Review of summer and autumn trawl survey time series from the Southland and Sub-Antarctic areas, 1991–98

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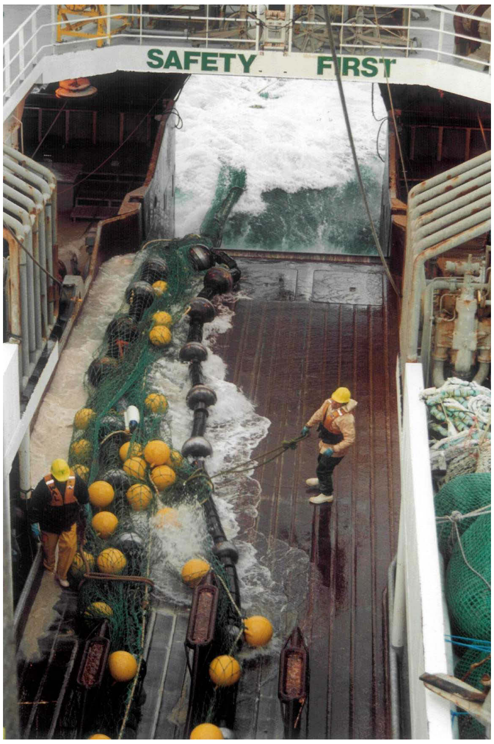

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Abstract

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Two time series of stratified random trawl surveys were carried out in the Southland and Sub-Antarctic region from RV *Tangaroa*: a summer series in 1991, 1992, and 1993; and an autumn series in 1992, 1993, 1996, and 1998. The key objectives of these surveys were to estimate biomass and collect biological samples from hoki, hake, and ling. All trawl surveys covered a core area of 300–800 m depth over the Southern Plateau and the Puysegur Bank. Additional strata in deeper water (800–1000 m) and in other areas (Bounty Platform) were surveyed in some years. Trends in estimated biomass, distribution, and length frequency are described for 12 major species (11 commercial and 1 non-commercial). Population age frequencies, maturity information and observations from relevant commercial catches are also presented for the three target species (hoki, hake, and ling).

Biomass of hoki, hake, and ling were estimated with acceptable levels of precision (c.v.s less than 15% for hoki and ling and less than 20% for hake) in all surveys except in summer 1991 when a single large catch of hake raised the c.v. for this species to 44%. Precise estimates of biomass (c.v. under 20%) were also obtained for pale ghost shark, ribaldo, and javelinfish. No significant trends in biomass were observed in the three years of the summer trawl series. Four species showed significant trends ($p < 0.05$) over the autumn trawl series. Biomass estimates for ling and hake in core strata decreased between 1992 and 1998, while southern blue whiting and pale ghost shark increased. Biomass estimates of hoki were consistently lower in autumn surveys than in the summer because an unknown proportion of hoki had already left the Southland and Sub-Antarctic residence area for the spawning grounds (presumed west coast) by the time of the autumn surveys (March–June).

The 1984, 1987, and 1991–94 hoki age classes appear strong and corresponding modes in length frequency were discernible in both research series and in commercial data. It was not possible to recognise variability in recruitment from ling or hake age data, but there was some indication that the proportion of younger smaller ling and hake had increased in 1996 and 1998. Precision of scaled age frequency estimates for hake were poor (c.v. 50–80%) because sample sizes were low.

Reproductive data from research and commercial observations indicated some ling were in spawning condition at the time of the summer survey (November–December). Biomass estimates of ling in the summer were lower than in autumn surveys and this may be related to spawning behaviour. The timing of hake spawning was uncertain.

It is recommended that the trawl survey series should be continued during the summer when hoki are most abundant on the Southern Plateau. Further research is necessary to determine the potential impacts of spawning on estimates of ling and hake biomass in summer. More hake should be sampled and aged to improve estimates of age frequency.

Introduction

Southland and Sub-Antarctic fisheries

The Southland and Sub-Antarctic trawl survey area (Figures 1a-1d) lies to the south of the South Island of New Zealand, within Quota Management Areas (QMAs) 5 and 6. The core survey area covers the 300–800 m depth range over the Puysegur Bank and Southern Plateau (including the southern and eastern Stewart-Snares shelf, waters around the Campbell and Auckland Islands, and the Pukaki Rise). This area supports important commercial fisheries for hoki (*Macruronus novaezelandiae*), southern blue whiting (*Micromesistius australis*), hake (*Merluccius australis*), and ling (*Genypterus blacodes*).

The Southern Plateau is important as the residence area for the "western" hoki stock that are presumed to spawn off the west coast of the South Island in winter. Catches of "western" stock hoki from adult spawning and residence areas combined were about 122 000 t in 1998–99, of which 26 000 t was caught in the Southland and Sub-Antarctic (Annala et al. 2000). Hoki is managed as a unit stock throughout the New Zealand Exclusive Economic Zone (EEZ), with a Total Allowable Commercial Catch (TACC) of 250 000 t. There are targeted trawl fisheries for hoki in the Southland and Sub-Antarctic throughout the year, with most of the catch taken between February and June (Ballara et al. 2000).

Southern blue whiting are almost entirely restricted to Sub-Antarctic waters. They are dispersed over much of the Southern Plateau and Bounty Platform during the year, but aggregate on known spawning grounds (Campbell Island Rise, Pukaki Rise, Bounty Platform, and Auckland Islands) during August and September. Trawl fisheries target spawning aggregations from August to October (Hanchet 2000). The TACC for southern blue whiting is 58 000 t, with a reported catch of 40 000 t in 1998–99 (Annala et al. 2000).

The TACC for hake in HAK 1, which includes the Sub-Antarctic area, is 3632 t, most of which is taken on the Southern Plateau. The relevant TACCs for ling are 3001 t (LIN 5, Southland) and 7100 t (LIN 6, Sub-Antarctic). Catches of both species have been increasing and are now at historically high levels (Annala et al. 2000). Hake and ling are taken as bycatch during the hoki trawl fishery, and also by targeted trawl fisheries particularly during the September to December spawning period. Ling are also caught in a targeted longline fishery. The line fishery has taken 35–45% of the total commercial catch of ling in LIN 5 and LIN 6 in 1996–1999 (Annala et al. 2000).

Several other Quota Management System (QMS) species are caught in the Southland and Sub-Antarctic trawl survey area, mainly in commercial fisheries targeting hoki, hake, and ling. These include pale ghost shark (*Hydrolagus* sp. B2), dark ghost shark (*Hydrolagus novaezelandiae*), ribaldo (*Mora moro*), white warehou (*Seriolella caerulea*), and silver warehou (*Seriolella punctata*).

The 1991–98 trawl survey time series

Trawl surveys of the Southland and Sub-Antarctic area provide valuable, fishery-independent indices of relative abundance for hoki, hake, and ling. There are few alternative estimates of abundance for these species in the southern area. Catch-per-unit-effort (CPUE) and acoustic survey indices for the "western" hoki stock are based on west coast South Island data and surveys, and require assumptions about the proportion of hoki which migrate to the area to spawn. CPUE data are used in the stock assessment of ling, mainly from longliners targeting ling on the Bounty Platform. Trawl surveys also provide biological data to estimate size and age structure, and gonad stage information for hoki, hake, and ling. Population trends of southern blue whiting in the Southland and Sub-Antarctic are not estimated from trawl survey time series. Targeted acoustic surveys of southern blue whiting in this region have been carried out since 1993. These surveys estimate biomass at known spawning locations during the spawning season (e.g., Hanchet et al. 2000).

Two time series of trawl surveys have been carried out in the Southland and Sub-Antarctic region from RV *Tangaroa*: a summer series in 1991, 1992, and 1993; and an autumn series in 1992, 1993, 1996, and 1998. Each of these surveys has been documented individually (Table 1), but there has been little comparison of the results between surveys. This report reviews the two time series and provides analyses of trends in the relative abundance, distribution and size frequency of 12 important middle depth species in the Southland and Sub-Antarctic region. They will provide a data summary that will be useful in designing future surveys. The 2000 Southland and Sub-Antarctic trawl survey will be conducted in the summer and it is timely to assess the relative merits of the summer and autumn time series.

Objectives within the two trawl survey time series varied. The main focus of the summer survey series (1991–93) was to estimate abundance of hoki. Summer surveys were conducted at the time when all adult "western" fish were expected to be in the southern residence area. There was a secondary objective in summer surveys to estimate abundance of southern blue whiting, hake, ling, and other associated species. Surveys in autumn 1992 and 1993 were aimed at determining the proportion of hoki that were maturing and were going to spawn during the winter. Later surveys (1996 and 1998) were designed primarily for estimating hake and ling abundance. These surveys were carried out during autumn because biomass estimates for hake and ling were generally higher and more precise at this time of year. Hoki biomass was estimated from all autumn surveys, but in autumn some fish have probably already left the southern area for the spawning grounds.

Despite the variations in survey objectives, all surveys within the two time series were carried out using the same trawl gear (eight-seam hoki bottom trawl) and vessel (RV *Tangaroa*). The same core area encompassing 300–800 m depth on the Southern Plateau and Puysegur Shelf was covered in all seven surveys (Figure 1a). Additional strata at the Bounties (300–600 m) and in deeper water (800–1000 m) were also included in some surveys (Figure 1b–d). Biological, bathymetric, and water temperature data were collected in all surveys.

Previous Southland and Sub-Antarctic trawl surveys

Hurst & Schofield (1995) summarised comparable research trawl surveys in the Southland and Sub-Antarctic areas from 1979 to 1990. Exploratory trawl surveys were carried out from *Wesermünde* in April–May, September–October, and October–November 1979 (Francis 1981), and from *Shinkai Maru* in March–April 1982 (van den Broek et al. 1984) and October–November 1983 (Hatanaka et al. 1989). A trawl survey series with the primary objective to estimate hoki biomass was initiated in October–November 1989 from *Amaltal Explorer* (Livingston & Schofield 1993), and continued from the same vessel in July–August and November–December 1990 (Hurst & Schofield 1995). Surveys on *Shinkai Maru* and *Amaltal Explorer* covered the same core area as the 1991–98 *Tangaroa* survey series, but uncertainties about the effect of differences in gear and catching ability between vessels (e.g., Hurst & Schofield 1991) make formal comparisons of abundance between these early surveys and the current *Tangaroa* series impossible.

An additional *Tangaroa* trawl survey in the Southland and Sub-Antarctic area was carried out in September–October 1992 to estimate proportion of hoki spawning at age (Schofield & Livingston 1994c). Although this survey was outside the two time series being considered (summer and autumn), we include biomass estimates from the September–October 1992 survey when plotting trends in abundance to illustrate the seasonality (or otherwise) of key species.

Trawl surveys around the Stewart-Snares shelf and Puysegur Bank at shallower depths (30–600 m) were carried out annually from RV *Tangaroa* in February–March, 1993–96. Results of these surveys were reviewed by Hurst & Bagley (1997).

Hydrology of the Southland and Sub-Antarctic area

Oceanic circulation over the trawl survey area was described by Morris et al. (in press) and illustrated by Carter et al. (1998). Circulation is strongly constrained by bathymetry. Current flow to the south of New Zealand is predominantly west to east (Heath 1975). The Southern Plateau acts as a flow barrier, forcing subtropical waters north along the edge of the Stewart-Snares shelf and southern ocean waters south around the southern edge of the Plateau. This results in a large, nearly homogeneous region of water over the Southern Plateau with generally weak current flows. The major water mass over the Southern Plateau is Sub-Antarctic Mode Water which is characterised by weak thermal stratification, relatively cool temperatures, and low salinity (Morris et al. in press). In the northern part of the survey area over Puysegur Bank and along the northwestern edge of the Stewart-Snares shelf, Sub-Antarctic Mode Water is bounded by warmer, more saline water of subtropical origin at the Subtropical Front. These waters mix and flow northeast along the continental shelf as the Southland Current (Chiswell 1996). To the south of the survey area, Sub-Antarctic Mode Water is bounded by the Sub-Antarctic Front. The Sub-Antarctic Front is the northern boundary of the Antarctic Circumpolar Current and there is an abrupt transition to colder, less saline water and a strong jet-like flow. The Sub-Antarctic Front extends northeast of the Southern Plateau crossing over the Bounty Platform.

Methods

Survey area and design

The core Southland and Sub-Antarctic trawl survey area (263 000 km^2) is bounded by latitudes 46° and 54° S and longitudes 165° and 176° E and divided into 15 strata by depth (300–600 m, 600–800 m) and area (Figure 1a). Known areas of foul ground are excluded from the area. This core area has remained virtually unchanged over the time series. Minor alterations have been made to some stratum boundaries because of better definition of depth boundaries and better identification of untrawlable ground (see individual survey reports for details), but the overall change to the core 300–800 m area has been less than 0.5%.

Only the 15 strata in the core area were covered in autumn surveys in 1992 and 1993. In the summer trawl series (1991–1993), two additional strata were added: a deeper stratum (800–1000 m) around Puysegur and a 300–600 m depth stratum around the Bounty Platform (Figure 1b). The Bounty stratum was not surveyed in summer 1991 due to time and weather constraints. Note that because of the inclusion of the deeper stratum around Puysegur, stratum numbers over the core area in summer surveys were different from stratum numbers in autumn surveys in 1992 and 1993. For example the West Pukaki 600–800 m stratum was called Stratum 9 in summer surveys and Stratum 8 in autumn surveys in 1992 and 1993.

The depth range of the survey was extended to 1000 m around most of the area in autumn 1996, with the exception of the eastern boundary where it was considered unlikely that any of the main species (hoki, hake, and ling) were present in significant quantities at 800–1000 m. Deeper areas were split into 800–900 m and 900–1000 m strata, adding an additional 8 strata to the 15 in the core area (Figure 1c). The Bounty Platform stratum was not surveyed. Core Puysegur strata were also extended slightly in 1996 relative to earlier surveys to include the western parts of Puysegur Bank. The survey area in autumn 1998 was the same as in autumn 1996, but the 800–900 m and 900–1000 m strata were combined as four 800–1000 m strata and re-numbered (Figure 1d).

All surveys followed a stratified random design. Most surveys (except autumn 1993 and 1996) were of a two-phase stratified random design (after Francis 1984), where additional phase 2 stations are allocated following completion of phase 1 stations to improve the precision of biomass estimates. However, because of time and weather limitations, no phase 2 stations were completed in summer 1993 or autumn 1992 (Table 2). First- or single-phase station allocation was based on stratum area and the distribution and catch rates of key species (hoki and hake) in previous surveys. A total of 76 (1998) to 160 (summer 1992) stations were successfully completed in each survey (Table 2).

Vessel and gear specifications

Tangaroa is a purpose-built research stern trawler of 70 m overall length, a beam of 14 m, with 3000 kW (4000 hp) of power and a gross tonnage of 2282 t. The net design was the same as that used in other surveys of middle depth species by *Tangaroa*: an eight-seam hoki bottom trawl with 100 m sweeps, 50 m bridles, 12 m backstrops, 58.8 m groundrope, 45 m headline, and 60 mm codend mesh (see Chatterton & Hanchet (1994) for net plan and rigging details). The trawl doors were Super Vee type with an area of 6.1 m^2. Measurements of doorspread, (from the Scanmar 400 system), vessel speed, and headline height (from a net monitor) were recorded during each tow and average values calculated.

Trawling procedure

Trawling in all surveys followed standardised procedures described by Hurst et al. (1992). Station positions were selected randomly before the voyage with a minimum distance between stations of 3 n. miles. If a station was found to be on foul ground, a search was made for suitable ground within 3 n. miles of the station position. If no suitable ground could be found, the station was abandoned and another random position was substituted. Tows were carried out in daylight hours (as defined by Hurst et al. 1992) only. At each station the trawl was towed for 3 n. miles at a speed over the ground of 3.5 knots. If foul ground was encountered, or the tow hauled early due to reducing daylight, the tow was included as valid only if at least 2 n. miles had been covered.

Towing speed and gear configuration were maintained as constant as possible during the survey, following the guidelines given by Hurst et al. (1992). Gear performance is summarised in Table 3. Doorspread values were not available for some tows in three of the seven trawl surveys. For summer 1992 and 1993 surveys the mean of the recorded values for the trip (121.4 m in TAN9211, and 120.7 m in TAN9310) was used to replace missing doorspread values. In autumn 1993 only one doorspread was recorded during the entire survey and an average value from all seven surveys (123.1 m) was used.

Hydrology

Surface temperatures were measured at the beginning of each tow with a hull-mounted temperature sensor (about 5 m depth) during all surveys. Bottom temperatures were also recorded from Scanmar (1991–93) or Furuno (1998) temperature sensors mounted on the headline of the trawl (about 7.0 m above the bottom) during five of the seven surveys. Bottom temperatures were not measured during summer 1992 or in autumn 1996. The calibration of temperature sensors was uncertain and temperature data should be regarded as relative within individual surveys only.

Catch and biological sampling

At each station all items in the catch were sorted into species and weighed on Seaway motion-compensating electronic scales accurate to about 0.3 kg. Where possible, finfish, squid, and crustaceans were identified to species and other benthic fauna to species or family.

For each species of commercial importance, samples of up to 200 individuals were randomly selected from the catch for measuring and determining sex. For hoki, hake, and ling (and sometimes other species such as southern blue whiting) more detailed biological data were also collected including fish length, weight, sex, gonad stage, gonad weight, otoliths (for age determination), and occasional observations on stomach fullness, and contents and prey condition. A description of the macroscopic gonad stages used for the three main species is given in Appendix 1.

Data analysis

Doorspread biomass was estimated by the swept area method of Francis (1981, 1989) using the formulae in Vignaux (1994). Biomass and coefficient of variation (c.v.) were calculated for the major commercial and non-commercial species. We defined "major" species as commercial species (QMS or non-QMS) having biomass estimates greater than 1000 t in two or more surveys and non-commercial species with biomass greater than 10 000 t in two or more surveys. These thresholds gave a total of 12 major species: 11 commercial (hoki, hake, ling, southern blue whiting, pale ghost shark, dark ghost shark, spiny dogfish (*Squalus acanthias*), black oreo (*Allocyttus niger*), lookdown dory (*Cyttus traversi*), ribaldo, white warehou); and one non-commercial (javelinfish, *Lepidorhynchus denticulatus*). Biomass estimate subtotals for each of the major species are compared over four areas:

1. The core 300–800 m area (Figure 1a, all surveys);
2. The core 300–800 m area and the 800–1000 m stratum around Puysegur (Figure 1b excluding Bounty Platform stratum 17, summer 1991–93, autumn 1994 and 1996);
3. The core 300–800 m area and all 800–1000 m strata (Figure 1c and 1d, 1994 and 1996);
4. The Bounty Platform 300–600 m stratum only (stratum 17 in Figure 1b, summer 1992–93).

Scaled length frequencies were calculated for the major species with the Trawlsurvey Analysis Program, version 3.2, as documented by Vignaux (1994). Scaled length frequency calculations used length-weight relationships (Table 4), which we re-calculated from biological data collected during each individual survey, or from combinations of surveys, depending on the sample size by trip and size characteristic of each species (Table 4). Where inadequate length weight data were available from the Southland and Sub-Antarctic trawl series, values from other relevant surveys were used (Table 4). Scaled length frequencies are presented by sex for the core 300–800 m area only and for "all data", which includes 800–1000 m strata (areas 2 or 3 above). Length frequencies were not available for javelinfish.

Data from all stations where the gear performance was satisfactory (codes 1 or 2) were included for estimating biomass and calculating length frequencies. The catchability coefficient (an estimate of the proportion of fish in the path of the net which are caught) is the product of vulnerability, vertical availability, and areal availability. These factors were all set at 1 for the analysis, the assumptions being that fish were randomly distributed over the bottom, that no fish were present above the height of the headline, and that all fish within the path of the doors were caught.

Biomass estimates and scaled length frequencies in this review may vary slightly from those published in the original survey reports (see Table 1) for the following reasons. First, where no doorspread values were available we used averaged values (see above). These averaged values may differ from those applied in the original analysis. For example, in the autumn 1993 survey, where only one doorspread was measured (see Table 3), Schofield & Livingston (1994a) applied this measured value (110.0 m) to all 100 tows. Based on measurements in the other six surveys we believe that this single value underestimated doorspread, so we applied an average value of 123.1 m to the 99 tows in the autumn 1993 survey where doorspread was missing. Thus our estimates of biomass for this survey are lower than those of Schofield & Livingston (1994a). Second, we discovered that when Puysegur strata were extended further west in 1996 and 1998 new strata definitions were based on 200 m rather than 300 m bathymetric contours. We corrected this error by adjusting the area of the 300–600 m Puysegur stratum in our analyses of 1996 and 1998 surveys. Finally, the length-weight keys we used to scale length frequency (see Table 4) differed from those used in the original reports. We used different groupings to calculate length-weight keys for less abundant species (e.g., pooling data over all seven surveys instead of using values from surveys at other times or in other areas). We also error-checked length-weight keys. Residuals of ±0.30 or over were considered to be outliers and were not used in calculating length-weight relationships.

Hoki, hake, and ling were aged from otoliths using published techniques (Horn 1993, 1997, Horn & Sullivan 1996). Population length frequencies were then scaled by age-length keys to give estimates of numbers at age. Ageing methods for hoki have evolved in recent years and earlier estimates of hoki age might differ from more recent interpretations (Cordue et al. 2000).

Commercial catch data

Length frequency and gonad stage data for hoki, hake, and ling from relevant commercial catches were extracted from the Ministry of Fisheries observer database. Data were selected from the database for the area south of 46° S, bottom depths greater than 300 m, and the period equivalent to the research trawl surveys (November and December for comparison with summer surveys, April and May for comparison with the autumn series). This selection included observations from bottom and midwater trawls and from bottom longlines. Commercial data are presented in raw format. Length frequency data have not been scaled to total commercial catch in the area.

Results and Discussion

Biomass estimates and precision

Where we use the term "biomass" in this report we are using it as an index in a "relative" sense, not as an "absolute" measure.

The estimated biomass and c.v.s for the 12 major species in the four area sub-divisions are given in Tables 5–8. The most abundant species in the core 300–800 m Southland and Sub-Antarctic trawl survey area was hoki, with biomass ranging from about 53 000 t in autumn 1993 to 100 000 t in summer 1993 (Table 5). This represented between 36 and 61% of the total survey fish biomass. Other abundant species in most surveys were ling (13–24% of total fish biomass), southern blue whiting (4–19%), javelinfish (4–10%), and pale ghost shark (3–9%). Hake, one of the three key survey species, typically made up 1–3% of the total fish biomass.

The inclusion of deeper 800–1000 m strata increased estimated biomass (Tables 6–7), but for most species the percentage increase in biomass was less than the percentage increase in the survey area (Tables 6–7). This suggests that fish densities were lower in deeper strata. The exceptions were black oreo and hake (Tables 6–7). Black oreo are a deepwater species and catches from 800–1000 m strata made up 96–100% of the total estimated biomass in 1996 and 1998 (Table 7). The biomass of hake in 800–1000 m strata was also relatively high. Between 28–36% of hake biomass came from 800–1000 m strata in 1996 and 1998, even though these strata made up only about 17% of the total survey area (Table 7). The 800–1000 m stratum around Puysegur appears to be particularly important for hake, with between 2–11% of hake biomass in this stratum, which was only 0.7% of the survey area. The deep Puysegur stratum may also be an important area for ribaldo, containing 2 and 12% of ribaldo biomass (Table 6).

Biomass estimates from the 300–600 m stratum around the Bounty Platform in summer 1992 and 1993 were generally low (Table 8). Very few hoki and no hake were caught in the Bounty stratum. Ling were captured in low numbers in both summer 1992 and 1993, but the biomass of ling from the Bounty area was only 1–3% of the biomass in the core survey area (Table 8). A relatively high proportion (9–18%) of southern blue whiting biomass was taken in the 300–600 m Bounty stratum in summer 1992 and 1993 (Table 8).

The c.v. is an indication of the precision of the biomass estimate. Target c.v.s of under 15% for hoki and ling and under 20% for hake have been set by the Ministry of Fisheries for recent surveys. These targets were achieved for all three key species in all surveys except for hake in summer 1991 (see Table 5). The high c.v. (44%) for hake in the summer 1991 survey resulted from a single large catch (see "Species distribution and length and age frequency" below). Precise estimates of biomass (c.v. under 20%) were also obtained for pale ghost shark, ribaldo and javelinfish in all surveys. Several of the less abundant species (e.g., black oreo, spiny dogfish, white warehou) had occasional high biomass estimates and these were usually associated with high c.v.s (over 50%). Biomass estimates of southern blue whiting typically had c.v.s between 20 and 30%, with lower precision (c.v. = 44%) in autumn 1992.

Biomass trends

Annual trends

Trends in the biomass of the 12 major species in the core 300–800 m trawl survey area are shown in Figure 2. The two survey time series (summer and autumn) are plotted independently. Biomass estimates from a comparable trawl survey on *Tangaroa* in September–October 1992 (Schofield & Livingston 1994c) are also presented.

Because both trawl survey time series were very short (3 or 4 years), we examined trends in biomass by comparing biomass estimates at the start and end of each time series using a two-sample t-test. There were no significant differences (at the $p = 0.05$ level) in the biomass of any of the 12 major species between the first (1991) and last (1993) years of the summer trawl series. Of the three target species, estimates of the biomass of hoki ($p = 0.07$) and ling ($p = 0.14$) both increased by 24%, while hake declined by 59% ($p = 0.18$). Four of the species showed significant trends ($p < 0.05$) in the autumn trawl series. Biomass estimates for ling (by 32%) and hake (by 50%) decreased between 1992 and 1998, while those for southern blue whiting (by 150%) and pale ghost shark (by 43%) increased. The estimate of hoki biomass in the autumn trawl series varied between 53 000 t (1993) and 89 000 t (1996), but biomass in 1998 was almost identical to that at the start of the series in 1992 (see Table 5).

Commercial CPUE indices of the western hoki stock on the west coast spawning ground (Ballara et al. 2000) and in the Sub-Antarctic (Dunn & Harley 1999) remained relatively flat between 1991 and 1998. This is consistent with the absence of a significant trend in hoki biomass in the Southland and Sub-Antarctic trawl series (Figure 2). However, an acoustic estimate of hoki biomass on the west coast spawning ground in 1997 suggested there had been a significant increase in the western hoki stock relative to the early 1990s (Ballara et al. 2000). The autumn trawl survey series did not show this increase, but interpretation of the autumn series is complicated by the possibility that different proportions of the hoki adult biomass left the survey area to spawn. It is hoped that moving the trawl survey back to the summer in 2000 will provide valuable additional information on the current levels of hoki abundance.

Unstandardised CPUE from the commercial longline fishery for ling on the Southern Plateau dropped by about 30% between 1992 and 1998 (Harley 1999), consistent with the decrease in ling biomass estimates from the autumn trawl series (Figure 2), but standardised CPUE showed no trend. No other estimates of hake abundance in this area were available for comparison with trawl survey results (Dunn 1998).

Seasonal trends

There was temporal overlap between the two trawl time series in 1991–93 (Figure 2). This allowed us to investigate the effect of survey timing on biomass. We compared core area biomass estimates of major species from summer surveys in 1991 and 1992 with estimates from the following autumn surveys in 1992 and 1993 respectively. Summer estimates were compared with the following autumn rather than with the previous autumn survey because the temporal separation was shorter. Also, the period from summer to the following autumn did not encompass the winter spawning period for hoki when fishing mortality is highest.

Of the 12 major species, 8 did not exhibit consistent seasonal differences in abundance. Either there were no significant differences (two-sample t-test, $p < 0.05$) between biomass estimates in consecutive summer and autumn surveys (southern blue whiting, dark ghost shark, black oreo, lookdown dory) or the summer estimate was higher in one pairing and the autumn estimate in the other (hake, pale ghost shark, ribaldo, white warehou). Four species showed a consistent and significant seasonal difference. Hoki and spiny dogfish biomass estimates were consistently higher in summer surveys than in autumn surveys, while ling and javelinfish were consistently more abundant in the autumn.

Seasonal differences in biomass are probably related to species' biology. It is generally assumed that hoki leave the Southland and Sub-Antarctic area to spawn on the west coast South Island. The exact timing of any migration is unknown, but some fish appear to have already left by the time of the autumn trawl series (see Table 1). The lowest hoki biomass estimate in the autumn series was in 1993 when the survey timing was the latest (1 May–4 June) and the highest biomass estimate was in 1996 when the survey was earliest (28 March–27 April). Likewise, it is uncertain exactly when all hoki return to the southern summer survey area. The very low biomass estimate from the comparable trawl survey in September–October 1992 (Figure 2) indicates that not all fish have returned by this time. We assume that most hoki are in the southern area at the time of the summer trawl surveys (mid November–December).

Bull et al. (2000) suggested that low ling biomass in spring surveys may be related to spawning behaviour. Peak spawning of ling is between October and December and a proportion of fish may be off the bottom and unavailable to the trawl at this time. High commercial catch rates of ling have been recorded in commercial midwater trawls (defined as over 10 m off the bottom) in the spring and summer, particularly along the western edge of the Stewart-Snares shelf (Bull et al. 2000). A similar pattern (fish off the bottom in the western part of the survey area) has been observed for hake and this may account for the variable (high c.v.) and sometimes low estimates of hake biomass in the summer trawl series.

Less is known about the biology and behaviour of the other two species that had consistent seasonal differences in abundance. The core 300–800 m survey area is considered to be deeper than the depth range usually occupied by spiny dogfish and biomass was dominated by one or two large catches around the edge of the survey area (see "Species distribution and length and age frequency" below). Javelinfish were caught throughout the survey area and at many stations. We are uncertain why biomass of this non-commercial species appears to be consistently higher in the autumn.

Species distribution and length and age frequency

The geographical distribution of catches in the seven surveys is presented for the 12 major species in Figure 3. Scaled length frequencies for the 11 commercial species are shown broken down by sex and survey in Figure 4. Age frequencies are also included for hoki, hake, and ling (Figure 5). Because age data were not included in the original survey reports except in 1998 (see Table 1), we have included tables of numbers-at-age in Appendix 2.

The distribution of major species can be summarised as follows. Hoki, ling, pale ghost shark and javelinfish were widespread over the survey area, occurring in a relatively high proportion of tows. Southern blue whiting and lookdown dory were also widely distributed, but were caught in fewer tows. Hake, ribaldo, and dark ghost shark had a predominantly western distribution, with most fish caught in tows west of 171° E. Black oreo, spiny dogfish, and white warehou were caught infrequently and then only along the survey boundaries. Black oreo were caught mainly in the deeper 800–1000 m strata, and spiny dogfish and white warehou occurred adjacent to shallower (less than 300 m) areas.

Black oreo

Black oreo are a deeper water species and were caught only occasionally within the core 300–800 m survey area (Figure 3a). Biomass estimates within the core area were usually based on one tow, and this accounts for the extreme levels of uncertainty (c.v.s close to 100%, Table 5). Catch rates (Figure 3a) and biomass estimates (Table 7) greatly increased with the inclusion of 800–1000 m strata around much of the survey area in 1996 and 1998. Length frequencies (Figure 4a) suggested that black oreo caught in deep (800–1000 m) strata in 1996 and 1998 were also larger than those caught in the core 300–800 m strata in 1991 and 1992.

Dark ghost shark

Dark ghost shark were caught mainly at 300–600 m depth in the western part of the survey area, particularly in strata adjacent to the Auckland Islands Shelf, on Puysegur Bank, and along the Stewart-Snares shelf (Figure 3b). No length data were collected on dark ghost shark in summer 1991 or autumn 1992. In other surveys, male ghost shark had a narrow length distribution, with most fish between 50–60 cm chimera length (Figure 4b). Females exhibited a broader length range with fish from 40 to 70 cm (Figure 4b). There were no obvious size differences between years.

Hake

Hake were also concentrated in the western part of the survey area, with peak catches on the Stewart-Snares shelf and on Puysegur Bank (Figure 3c). Most hake were taken in the 600–1000 m depth range, but occasional large catches were made at 300–600 m. A very high catch (3835 kg km^{-2}) of ripe male hake was taken in 300–400 m of water in summer 1991. Bull et al. (2000) examined catch rates of hake from Southland and Sub-Antarctic trawl surveys by length class and concluded that smaller hake (under 66 cm) were found almost exclusively on Puysegur Bank in 600–1000 m depth. Middle-sized hake (67–90 cm) were more widely distributed along the edge of the Stewart-Snares shelf and over the western half of the Southern Plateau. Large hake (over 90 cm) also occurred in deeper water (800–1000 m) along the northern edge of the Pukaki Rise in 1996 and 1998 when these strata were surveyed.

Hake length frequencies were patchy with no clear modes except for the summer survey 1991 when males between 80–90 cm were dominant (Figure 4c). This mode reflects the length composition of the single large catch taken during this 1991 survey. Females had a wider range of lengths than males, with a higher proportion of females under 70 cm and over 100 cm. Hake of all sizes were caught outside the core 300–800 m area in 800–1000 m strata in 1996 and 1998 (grey portions of bars in Figure 4c). This suggests that the deeper areas are an important habitat for a wide size range of hake, not just older fish.

Weighted c.v.s across all ages of hake were high, indicating low precision of the age frequency distributions. This was related to small sample sizes. An objective of the 2000 Southland and Sub-Antarctic survey is to provide improved sampling of hake age frequency by allocating more effort to strata where hake are found. Hake exhibited a relatively wide age frequency with little evidence of dominant year-classes (Figure 5a). Summer surveys typically caught a narrower range of ages with a modal age of between 12–14 for both males and females. In recent years autumn surveys have caught a broader range of ages, with a higher proportion of younger fish and no clear mode.

Hoki

Hoki were widely distributed throughout the core 300–800 m survey area with very few tows catching no hoki (Figure 3d). High catches occurred more frequently in the west, on the Stewart-Snares shelf, around the Auckland Islands, on the western side of the Campbell Rise, and at Puysegur. Hoki were also caught in low numbers in 800–1000 m strata.

Length frequencies (Figure 4d) showed clear modes corresponding with strong hoki age-classes (Figure 5b). Surveys in the early 1990s were dominated by the 1987 year-class (hoki are assigned a "birthday" of 1 August (Horn & Sullivan 1996) which were captured as 4+ in summer 1991 and autumn 1992, as 5+ in summer 1992 and autumn 1993, and as 6+ in summer 1993. This strong 1987 year-class was still apparent as a mode at 8+ in autumn 1996. Another mode corresponding to the 1984 year-class can be similarly tracked through early surveys from age 7+ in summer 1991 to 9+ in summer 1993. Length frequencies of adult hoki (over 60 cm), particularly females, are bimodal in early surveys reflecting these two strong age-classes. Length modes at smaller sizes reflect abundance and growth of younger age-classes. For example, the 1991 year-class first appears in autumn 1993 as a peak at around 43 cm, and then again in summer 1993 at around 50 cm. Surveys in 1996 and 1998 indicated the presence of four strong hoki age-classes corresponding to the 1991, 1992, 1993, and 1994 year-classes (Figure 5b). Length frequencies in 1996 and 1998 reflected these age-classes and also the presence of older fish born in the late 1980s. Subsequent year-classes in 1995 and 1996 appear to have been relatively weak and very few small fish (under 60 cm) were caught in autumn 1998.

Length and age frequencies from the Southland and Sub-Antarctic trawl surveys are consistent with our understanding of the population structure of the western hoki stock from other sources. Least squares estimates of year-class strength based on data from commercial CPUE, acoustic surveys and trawl surveys (Ballara et al. 2000) show strong year classes in 1984, 1987, and 1991–94.

There were no obvious differences in the shape of length and age frequencies between consecutive summer and autumn surveys in 1991–92 and 1992–93. This suggests that fish that depart early for spawning (before the autumn survey) are an unbiased sample of the population. There is no evidence, for example, that larger or smaller hoki leave the summer area earlier.

Javelinfish

Javelinfish were the most abundant non-commercial species (Table 5) and were widely distributed from 300 to 1000 m with no consistent "hot-spots" (Figure 3e). No length frequency data were available because, as a non-commercial species, javelinfish were not measured as part of the standard protocol.

Ling

Ling were also widely distributed, particularly during autumn surveys (Figure 3f). In summer surveys largest catches were in the Puysegur area and these may have been spawning aggregations (Bull et al. 2000). Ling were seldom caught at depths greater than 800 m. Some ling were caught round the Bounty Platform in summer 1992 and there is a commercial longline fishery for ling in this area. On a survey of the Southland and Sub-Antarctic area from *Amaltal Explorer* in 1989 12.6% of the total ling biomass was in the Bounty stratum. The proportion of ling from the Bounty stratum in *Tangaroa* summer 1992 and 1993 surveys was much lower, but c.v.s were high (Table 8).

Length (Figure 4e) and age (Figure 5c) frequencies were generally similar between surveys. There was some indication of an increase in the numbers of smaller, younger fish in 1996 and 1998 and this may reflect good year-classes in the early 1990s. However, the lack of consistent modes between years suggests that there has been relatively little variability in the strength of ling recruitment.

Lookdown dory

Small numbers of lookdown dory were caught throughout the survey area, including the Bounty Platform, in summer surveys from 1991 to 1993 (Figure 3g). Catches appeared to be less frequent and more patchy in autumn surveys, and this is reflected in the lower precision of biomass estimates from autumn surveys (see Table 5). Highest catches were taken along the northeast Pukaki Rise in autumn 1992 and autumn 1993 (Figure 3g). Female lookdown dory were typically 10 cm longer than males (Figure 4f). Length frequencies were scattered. There was some evidence of an increase in modal length of females through the early 1990s, perhaps related to growth of strong cohorts. The number of small (under 30 cm) lookdown dory was much higher in 1996 and 1998 than in earlier surveys. This may reflect strong recent recruitment.

Pale ghost shark

Pale ghost shark were taken in a high proportion of tows (Figure 3h). Distribution was widespread, with highest catches taken from the Snares and Auckland Island areas and around the Pukaki Rise. In contrast to several other major species, catches in the Puysegur strata were usually relatively low. In summer 1991 lengths of pale ghost sharks were recorded as total length rather than chimaera length as in more recent surveys (Figure 4g). This makes comparison of length frequencies between summer 1991 and other surveys difficult. Length distributions tended to be unimodal with modal lengths of 65–75 cm for males and 70–80 cm for females (Figure 4g).

Ribaldo

Catches of ribaldo were variable (Figure 3i). Catch rates were consistently high in the Puysegur area, with smaller catches on the Stewart-Snares shelf and around the Auckland Islands. Ribaldo were seldom caught in the eastern part of the survey area or in strata deeper than 800 m. Very few male ribaldo were measured (Figure 4h). This may be because males were smaller and thus not selected by the gear, or it may be a sampling artefact. Ribaldo were not measured from all tows and by chance measured tows (typically those with highest catches) may have contained more females. Distributions of female lengths were patchy reflecting the small sample sizes, but most female ribaldo were typically between 50 and 70 cm (Figure 4h).

Southern blue whiting

The distribution of southern blue whiting was very patchy with a few large catches and a high proportion of zeros (Figure 3j). Most southern blue whiting were caught at 300–600 m depth in the eastern part of the survey area on the Campbell Plateau and Pukaki Rise, but there were also high catch rates round the Auckland Islands Shelf and on the Bounty Platform. Few southern blue whiting were taken from strata deeper than 600 m.

Males and females showed similar length distributions with clear modes probably related to strong year classes (Figure 4i). Southern blue whiting exhibit considerable variability in year-class strength (Hanchet 2000). Early growth is rapid with fish reaching about 20 cm fork length after 1 year and about 30 cm after 2 years (Annala et al. 2000). Growth is slower as the fish gets older and virtually ceases beyond the age of 10 years. This causes length frequencies of older fish to merge and overlap. Interpretation of year-class strength from length frequency distributions is also difficult because the Southland and Sub-Antarctic core survey area probably encompasses at least three separate southern blue whiting stocks (Campbell Rise, Pukaki Rise, Auckland Islands Shelf), each of which have experienced variable recruitment (Hanchet 2000). We interpret the three clear modes in summer 1993 as representing fish from the 1991, 1990, and 1986–88 year-classes. The 1986 and 1990 year-classes were strong for the Pukaki Rise stock while 1988 and 1991 were strong years for the Campbell Rise stock. The very strong 1991 year-class dominated the southern blue whiting fishery in the mid to late 1990s (Hanchet 2000). It is probably this 1991 year-class that is responsible for the length mode at about 36 cm in 1996 and 39 cm in 1998 (Figure 4i). The smaller mode at about 30 cm in the 1998 survey is probably the 1995 year-class.

Spiny dogfish

Spiny dogfish were caught infrequently and only in the shallowest (300–600 m) strata on the Stewart-Snares shelf, the Auckland Islands Shelf and at Puysegur (Figure 3k). The length frequency data are sparse because few spiny dogfish were measured (Figure 4j). Most dogfish were adults over 60 cm.

White warehou

Only two large catches of white warehou were made during the trawl series, in summer 1991 and in autumn 1998 (Figure 3l). Both these large catches and several of the smaller catches were taken in 300–600 m strata on the Stewart-Snares shelf. White warehou were also caught in very small numbers on the eastern Campbell Plateau, on the Auckland Islands Shelf and at Puysegur. Length frequency data are again patchy with relatively high c.v.s because few fish were measured. The large catch in 1998 contained a high proportion of males with modal lengths at about 35 cm and about 45 cm.

Reproductive condition

The numbers of hoki, hake, and ling in each reproductive stage are summarised in Table 9 and plotted (as a percentage) in Figure 6.

Gonads of mature male and female hoki were mainly in the resting phase during summer surveys: there was a small proportion of spent and partly spent fish (Figure 6). In autumn surveys 5–40% of hoki gonads were ripening. The proportion of ripening hoki was higher in autumn surveys in 1993 and 1994 than in 1996 and 1998. This reflects the earlier timing (by 2–4 weeks) of surveys in 1996 and 1998 (see Table 1). The latest survey was in autumn 1993 when some ripe males were recorded (Table 9). Few immature hoki were observed, consistent with our understanding of the Southland and Sub-Antarctic as an adult residence area for the western hoki stock.

Hake were in varied reproductive condition (Table 9, Figure 6). Ripe or running ripe male hake were present in all surveys (Table 9). Concern has been expressed about the overlap between summer surveys and the timing of hake spawning (Bull et al. 2000), but the highest proportions of ripe and running ripe male hake were observed in autumn surveys in 1992 (84%) and 1998 (48%) (Figure 6). Ripe or running ripe female hake were seldom sampled. Variable proportions of resting, ripening, partially spent, and spent female hake occurred in all surveys. More work is necessary to address the timing of hake spawning in the Southland and Sub-Antarctic area. Spawning hake have been reported in commercial and research catches from this area in every month of the year (Bull et al. 2000).

Ripe male ling were also observed in all surveys except autumn 1993. The proportion of ripening and ripe male ling was generally similar between summer and autumn surveys. A high number of partly spent male ling were recorded in autumn 1993, but we are unsure whether this represents a late spawning event or difficulties interpreting gonad stages. Female ling gonads were almost all in resting condition. Some (30%) ripening female ling were observed in summer 1991 and this may indicate potential overlap between the timing of this survey and ling spawning. From a more extensive analysis of commercial and research data, Bull et al. (2000) suggested that peak ling spawning in the survey area occurs from October to December.

Observations from the commercial fishery

Most observer data on hoki, hake, and ling came from bottom and midwater trawls targeting hoki, but there was additional information from ling bottom longline catches, especially in November–December 1993 and April–May 1998. Some data were also collected from trawls targeting scampi, silver warehou, orange roughy, oreo, and southern blue whiting. The degree of coverage was variable (Figure 7), with groups of tows concentrated mainly in the western part of the survey area on the Stewart-Snares shelf and around Auckland and Campbell Islands. A group of 51 trawls targeting southern blue whiting was observed on the Pukaki Rise in April-May 1992 (Figure 7).

Commercial length frequency

Unscaled length frequencies from observed commercial catches (Figure 8) were generally similar to scaled length frequencies from research trawls (see Figure 4). Hoki from commercial catches showed an increase in modal length in the early 1990s (Figure 8b), probably corresponding to the growth of the strong 1984 and 1987 age classes. Catches from 1996 and 1998 exhibited a broader, flatter range of sizes reflecting the succession of strong year classes in the early 1990s. Small hoki (under 50 cm) were seldom taken in the commercial catch, so the fishery does not provide as much information as the research surveys on the potential strength of recent age classes.

Hake and ling also show similar length frequencies to those estimated from the research surveys (Figure 8). Detailed comparisons and interpretation of hake lengths are difficult because sample sizes from both research and observer data were low. Larger ling were taken in the commercial fishery than in the trawl survey. This difference is especially apparent for female ling in summer 1993 and autumn 1998 (Figure 8c) when much of the observer data on ling came from the longline fishery which targets large ling.

Commercial reproductive condition

Observers recorded gonad stages only for female fish. Gonads were ranked according to a 5-stage scale instead of the 7-stage scale used on research surveys (Appendix 1). Percentage frequencies of hake, hoki, and ling in each gonad stage for the periods corresponding to each research survey are plotted in Figure 9.

Observations from commercial catches (Figure 9) showed a similar pattern to reproductive data from research surveys (see Figure 6). The seasonality of hake spawning was unclear. There was a relatively high proportion of mature (ripening) female hake in both summer and autumn. Ripe female hake were recorded in November–December 1991 and in April–May 1996 and 1998. Hoki were resting or spent in summer, with 6–35% of female hoki maturing (ripening) in April–May. A higher proportion of female hoki were mature in autumn 1996 and 1998 than in 1992 and 1993 (Figure 9). This is the opposite pattern to that observed in the research data, where more ripening hoki were recorded in autumn 1992 and 1993 when the trawl surveys were later (see Figure 6). The difference between years in the commercial observations was not due to timing of sampling because the same months (April and May) were extracted from the observer database all years. Ling from the observed commercial catch were usually immature or resting. In November–December 1993, 29% of female ling were running ripe suggesting that these fish were caught from a spawning aggregation.

Hydrology

Surface water temperatures ranged from 5.5–14.3 °C. In all surveys there was a general gradation of surface water temperatures, with warmest temperatures in the north around Puysegur and coolest temperatures in the south along the southern edge of the Campbell Plateau (Figure 10). Bottom temperatures showed a similar spatial pattern, but were typically 1–2 °C lower than surface temperatures, ranging from 4.6 to 11.6 °C. The spatial variation in water temperature was consistent with our understanding of the circulation (Morris et al. in press). Higher temperatures around Puysegur and sometimes extending across the northern Stewart-Snares shelf are due to the influence of Subtropical waters and the position of the Subtropical Front. There is a relatively uniform body of cooler Sub-Antarctic Mode Water over the Southern Plateau with lowest temperatures in the south closer to the Sub-Antarctic Front and the cold waters of the Antarctic Circumpolar Current.

There was relatively little variation in water temperature between surveys. Average surface temperatures in summer surveys (9.2–9.6 °C) were usually higher than in autumn surveys (8.3–9.0 °C), except in autumn 1996 when the survey was earlier (see Table 1) and the water was warmer (average surface temperature = 10.2 °C). Average bottom temperatures were similar between surveys (6.4–6.9 °C). No more-detailed analyses of trends in temperature were done because of the uncertainties about the calibration of the sensors.

Conclusions and Recommendations

1. Levels of precision from the *Tangaroa* trawl survey series were usually adequate to monitor the changes in biomass of the three key species (hoki, hake, and ling). Precision was within the criteria set by the Ministry of Fisheries (c.v.s less than 15% for hoki and ling and less than 20% for hake) in all surveys except in summer 1991 when a single large catch of hake raised the c.v. for this species to 44%. Precise estimates of biomass (c.v. under 20%) were also obtained for pale ghost shark, ribaldo, and javelinfish.

2. Changes in the area surveyed did not have a major influence on biomass estimates of hoki and ling which tended to be distributed within the core 300–800 m survey area. Inclusion of deeper 800–1000 m strata around much of the survey area in autumn 1996 and 1998 increased biomass estimates for hake. The Bounty Platform which was surveyed in summer 1992 and 1993 contributed relatively little biomass, although it may be an important area for ling.

3. Highest catches of hoki, hake, ling, dark ghost shark, and ribaldo were often taken from strata in the Puysegur area and on the Stewart-Snares shelf in the western part of the survey area. Increased survey effort in these strata would increase precision of biomass estimates for these species and age frequency estimates for hake.

4. Summer and autumn trawl survey time series were short. No significant trends in abundance were observed in the 3 years of the summer series. Four species showed significant trends ($p < 0.05$) over the autumn trawl series. Biomass estimates for ling and hake decreased between 1992 and 1998, while southern blue whiting and pale ghost shark increased. Hoki biomass in the autumn trawl series varied between 53 000 t (1993) and 89 000 t (1996), but biomass in 1998 was almost identical to that at the start of the series in 1992. Longer time series are required to further quantify trends in abundance.

5. Biomass estimates of hoki were consistently lower in autumn surveys than in the summer because an unknown proportion of hoki had already left the Southland and Sub-Antarctic residence area for the west coast spawning grounds by the time of the autumn surveys (March–June). Biomass of hoki in autumn surveys was highly dependent on survey timing, with the highest estimate from the earliest survey in 1996 and the lowest estimate from the latest survey in 1993. Surveys for hoki on the Southern Plateau should be conducted in the summer to avoid this problem.

6. Reproductive data from research and commercial observations indicate some ling may still be spawning at the time of the summer survey (November–December). This could lead to sampling problems if spawning ling are highly aggregated (reduced precision) or unavailable to the gear, e.g., in midwater (reduced biomass). There was some indication that biomass estimates of ling in the summer were lower than in autumn surveys and this requires further investigation. The timing of hake spawning is uncertain. Ripening hake were observed in summer and autumn.

7. There were clear age classes of hoki from the *Tangaroa* surveys. The 1984, 1987, and 1991–94 age classes appear strong and corresponding modes in length frequency were discernible in both research and commercial data. It was not possible to recognise variability in recruitment from ling or hake age data. There was some indication that the proportion of younger smaller ling and hake had increased in 1996 and 1998. Female ling from the commercial catch tended to be larger than those recorded in research surveys. This is due to targeting of larger ling by the commercial longline fishery.

8. Precision of scaled age frequency estimates for hake were very poor (c.v. 50–80%) because sample sizes were low. More hake need to be sampled and aged to improve estimates of age frequency.

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Table 1: **Timing and references for summer and autumn *Tangaroa* trawl survey series.**

Survey	Dates	Trip code	Reference
Summer			
1991	13/11–23/12	TAN9105	Chatterton & Hanchet 1994
1992	14/11–22/12	TAN9211	Ingerson et al. 1995
1993	12/11–22/12	TAN9310	Ingerson & Hanchet 1995
Autumn			
1992	17/4–21/5	TAN9204	Schofield & Livingston 1994a
1993	1/5–4/6	TAN9304	Schofield & Livingston 1994b
1996	28/3–27/4	TAN9605	Colman 1996
1998	7/4–1/5	TAN9805	Bagley & McMillan 1999

Table 2: **Number of stations occupied in each group of survey strata. Areas are defined in Figure 1. Symbol "-" indicates strata in these areas were not included in the survey design.**

	Number of Stations								
	Core 300–800 m		Puysegur 800–1000 m		Other 800–1000 m		Bounty 300–600 m		
Survey	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Total
Summer									
1991	139	11	4	0	-	-	0	0	154
1992	141	8	4	2	-	-	5	0	160
1993	130	0	4	0	-	-	4	0	138
Autumn									
1992	90	0	-	-	-	-	-	-	90
1993	100	0	-	-	-	-	-	-	100
1996	79	0	5	0	17	0	-	-	101
1998	58	0	3	0	10	5	-	-	76

Table 3: **Gear parameters averaged over all depths by survey (s.d. is standard deviation).**

Survey	Tow length (n. mile)		Tow speed (knots)		Doorspread (m)		Headline Height (m)	
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
Summer								
1991	3.0	0.15	3.5	0.06	126.5	7.05	6.6	0.31
1992	3.0	0.16	3.5	0.12	121.4	6.03	7.4	0.38
1993	3.0	0.13	3.5	0.06	120.7	7.14	7.1	0.33
Autumn								
1992	3.0	0.23	3.5	0.13	125.8	6.32	6.5	0.20
1993	3.0	0.32	3.5	0.09	110.0*		6.7	0.36
1996	3.0	0.13	3.5	0.16	123.1	5.75	6.9	0.26
1998	3.0	0.11	3.4	0.18	120.2	7.27	7.2	0.21

*1993 autumn survey doorspread value based on only one measured tow.

Table 4: **Length-weight relationship parameters *a* and *b* used in the Trawlsurvey Analysis Program to calculate scaled length frequencies. $W = aL^b$ where *W* is weight (g) and *L* is length (cm), *n* is sample number, r^2 is correlation coefficient, range is the length range of fish (cm).**

	a	*b*	*n*	r^2	Range	Data source
Hoki						
TAN9105	0.004771	2.879563	1 175	0.95	35–107	This survey
TAN9204	0.008453	2.773509	1 666	0.94	43–106	This survey
TAN9211	0.005837	2.833544	1 713	0.95	31–107	This survey
TAN9304	0.012787	2.680873	1 845	0.91	41–113	This survey
TAN9310	0.003551	2.947305	1 141	0.96	36–102	This survey
TAN9605	0.005572	2.854179	1 043	0.96	35–106	This survey
TAN9805	0.006035	2.839169	1 617	0.95	41–106	This survey
Ling						
TAN9105	0.001213	3.305895	1 096	0.97	41–129	This survey
TAN9204	0.001623	3.247232	770	0.96	43–131	This survey
TAN9211	0.001587	3.252721	1 032	0.97	43–141	This survey
TAN9304	0.002423	3.164389	1 022	0.95	43–152	This survey
TAN9310	0.001055	3.343872	969	0.98	45–137	This survey
TAN9605	0.001305	3.295847	648	0.97	38–124	This survey
TAN9805	0.001284	3.305705	1 036	0.98	37–123	This survey
Southern blue whiting						
TAN9105	0.001411	3.405542	328	0.97	23–58	This survey
TAN9204	0.001348	3.454410	286	0.98	30–55	This survey
TAN9211	0.002481	3.259419	546	0.98	21–55	This survey
TAN9304	0.003473	3.210291	259	0.98	22–55	This survey
TAN9310	0.003160	3.186808	628	0.99	25–56	This survey
TAN9605	0.003662	3.163455	142	0.98	31–56	This survey
TAN9805	0.004688	3.093100	441	0.98	21–57	This survey
Hake						
Summer series	0.002173	3.271889	815	0.98	48–128	3 summer surveys
Autumn series	0.001982	3.292016	822	0.98	46–127	4 autumn surveys
Other species						
Black oreo	0.024800	2.950000	9 720	0.98	11–44	Schofield & Livingston 1996
Dark ghost shark	0.004025	3.111198	438	0.96	32–73	All surveys[1]
Lookdown dory	0.028582	2.947133	254	0.99	15–56	All surveys[1]
Pale ghost shark	0.008840	2.898754	1 577	0.98	24–86	All surveys[1]
Ribaldo	0.003657	3.276099	413	0.97	27–73	All surveys[1]
Spiny dogfish	0.0002	3.74	845	0.94	49–107	Bagley & Hurst 1996
White warehou	0.015431	3.104819	207	0.99	23–62	All surveys[1]

[1] Length-weight data were not collected from every Sub-Antarctic *Tangaroa* trawl survey.

Table 5: **Estimated biomass (t) and coefficient of variation (c.v. %) for the 12 major species and all fish species combined in the 300–800 m core Southland and Sub-Antarctic survey area 1991–98.**

	Summer series						Autumn series							
	1991		1992		1993		1992		1993		1996		1998	
	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.
Black oreo	4 143	97	1 932	97	0	0	63	83	0	0	230	94	0	0
Dark ghost shark	1 034	25	708	43	1 060	34	3 741	49	673	45	2 667	50	2 449	45
Hake	5 553	44	1 822	12	2 286	12	5 028	15	3 221	13	2 026	12	2 506	18
Hoki	80 285	7	87 359	6	99 695	9	67 831	8	53 466	10	89 029	9	67 709	11
Javelinfish	13 585	13	5 288	8	13 165	11	17 961	11	15 583	9	22 562	13	17 626	11
Ling	24 085	7	21 368	6	29 747	12	42 334	6	33 553	5	32 133	8	30 776	9
Lookdown dory	1 079	13	1 031	11	816	13	1 154	40	1 747	44	1 042	18	489	34
Pale ghost shark	11 203	6	4 746	7	11 669	9	10 531	10	13 081	9	16 005	10	15 105	10
Ribaldo	1 069	11	513	20	1 100	13	768	17	1 039	15	989	17	813	14
Southern blue whiting	6 131	27	7 570	23	9 306	24	8 863	44	5 560	31	45 606	31	22 199	23
Spiny dogfish	8 502	55	1 150	15	1 585	21	926	30	440	38	207	56	1 532	36
White warehou	1 419	55	240	26	279	29	256	30	811	24	234	31	2 887	68
Total fish	171 725	6	142 793	5	188 884	6	174 448	5	148 800	5	239 089	8	188 473	7

Table 6: **Estimated biomass (t) and coefficient of variation (c.v. %) for the 12 major species in the core area and 800–1000 m Puysegur stratum combined. Figure in parentheses below biomass is the percentage of biomass from the 800–1000 m Puysegur stratum. The Puysegur stratum makes up about 0.7% of the total survey area.**

	Summer series						Autumn series			
	1991		1992		1993		1996		1998	
	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.
Black oreo	4 143	97	1 932	97	0	0	230	94	0	0
	(0)		(0)		(0)		(0)		(0)	
Dark ghost shark	1 034	25	709	43	1 060	34	3 074	48	2 490	44
	(0)		(0)		(0)		(13)		(2)	
Hake	5 686	43	1 944	12	2 567	12	2 281	11	2 643	17
	(2)		(6)		(11)		(11)		(5)	
Hoki	80 364	7	87 500	6	99 901	9	92 753	9	68 223	11
	(0)		(0)		(0)		(4)		(1)	
Javelinfish	13 751	13	5 353	8	13 285	11	22 789	13	17 734	11
	(1)		(1)		(1)		(1)		(1)	
Ling	24 102	7	21 376	6	29 753	12	32 285	8	30 850	9
	(0)		(0)		(0)		(0)		(0)	
Lookdown dory	1 079	13	1 031	11	816	13	1 058	18	529	33
	(0)		(0)		(0)		(2)		(8)	
Pale ghost shark	11 205	6	4 747	7	11 670	9	16 040	10	15 133	10
	(0)		(0)		(0)		(0)		(0)	
Ribaldo	1 088	11	537	19	1 128	13	1 041	16	920	13
	(2)		(4)		(2)		(5)		(12)	
Southern blue whiting	6 131	27	7 570	23	9 306	24	45 606	31	22 199	23
	(0)		(0)		(0)		(0)		(0)	
Spiny dogfish	8 501	55	1 150	15	1 585	21	242	54	2 125	48
	(0)		(0)		(0)		(14)		(28)	
White warehou	1 422	55	241	26	284	28	239	31	2 887	68
	(0)		(0)		(2)		(2)		(0)	

Table 7: **Estimated biomass (t) and coefficient of variation (c.v. %) for the 12 major species in the core area and all 800–1000 m strata combined. Figure in parentheses below biomass is the percentage of biomass from the 800–1000 m strata. The 800–1000 m strata make up about 17 % of the total survey area.**

	Autumn series			
	1996		1998	
	Biomass	c.v.	Biomass	c.v.
Black oreo	5 240	41	11 602	63
	(96)		(100)	
Dark ghost shark	2 672	50	2 449	45
	(0)		(0)	
Hake	2 825	12	3 898	16
	(28)		(36)	
Hoki	92 650	9	71 738	10
	(4)		(6)	
Javelinfish	24 264	12	18 890	10
	(7)		(7)	
Ling	32 363	8	30 893	9
	(1)		(0)	
Lookdown dory	1 065	18	489	34
	(2)		(0)	
Pale ghost shark	16 350	10	15 745	10
	(2)		(4)	
Ribaldo	1 132	15	1 067	13
	(13)		(24)	
Southern blue whiting	45 606	31	22 199	23
	(0)		(0)	
Spiny dogfish	207	56	2 125	48
	(0)		(28)	
White warehou	234	31	2 887	68
	(0)		(0)	

Table 8: **Estimated biomass (t) and coefficient of variation (c.v. %) for the 12 major species in the 300–600 m Bounty stratum. Figure in parentheses below biomass is the percentage of biomass in the Bounty stratum relative to the core 300–800 m area. The area of the Bounty stratum was about 4 % of the core survey area.**

	Summer series			
	1992		1993	
	Biomass	c.v.	Biomass	c.v.
Black oreo	0	0	0	0
	(0)		(0)	
Dark ghost shark	0	0	0	0
	(0)		(0)	
Hake	0	0	0	0
	(0)		(0)	
Hoki	7	100	0	0
	(0)		(0)	
Javelinfish	9	65	20	34
	(0)		(0)	
Ling	589	55	144	100
	(3)		(1)	
Lookdown dory	32	24	47	50
	(3)		(6)	
Pale ghost shark	361	42	301	23
	(8)		(3)	
Ribaldo	0	0	0	0
	(0)		(0)	
Southern blue whiting	1 380	51	825	65
	(18)		(9)	
Spiny dogfish	0	0	0	0
	(0)		(0)	
White warehou	36	100	0	0
	(15)		(0)	

Table 9: **Numbers of hake, hoki, and ling at each reproductive stage from research surveys. See Appendix 1 for description of gonad stages.**

	Summer series						Autumn series							
	1991		1992		1993		1992		1993		1996		1998	
Reproductive stage	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
Hake														
1	6	1	2	2	49	121	0	0	4	0	9	24	30	100
2	34	73	30	89	18	55	7	23	7	33	17	76	5	37
3	5	21	2	40	1	26	1	65	1	20	12	41	5	43
4	33	2	1	1	14	0	6	2	3	0	0	0	24	0
5	7	0	1	0	5	0	43	1	7	0	4	0	20	0
6	1	0	6	5	17	7	1	5	14	47	35	0	7	6
7	0	87	0	56	0	18	0	9	0	24	2	0	0	2
Hoki														
1	40	10	20	2	61	55	40	14	51	4	33	39	61	108
2	350	752	508	1 081	308	654	280	743	341	926	327	599	471	892
3	0	2	0	1	0	1	263	323	240	267	36	18	58	41
4	1	0	0	0	0	1	6	0	23	0	0	0	0	0
5	0	0	0	0	0	0	0	1	0	0	0	0	0	0
6	0	0	2	0	21	0	0	0	0	0	0	0	0	0
7	1	3	74	7	19	17	0	0	0	0	0	4	0	0
Ling														
1	58	45	34	69	126	101	17	7	8	4	17	21	108	156
2	213	370	140	484	224	558	135	307	31	458	215	248	208	308
3	91	186	65	11	63	42	153	23	1	0	98	6	137	0
4	98	10	83	11	31	36	125	0	0	0	30	5	71	0
5	8	0	0	0	10	1	0	0	0	0	0	0	2	0
6	13	7	101	3	285	63	0	0	498	15	0	0	0	0
7	1	3	26	15	7	0	0	0	4	15	0	0	0	0

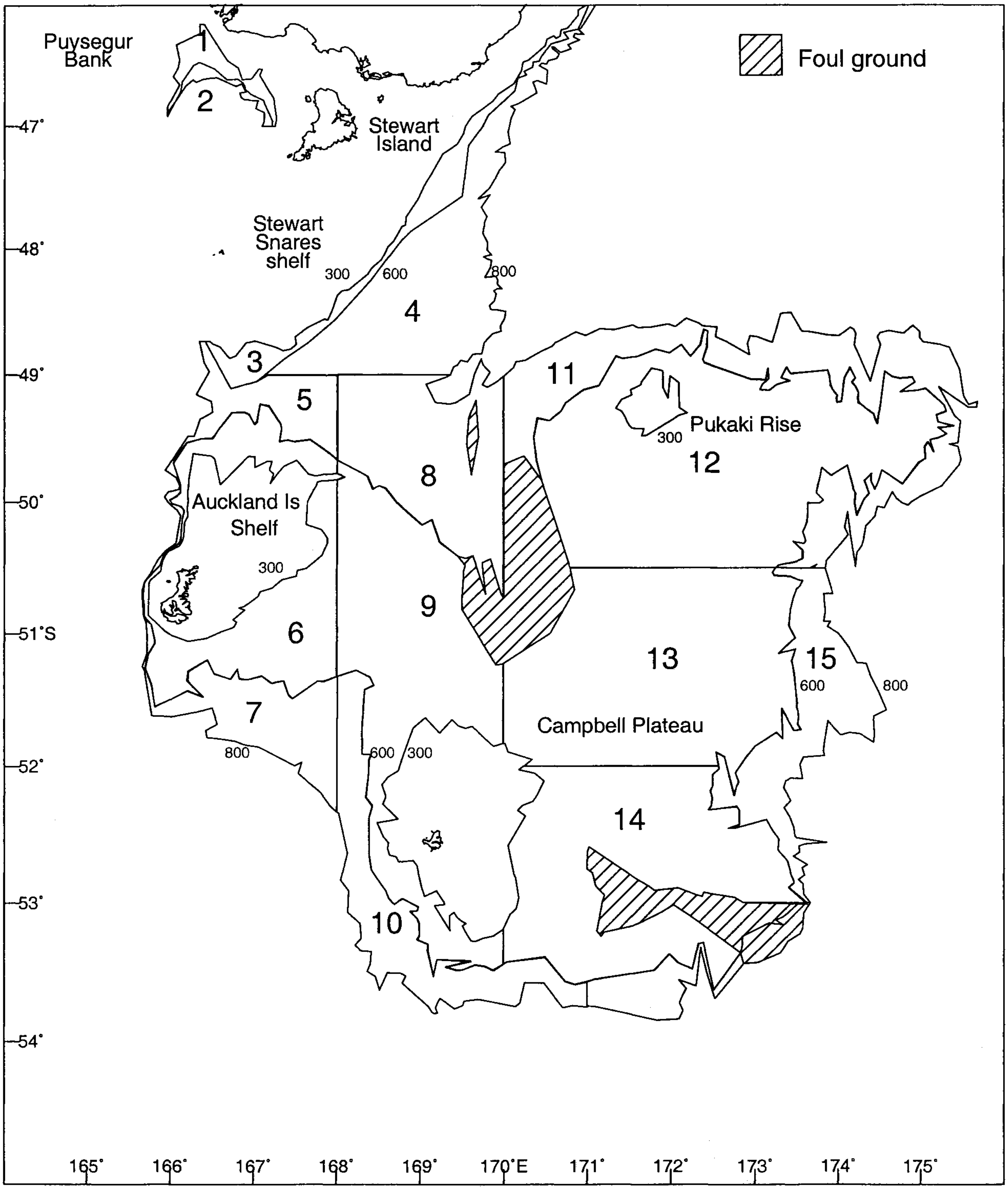


Figure 1a: **Core Southland and Sub-Antarctic trawl survey area covering 300–800 m depth. Strata definitions and numbering are as in autumn 1992 and 1993.**

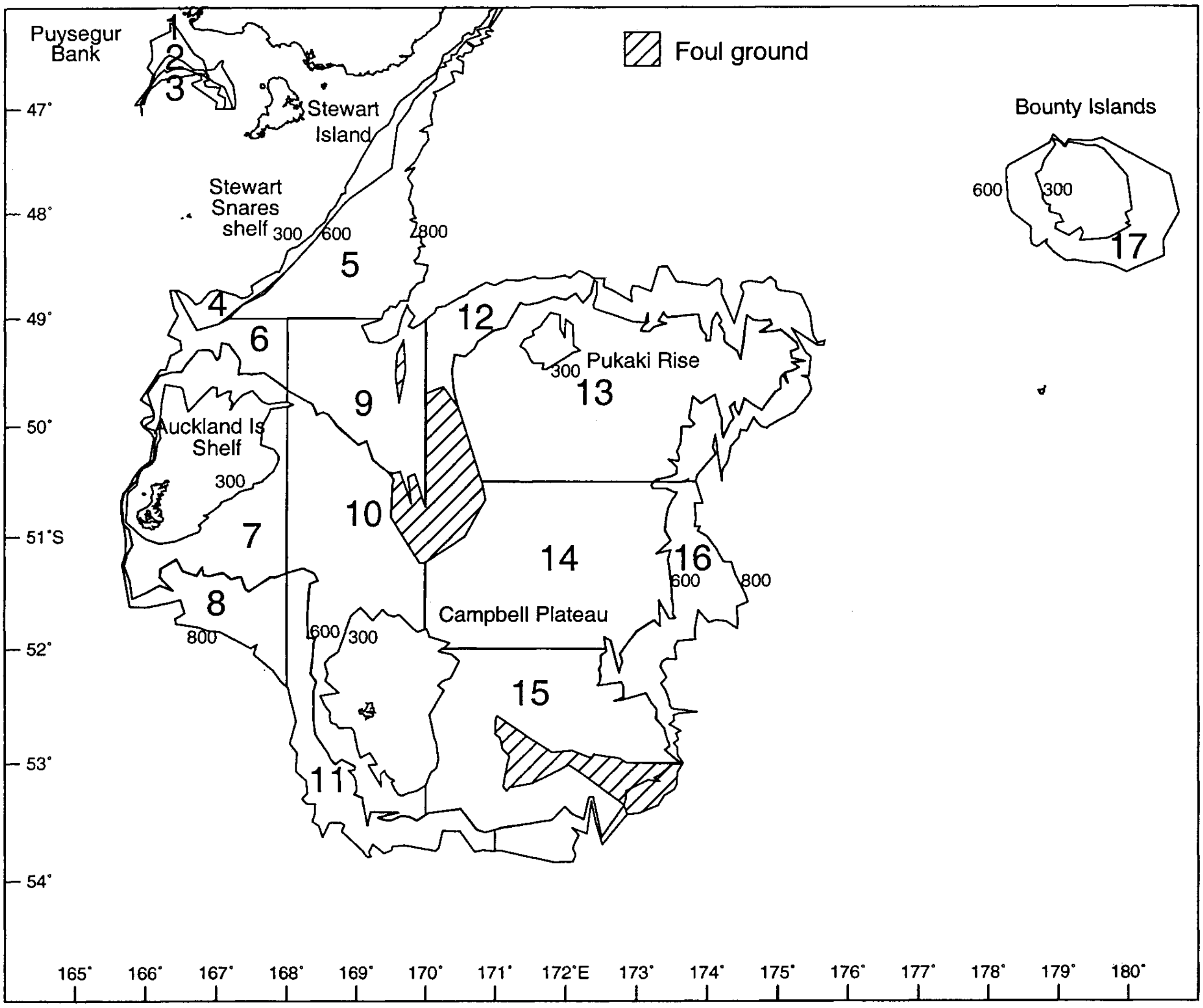


Figure 1b: **Survey area, strata definitions, and numbering for summer trawl series. Survey area included the core 300–800 m area, an 800–1000 m stratum off Puysegur and a 300–600 m stratum on the Bounty Platform. The Bounty stratum was not surveyed in summer 1991.**

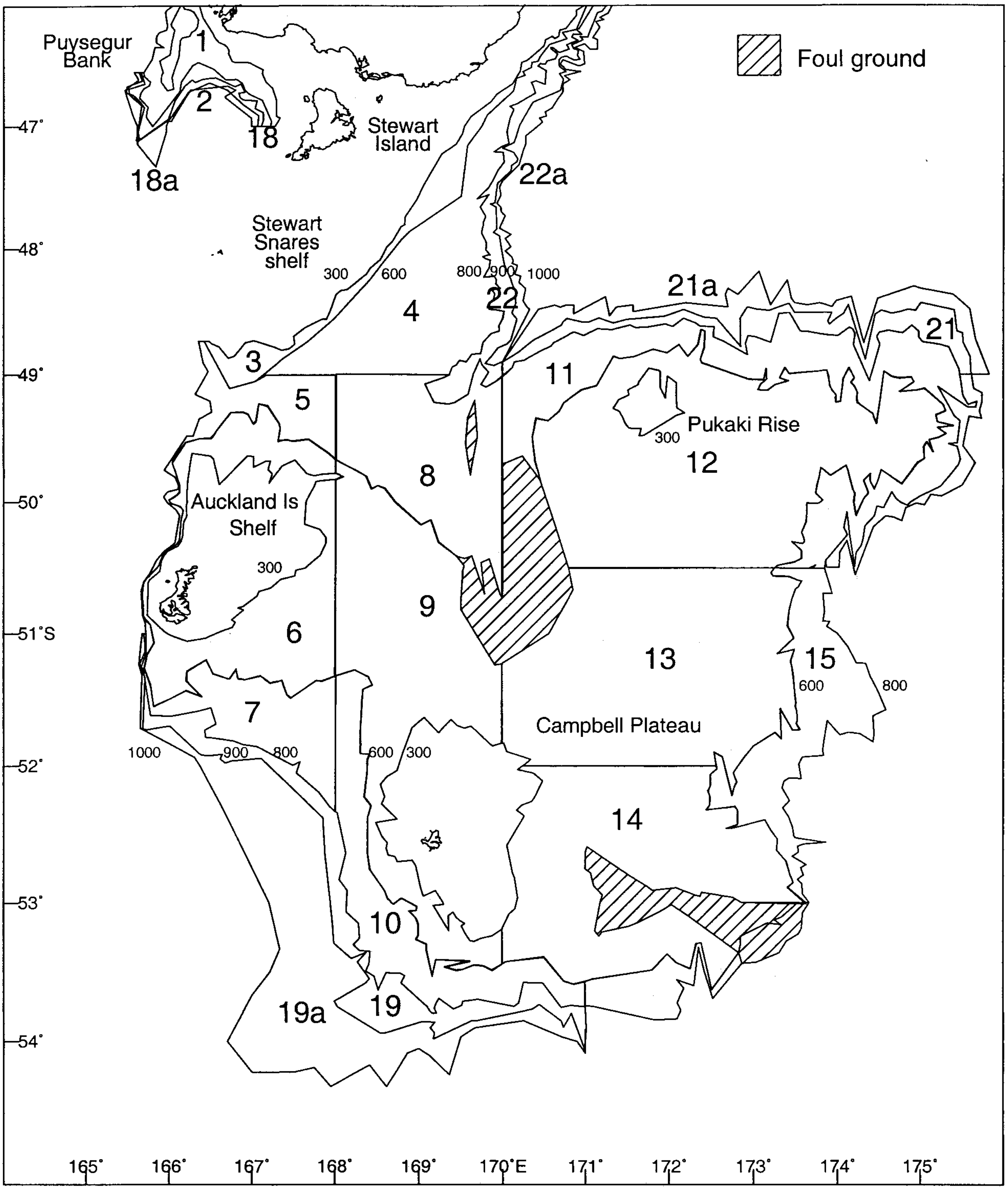


Figure 1c: **Survey area, strata definitions and numbering for autumn 1996 survey. Survey area included the core 300–800 m area and 800–1000 m round Puysegur and much of the Southern Plateau. Deeper areas were subdivided into 800–900 m and 900–1000 m strata.**

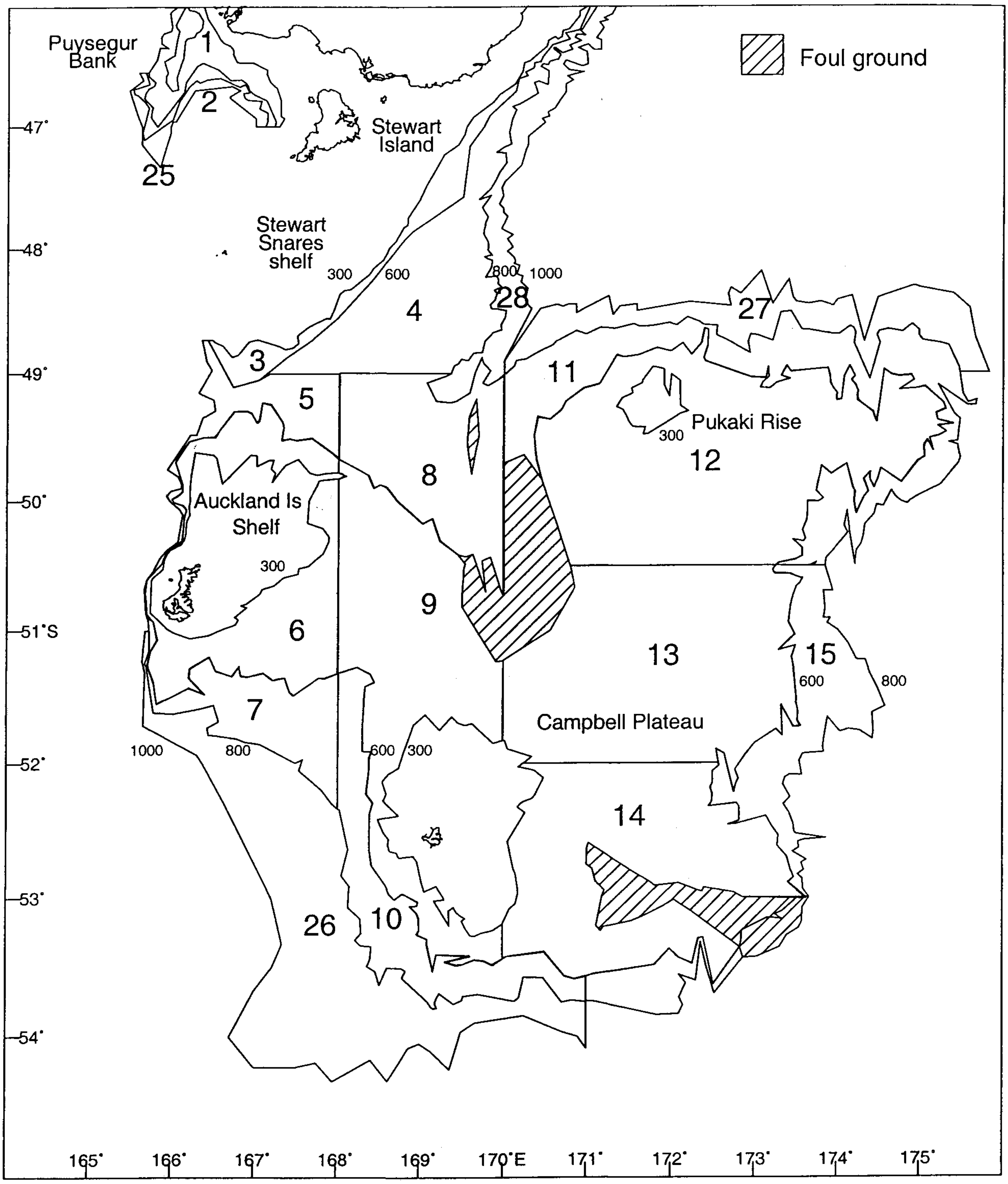


Figure 1d: **Survey area, strata definitions and numbering for autumn 1998 survey. Survey area was the same as in autumn 1996 (Figure 1c), but 800–900 m and 900–1000 m strata were combined and re-numbered.**

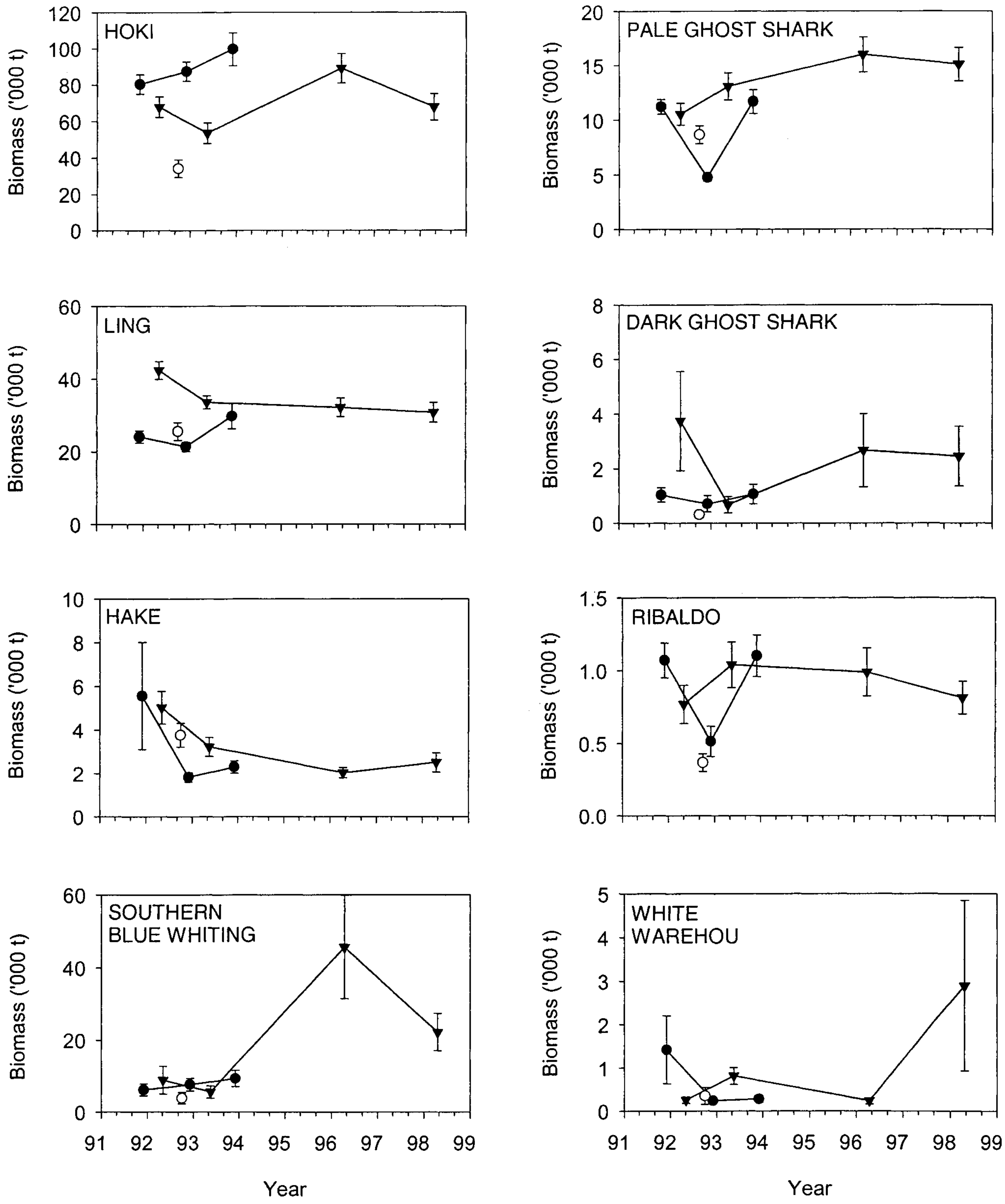


Figure 2: **Estimated biomass (+/- 1 standard error) of major species in the core 300-800 m strata. Solid circles show the summer time series and solid triangles the autumn time series. The open circle shows biomass estimated from a *Tangaroa* survey of the same area in September-October 1992 (Schofield & Livingston 1994c).**

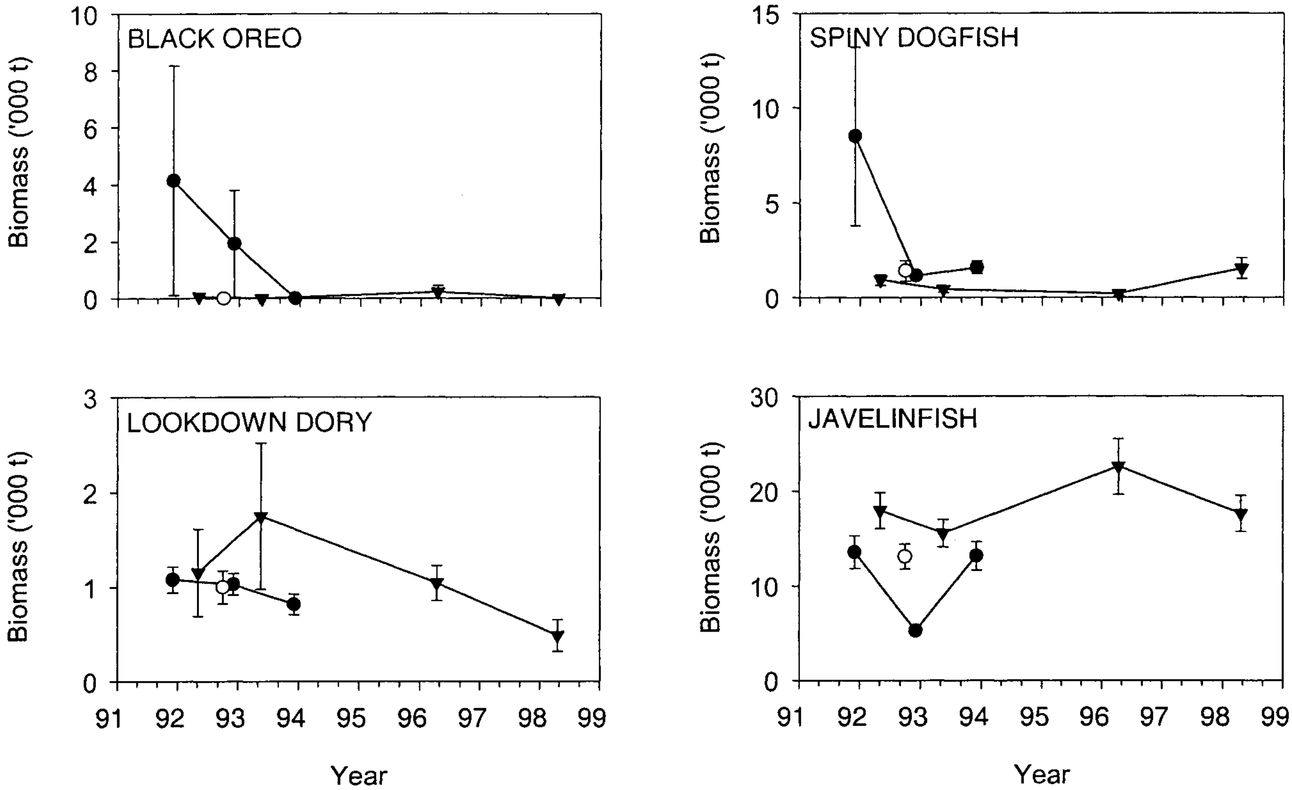


Figure 2 cntd: **Estimated biomass (+/- 1 standard error) of major species in the core 300-800 m strata.**

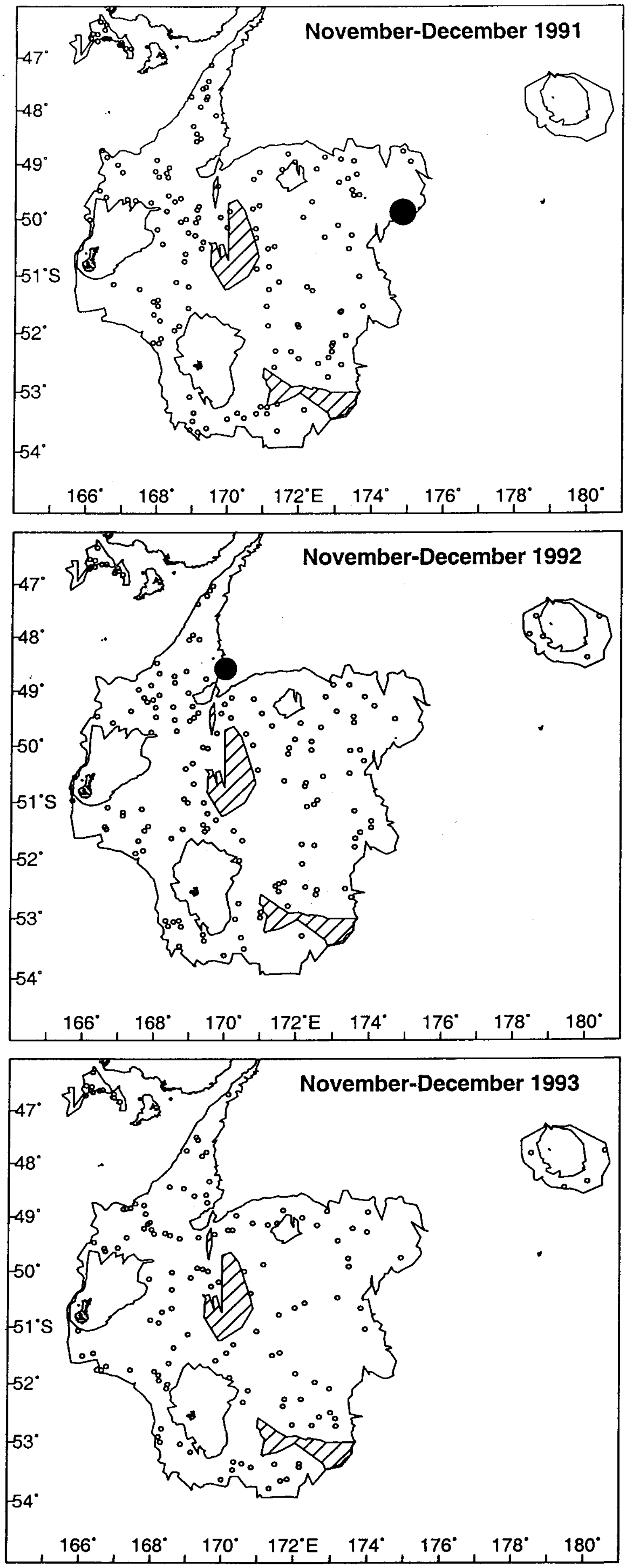


Figure 3a: **Distribution and catch rates of black oreo in the summer trawl series (maximum catch rate = 4412 kg km^{-2}). The boundary of the core 300–800 m survey area is shown.**

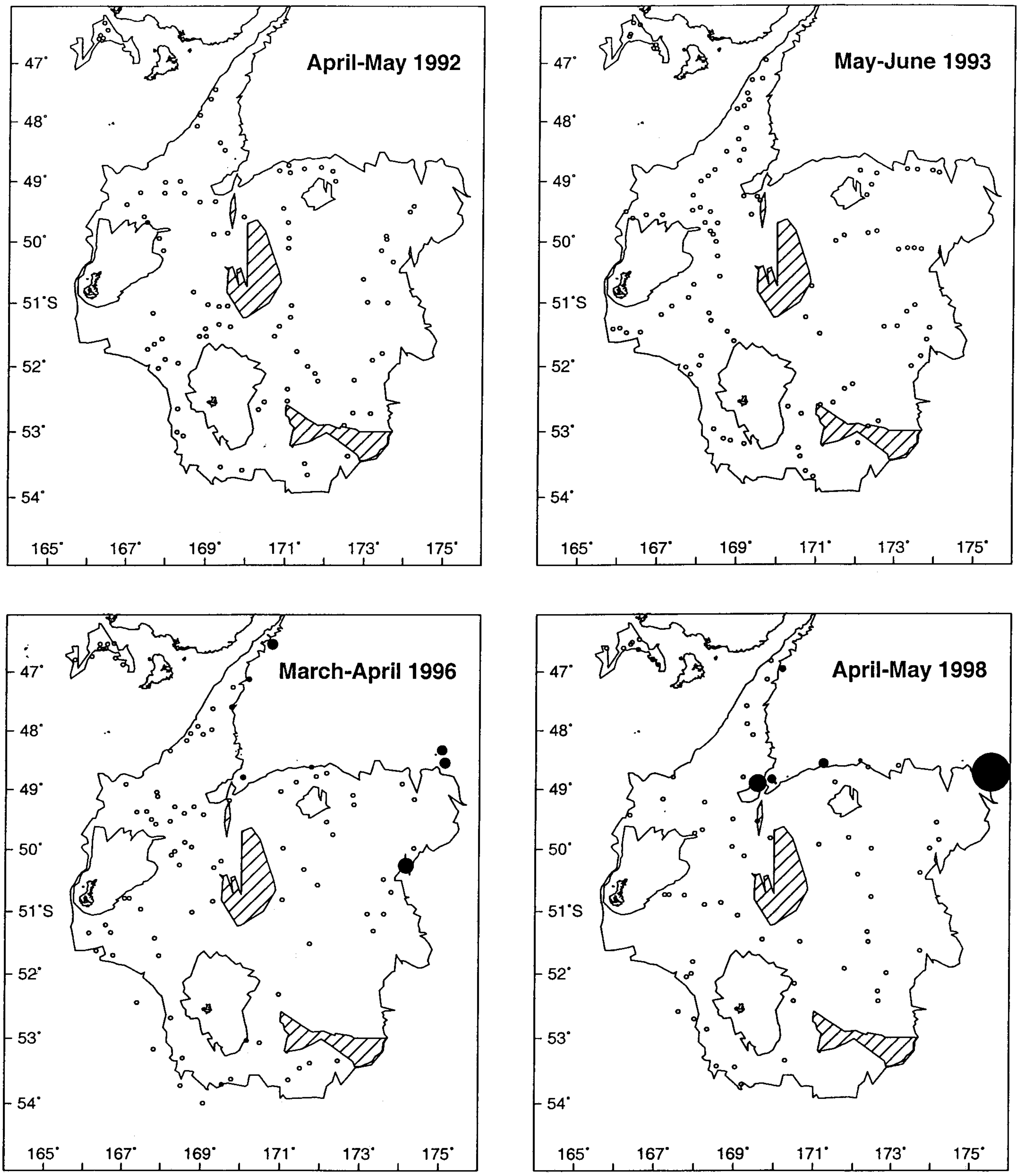


Figure 3a cntd: **Distribution and catch rates of black oreo in the autumn trawl series (maximum catch rate = 4412 kg km^{-2}).**

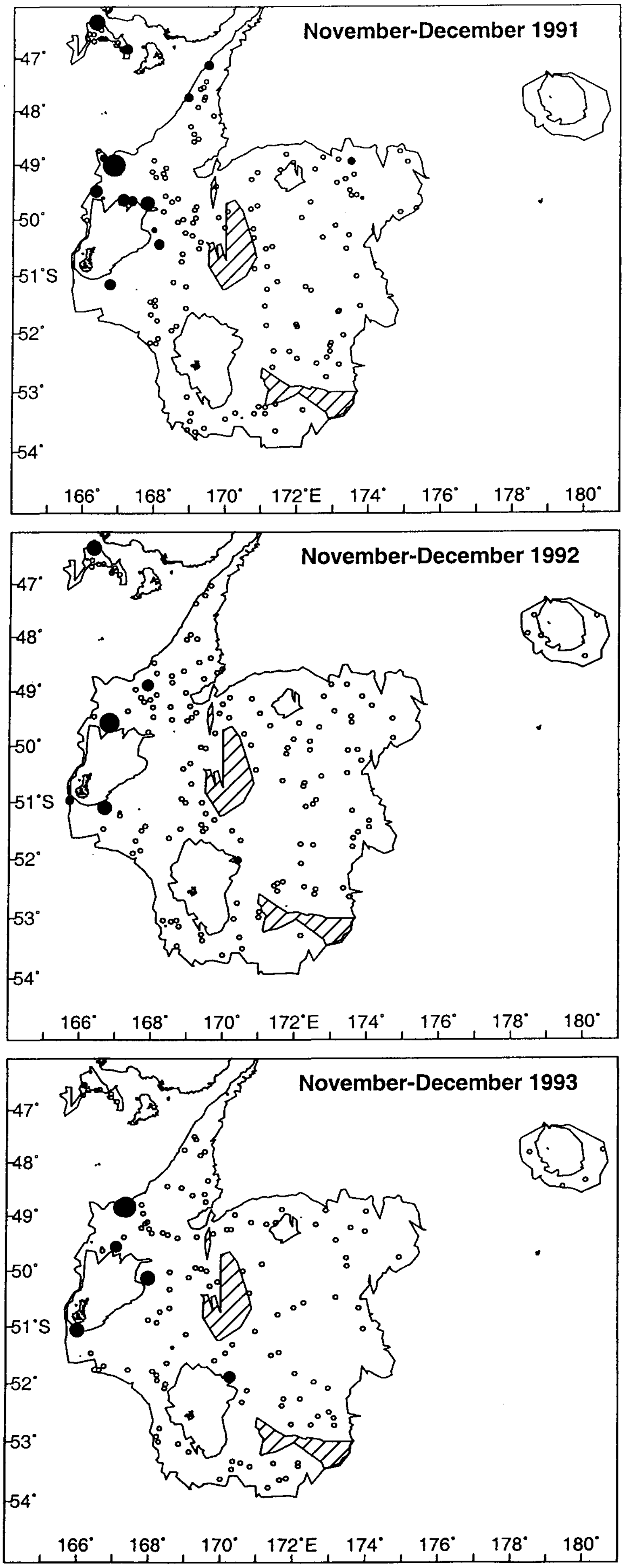


Figure 3b: **Distribution and catch rates of dark ghost shark in the summer trawl series (maximum catch rate = 753 kg km^{-2}).**

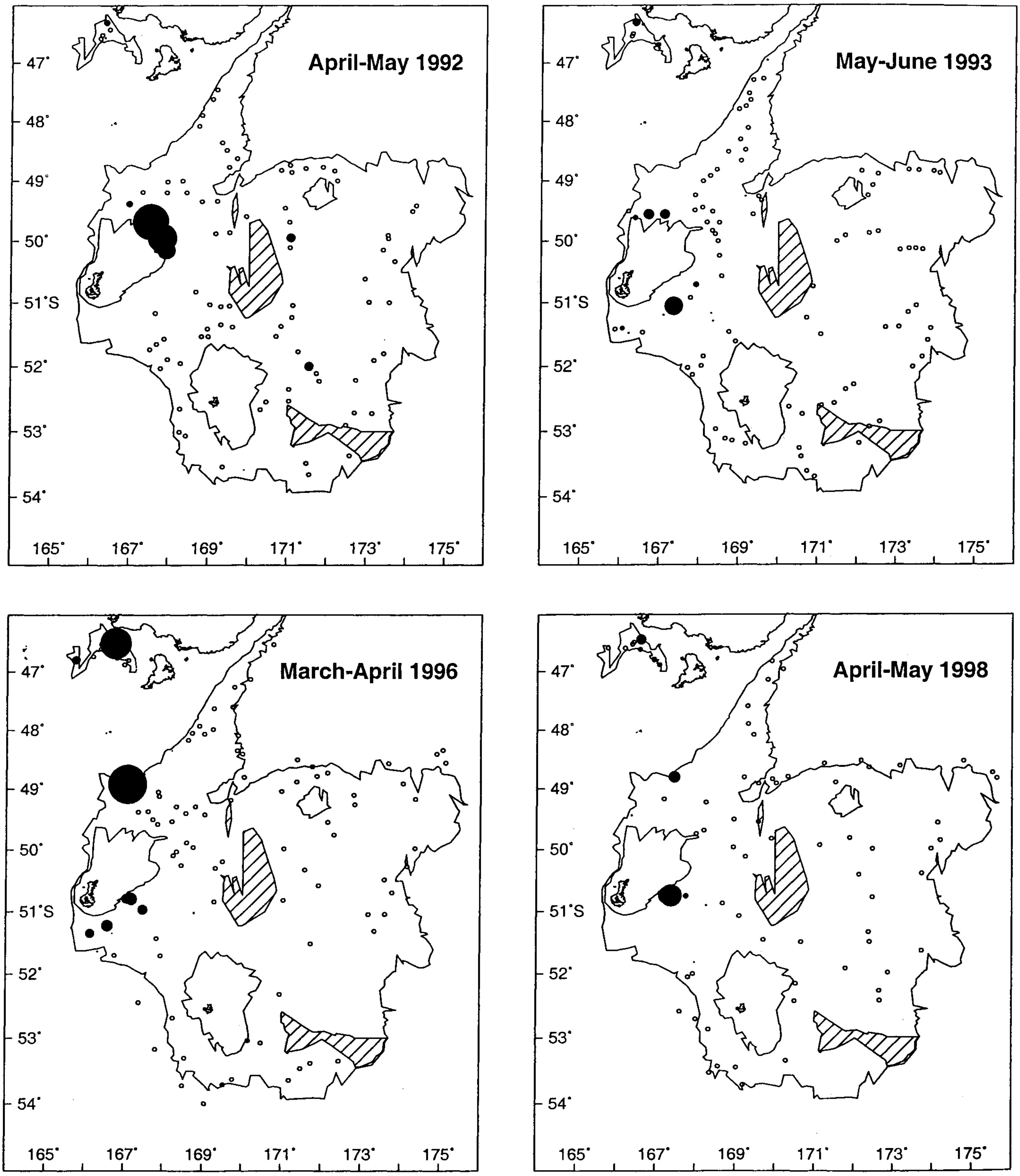


Figure 3b cntd: **Distribution and catch rates of dark ghost shark in the autumn trawl series (maximum catch rate = 753 kg km^{-2}).**

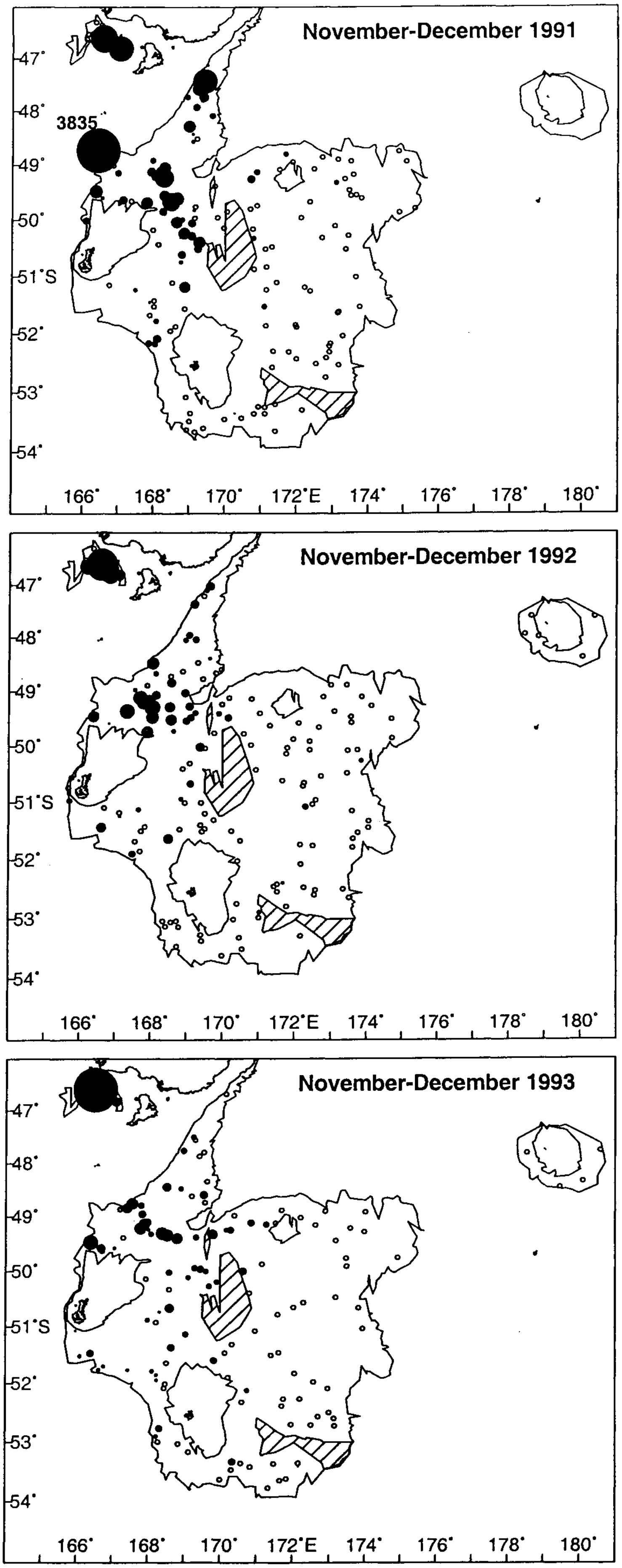


Figure 3c: **Distribution and catch rates of hake in the summer trawl series (maximum catch rate = 835 kg km^{-2} except large catch 3835 kg km^{-2} noted).**

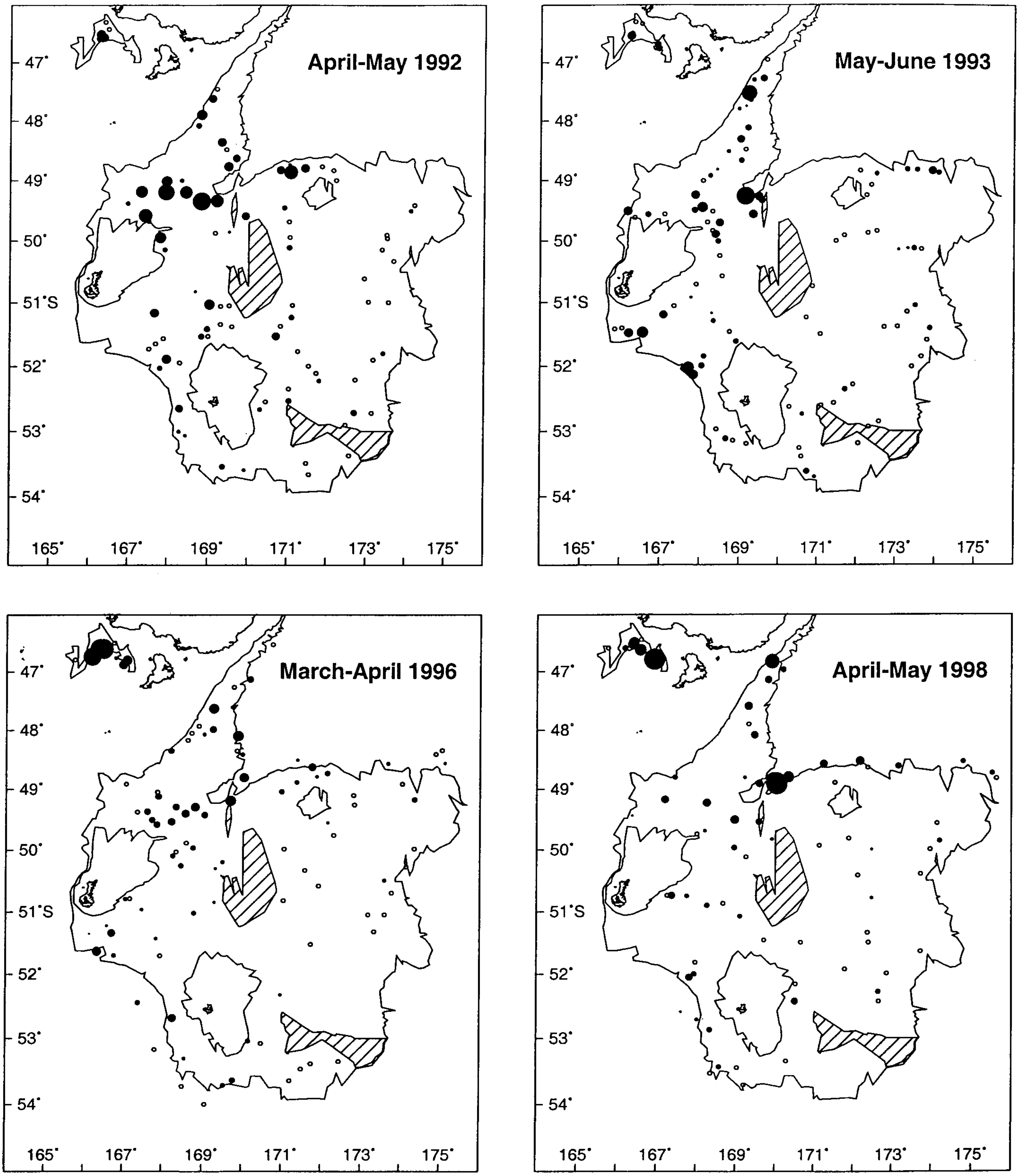


Figure 3c cntd: **Distribution and catch rates of hake in the autumn trawl series (maximum catch rate = 835 kg km^{-2}).**

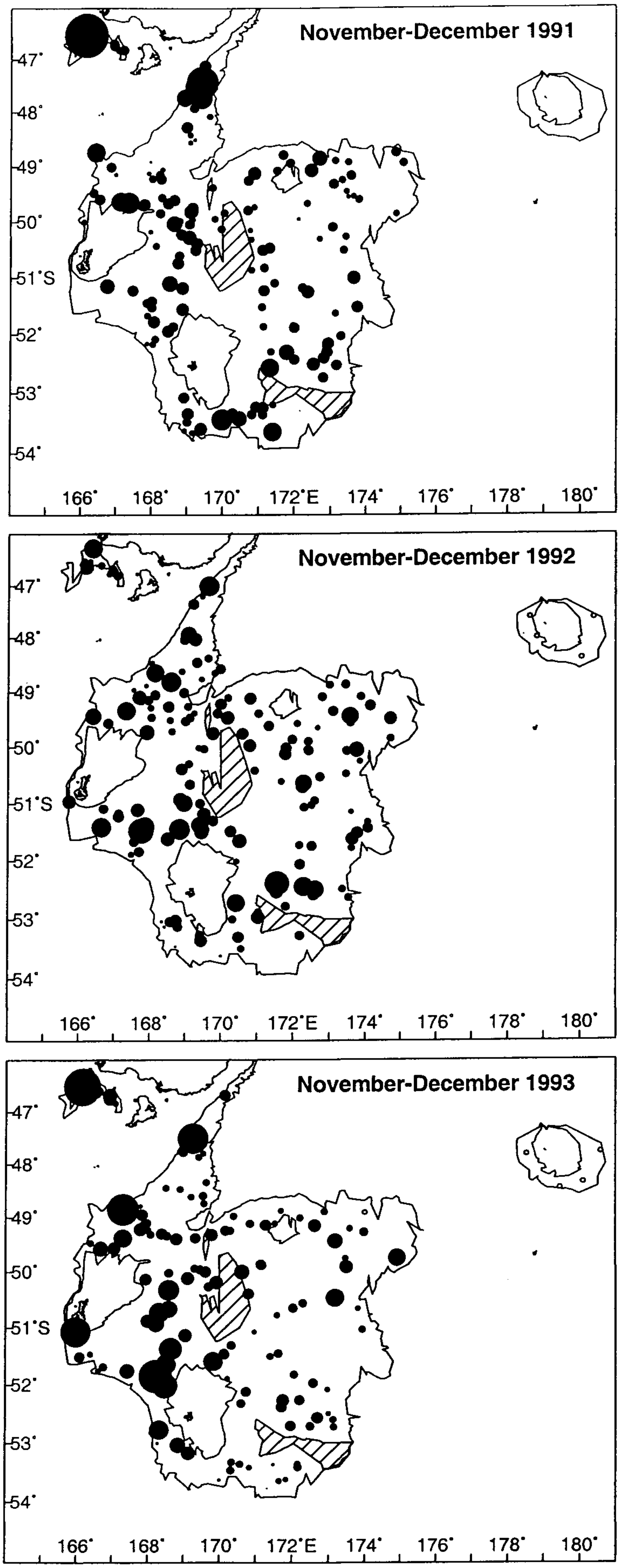


Figure 3d: **Distribution and catch rates of hoki in the summer trawl series (maximum catch rate = 5156 kg km^{-2}).**

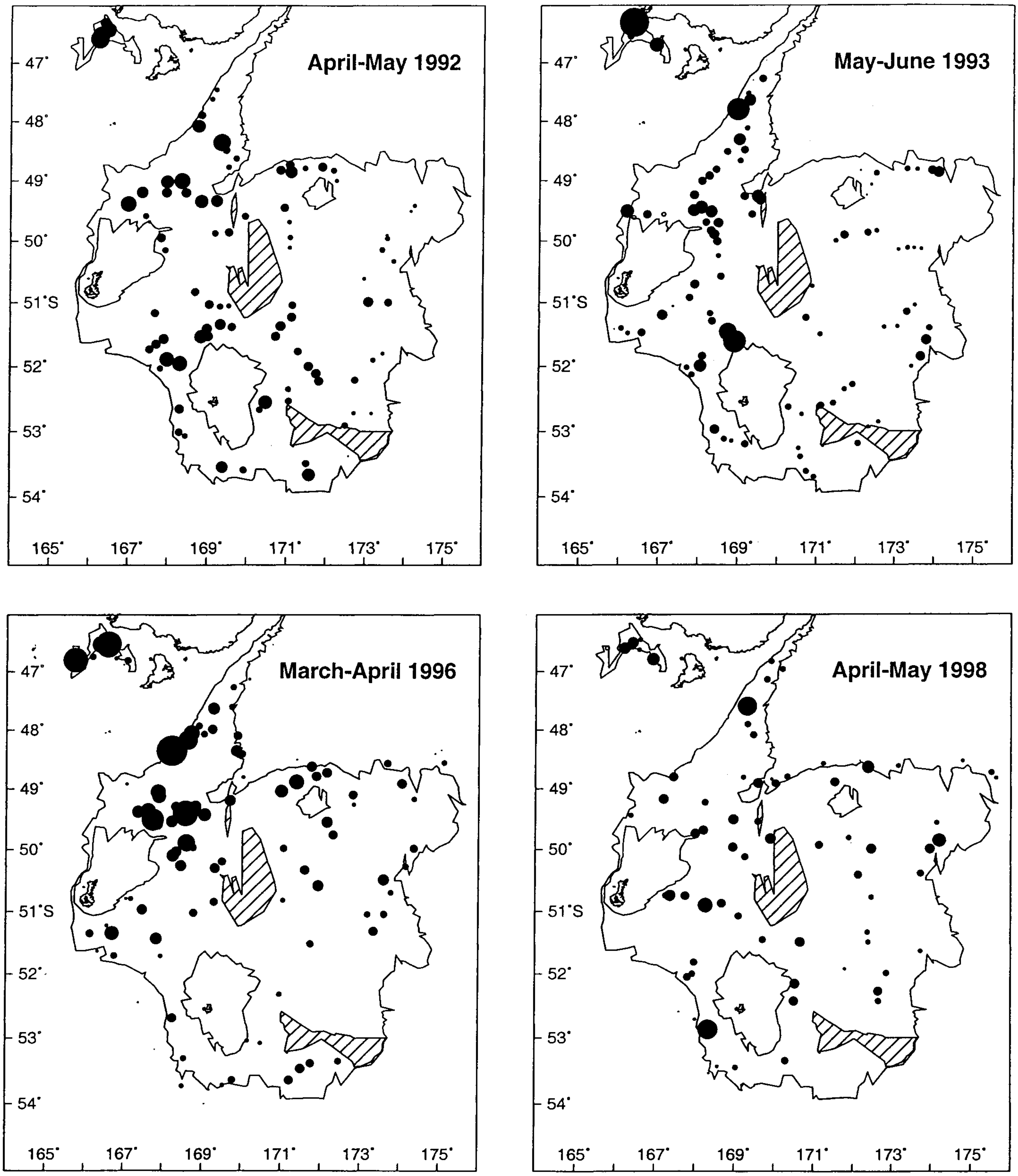


Figure 3d cntd: **Distribution and catch rates of hoki in the autumn trawl series (maximum catch rate = 5156 kg km^{-2}).**

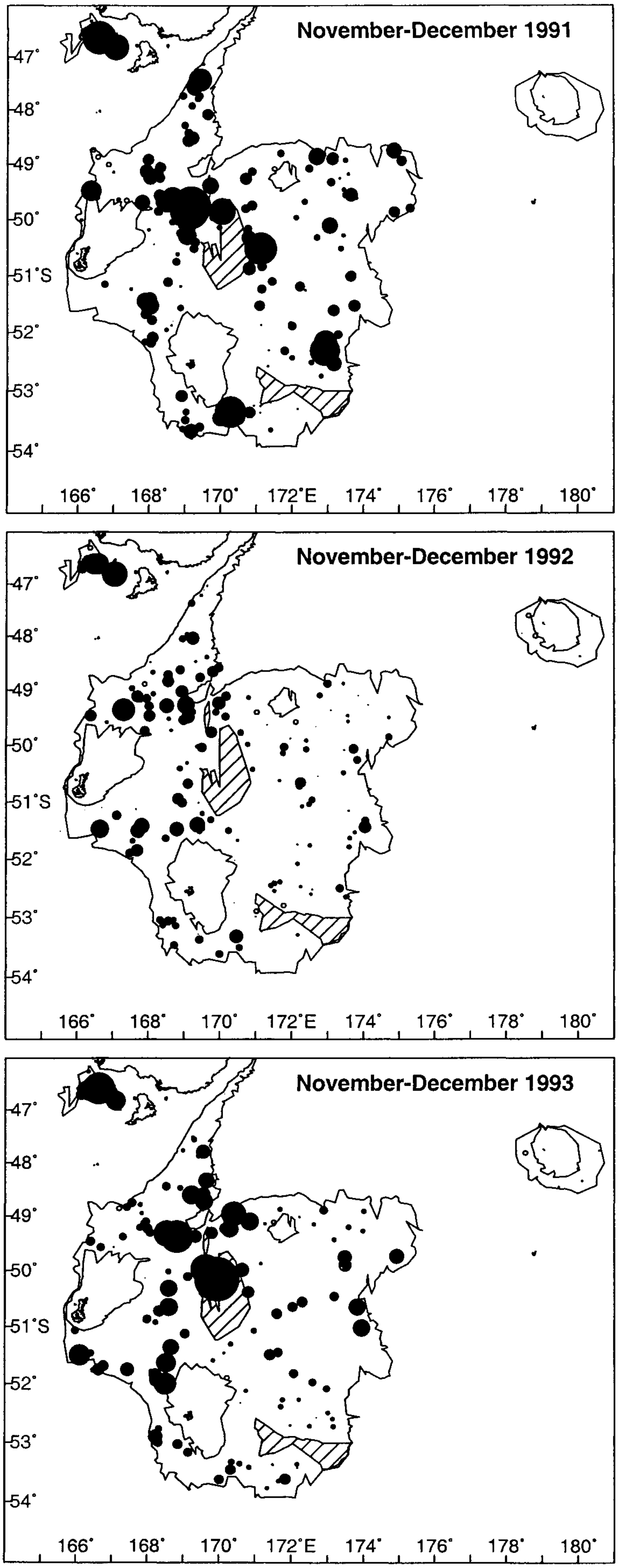


Figure 3e: **Distribution and catch rates of javelinfish in the summer trawl series (maximum catch rate = 735 kg km^{-2}).**

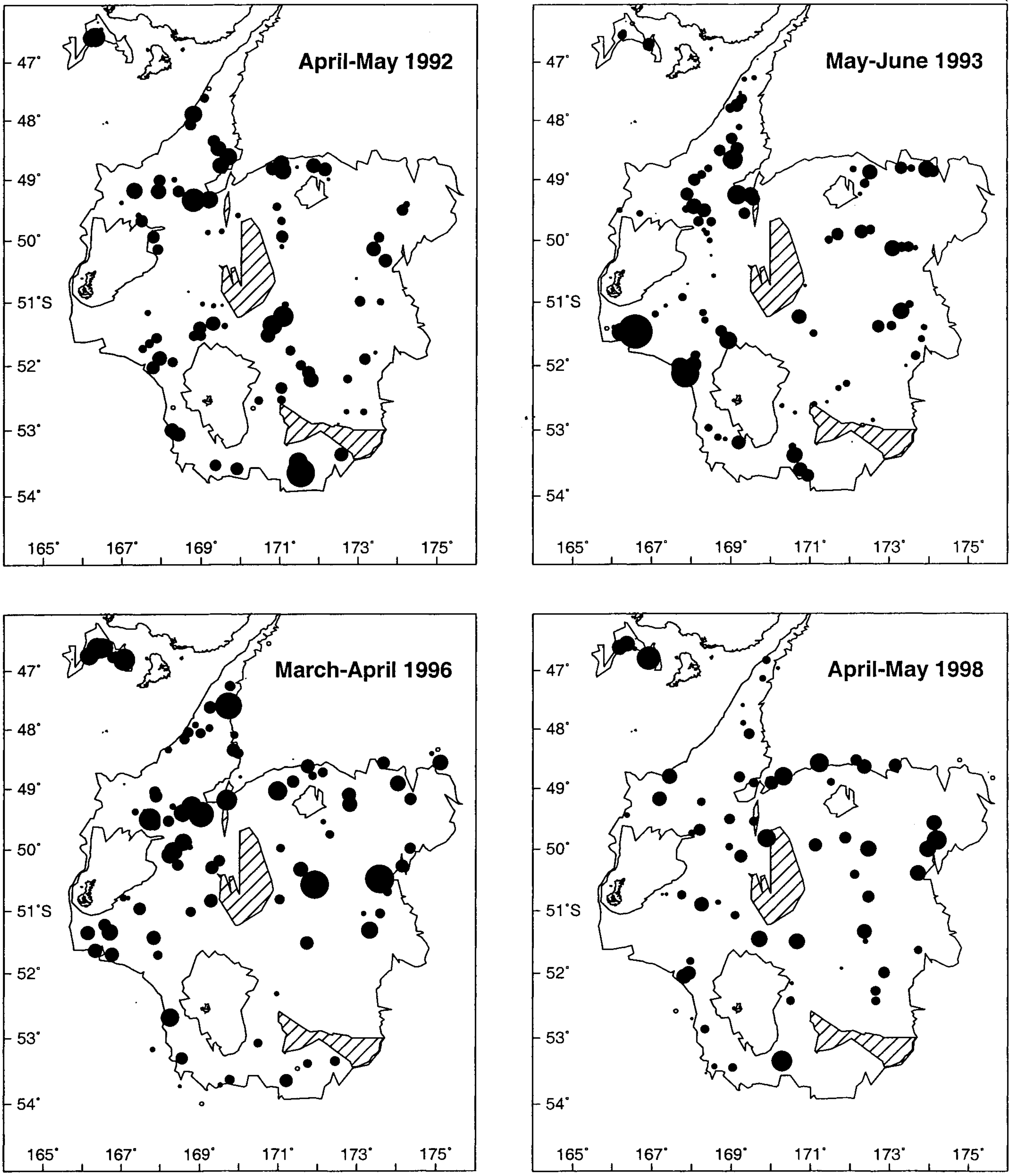


Figure 3e cntd: **Distribution and catch rates of javelinfish in the autumn trawl series (maximum catch rate = 735 kg km^{-2}).**

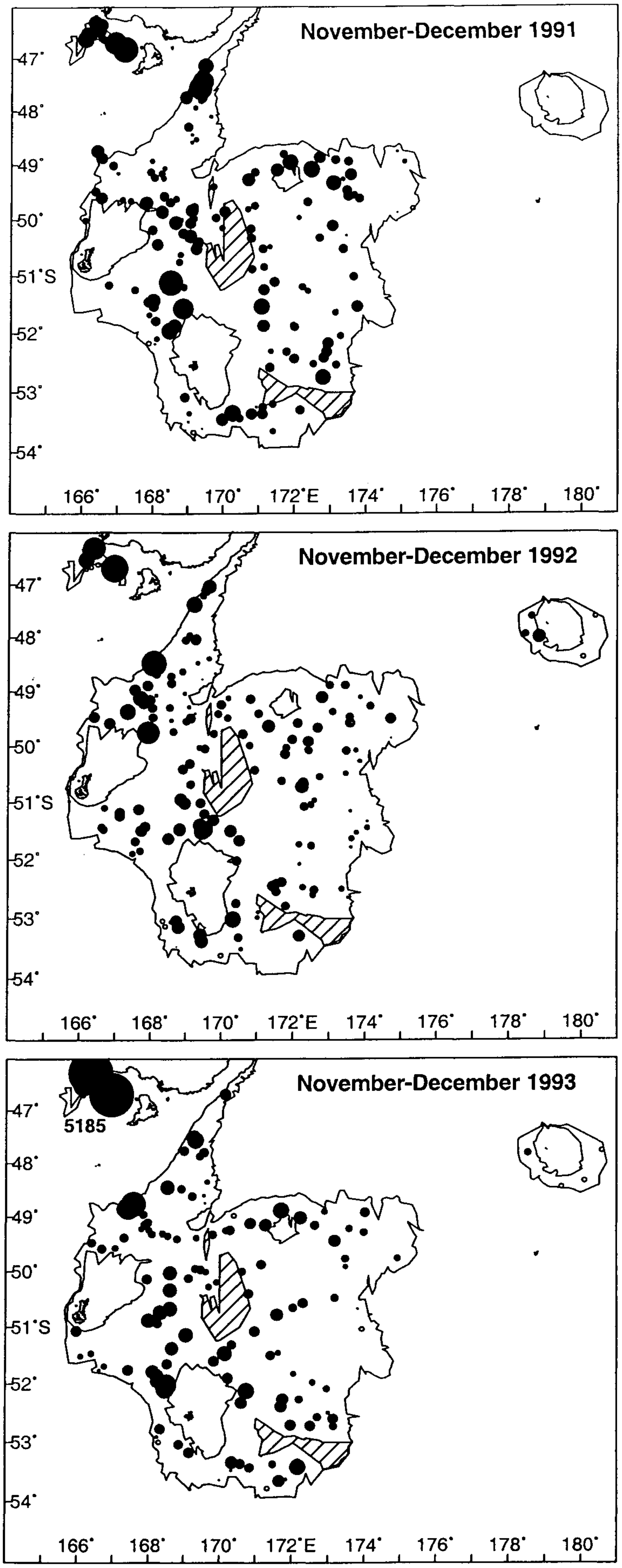


Figure 3f: **Distribution and catch rates of ling in the summer trawl series (maximum catch rate = 1801 kg km^{-2} except large catch 5185 kg km^{-2} noted).**

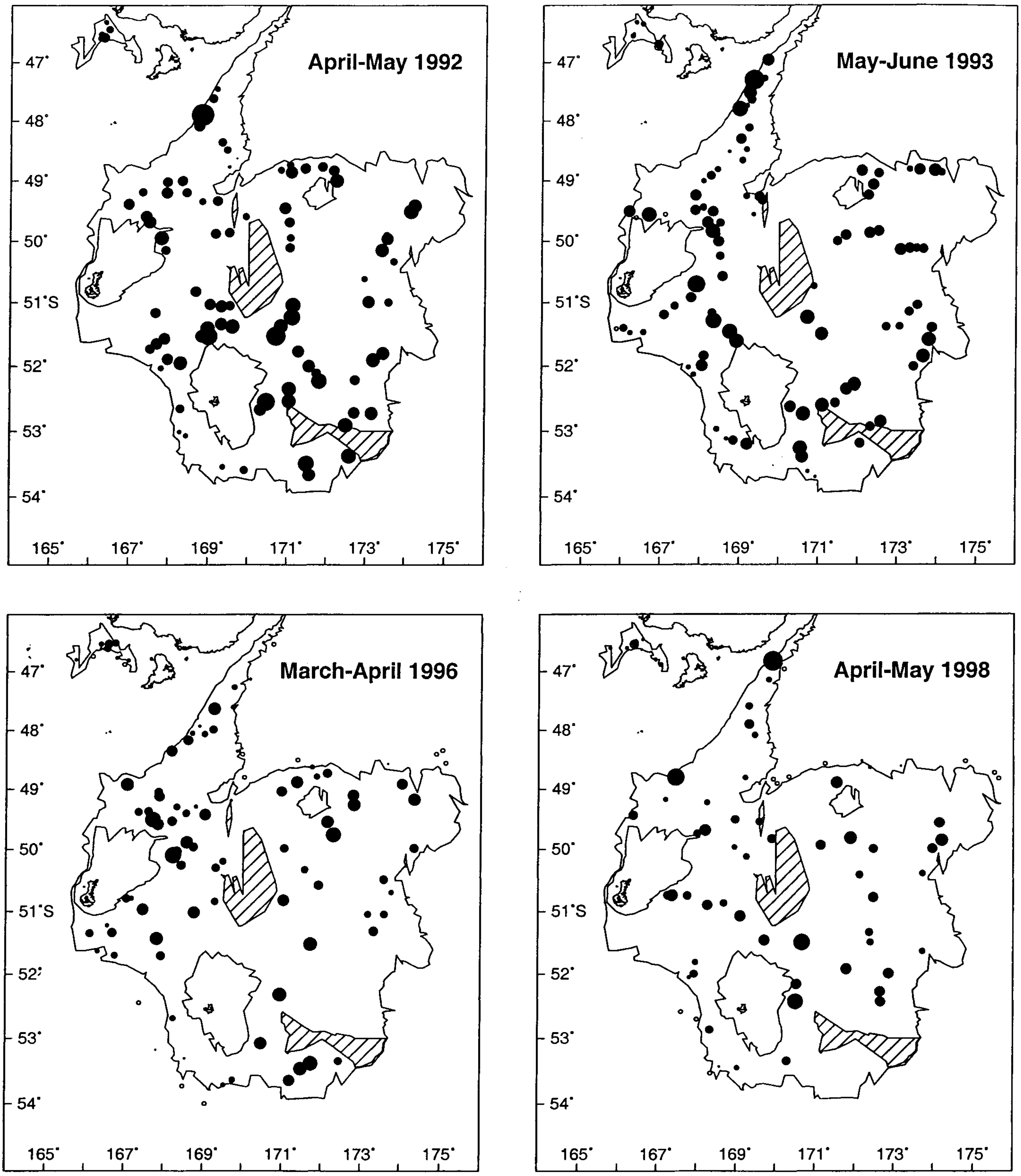


Figure 3f cntd: **Distribution and catch rates of ling in the autumn trawl series (maximum catch rate = 1801 kg km^{-2}).**

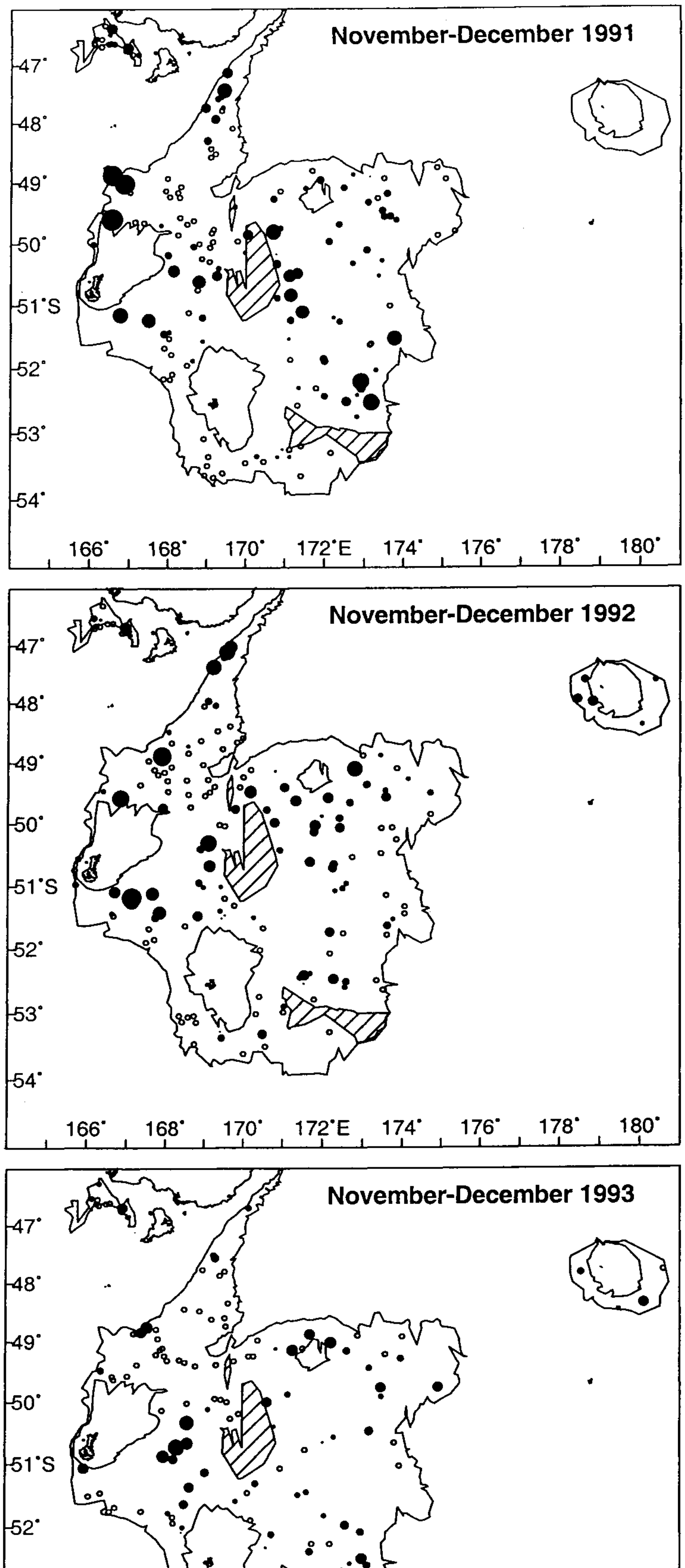


Figure 3g: **Distribution and catch rates of lookdown dory in the summer trawl series (maximum catch rate = 208 kg km^{-2}).**

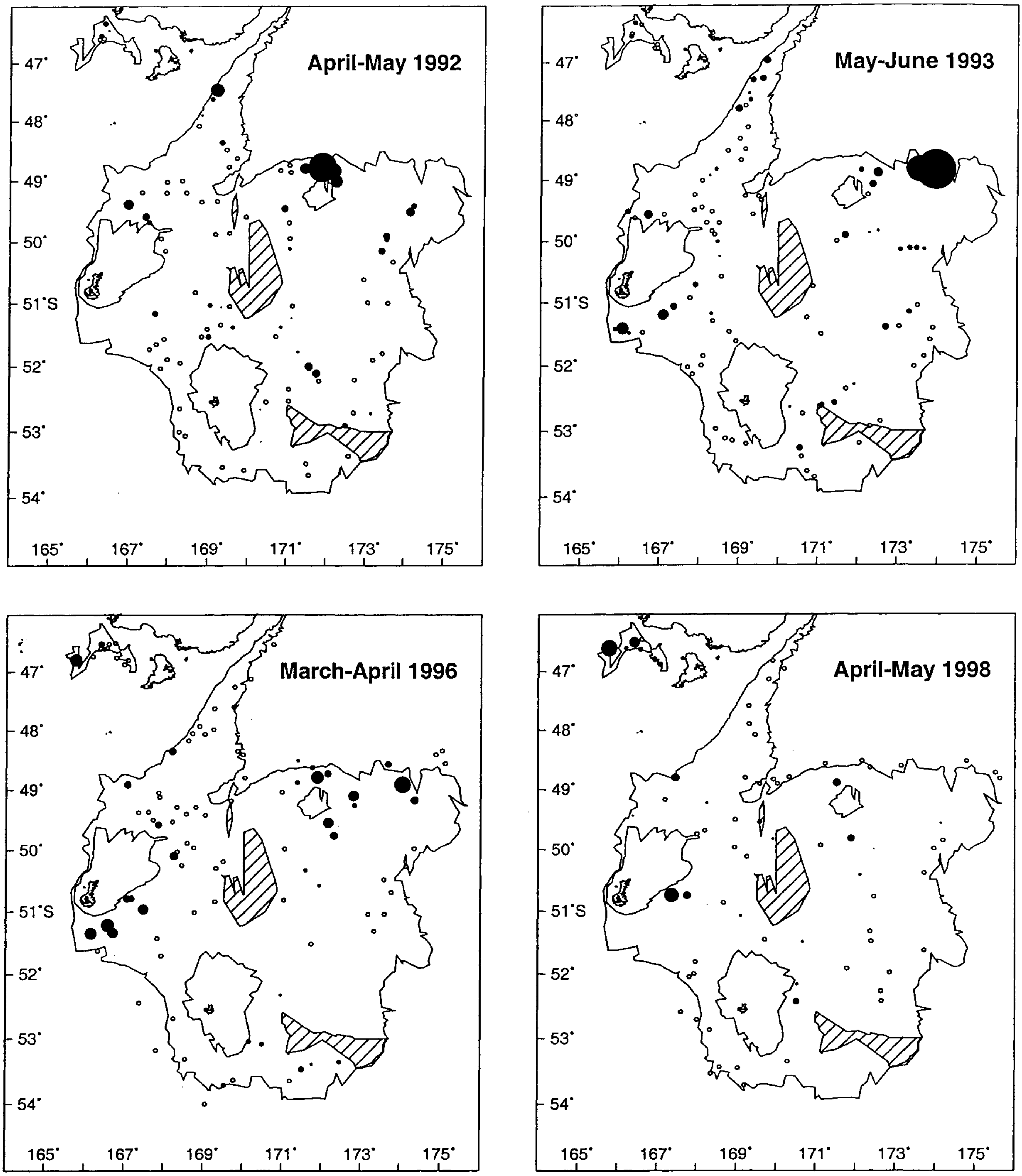


Figure 3g cntd: **Distribution and catch rates of lookdown dory in the autumn trawl series (maximum catch rate = 208 kg km^{-2}).**

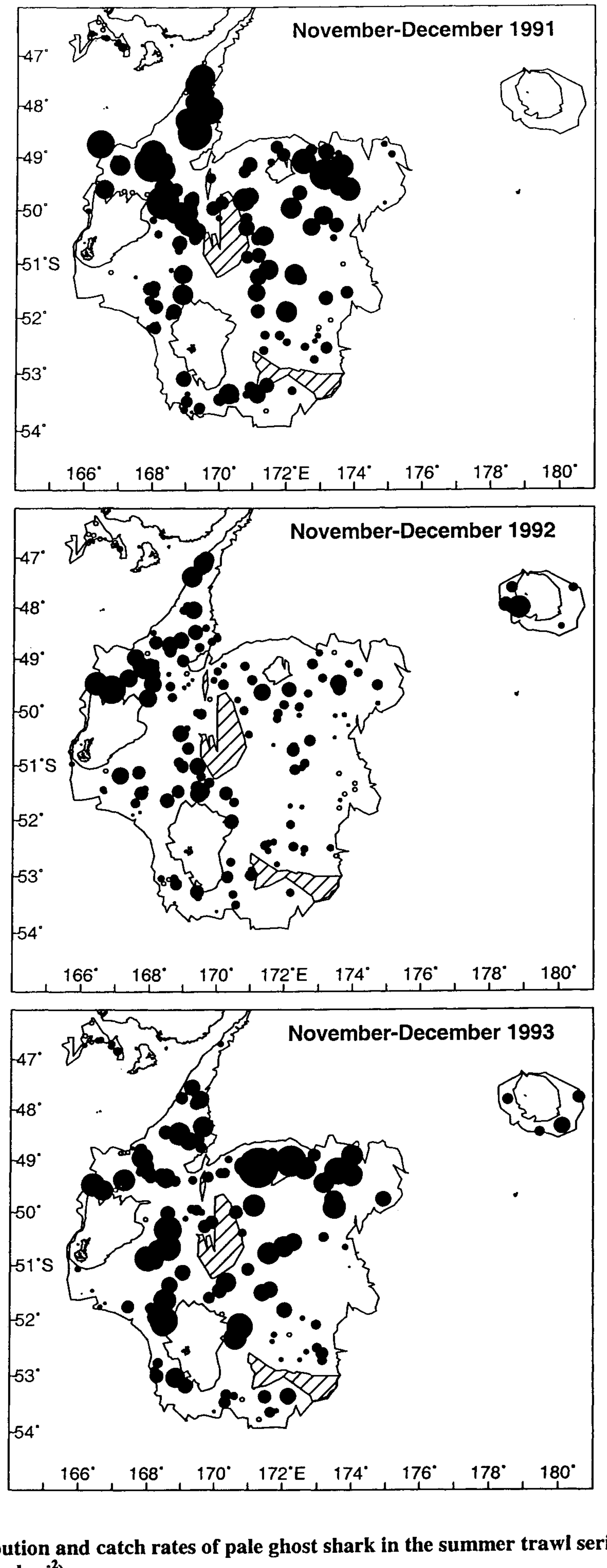


Figure 3h: **Distribution and catch rates of pale ghost shark in the summer trawl series (maximum catch rate = 294 kg km^{-2}).**

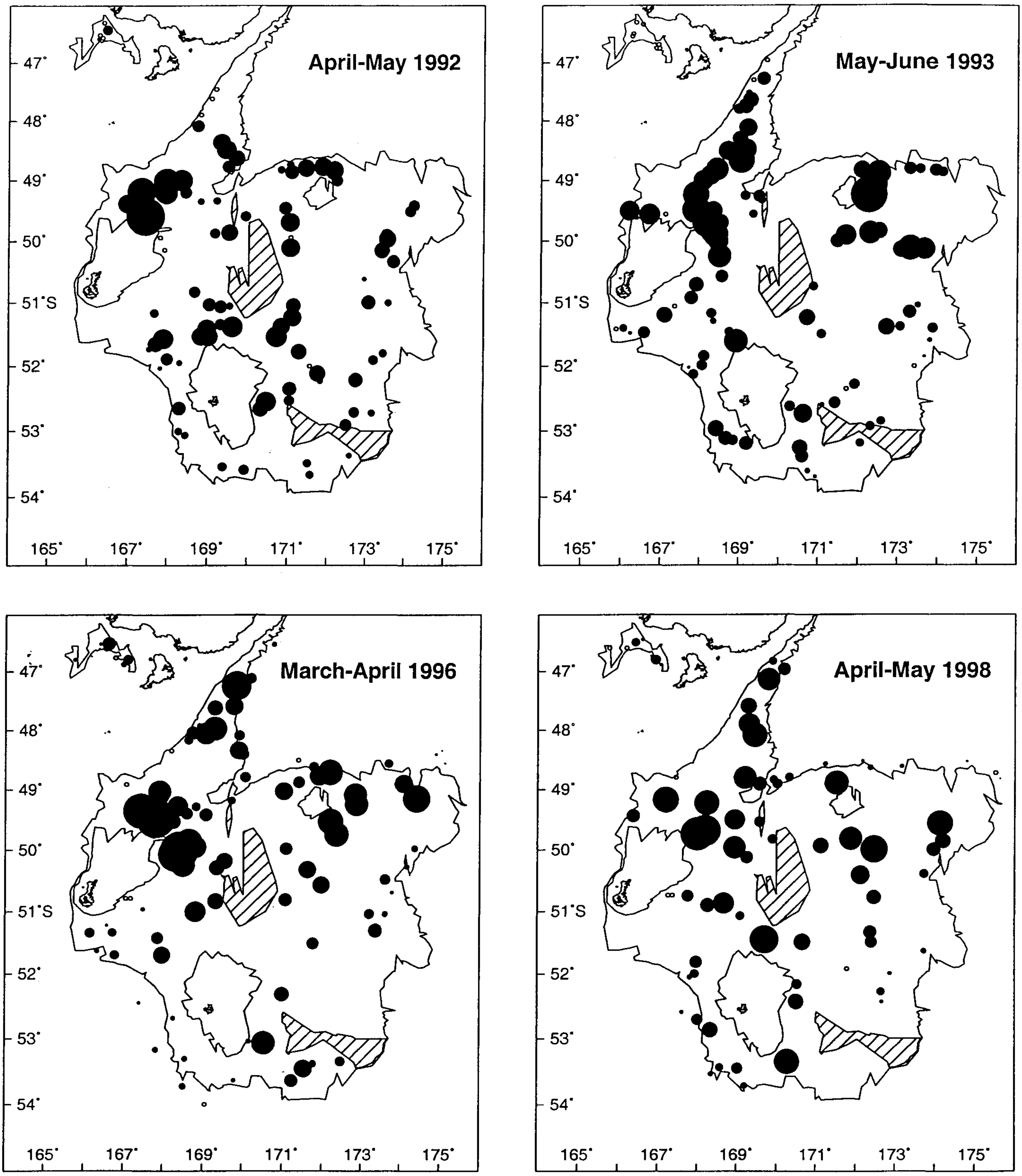


Figure 3h cntd: **Distribution and catch rates of pale ghost shark in the autumn trawl series (maximum catch rate = 294 kg km^{-2}).**

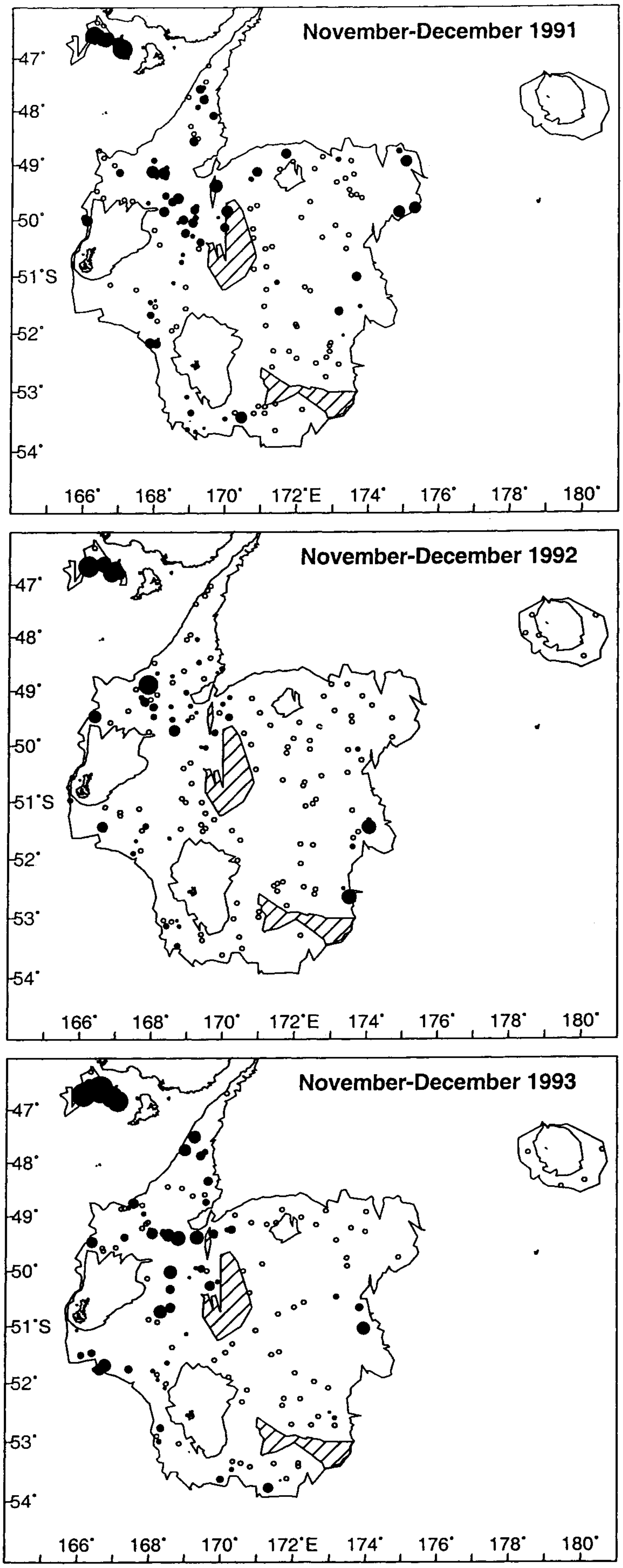


Figure 3i: **Distribution and catch rates of ribaldo in the summer trawl series (maximum catch rate = 292 kg km^{-2}).**

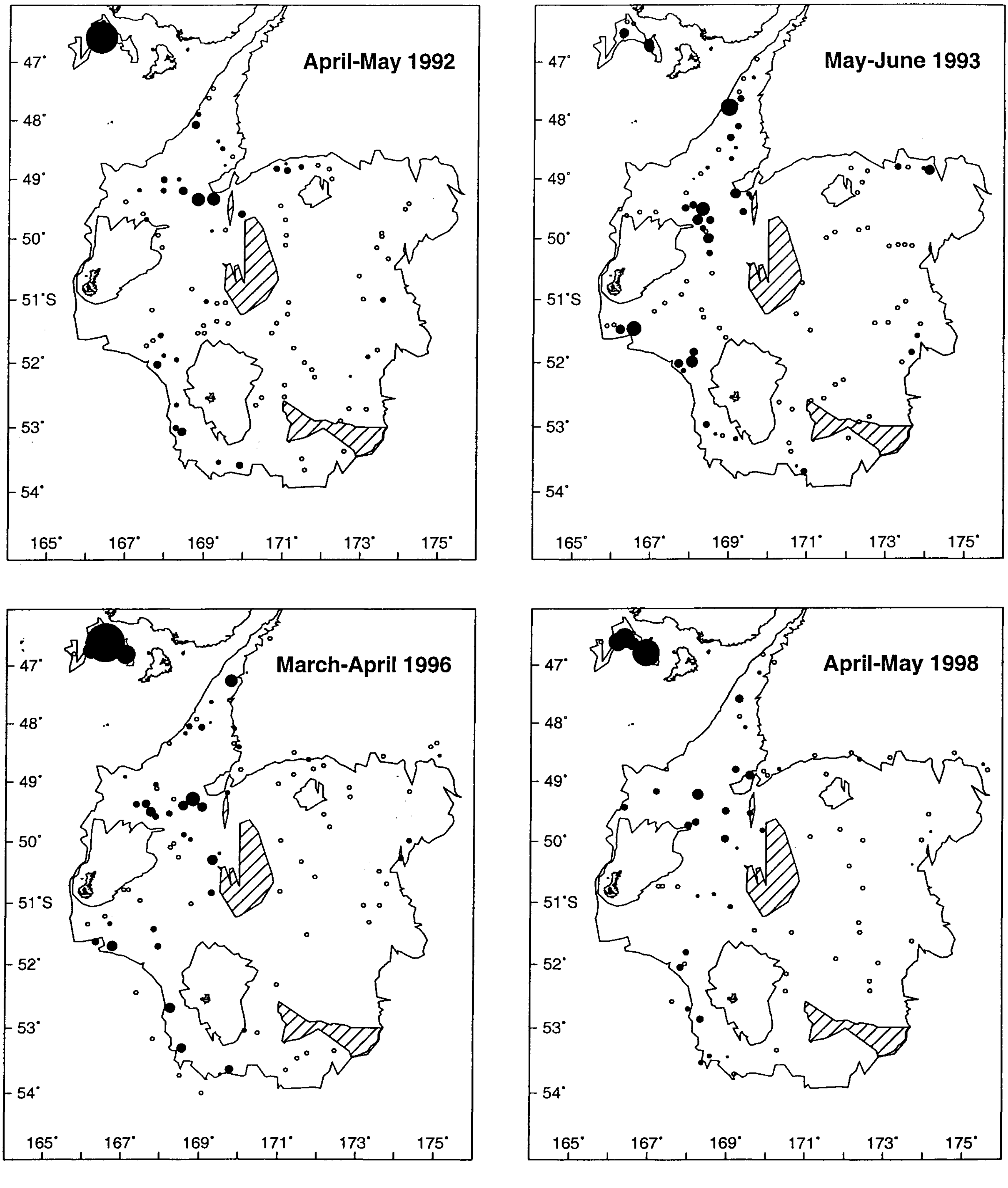


Figure 3i cntd: **Distribution and catch rates of ribaldo in the autumn trawl series (maximum catch rate = 292 kg km^{-2}).**

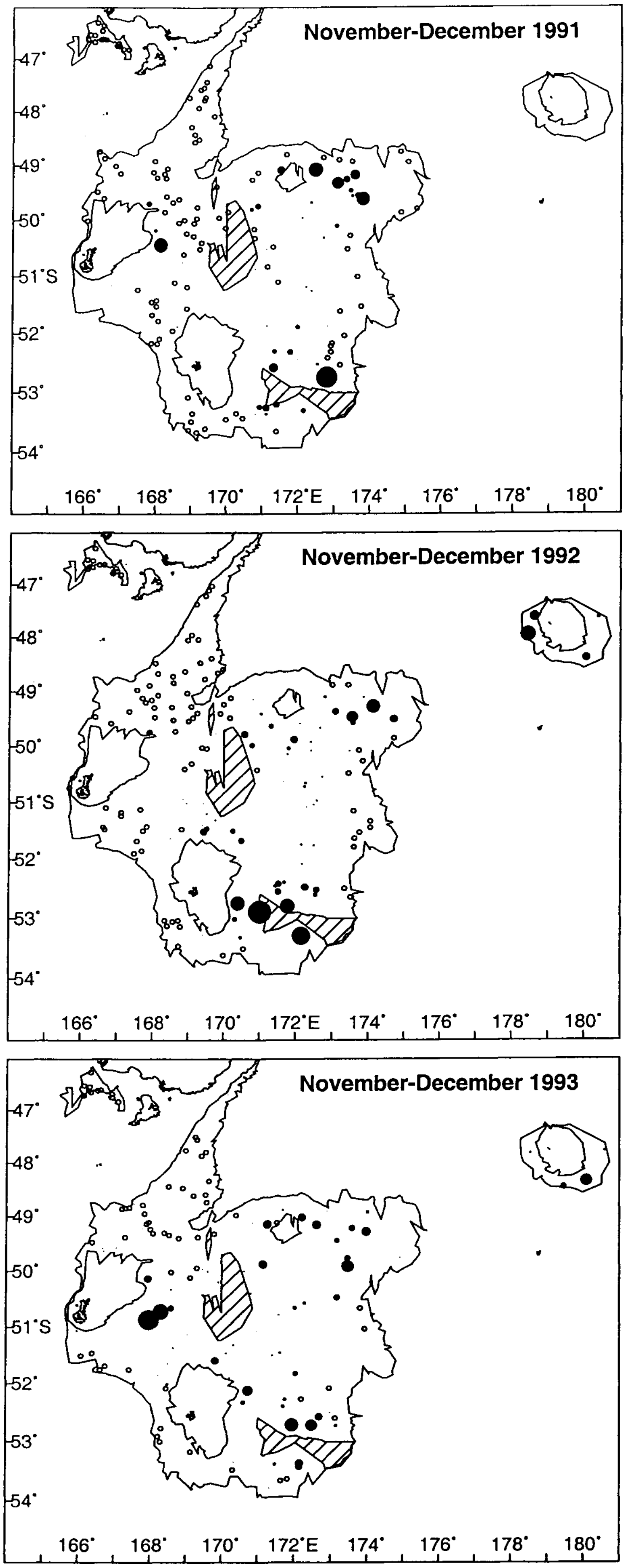


Figure 3j: **Distribution and catch rates of southern blue whiting in the summer trawl series (maximum catch rate = 3064 kg km^{-2}).**

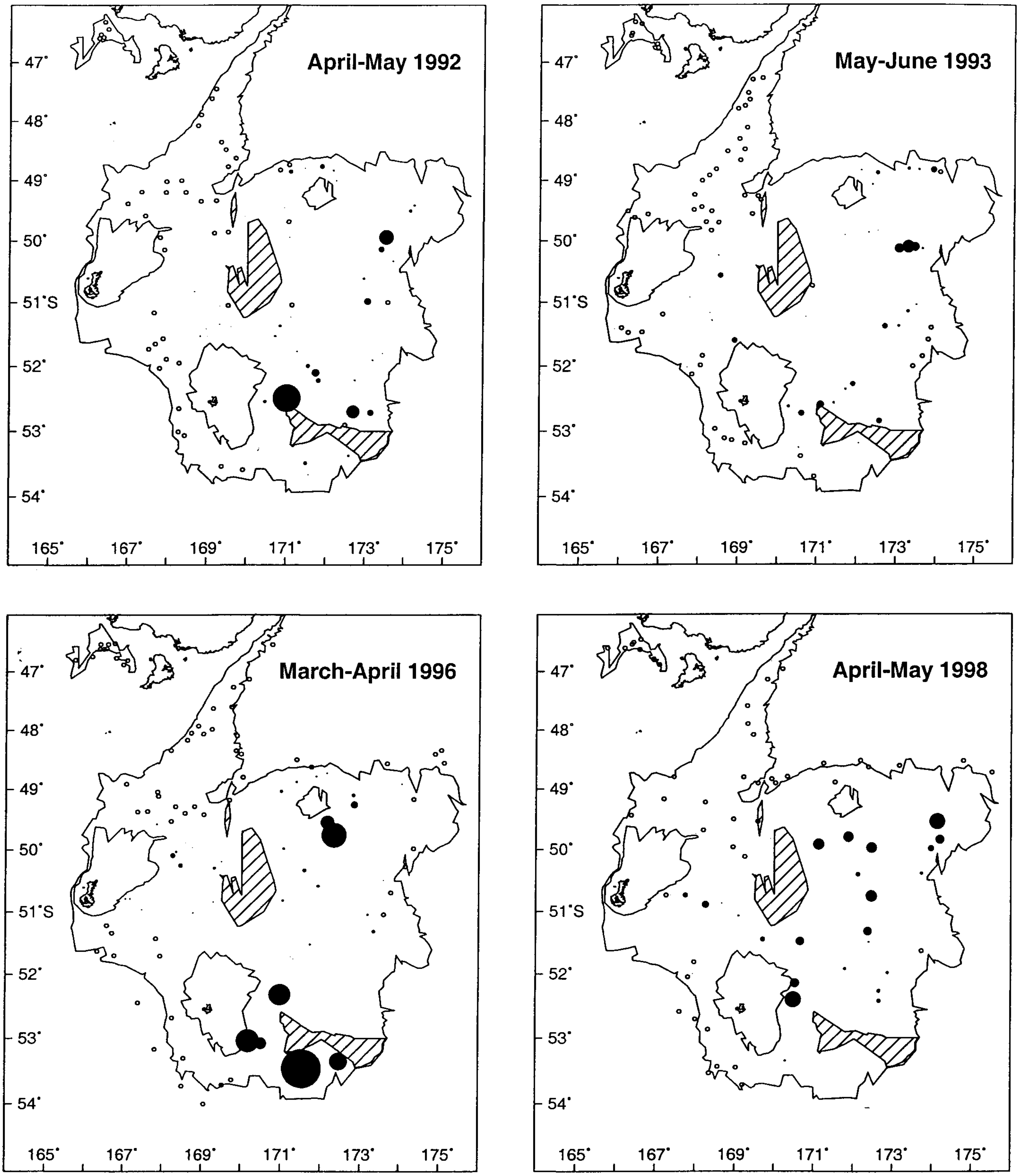


Figure 3j cntd: **Distribution and catch rates of southern blue whiting in the autumn trawl series (maximum catch rate = 3064 kg km^{-2}).**

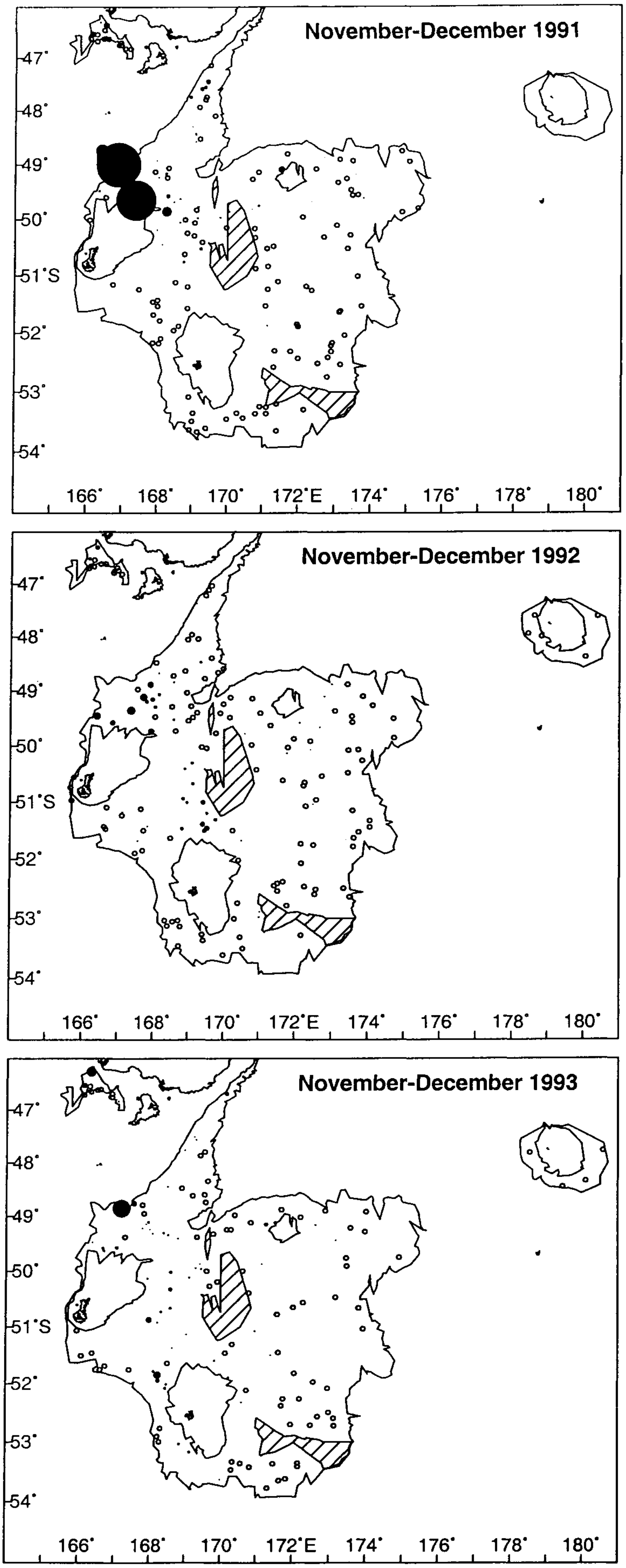


Figure 3k: **Distribution and catch rates of spiny dogfish in the summer trawl series (maximum catch rate = 2610 kg km^{-2}).**

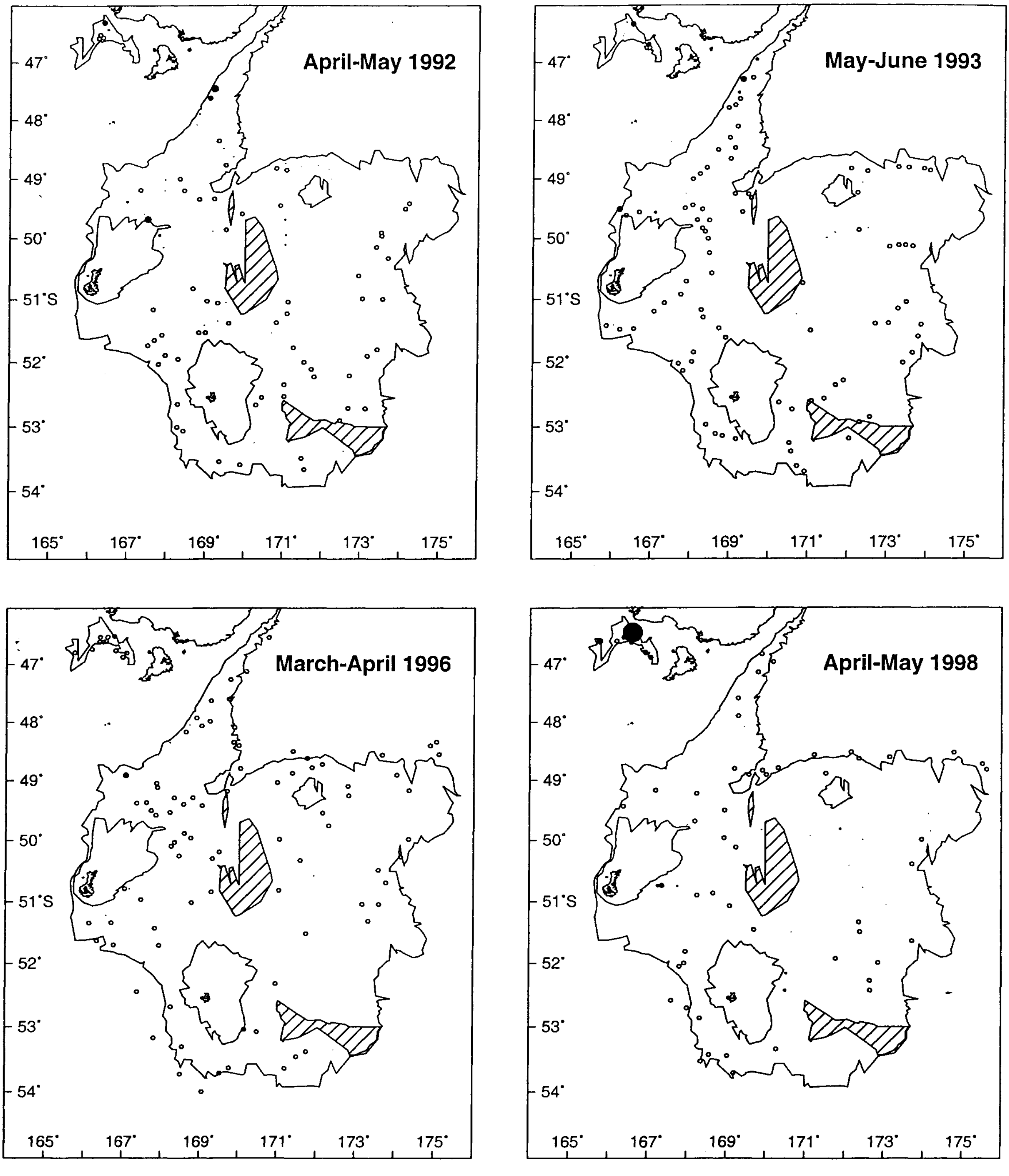


Figure 3k cntd: **Distribution and catch rates of spiny dogfish in the autumn trawl series (maximum catch rate = 2610 kg km^{-2}).**

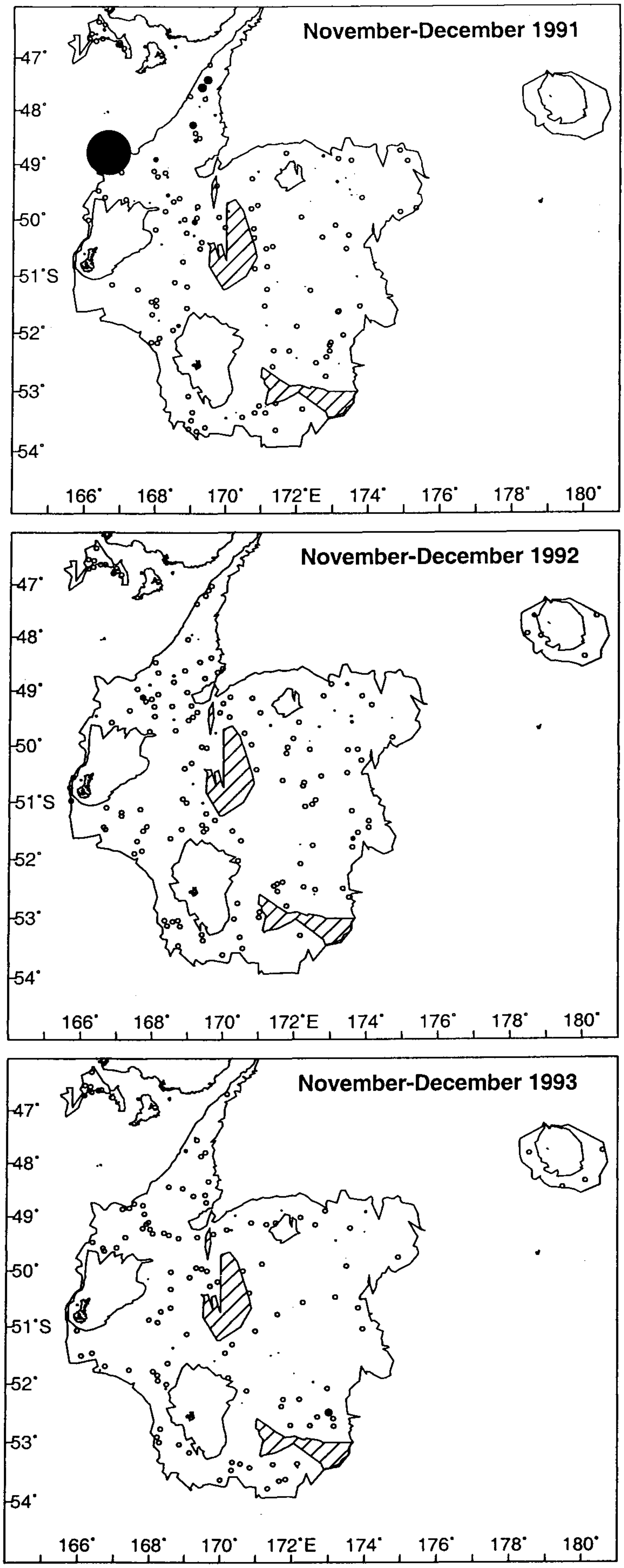


Figure 3l: **Distribution and catch rates of white warehou in the summer trawl series (maximum catch rate = 1240 kg km^{-2}).**

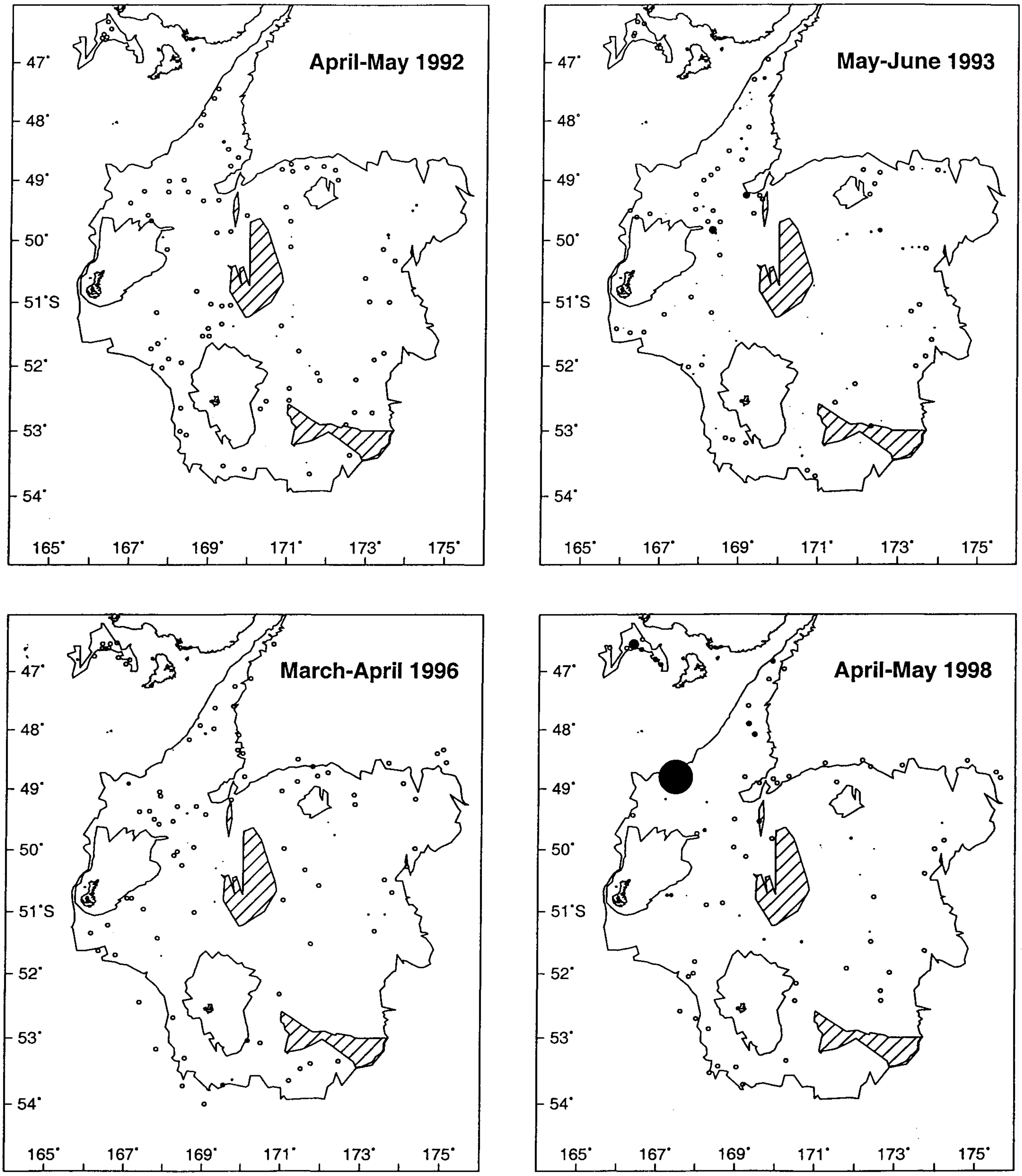


Figure 31 cntd: **Distribution and catch rates of white warehou in the autumn trawl series (maximum catch rate = 1240 kg km^{-2}).**

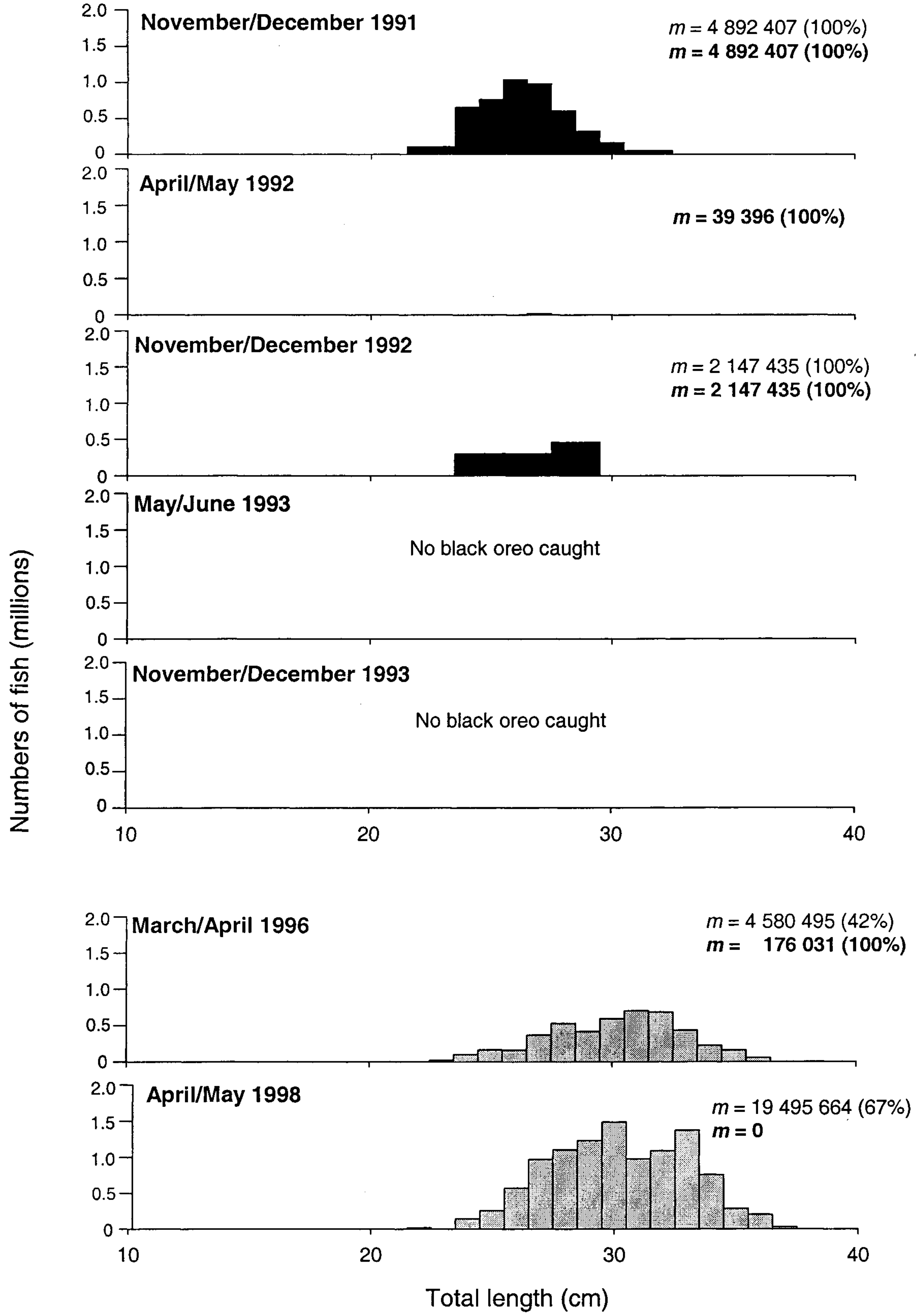


Figure 4a : **Scaled length frequencies for male black oreo from Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all stations as grey bars. N values above are for all strata and below (in bold) for core strata.**

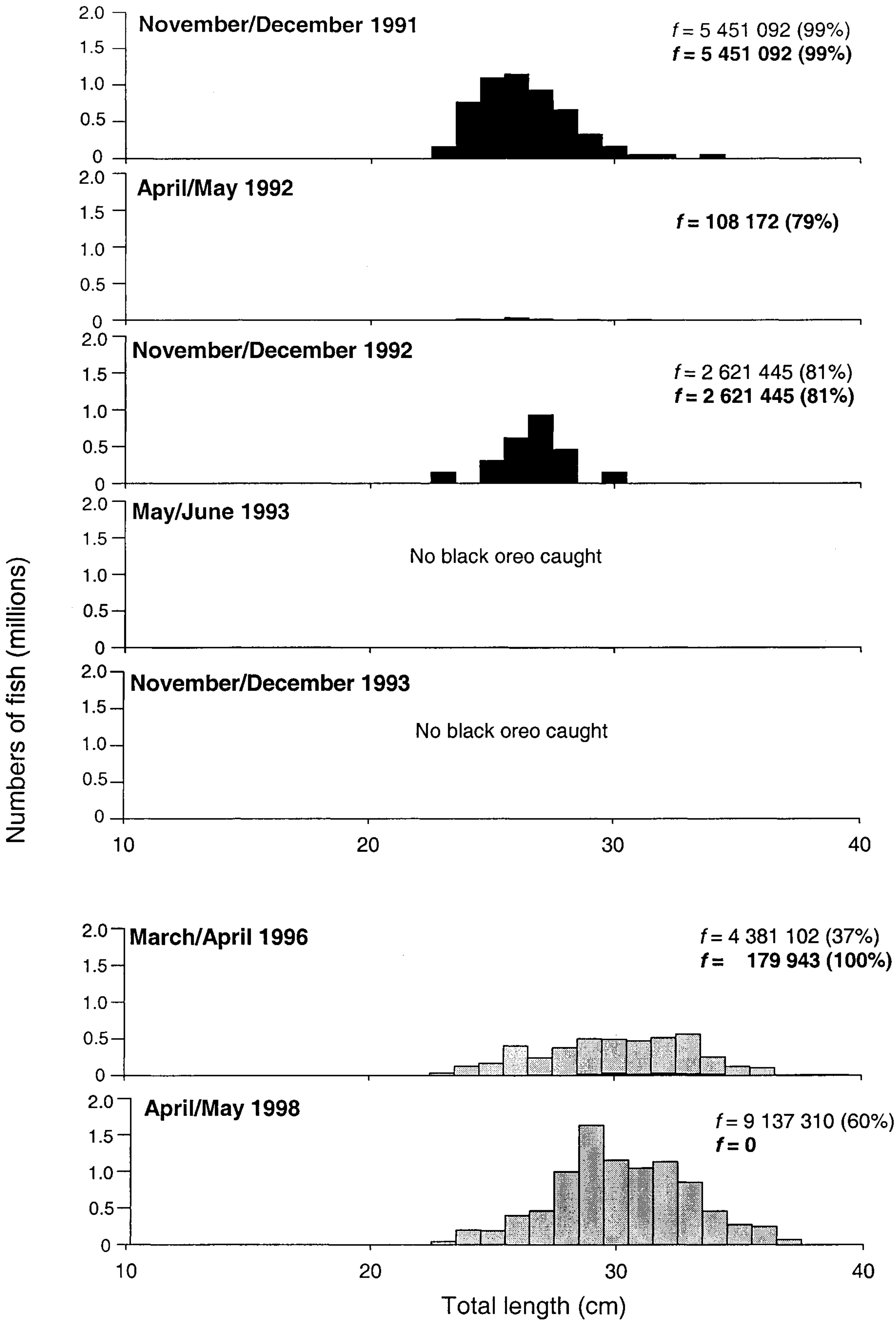


Figure 4a cntd **: Scaled length frequencies for female black oreo from Sub-Antarctic *Tangaroa* trawl surveys.**

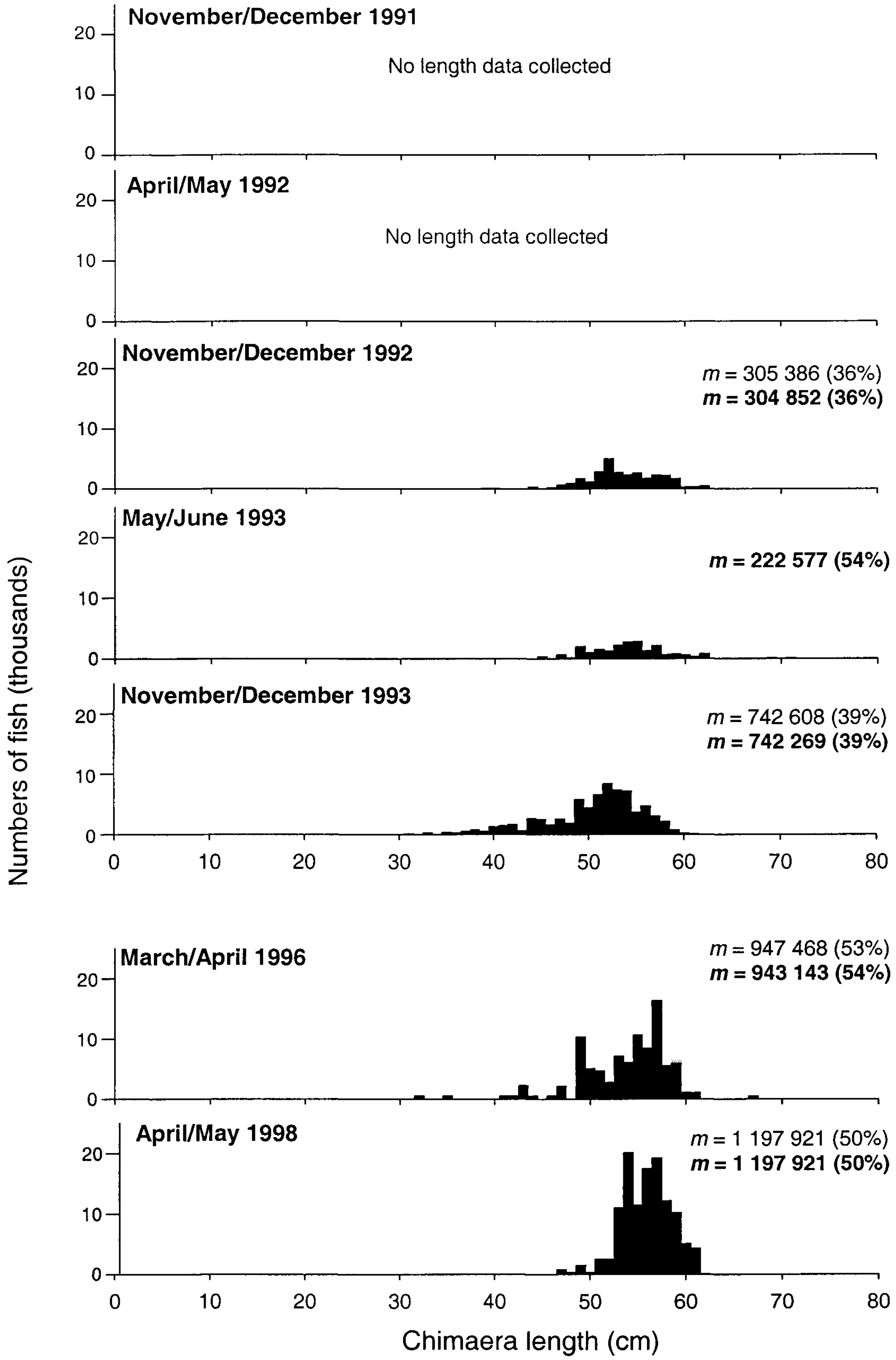


Figure 4b: **Scaled length frequencies for male dark ghost shark from Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all stations as grey bars. N values above are for all strata and below (in bold) for core strata.**

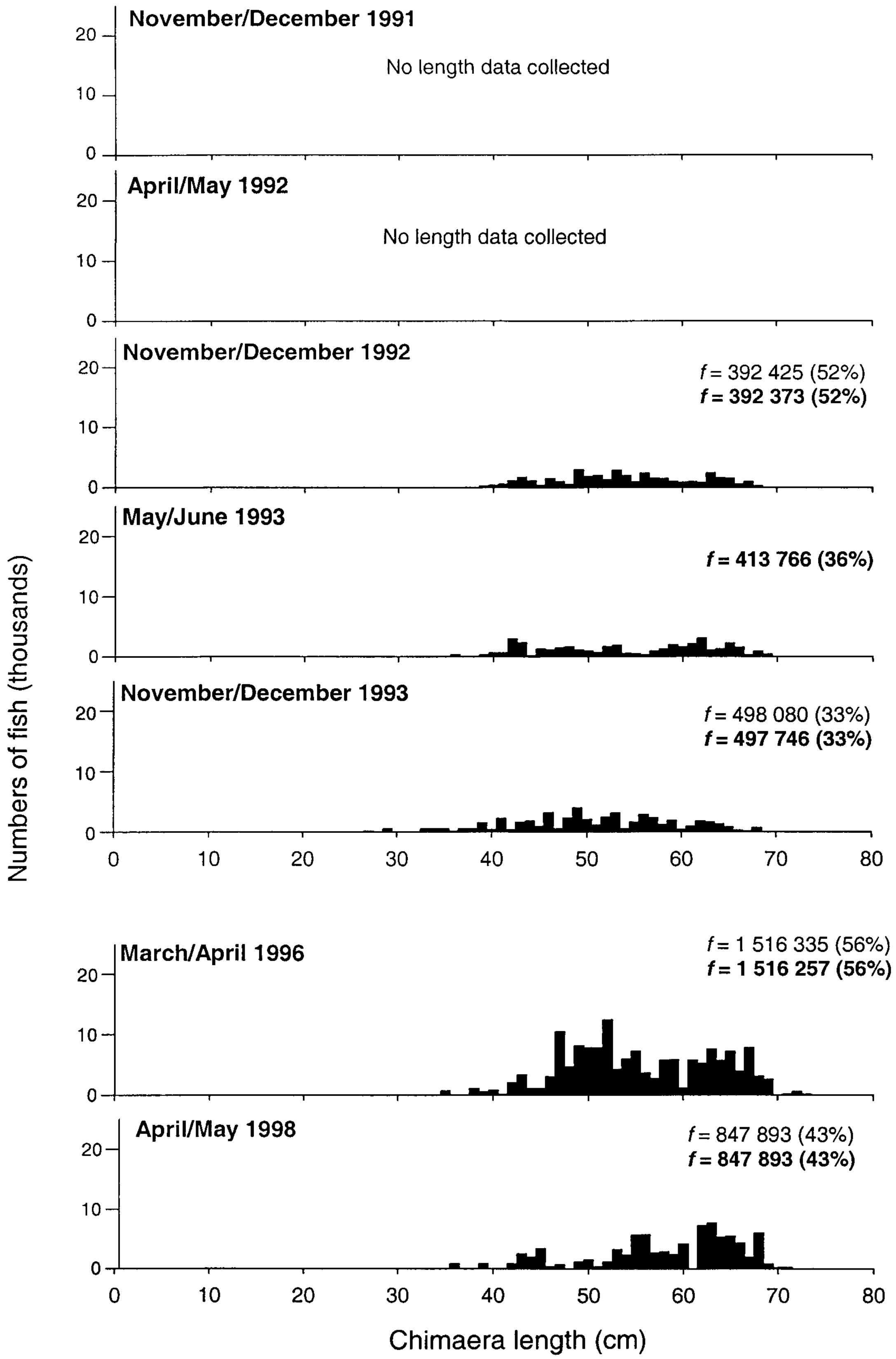


Figure 4b cntd: **Scaled length frequencies for female dark ghost shark from Sub-Antarctic *Tangaroa* trawl surveys.**

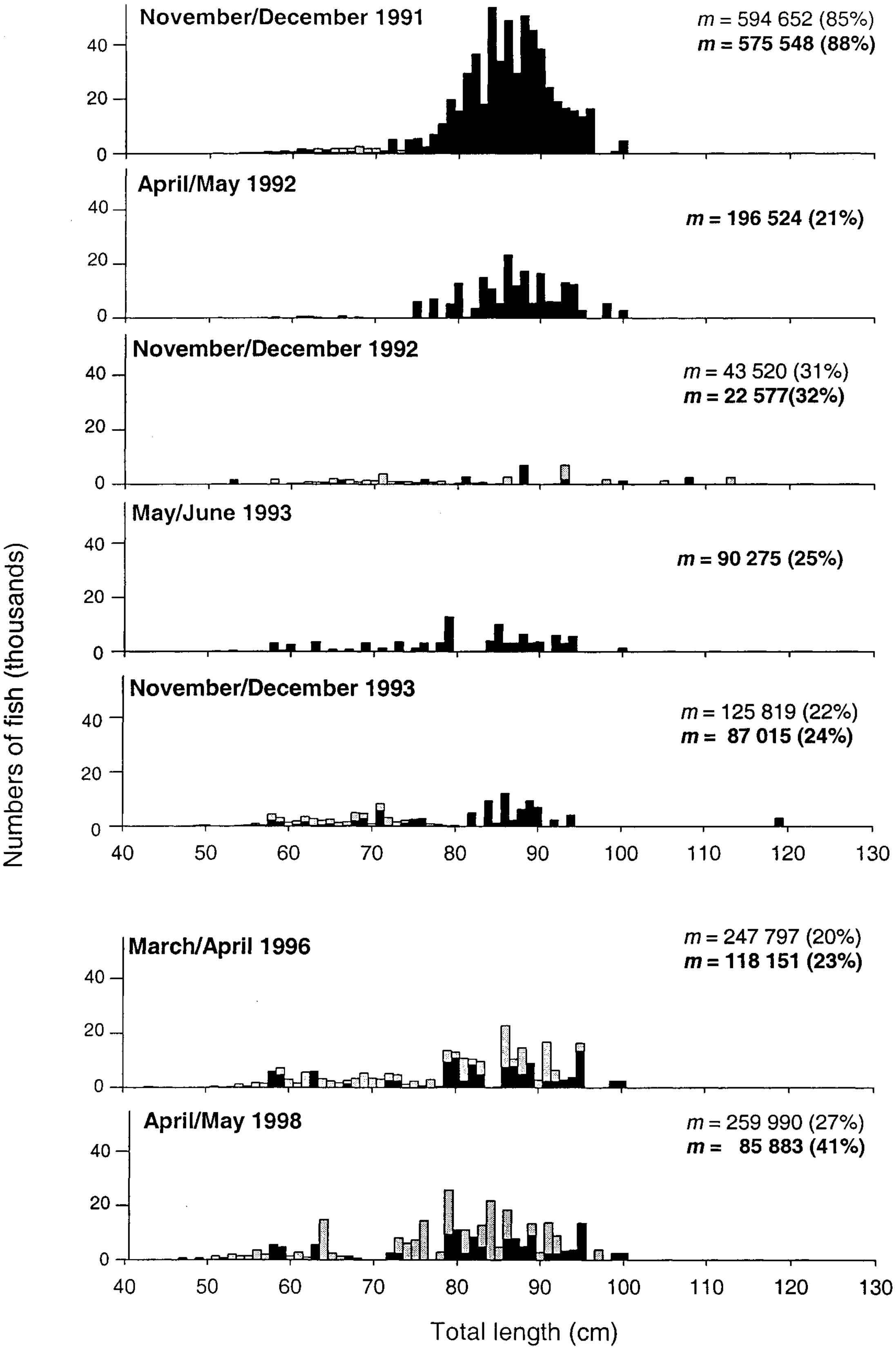


Figure 4c : **Scaled length frequencies for male hake from Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all stations as grey bars. N values above are for all strata and below (in bold) for core strata.**

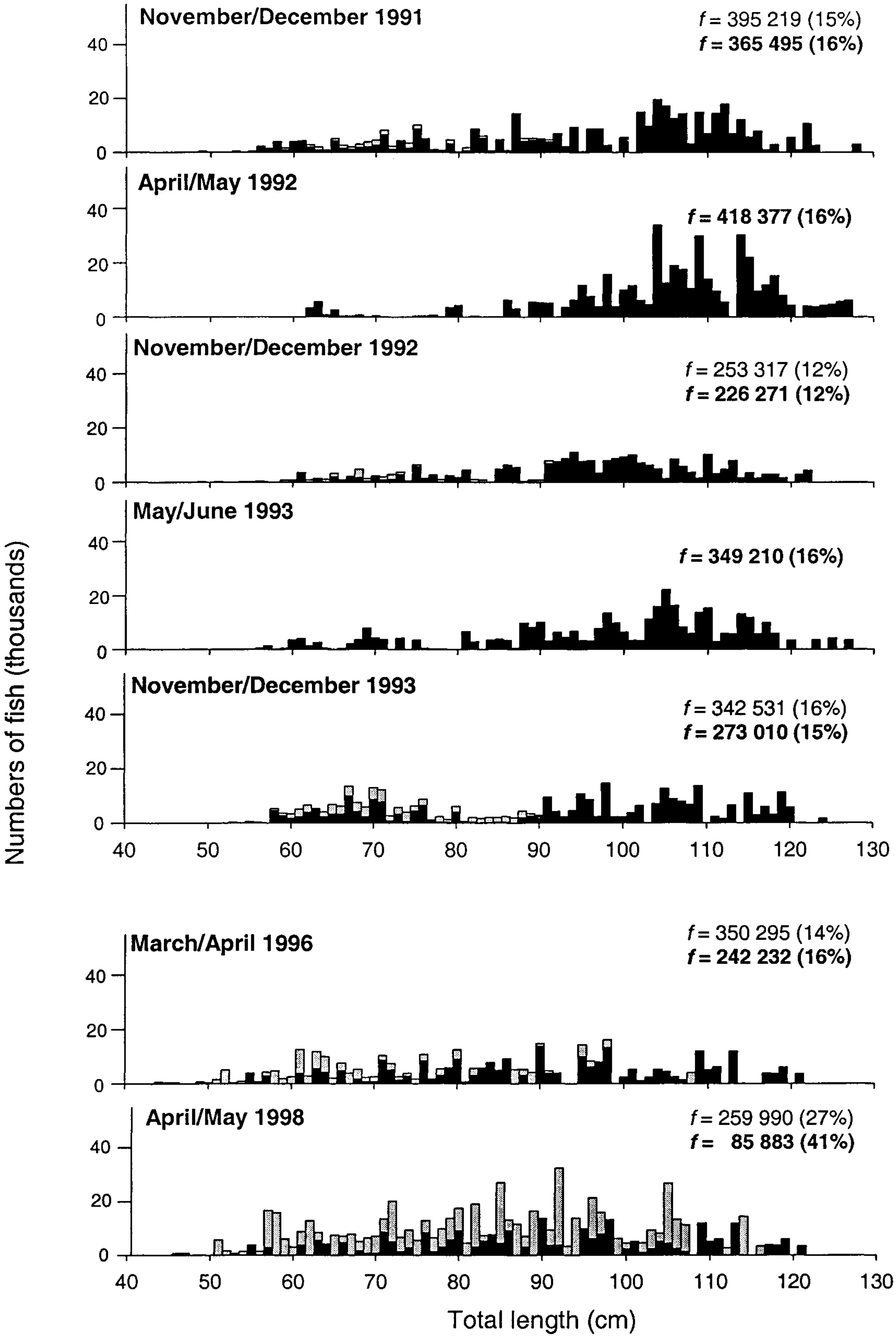


Figure 4c cntd : **Scaled length frequencies for female hake from Sub-Antarctic *Tangaroa* trawl surveys.**

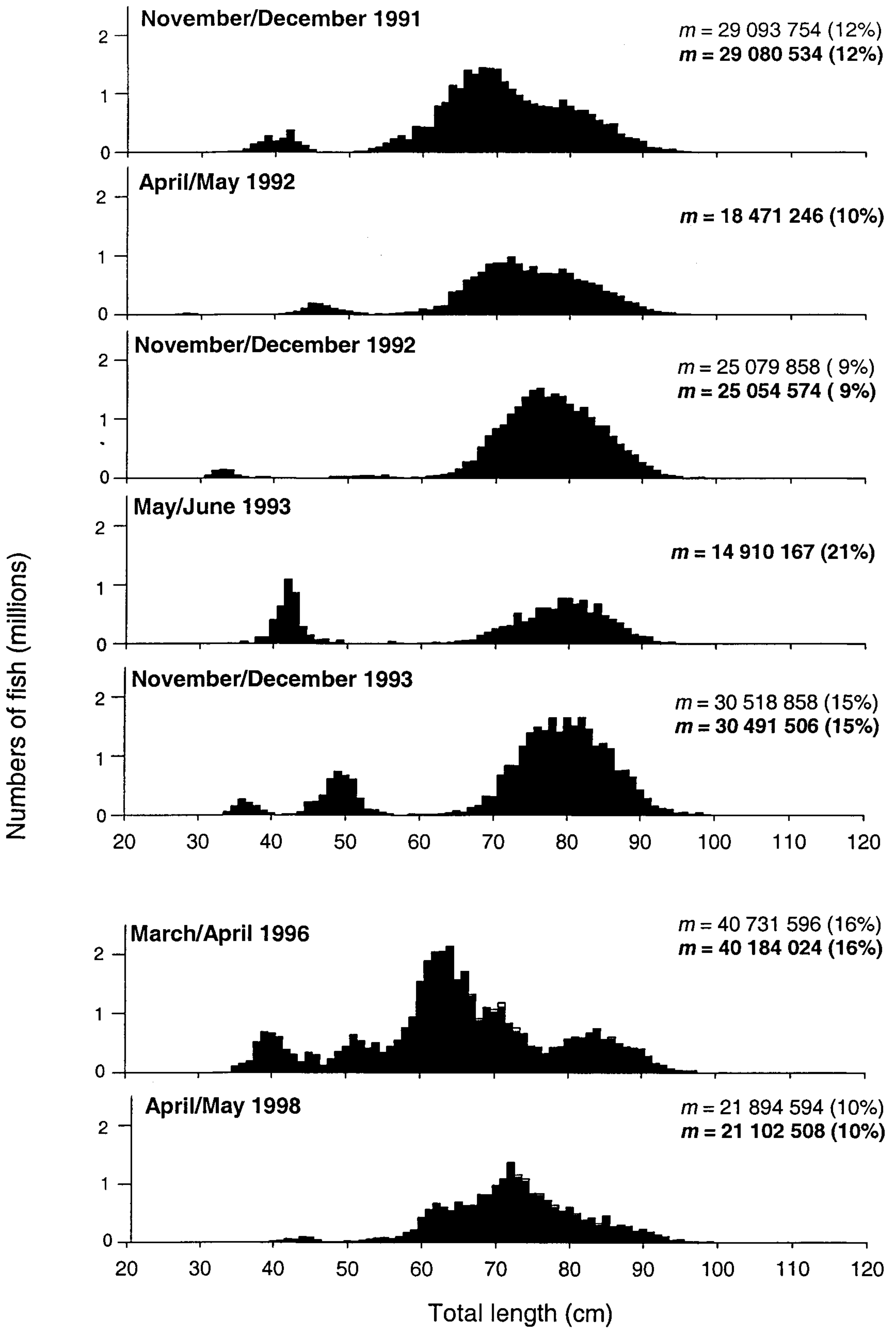


Figure 4d: **Scaled length frequencies for male hoki from Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all stations as grey bars. N values above are for all strata and below (in bold) for core strata.**

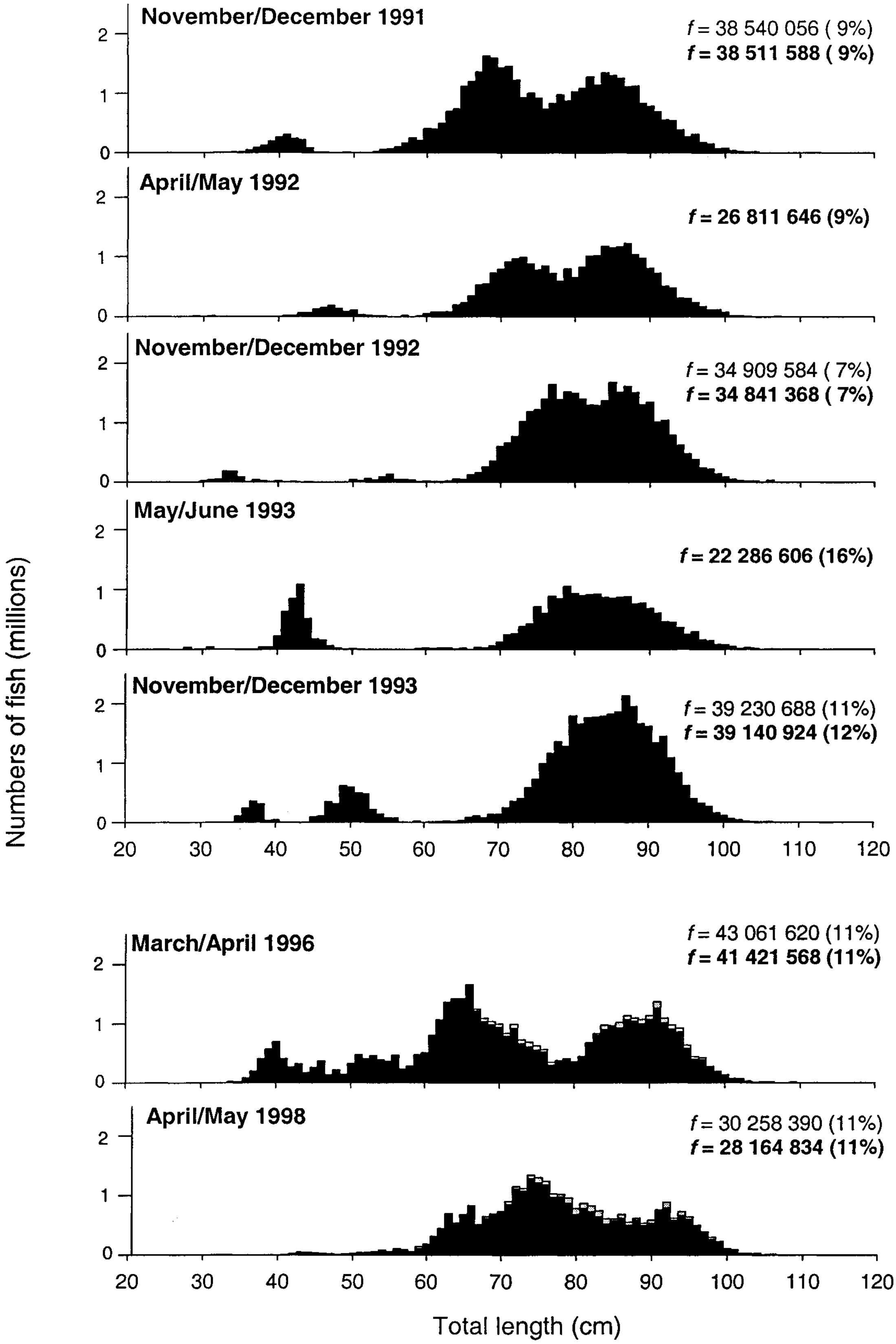


Figure 4d cntd : **Scaled length frequencies for female hoki from Sub-Antarctic *Tangaroa* trawl surveys.**

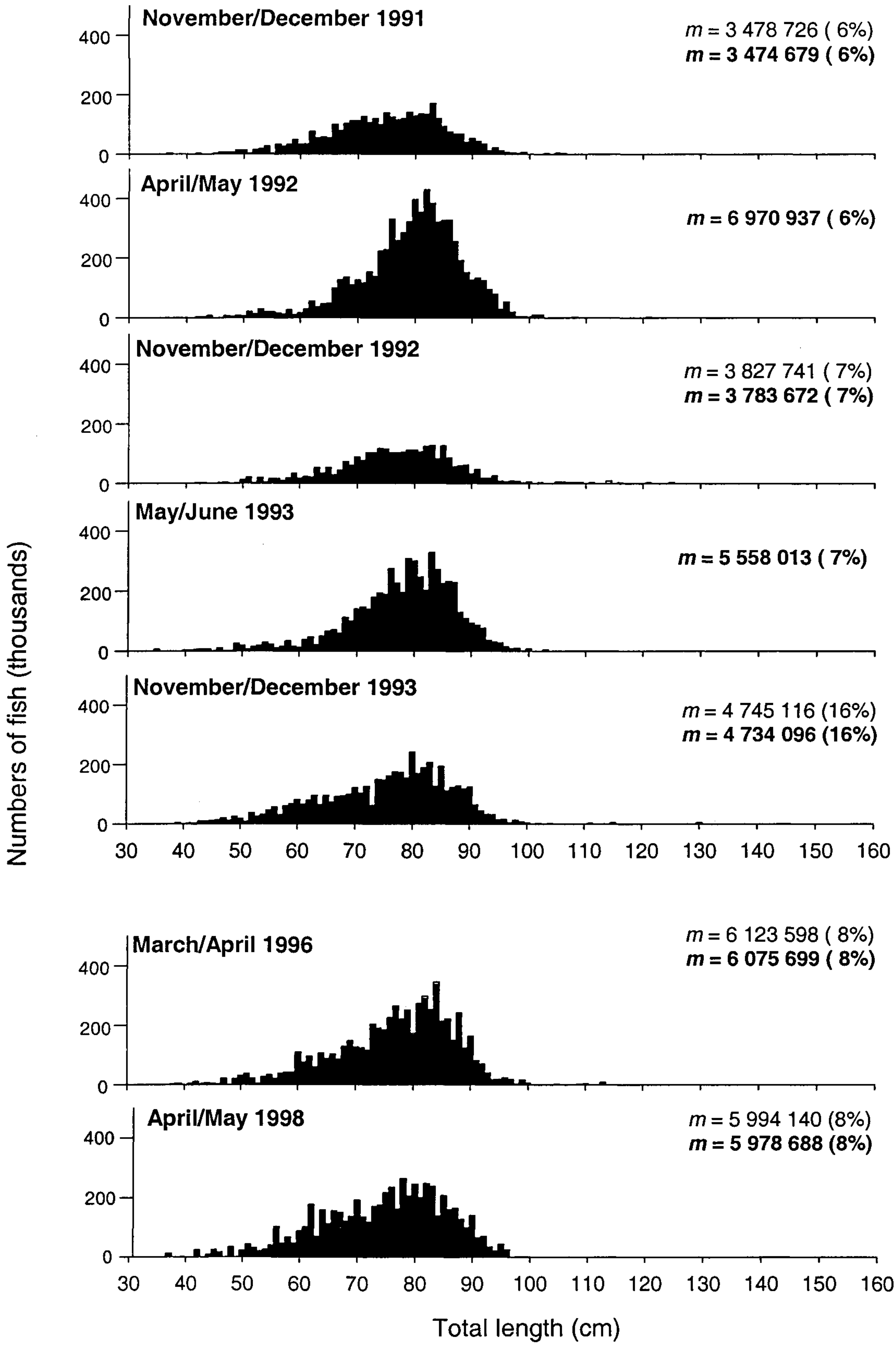


Figure 4e: **Scaled length frequencies for male ling from Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all stations as grey bars. N values above are for all strata and below (in bold) for core strata.**

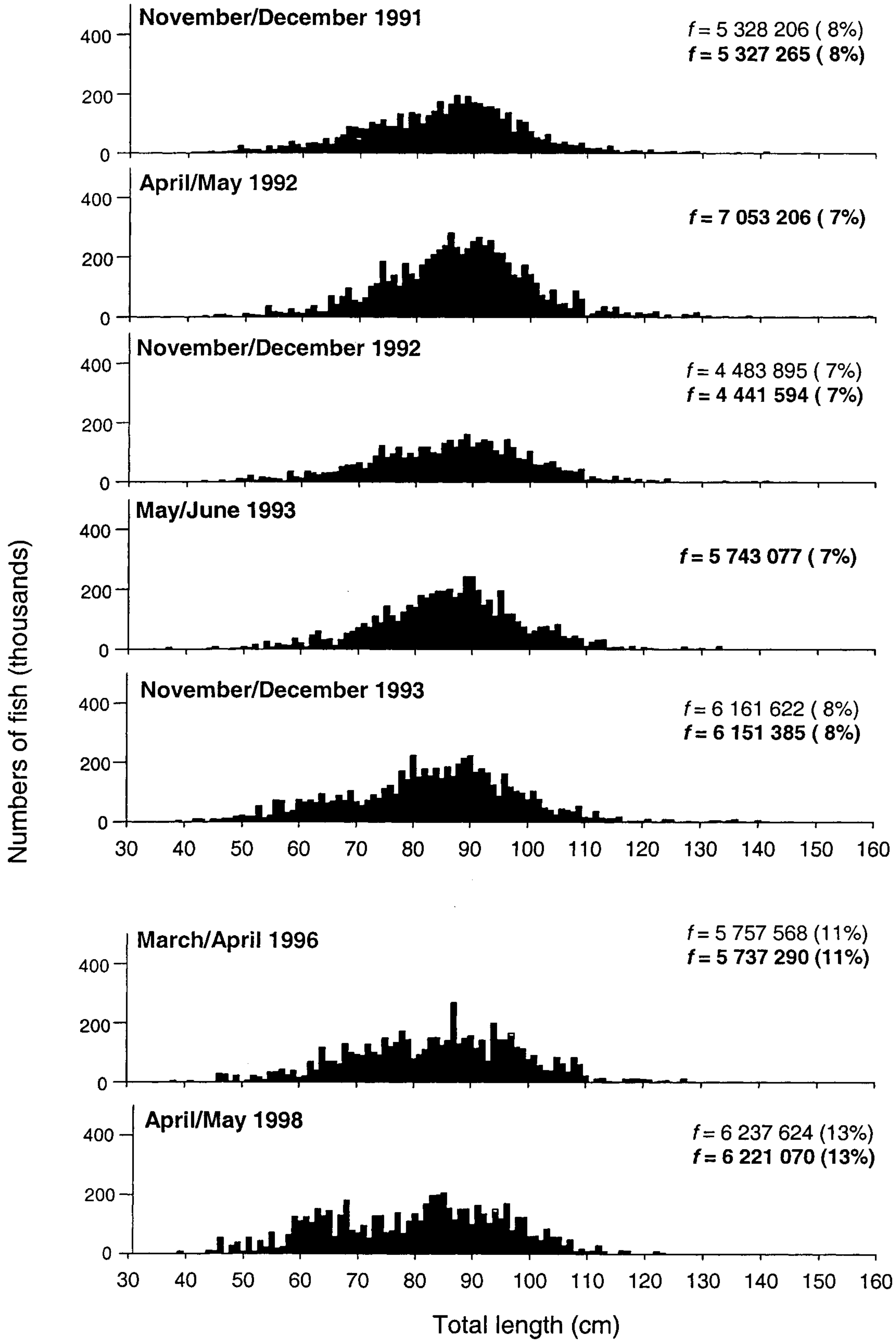


Figure 4e cntd **: Scaled length frequencies for female ling from Sub-Antarctic *Tangaroa* trawl surveys.**

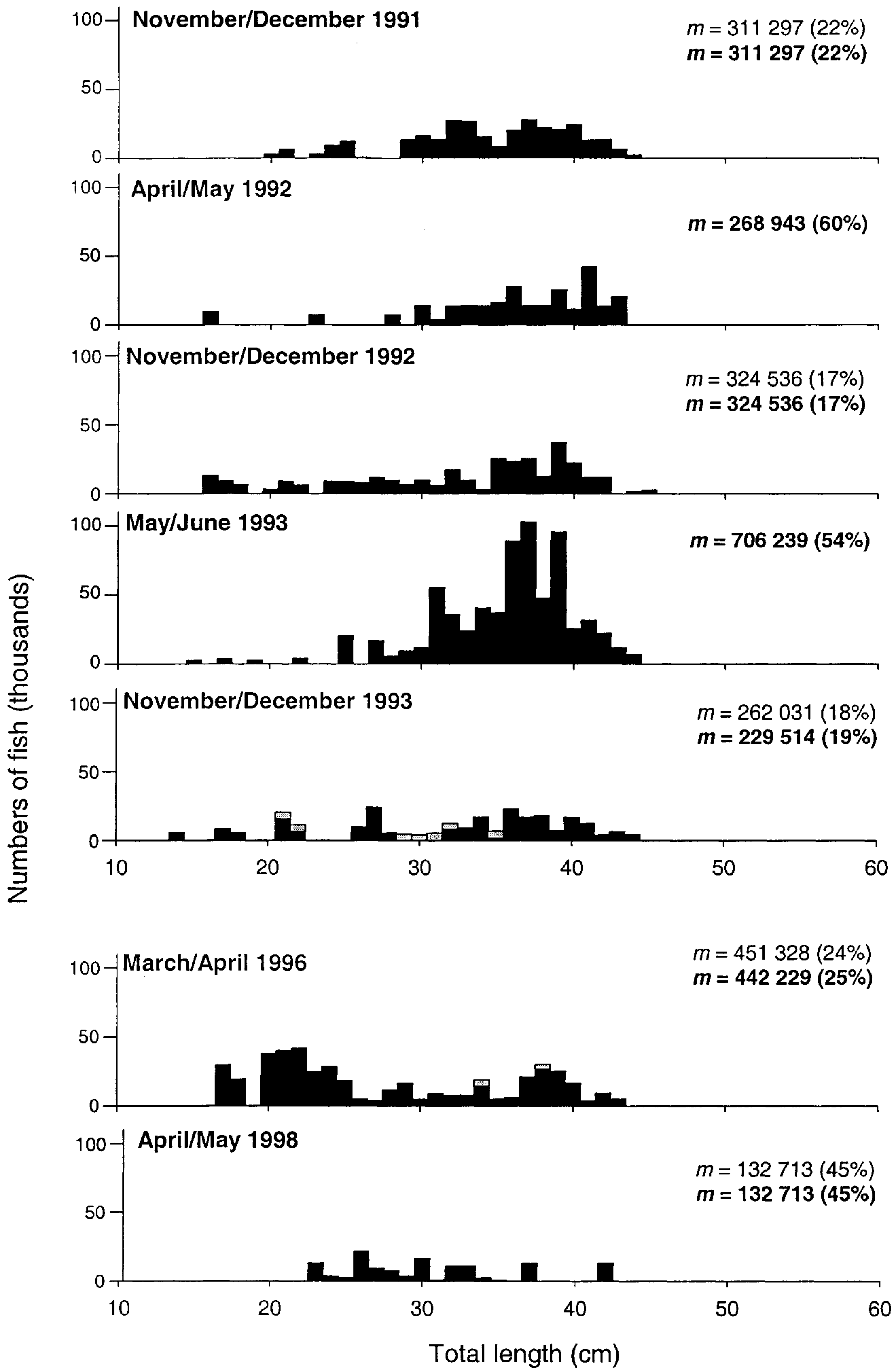


Figure 4f : **Scaled length frequencies for male lookdown dory from Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all stations as grey bars. N values are for all strata and below (in bold) for core strata.**

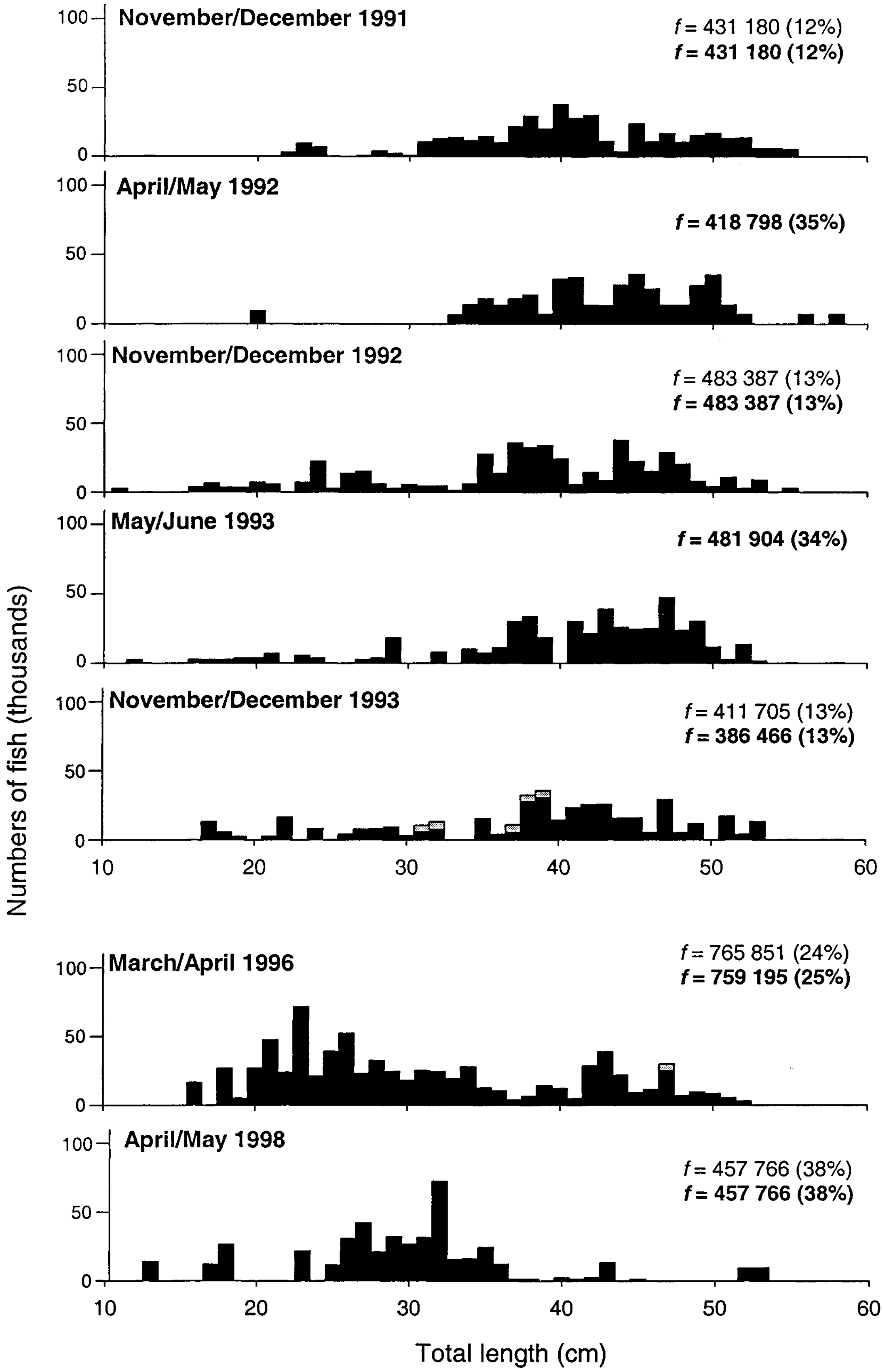


Figure 4f cntd : **Scaled length frequencies for female lookdown dory from Sub-Antarctic *Tangaroa* trawl surveys.**

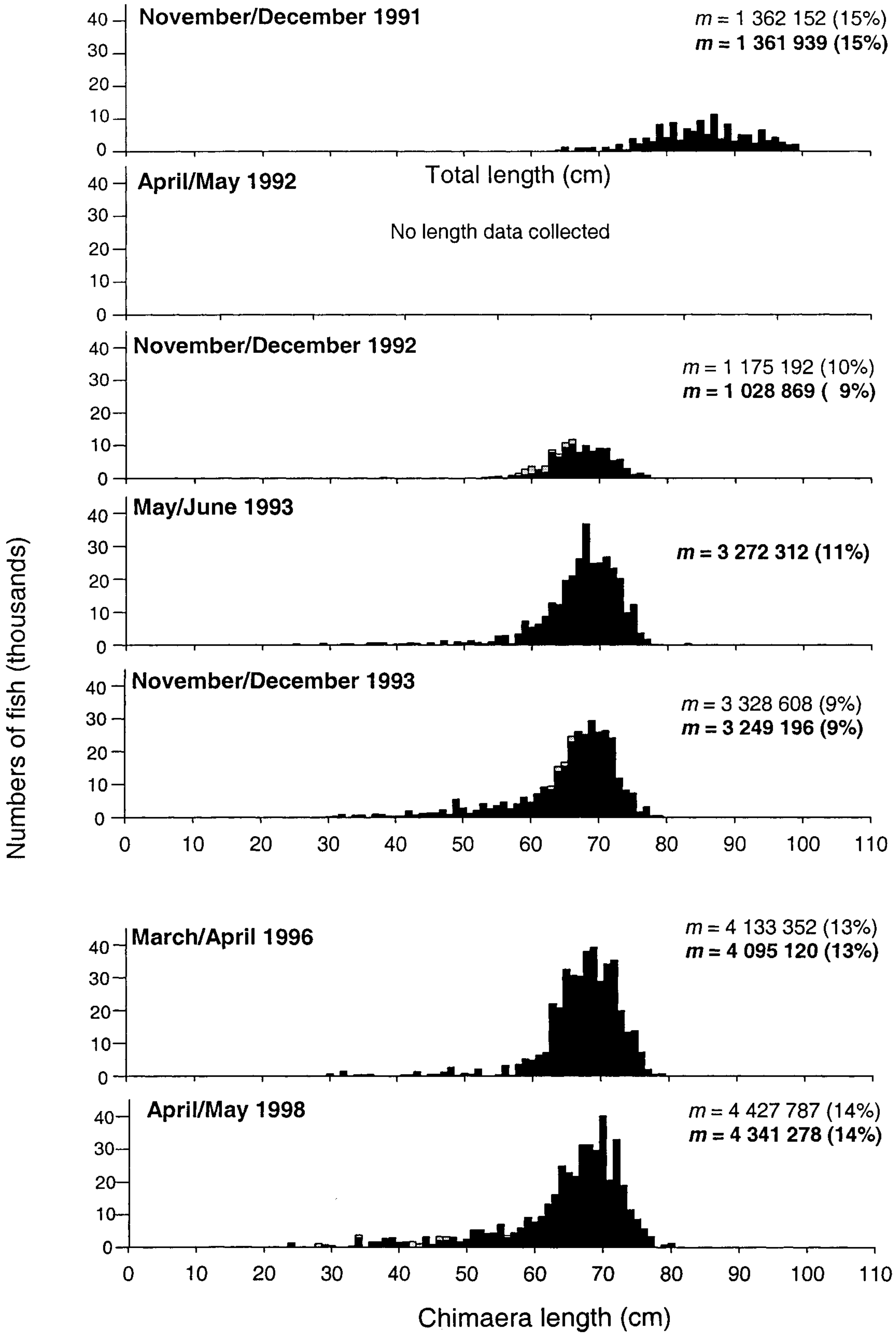


Figure 4g: **Scaled length frequencies for male pale ghost shark from Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all stations as grey bars. N values above are for all strata and below (in bold) for core strata.**

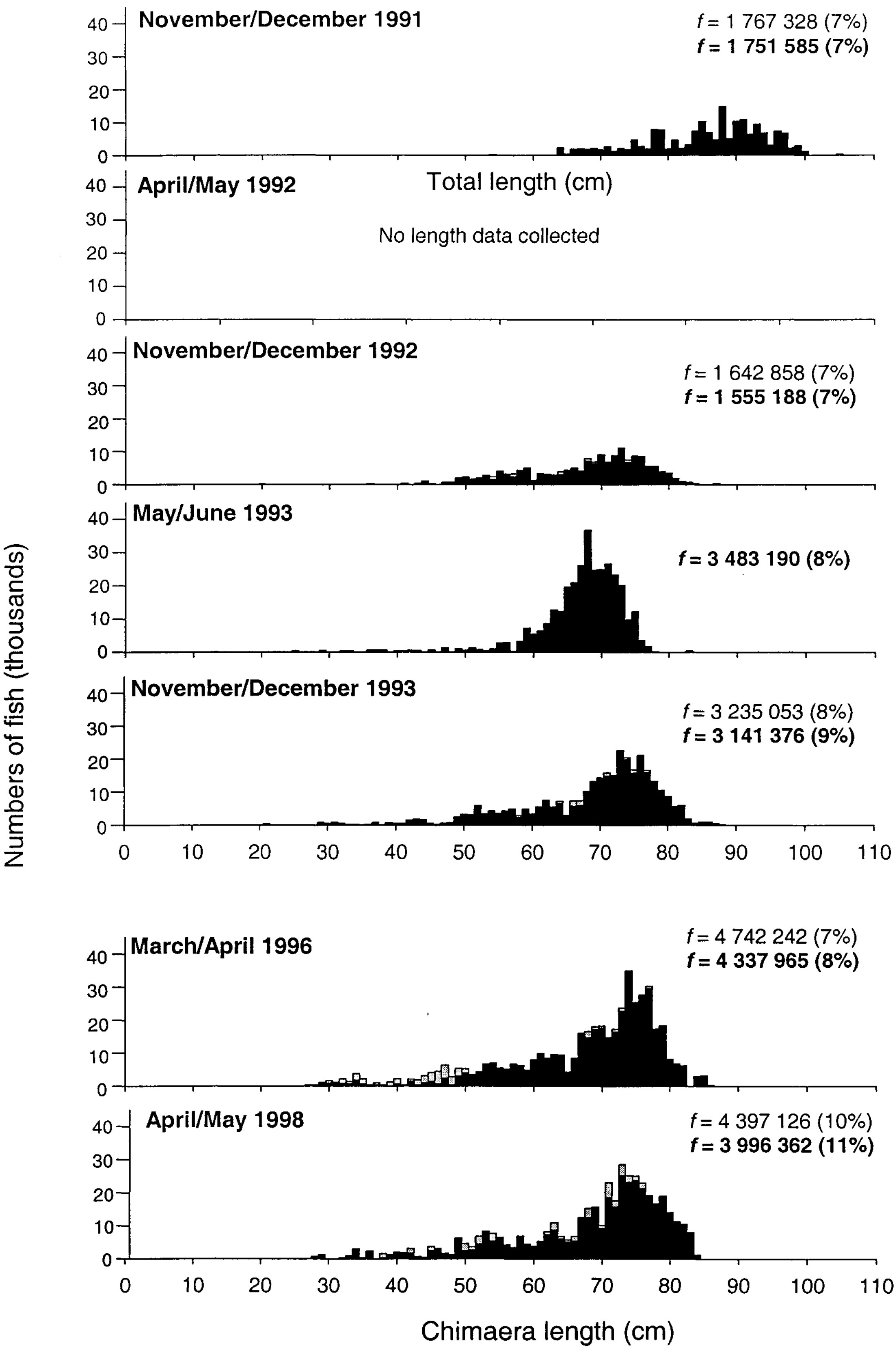


Figure 4g cntd: **Scaled length frequencies for female pale ghost shark from Sub-Antarctic *Tangaroa* trawl surveys.**

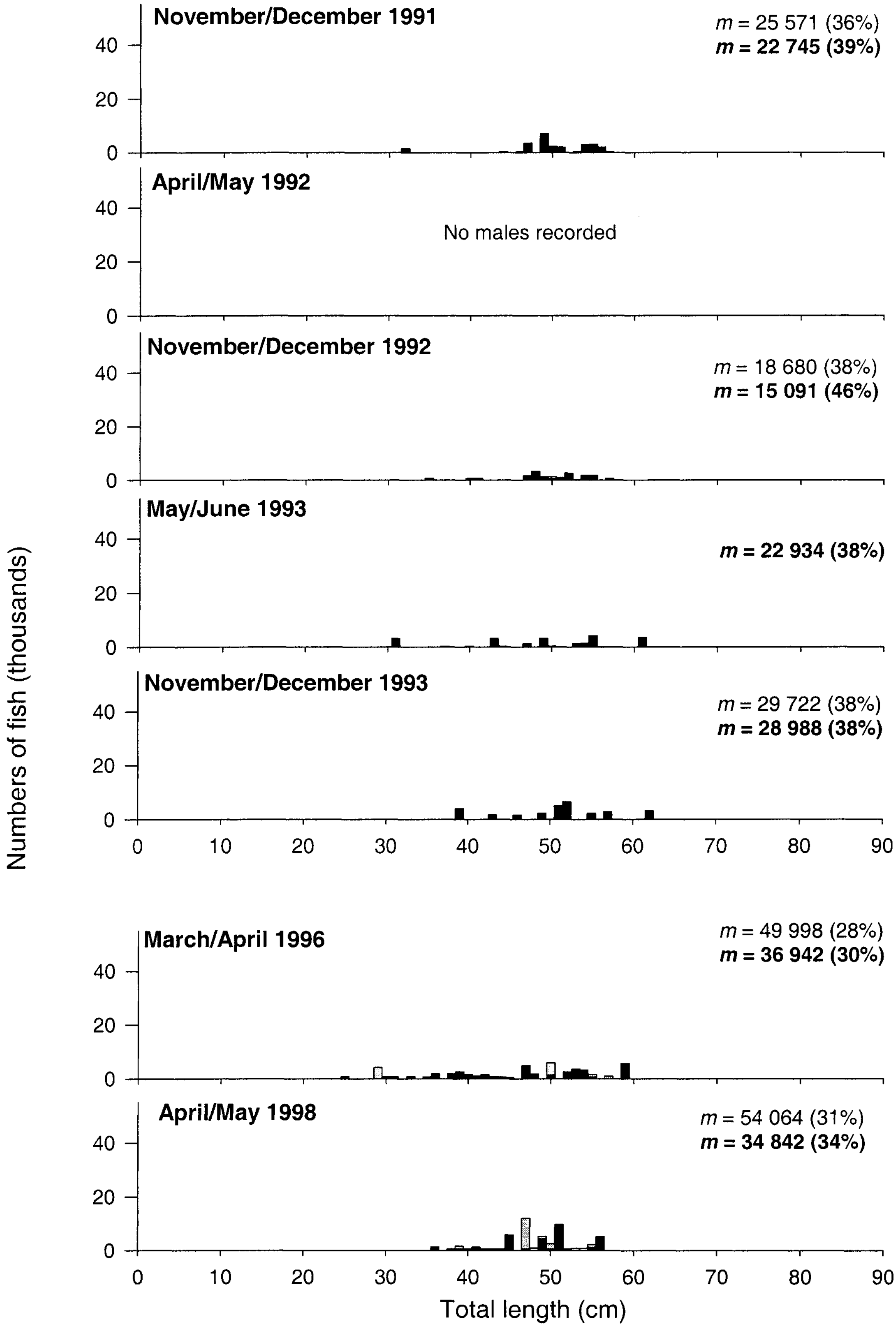


Figure 4h : **Scaled length frequencies for male ribaldo from Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all stations as grey bars. N values above are for all strata and below (in bold) for core strata.**

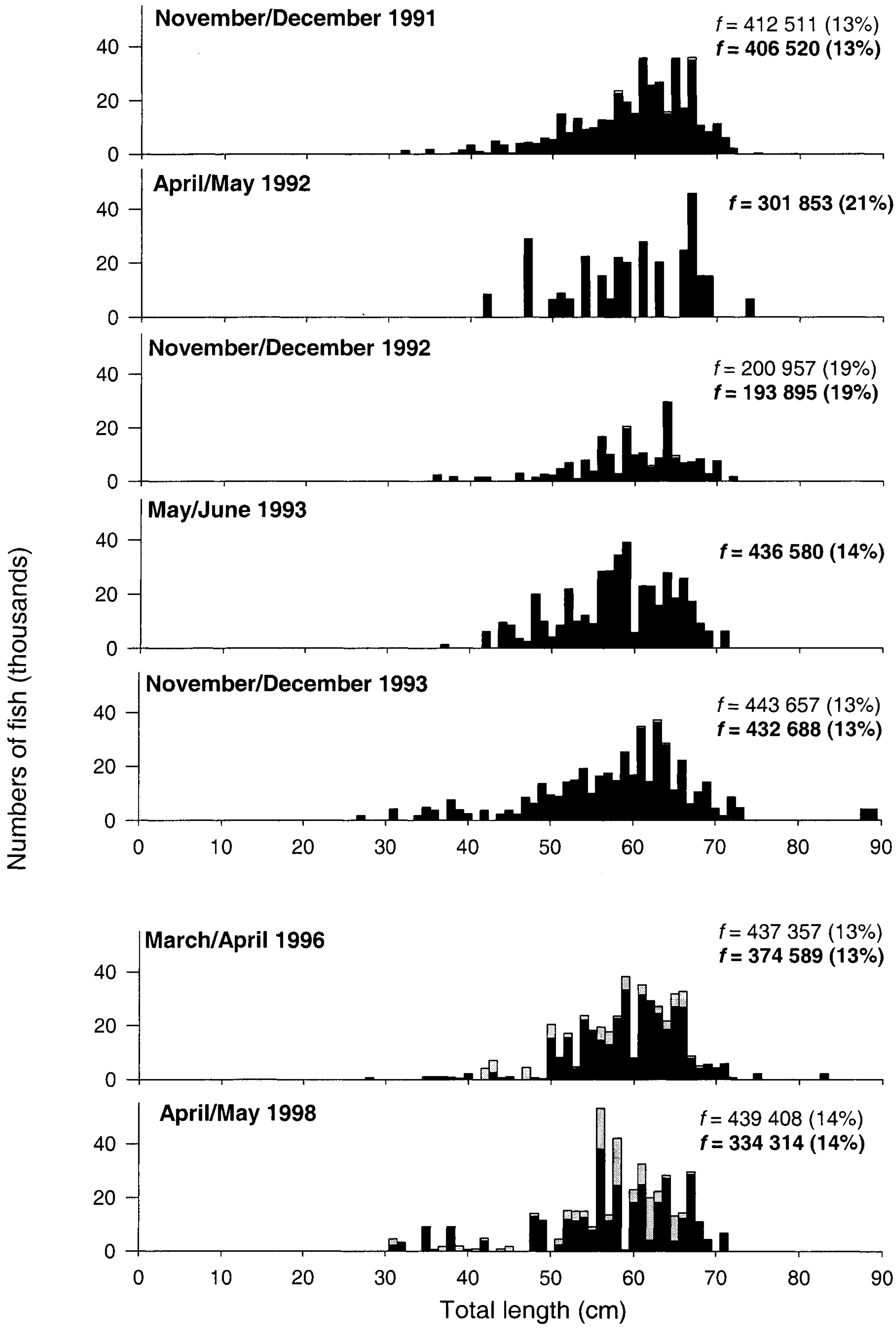


Figure 4h cntd : **Scaled length frequencies for female ribaldo from Sub-Antarctic *Tangaroa* trawl surveys.**

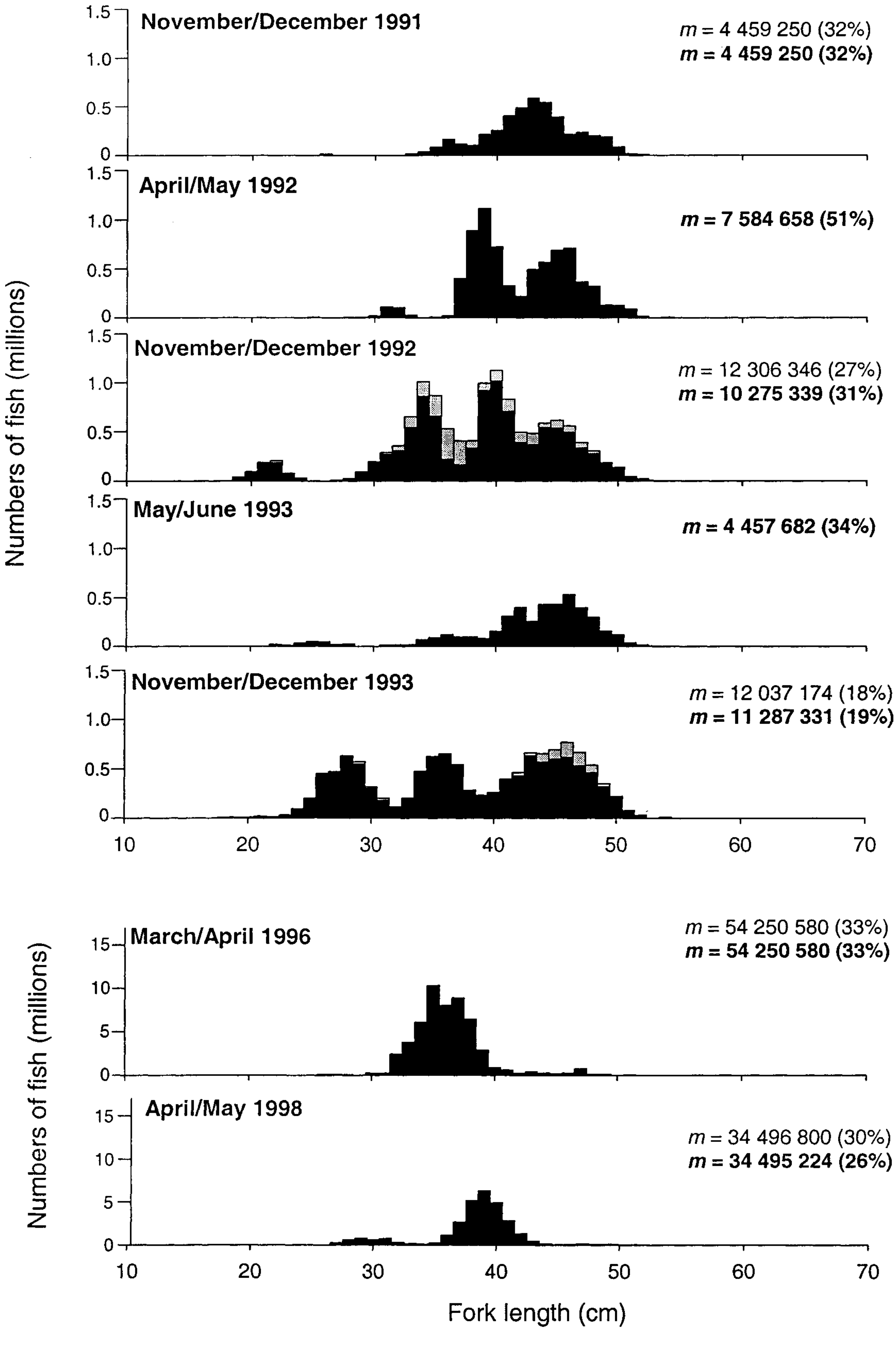


Figure 4i : **Scaled length frequencies for male southern blue whiting from Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all stations as grey bars. N values above are for all strata and below (in bold) for core strata.**

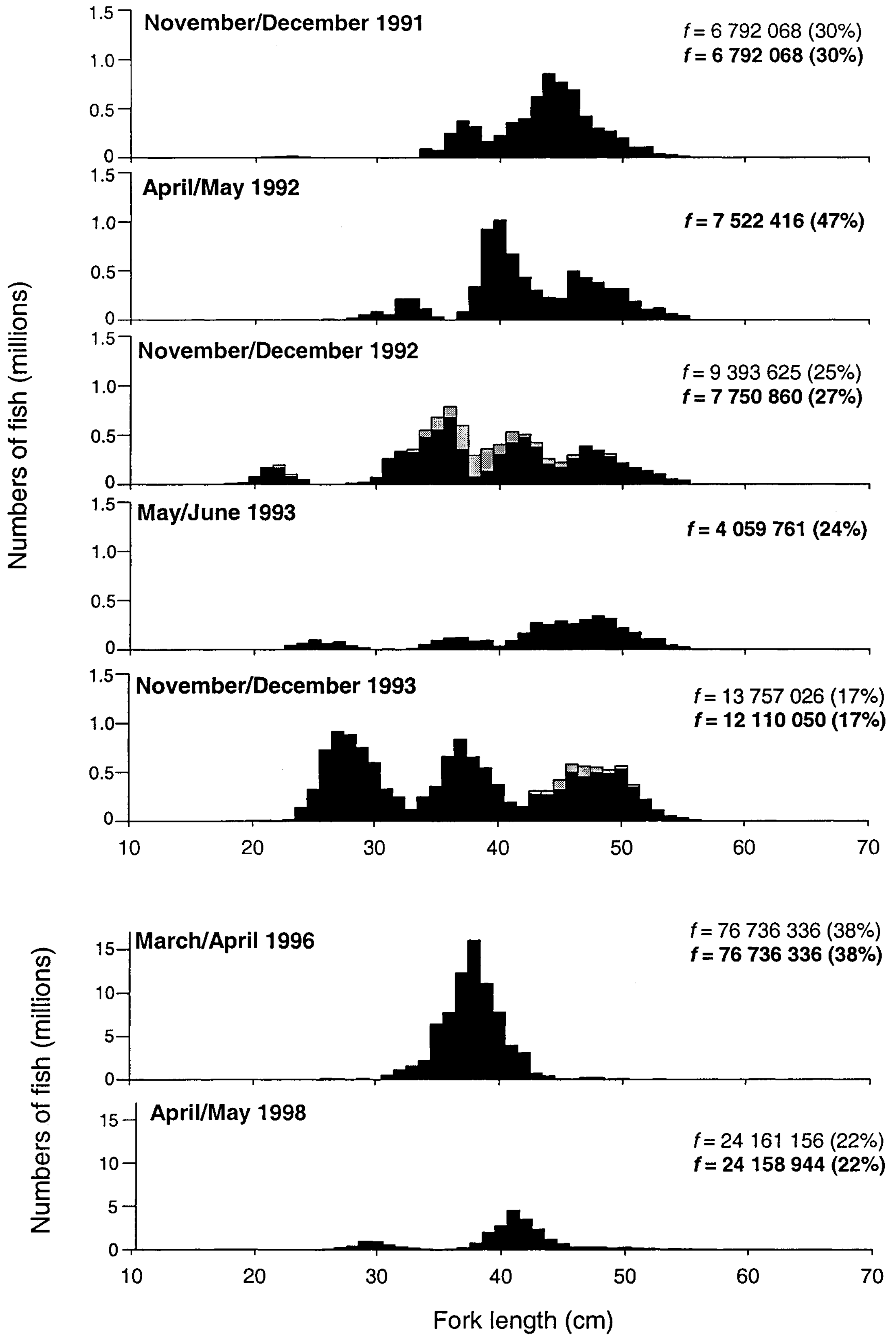


Figure 4i cntd : **Scaled length frequencies for female southern blue whiting from Sub-Antarctic *Tangaroa* trawl surveys.**

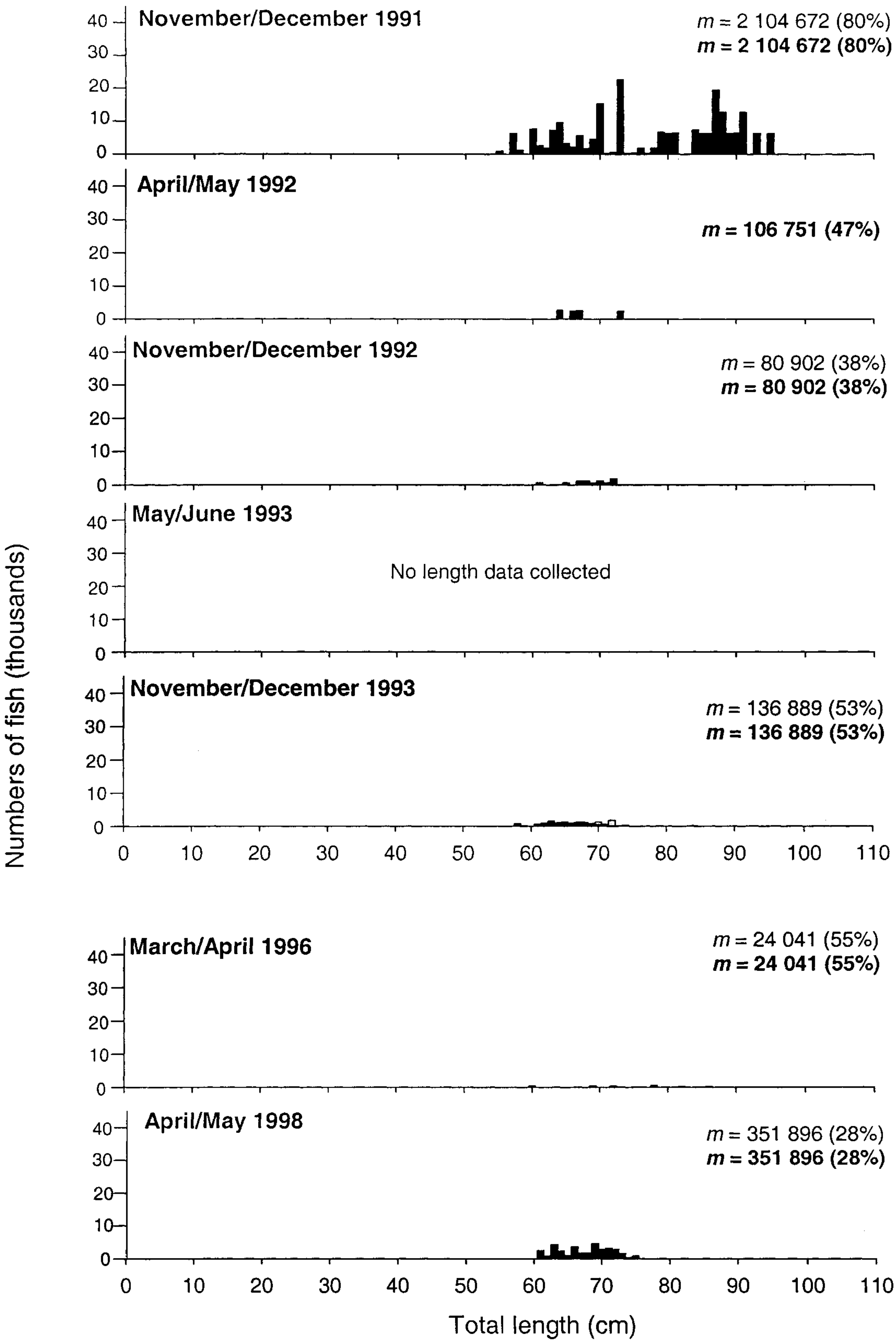


Figure 4j : **Scaled length frequencies for male spiny dogfish from Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all stations as grey bars. N values above are for all strata and below (in bold) for core strata.**

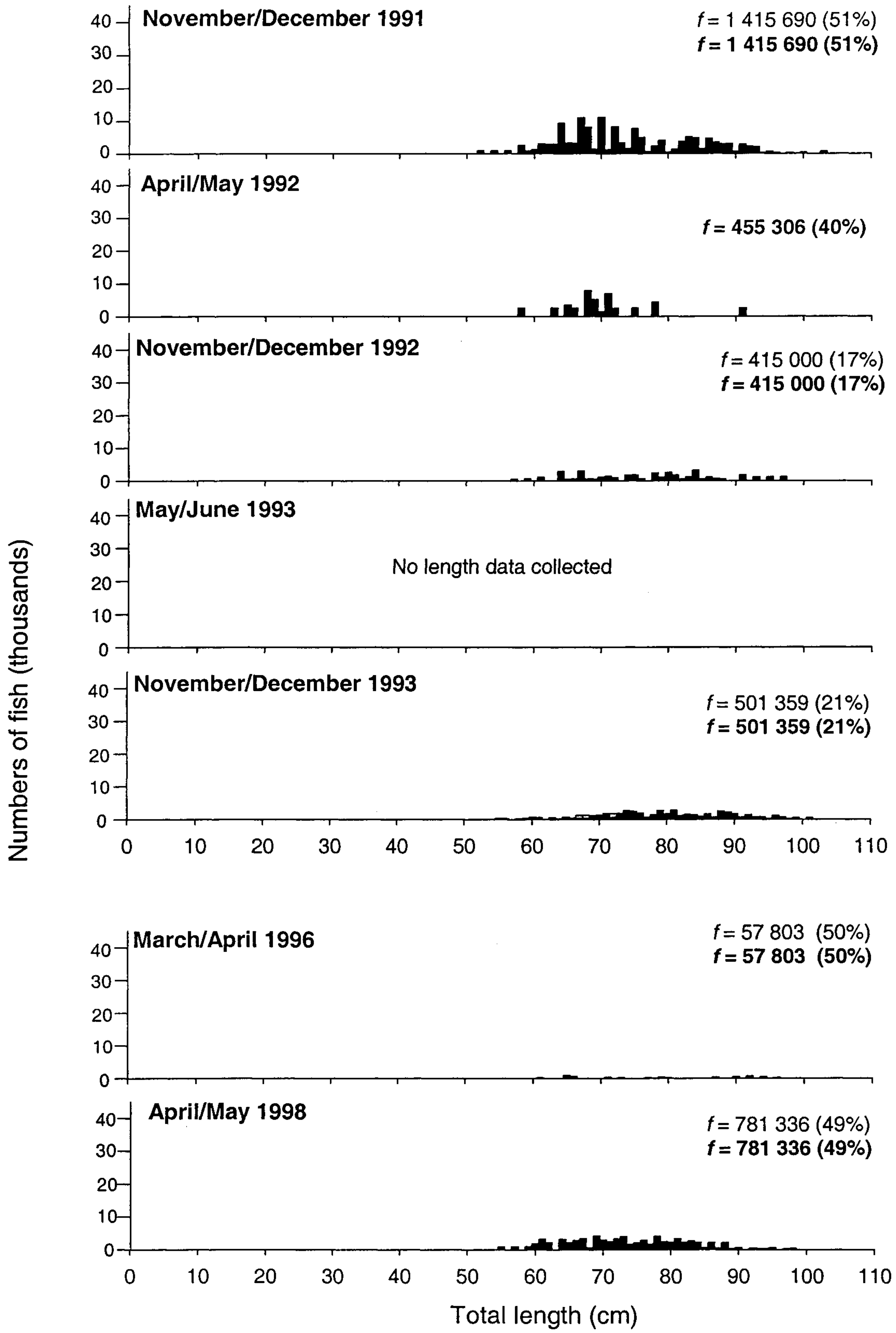


Figure 4j cntd **: Scaled length frequencies for female spiny dogfish from Sub-Antarctic *Tangaroa* trawl surveys.**

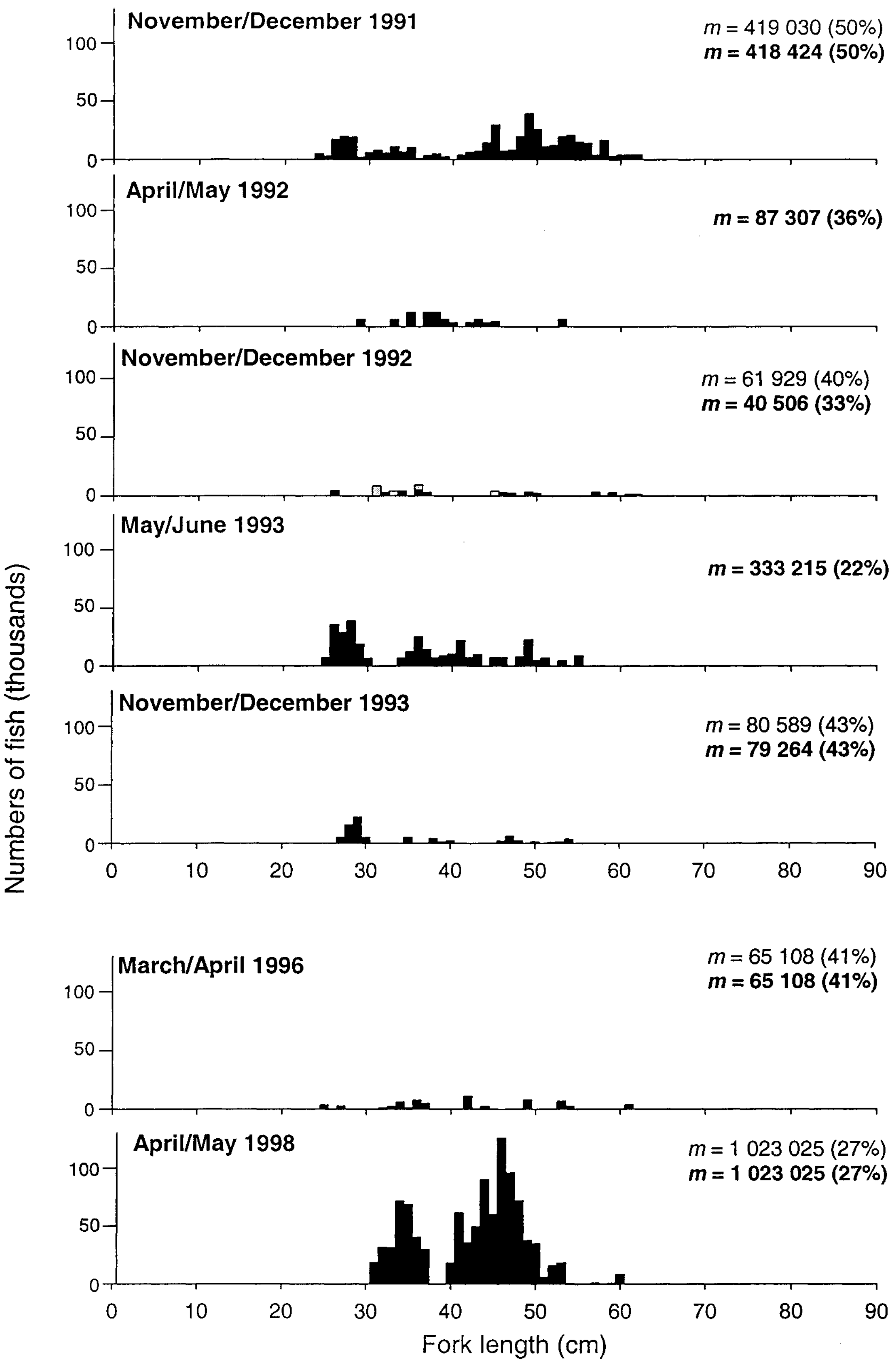


Figure 4k : **Scaled length frequencies for male white warehou from Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all stations as grey bars. N values above are for all strata and below (in bold) for core strata.**

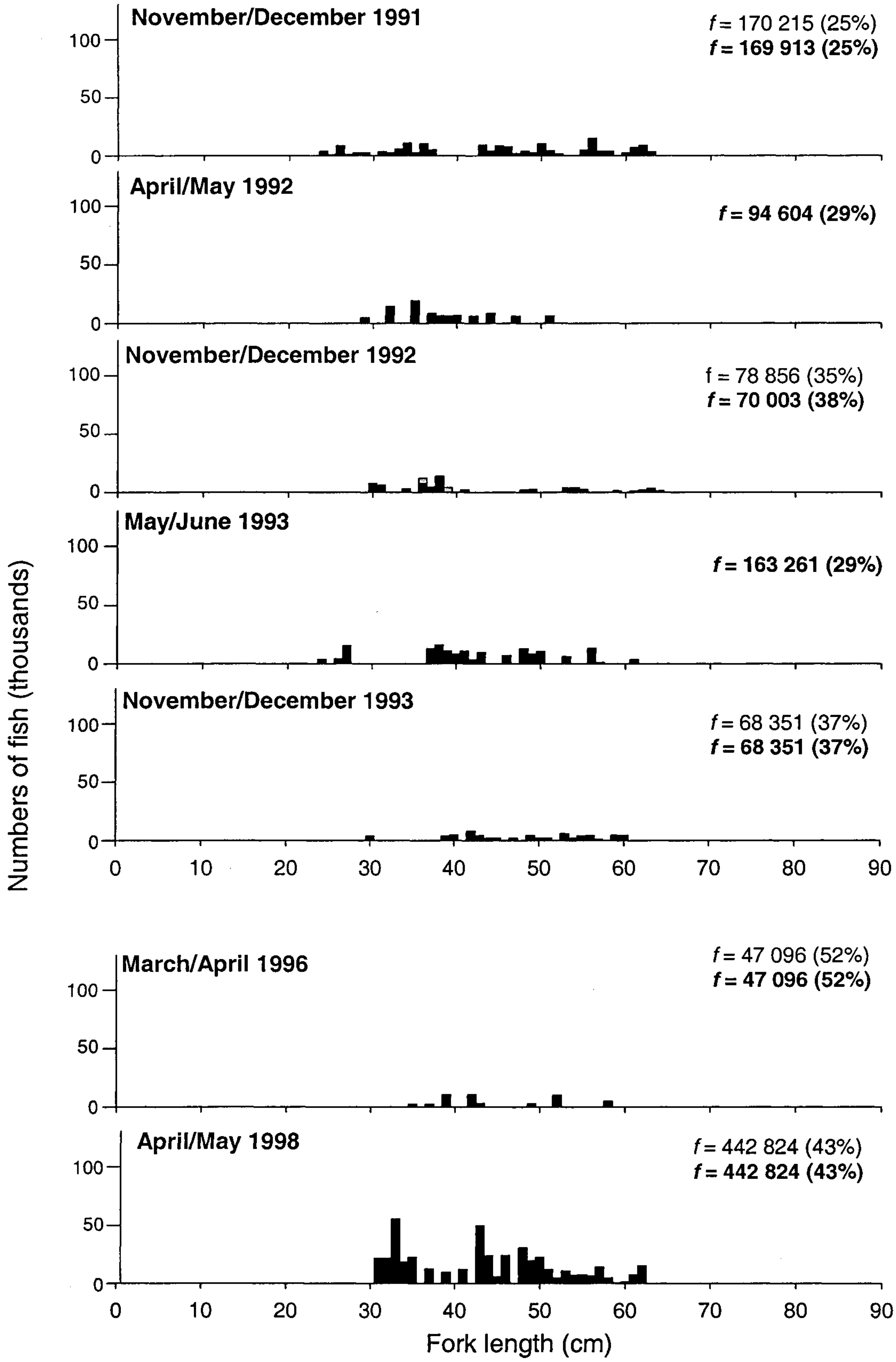


Figure 4k cntd : **Scaled length frequencies for female white warehou from Sub-Antarctic *Tangaroa* trawl surveys.**

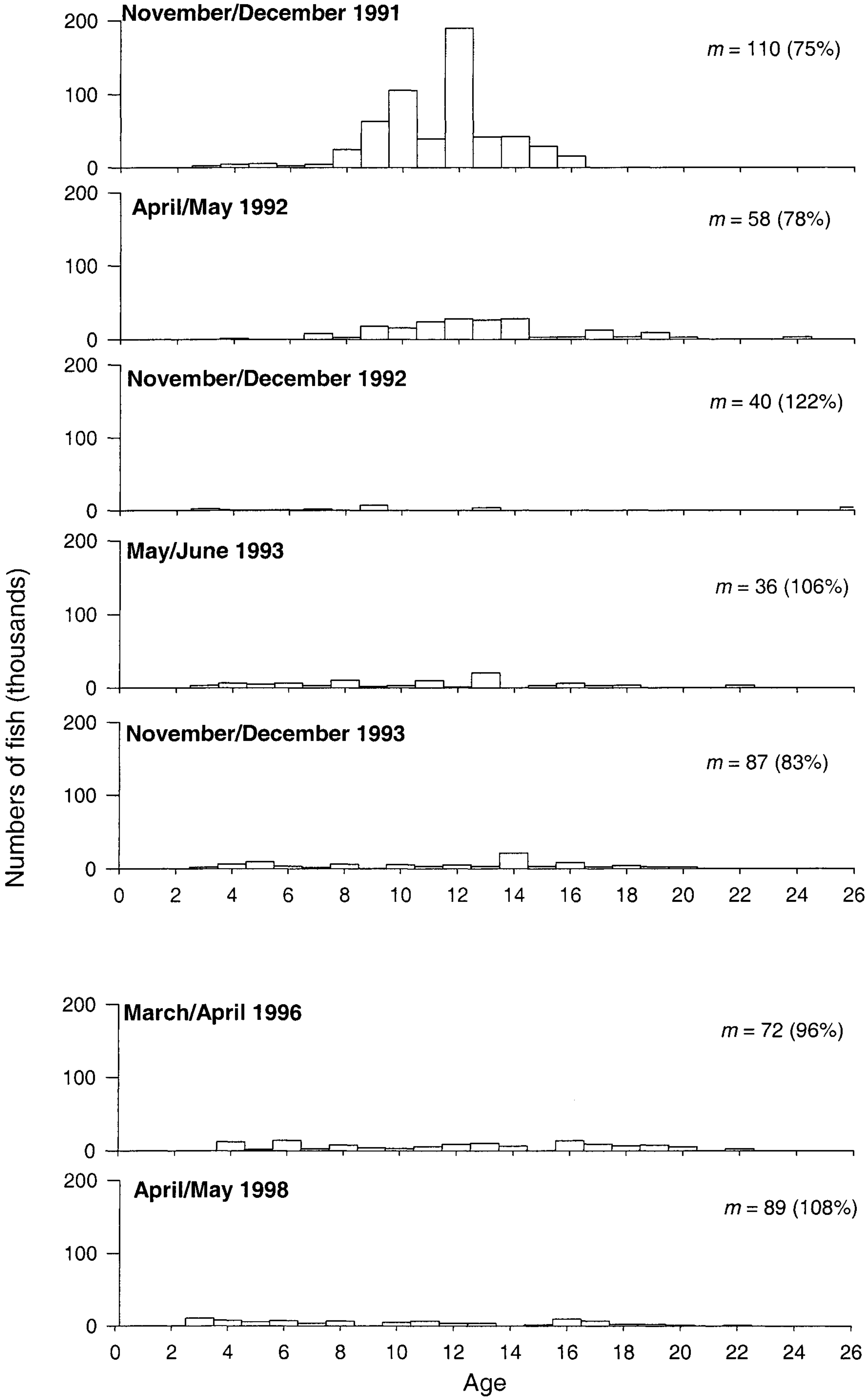


Figure 5a: **Scaled age frequencies for male hake from Sub-Antarctic *Tangaroa* time series core strata. Coefficients of variation (c.v.) are given in parentheses.**

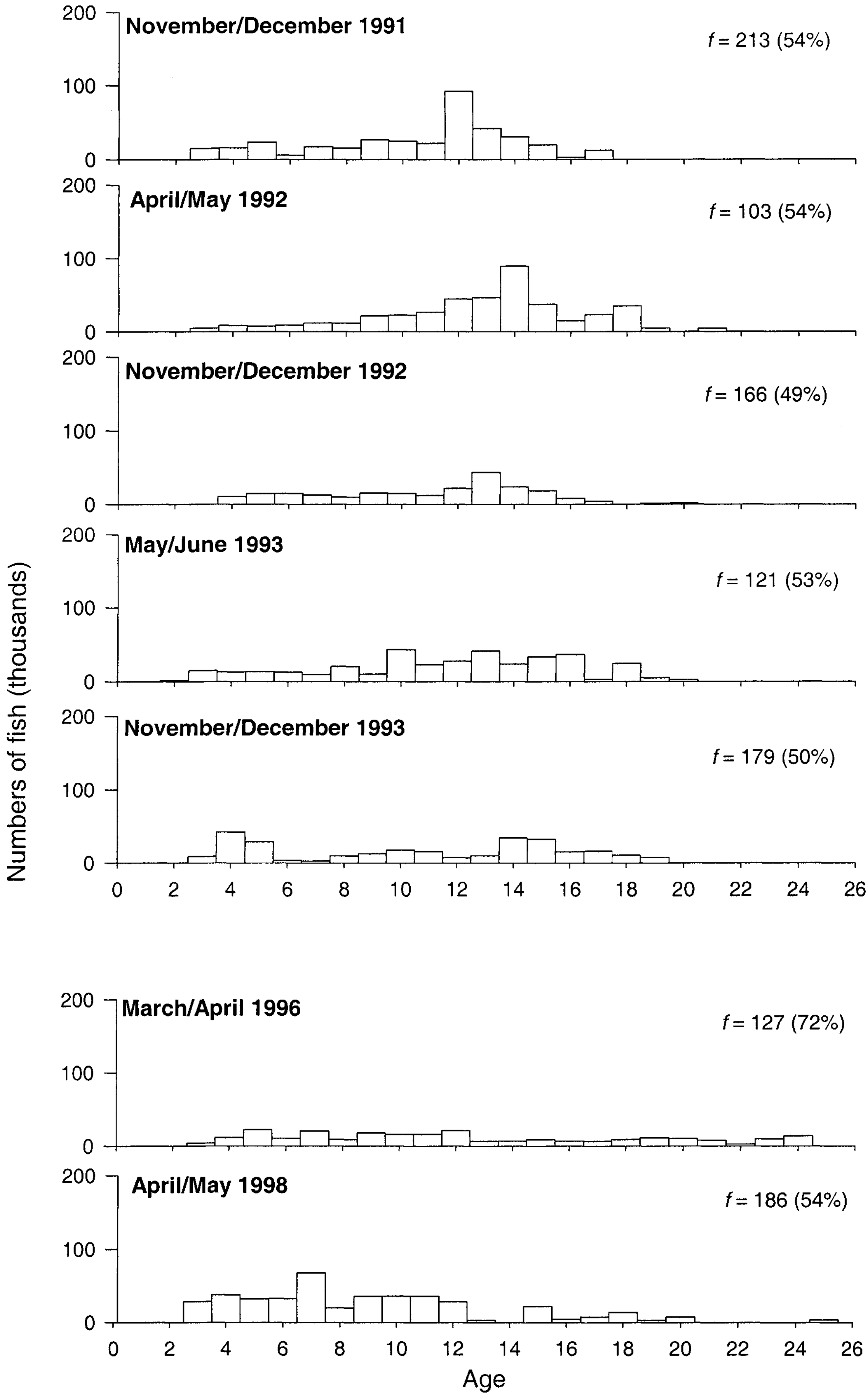


Figure 5a cntd: **Scaled age frequencies for female hake from Sub-Antarctic *Tangaroa* time series.**

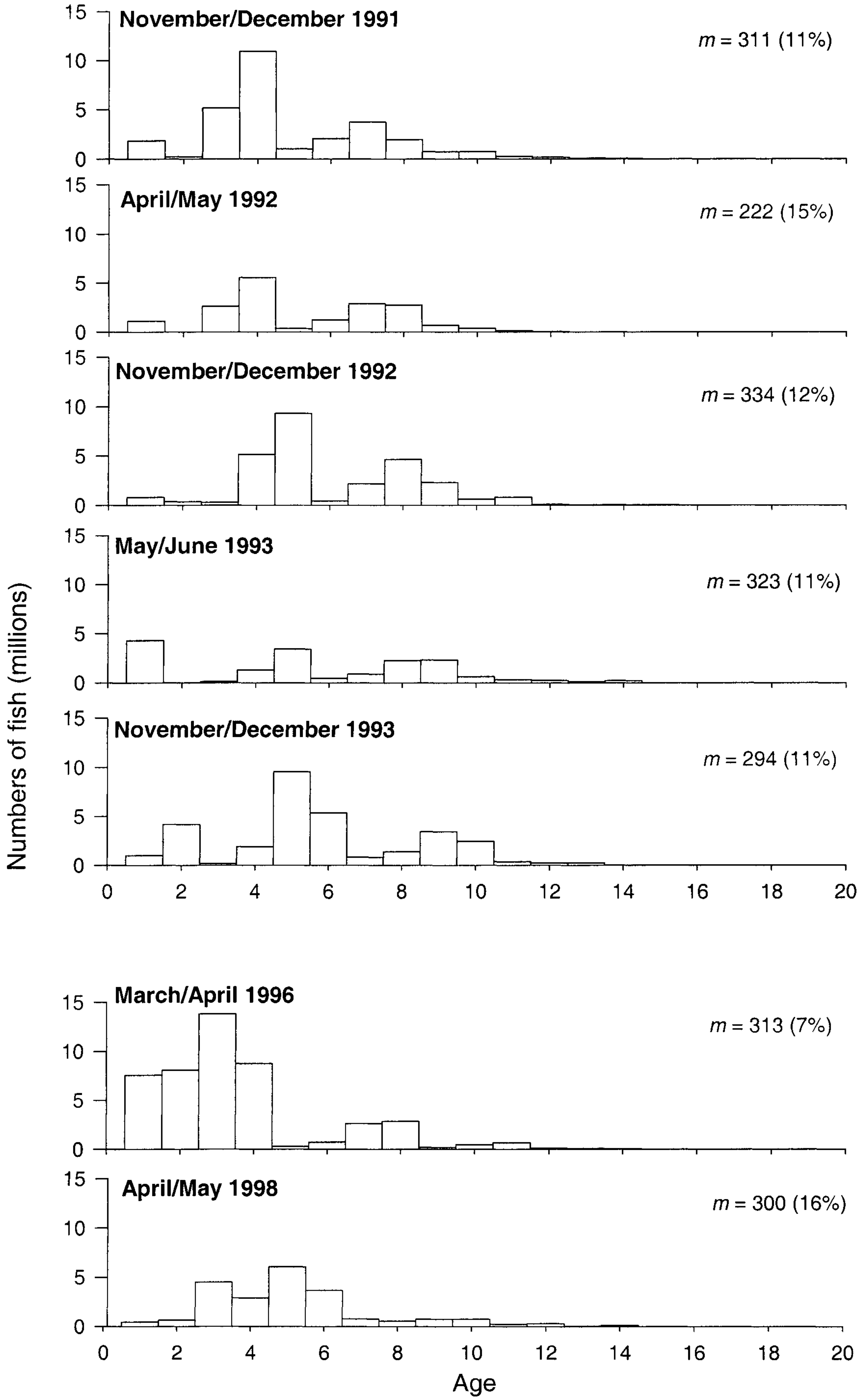
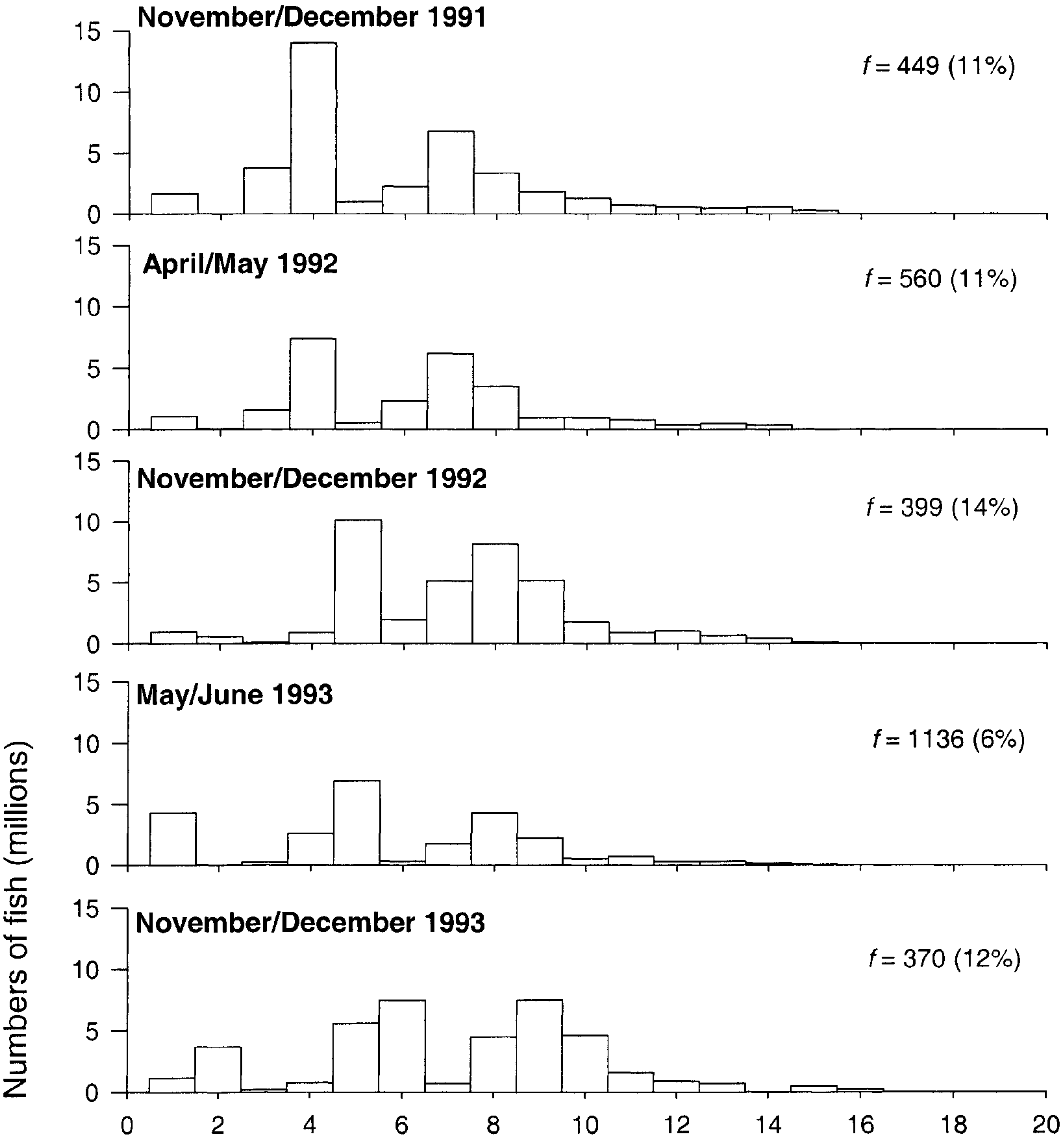


Figure 5b: **Scaled age frequencies for male hoki from Sub-Antarctic *Tangaroa* time series all strata. Coefficients of variation (c.v.) are given in parentheses.**



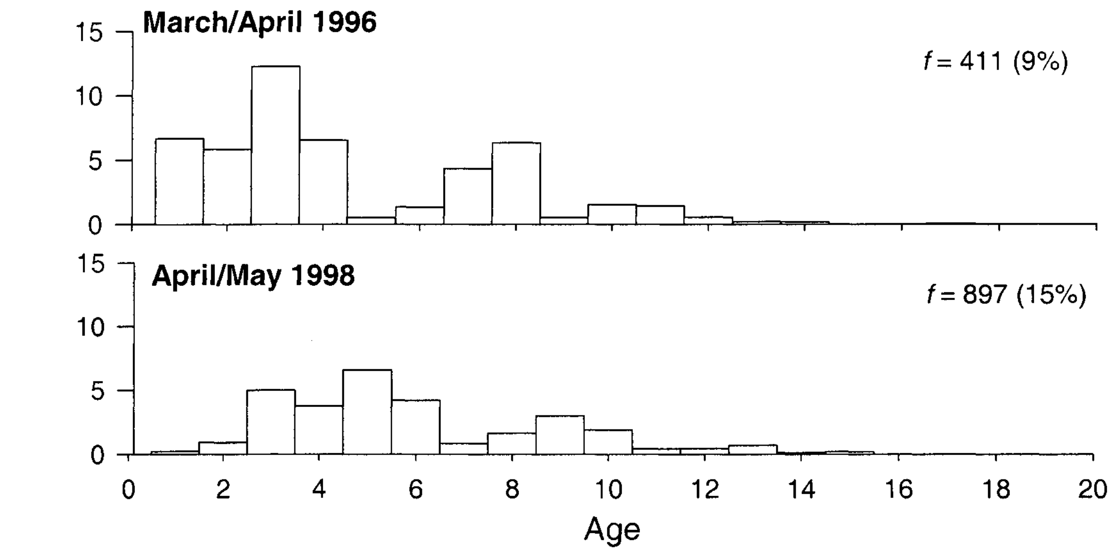


Figure 5b cntd: **Scaled age frequencies for female hoki from Sub-Antarctic *Tangaroa* time series.**

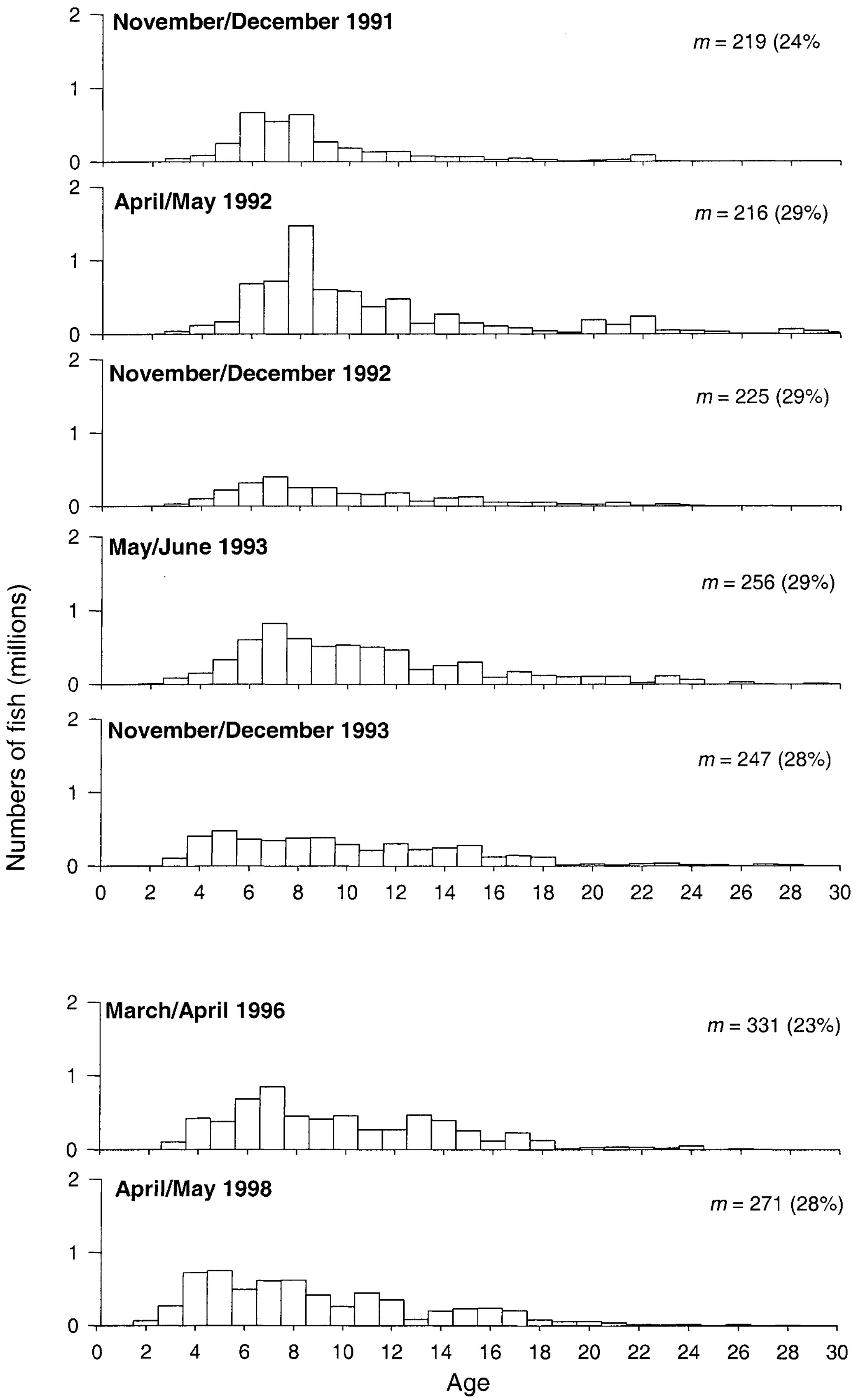


Figure 5c: **Scaled age frequencies for male ling from Sub-Antarctic *Tangaroa* time series all strata. Coefficients of variation (c.v.) are given in parentheses.**

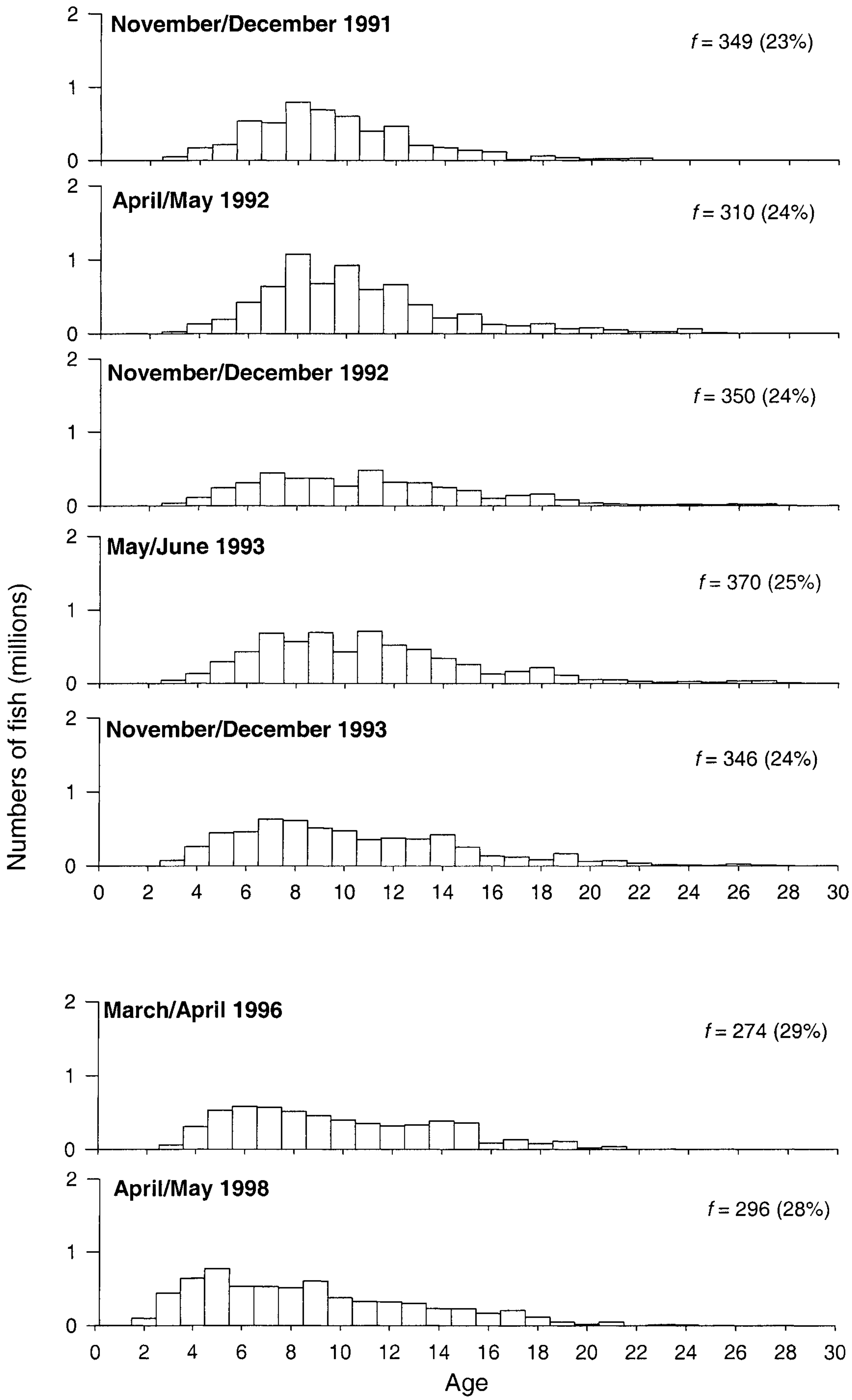


Figure 5c cntd: **Scaled age frequencies for female ling from Sub-Antarctic *Tangaroa* time series.**

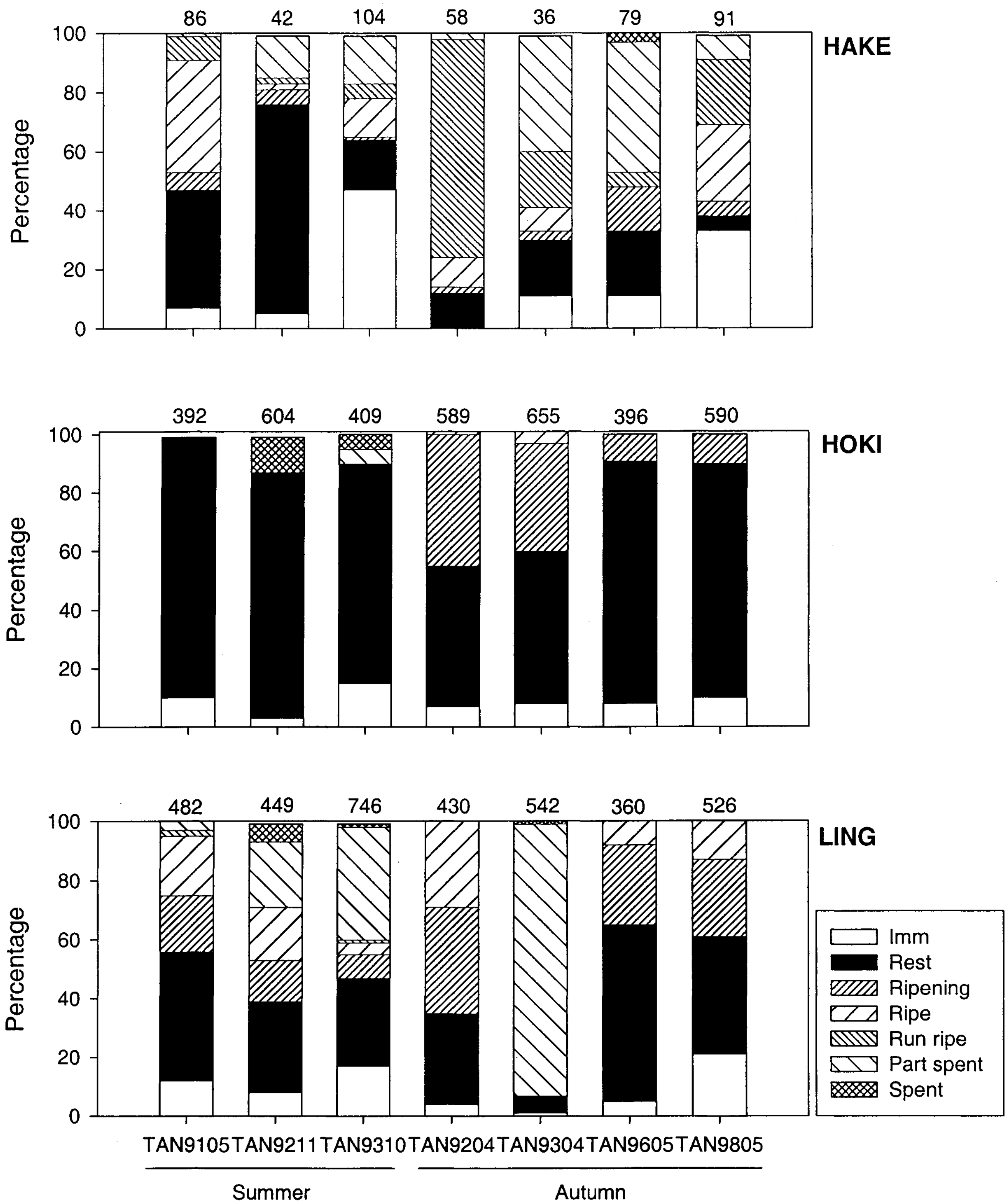


Figure 6a: **Reproductive condition of male hake, hoki, and ling from research trawl catches. Sample sizes are given on top of bars.**

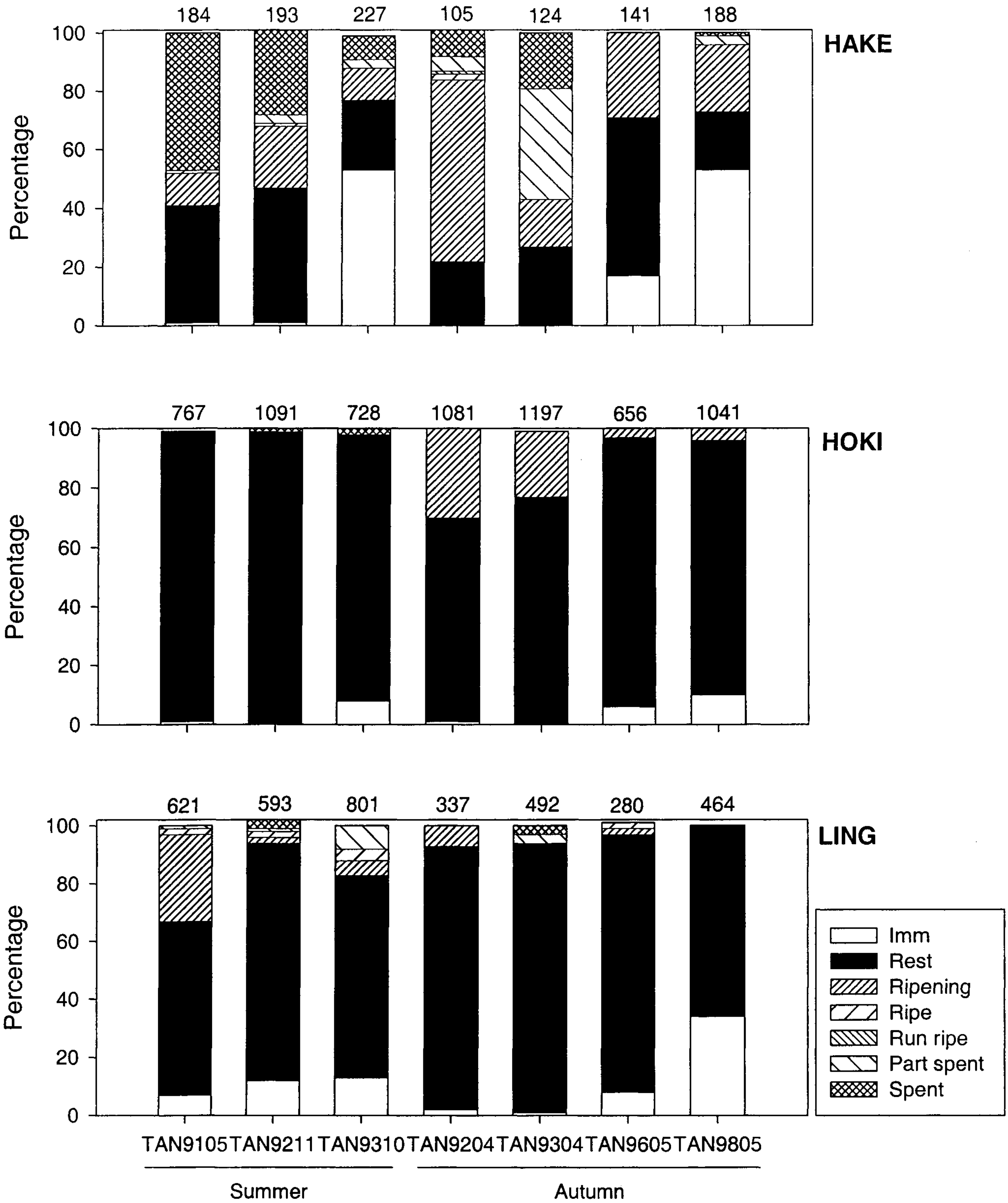


Figure 6b: **Reproductive condition of female hake, hoki, and ling from research trawl catches. Sample sizes are given on top of bars.**

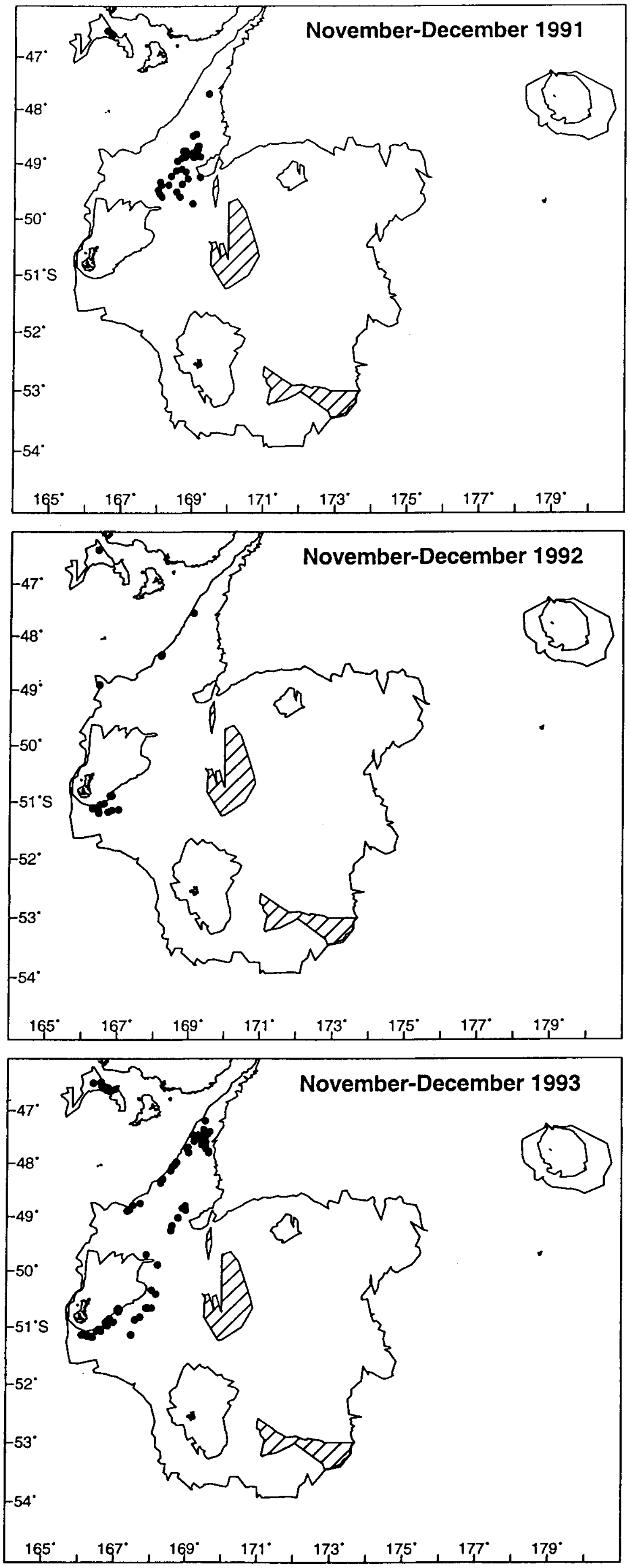


Figure 7: **Locations of catches sampled by scientific observers, November–December 1991–93.**

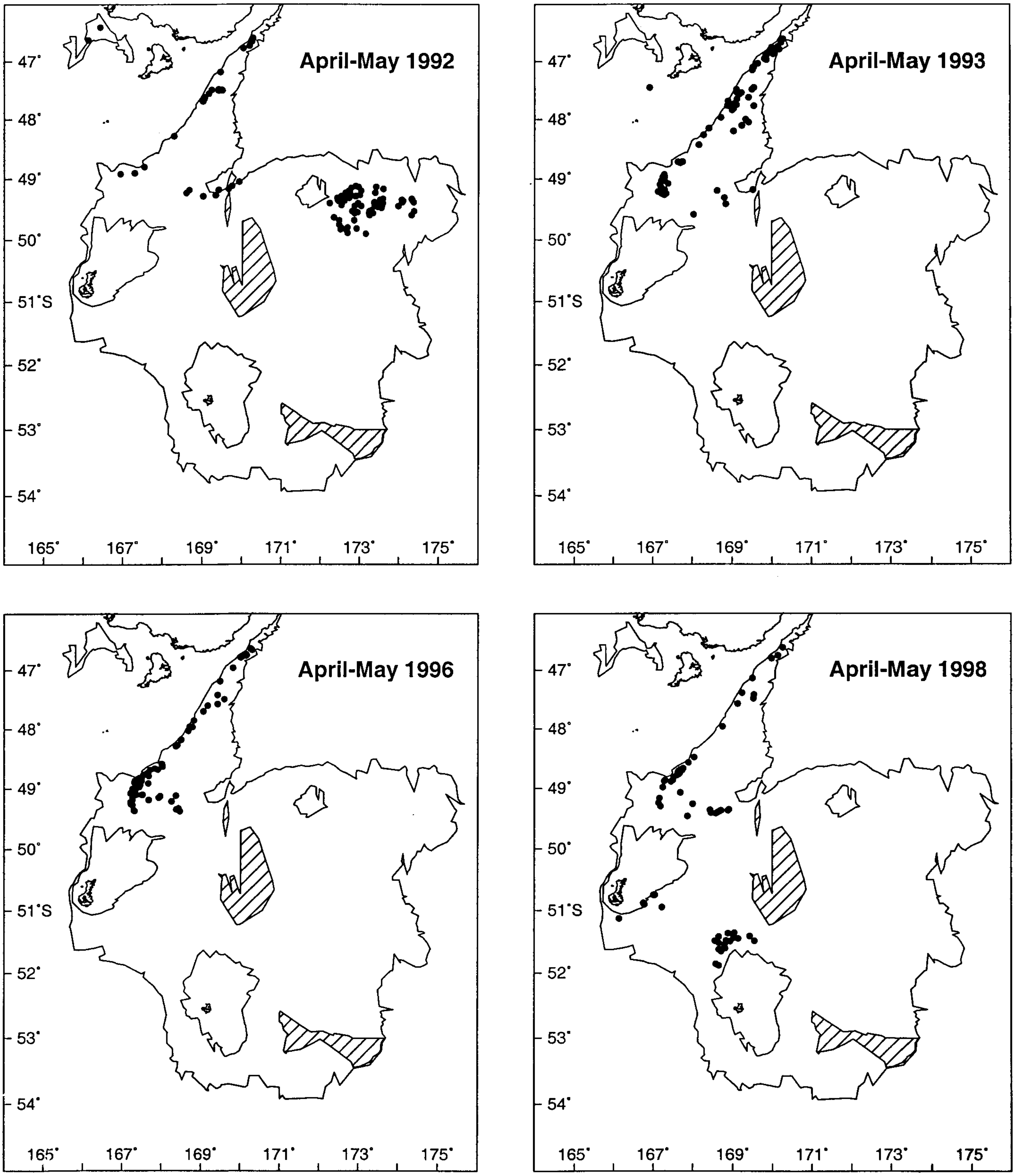


Figure 7 cntd: **Locations of catches sampled by scientific observers, April–May 1992–93, 1996, and 1998.**

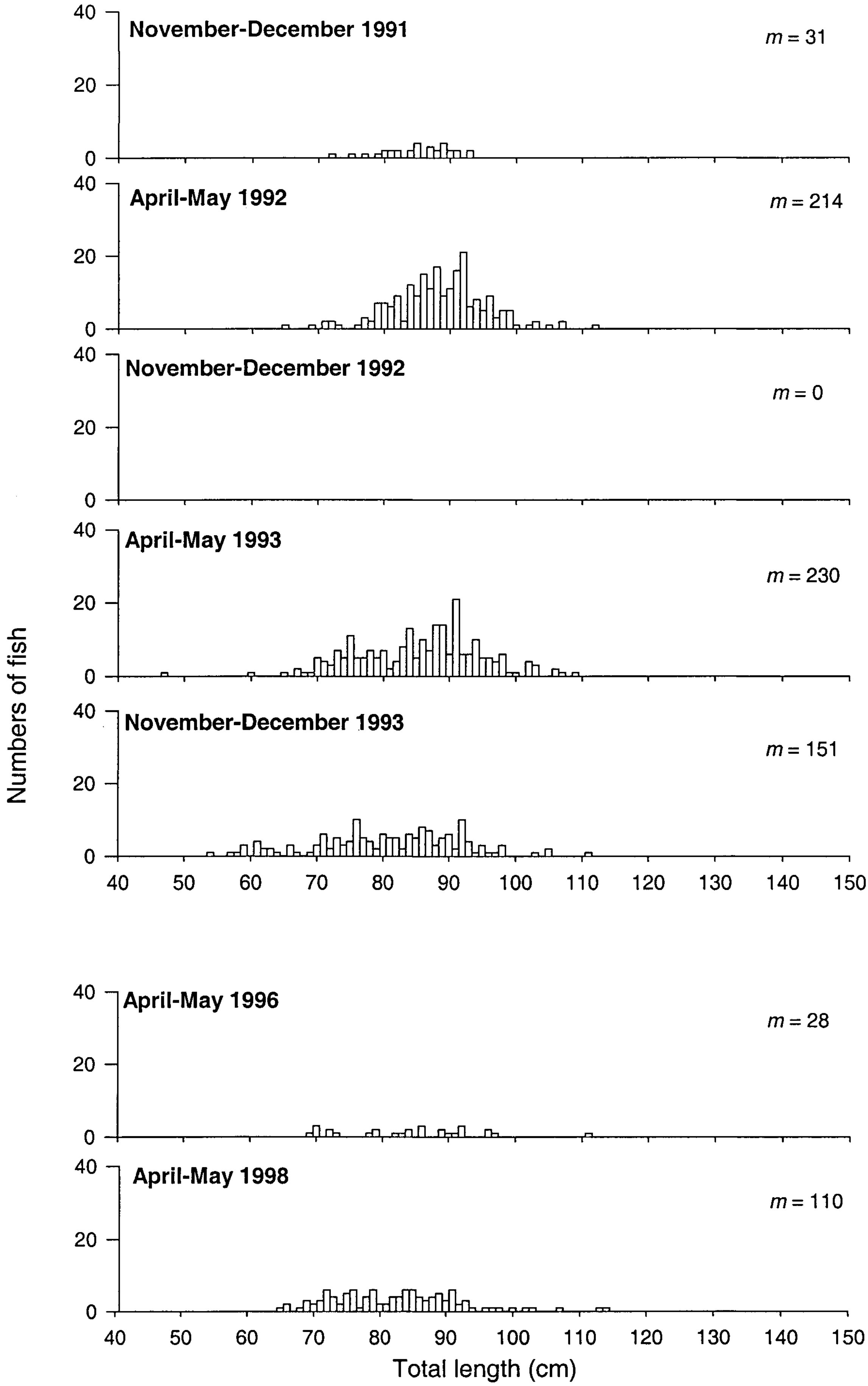
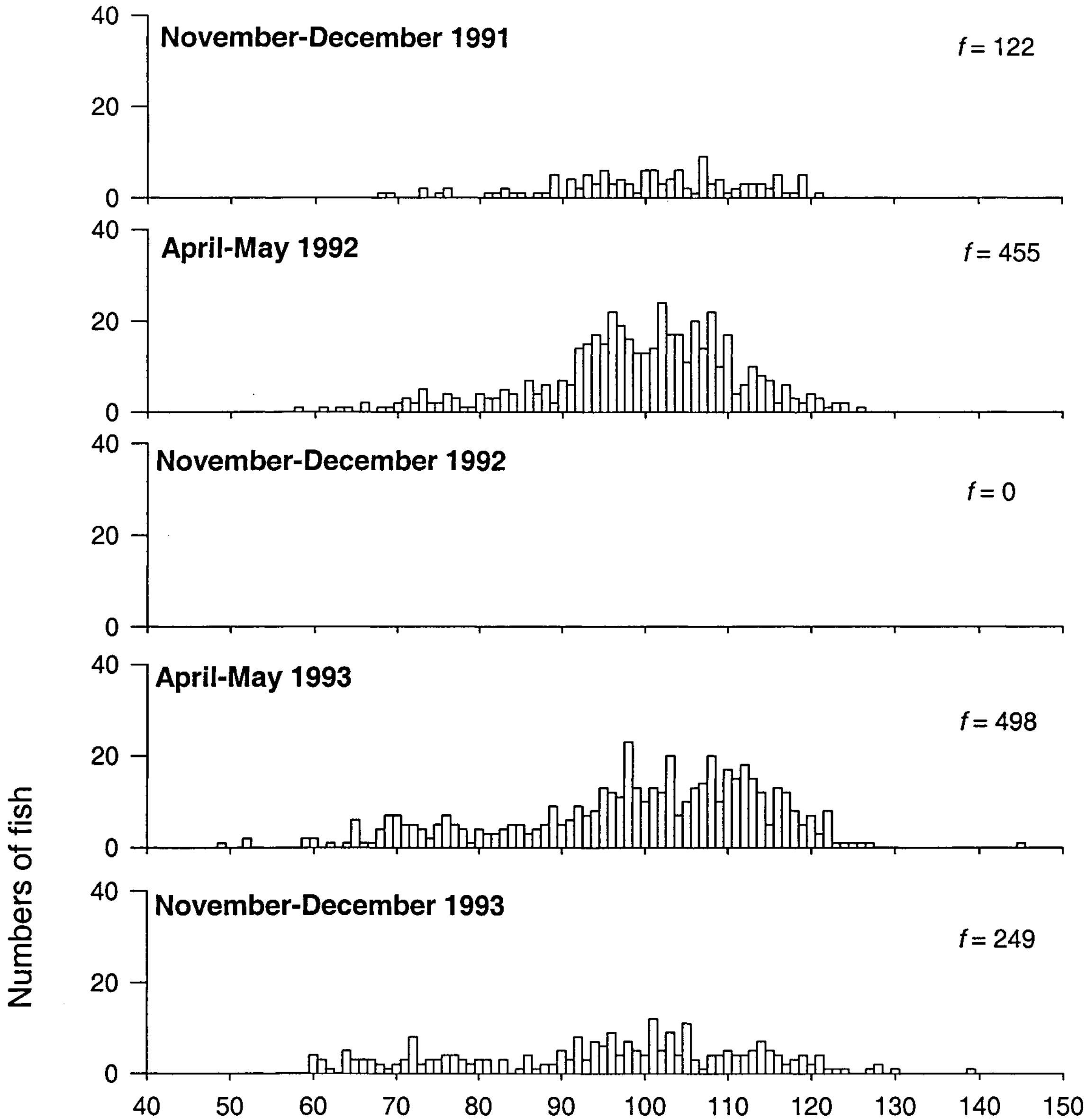


Figure 8a: **Unscaled length frequencies of male hake measured by observers on commercial vessels in the Southland and Sub-Antarctic during months corresponding to the trawl series. Numbers given are totals measured.**



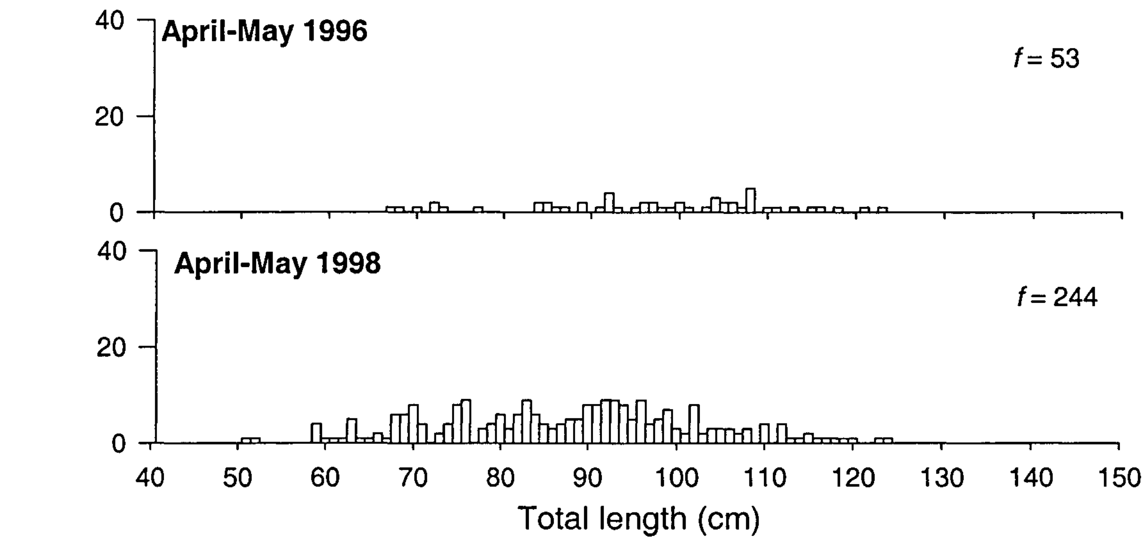


Figure 8a cntd: **Unscaled length frequencies of female hake measured by observers on commercial vessels in the Southland and Sub-Antarctic during months corresponding to the trawl series. Numbers given are totals measured.**

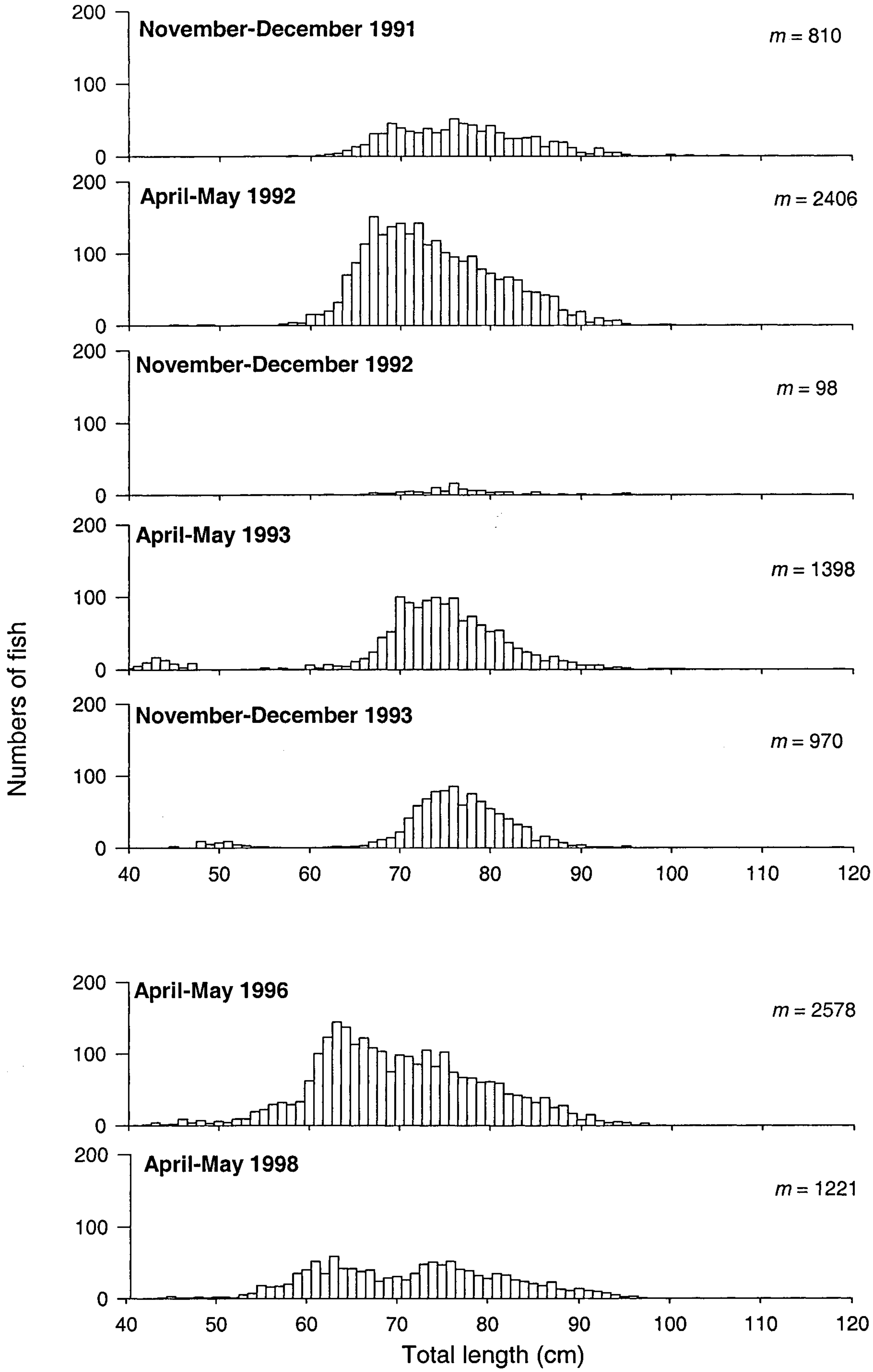


Figure 8b: **Unscaled length frequencies of male hoki measured by observers on commercial vessels in the Southland and Sub-Antarctic during months corresponding to the trawl series. Numbers given are totals measured.**

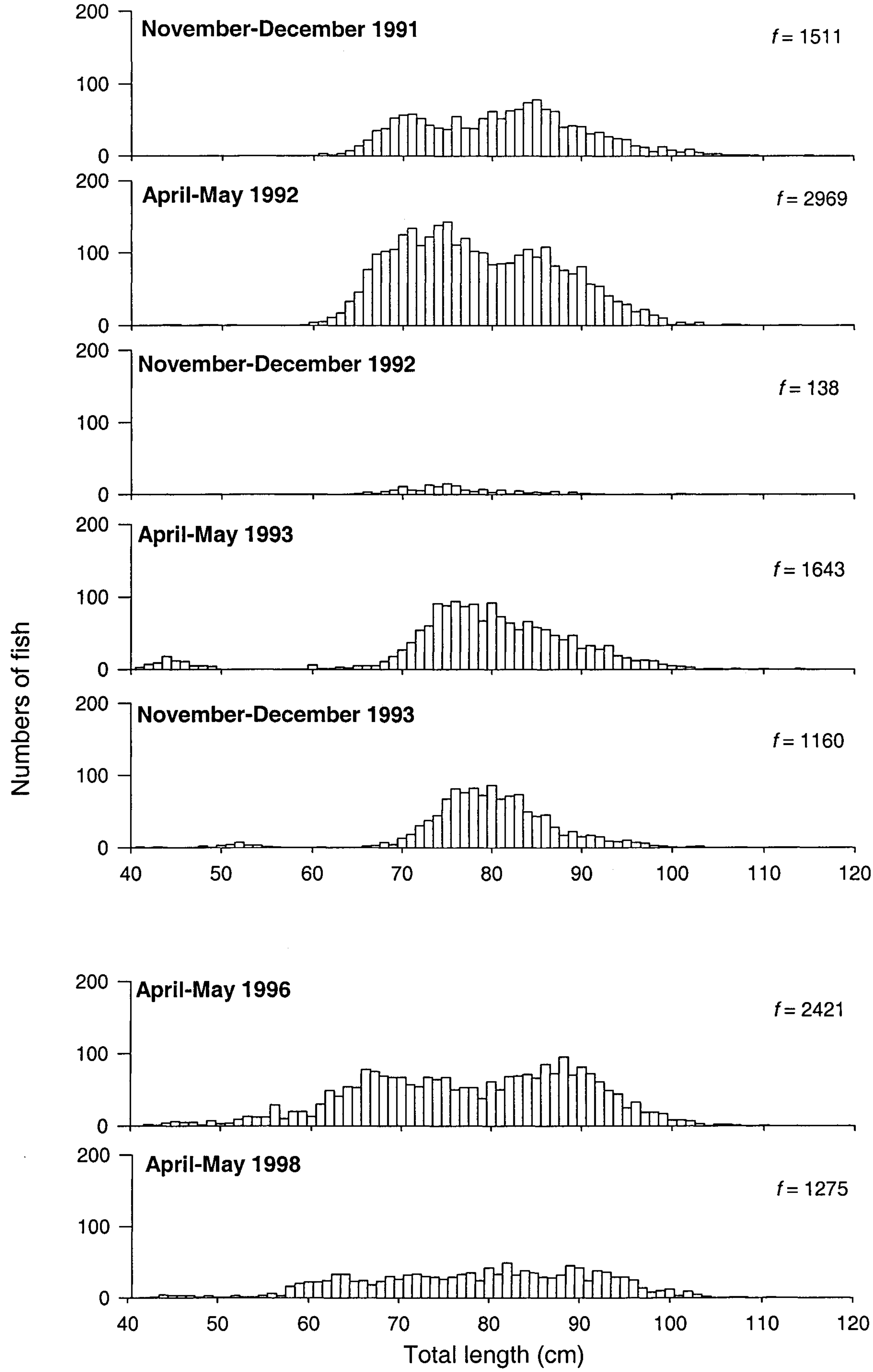


Figure 8b cntd: **Unscaled length frequencies of female hoki measured by observers on commercial vessels in the Southland and Sub-Antarctic during months corresponding to the trawl series. Numbers given are totals measured.**

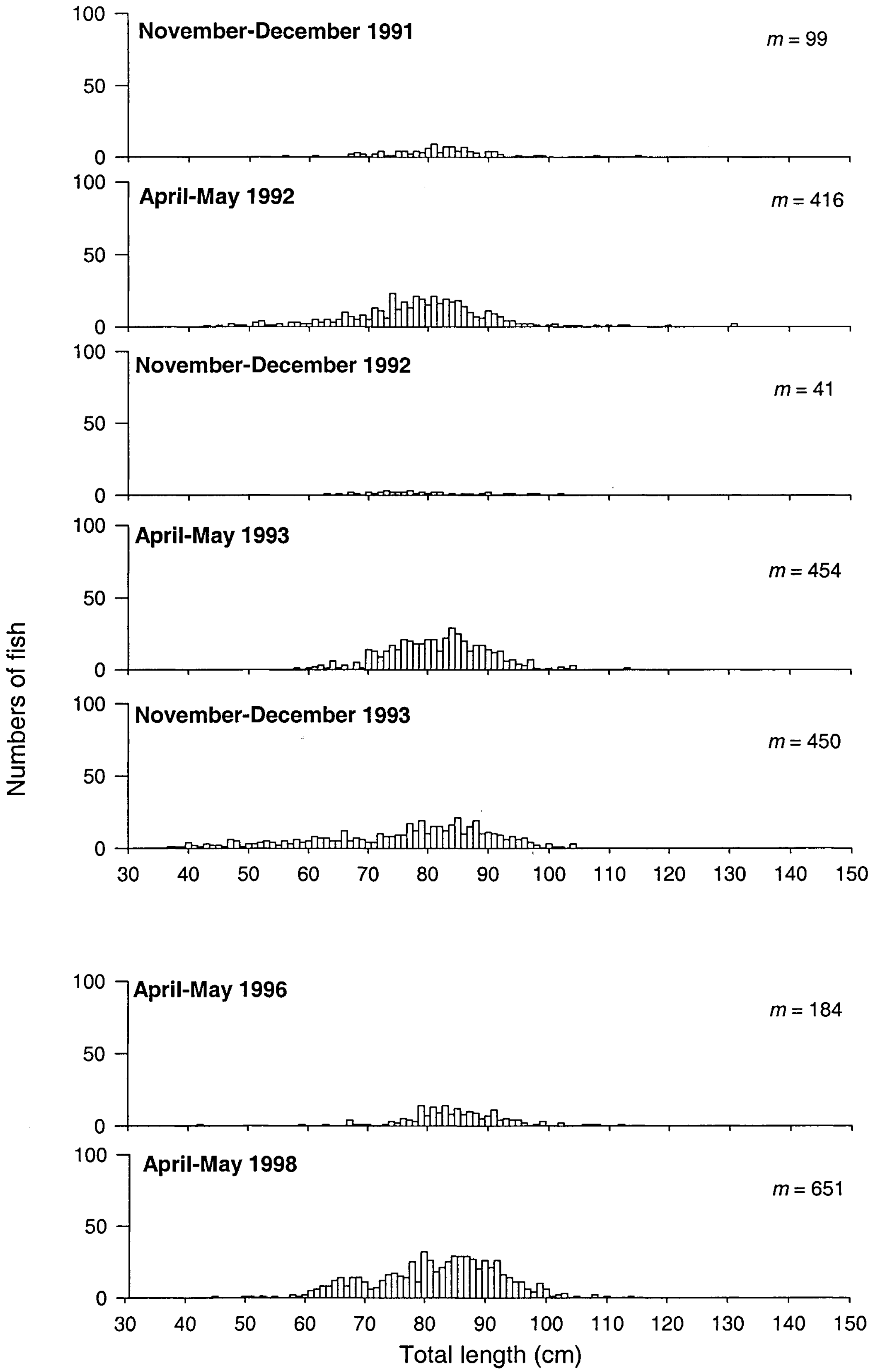


Figure 8c: **Unscaled length frequencies of male ling measured by observers on commercial vessels in the Southland and Sub-Antarctic during months corresponding to the trawl series. Numbers given are totals measured.**

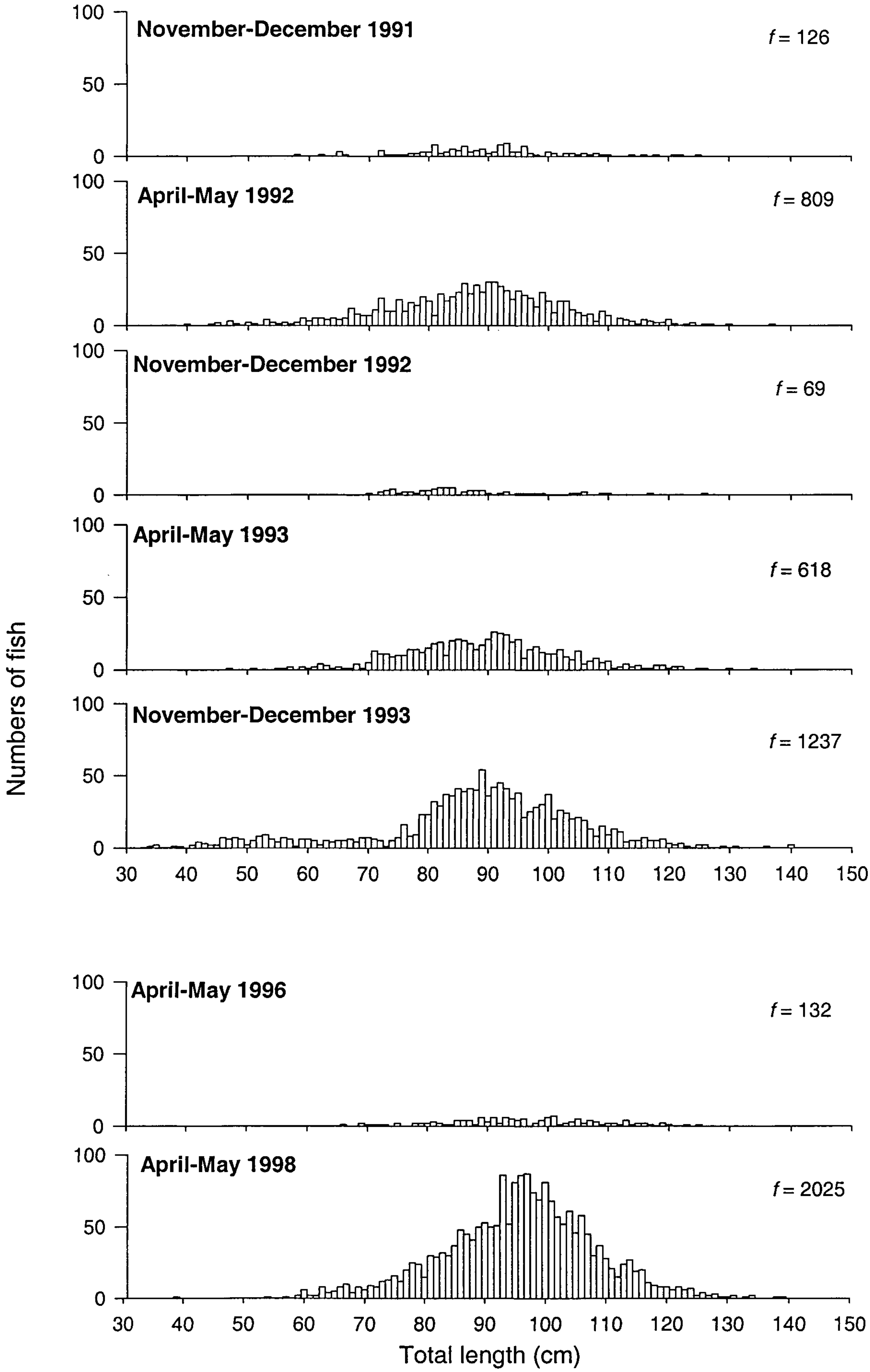


Figure 8c cntd: **Unscaled length frequencies of female ling measured by observers on commercial vessels in the Southland and Sub-Antarctic during months corresponding to the trawl series. Numbers given are totals measured.**

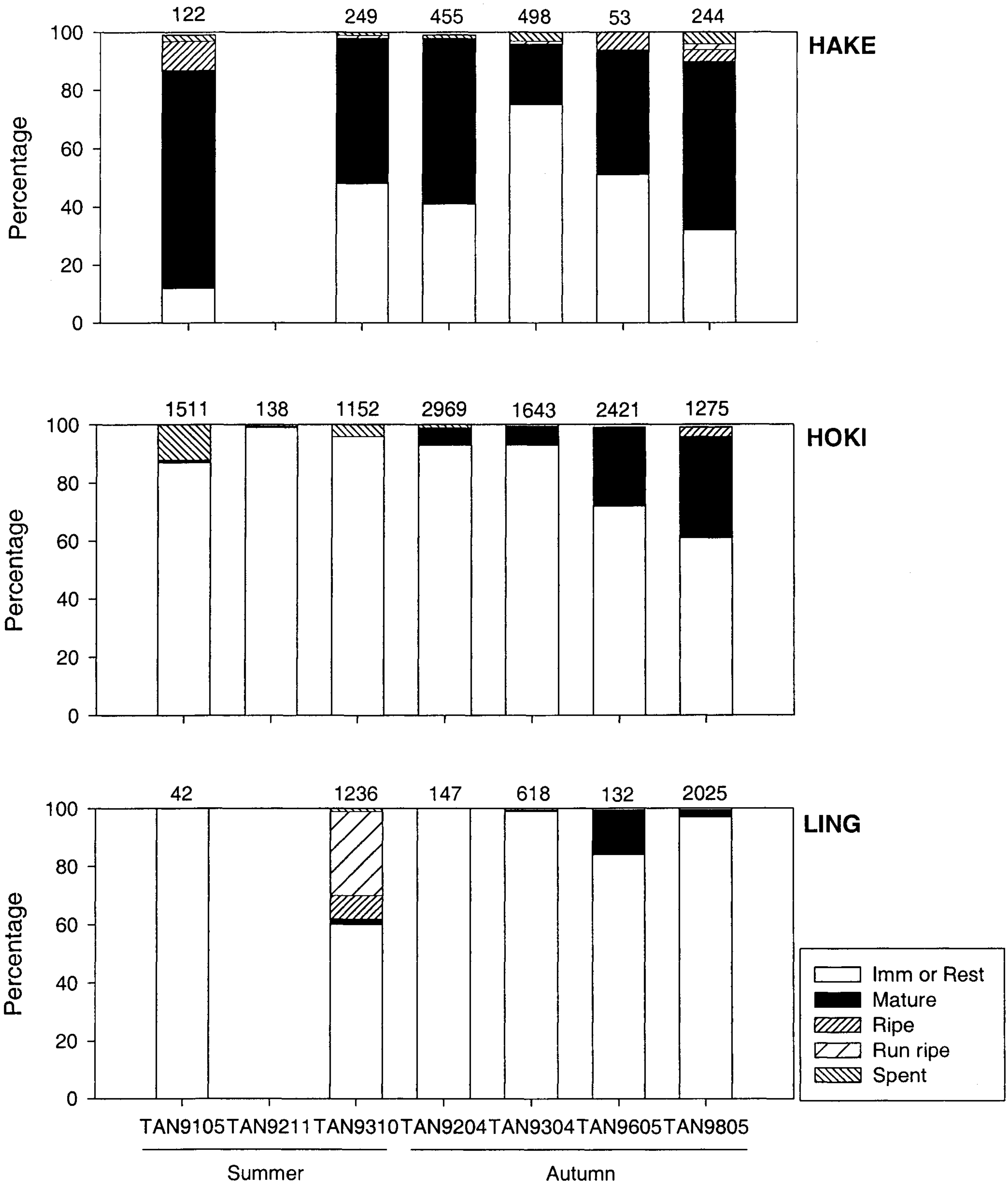


Figure 9: **Reproductive condition of female hake, hoki, and ling from observed commercial catches during the periods corresponding with research surveys. Sample sizes are given on top of bars.**

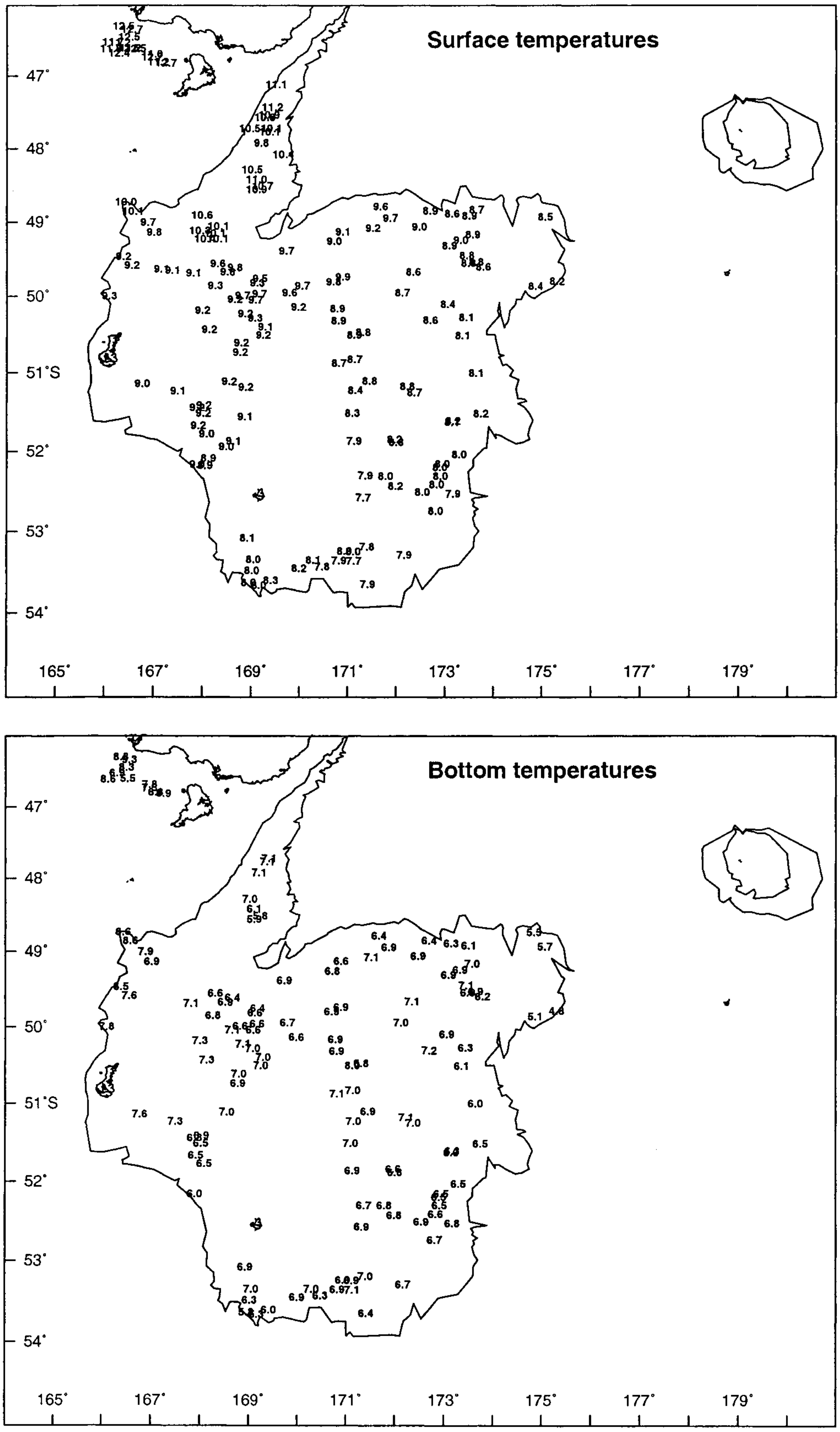


Figure 10a: **Surface and bottom temperatures recorded on TAN9105, November–December 1991.**

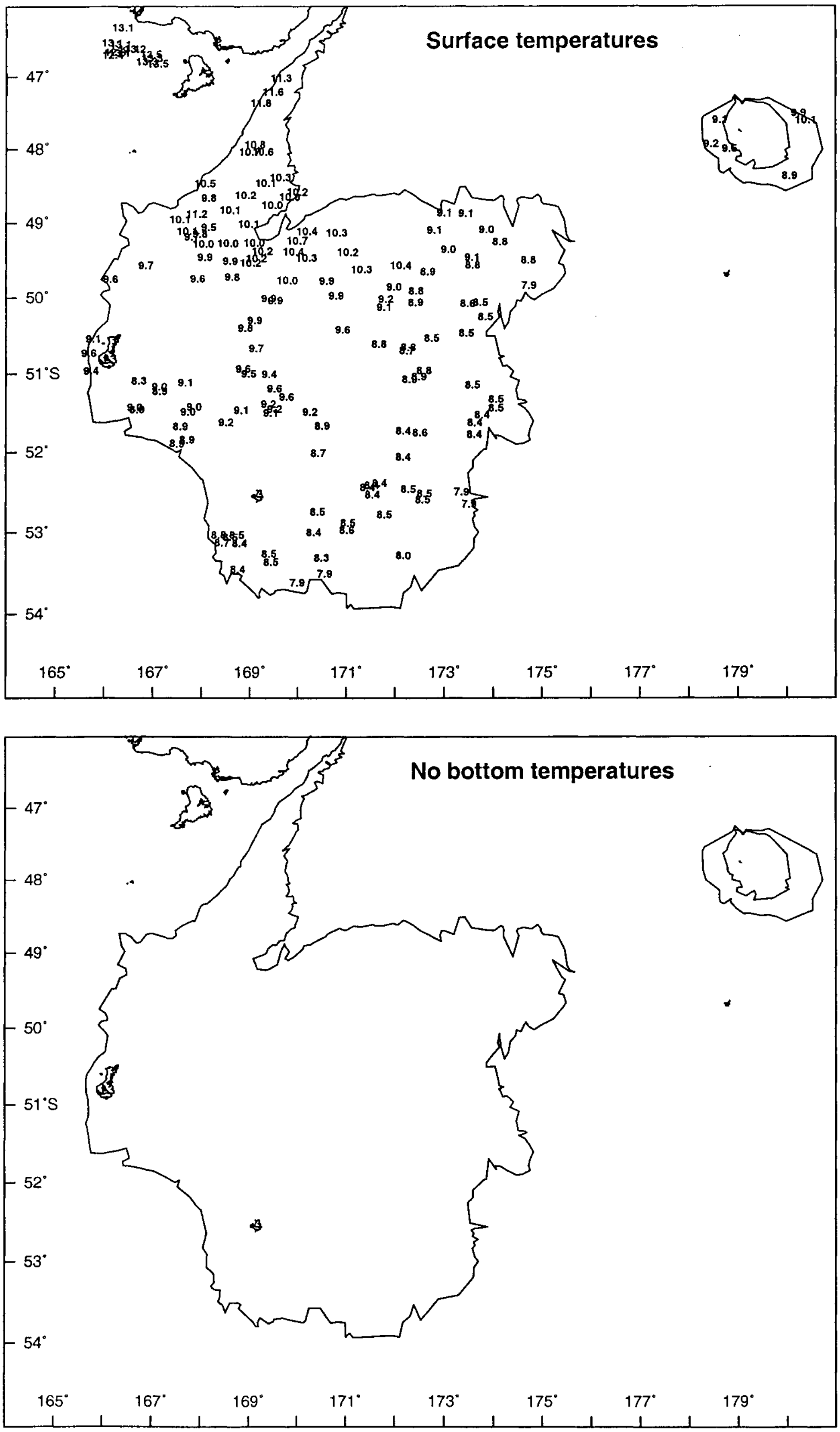
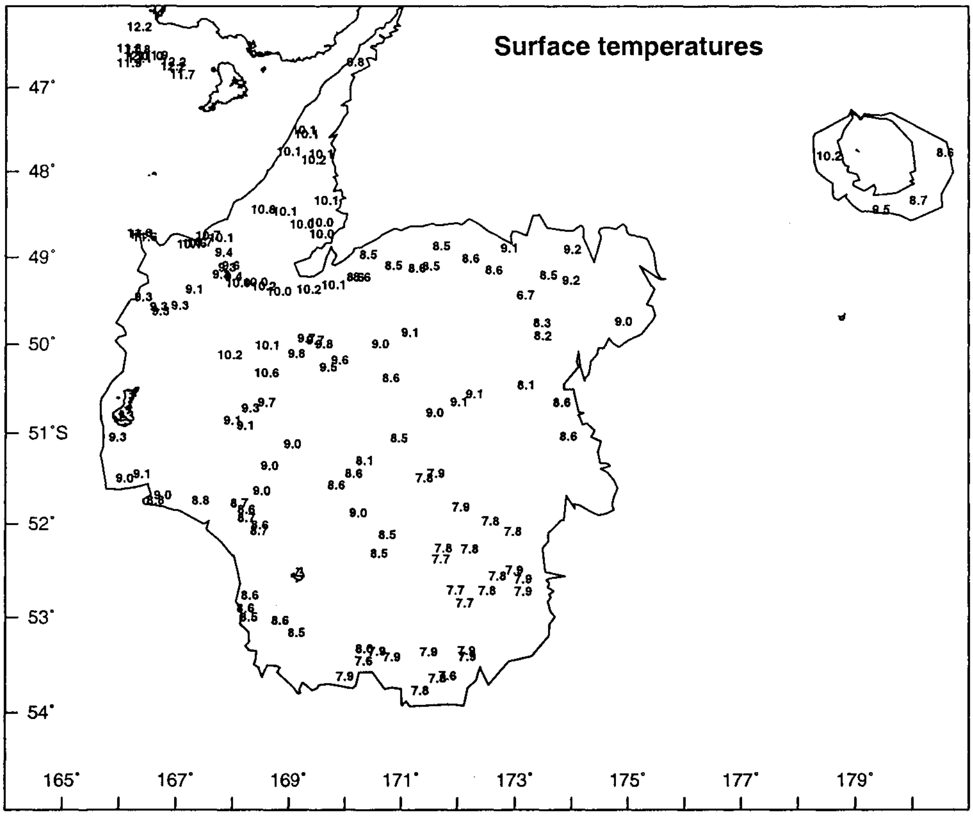


Figure 10b: **Surface temperatures recorded on TAN9211, November–December 1992.**



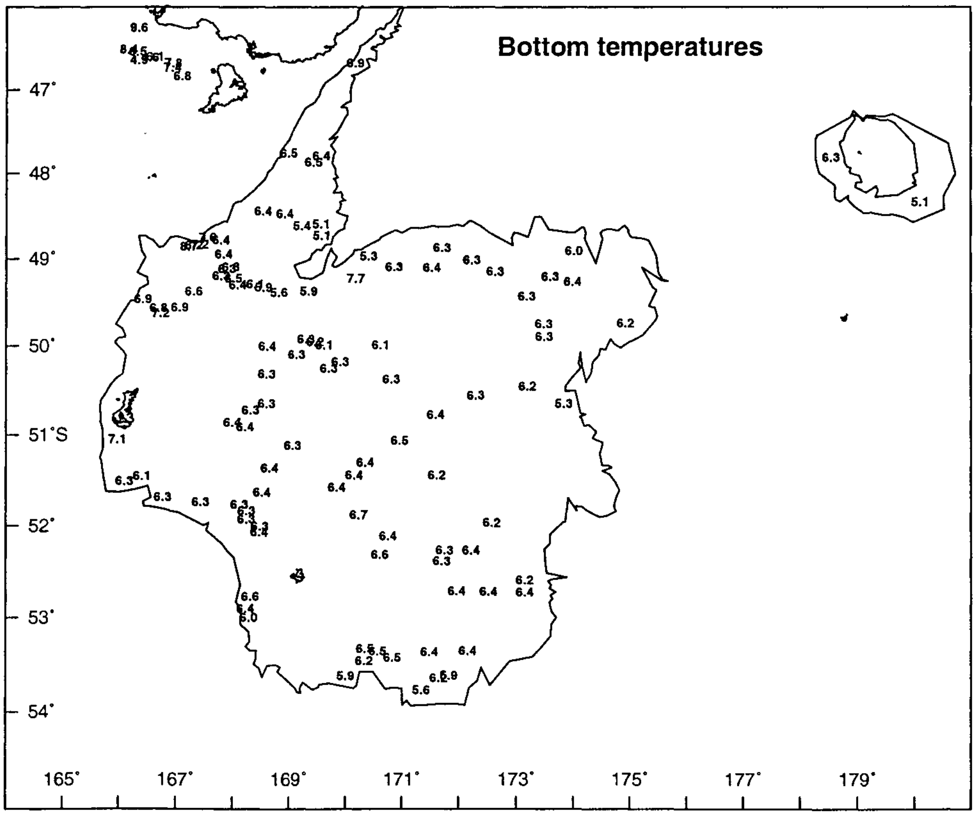


Figure 10c: **Surface and bottom temperatures recorded on TAN9310, November–December 1993.**

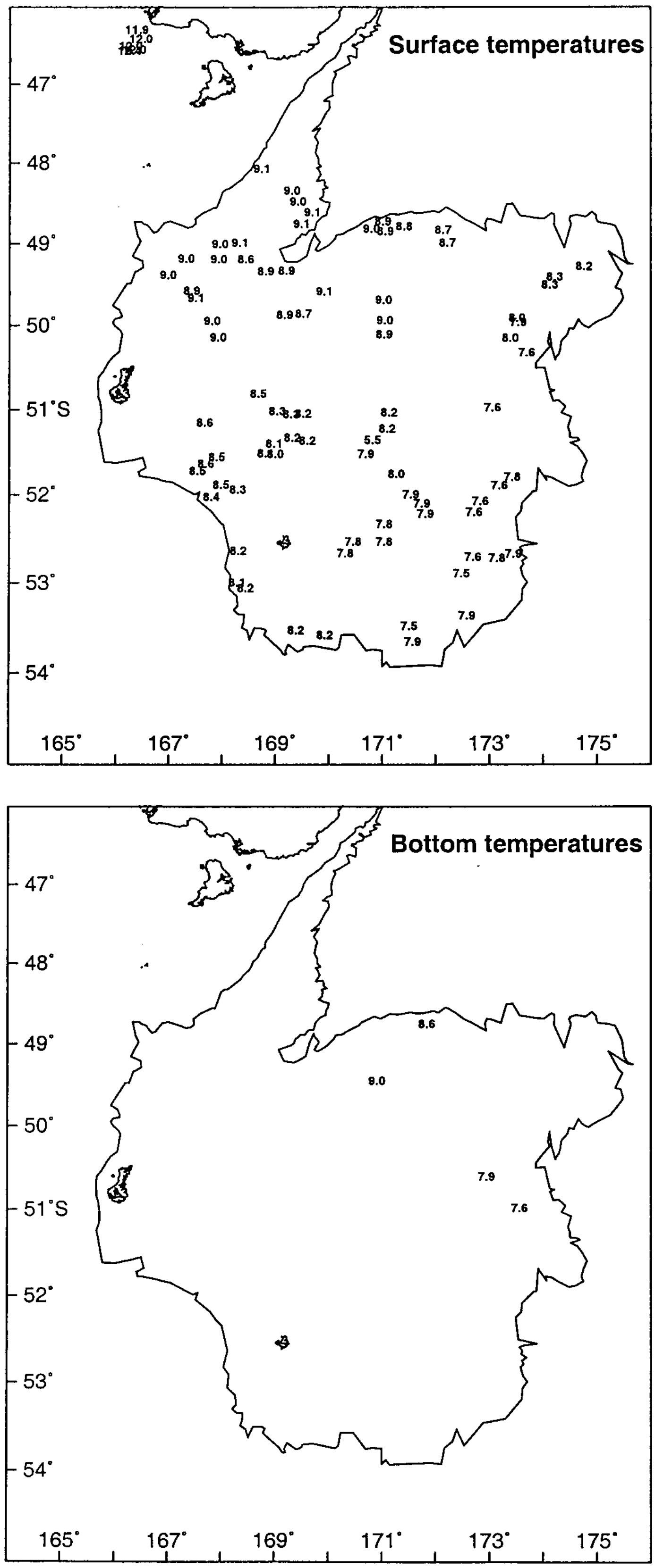


Figure 10d: **Surface and bottom temperatures recorded on TAN9204, April–May 1992. Only four bottom temperatures were recorded due to a sensor failing.**

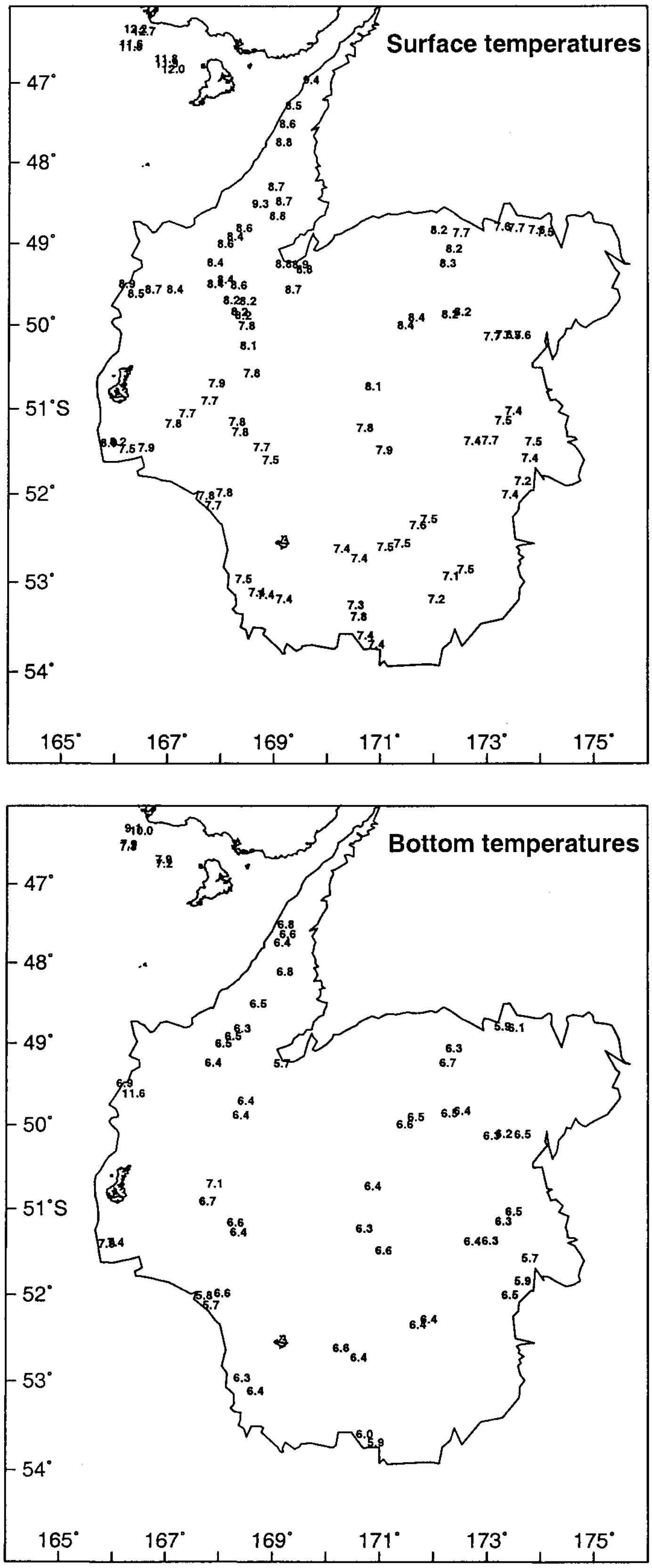


Figure 10e: **Surface and bottom temperatures recorded on TAN9304, May–June 1993.**

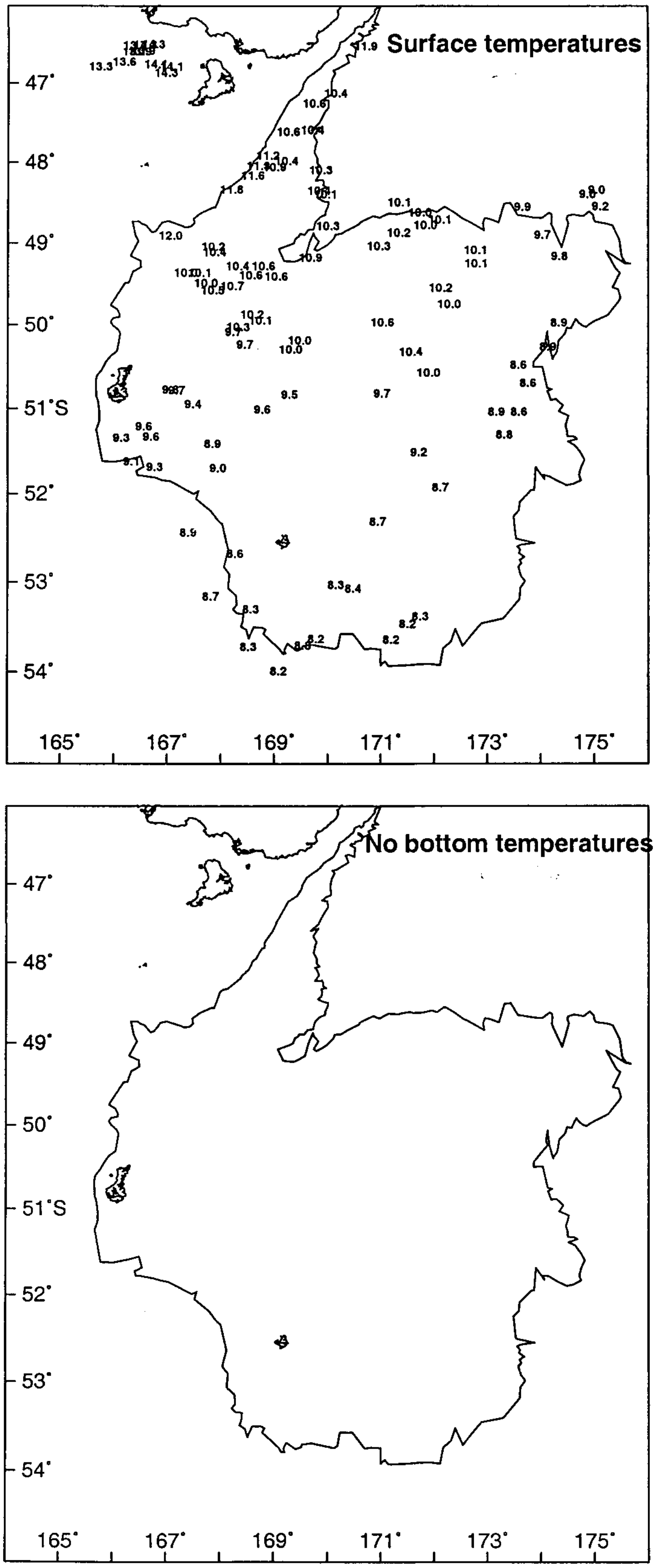


Figure 10f: **Surface temperatures recorded on TAN9605, March–April 1996.**

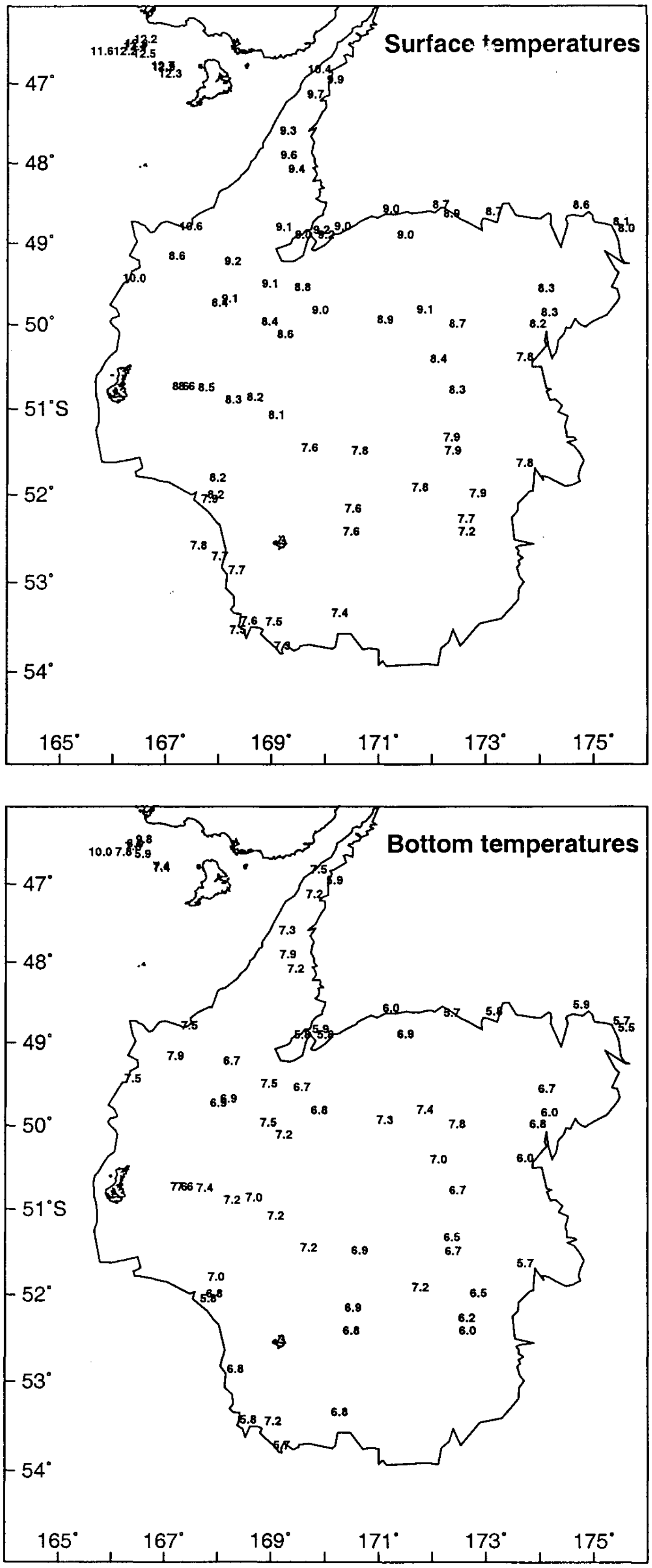


Figure 10g: **Surface and bottom temperatures recorded on TAN9805, April–May 1998.**

Appendix 1: **Description of gonad development used for staging male and female teleosts.**

Research gonad stage		Males	Females
1	Immature	Testes small and translucent, threadlike or narrow membranes.	Ovaries small and translucent. No developing oocytes.
2	Resting	Testes are thin and flabby; white or transparent.	Ovaries are developed, but no developing eggs are visible.
3	Ripening	Testes are firm and well developed, but no milt is present.	Ovaries contain visible developing eggs, but no hyaline eggs present.
4	Ripe	Testes large, well developed; milt is present and flows when testis is cut, but not when body is squeezed.	Some or all eggs are hyaline, but eggs are not extruded when body is squeezed.
5	Running-ripe	Testis is large, well formed; milt flows easily under pressure on the body.	Eggs flow freely from the ovary when it is cut or the body is pressed.
6	Partially spent	Testis somewhat flabby and may be slightly bloodshot, but milt still flows freely under pressure on the body.	Ovary partially deflated, often bloodshot. Some hyaline and ovulated eggs present and flowing from a cut ovary or when the body is squeezed.
7	Spent	Testis is flabby and bloodshot. No milt in most of testis, but there may be some remaining near the lumen. Milt not easily expressed even when present.	Ovary bloodshot; ovary wall may appear thick and white. Some residual ovulated eggs may still remain but will not flow when body is squeezed.

Observer gonad stage (females only)

1	Immature or Resting (equivalent to Research stages 1 and 2)
2	Mature (Research stage 3)
3	Ripe (Research stage 4)
4	Running ripe (Research stages 5 and 6)
5	Spent (Research stage 7)

Appendix 2a: **Calculated numbers at age (*n*) of the populations of hake in the core 300–800 m survey area, by sex and survey. Coefficients of variation are presented for individual year classes (c.v.) and as a mean weighted value for each survey (mean c.v.).**

	TAN9105				TAN9204				TAN9211			
	Male		Female		Male		Female		Male		Female	
Age	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	410	1.513	0	0	0	0	0	0	0	0
3	2 531	0.755	15 104	0.517	443	1.908	4 605	1.561	2 422	1.887	207	4.008
4	4 462	0.512	15 789	0.485	1 394	1.078	8 211	0.950	812	1.619	10 529	0.829
5	5 318	0.839	23 581	0.396	443	1.897	7 540	1.143	976	1.252	14 662	0.627
6	2 561	1.489	5 928	0.906	493	2.075	8 764	1.223	838	1.425	14 895	0.533
7	4 218	1.136	17 122	0.533	8 191	1.020	11 715	0.876	1 859	1.421	12 501	0.545
8	24 732	0.758	15 573	0.578	2 766	1.455	11 484	0.781	138	2.304	9 807	0.594
9	63 006	0.738	26 968	0.497	17 956	0.662	21 299	0.610	7 008	1.093	15 577	0.545
10	105 487	0.672	24 868	0.577	15 569	0.882	22 583	0.590	0	0	14 649	0.448
11	39 212	0.848	21 862	0.784	23 731	0.633	26 538	0.556	0	0	11 960	0.530
12	189 974	0.627	92 144	0.444	27 822	0.623	44 397	0.400	0	0	21 677	0.412
13	42 156	1.019	41 798	0.532	26 120	0.588	46 304	0.400	3 674	0.999	43 523	0.271
14	42 434	0.907	30 620	0.535	27 938	0.613	89 466	0.306	0	0	23 722	0.359
15	29 423	0.983	19 906	0.591	3 149	1.383	37 051	0.459	0	0	18 583	0.447
16	15 833	0.860	2 848	1.302	3 367	1.361	14 810	0.693	0	0	7 941	0.645
17	0	0	12 449	0.744	12 236	0.857	23 084	0.599	0	0	4 004	0.967
18	0	0	0	0	3 367	1.124	34 877	0.520	0	0	0	0
19	0	0	0	0	9 074	1.022	4 998	1.133	0	0	1 575	1.527
20	0	0	0	0	2 735	1.629	0	0	0	0	1 616	1.141
21	0	0	0	0	0	0	4 562	1.388	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	3 149	1.286	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
>25	0	0	0	0	0	0	0	0	4 140	1.006	0	0
No. aged	110		213		58		103		40		166	
Mean c.v.				0.669				0.617				0.555

Appendix 2a cntd: **Calculated numbers at age (*n*) of the populations of hake in the core survey area, by sex and survey.**

	TAN9304				TAN9310				TAN9605			
	Male		Female		Male		Female		Male		Female	
Age	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	1 598	1.117	0	0	285	2.135	0	0	0	0
3	3 203	1.936	14 968	0.506	2 160	1.036	8 714	0.810	0	0	4 033	2.043
4	6 438	1.226	13 026	0.712	5 953	0.567	41 836	0.300	12 173	0.854	11 259	0.756
5	5 114	0.995	13 709	0.613	9 452	0.615	28 637	0.375	1 500	1.523	22 140	0.471
6	6 239	1.011	12 776	0.683	3 470	0.560	3 219	0.789	13 863	0.794	10 264	0.661
7	3 045	1.622	9 682	0.727	1 281	1.665	2 453	1.474	2 741	1.606	20 352	0.566
8	10 516	0.820	20 561	0.790	6 059	0.753	9 525	0.686	7 693	1.043	8 666	0.592
9	1 681	1.785	10 132	0.831	0	0	12 331	0.730	4 003	1.653	17 558	0.548
10	2 807	1.500	42 815	0.388	5 258	0.964	17 451	0.543	3 100	1.181	15 508	0.555
11	9 835	0.891	22 614	0.546	2 934	0.998	15 472	0.525	5 482	1.310	15 576	0.614
12	1 337	1.728	27 701	0.471	5 139	0.809	7 028	0.754	8 789	0.823	21 117	0.577
13	20 361	0.587	40 853	0.385	2 992	1.449	9 691	0.585	10 098	0.849	6 286	0.936
14	0	0	23 729	0.546	21 009	0.517	34 155	0.358	6 231	1.105	6 634	1.048
15	3 037	1.534	33 453	0.434	2 992	1.233	32 044	0.423	0	0	8 415	0.943
16	5 889	0.999	36 262	0.351	8 385	0.751	15 059	0.485	13 760	0.794	6 704	0.928
17	2 852	1.523	3 015	1.481	2 428	1.430	16 024	0.523	9 061	0.744	6 256	0.817
18	3 204	1.506	24 355	0.514	3 901	0.920	10 443	0.656	6 403	1.080	8 770	0.871
19	0	0	4 916	0.887	2 428	1.560	7 287	0.794	7 572	0.763	10 925	0.772
20	0	0	2 736	1.462	1 951	1.695	0	0	5 265	1.126	10 121	0.901
21	0	0	0	0	0	0	0	0	0	0	7 608	0.994
22	3 203	1.568	0	0	0	0	0	0	2 639	1.178	2 503	1.267
23	0	0	0	0	0	0	0	0	0	0	9 472	0.827
24	0	0	0	0	0	0	0	0	0	0	13 409	0.683
25	0	0	0	0	0	0	0	0	0	0	0	0
>25	0	0	0	0	1 951	1.576	0	0	0	0	0	0
No. aged	36		121		87		179		72		127	
Mean c.v.				0.636				0.581				0.800

Appendix 2a cntd: **Calculated numbers at age (*n*) of the populations of hake in the core survey area, by sex and survey.**

	TAN9805			
	Male		Female	
Age	*n*	c.v.	*n*	c.v.
1	0	0	0	0
2	0	0	0	0
3	10 504	0.805	28 710	0.569
4	7 614	0.829	37 496	0.500
5	5 428	0.964	32 303	0.476
6	7 352	0.921	32 793	0.476
7	3 558	0.950	67 696	0.368
8	6 423	1.012	19 869	0.601
9	0	0	35 470	0.483
10	4 833	0.897	36 007	0.501
11	6 620	1.233	36 133	0.478
12	3 414	1.030	28 557	0.440
13	3 447	1.576	3 079	1.495
14	0	0	0	0
15	1 707	1.388	22 364	0.612
16	9 732	1.068	4 221	0.989
17	7 178	1.081	7 667	0.874
18	2 208	1.976	14 099	0.851
19	2 208	2.167	3 079	1.638
20	1 149	1.857	7 416	0.778
21	0	0	0	0
22	1 149	1.549	0	0
23	0	0	0	0
24	0	0	0	0
25	0	0	3 494	1.513
>25	0	0	0	0
No. aged	89		186	
Mean c.v.				0.627

Appendix 2b: **Calculated numbers at age (*n*) of the populations of hoki in the whole survey area (300–1000 m), by sex and survey. Fish of "unknown" age are those for which there was no age data at length. In the hoki stock assessment fish of unknown age were divided across ages 4 and older in proportion to estimated numbers at age (Patrick Cordue *pers comm.*).**

	TAN9105				TAN9204				TAN9211			
	Male		Female		Male		Female		Male		Female	
Age	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.
1	1 832 881	0.003	1 654 986	0.003	1 105 654	0.001	1 077 071	0.001	807 791	0.004	953 037	0.004
2	230 132	0.363	42 145	0.004	59 851	0.002	73 585	0.319	367 969	0.003	570 761	0.004
3	5 164 247	0.082	3 791 037	0.109	2 611 910	0.119	1 580 342	0.146	279 010	0.185	95 418	0.002
4	10 921 326	0.052	13 988 126	0.042	5 561 105	0.081	7 362 588	0.051	5 132 270	0.075	899 377	0.196
5	1 002 003	0.289	988 099	0.281	372 275	0.495	555 454	0.339	9 300 056	0.067	10 099 019	0.08
6	2 064 842	0.17	2 237 886	0.181	1 226 462	0.248	2 325 926	0.141	443 441	0.444	1 925 181	0.268
7	3 744 981	0.111	6 780 703	0.085	2 890 912	0.134	6 176 427	0.063	2 187 888	0.201	5 116 311	0.156
8	1 954 475	0.145	3 371 336	0.124	2 726 537	0.146	3 516 081	0.099	4 622 014	0.107	8 146 126	0.113
9	732 527	0.242	1 816 960	0.187	680 344	0.329	973 345	0.19	2 302 272	0.167	5 168 141	0.141
10	727 248	0.216	1 245 133	0.185	379 299	0.514	948 945	0.187	621 356	0.281	1 748 508	0.224
11	249 745	0.422	690 416	0.253	139 573	0.564	778 162	0.206	815 846	0.274	872 137	0.3
12	185 493	0.493	546 592	0.328	65 318	0.953	402 832	0.303	108 574	0.481	1 027 559	0.295
13	85 033	0.682	459 405	0.376	55 319	0.926	511 371	0.249	62 722	0.735	649 132	0.394
14	73 276	0.596	549 267	0.341	55 319	0.926	386 524	0.31	70 274	0.622	430 850	0.425
15	20 364	0.866	299 950	0.461	0	0	25 784	0.894	68 217	0.964	117 237	0.619
16	0	0	0	0	0	0	40 951	0.981	18 311	0.935	13 405	0.972
17	0	0	0	0	0	0	25 784	0.894	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	22 028	0.973
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
Unknown	105 518	0.002	61 959	0.271	457 447	0.2	141 700	0.313	30 159	0.276	13 654	0.269
No. aged	311		449		222		560		334		399	
Mean c.v.				0.106				0.126				0.133

Appendix 2b cntd: **Calculated numbers at age (*n*) of the populations of hoki in the survey area, by sex and survey.**

	TAN9304				TAN9310				TAN9605			
	Male		Female		Male		Female		Male		Female	
Age	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.
1	4 285 822	0.004	4 291 360	0.004	983 050	0.004	1 142 502	0.005	7 573 765	0.003	6 661 602	0.003
2	23 429	0.707	50 279	0.262	4 184 927	0.002	3 670 157	0.002	8 067 554	0.053	5 824 211	0.016
3	120 171	0.203	262 429	0.05	158 097	0.002	175 341	0.003	13 793 501	0.053	12 253 076	0.054
4	1 289 050	0.111	2 604 966	0.063	1 862 932	0.161	758 465	0.182	8 755 407	0.069	6 529 188	0.102
5	3 406 990	0.076	6 942 002	0.036	9 563 182	0.065	5 585 316	0.095	276 131	0.397	494 441	0.319
6	442 114	0.323	334 970	0.226	5 345 356	0.117	7 449 596	0.092	707 797	0.244	1 324 378	0.211
7	882 072	0.205	1 763 740	0.094	797 499	0.345	709 541	0.391	2 612 933	0.11	4 308 271	0.108
8	2 249 796	0.122	4 303 935	0.052	1 383 247	0.233	4 474 405	0.142	2 843 760	0.099	6 315 972	0.08
9	2 298 728	0.119	2 223 261	0.076	3 422 512	0.129	7 473 432	0.1	167 913	0.515	536 757	0.372
10	632 099	0.24	530 148	0.167	2 429 266	0.163	4 613 691	0.132	464 487	0.273	1 527 880	0.195
11	325 698	0.301	706 167	0.136	358 955	0.433	1 567 896	0.229	658 043	0.261	1 420 050	0.222
12	245 404	0.384	290 282	0.233	235 104	0.463	875 851	0.291	99 046	0.553	542 864	0.344
13	131 886	0.41	344 026	0.195	224 745	0.62	709 835	0.338	78 513	0.679	202 101	0.58
14	235 454	0.406	168 130	0.286	0	0	41 550	0.935	45 265	0.953	174 817	0.56
15	0	0	85 248	0.41	11 004	0.866	472 699	0.428	4 396	0.707	23 350	0.957
16	18 288	0.876	23 763	0.694	42 129	0.926	227 763	0.659	0	0	35 227	0.957
17	0	0	0	0	0	0	0	0	0	0	52 981	0.957
18	0	0	14 770	0.866	0	0	39 368	0.926	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
Unknown	17 788	0.077	27 515	0.225	137 295	0.383	53 581	0.128	125 636	0.382	82 853	0.311
No. aged	323		1136		294		370		313		411	
Mean c.v.				0.081				0.118				0.078

Appendix 2b cntd: **Calculated numbers at age (*n*) of the populations of hoki in the survey area, by sex and survey.**

	TAN9805			
	Male		Female	
Age	*n*	c.v.	*n*	c.v.
1	460 770	0.562	226 084	0.637
2	636 244	0.202	889 774	0.143
3	4 500 208	0.089	4 995 112	0.074
4	2 892 831	0.161	3 745 769	0.15
5	6 054 755	0.096	6 565 258	0.104
6	3 683 777	0.13	4 208 299	0.128
7	768 675	0.281	838 699	0.308
8	554 852	0.302	1 659 277	0.204
9	764 584	0.232	3 012 056	0.147
10	762 536	0.257	1 904 195	0.193
11	224 343	0.466	417 702	0.409
12	308 021	0.414	457 732	0.377
13	45 604	0.967	690 486	0.312
14	134 005	0.539	108 604	0.68
15	0	0	208 361	0.531
16	0	0	33 010	0.828
17	0	0	0	0
18	0	0	0	0
19	0	0	0	0
20	0	0	0	0
Unknown	0	0	0	0
No. aged	300		897	
Mean c.v.				0.155

Appendix 2c: **Calculated numbers at age (*n*) of the populations of ling in the whole survey area (300–1000 m), by sex and survey.**

	TAN9105				TAN9204				TAN9211			
	Male		Female		Male		Female		Male		Female	
Age	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.
1	0	0	0	0	0	0	0	0	0	0	0	0
2	3 486	0.883	0	0	0	0	0	0	0	0	0	0
3	43 869	0.542	50 058	0.548	37 335	0.482	26 138	0.535	33 105	0.429	36 000	0.504
4	82 966	0.297	170 751	0.274	116 359	0.267	131 905	0.276	100 578	0.262	111 267	0.354
5	245 546	0.204	212 442	0.269	165 966	0.329	193 546	0.357	219 147	0.203	243 187	0.213
6	665 219	0.136	538 696	0.17	677 661	0.171	420 317	0.226	314 649	0.202	308 146	0.186
7	545 252	0.173	514 858	0.197	712 208	0.206	636 003	0.194	399 723	0.18	443 233	0.164
8	638 787	0.157	792 342	0.143	1 470 440	0.139	1 075 749	0.153	251 445	0.237	373 303	0.185
9	263 433	0.269	690 246	0.167	598 055	0.263	678 386	0.209	251 087	0.237	366 297	0.185
10	184 270	0.287	602 447	0.174	578 405	0.241	922 289	0.178	171 748	0.285	264 622	0.227
11	133 586	0.351	396 470	0.231	370 357	0.325	597 893	0.217	157 242	0.295	479 008	0.172
12	138 326	0.334	469 281	0.226	470 269	0.29	662 036	0.198	182 611	0.28	317 381	0.211
13	74 965	0.447	204 336	0.279	143 532	0.513	391 850	0.25	69 812	0.423	309 309	0.207
14	69 307	0.355	172 174	0.282	267 788	0.315	211 904	0.336	113 773	0.339	249 056	0.236
15	68 567	0.397	137 076	0.287	149 243	0.366	267 215	0.296	128 186	0.339	206 239	0.246
16	29 926	0.443	118 772	0.359	109 050	0.452	123 048	0.36	55 403	0.521	103 558	0.337
17	42 979	0.569	14 774	0.78	84 662	0.59	109 142	0.539	52 531	0.439	142 302	0.297
18	29 770	0.548	61 845	0.407	43 403	0.746	134 018	0.343	54 367	0.412	158 094	0.275
19	9 212	0.744	37 578	0.646	20 809	0.936	66 685	0.563	31 662	0.623	80 503	0.386
20	13 489	0.811	21 792	0.863	188 135	0.446	81 730	0.53	24 111	0.532	37 402	0.592
21	29 490	0.801	23 105	1.218	127 149	0.593	51 583	0.503	51 806	0.539	25 535	0.726
22	87 170	0.397	26 892	0.528	239 322	0.406	29 822	0.66	12 642	0.867	15 845	0.83
23	8 678	0.97	4 856	1.041	49 135	0.702	22 202	0.64	29 648	0.556	13 924	0.906
24	2 987	1.233	5 946	1.79	45 426	0.843	64 726	0.617	10 949	0.972	21 845	0.708
25	0	0	6 527	0.98	30 214	0.832	11 650	0.89	0	0	10 908	1.046
>25	0	0	4 947	1.422	134 276	0.923	3 240	5.453	10 544	0.708	45 263	0.843
No. aged	219		349		216		310		225		350	
Mean c.v.				0.233				0.265				0.257

Appendix 2c cntd: **Calculated numbers at age (*n*) of the populations of ling in the survey area, by sex and survey.**

	TAN9304				TAN9310				TAN9605			
	Male		Female		Male		Female		Male		Female	
Age	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.	*n*	c.v.
1	0	0	0	0	0	0	0	0	0	0	0	0
2	9 361	1.211	0	0	0	0	0	0	0	0	0	0
3	86 294	0.546	43 105	1.052	102 794	0.451	73 211	0.328	102 616	0.323	61 996	0.456
4	150 938	0.244	134 958	0.389	404 140	0.19	258 419	0.256	418 378	0.211	306 839	0.437
5	330 585	0.233	296 532	0.235	474 824	0.178	445 961	0.235	372 581	0.261	529 490	0.252
6	599 439	0.199	429 235	0.198	359 851	0.23	458 360	0.174	679 343	0.18	578 314	0.271
7	823 311	0.184	685 500	0.166	342 836	0.239	628 083	0.161	846 483	0.138	564 309	0.219
8	617 863	0.225	569 995	0.184	377 613	0.228	612 601	0.169	448 474	0.202	513 220	0.202
9	512 400	0.245	695 147	0.182	383 033	0.211	509 699	0.187	411 983	0.203	456 862	0.229
10	530 813	0.246	430 485	0.234	289 791	0.255	473 307	0.193	456 270	0.203	394 654	0.229
11	505 893	0.257	709 969	0.168	208 113	0.295	354 338	0.223	270 257	0.245	349 263	0.276
12	465 582	0.259	523 093	0.208	300 772	0.245	376 257	0.217	268 787	0.242	321 522	0.272
13	198 480	0.418	464 460	0.214	218 355	0.29	362 455	0.224	467 347	0.186	331 842	0.259
14	252 272	0.346	343 102	0.234	247 405	0.26	418 073	0.187	392 279	0.207	382 997	0.387
15	298 846	0.329	258 856	0.275	276 853	0.266	252 717	0.264	256 562	0.252	361 139	0.254
16	97 278	0.549	128 165	0.375	118 881	0.354	133 983	0.359	114 432	0.436	86 871	0.482
17	171 248	0.404	167 346	0.334	138 680	0.327	121 415	0.348	225 839	0.269	132 423	0.442
18	119 106	0.394	217 817	0.284	120 582	0.359	84 020	0.397	125 643	0.387	76 313	0.51
19	102 963	0.577	115 883	0.379	15 474	0.919	166 672	0.287	11 682	1.025	110 985	0.452
20	107 165	0.496	55 997	0.662	27 485	0.748	61 463	0.498	24 703	0.728	20 606	1.182
21	111 550	0.491	51 351	0.632	12 580	1.029	68 549	0.515	36 045	0.601	34 055	0.517
22	22 467	0.719	28 838	0.735	32 006	0.782	37 122	0.698	33 679	0.706	0	0
23	113 316	0.441	15 781	1.15	37 718	0.603	13 070	0.934	18 597	0.792	0	0
24	62 032	0.619	26 976	0.715	16 062	1.058	15 359	0.907	50 719	0.522	0	0
25	0	0	12 528	1.041	12 987	0.998	6 758	1.132	0	0	0	0
>25	42 226	0.930	80 407	0.764	51 734	1.011	45 372	1.527	11 896	0.96	0	0
No. aged	256		370		247		346		331		274	
Mean c.v.				0.267				0.254				0.257

Appendix 2c cntd: **Calculated numbers at age (*n*) of the populations of ling in the survey area, by sex and survey.**

	TAN9805			
	Male		Female	
Age	*n*	c.v.	*n*	c.v.
1	0	0	0	0
2	64 324	0.522	98 804	0.631
3	270 431	0.271	439 282	0.262
4	722 914	0.185	634 221	0.215
5	746 835	0.186	769 880	0.179
6	488 161	0.231	525 512	0.215
7	608 391	0.222	525 028	0.218
8	620 412	0.22	508 310	0.232
9	412 598	0.277	601 825	0.226
10	259 363	0.338	376 171	0.278
11	446 643	0.268	322 754	0.297
12	350 274	0.285	321 985	0.312
13	85 830	0.521	299 375	0.298
14	198 515	0.358	229 846	0.337
15	232 012	0.328	228 994	0.323
16	241 599	0.305	164 562	0.357
17	206 884	0.37	207 940	0.33
18	83 027	0.547	117 701	0.464
19	55 350	0.606	48 843	0.762
20	60 647	0.686	20 849	1.216
21	38 106	0.753	48 293	0.935
22	16 151	0.897	0	0
23	8 814	1.487	12 747	1.396
24	18 478	1.065	12 585	1.347
25	0	0	0	0
>25	24 789	1.071	0	0
No. aged	271		296	
Mean c.v.				0.278