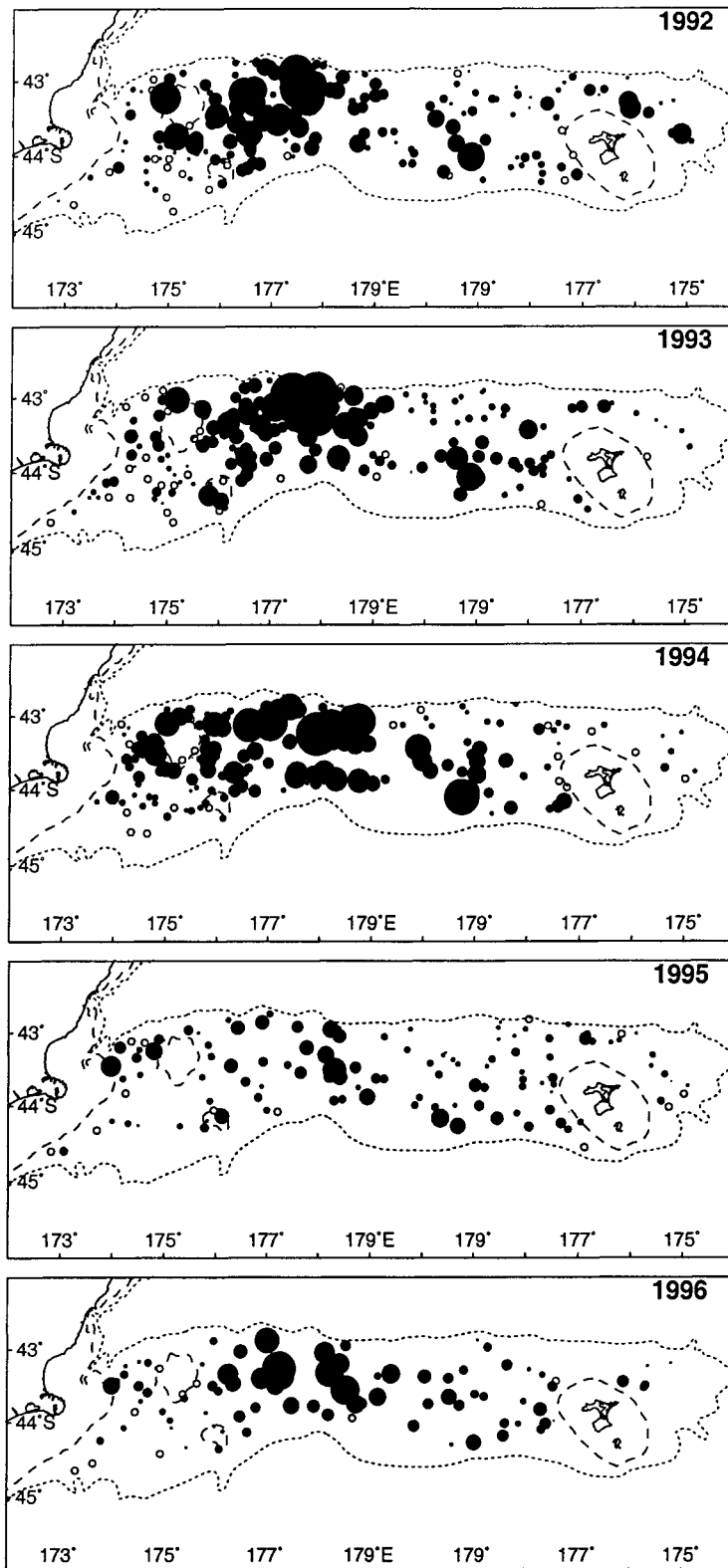


Figure 7r: Catch rates ( $\text{kg}\cdot\text{km}^{-2}$ ) of sea perch. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $287 \text{ kg}\cdot\text{km}^{-2}$ . (See Table 3 for station numbers).

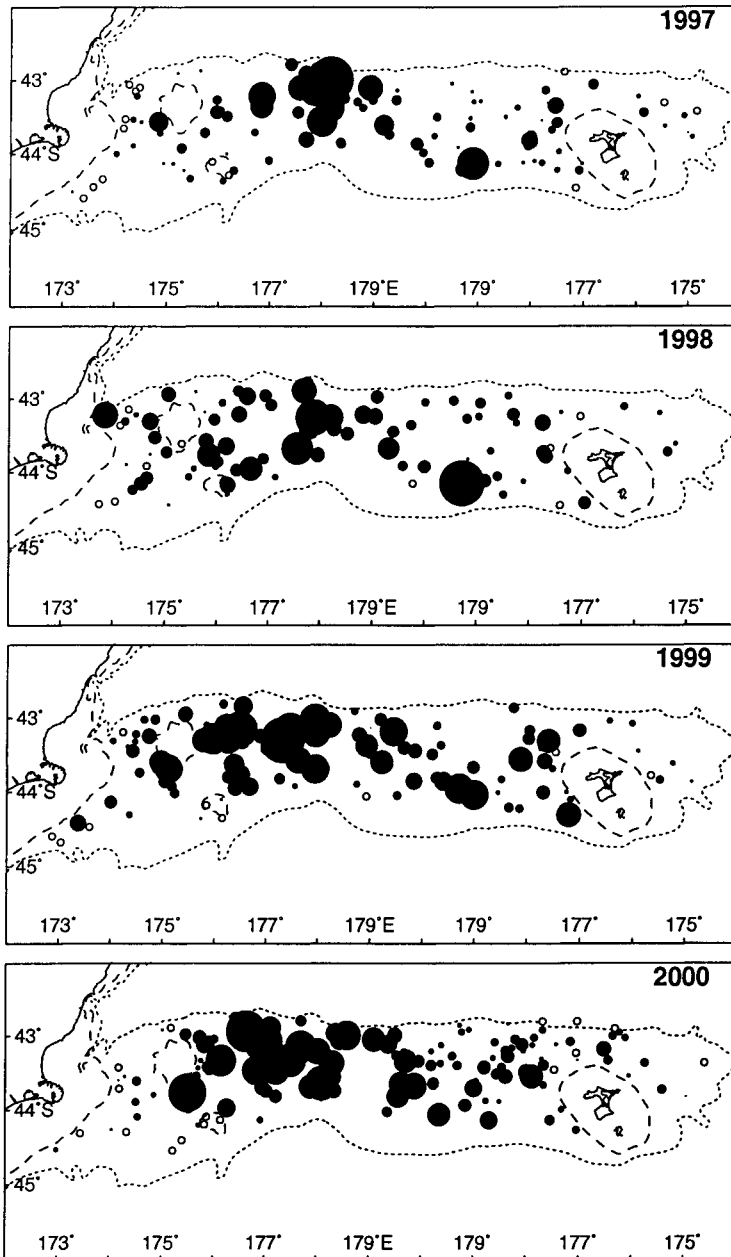


Figure 7r: *continued.*

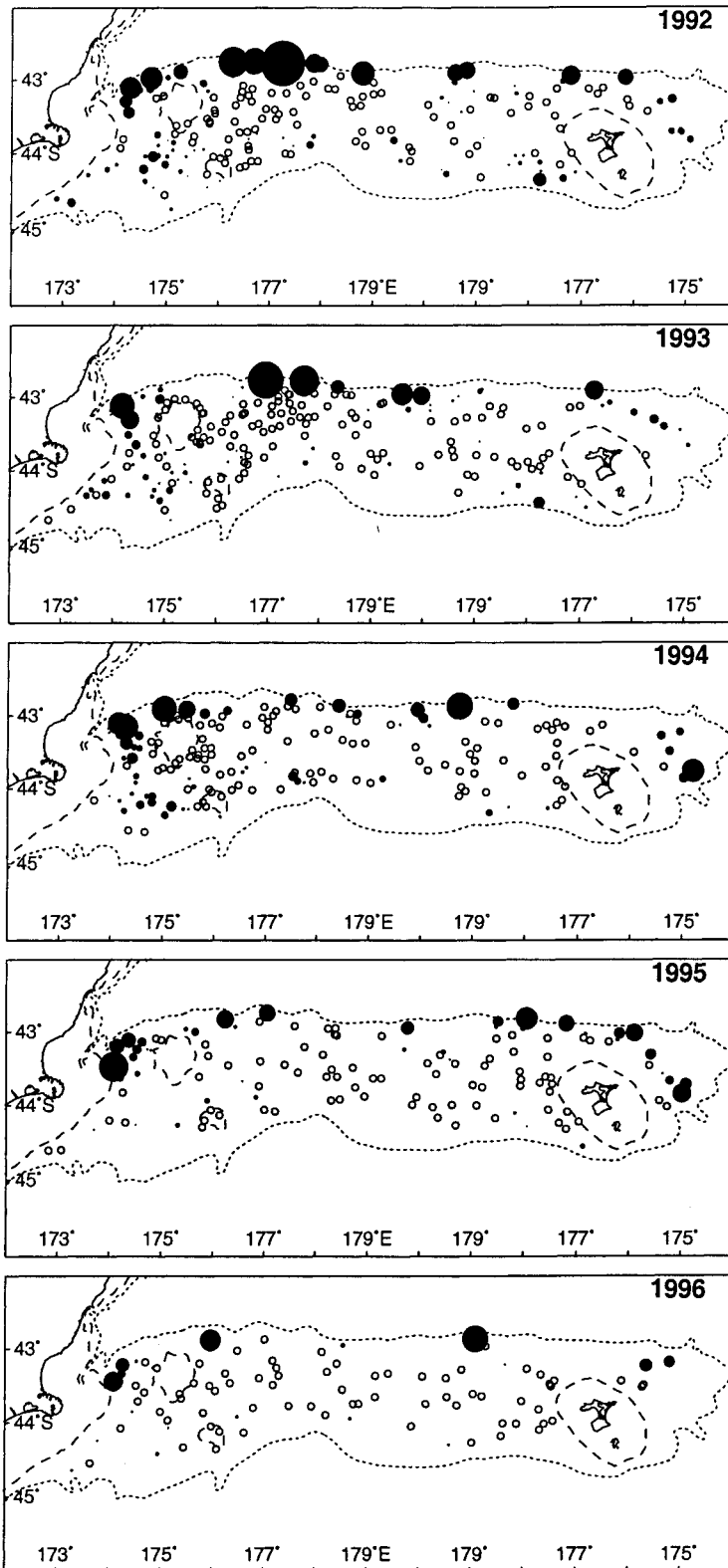


Figure 7s: Catch rates ( $\text{kg}\cdot\text{km}^{-2}$ ) of shovelnose dogfish. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $1\,556\text{ kg}\cdot\text{km}^{-2}$ . (See Table 3 for station numbers).

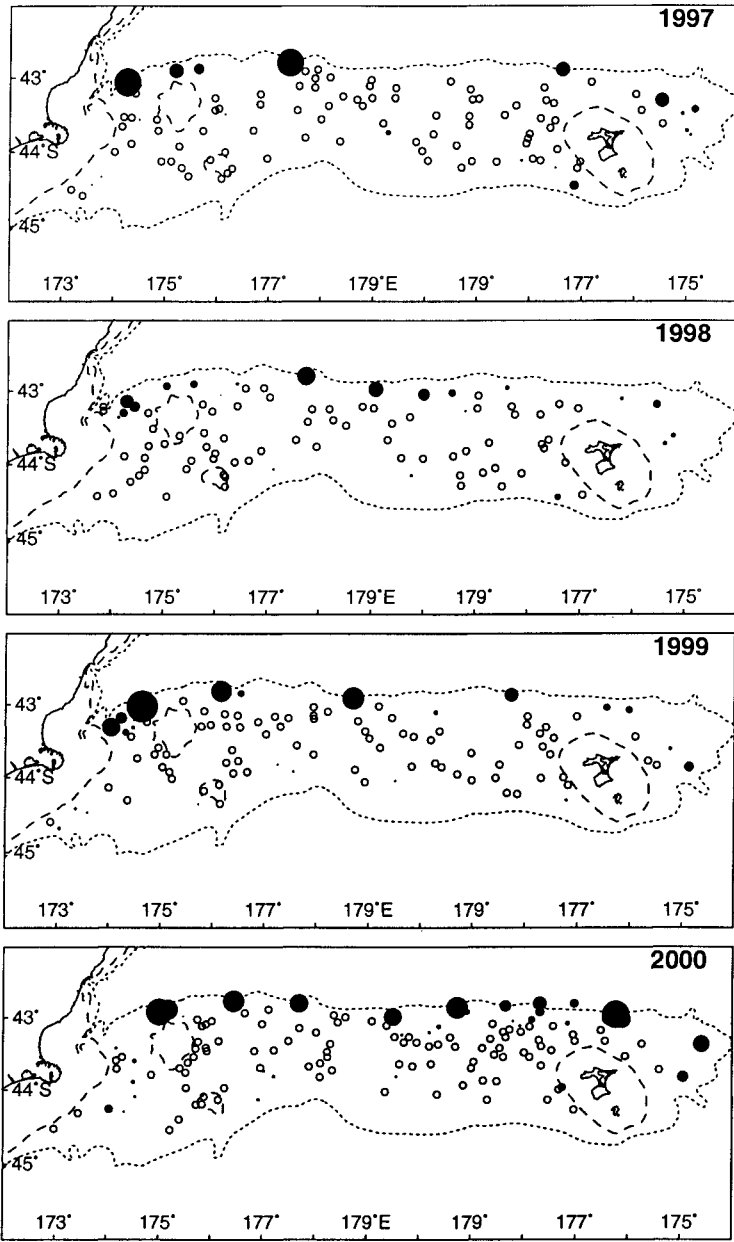


Figure 7s: *continued.*

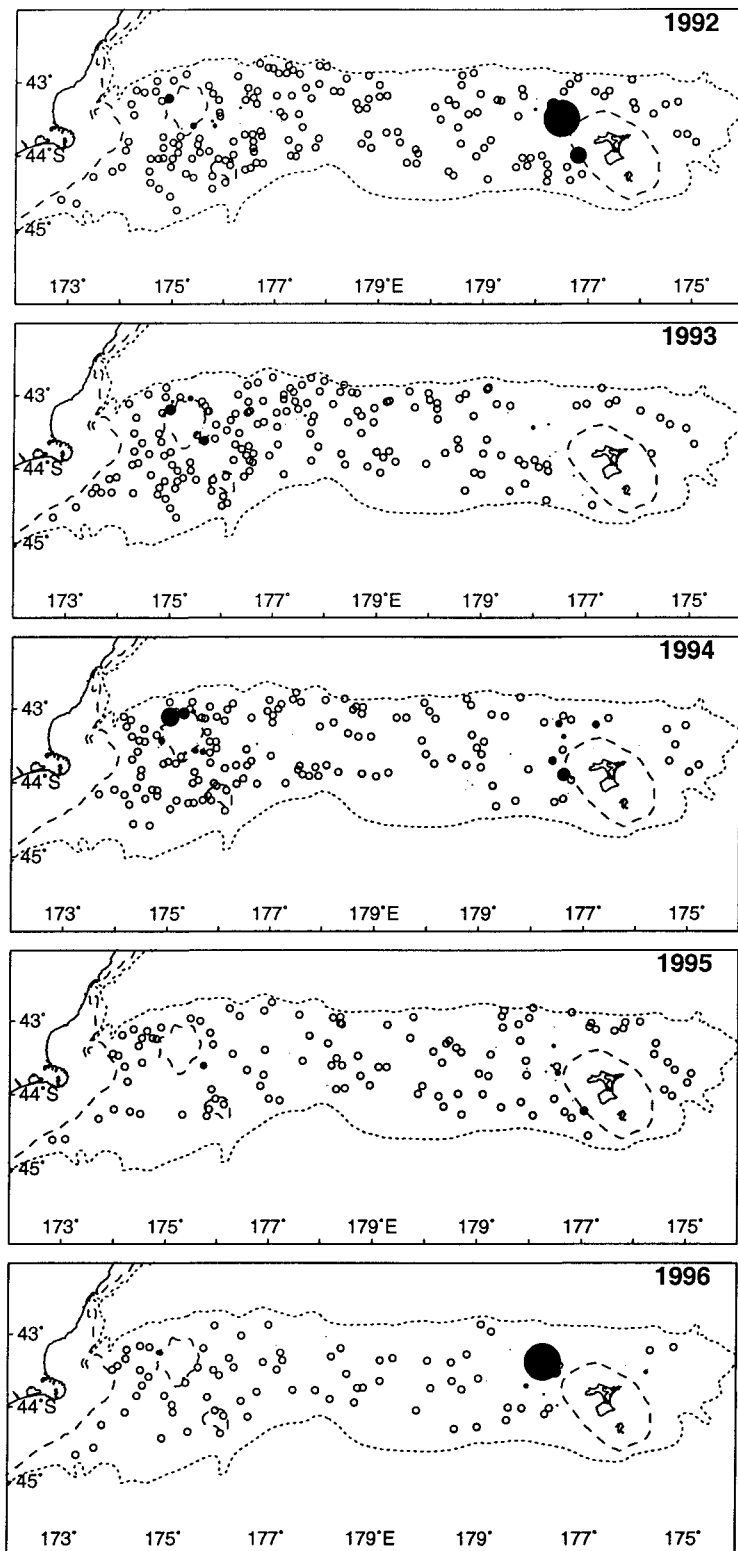


Figure 7t: Catch rates ( $\text{kg}\cdot\text{km}^{-2}$ ) of silver dory. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $3\ 165\ \text{kg}\cdot\text{km}^{-2}$ . (See Table 3 for station numbers).

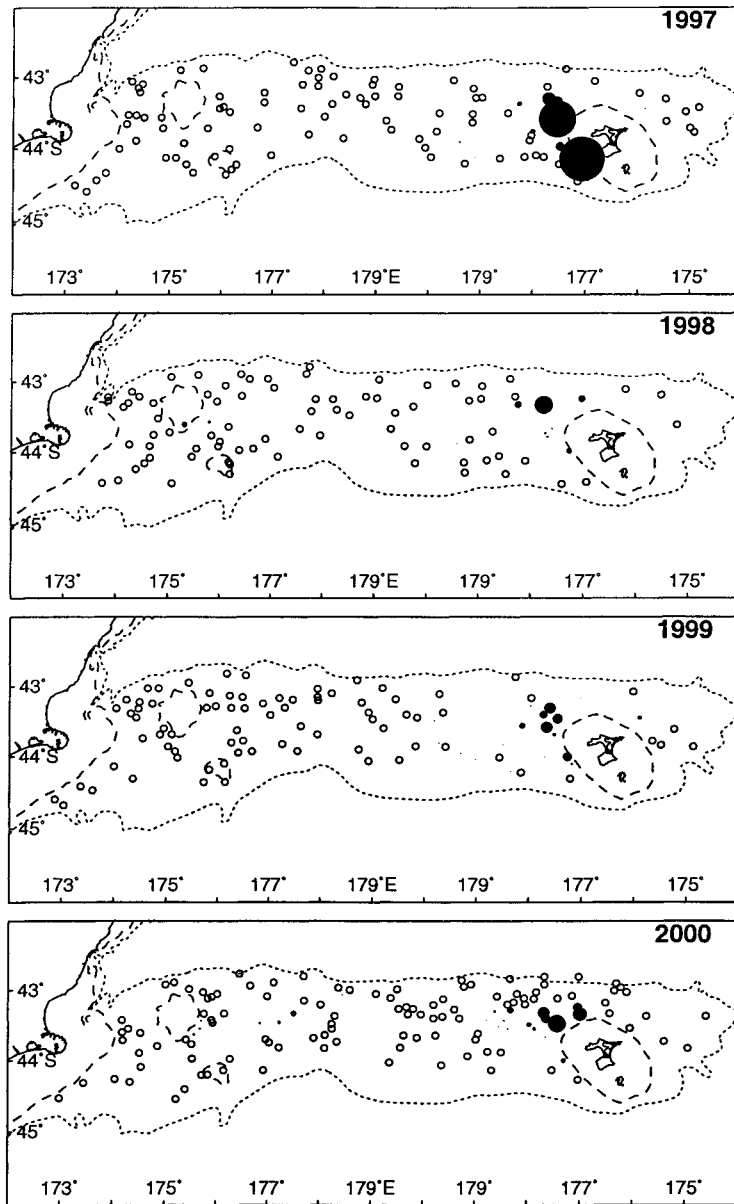


Figure 7t: *continued.*

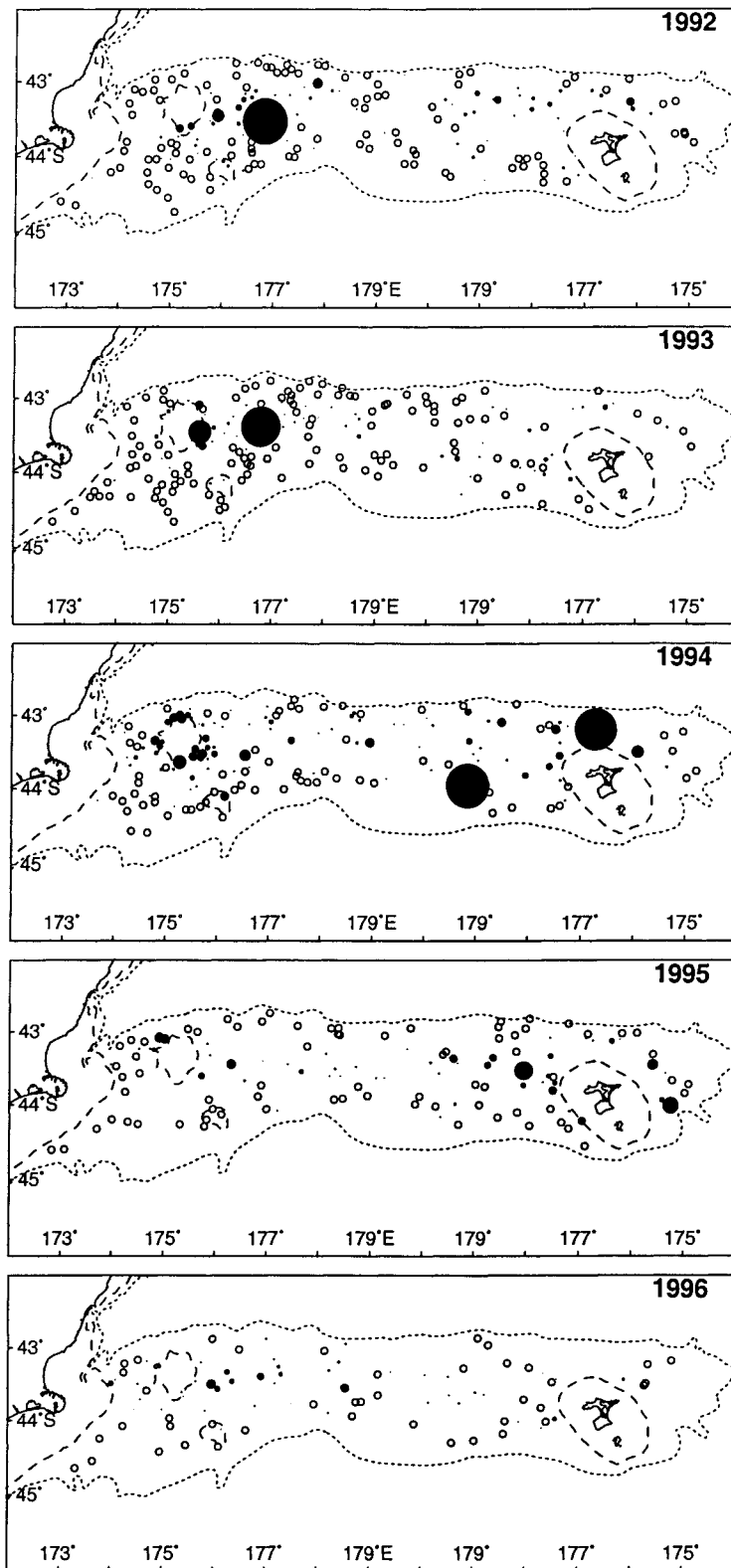


Figure 7u: Catch rates ( $\text{kg.km}^{-2}$ ) of silver warehou. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate 4 729  $\text{kg.km}^{-2}$ . (See Table 3 for station numbers).

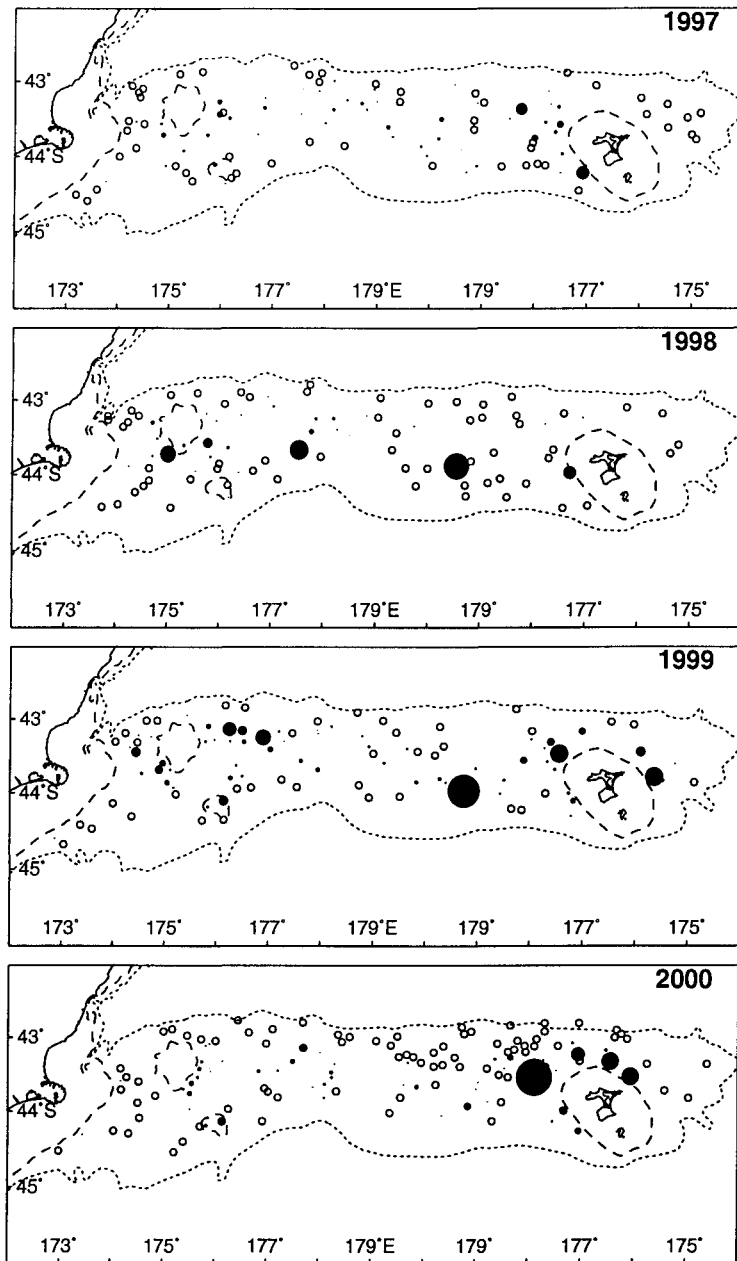


Figure 7u: *continued.*

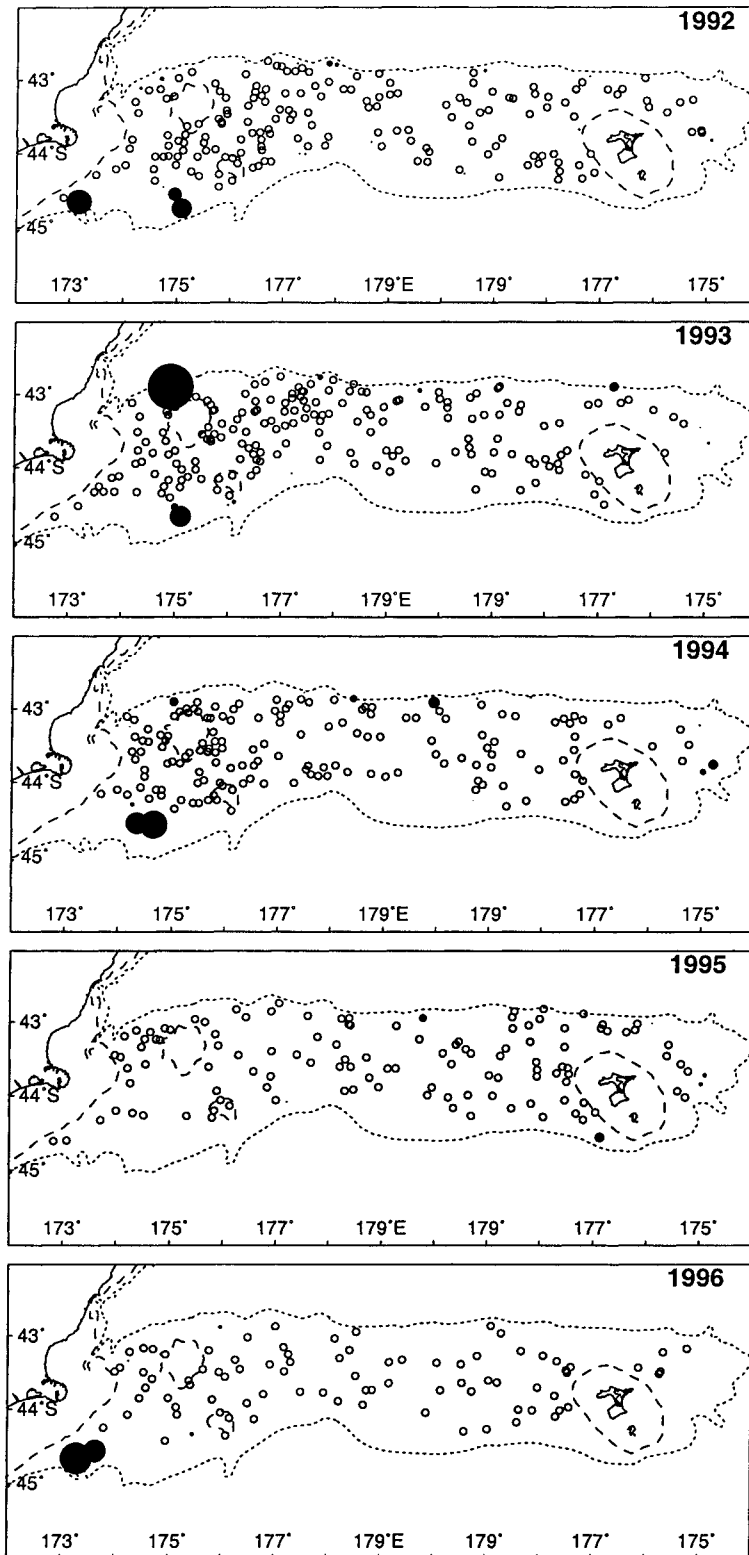


Figure 7v: Catch rates ( $\text{kg}\cdot\text{km}^{-2}$ ) of smooth oreo. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $755 \text{ kg}\cdot\text{km}^{-2}$ . (See Table 3 for station numbers).

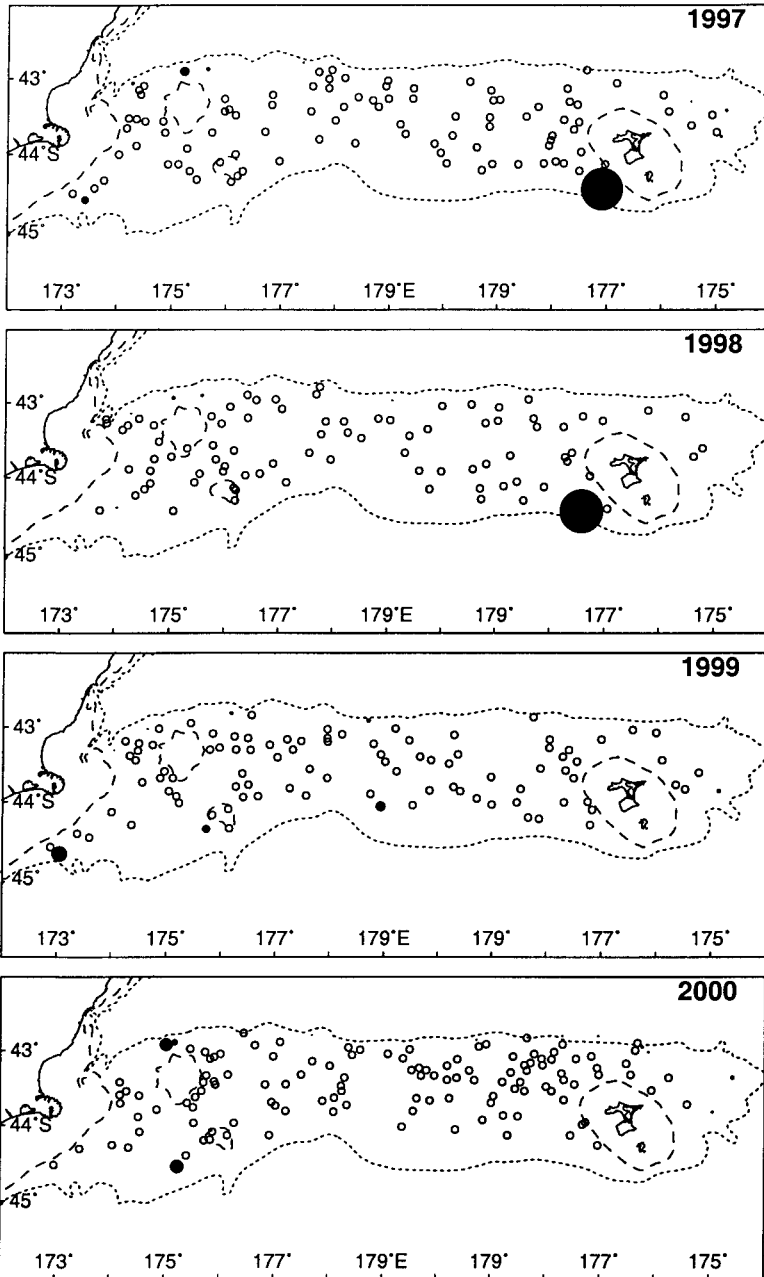


Figure 7v: continued

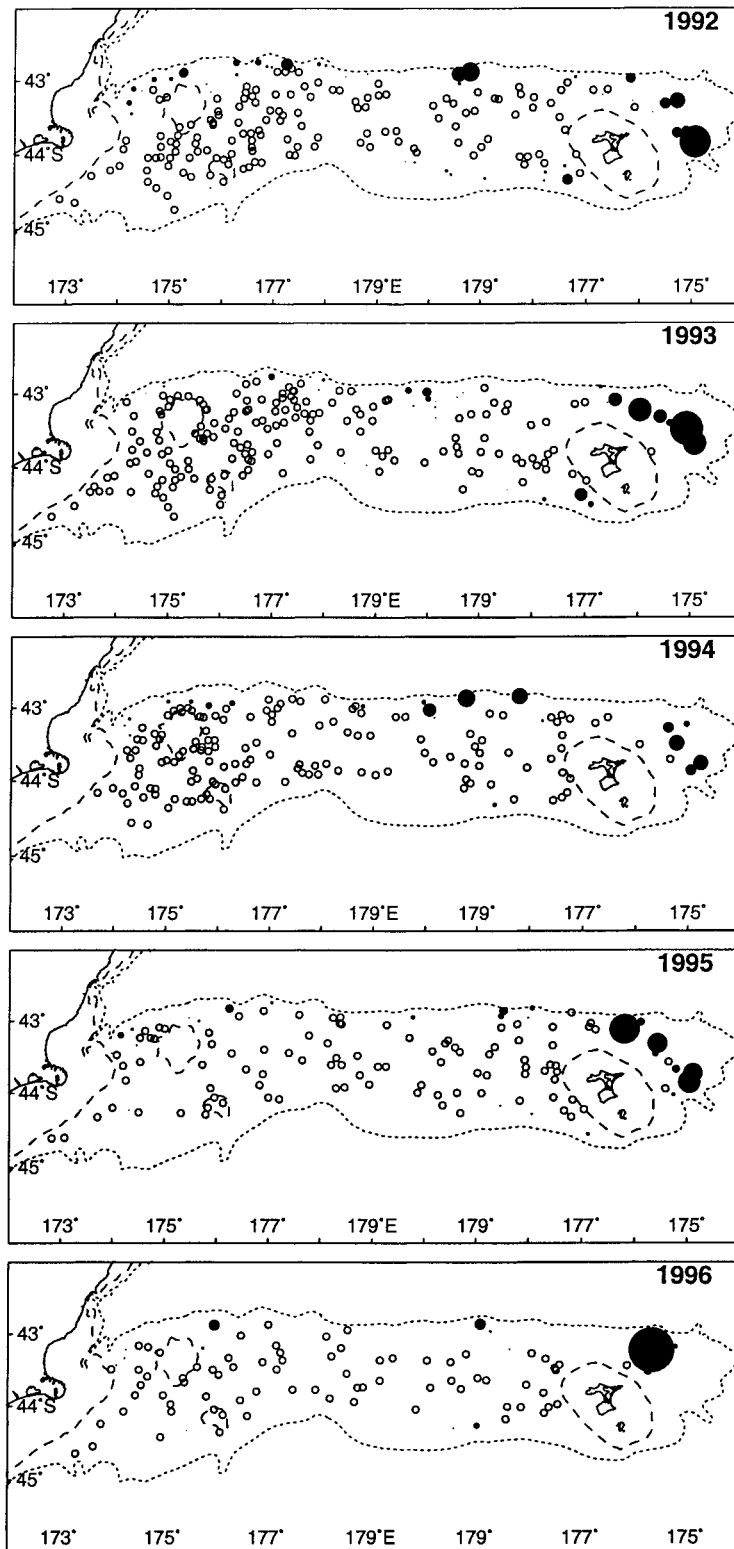


Figure 7w: Catch rates ( $\text{kg.km}^{-2}$ ) of spiky oreo. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $2\,649\text{ kg.km}^{-2}$ . (See Table 3 for station numbers).

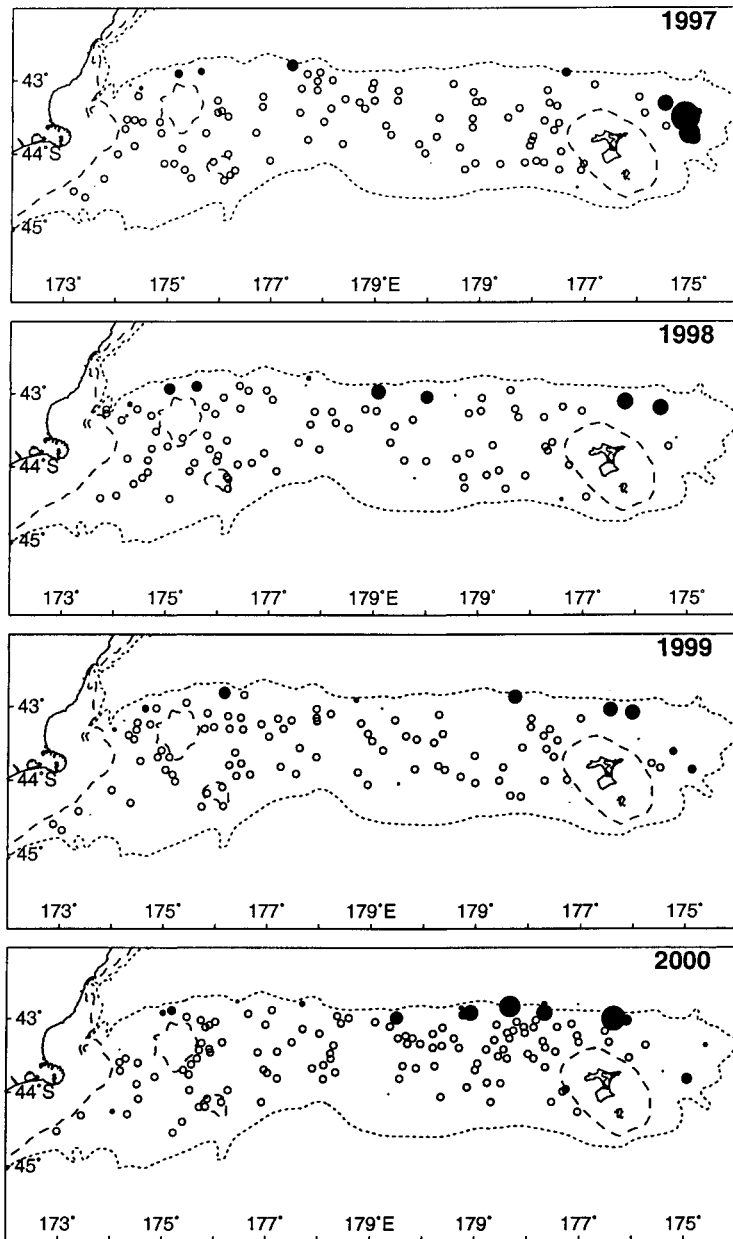


Figure 7w: *continued.*

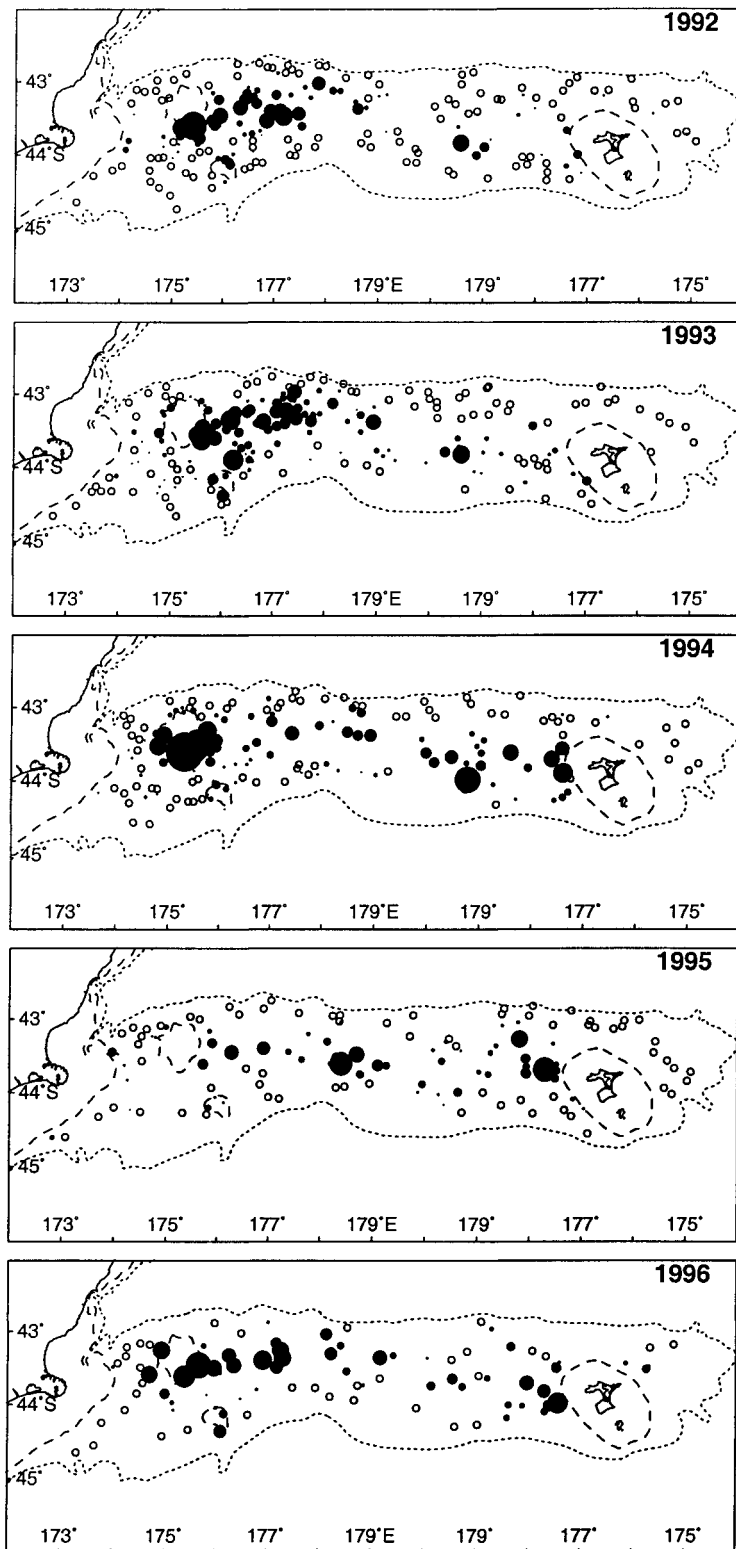


Figure 7x: Catch rates ( $\text{kg.km}^{-2}$ ) of spiny dogfish. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $1\,290\text{ kg.km}^{-2}$ . (See Table 3 for station numbers).

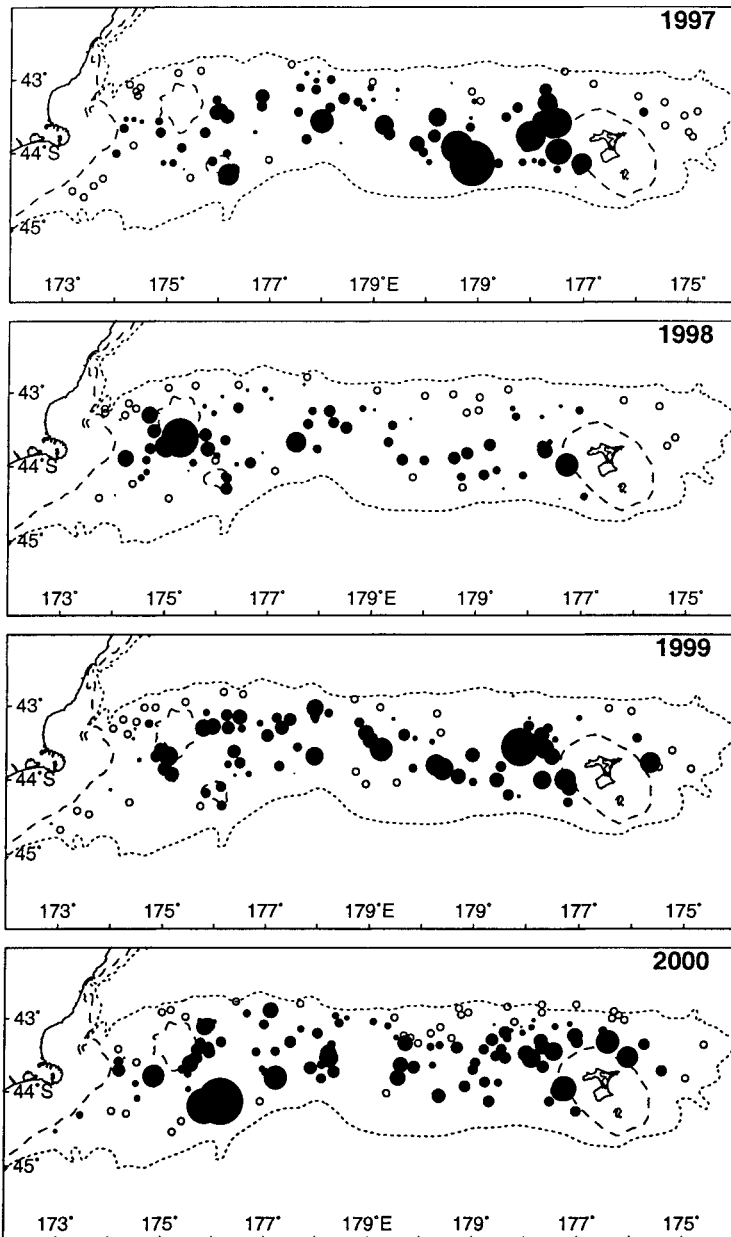


Figure 7x: *continued.*

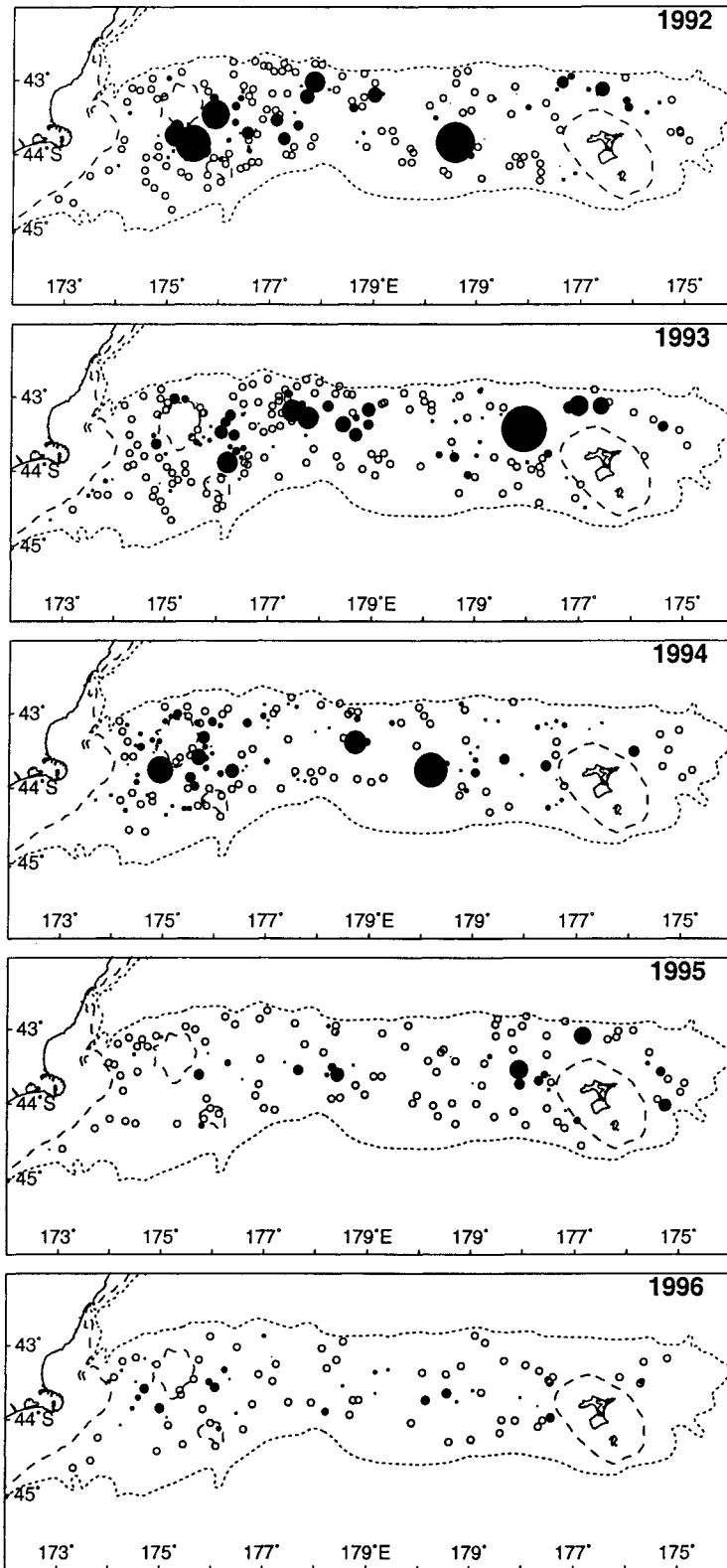


Figure 7y: Catch rates ( $\text{kg.km}^{-2}$ ) of white warehou. Filled circle area is proportional to catch rate. Open circles are zero catch. Maximum catch rate  $828 \text{ kg.km}^{-2}$ . (See Table 3 for station numbers).

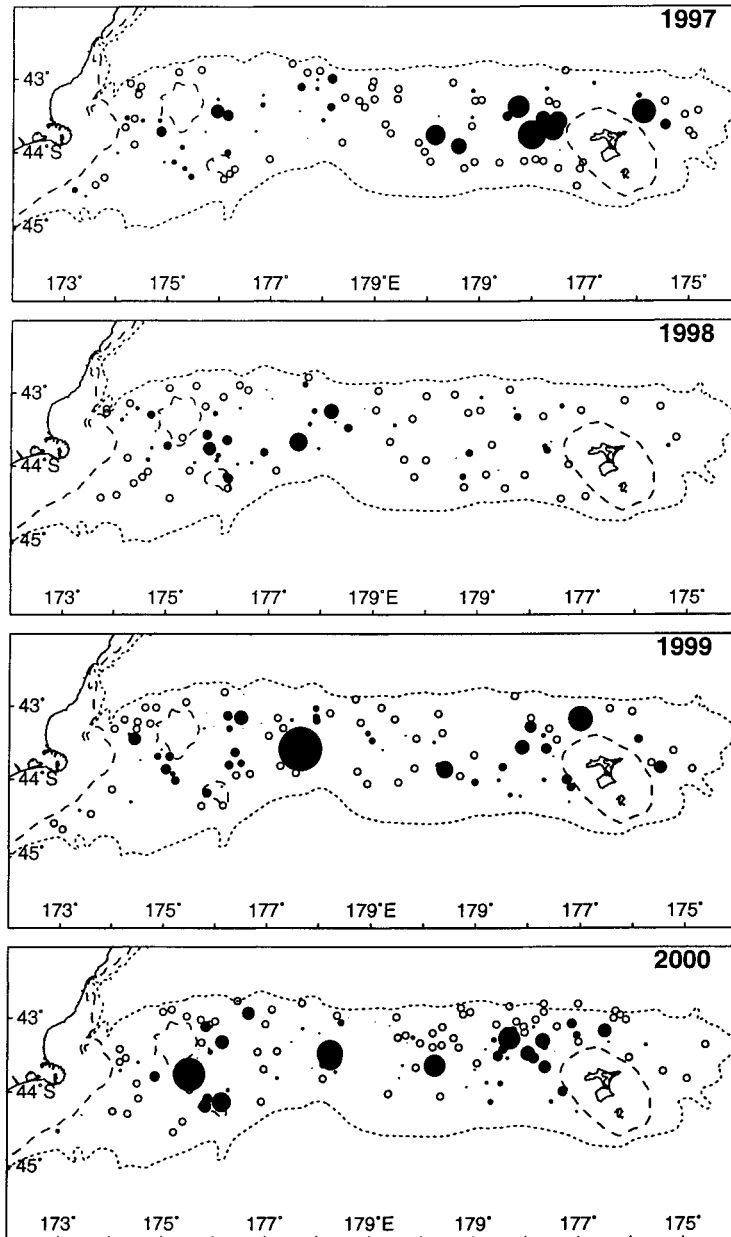


Figure 7y: *continued.*

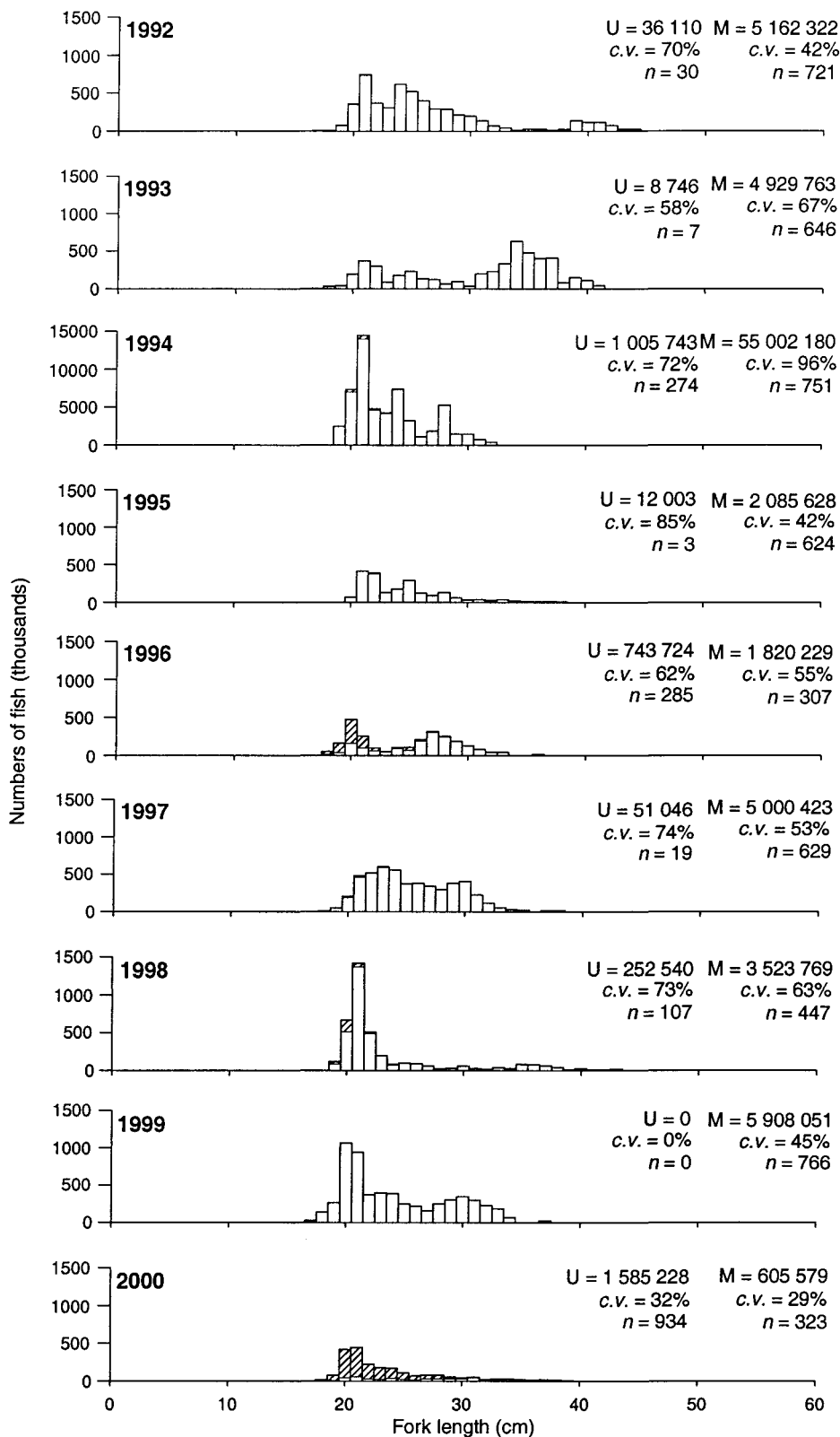


Figure 8a: Scaled length frequencies for male and unsexed alfonsino from Chatham Rise trawl survey time series. (Note scale change in 1994, c.v.; coefficient of variation; n, number of fish measured; M, number of male fish in population estimate, U, number of unsexed fish in population estimate.)

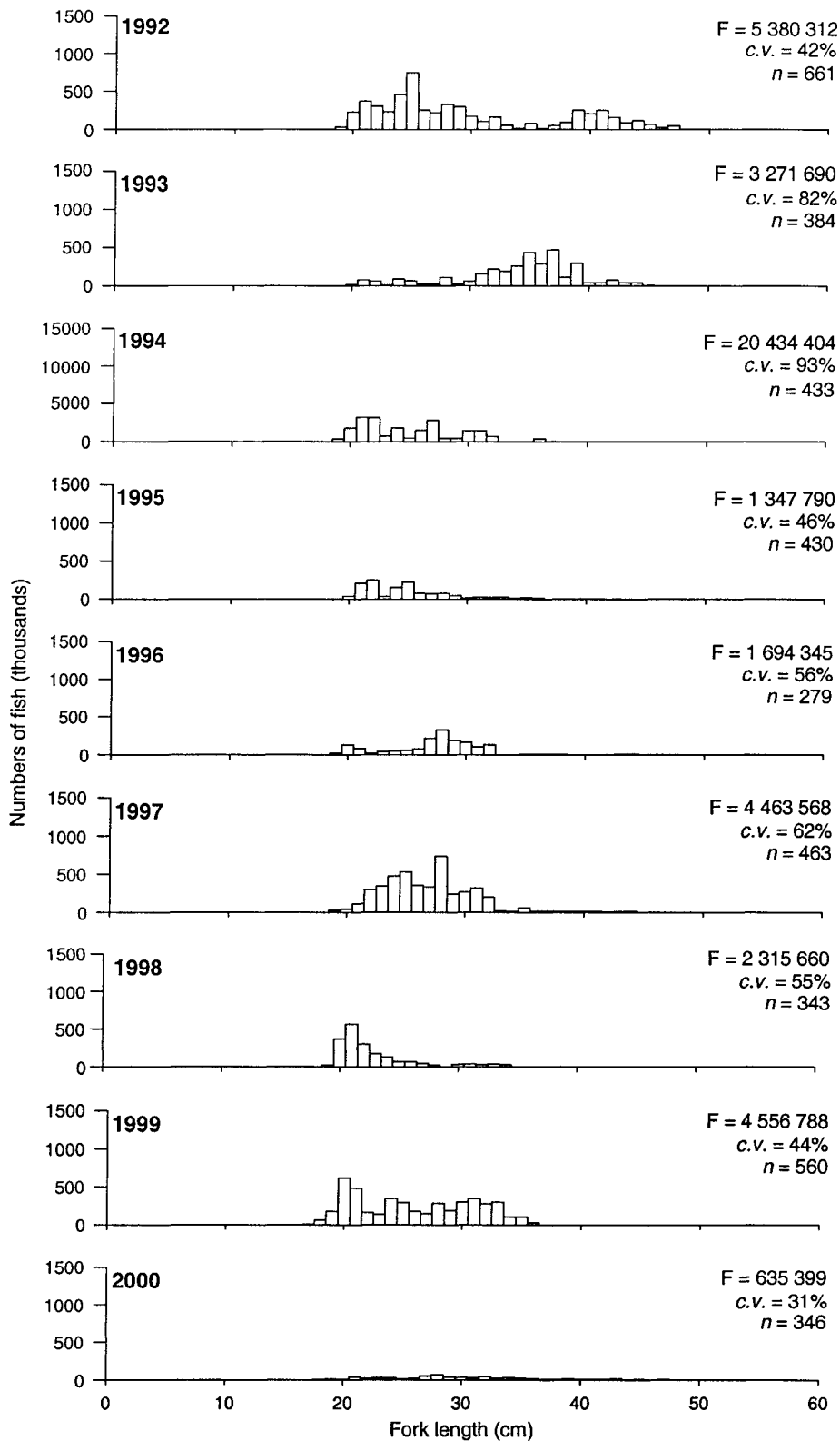


Figure 8b: Scaled length frequencies for female alfonsino from Chatham Rise trawl survey time series. (Note scale change in 1994, c.v.; coefficient of variation; n, number of fish measured; F, number of male fish in population estimate.)

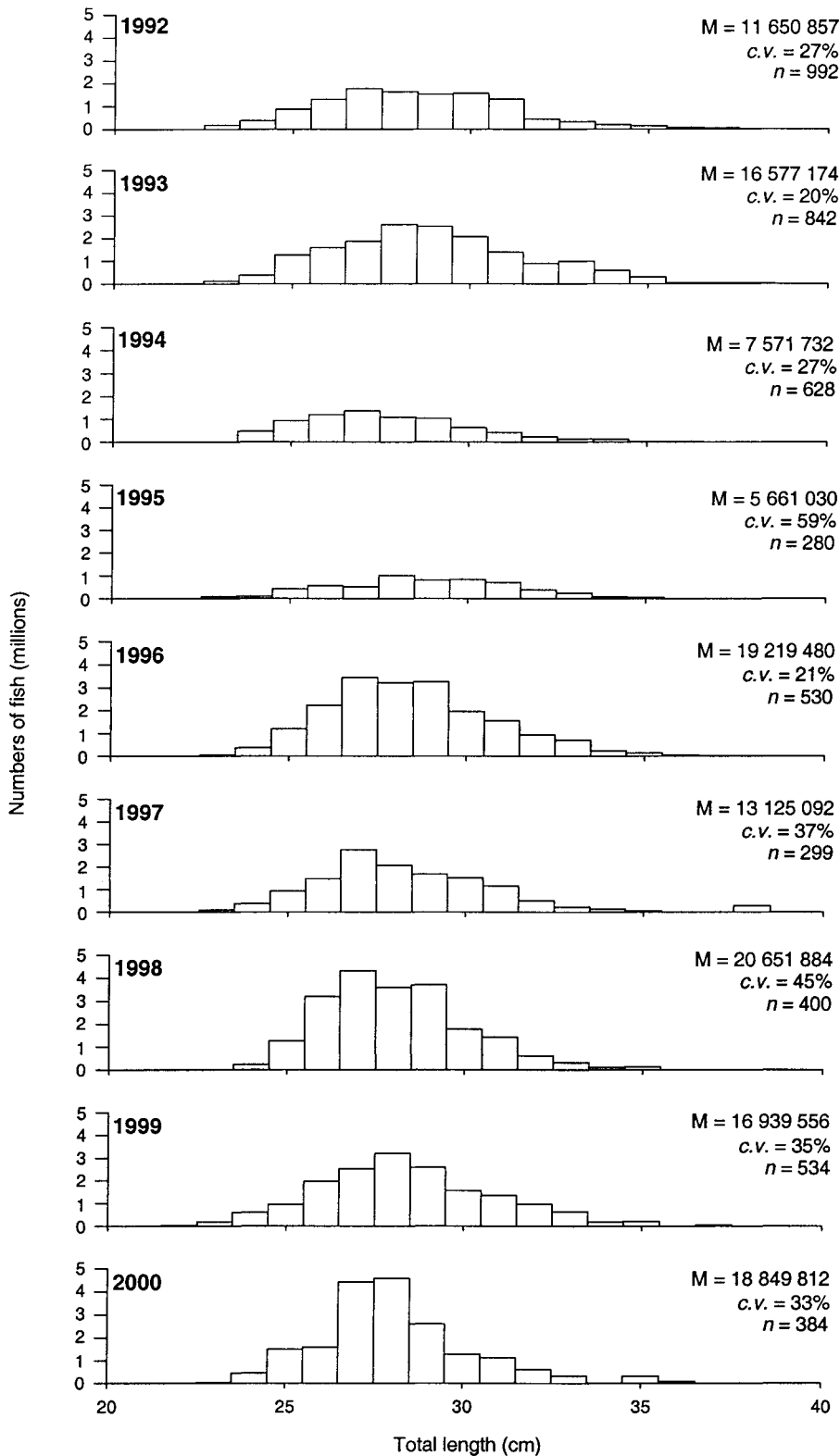


Figure 9a: Scaled length frequencies for male black oreo from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; M, number of male fish in population estimate.)

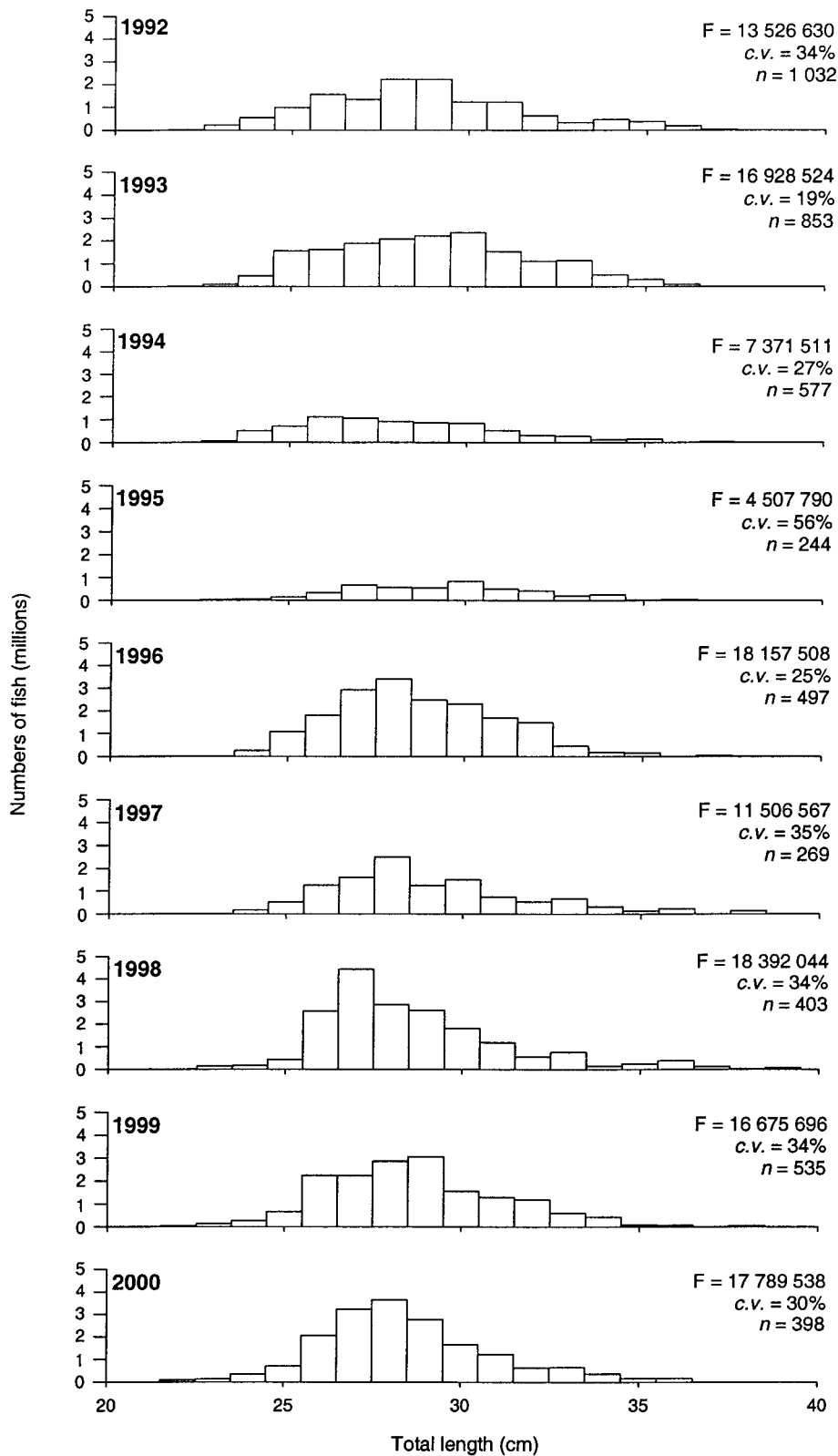
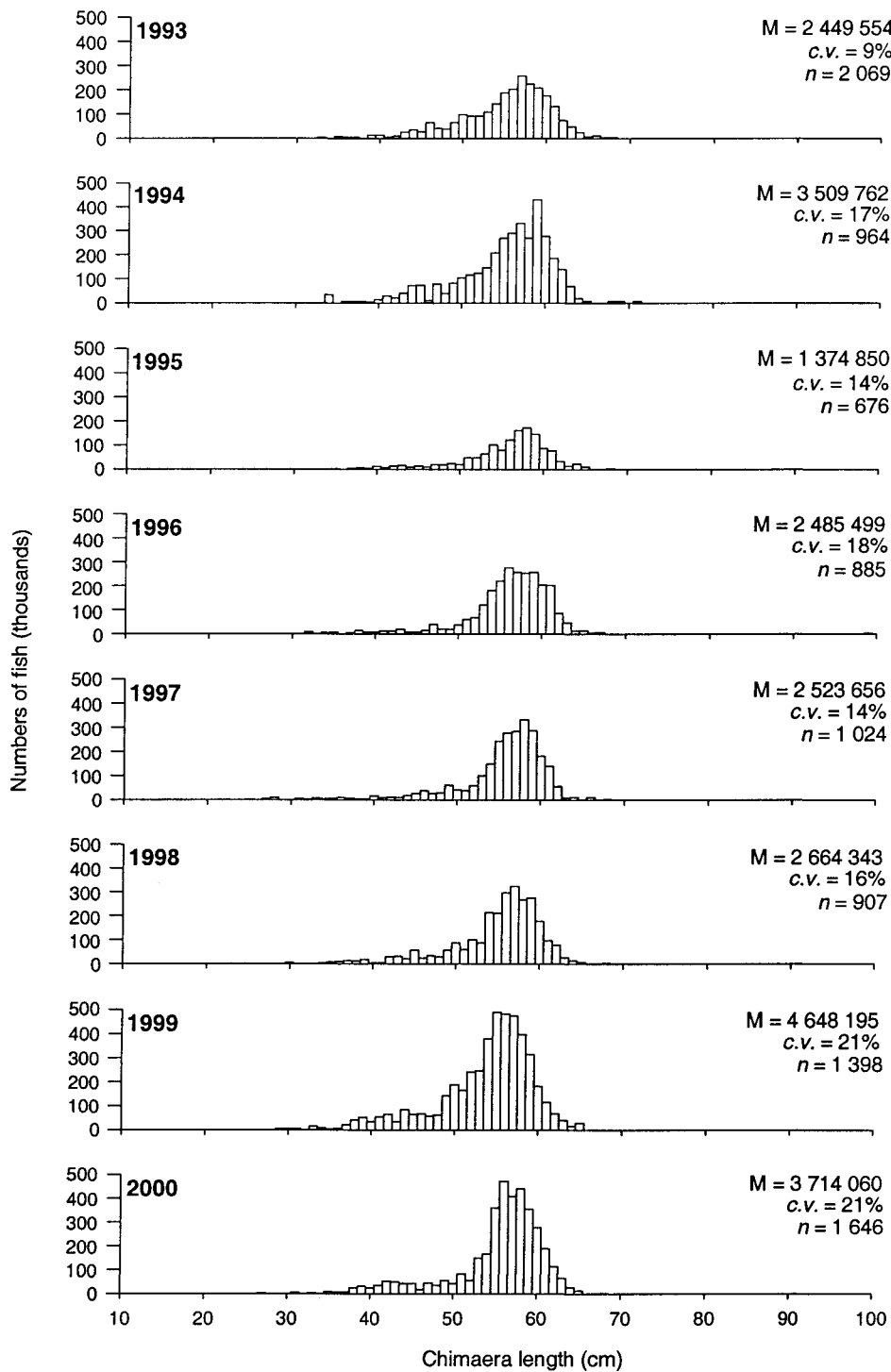
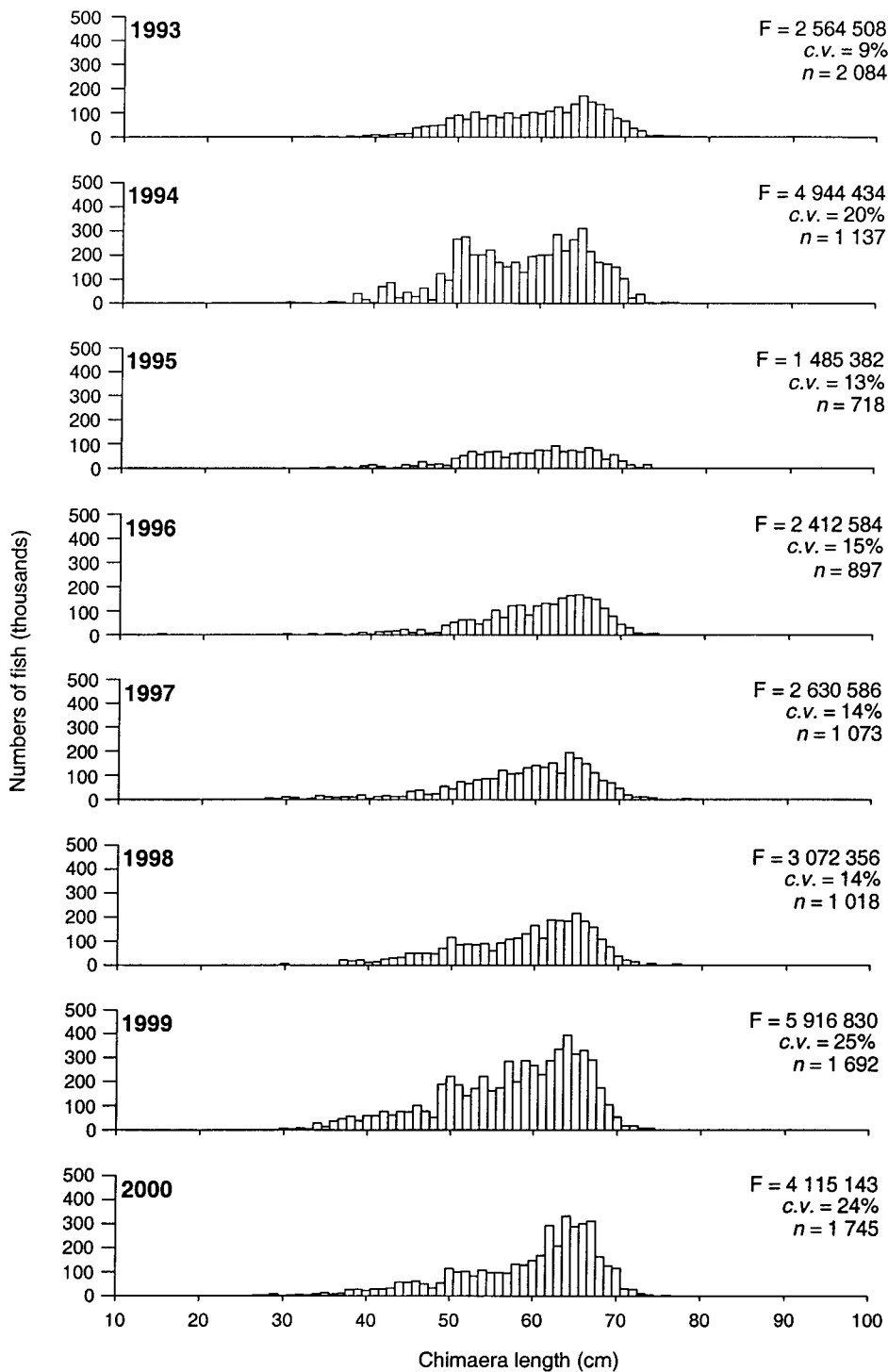


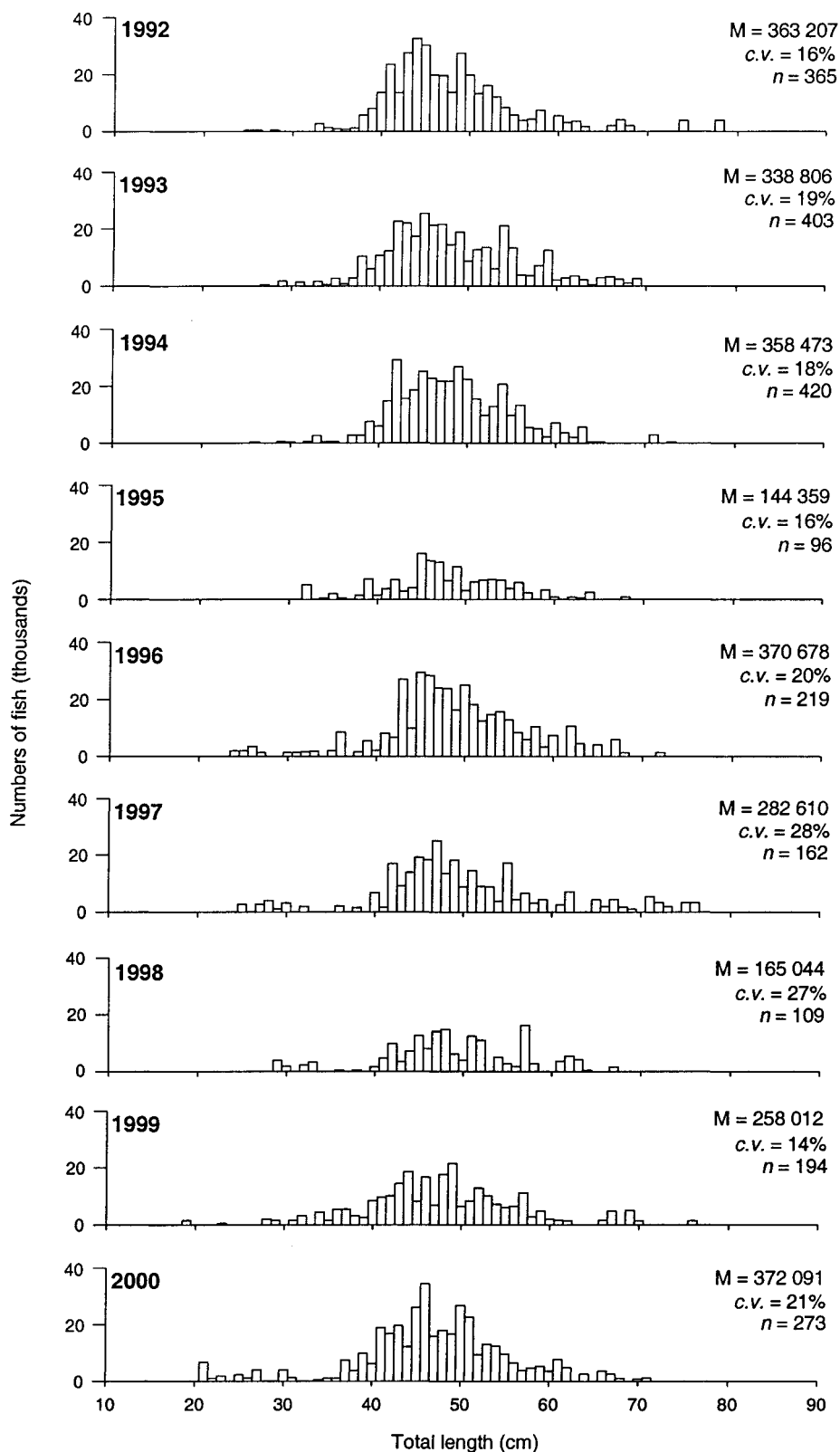
Figure 9b: Scaled length frequencies for female black oreo from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; F, number of male fish in population estimate.)



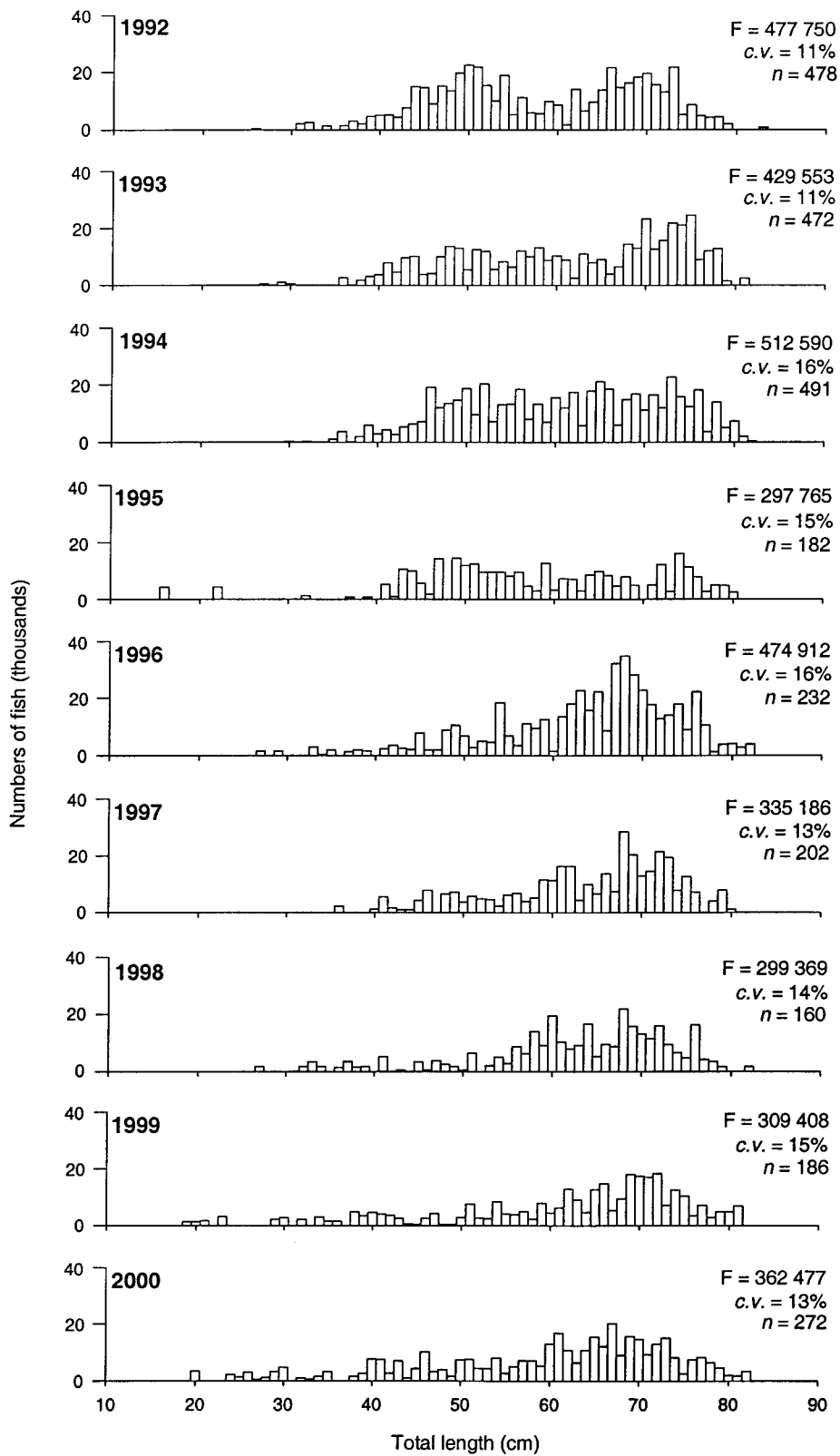
**Figure 10a: Scaled length frequencies for male dark ghost shark from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; M, number of male fish in population estimate.)**



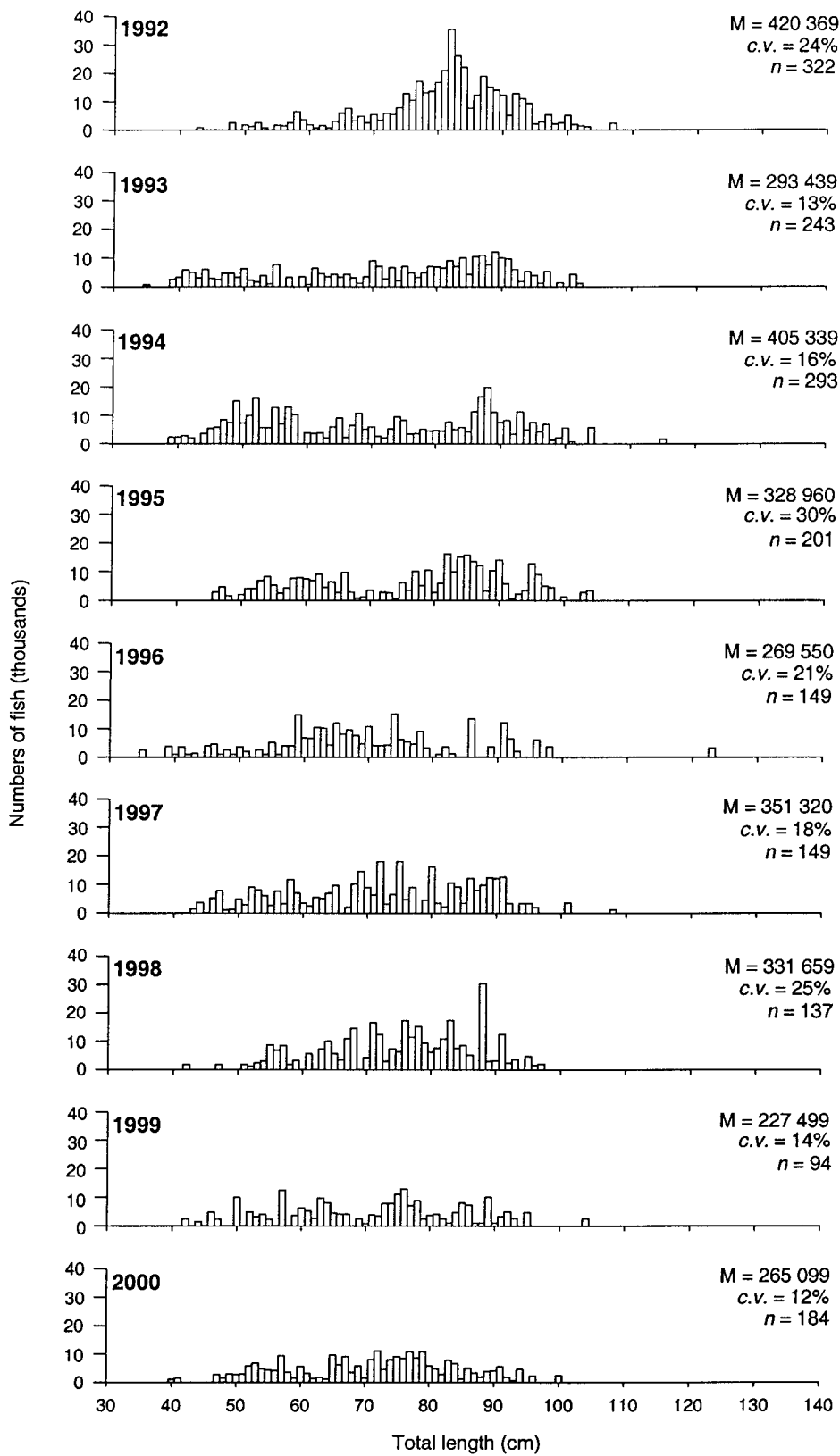
**Figure 10b: Scaled length frequencies for female dark ghost shark from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; F, number of female fish in population estimate.)**



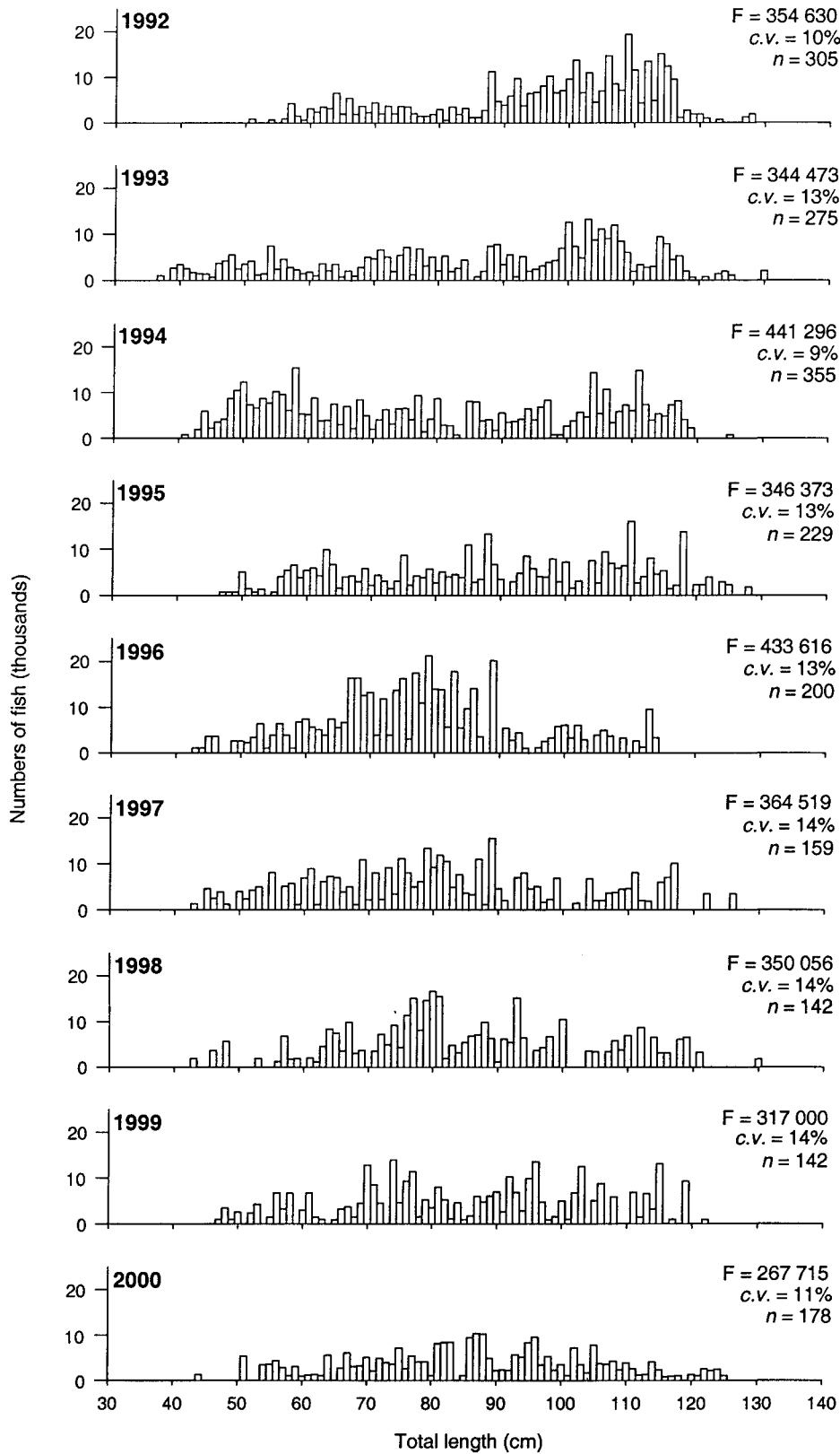
**Figure 11a; Scaled length frequencies for male giant stargazer from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; M, number of male fish in population estimate.)**



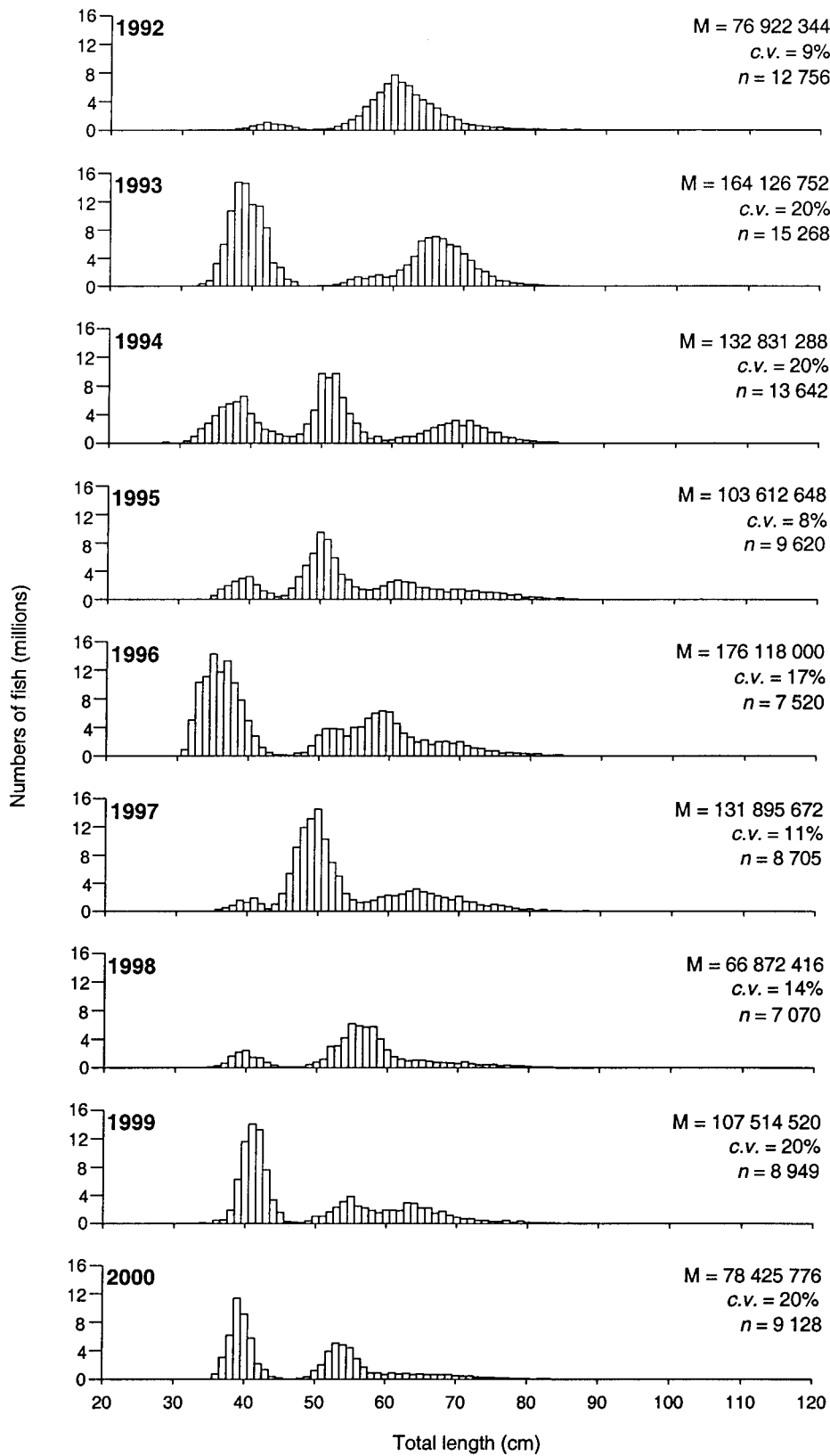
**Figure 11b: Scaled length frequencies for female giant stargazer from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; F, number of male fish in population estimate.)**



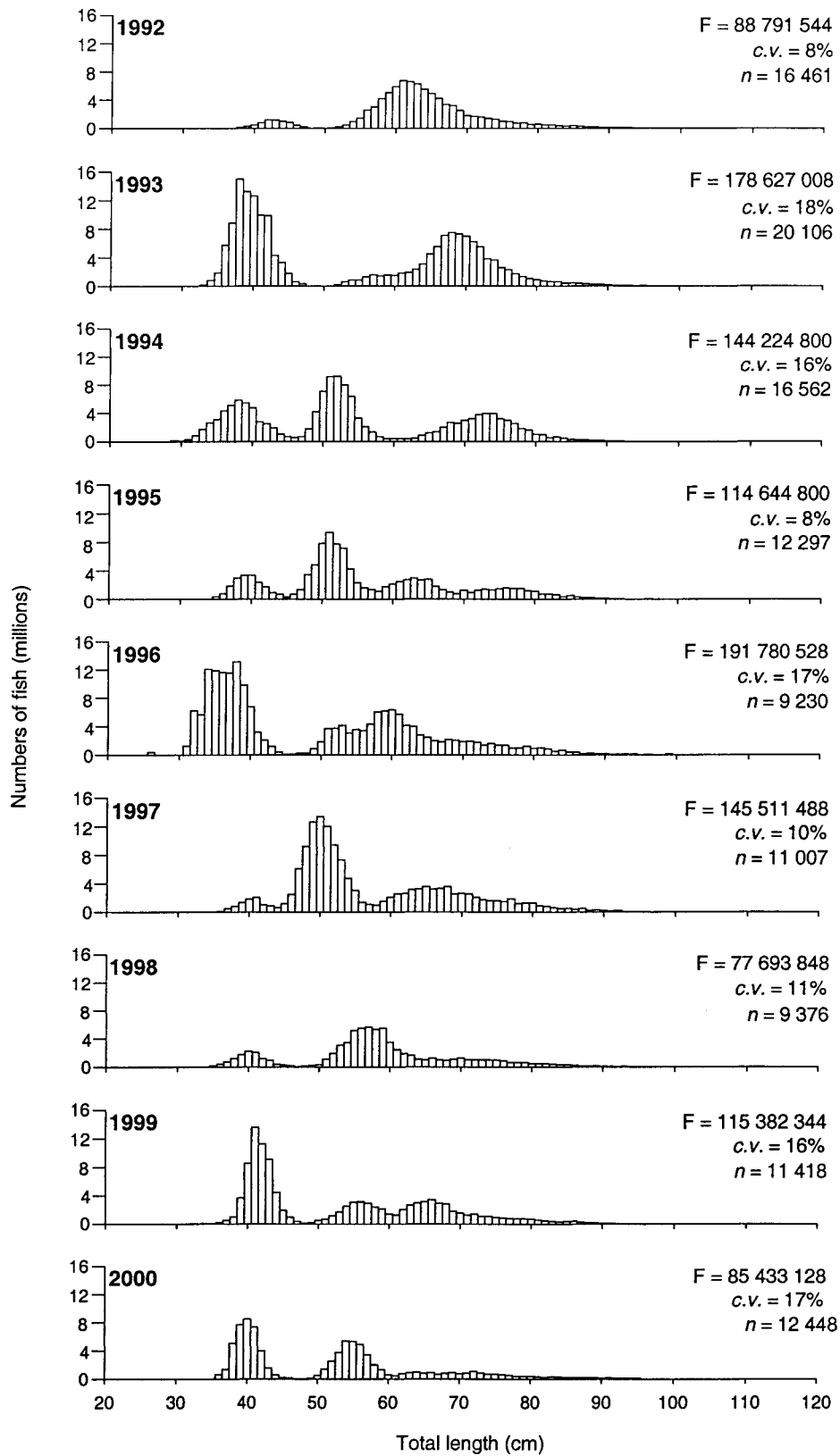
**Figure 12a: Scaled length frequencies for male hake from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; M, number of male fish in population estimate.)**



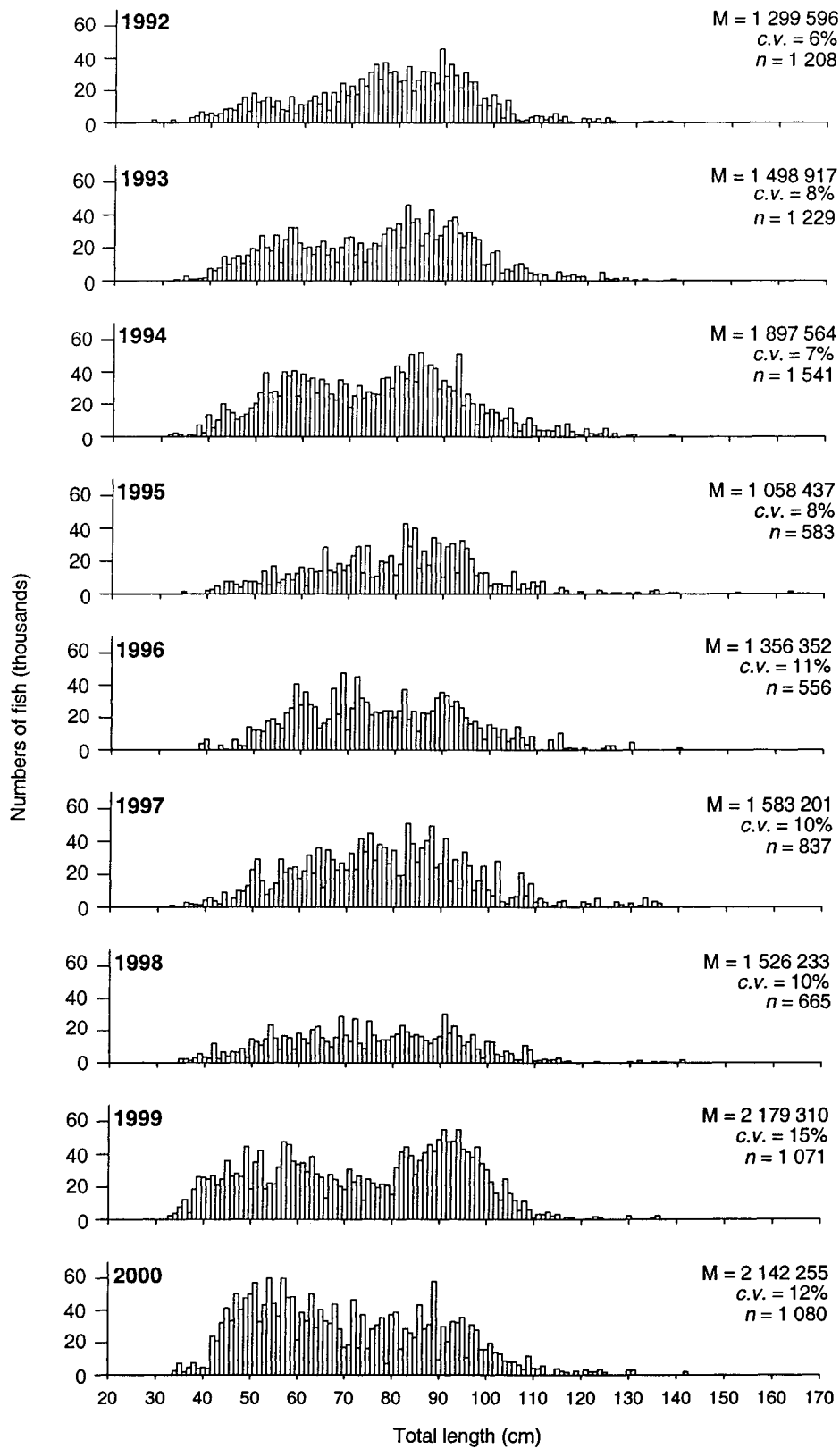
**Figure 12b: Scaled length frequencies for female hake from Chatham Rise trawl survey time series. (Note scale change from males, c.v.; coefficient of variation; n, number of fish measured; F, number of male fish in population estimate.)**



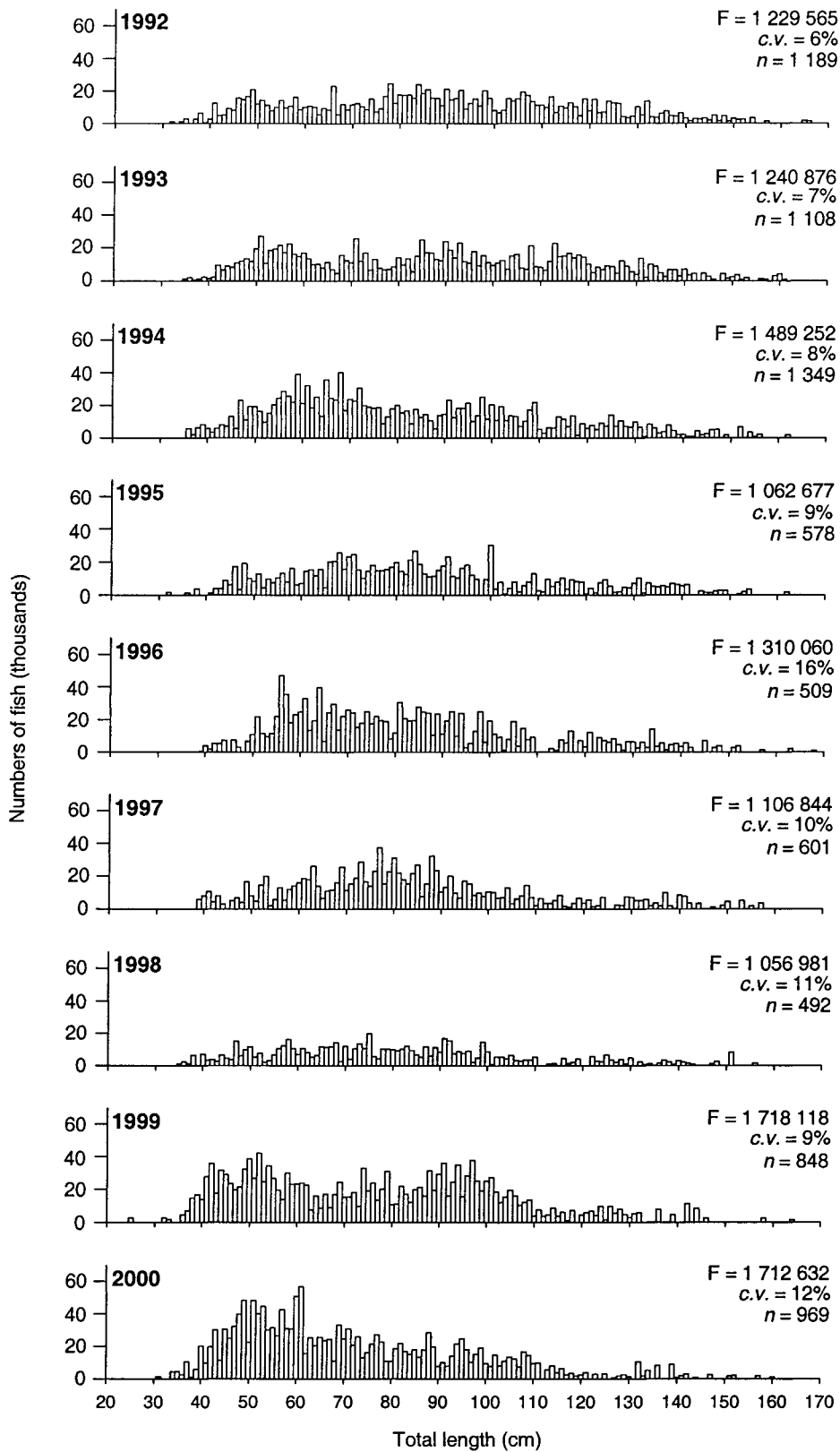
**Figure 13a: Scaled length frequencies for male hoki from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; M, number of male fish in population estimate.)**



**Figure 13b: Scaled length frequencies for female hoki from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; F, number of male fish in population estimate.)**



**Figure 14a: Scaled length frequencies for male ling from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; M, number of male fish in population estimate.)**



**Figure 14b: Scaled length frequencies for female ling from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; F, number of male fish in population estimate.)**

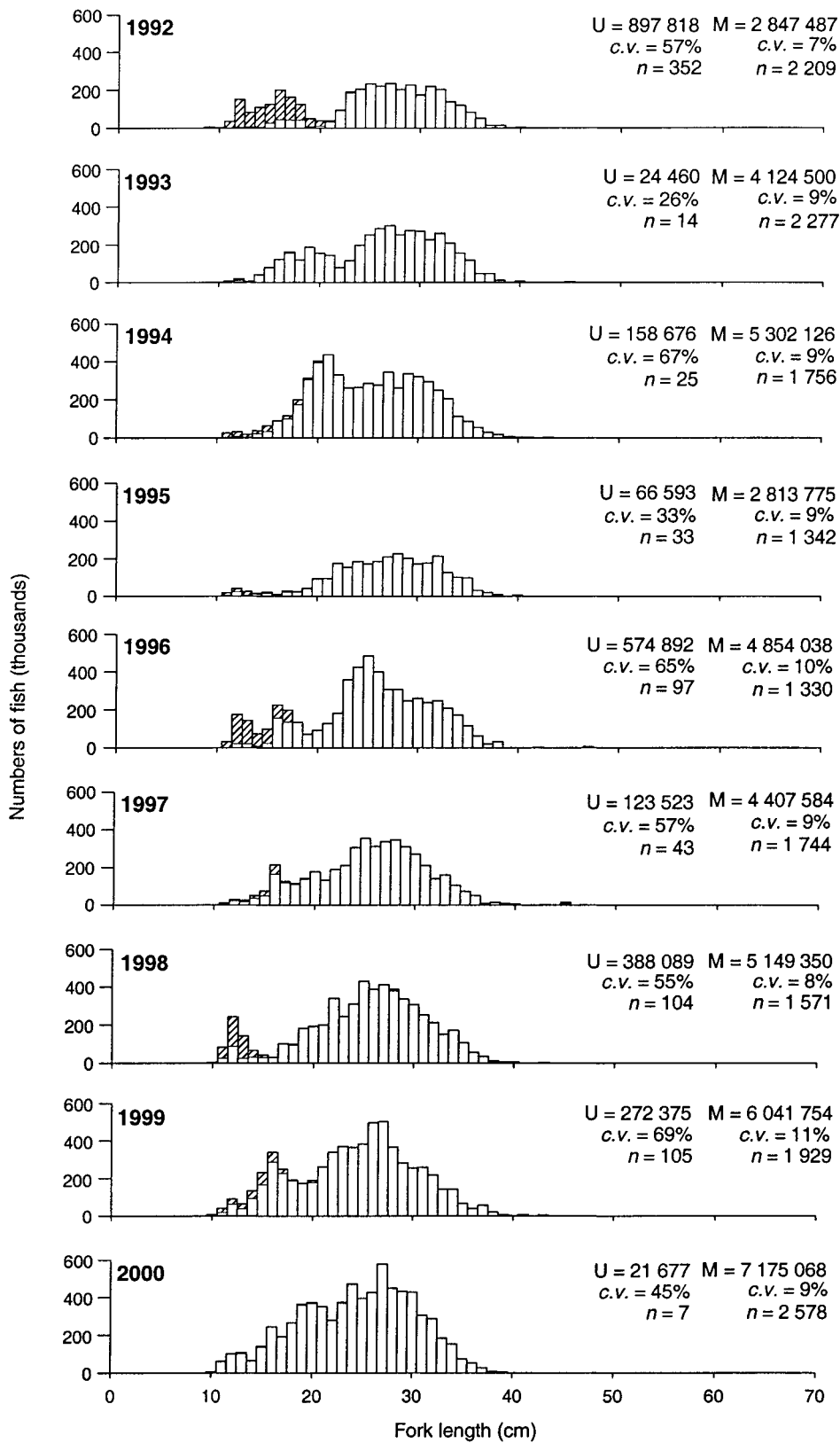
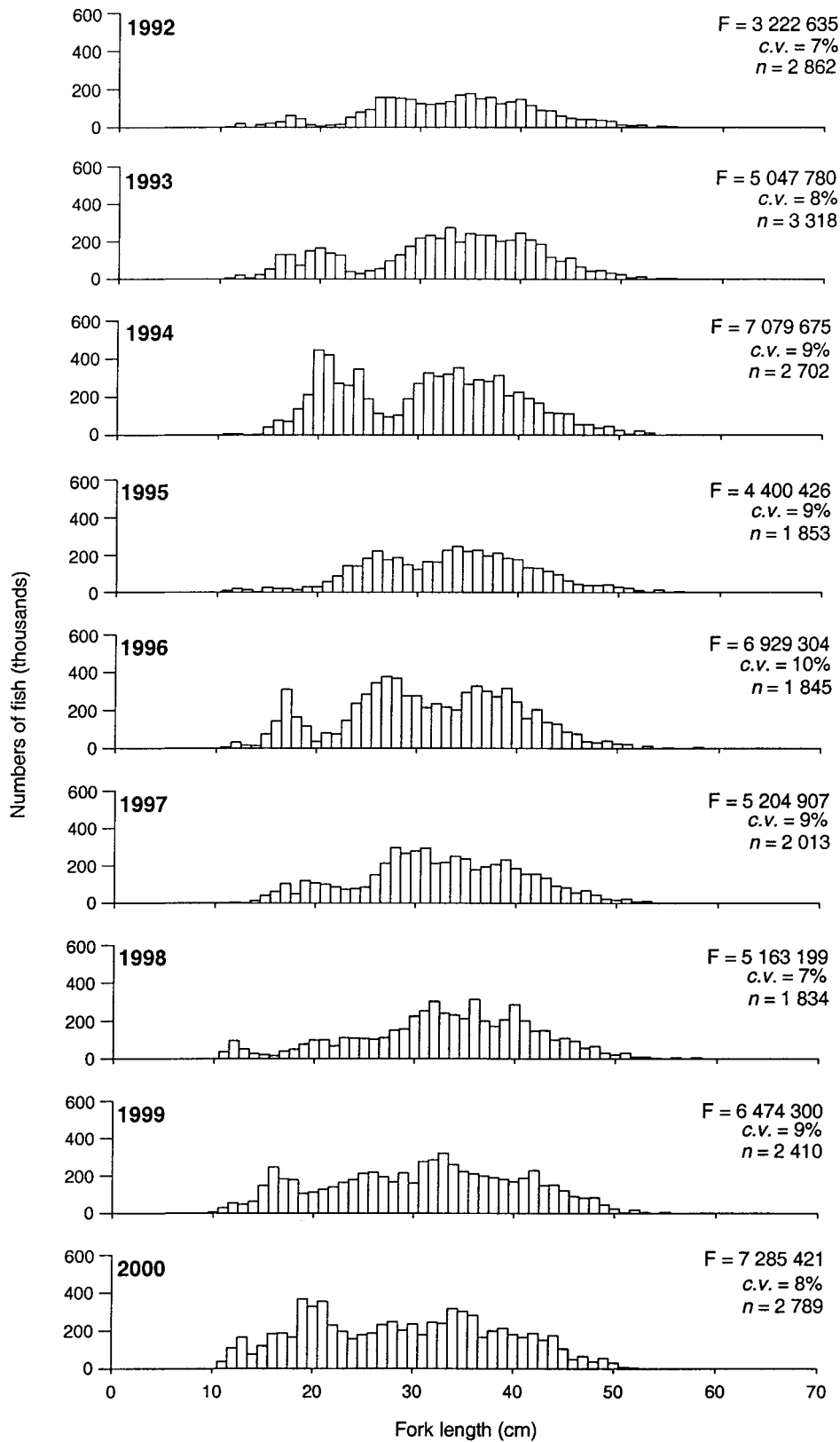
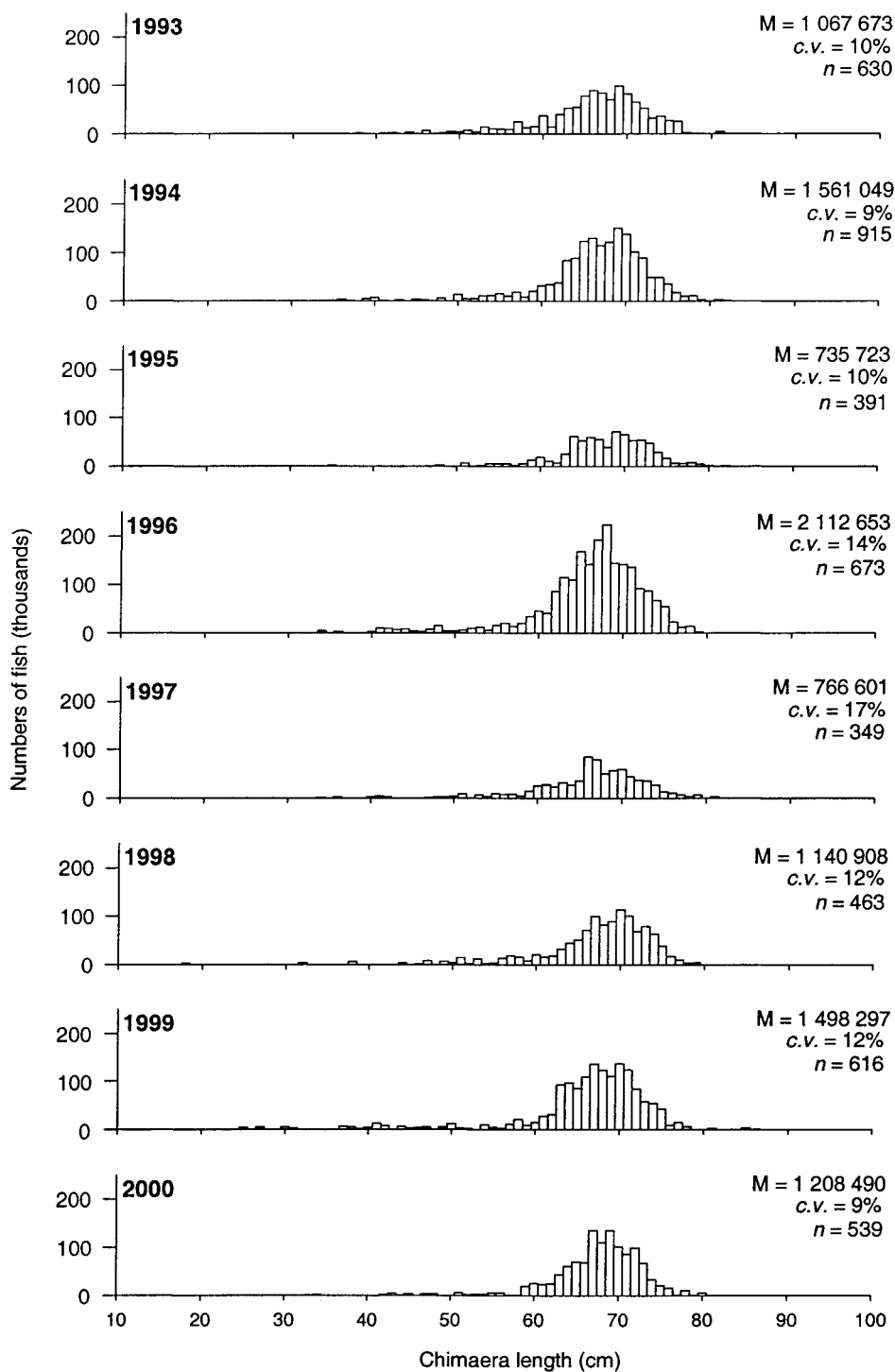


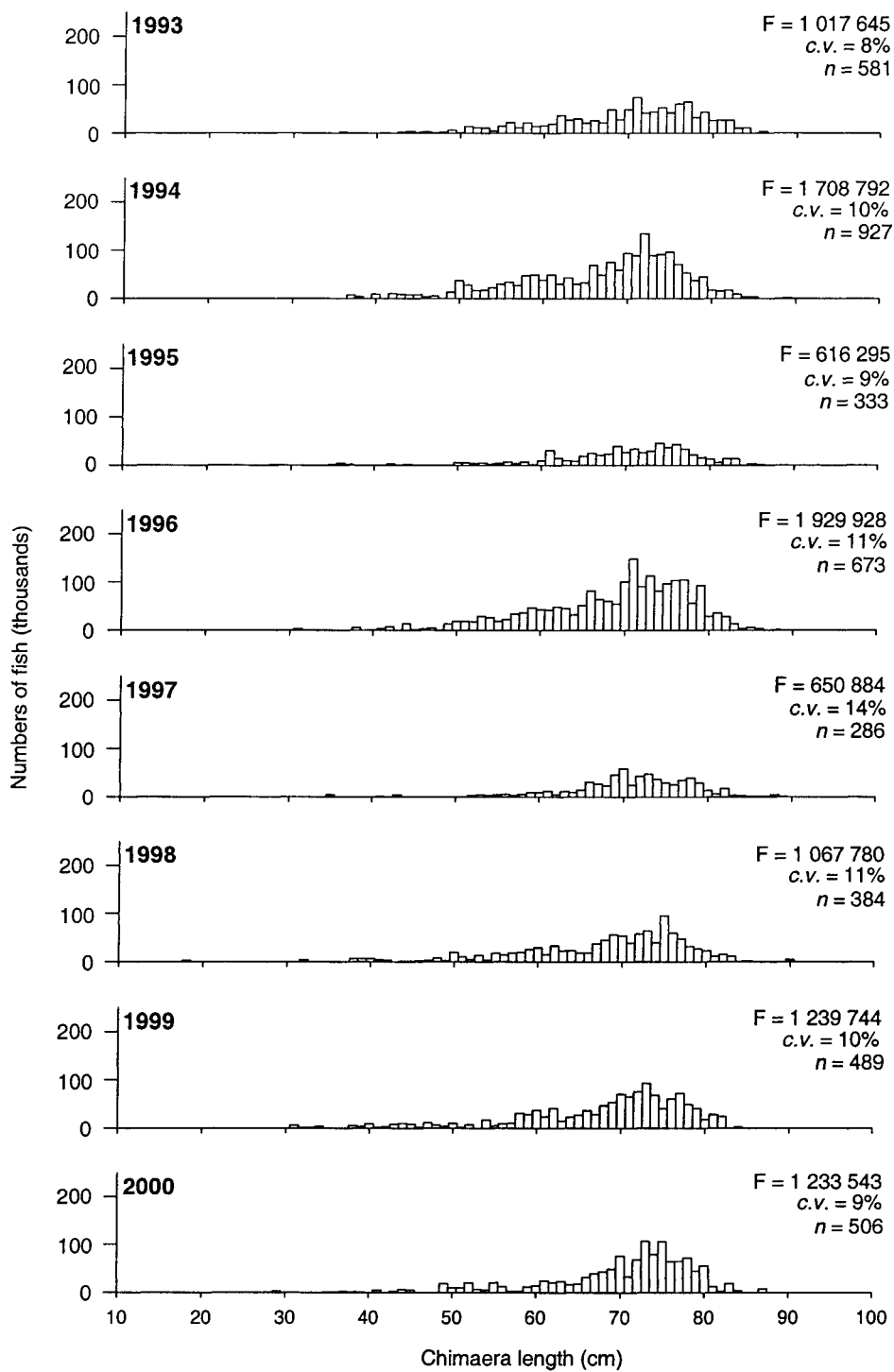
Figure 15a: Scaled length frequencies for male and unsexed lookdown dory from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; M, number of male fish in population estimate, U, number of unsexed fish in population estimate.)



**Figure 15b: Scaled length frequencies for female lookdown dory from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; F, number of male fish in population estimate.)**



**Figure 16a: Scaled length frequencies for male pale ghost shark from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; M, number of male fish in population estimate.)**



**Figure 16b: Scaled length frequencies for female pale ghost shark from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; F, number of male fish in population estimate.)**

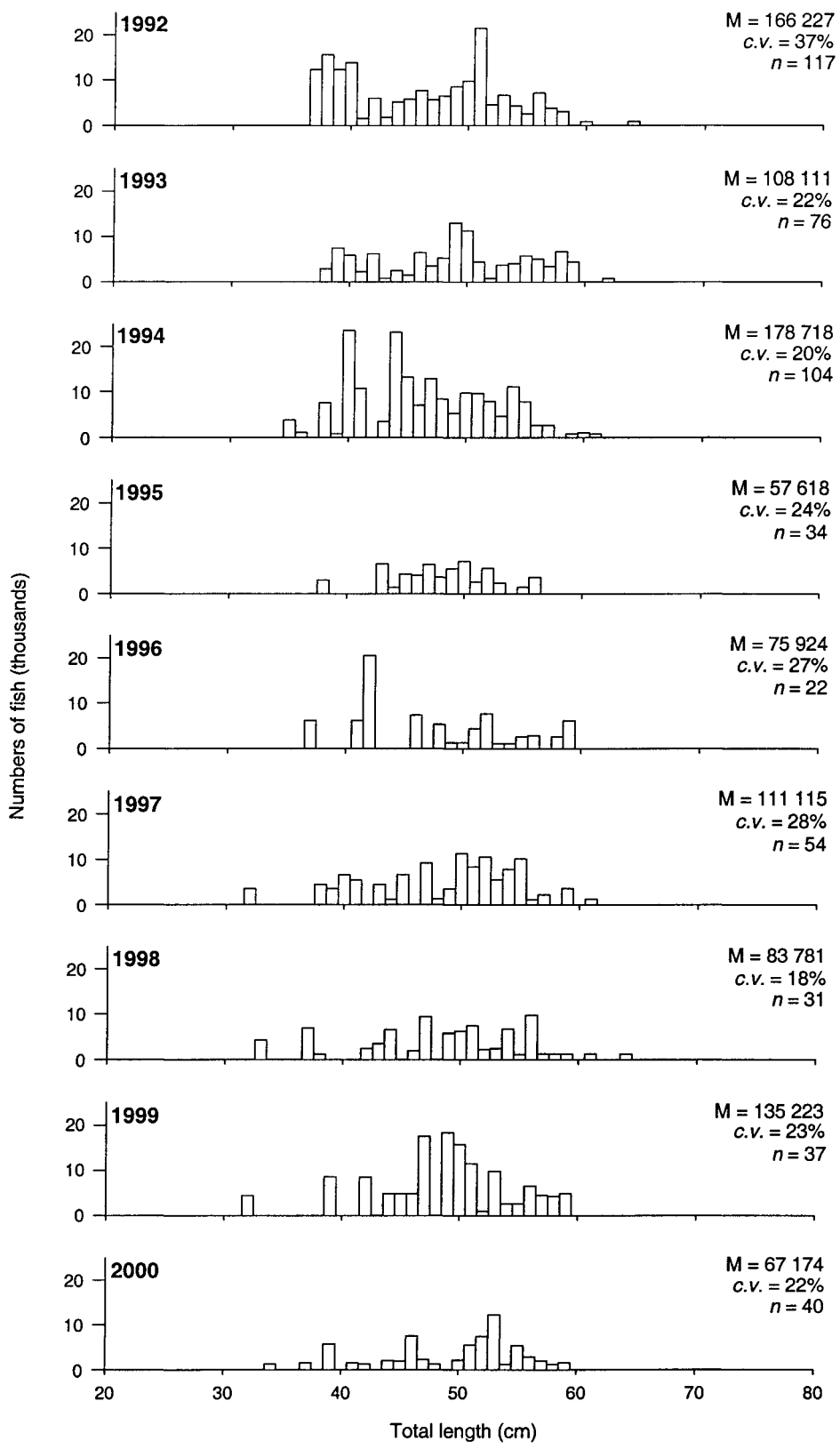
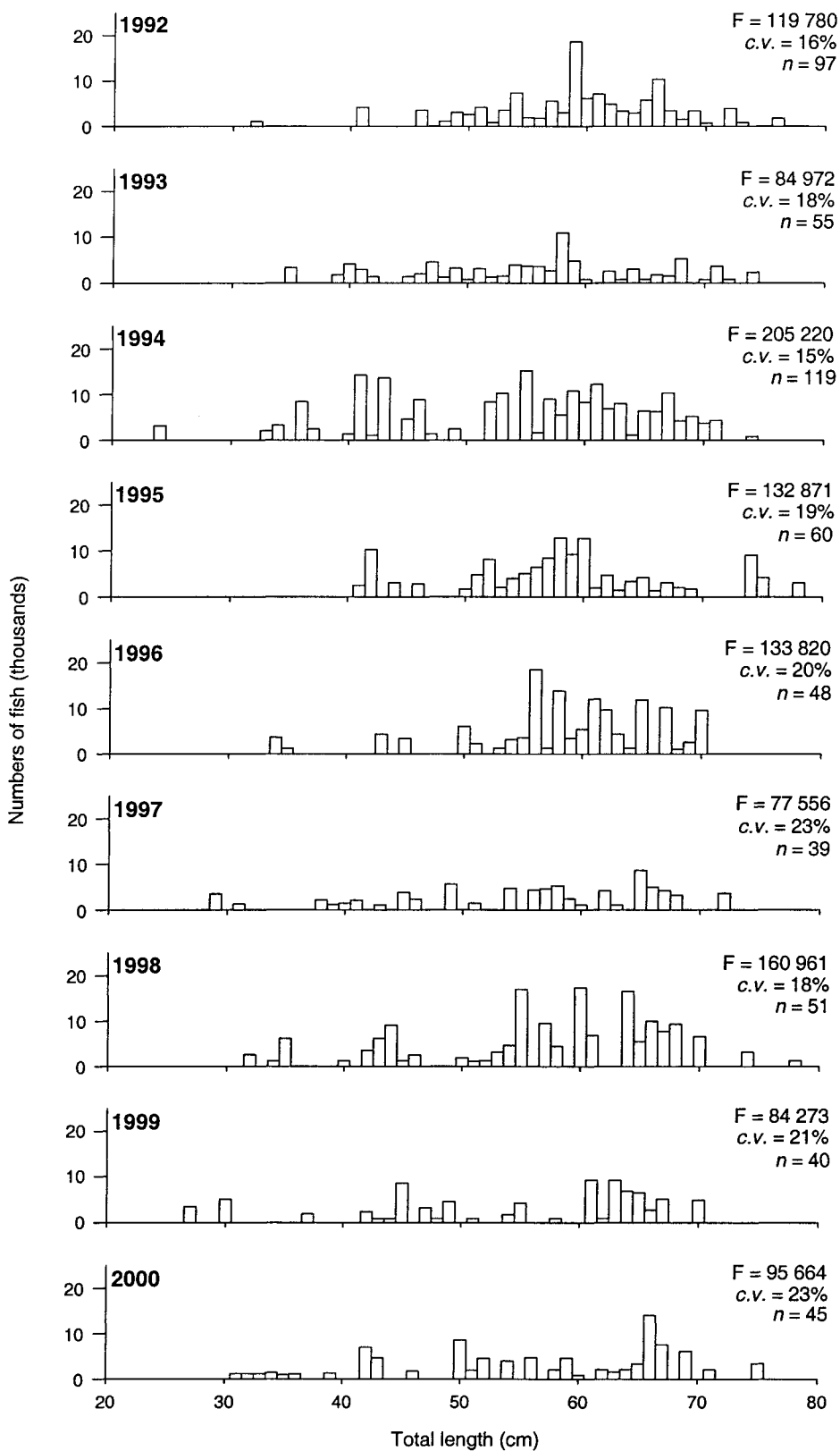
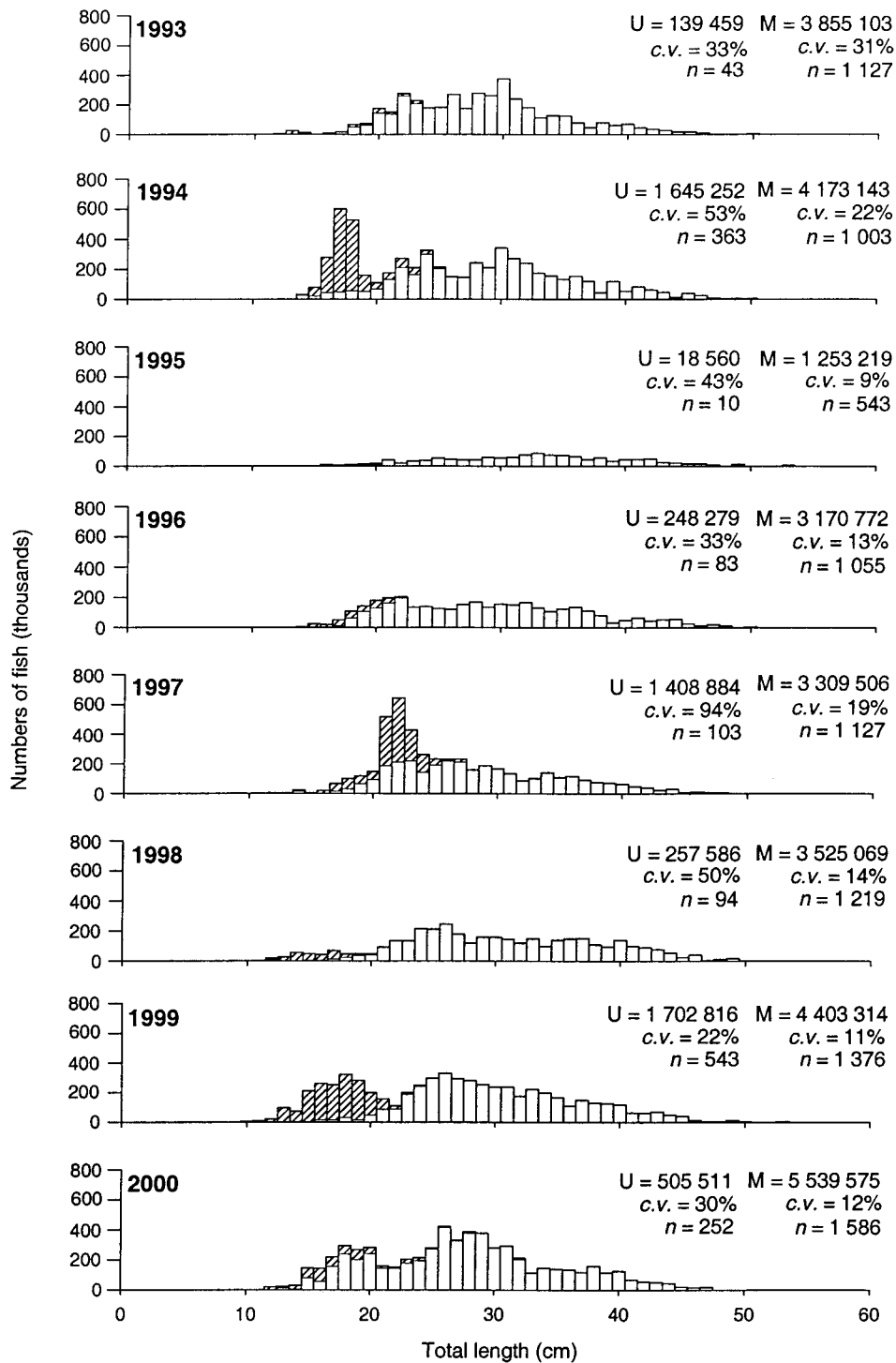


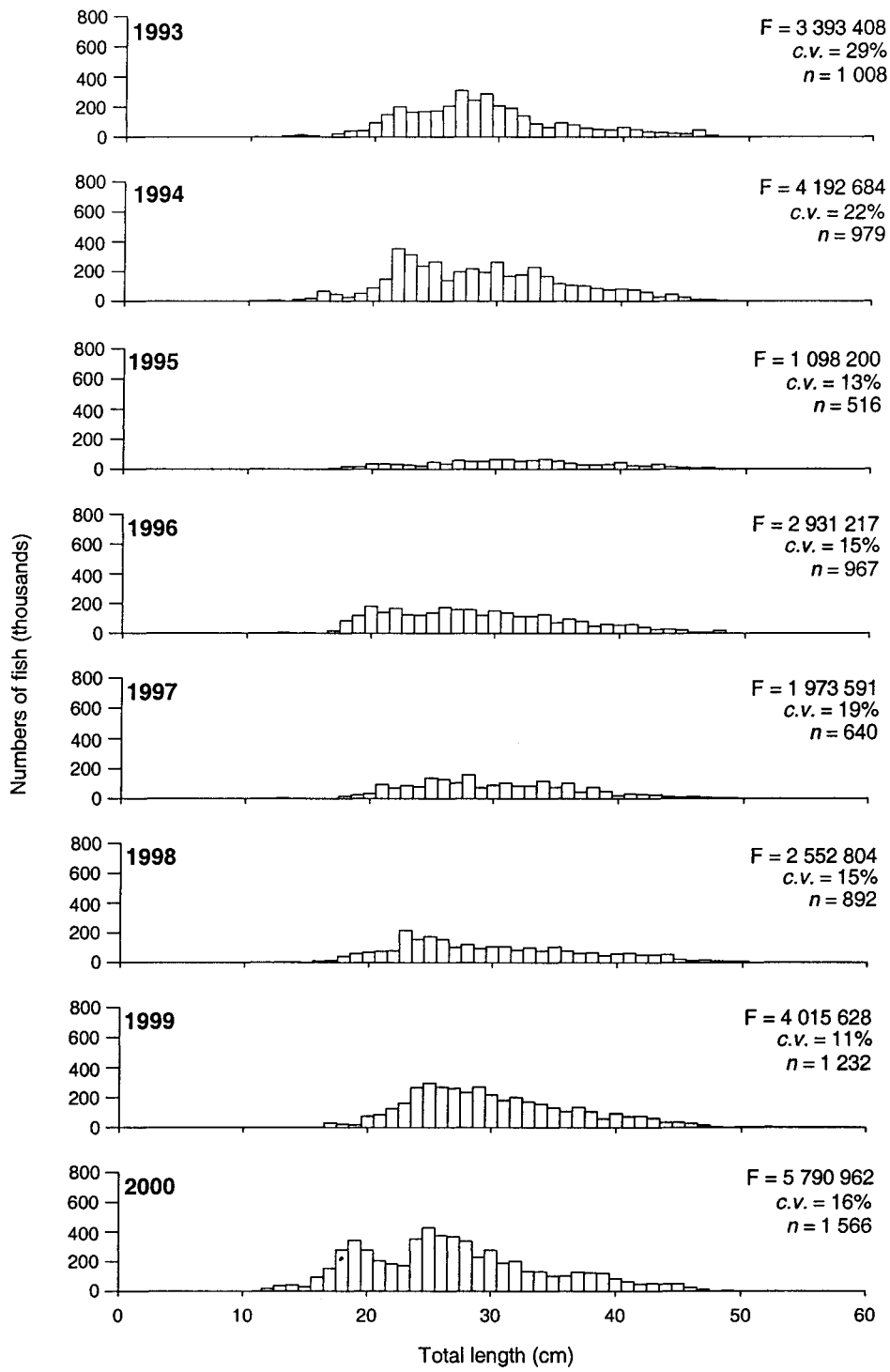
Figure 17a: Scaled length frequencies for male ribaldo from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; M, number of male fish in population estimate.)



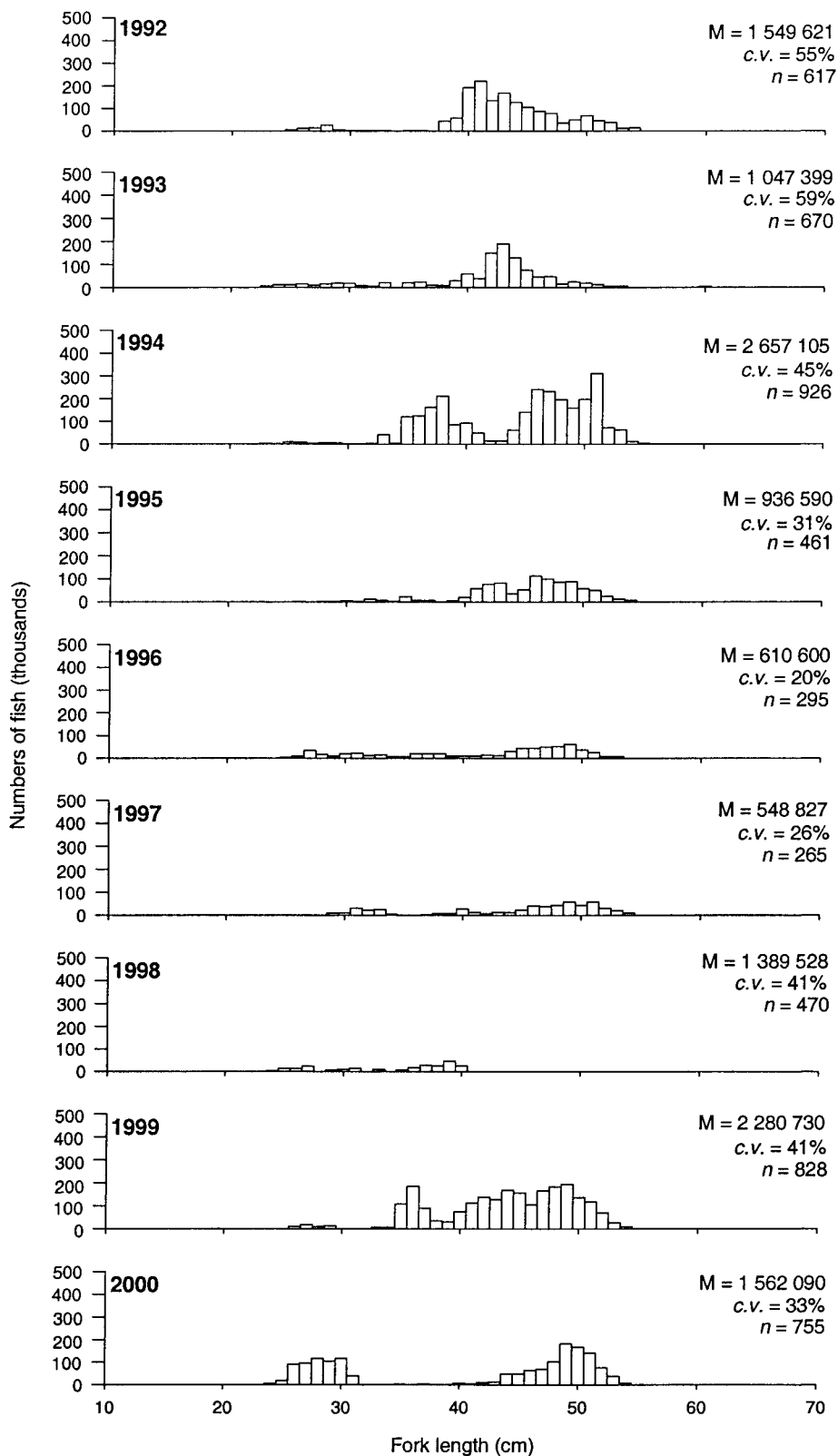
**Figure 17b: Scaled length frequencies for female ribaldo from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; F, number of male fish in population estimate.)**



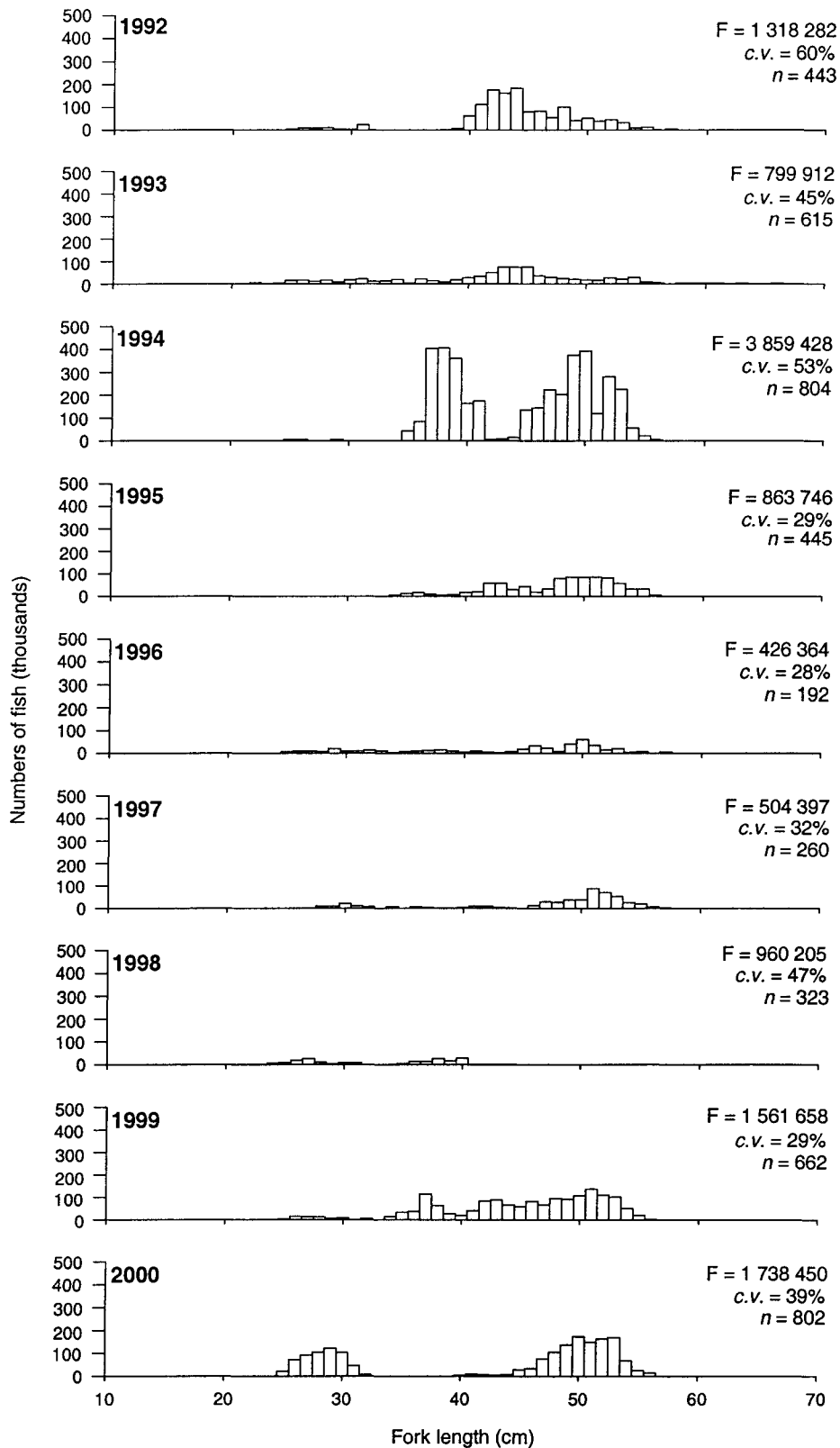
**Figure 18a: Scaled length frequencies for male and unsexed sea perch from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; M, number of male fish in population estimate, U, number of unsexed fish in population estimate.)**



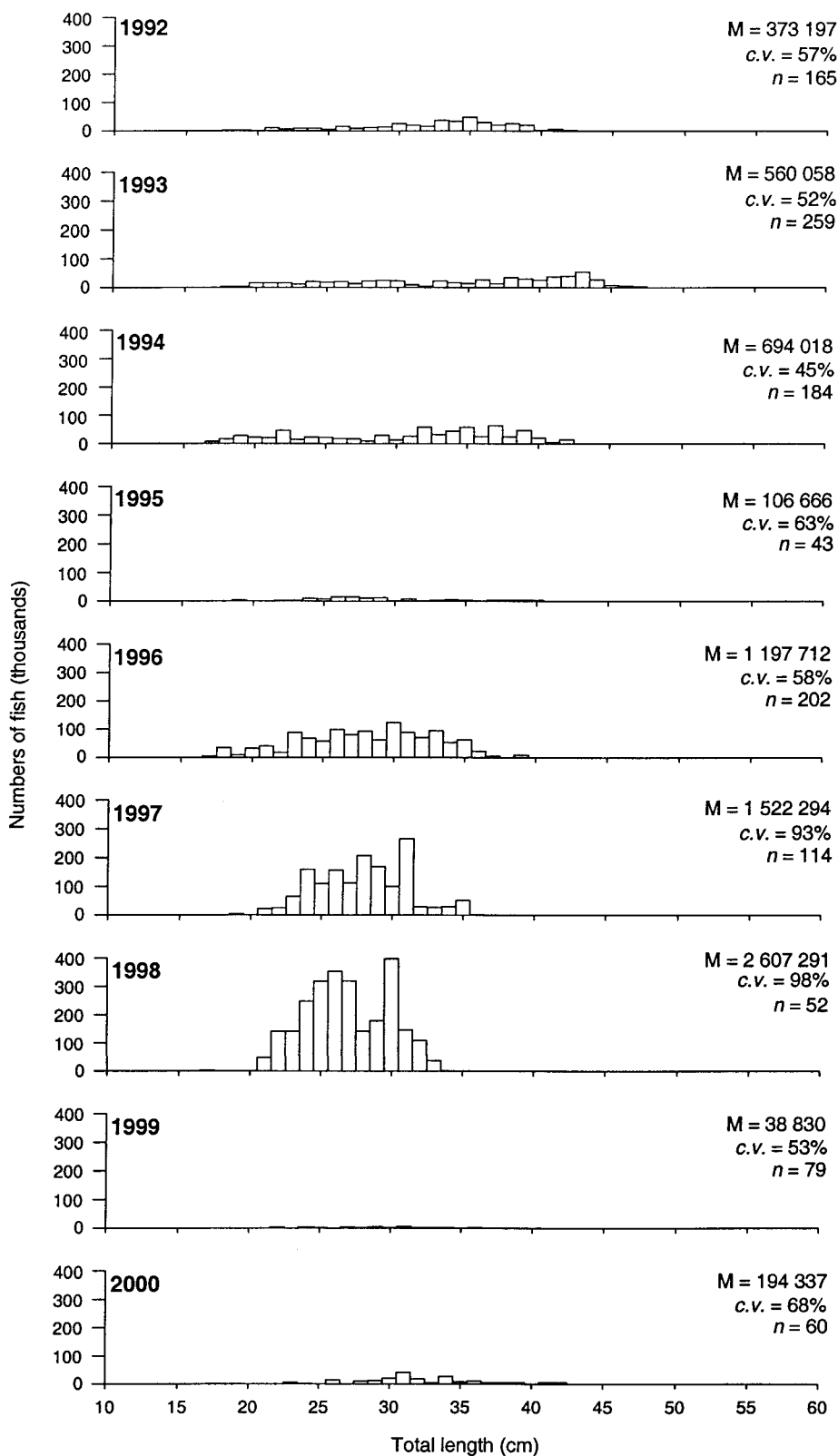
**Figure 18b: Scaled length frequencies for female sea perch from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; F, number of male fish in population estimate.)**



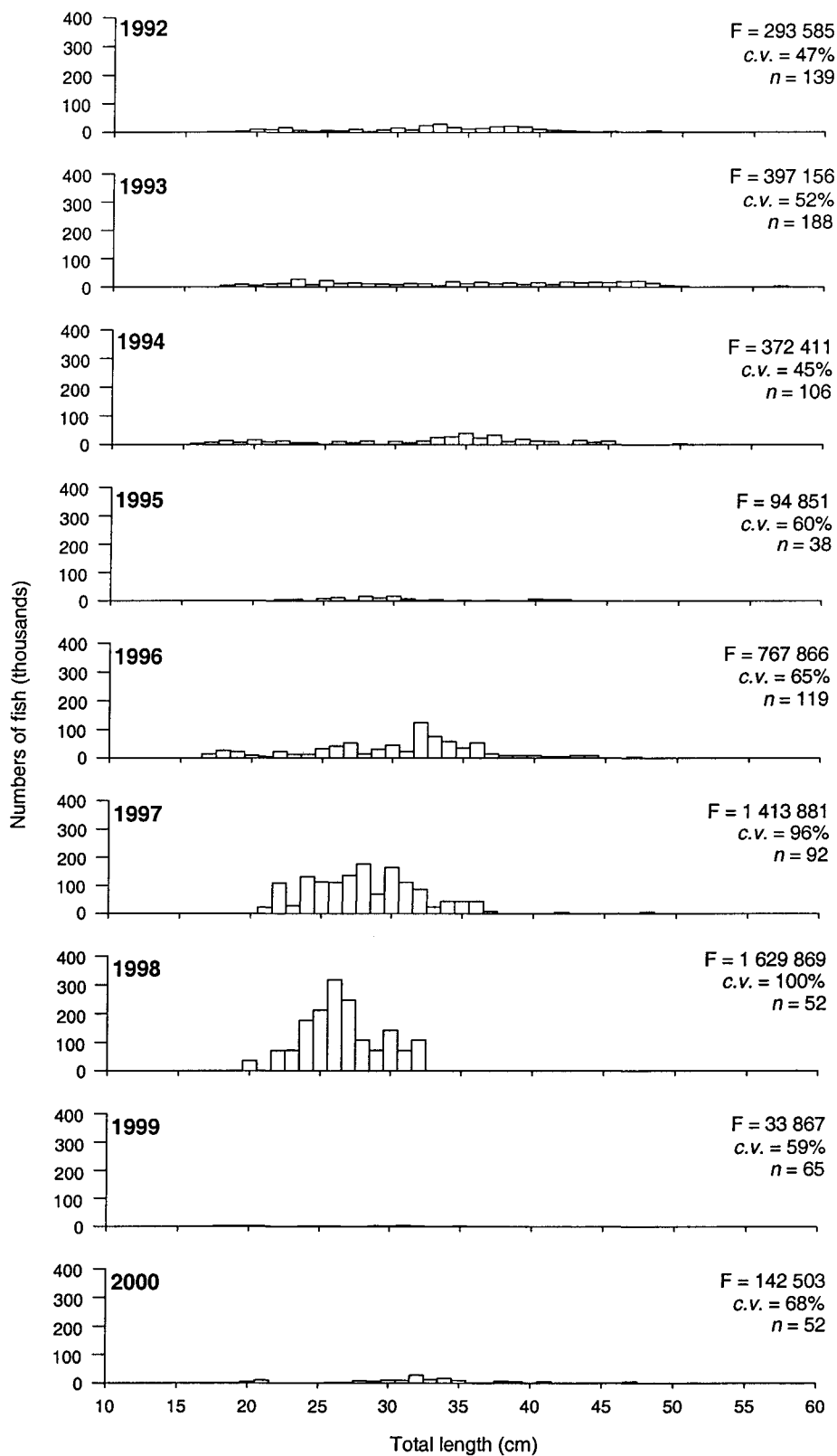
**Figure 19a: Scaled length frequencies for male silver warehou from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; M, number of male fish in population estimate.)**



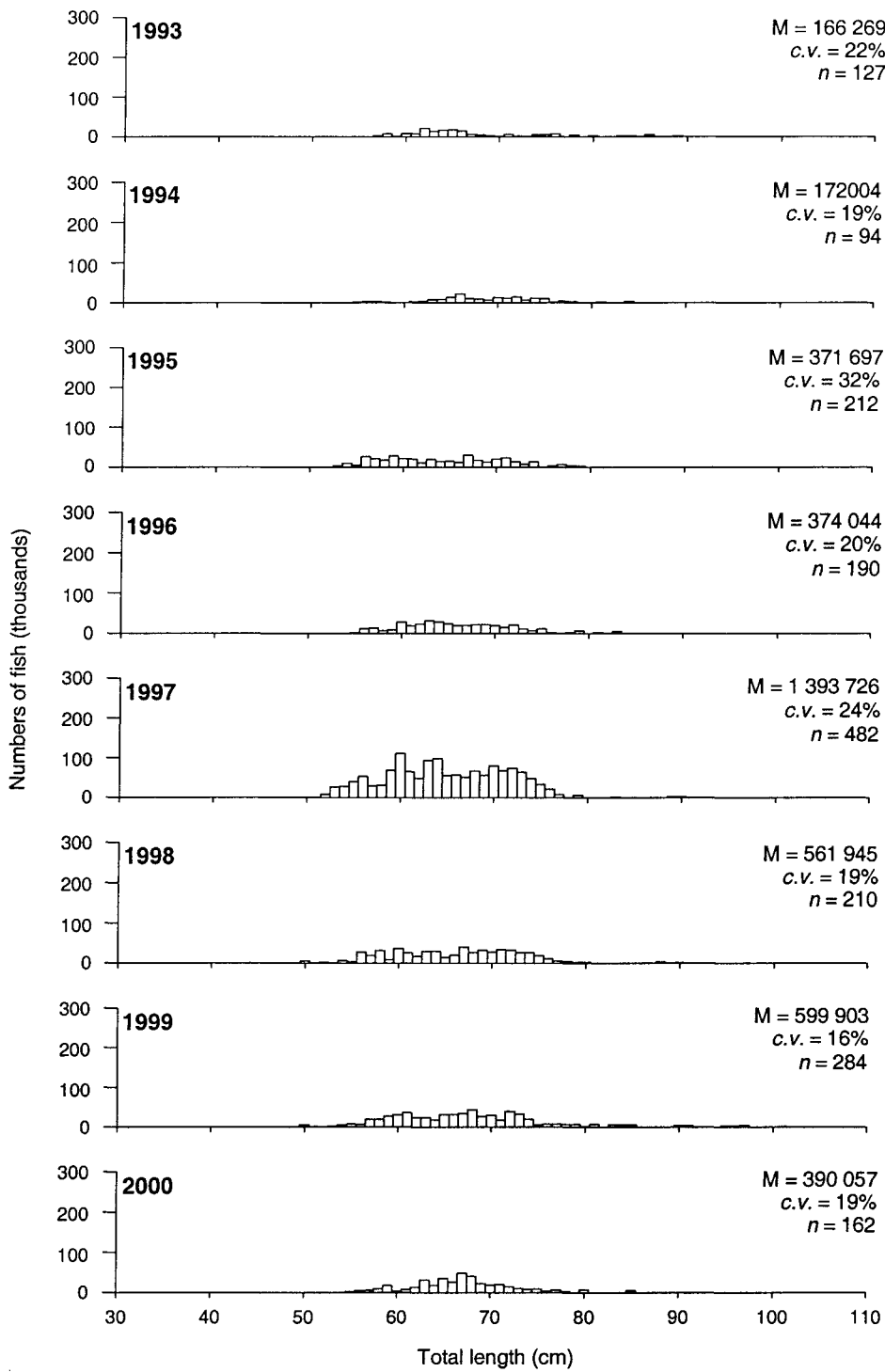
**Figure 19b: Scaled length frequencies for female silver warehou from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; F, number of male fish in population estimate.)**



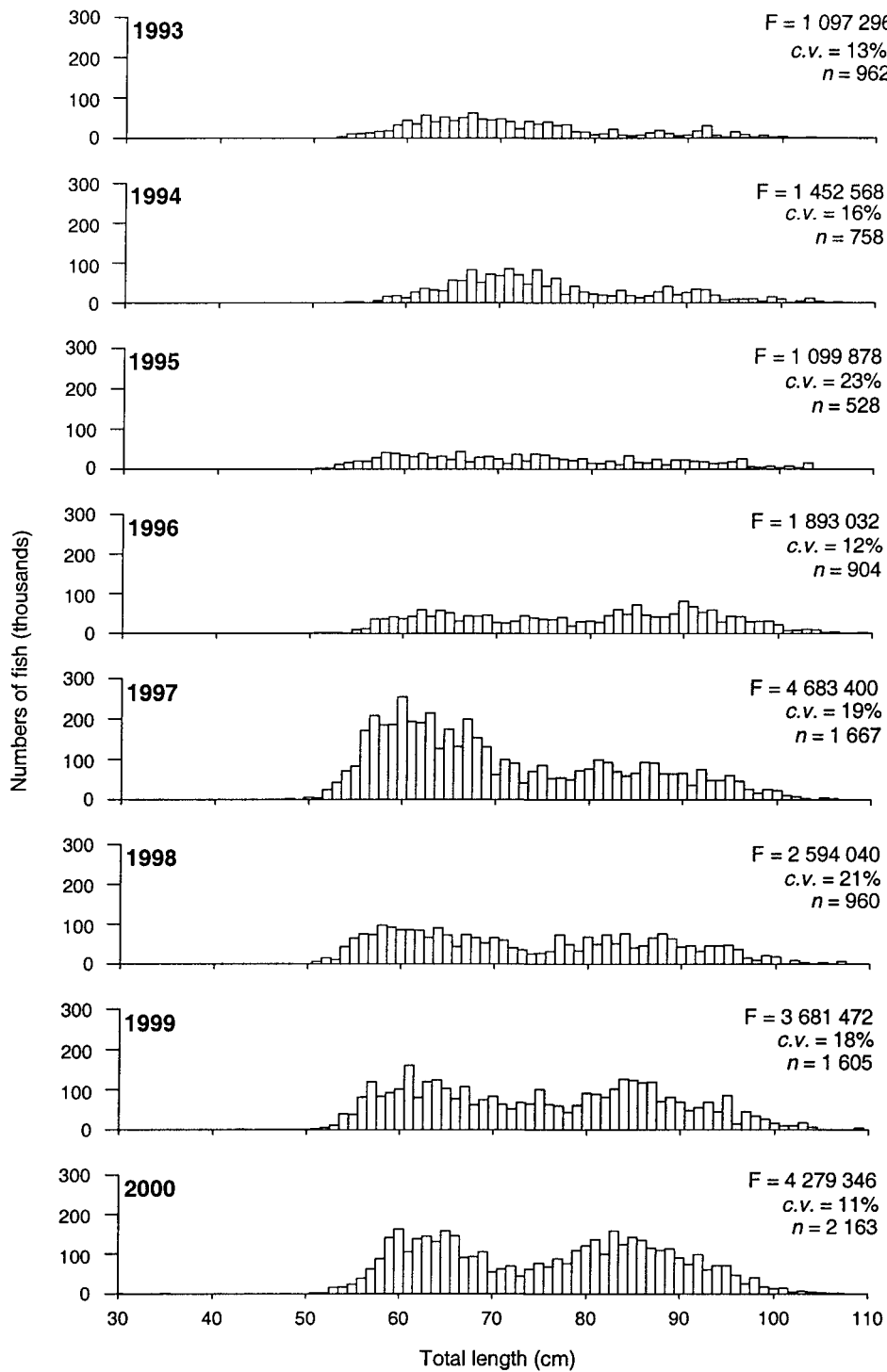
**Figure 20a: Scaled length frequencies for male smooth oreo from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; M, number of male fish in population estimate.)**



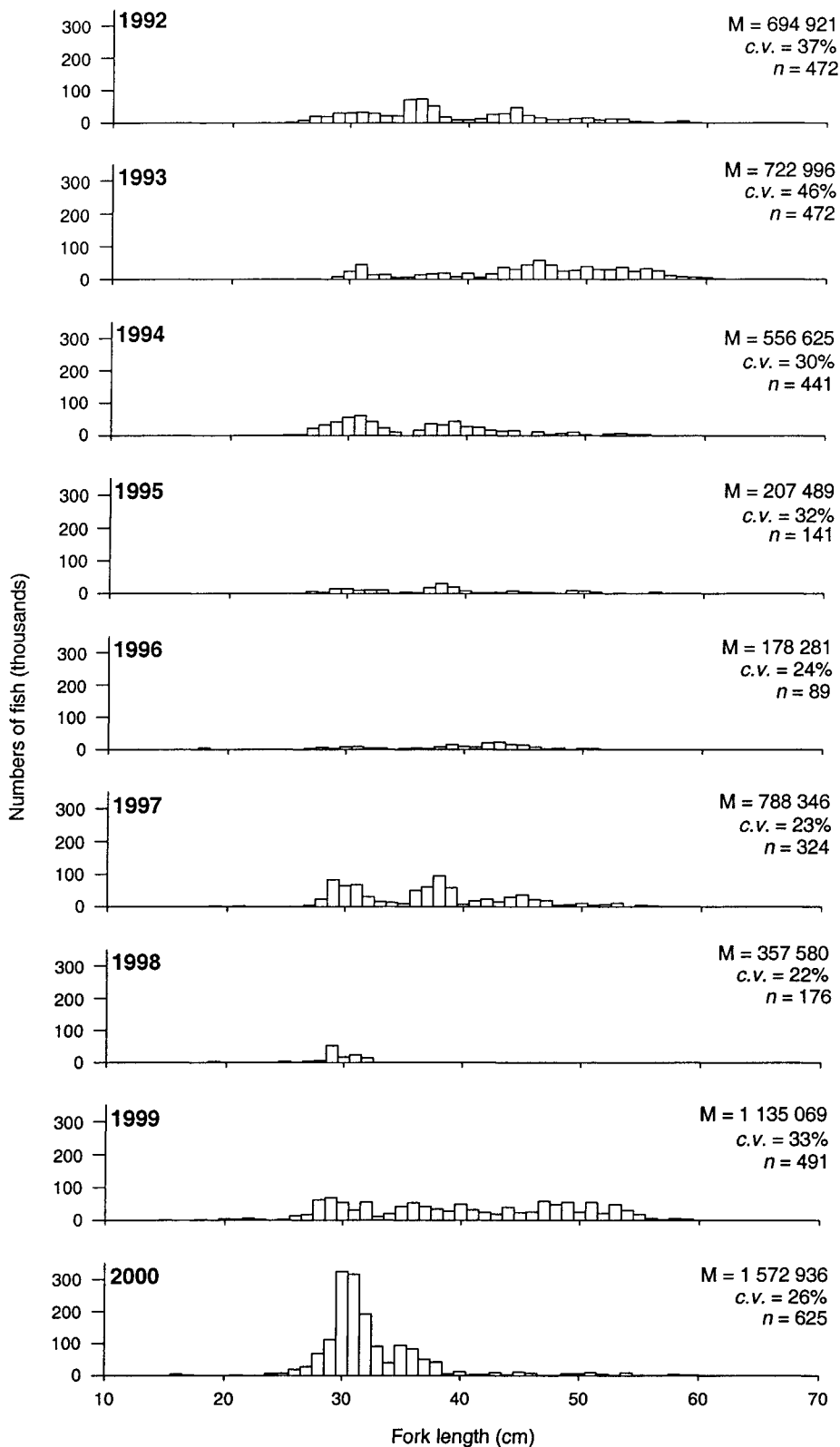
**Figure 20b: Scaled length frequencies for female smooth oreo from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; F, number of male fish in population estimate.)**



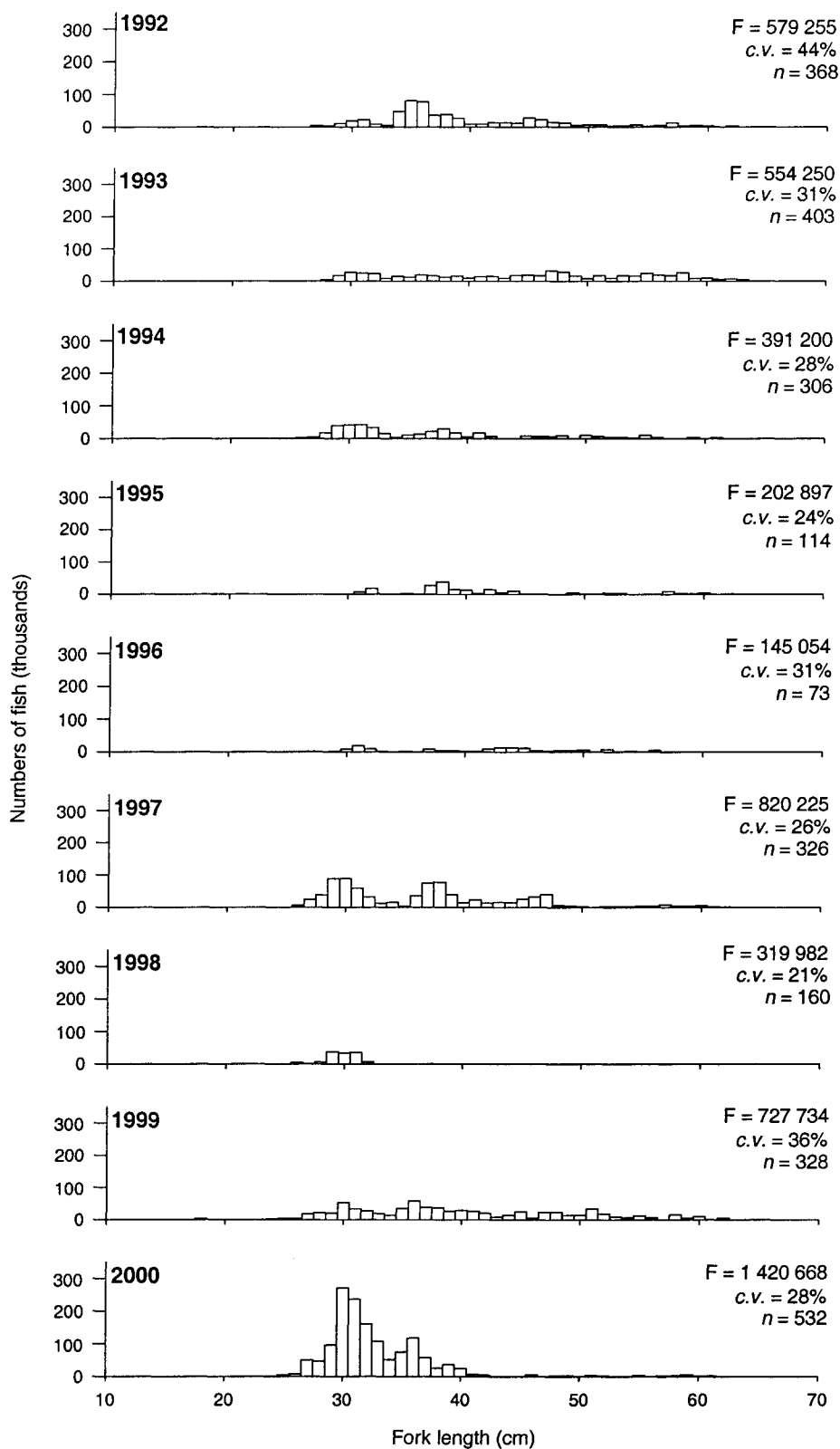
**Figure 21a: Scaled length frequencies for male spiny dogfish from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; M, number of male fish in population estimate.)**



**Figure 21b: Scaled length frequencies for female spiny dogfish from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; F, number of male fish in population estimate.)**



**Figure 22a: Scaled length frequencies for male white warehou from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; M, number of male fish in population estimate, U.)**



**Figure 22b: Scaled length frequencies for female white warehou from Chatham Rise trawl survey time series. (c.v.; coefficient of variation; n, number of fish measured; F, number of male fish in population estimate.)**

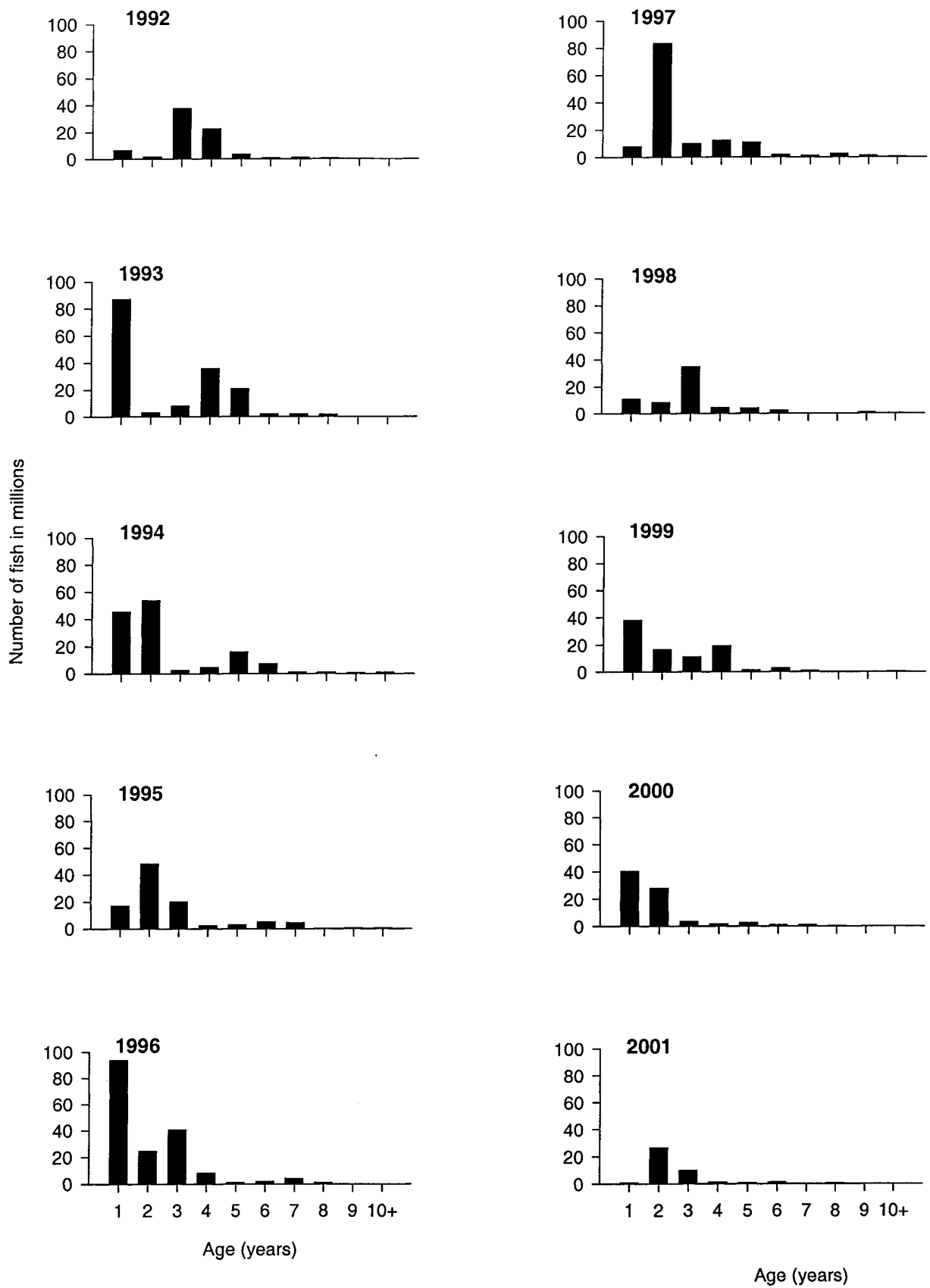


Figure 23a: Hoki numbers at age in millions (males) from Chatham Rise trawl survey series, January 1992 to 2001.

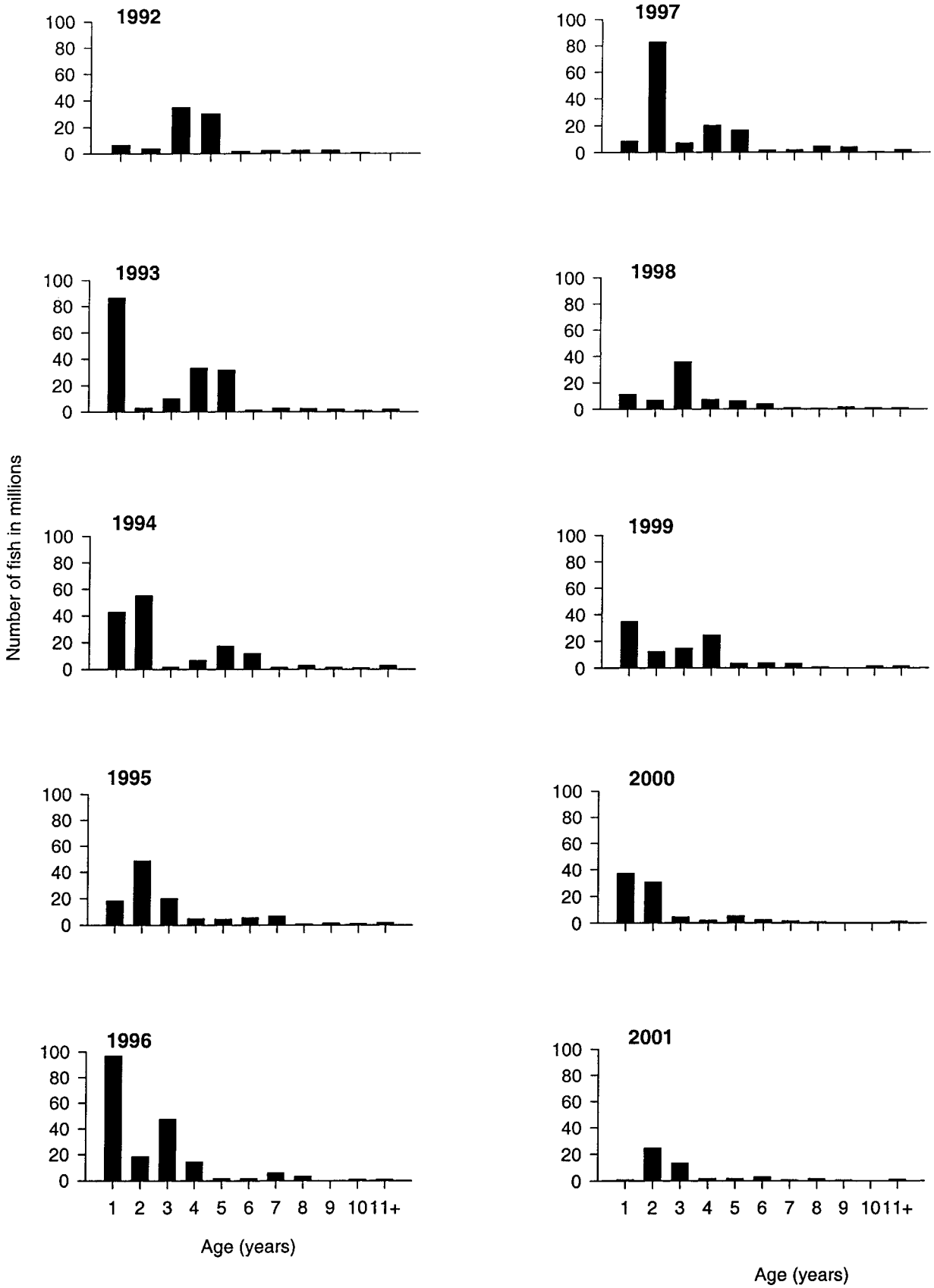


Figure 23b: Hoki numbers at age in millions (females) from Chatham Rise trawl survey series, January 1992 to 2001.

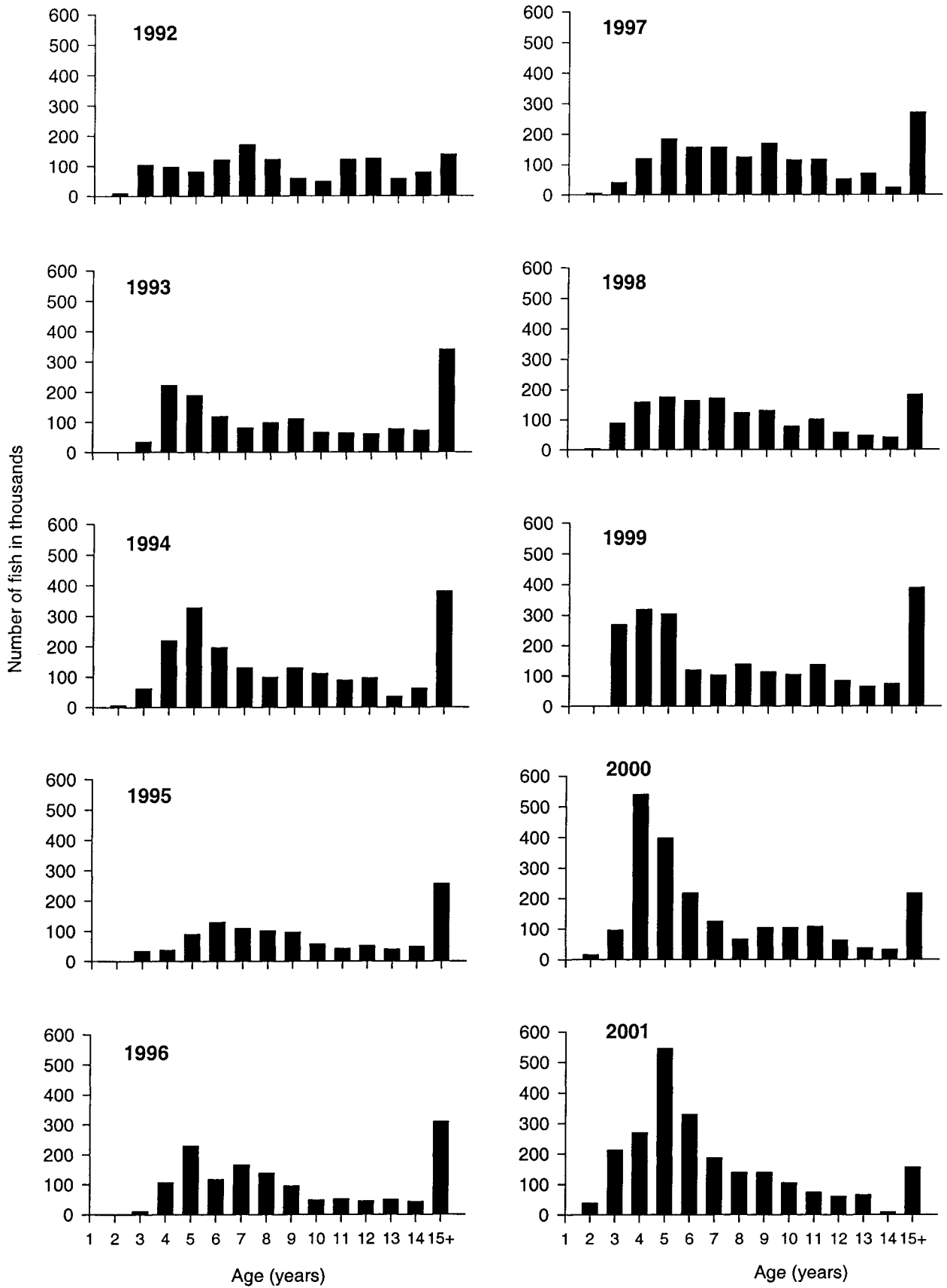


Figure 24a: Ling numbers at age in thousands (males) from Chatham Rise trawl survey series January 1992 to 2001.

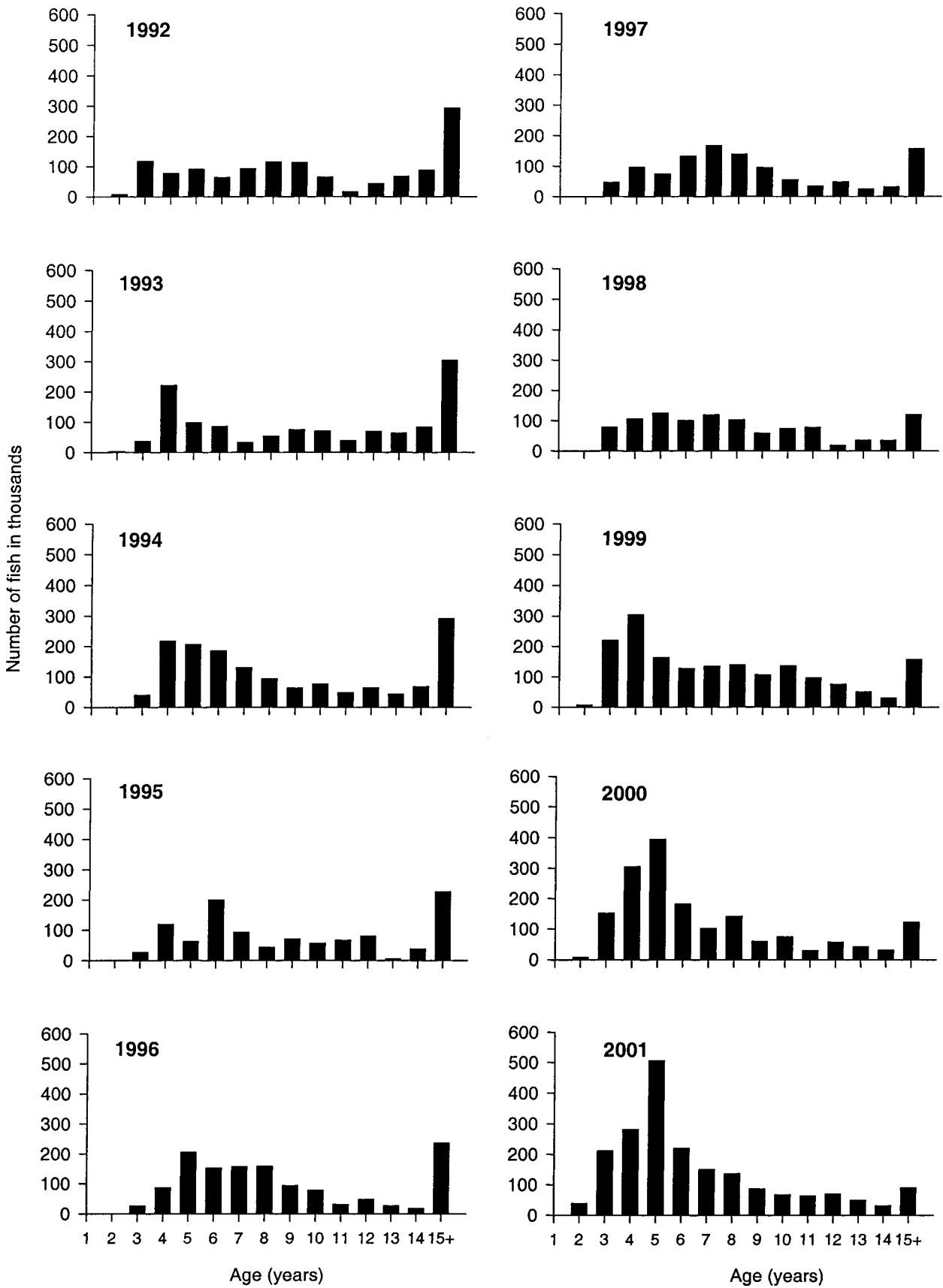


Figure 24b: Ling numbers at age in thousands (females) from Chatham Rise trawl survey series January 1992 to 2001.

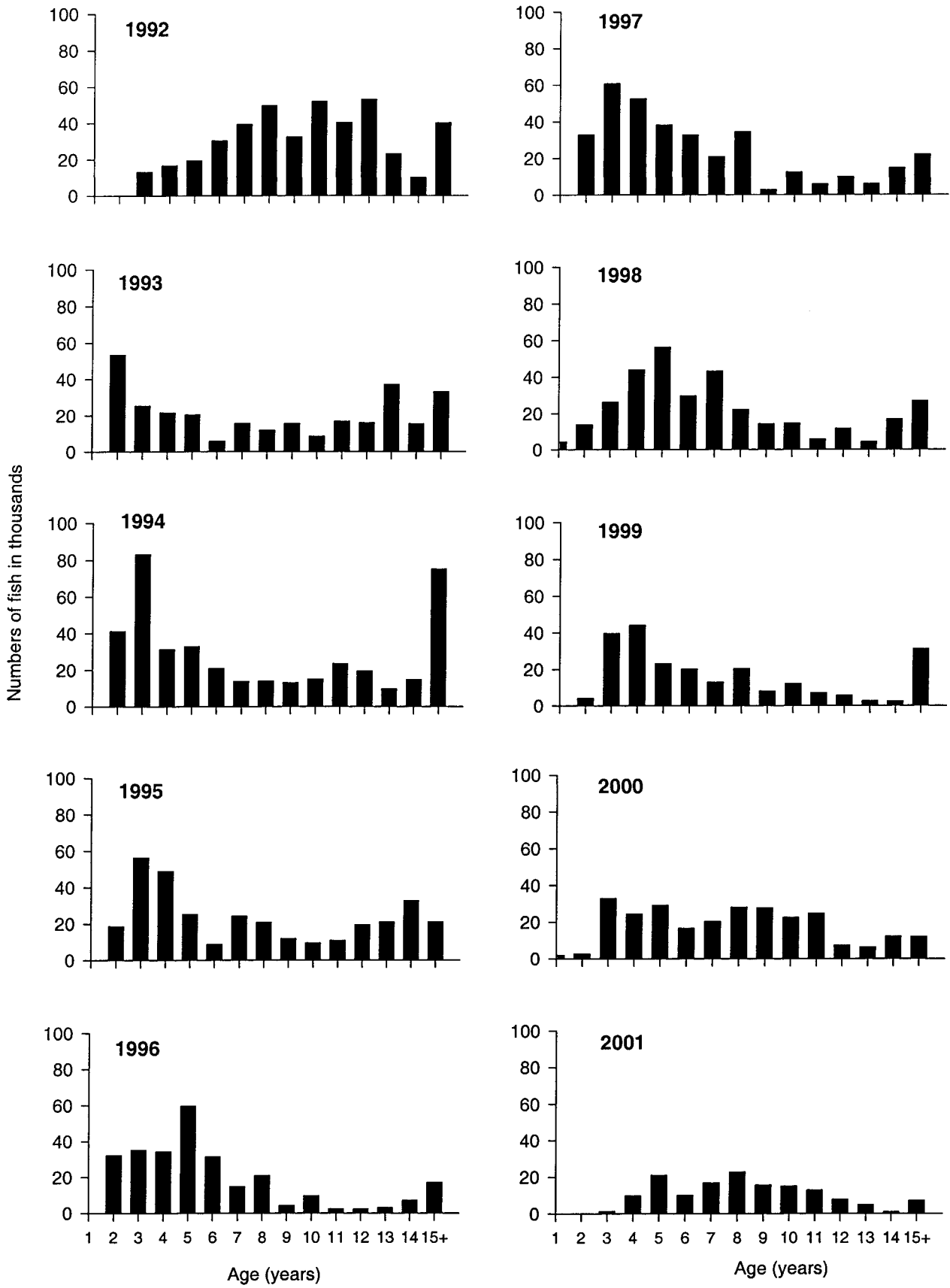


Figure 25a: Hake numbers at age in thousands (males) from Chatham Rise trawl survey series January 1992 to 2001.

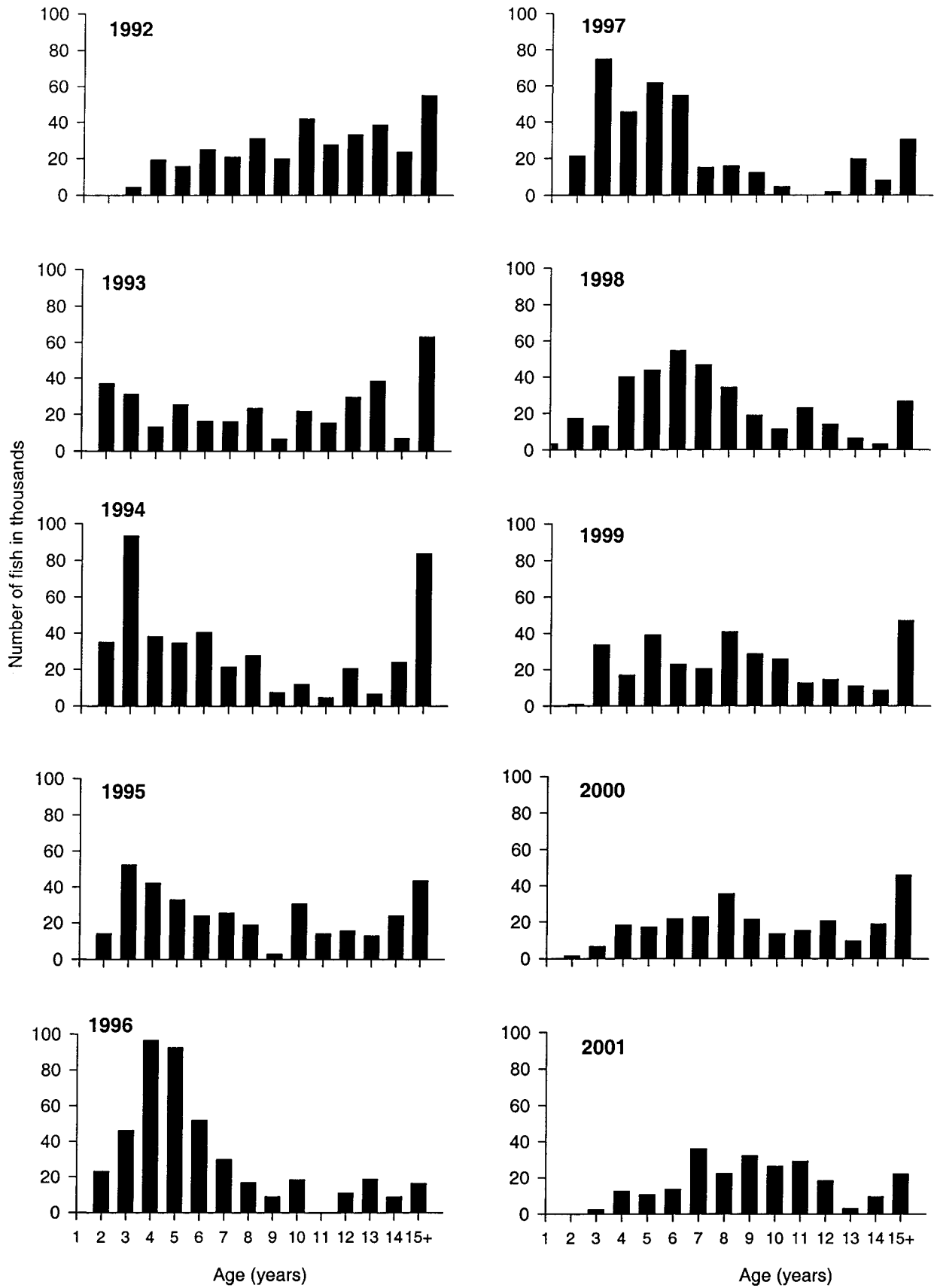


Figure 25b: Hake numbers at age in thousands (females) from Chatham Rise trawl survey series January 1992 to 2001.

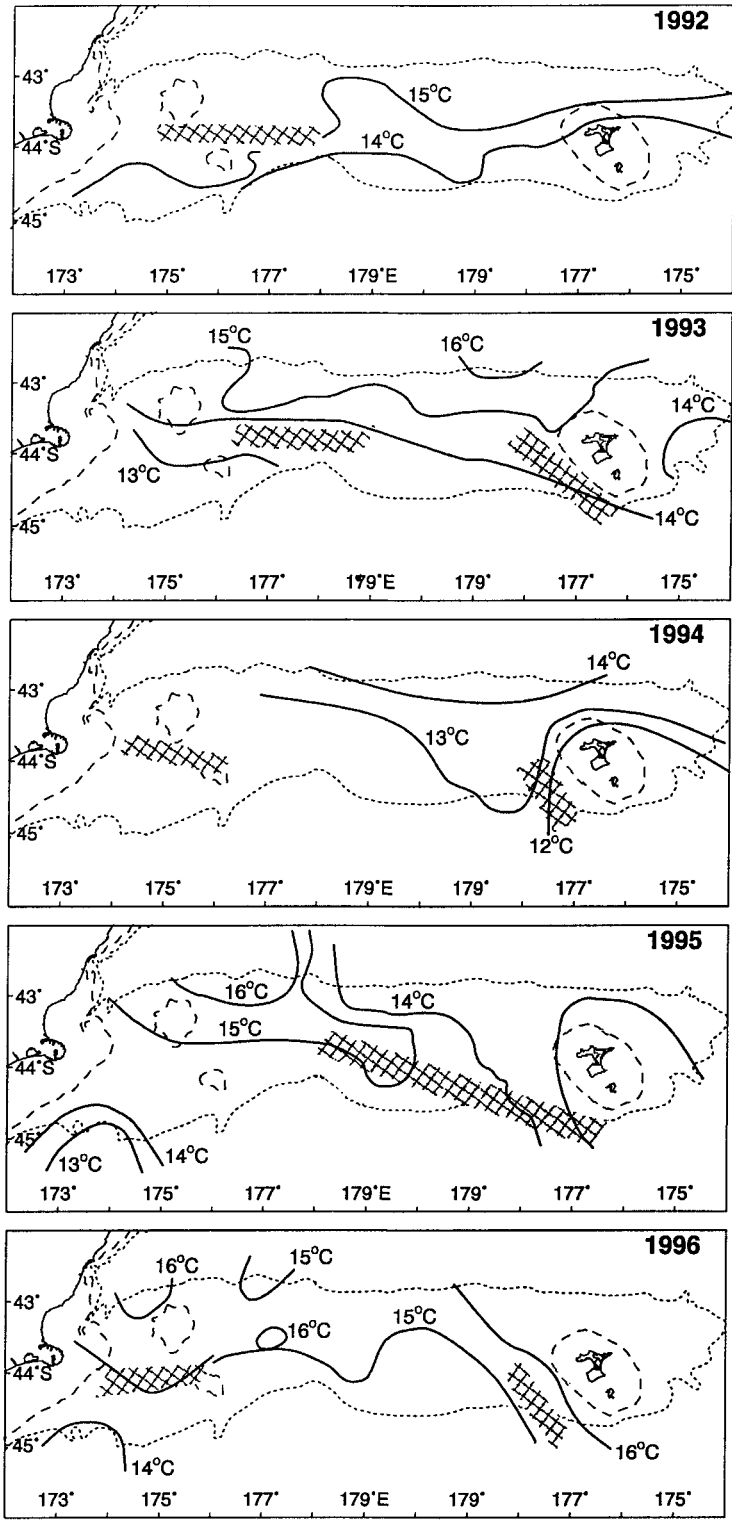


Figure 26: Surface isotherms from surface temperature data measured at trawl stations occupied during trawl surveys of the Chatham Rise, January 1992–2000. (Cross hatching shows bottom temperature expression of the Sub-Tropical Front in areas of greatest thermal gradient.)

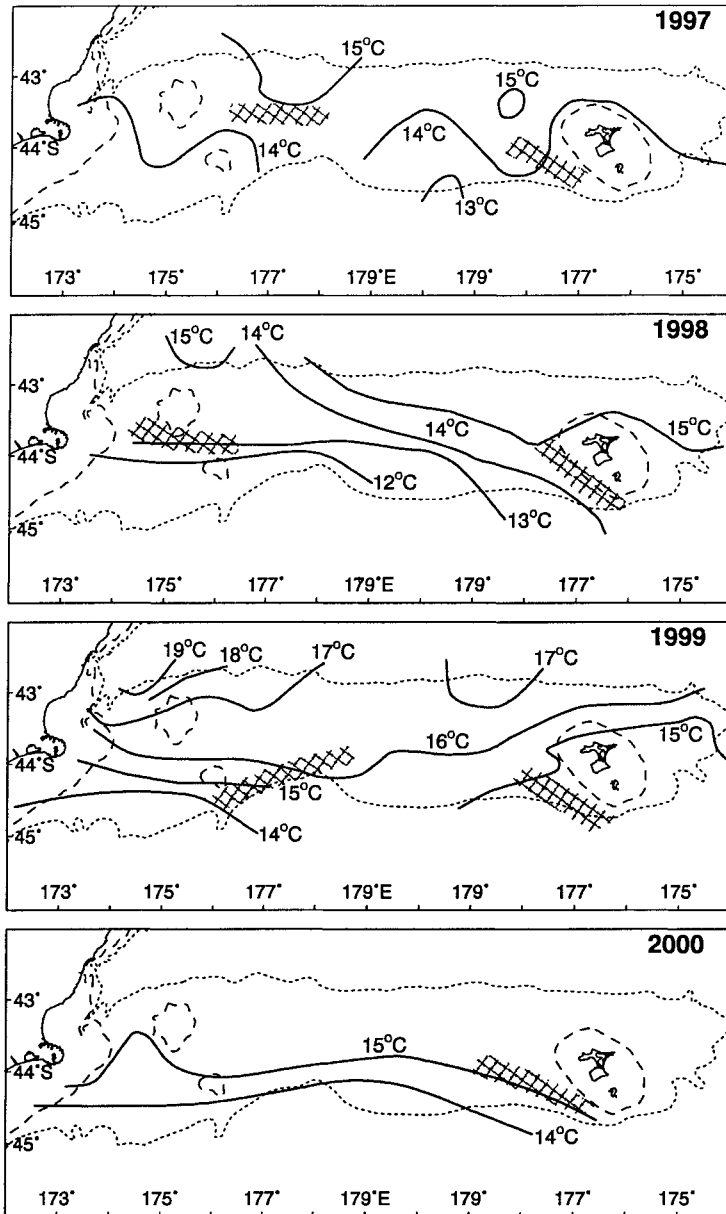
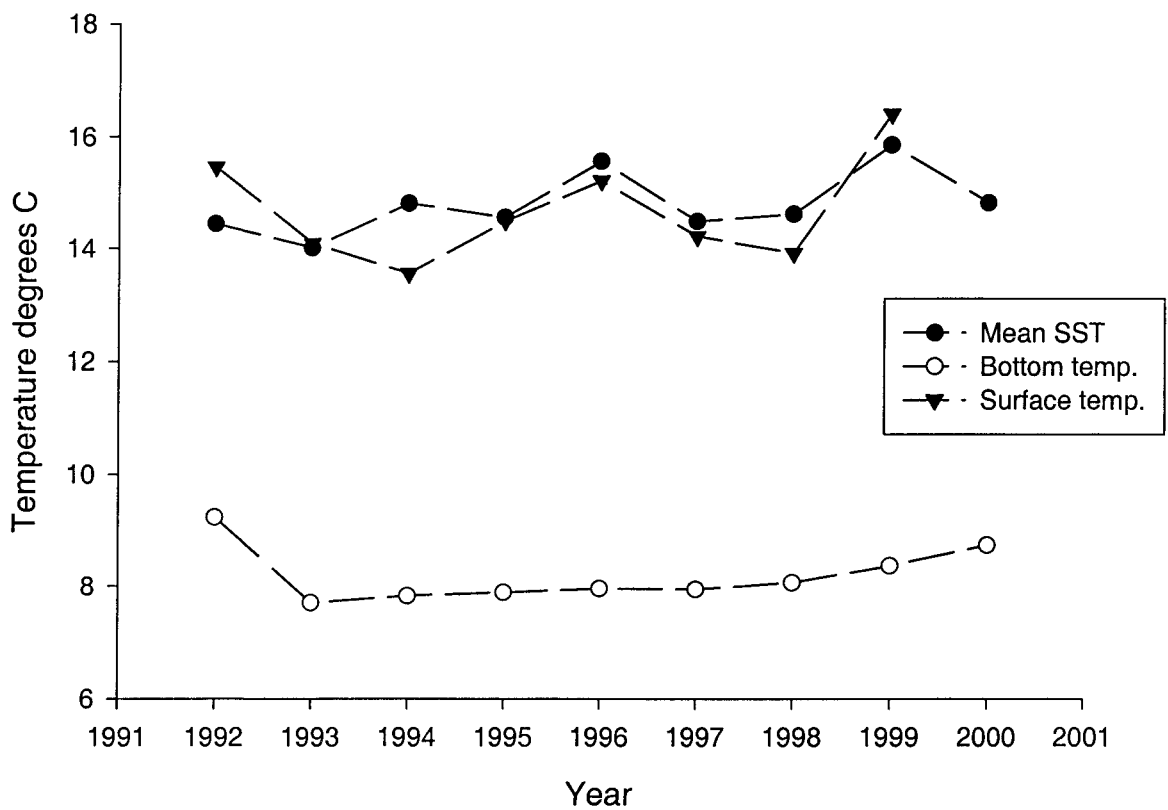
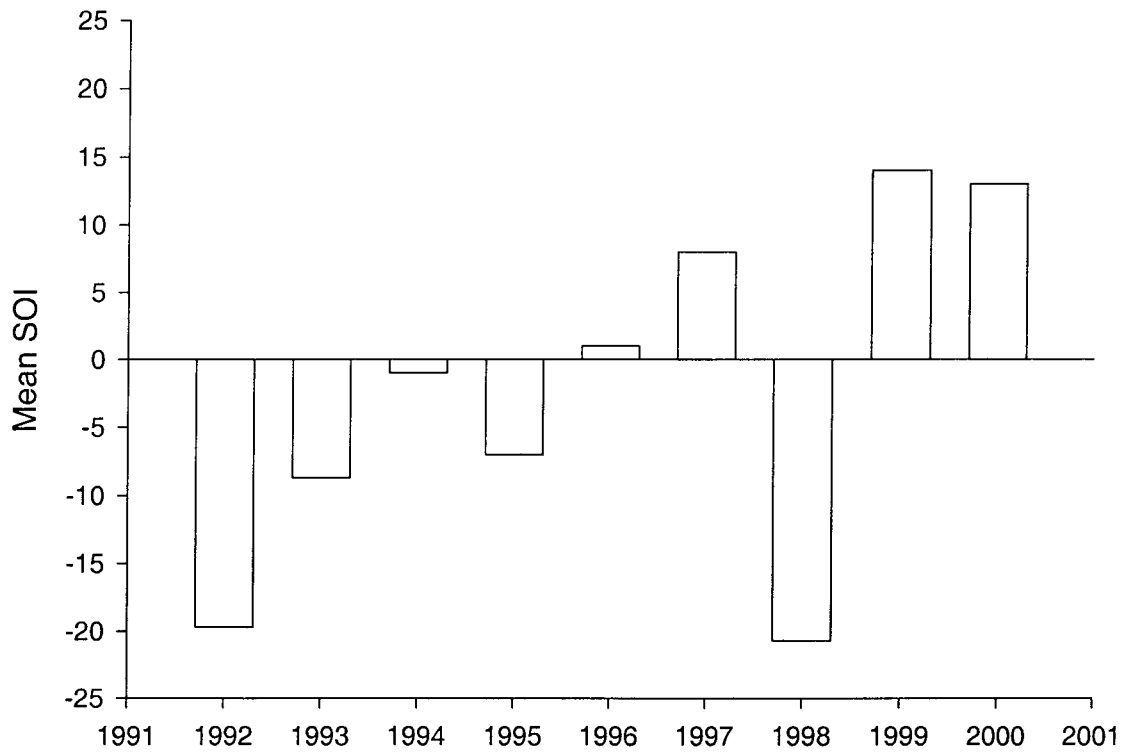


Figure 26: *continued.*



**Figure 27: Mean Southern Oscillation Index (SOI) (top panel), and satellite sea surface temperatures (SST), mean surface and bottom temperatures recorded during survey (all as degrees C x 100) for Chatham Rise trawl surveys 1992-2000. (SST, mean of December, January, February.) Data sources: NIWA Climate Database, NIWA Trawlsurvey Database.**

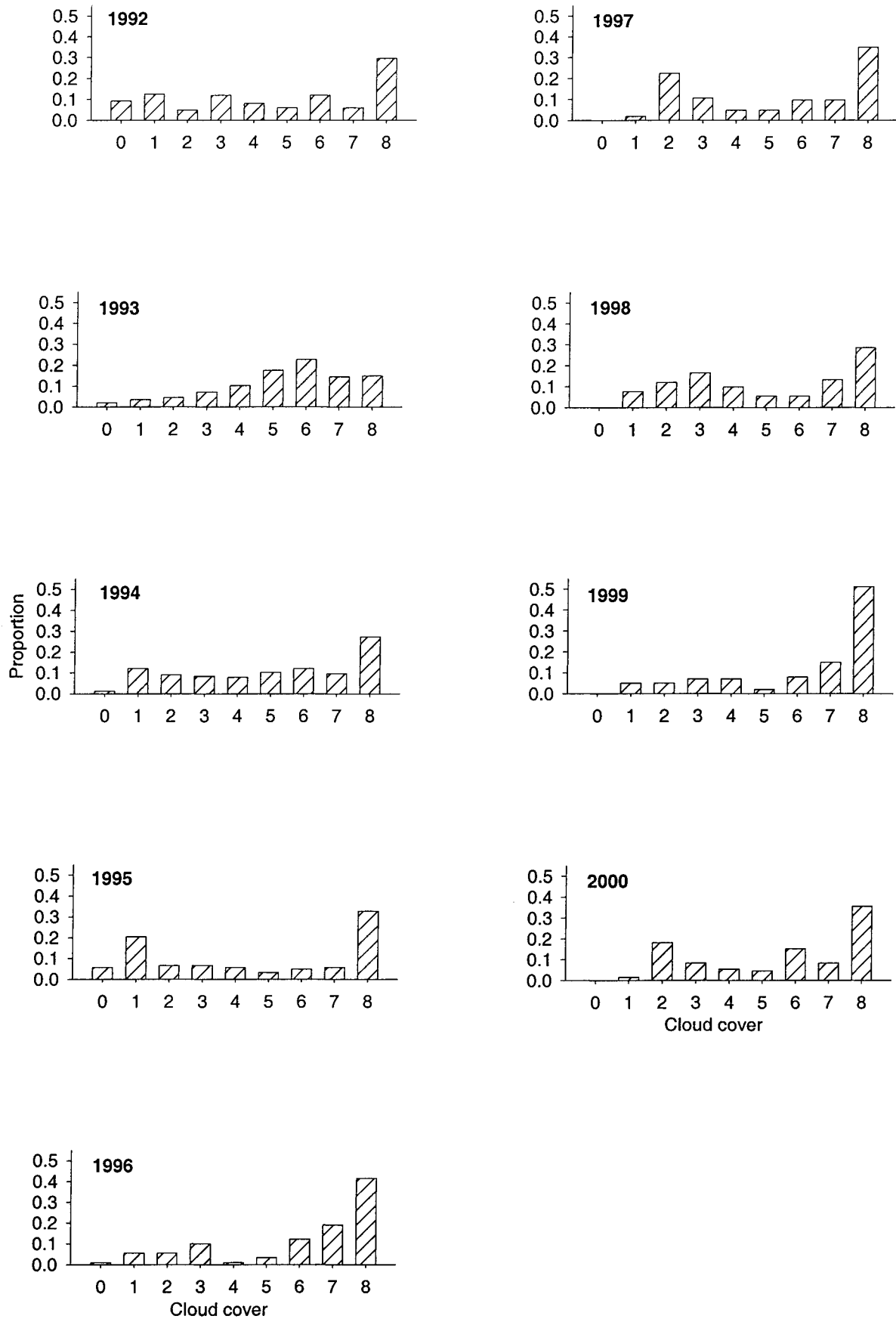
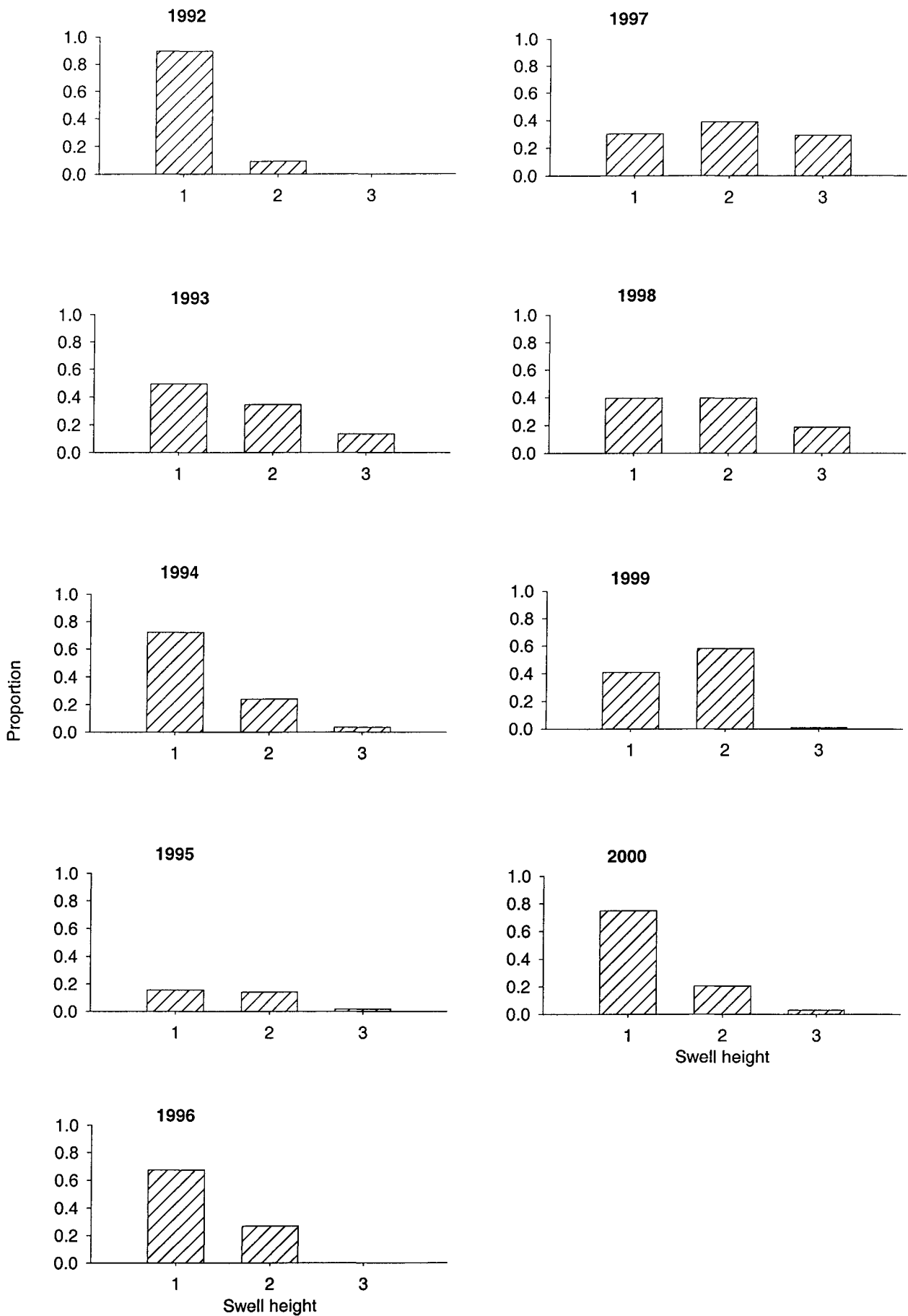
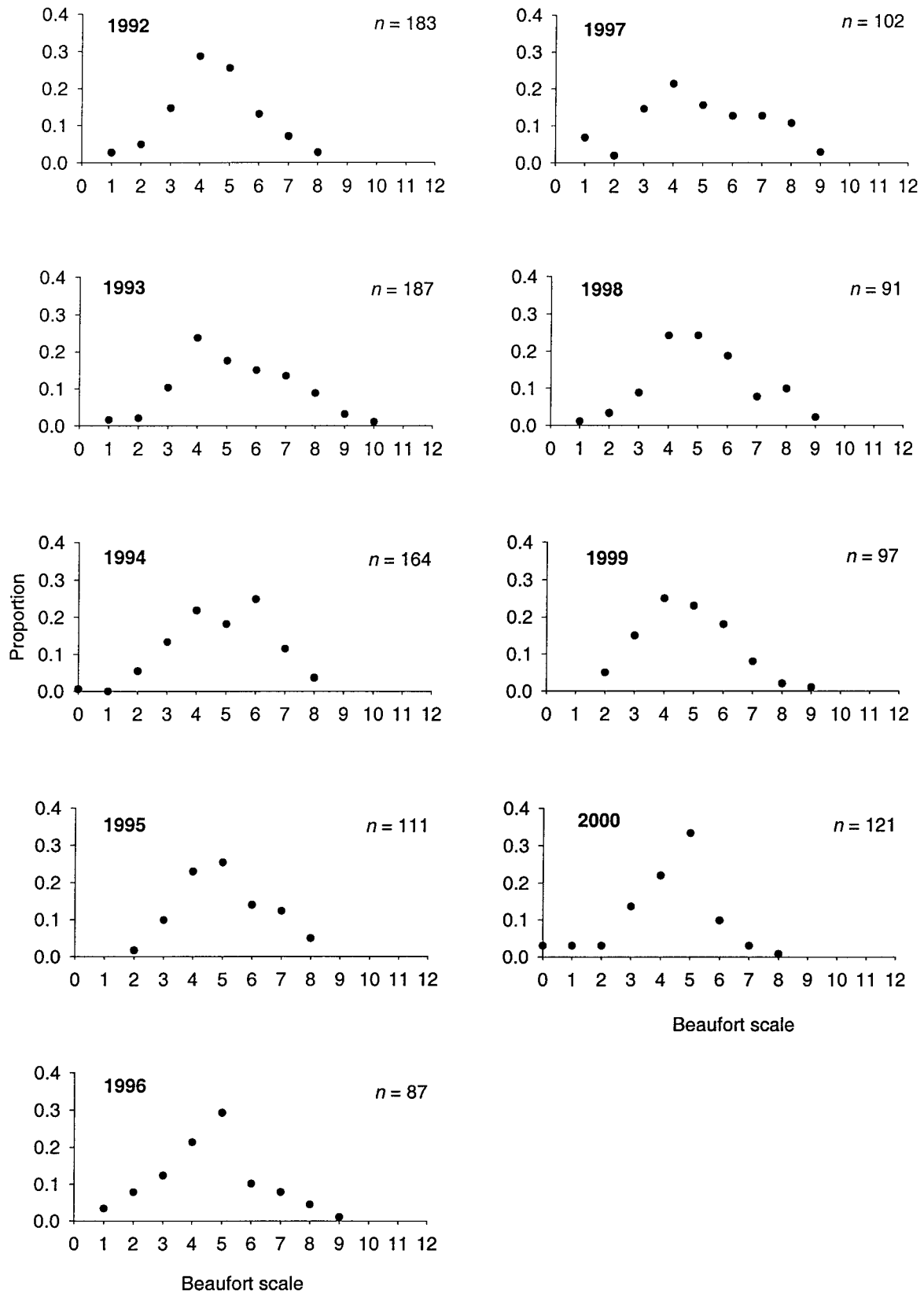


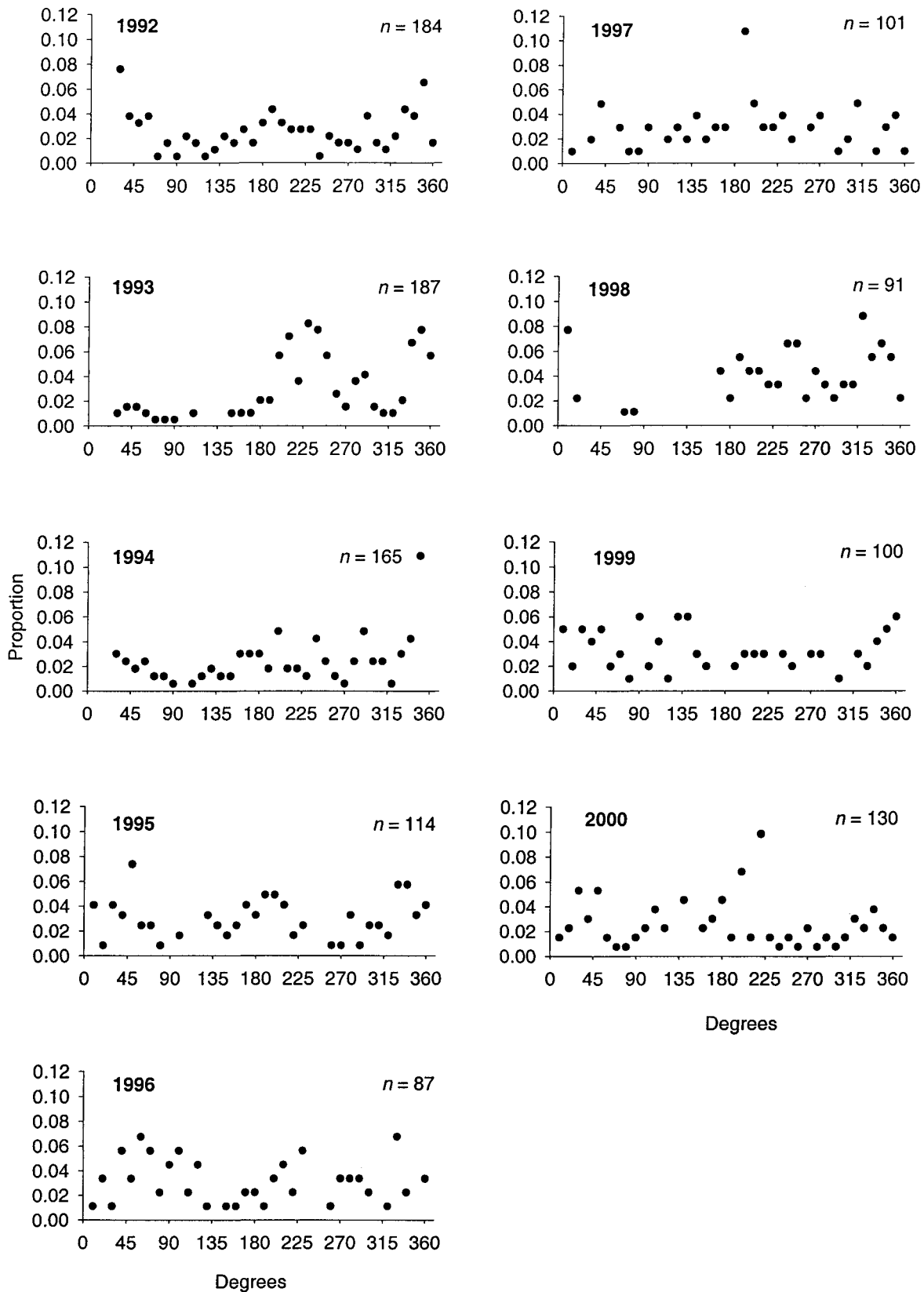
Figure 28: Cloud cover during Chatham Rise trawl surveys, January 1992 to 2000. (Expressed as proportion of tows classed as follows: 0, clear sky; 1-8, number of eighths of sky covered.)



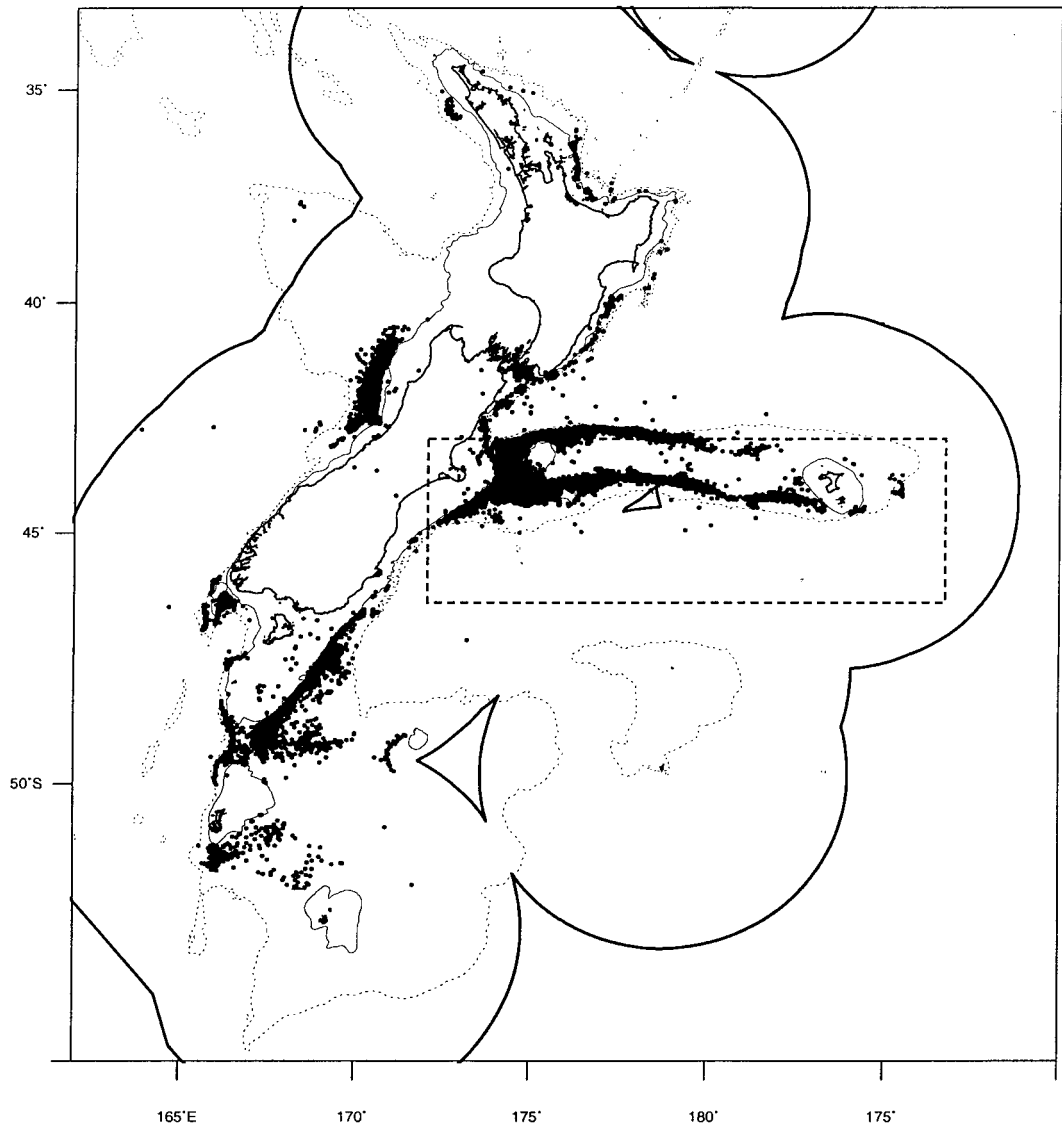
**Figure 29: Swell height during Chatham Rise trawl surveys, January 1992-2000. (Expressed as proportion of tows with swell height classed as follows: 1, 0-2.0 m; 2, 2.0-4.0 m; 3, over 4.0 m.)**



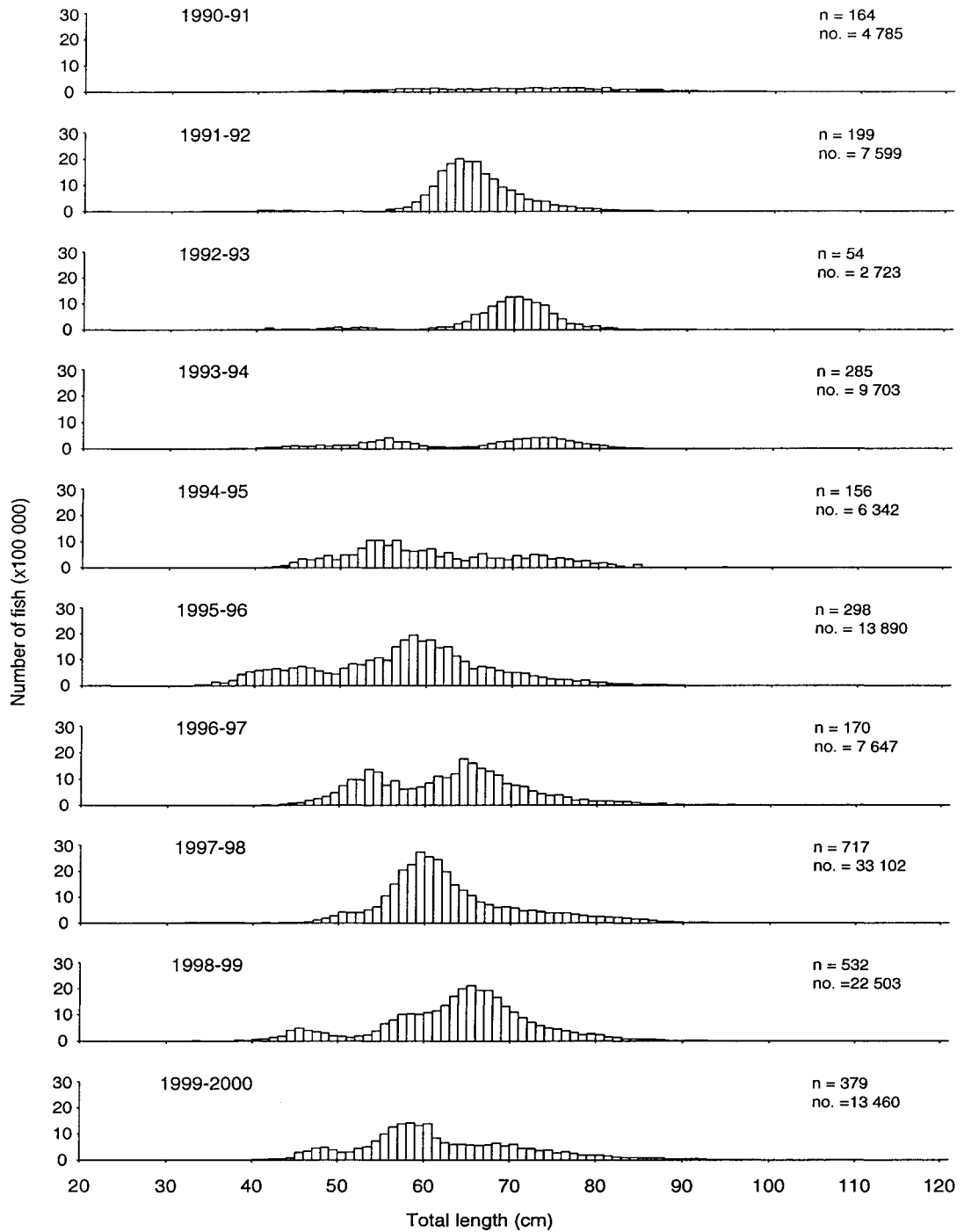
**Figure 30: Wind force (Beaufort Scale) from Chatham Rise trawl surveys, January 1992-2000. (Expressed as proportion of tows for each category of Beaufort Scale classes (112) occurred. *n* number of Beaufort Scale records during survey.)**



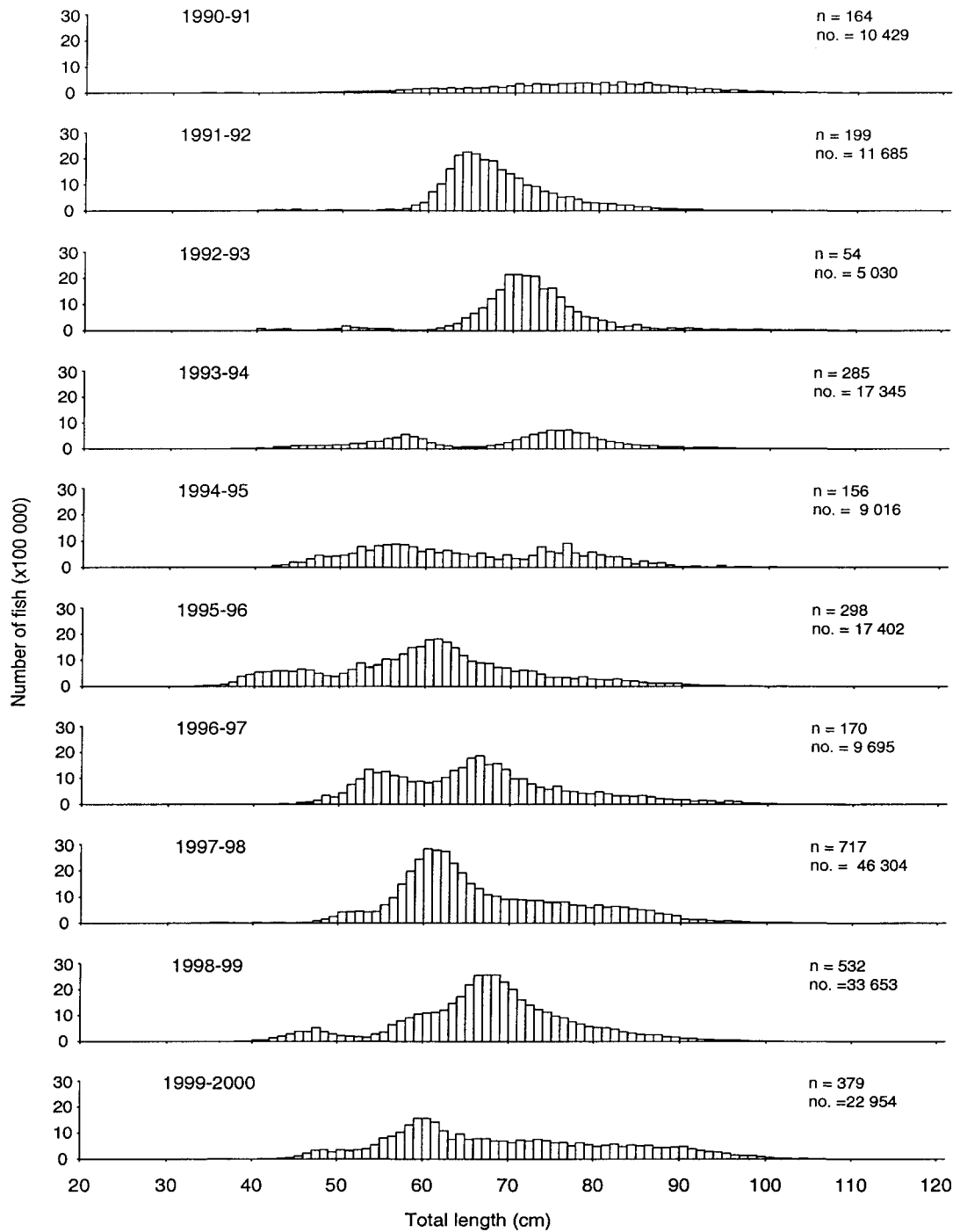
**Figure 31: Wind direction during Chatham Rise trawl surveys, January 1992-2000. (Expressed as proportion of  $n$  number of tows with wind speed data recorded during survey.)**



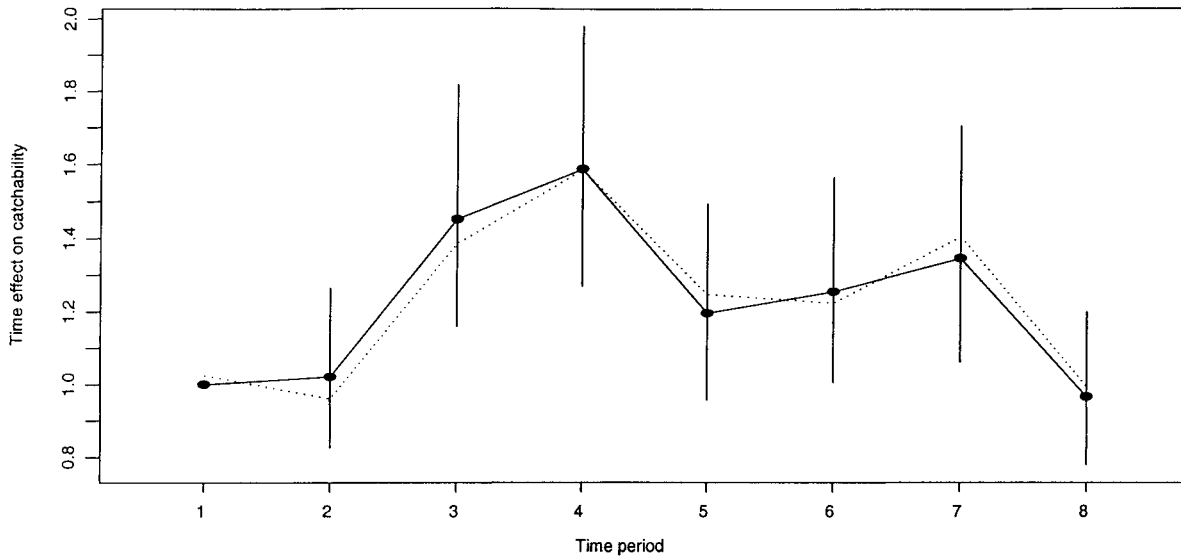
**Figure 32: Distribution of commercial target fishing for hoki in New Zealand waters during the 1999–2000 fishing year. Commercially sensitive positions have been removed. (Box identifies Chatham Rise.)**



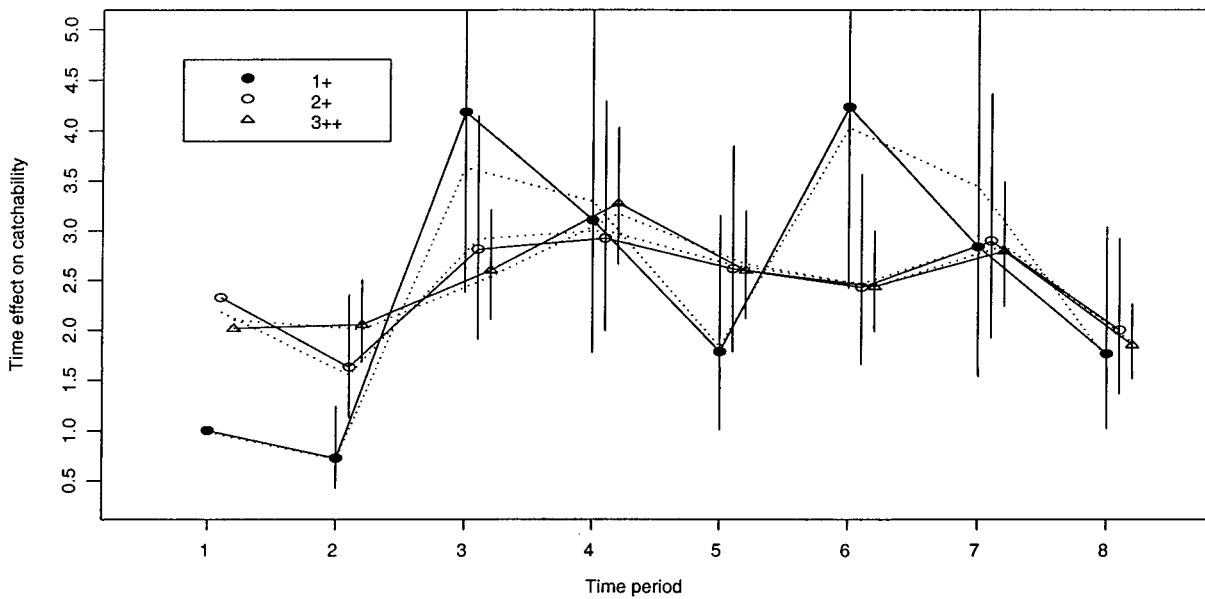
**Figure 33a: Length frequency of male hoki taken in commercial catches from the Chatham Rise non-spawning fishery from 1990-91 to 1999-00 fishing years (sampled at sea by Scientific Observer Programme; n, the number of tows sampled; no., the number of fish sampled).**



**Figure 33b: Length frequency of female hoki taken in commercial catches from the Chatham Rise non-spawning fishery from 1990-91 to 1999-00 fishing years (sampled at sea by Scientific Observer Programme; n, the number of tows sampled; no., the number of fish sampled).**



**Figure 34:** Time effect on Chatham Rise hoki catchability, from the GLM model. The eight time periods are equally spaced intervals from sunrise to sunset (about two hours each). The dotted line represents the time effect recalculated with catch rates over 5000 kg/km<sup>2</sup> removed. (See Table 4 for definitions of time periods.)



**Figure 35.** Time effect on Chatham Rise hoki catchability, by age group, from the GLM model. The dotted lines represent time effects recalculated with catch rates over 5000 kg/km<sup>2</sup> removed. (See Table 4 for definitions of time periods.)

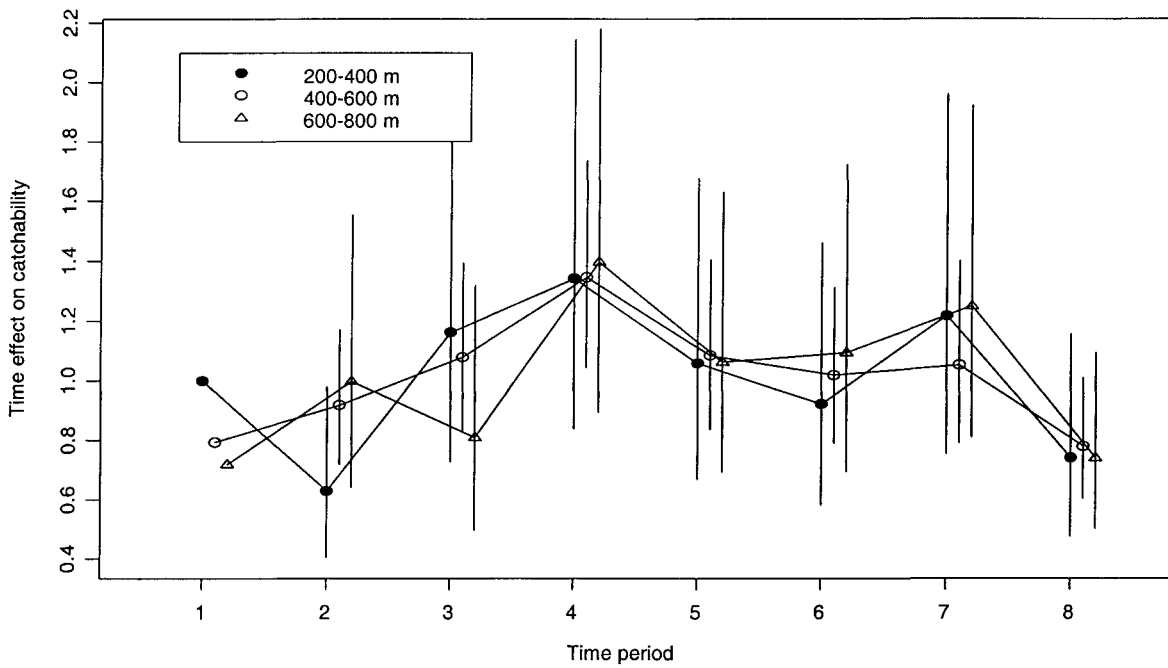


Figure 36: Time effect on Chatham Rise hoki catchability, by depth range, from the GLM model. The dotted lines represent time effects recalculated with catch rates over 5000 kg/km<sup>2</sup> removed. (See Table 4 for definitions of time periods.)

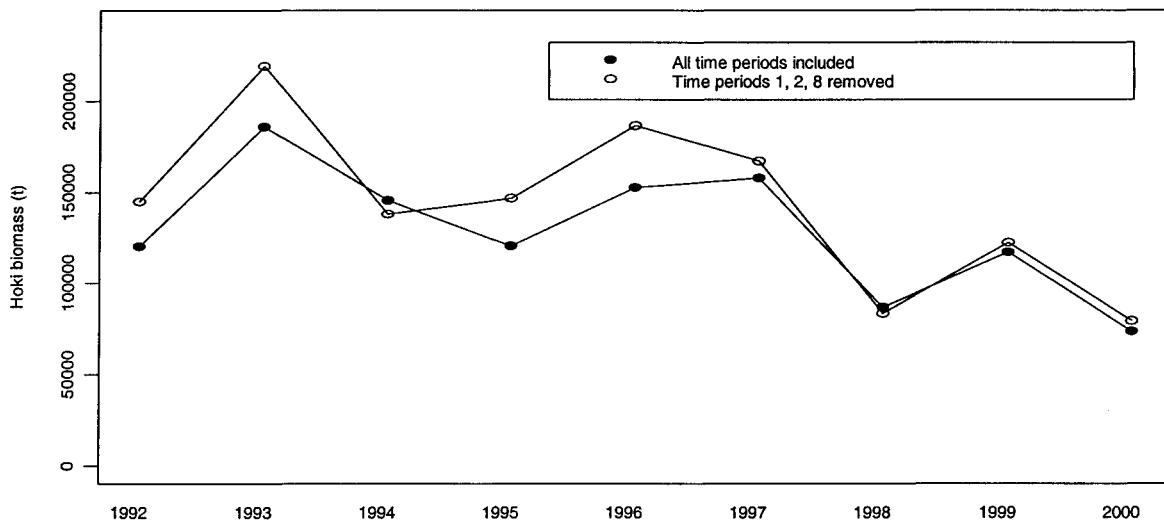


Figure 37: Hoki biomass trajectories, including and excluding time periods 1, 2, and 8, i.e. the four hours after sunrise and two hours before sunset in which hoki catchability is low. (See Table 4 for definitions of time period)

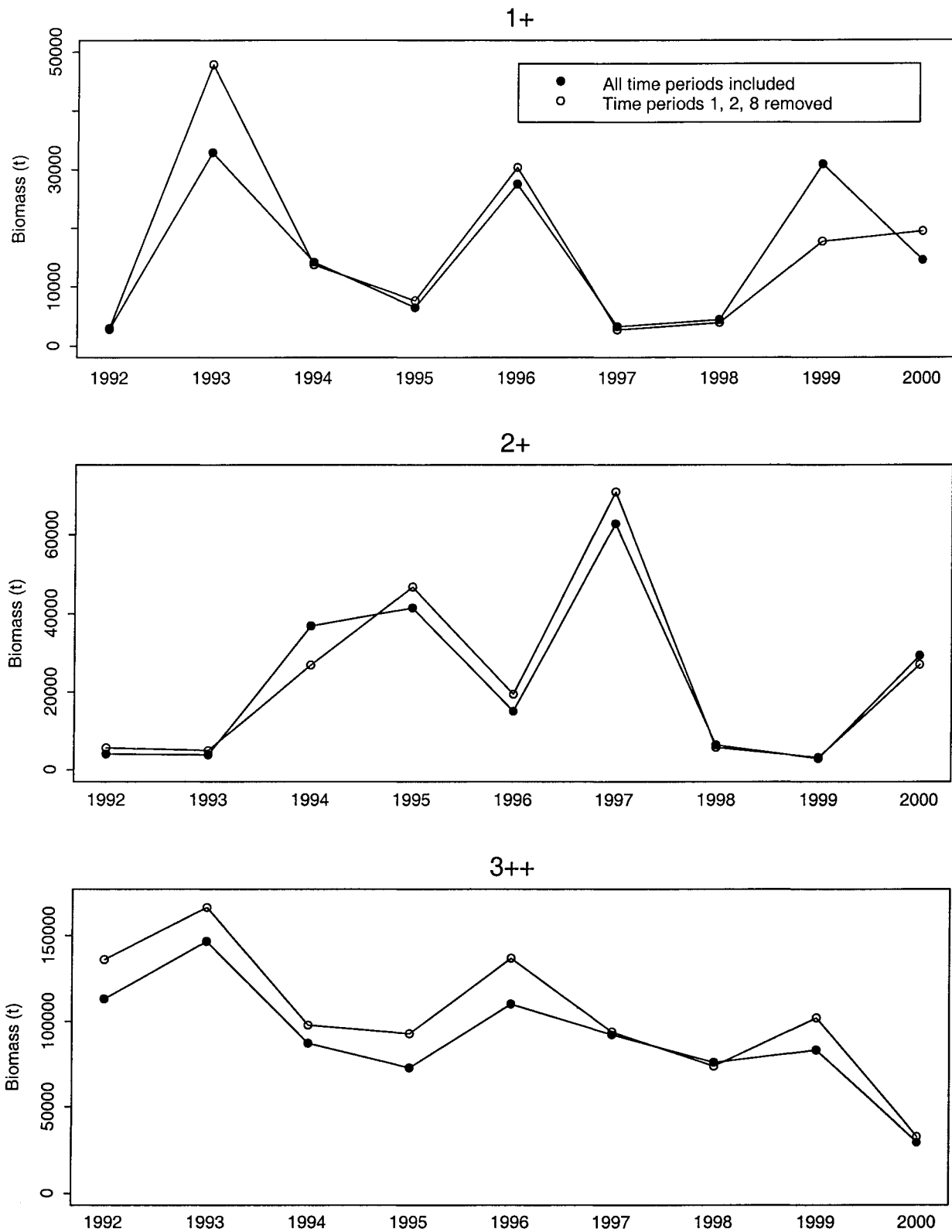


Figure 38: Hoki biomass trajectories by age group, including and excluding time periods 1, 2, and 8. (See Table 4 for definition of time periods.)

**Appendix 1. Mean, median and ranges of length measurements for male, female and unsexed fish by species, Chatham Rise, January 1992-2000. (see Figures 8–22b).**

Year	Males			Females			Unsexed		
	Mean	Med	Range	Mean	Med	Range	Mean	Med	Range
<b>Alfonsino</b>									
1992	26.2	26	18–44	29.5	29	17–48	19.3	20	17–21
1993	30.6	34	17–50	34.1	35	17–51	19	19	17–21
1994	23.3	23	18–45	25	26	19–52	20.9	21	17–27
1995	24.6	24	19–47	25.3	25	20–48	22.2	22	22–23
1996	26.3	27	18–40	27.5	28	19–44	20.7	20	17–28
1997	25.5	26	17–45	26.9	27	19–48	20.9	21	18–28
1998	23.6	22	18–47	25.5	23	19–46	20.4	20	18–26
1999	24.3	24	17–41	26.1	28	17–45	0		
2000	28.2	30	17–50	30.3	31	17–49	22.2	22	18–35
<b>Black oreo</b>									
1992	28.5	29	23–37	28.7	29	22–38	0		
1993	28.9	29	22–38	28.9	29	22–37	0		
1994	27.7	28	23–37	28.1	28	21–37	0		
1995	28.8	29	23–36	29.3	30	23–36	0		
1996	28.4	28	23–36	28.7	29	23–37	26.4	27	24–28
1997	28.4	28	23–38	29	29	24–38	0		
1998	28.1	28	23–35	28.6	28	23–39	0		
1999	28.4	28	22–37	28.7	29	22–38	0		
2000	28.1	28	23–36	28.1	28	22–38	0		
<b>Dark ghost shark</b>									
1992	nil			nil			nil		
1993	55.1	57	23–73	59	61	19–76	47.3	48	44–49
1994	55.2	57	27–73	57.8	60	30–76	26.5	27	26–27
1995	55.5	57	23–73	58.9	61	28–81	48	48	48
1996	56.2	57	32–99	60	62	15–74	0		
1997	55.4	57	25–68	58.5	61	28–78	0		
1998	55	57	30–68	58.6	62	30–77	0		
1999	53.7	55	28–73	57.3	60	30–75	0		
2000	55.4	57	27–68	59.5	63	27–76	45.2	48	40–48
<b>Giant stargazer</b>									
1992	48	48	25–78	58.2	63	26–83	35.6	40	19–51
1993	48.2	48	27–69	61.6	68	27–81	24	24	24
1994	48.4	49	26–73	60.8	64	30–82	31.6	60	15–60
1995	47.7	48	32–68	58.2	62	16–80	22	22	22
1996	48.8	49	24–72	63.8	67	27–82	0		
1997	50	50	25–76	63.8	68	36–80	20.3	21	20–21
1998	48.8	49	29–67	62.9	67	27–82	0		
1999	47.9	49	19–76	62	68	19–81	16	16	16
2000	47.1	48	21–71	59.8	66	20–82	26.4	28	20–39

**Appendix 1: continued**

Year	Males			Females			Unsexed		
	Mean	Med	Range	Mean	Med	Range	Mean	Med	Range
<b>Hake</b>									
1992	80.9	64	43–128	96.1	65	43–128	0		
1993	72.8	81	35–102	86.4	100	37–130	100	100	100
1994	71.3	80	39–115	79.9	91	41–125	0		
1995	76.4	83	46–104	88.9	96	47–128	83.3	91	61–91
1996	69.4	71	35–123	77.8	79	43–114	0		
1997	72.4	75	43–108	81.8	84	43–126	0		
1998	75.2	78	42–97	84.9	87	43–130	63	63	63
1999	71	75	42–104	86	92	47–122	0		
2000	71.1	75	26–100	86.6	90	44–125	0		
<b>Hoki</b>									
1992	60.3	61	35–99	63.1	63	35–110	55.9	59	34–84
1993	51.6	62	29–100	54.5	65	30–107	70	77	36–91
1994	51.4	52	28–99	54.8	54	29–105	75.1	78	39–89
1995	53.9	53	34–99	56.2	55	27–107	56.5	57	46–76
1996	47.3	53	30–101	49.4	56	26–109	61.8	57	42–101
1997	53.9	51	34–97	57.2	54	36–109	52.5	53	52–53
1998	55.6	57	32–95	58.4	59	32–108	52.6	54	40–67
1999	49.8	52	31–104	53.7	57	30–107	78.3	117	38–117
2000	48.4	52	33–96	52.1	55	33–113	58.8	62	38–85
<b>Ling</b>									
1992	77.4	83	28–137	88.8	98	32–166	60.5	49	33–102
1993	76	83	33–138	88.2	98	35–161	88.2	114	45–122
1994	74.9	81	32–138	82.2	91	36–161	0		
1995	79.3	84	35–163	85.1	90	32–162	49	49	49
1996	77.1	81	39–140	82.5	86	39–168	52.3	63	43–63
1997	77.7	83	33–136	83.5	87	39–157	41.6	52	30–52
1998	75.3	81	35–141	80.5	87	35–156	72.8	112	39–112
1999	73.6	84	33–136	76.6	88	25–164	57	57	57
2000	70.2	76	34–142	71.9	76	31–160	62.8	64	43–86

**Appendix 1: continued**

Year	Males			Females			Unsexed		
	Mean	Med	Range	Mean	Med	Range	Mean	Med	Range
<b>Lookdown dory</b>									
1992	27.5	29	12–41	33.3	35	10–55	15.2	16	9–30
1993	26.3	28	11–45	32.5	36	11–61	15.3	16	11–32
1994	25.4	27	9–47	30.8	34	11–55	14.9	15	11–21
1995	27.1	28	11–44	33.1	35	11–56	18	18	16–20
1996	26.2	27	12–47	31.2	34	11–58	13.8	14	11–17
1997	25.7	27	11–45	32.4	35	11–53	16.2	16	11–45
1998	25.9	27	11–43	33.1	36	11–58	12.8	12	10–28
1999	24.7	26	11–44	30.8	34	10–55	14.5	15	10–21
2000	24.5	27	10–41	29.1	33	11–55	19.7	20	13–38
<b>Pale ghost shark</b>									
1992									
1993	66.3	67	38–81	69.6	72	36–86	26	26	26
1994	66.6	68	35–82	67	71	37–89	0		
1995	67.7	69	35–82	69.7	72	28–86	0		
1996	66.2	68	34–79	68.7	71	31–88	0		
1997	66.3	67	34–81	71	72	35–89	0		
1998	67.3	69	18–79	68	72	18–90	0		
1999	66.3	68	25–85	68.2	72	31–84	0		
2000	67.5	69	33–80	70.1	73	28–87	83	83	83
<b>Ribaldo</b>									
1992	46.2	48	37–64	58.5	60	19–76	40	40	40
1993	48.9	50	38–62	55.2	58	35–74	0		
1994	46.4	47	35–61	54.2	59	24–74	0		
1995	48.1	49	38–56	58.2	59	41–78	0		
1996	47.3	48	37–59	58.7	61	34–70	46.1	61	24–61
1997	48.4	51	32–61	55.4	59	29–72	21	21	21
1998	48.4	50	33–64	57.3	60	32–78	0		
1999	48.8	50	32–59	54.7	62	27–70	0		
2000	49.3	52	34–59	56.6	63	31–75	0		
<b>Sea perch</b>									
1992									
1993	28.5	30	13–50	28.7	29	13–49	18.7	20	12–23
1994	29.4	31	12–52	28.7	30	14–49	17.9	18	14–28
1995	32.9	34	16–53	31.4	33	16–49	18	18	16–20
1996	29.5	31	14–50	28.6	30	13–48	18.5	19	13–22
1997	28.7	29	12–49	30	31	13–49	21.5	22	12–27
1998	31.1	33	11–51	29.9	31	13–50	15.6	16	12–20
1999	30.5	31	13–53	30.1	31	13–52	17.2	18	10–24
2000	28	29	12–52	27	28	12–51	18.2	18	11–32

**Appendix 1: continued**

Year	Males			Females			Unsexed		
	Mean	Med	Range	Mean	Med	Range	Mean	Med	Range
<b>Silver warehou</b>									
1992	43.1	43	25–54	44.3	44	23–57	26.8	27	26–28
1993	41.3	43	22–60	42.2	44	22–66	24.9	25	14–30
1994	44.3	47	20–55	44.6	47	21–61	25.7	26	22–29
1995	45.2	46	26–54	47.7	49	34–56	36.3	42	27–52
1996	41.8	46	25–53	43.3	48	25–57	51	51	51
1997	44.6	48	28–57	47.5	51	26–57	0		
1998	45.6	48	24–54	46.7	50	24–56	32.8	33	29–47
1999	43.8	45	22–56	45.3	48	25–56	37	37	37
2000	41	48	24–56	43.1	50	24–59	32.8	51	16–51
<b>Smooth oreo</b>									
1992	32.4	34	17–42	32.4	34	17–48	21	19	17–31
1993	34.5	38	18–47	34.6	38	18–57	21	21	21
1994	30.7	34	17–46	32.4	35	16–50	24.2	24	22–28
1995	28.7	28	19–40	30.1	30	22–42	22	22	22
1996	28.1	30	17–39	30.3	32	17–47	0		
1997	27.9	28	19–45	28.1	28	21–48	0		
1998	27	27	17–34	26.6	27	20–34	0		
1999	28.7	30	19–40	27.2	30	16–43	31	31	31
2000	28.1	28	23–36	28.5	28	22–38	33.3	32	30–38
<b>Spiny dogfish</b>									
1992									
1993	67.2	65	54–89	71.1	70	52–104	0		
1994	68.7	69	55–84	75.2	74	54–106	0		
1995	64.3	65	50–86	73.7	75	51–103	0		
1996	65.9	66	55–83	78.9	84	51–109	0		
1997	65	65	51–90	70.5	69	48–106	0		
1998	66.1	67	50–90	73.5	77	51–107	0		
1999	67.3	68	50–101	75.0	79	43–109	75.9	85	59–91
2000	67	67	55–85	75.7	80	13–107	0		
<b>White warehou</b>									
1992	38.2	37	25–61	39.5	38	22–65	25.4	28	18–35
1993	45.1	47	26–61	44.6	48	27–63	30.3	27	20–34
1994	35.6	37	24–55	36.8	37	26–63	31.6	31	20–39
1995	38	38	27–56	40.9	40	19–62	30.7	28	21–33
1996	39.5	42	18–52	40.9	43	27–56	0		
1997	36.9	38	19–56	36.7	38	26–62	29.1	29	14–33
1998	39.4	43	19–58	37.4	38	21–60	18.4	19	16–20
1999	40.1	44	15–59	39.7	40	16–62	17.6	18	15–21
2000	32.4	31	16–60	32.8	32	24–61	29.5	30	18–37

**Appendix 2: Length weight relationships (males and females combined) calculated from fish measured in each survey, Chatham Rise January 1992–2001, as given in published reports (see Table 2). (\* corrected from original report.)  $W = aL^b$  where W is weight (g) and L is length (cm).**

<b>January 1992</b>	a (intercept)	b (slope)	No. measured	R squared	Length range
Alfonsino	0.0226	3.018	–	–	–
Black oreo	0.0248	2.950	9790	–	–
Giant stargazer	0.0136	3.059	350	–	–
Hake	0.00209	3.273	506	–	–
Hoki	0.00337	2.965	1353	–	–
Ling	0.00126	3.294	1045	–	–
Lookdown dory	0.0288	2.939	197	–	–
Silver warehou	0.0264	2.901	256	–	–
Smooth oreo	0.0309	2.895	9147	–	–
White warehou	0.029	2.971	–	–	–
<b>January 1993</b>					
Alfonsino	0.0226	3.018	–	–	–
Black oreo	0.0248	2.950	9790	0.98	11–44
Dark ghost shark	0.00316	3.161	221	0.98	36–74
Giant stargazer	0.0154	3.022	1546	0.98	11–80
Hake	0.00196	3.292	420	0.99	37–123
Hoki	0.00457	2.896	1206	0.97	34–102
Ling	0.00124	3.298	885	0.99	35–148
Lookdown dory	0.03141	2.896	176	0.96	18–54
Pale ghost shark	0.01780	2.713	107	0.97	26–82
Sea perch	0.01005	3.133	224	0.99	12–48
Silver warehou	0.00740	3.242	172	0.99	22–56
Smooth oreo	0.0309	2.895	9147	0.98	10–57
Spiny dogfish	0.000323	3.620	937	0.94	55–102
White warehou	0.0123	3.152	203	0.99	20–61
<b>January 1994</b>					
Alfonsino	0.016687	3.108198	183	0.99	19–52
Black oreo	0.0248	2.950	9790	0.98	11–44
Dark ghost shark	0.000919	3.476190	50	0.92	50–71
Giant stargazer	0.007300	3.202134	99	0.98	27–79
Hake	0.001785	3.313532	444	0.99	39–125
Hoki	0.002824	3.006239	1002	0.98	34–105
Ling	0.001026	3.343948	896	0.99	36–162
Lookdown dory	0.020022	3.023065	201	0.99	11–45
Pale ghost shark	0.005080	3.031583	79	0.97	38–82
Ribaldo	0.002398	3.400389	116	0.98	24–70
Sea perch	0.012401	3.067271	194	0.99	14–46
Silver warehou	0.013979	3.081886	160	0.99	22–56
Smooth oreo	0.0309	2.895	9147	0.98	10–57
Spiny dogfish	0.000323	3.620	937	0.97	55–102
White warehou	0.016988	3.091715	52	0.96	31–46

**Appendix 2: continued**

<b>January 1995</b>	a (intercept)	b (slope)	No. measured	R squared	Length range
Alfonsino	0.013989	3.152496	168	0.99	19–46
Black oreo	0.0248	2.950	9790	0.98	11–44
Dark ghost shark	0.002243	3.251260	299	0.97	23–81
Giant stargazer	0.009306	3.147073	190	0.96	34–80
Hake	0.001505	3.350649	373	0.99	46–128
Hoki	0.002912	2.999873	881	0.97	38–111
Ling	0.001054	3.341131	482	0.98	32–162
Lookdown dory	0.022979	2.986349	295	0.99	11–51
Pale ghost shark	0.008394	2.924805	237	0.92	35–85
Ribaldo	0.008106	3.089947	55	0.95	42–78
Sea perch	0.010740	3.121018	232	0.98	16–49
Silver warehou	0.012763	3.116759	283	0.95	26–56
Smooth oreo	0.0309	2.895	9147	0.98	10–57
Spiny dogfish	0.001399	3.286653	216	0.97	51–103
White warehou	0.018047	3.069769	190	0.98	19–62
<b>January 1996</b>					
Alfonsino	0.013041	3.167414	235	0.99	19–45
Black oreo	0.0248	2.950	9790	0.98	11–44
Dark ghost shark	0.001804	3.301619	525	0.97	30–74
Giant stargazer	0.005893	3.255780	350	0.97	26–82
Hake	0.001393	3.376991	333	0.98	35–123
Hoki	0.003562	2.949023	1511	0.99	34–102
Ling	0.000910	3.375572	758	0.99	40–168
Lookdown dory	0.016634	3.069184	359	0.99	13–58
Pale ghost shark	0.004158	3.091938	342	0.97	36–87
Ribaldo	0.002300	3.408922	54	0.97	35–71
Sea perch	0.007767	3.219132	453	0.99	17–49
Silver warehou	0.006864	3.271782	268	0.99	26–57
Smooth oreo	0.0309	2.895	9147	0.98	10–57
Spiny dogfish	0.001890	3.194061	170	0.97	53–106
White warehou	0.016503	3.092372	95	0.98	18–56
<b>January 1997</b>					
Alfonsino	0.013041	3.167414	235	0.99	19–45
Black oreo	0.0248	2.950	9790	0.98	11–44
Dark ghost shark	0.003336	3.154065	114	0.97	28–74
Giant stargazer	0.004751	3.315037	18	0.98	42–70
Hake	0.001806	3.313273	295	0.98	43–126
Hoki	0.003262	2.973415	793	0.98	38–109
Ling	0.001027	3.349249	588	0.99	38–155
Lookdown dory	0.026059	2.955319	39	0.99	23–53
Pale ghost shark	0.039787	2.559277	24	0.82	63–81
Ribaldo	0.002300	3.408922	54	0.97	35–71
Sea perch	0.005876	3.299961	101	0.99	17–38
Silver warehou	0.006840	3.263780	144	0.87	41–57
Smooth oreo	0.0309	2.895	9147	0.98	10–57
Spiny dogfish	0.001890	3.194061	170	0.97	53–106
White warehou	0.019447	3.044881	128	0.98	19–62

**Appendix 2: continued**

<b>January 1998</b>	a (intercept)	b (slope)	No. measured	R squared	Length range
Alfonsino	0.016244	3.089867	358	0.99	19–47
Black oreo	0.0248	2.950	9790	0.98	11–44
Dark ghost shark	0.001465	3.348698	356	0.98	30–61
Giant stargazer	0.009003	3.150386	208	0.97	27–82
Hake	0.001484	3.354876	280	0.98	42–130
Hoki	0.004059	2.922190	982	0.98	36–101
Ling	0.001890	3.309269	676	0.99	35–156
Lookdown dory	0.029443	2.911941	520	0.99	11–52
Pale ghost shark	0.005897	2.990722	284	0.96	18–90
Ribaldo	0.002371	3.394730	79	0.98	32–78
Sea perch	0.010757	3.124765	235	0.99	14–51
Silver warehou	0.006479	3.281561	279	0.99	24–55
Smooth oreo	0.0309	2.895	9147	0.98	10–57
Spiny dogfish	0.001890	3.194061	170	0.97	53–106
White warehou	0.017191	3.074470	264	0.99	16–60
<b>January 1999</b>					
Alfonsino	0.024253	2.982670	514	0.97	18–43
Black oreo	0.0248	2.950	9790	0.98	11–44
Dark ghost shark	0.002764	3.201944	429	0.98	28–71
Giant stargazer	0.008959	3.148286	266	0.99	19–81
Hake	0.002597	3.225967	264	0.98	40–122
Hoki	0.003788	2.940880	1775	0.98	37–107*
Ling	0.001136	3.320987	996	0.99	25–164
Lookdown dory	0.028384	2.917760	551	0.99	12–55
Pale ghost shark	0.006195	2.994958	256	0.96	25–85
Ribaldo	0.002025	3.450293	58	0.98	30–70
Sea perch	0.012720	3.091254	558	0.99	12–53
Silver warehou	0.010953	3.143978	631	0.98	22–56
Smooth oreo	0.0309	2.895	9147	0.98	10–57
Spiny dogfish	0.001334	3.278974	368	0.96	51–103
White warehou	0.011986	3.168799	402	0.99	15–62
<b>January 2000</b>					
Alfonsino	0.024446	2.971760	145	0.99	19–50
Black oreo	0.0248	2.950	9790	0.98	11–44
Dark ghost shark	0.001532	3.327454	292	0.98	27–76
Giant stargazer	0.009574	3.129751	318	0.98	20–82
Hake	0.001975	3.285028	360	0.99	26–125
Hoki	0.002837	3.005508	2274	0.99	33–113
Ling	0.001133	3.316120	1852	0.99	31–160
Lookdown dory	0.020961	3.002427	347	0.99	12–55
Pale ghost shark	0.005726	3.008041	170	0.98	28–87
Ribaldo	0.002025	3.450293	58	0.98	30–70
Sea perch	0.005705	3.304976	174	0.99	14–49
Silver warehou	0.006552	3.270693	199	0.99	25–55
Smooth oreo	0.0309	2.895	9147	0.98	10–57
Spiny dogfish	0.002365	3.130318	256	0.96	55–101
White warehou	0.013459	3.123951	186	0.99	27–61

**Appendix 2: continued**

<b>January 2001</b>	a (intercept)	b (slope)	No. measured	R squared	Length range
Alfonsino	0.025637	2.970389	372	0.99	18–51
Black oreo	0.0248	2.950	9790	0.98	11–44
Dark ghost shark	0.001842	3.292118	1121	0.98	24–72
Giant stargazer	0.008100	3.172980	222	0.99	23–81
Hake	0.001728	3.320535	265	0.98	42–124
Hoki	0.004088	2.926636	2357	0.98	38–113
Ling	0.001367	3.274187	1762	0.99	30–159
Lookdown dory	0.025911	2.949984	1058	0.99	11–57
Pale ghost shark	0.007470	2.937547	869	0.97	21–88
Ribaldo	0.004182	3.257220	188	0.98	27–72
Sea perch	0.007209	3.234593	835	0.99	10–49
Silver warehou	0.010588	3.131576	635	0.99	24–57
Smooth oreo	0.0309	2.895	9147	0.98	10–57
Spiny dogfish	0.001856	3.193229	991	0.96	48–105
White warehou	0.013570	3.119643	517	0.98	14–65

### Appendix 3: Scientific and common names used in this document.

Common name	Scientific name
Alfonsino	<i>Beryx splendens</i>
Arrow squid	<i>Nototodarus sloanii</i> & <i>N. gouldi</i>
Barracouta	<i>Thyrsites atun</i>
Big-eye rattail	<i>Caelorinchus bollonsi</i>
Black oreo	<i>Allocyttus niger</i>
Dark ghost shark	<i>Hydrolagus novaezealandiae</i>
Giant stargazer	<i>Kathetostoma giganteum</i>
Hake	<i>Merluccius australis</i>
Hapuku	<i>Polyprion oxygeneios</i>
Hoki	<i>Macruronus novaezealandiae</i>
Javelinfish	<i>Lepidorhynchus denticulatus</i>
Lemon sole	<i>Pelotretis flavilatus</i>
Ling	<i>Genypterus blacodes</i>
Lookdown dory	<i>Cyttus traversi</i>
Peruvian mackerel	<i>Trachurus murphyi</i>
Oblique banded rattail	<i>Caelorinchus asp.ercephalus</i>
Oliver's rattail	<i>Caelorinchus oliverianus</i>
Orange perch	<i>Lepidoperca aurantia</i>
Pale ghost shark	<i>Hydrolagus</i> sp. B2
Red bait	<i>Emmelichthys nitidus</i>
Red cod	<i>Pseudophycis bachus</i>
Ribaldo	<i>Mora moro</i>
School shark	<i>Galeorhinus galeus</i>
Sea perch	<i>Helicolenus</i> sp.
Shovelnose dogfish	<i>Deania calcea</i>
Silver warehou	<i>Seriolella punctata</i>
Smooth oreo	<i>Pseudocyttus maculatus</i>
Spiky oreo	<i>Neocyttus rhomboidalis</i>
Spiny dogfish	<i>Squalus acanthias</i>
Tarakihi	<i>Nemadactylus macropterus</i>
White warehou	<i>Seriolella caerulea</i>