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Trawl survey of middle depth species in the Southland and Sub-Antarctic areas, November–December 2008 (TAN0813)

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EXECUTIVE SUMMARY

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The twelfth *Tangaroa* summer trawl survey of the Southland and Sub-Antarctic areas was carried out from 24 November to 23 December 2008. Ninety-five trawls were successfully completed in 21 strata.

Biomass estimates (and c.v.s) for all strata were 48 341 t (14%) for hoki, 22 880 t (10%) for ling, and 2354 t (16%) for hake. The hoki biomass was similar to the 2007 estimate of 46 003 t, confirming the large increase from 2006 (14 747 t). The hake estimate from all strata was also similar to that from 2007 (2622 t), although the estimate from core 300–800 m strata was lower because almost half of the hake biomass in 2008 was in stratum 25 (800–1000 m) at Puysegur. Ling were down slightly (by 14%) from 2007 (26 494 t). The biomass of javelinfish was the highest in the Sub-Antarctic trawl time series and four times higher than in 2007. Southern blue whiting and white warehou were also up from 2007, while estimates for some other species like ribaldo and pale ghost shark were down.

The size distribution of hoki was relatively broad, from 35–110 cm. The main age modes showed progression of cohorts from the 2007 survey, with a mode at age 6 (2002 year-class) for both males and females and at age 8 (2000 year-class) for females in 2008. Some larger older hoki (ages 9–16) were also present. The age distributions for hake and ling were also broad, with most hake aged between 4 and 18 years, and most ling between 3 and 15 years. The numbers of ling at ages 3 and 4 were the highest recorded in the summer time series for both sexes and may be indicative of good recent recruitment.

Acoustic data were also collected during the trawl survey. Total acoustic backscatter within 10 m of the bottom was the highest in the recent (since 2000) summer series. Total backscatter throughout the water column was also high. There was a weak positive correlation between acoustic density from bottom marks and trawl catch rates.

1. INTRODUCTION

Trawl surveys of the Southland and Sub-Antarctic region (collectively referred to as the "Southern Plateau") provide fishery-independent abundance indices for hoki, hake, and ling. Although the TACC for hoki has been reduced from 250 000 t to 90 000 t since 2000–01, hoki is still New Zealand's largest fishery. The Southland and Sub-Antarctic region is believed to be the principal residence area for the hoki that spawn off the west coast of the South Island (WCSI) in winter ("western" stock). Annual catches of hoki from the Southern Plateau (including Puysegur) peaked between 35 000 and 36 500 t from 1999–2000 to 2001–02, but have declined to 8000–9000 t in 2005–06 to 2007–08 (Ballara et al., NIWA, unpublished results). Hoki are managed as a single stock throughout the EEZ, but there is an agreement to split the catch between western and eastern areas. The catch limit for hoki from western areas (including the Southern Plateau) was 25 000 t in 2007–08. Hake and ling are also important commercial species in Southland and the Sub-Antarctic. The catches of hake and ling in the southern areas in 2007–08 were 2445 t (HAK 1, includes the western Chatham Rise), 4145 t (LIN 5, Southland), and 4502 t (LIN 6, Sub-Antarctic).

Two time series of trawl surveys have been carried out from *Tangaroa* in the Southland and Sub-Antarctic region: a summer series in November–December 1991, 1992, 1993, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007 and 2008; and an autumn series in March–June 1992, 1993, 1996 and 1998 (reviewed by O'Driscoll & Bagley (2001)). The main focus of the early surveys (1991–93) was to estimate the abundance of hoki. The surveys in 1996 and 1998 were developed primarily for hake and ling. Autumn was chosen for these species as the biomass estimates were generally higher and more precise at this time of year. Autumn surveys also allowed the proportion of hoki maturing to spawn to be estimated (Livingston et al. 1997, Livingston & Bull 2000). However, interpretation of trends in the autumn trawl survey series was complicated by the possibility that different proportions of the hoki adult biomass may have already left the survey area to spawn. The timing of the trawl survey was moved back to November–December in 2000 to obtain an estimate of total adult hoki biomass at a time when abundance should be at a maximum in the Southland and the Sub-Antarctic areas.

The hoki biomass estimate from the four Southern Plateau surveys in 2003 to 2006 were the lowest observed in either the summer or autumn Sub-Antarctic trawl time-series (O'Driscoll & Bagley 2004, 2006a, 2006b, 2008). The biomass estimate in 2006 was 28% lower than in 2005, the second lowest in the time series (after 2003), and less than 20% of the biomass observed in the Sub-Antarctic in the early 1990s (O'Driscoll & Bagley 2008). The biomass estimate for hoki in 2007 was 46 003 t, which was three times that of 2006 survey and back to the 2001–02 biomass levels (Bagley et al. 2009). However, the large increase between the 2006 and 2007 surveys could not be fitted by the assessment model (Francis 2009a), and there was concern that this increase was caused by a change in trawl catchability (Bagley et al. 2009). The apparent change in catchability was not related to changes in gear or gear performance. The trawl was repeatedly measured in 2007 and gear parameters were consistent with specifications obtained on previous surveys (Bagley et al. 2009). Despite the large increase in the estimated hoki biomass, back to the 2001–02 levels, the 2007 estimate was still less than 50% of the biomass observed in the Sub-Antarctic in the early 1990s.

The stock status for "western" hoki stock from the 2008 assessment suggested that median estimates of current biomass were 28–30% B_0 and that there was an extended period of poor recruitment from 1995 to 2001 (Francis 2009a). The 2008 survey, carried out from 24 November to 23 December 2008 (TAN0813) provided a twelfth summer estimate of western hoki biomass in time for the 2009 assessment. With the discontinuation of the WCSI acoustic surveys, this is the only abundance index available for western hoki.

1.1 Project objectives

The trawl survey was carried out under contract to the Ministry of Fisheries (project MDT2007/01B). The specific objectives for the project were as follows.

1. To continue the time series of relative abundance indices for hoki, hake (HAK 1), and ling (LIN 5 and 6) on the Southern Plateau.

2. To determine the population age and size structure and reproductive biology of hoki, hake, and ling.

3. To determine the proportions at age of hoki taken in the survey using otolith samples.

4. To collect acoustic and related data during the trawl survey.

5. To collect gonad samples from female hoki for studies on the proportion spawning.

6. To collect and preserve specimens of unidentified organisms taken during the trawl survey, and identify them later ashore.

2. METHODS

2.1 Survey design

As in previous years, the survey was a two-phase stratified random design (after Francis 1984). The survey area was divided into 21 strata by depth (300–600, 600–800, and 800–1000 m) and area (Figure 1). There are 15 core 300–800 m strata (Strata 1 to 15) which have been surveyed in all previous summer and autumn surveys (Table 1). Strata 3 and 5 were subdivided in 2000 to increase the coverage in the region where hake and ling aggregations were thought to occur (Bull et al. 2000). Deeper 800–1000 m strata (Strata 25–28) have been surveyed since 1996. There is no 800–1000 m stratum along the eastern side of the survey area as catches of hake, hoki, and ling from adjacent strata are small. Known areas of foul ground were excluded from the survey.

The allocation of stations in phase 1 was based on a statistical analysis of catch rate data from the eight most recent surveys (2000–07) using the ‘allocate’ procedure of Bull et al. (2000) as modified by Francis (2006). A minimum of three stations per stratum was used. Conservative target coefficients of variation (c.v.s) of 17% for hake and 12% for hoki and ling were used in the statistical analysis to increase the chance that the usual Ministry of Fisheries target c.v.s of 20% for hake and 15% for hoki and ling would be met. Additional stations were added to some strata outside the statistical framework because of the need to focus effort on covering the full distributional range of hake age classes. A total of 84 stations was originally planned for phase 1 (Table 1), with phase 2 stations to be allocated at sea to improve c.v.s for hoki, hake, ling, and southern blue whiting, and to increase the number of hake sampled.

2.2 Vessel and gear specifications

R.V. *Tangaroa* is a purpose-built research stern trawler of 70 m overall length, a beam of 14 m, 3000 kW (4000 hp) of power, and a gross tonnage of 2282 t.

The trawl was the same as that used on previous surveys of middle depth species by *Tangaroa.* The net is 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.

The winch control system was changed from the original Brattvaag system, in use from 1991 to mid 2008, to a Scantrol system. Care was taken to ensure the new controls emulated the old system.

2.3 Trawling procedure

Trawling followed the standardised procedures described by Hurst et al. (1992). Station positions were selected randomly before the voyage using the Random Stations Generation Program (Version 1.6) developed at NIWA, Wellington. A minimum distance between stations of 3 n. miles was used. 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 during daylight hours (as defined by Hurst et al. (1992)), with all trawling between 0448 h and 1936 h NZST. 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. If time ran short at the end of the day and it was not possible to reach the last station, the vessel headed towards the next station and the trawl was shot on that course before 1900 h NZST, if at least 50% of the steaming distance to the next station was covered.

Towing speed and gear configuration were maintained as constant as possible during the survey, following the guidelines given by Hurst et al. (1992). Measurements of doorspread (from a Scanmar 400 system), headline height (from a Furuno net monitor), and vessel speed were recorded every 5 min during each tow and average values calculated.

2.4 Acoustic data collection

Acoustic data were collected during trawling and while steaming between trawl stations (both day and night) with the new *Tangaroa* multi-frequency (18, 38, 70, 120, and 200 kHz) Simrad EK60 echosounders with hull-mounted transducers. All five frequencies were calibrated following standard procedures (Foote et al. 1987) on 30 May 2008 during a fisheries oceanography voyage (TAN0806). The system and calibration parameters are given in Table 2.

2.5 Hydrology

Temperature and salinity data were collected using a calibrated Seabird SM-37 Microcat CTD datalogger (serial number 2958) mounted on the headline of the trawl. Data were collected at 5 s intervals throughout the trawl, providing vertical profiles. Surface values were read off the vertical profile at the beginning of each tow at a depth of about 5 m, which corresponded to the depth of the hull temperature sensor used in previous surveys. Bottom values were about 7.0 m above the sea-bed (i.e., the height of the headline).

2.6 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 were identified to species, genus, or family.

Unidentified organisms were collected and frozen at sea. Specimens are being stored at NIWA for subsequent identification.

An approximately random sample of up to 200 individuals of each commercial, and some common non-commercial, species from every successful tow was measured and sex determined. More detailed biological data were also collected on a subset of species and included fish weight, sex, gonad stage, gonad weight, and occasional observations on stomach fullness, contents, and prey condition. Otoliths were taken from hake, hoki, and ling for age determination. A description of the macroscopic gonad stages used for the three main species is given in Appendix 1.

Liver and gutted weights were recorded from up to 20 hoki per station to determine condition indices. Female gonads from the subset of hoki with recorded organ weights were preserved in formalin and are available for histological examination to estimate proportion spawning (Grimes & O'Driscoll 2006).

Spines were also taken from shovelnosed dogfish and deepwater spiny dogfish for MFish project ENV2008/04.

2.7 Estimation of biomass and length frequencies

Doorspread biomass was estimated by the swept area method of Francis (1981, 1989). The new analysis programme SurvCalc (Francis 2009b) was used to calculate biomass. Formulae followed those of the original Trawl Survey Analysis program (Vignaux 1994). Total survey biomass was estimated for the top 20 species in the catch by weight. Biomass and c.v. were also calculated by stratum for major species. The group of 12 major species was defined by O'Driscoll & Bagley (2001), and comprises the three target species (hoki, hake, ling), eight other commercial species (black oreo, dark ghost shark, lookdown dory, pale ghost shark, ribaldo, southern blue whiting, spiny dogfish, white warehou), and one non-commercial species (javelinfish).

The catchability coefficient (an estimate of the proportion of fish in the path of the net which is caught) is the product of vulnerability, vertical availability, and areal availability. These factors were 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 trawl doors were caught.

Scaled length frequencies were calculated for the major species with SurvCalc, using length-weight data from this survey.

Only data from stations where the gear performance was satisfactory (codes 1 or 2) were included for estimating biomass and calculating length frequencies.

2.8 Estimation of numbers at age

Hoki, hake, and ling otoliths were prepared and aged using validated ageing methods (hoki, Horn & Sullivan (1996) as modified by Cordue et al. (2000); hake, Horn (1997); ling, Horn (1993)).

Subsamples of 759 hoki otoliths, 583 ling otoliths, and 600 hake otoliths were selected from those collected during the trawl survey. Subsamples were obtained by randomly selecting otoliths from 5 cm length bins covering the bulk of the catch and then systematically selecting additional otoliths to ensure the tails of the length distributions were represented. The numbers aged approximated the sample size necessary to produce mean weighted c.v.s of less than 20% across all age classes.

Numbers at age were calculated from observed length frequencies and age-length keys using customised NIWA catch-at-age software (Bull & Dunn 2002). For hoki, this software also applied the "consistency scoring" method of Francis (2001), which uses otolith ring radii measurements to improve the consistency of age estimation.

2.9 Acoustic data analysis

Acoustic analysis generally followed the methods applied to recent Sub-Antarctic trawl surveys (e.g., Bagley et al. 2009). All acoustic recordings made during the survey were visually examined. Marks were classified into seven main categories based on the relative depth of the mark in the water column, mark orientation (surface or bottom-referenced), mark structure (layers or schools), and the relative strength of the mark on the five frequencies. Most of the analyses in this report are based on the 38 kHz data as this frequency was the only one available (along with uncalibrated 12 kHz data) for all previous surveys that used the old CREST acoustic system (Coombs et al. 2003). We did not attempt to do a full multifrequency analysis of mark types for this report.

Descriptive statistics were produced on the frequency of occurrence of different marks. Brief descriptions of the mark types are given below. Example (38 kHz) echograms may be found in O'Driscoll (2001).

1. Surface layers
These occurred within the upper 100 m of the water column and tended to be stronger on 18 kHz (previously 12 kHz) than on other frequencies.

2. Pelagic layers
Surface-referenced midwater layers which were typically continuous for more than 1 km. Like surface layers these were typically strongest on 18 kHz.

3. Pelagic schools
Well defined schools in midwater which are generally similar on all frequencies.

4. Pelagic clouds
Surface-referenced midwater marks which were more diffuse and dispersed than pelagic layers, typically over 100 m thick with no clear boundaries.

5. Bottom layers
Bottom-referenced layers which were continuous for more than 1 km and were generally stronger on 38 kHz and 70 kHz than on 18 kHz.

6. Bottom clouds
Bottom-referenced marks which were more diffuse and dispersed than bottom layers with no clear upper boundary.

7. Bottom schools
Distinct schools close to the bottom.

As part of the qualitative description, the quality of acoustic data recordings was subjectively classified as 'good', 'marginal', or 'poor' (see appendix 2 of O'Driscoll & Bagley (2004) for examples). Only good or marginal quality recordings were considered suitable for quantitative analysis.

A quantitative analysis was carried out on daytime trawl recordings. Acoustic data collected on 38 kHz during each tow were integrated using custom Echo Sounder Package (ESP2) software (McNeill 2001). Three values of the mean acoustic backscatter per square kilometre were calculated for each trawl. The first estimate was based an integration height of 10 m above the acoustic bottom, which was similar to the measured headline height of the trawl (average 7.0 m). The second acoustic estimate integrated all backscatter from bottom referenced marks (bottom layers, clouds, and schools) up to 100 m off the bottom, but excluded all other mark types. The final acoustic estimate was of the total acoustic backscatter throughout the water column. Acoustic density estimates (backscatter per km^2) from bottom-referenced marks were then compared with trawl catch rates (kg per km^2). No attempt was made to scale acoustic estimates by target strength, correct for differences in catchability, or carry out species decomposition (O'Driscoll 2002, 2003).

3. RESULTS

3.1 Survey coverage

The trawl survey and acoustic work contracted for this voyage were successfully completed. Weather conditions were calm to moderate for much of the voyage and only 8 hours was lost due to unfavourable sea conditions. A further 24 hours were lost before the survey started because of a hydraulic pipe on a gilson winch failing during a gear trial.

Ninety-five successful trawl survey stations were completed in 21 strata (Figure 2, Table 1). This total included 83 phase 1 stations and 12 phase 2 stations. One phase 1 station in stratum 5A was dropped because the ground in the vicinity of the final station in this stratum was foul, and substitute stations required a considerable steam.

One additional station was completed in stratum 13 during phase 1 of the survey due to variable catches of hoki and ling and because of the long steaming distance to return to these areas for any phase 2 work. Most phase 2 effort was directed at reducing the c.v. for hake and increasing the number of hake sampled in strata 4, 11, 25, and 28.

Three stations were considered unsuitable for biomass estimation: station 1 came fast, station 18 was hauled early because of deteriorating weather, and station 62 was rejected due to gear damage.

Stratum 26, south of Campbell Island was, completed this year. Often this stratum is dropped should time be lost due to weather or other factors (as in 2003, 2004 and 2006). No hoki, hake, or ling were caught in this stratum.

3.2 Gear performance

Gear parameters by depth and for all observations are summarised in Table 3. The headline height was obtained for all successful tows, and doorspread readings were available for 92 of the 95 tows. Missing doorspread values were calculated from data collected in the same depth range on this voyage. Measured gear parameters in 2008 were within the range of those obtained on other voyages of *Tangaroa* in this area when the same gear was used (Table 4). The new Scantrol winch controllor behaved similarly to the original Brattvaag system with no change to gear parameters. Warp-to-depth ratios were the same as in previous years, following the recommendations of Hurst et al. (1992).

3.3 Catch

A total catch of 57.1 t was recorded from all trawl stations (56.2 t from valid biomass tows). From the 198 species or species groups caught: 96 were teleosts, 27 elasmobranchs, 10 cephalopods, and 17 crustaceans (Appendix 2). For the key species hoki accounted for 22.4%**,** ling 11.4%, and hake 6.0% of the total catch, while 16% if the catch was javelinfish. Specimens retained for later identification ashore are listed in Appendix 3.

3.4 Biomass estimates

Total survey biomass estimates for the 20 species with highest catch weights are given in Table 5. Biomass estimates are presented by stratum for the 12 major species (as defined by O'Driscoll & Bagley (2001)) in Table 6. Subtotals for these species are given for the core 300–800 m depth range (strata 1–15) and core + Puysegur 800–1000 m (strata 1–25) in Table 6 to allow comparison with results of previous surveys where not all deep (800–1000 m) strata were surveyed (Table 7). The time series of core estimates for the 12 major species are plotted in Figure 3.

Biomass estimates for hoki for all strata in 2008 was 48 340 t. The hoki biomass was similar to the 2007 estimate of 46 003 t, confirming the large increase from 2006 (14 747 t) (Figure 3). Despite the large increases in 2007 and 2008 the hoki biomass is still much lower than the biomass observed in the Sub-Antarctic in the early 1990s (Table 7). The biomass estimates for length ranges corresponding to 1+ (less than 46 cm) and 2+ (46–57 cm) hoki were 948 t (c.v. 48%) and 1563 t (c.v. 37%) respectively.

The hake estimate from all strata was 2355 t, also similar to that from 2007 (2622 t), although the estimate from core 300–800 m strata was lower because almost half of the hake biomass (1088 t) in 2008 was in stratum 25 (800–1000 m) at Puysegur (see Table 6). The ling estimate was 22 879 t, down slightly (by 14%) from 2007 (26 492 t).

Six of the nine other major species also increased from 2007 for the total survey area. Most changes were generally small and within the levels of the sampling uncertainty (Figure 3). However, the biomass of javelinfish was the highest in the Sub-Antarctic trawl time series and four times higher than last year's estimate. Southern blue whiting biomass was nearly double the estimate from 2007 at 15 219 t. Estimates for pale ghost shark, ribaldo, and spiny dogfish were lower than 2007.

3.5 Species distribution

The distribution and catch rates at each station for hoki, hake, and ling are given in Figures 4–6. Hoki were widespread throughout the core survey area, occurring in 90 of the 95 successful trawl stations. As in previous surveys, hoki catch rates were generally higher in the west, on the edge of the Stewart-Snares shelf, on the western side of the Campbell Rise, and at Puysegur (Figure 4a). A moderately large catch of 801 kg was made to the northeast of the Pukaki Rise in stratum 11. Catches of small (1 and 2 year-old) hoki followed a similar distribution to those observed in previous surveys, and were taken in stratum 1 (300–600 m) at Puysegur and in the 300–600 m strata along the edge of the Stewart-Snares shelf (Figures 4b and 4c).

Hake were concentrated in deeper water at Puysegur in stratum 25 (800–1000 m). Catches to the south and east of the Stewart-Snares shelf were small, less than 65 kg per tow (Figure 5) while most stations in the east and south of the survey area caught no hake. Ling were caught on all but three stations between 300 and 800 m depth (Figure 6). One large catch of ling of 1.7 t was taken at Puysegur in stratum 1 (300–600 m). Both hoki and ling were seldom caught deeper than 800 m. No hoki or ling were taken in the southern most stratum, 26 (800–1000 m)

3.6 Biological data

The numbers of fish of each species measured or selected for biological analysis are shown in Table 8. Pairs of otoliths were removed from 1360 hoki, 1051 ling, and 827 hake. Length-weight relationships used to scale length frequency data are given in Table 9. Length frequency histograms by sex for hoki, hake, and ling are compared to those observed in previous surveys in Figures 7–9. Length frequencies for the other major species are shown in Figure 10.

Hoki length frequencies in 2008 show a broad size range with a similar length distribution to the 2007 survey (Figure 7). Population scaled numbers of hoki were similar to those recorded in 2007. There were fewer small 1+ and 2+ hoki than in the 2003 and 2004 surveys. Modes at 33–46 cm and 47–57 cm correspond to hoki from the 2007 and 2006 year-classes (Figure 7). Although these juvenile year-classes were abundant by number, they contributed relatively little to the biomass (see Section 3.4). Modes from about 70–95 cm consisted of fish from the 2002–04 year classes at ages 4–6 and followed modes at ages 3–5 from the 2007 survey. Ageing indicated a mode at age 6 (2002 year-class) for both males and females (Figure 11). Some larger older hoki were also present between 90 and 110 cm for the females and 90 and 98 cm for the males (see Figure 11a), with a strong showing of females from the 2000 year class at age 8 (see Figure 11b).

The length frequency distribution of hake showed no clear modes (see Figure 8). As in some previous surveys small (50–70 cm) hake were captured in quite high numbers at 800–1000 m depth at Puysegur (stratum 25). Hake were taken in low numbers outside stratum 25 and this is reflected in the core strata length and age frequencies. Since 1998 there has been a lower proportion of large hake (older than age 12) than were observed in surveys in the early 1990s (Figure 12).

The length frequency distribution of ling was broad, with a slight increase in the numbers of fish under 50 cm for both sexes (see Figure 9). These smaller fish were reflected in the age frequencies, with the highest numbers of fish at age 3 and age 4 recorded for any of the surveys in the summer times series (Figure 13). The age frequency for ling showed most fish were between 3 and 15 years old, with the mode at age 4 for males and no clear mode for females (Figure 13).

The length frequency distribution of southern blue whiting caught in 2008 had a strong mode between 24 and 31 cm for both sexes (see Figure 10). These are probably fish of age 2 (2006 year-class). Black oreo were slightly larger than those observed in 2007, with modal lengths of 31 cm for males and 32 cm for females (see Figure 10). Other points of interest in Figure 10 included: a large mode at 31 cm in the length distribution of javelinfish, different from the past four surveys where bimodal length frequencies were recorded (O'Driscoll & Bagley 2006a, 2006b, 2008, Bagley et al. 2009); the continuing high proportion of female ribaldo; and the difference in the length frequencies of male and female spiny dogfish.

Gonad stages for hoki, hake, and ling are summarised in Table 10. Immature hoki made up 25% of fish examined, and these were typically fish smaller than 70 cm. Most adult hoki (67%) were in the resting phase. About 2% of female hoki and 8% of male hoki were macroscopically staged as partially spent or spent. Female ling were mostly resting (65%) or immature (20%), but male ling of all gonad stages were recorded, with 45% in spawning condition (ripe and running ripe). Immature stage hake made up 60% of the observations for both sexes. About 20% of male hake were ripe or running ripe, while few female hake in these stages were recorded.

3.7 Hoki condition indices

Liver and gutted weights were recorded from 1333 hoki. Mean hoki liver condition index (LCI = liver weight divided by gutted weight) and somatic condition factor (CF = gutted weight divided by length cubed) are given in Table 11. Somatic condition was relatively high in 2008, but liver condition (of all fish combined) was lower than in the four previous years (Table 11). This suggests good overall body condition, but less good recent feeding, and/or later spawning, both of which would reduce liver condition.

A comparison of LCI of hoki in the Chatham Rise and Sub-Antarctic trawl surveys showed consistent patterns between the areas (Figure 14). The comparison was restricted to 60–80 cm hoki, because LCI can vary with size, and the length distributions of fish differ between the two areas (see Stevens et al. (2009) for Chatham Rise data). The consistent pattern in liver condition of hoki from the Chatham Rise and Sub-Antarctic suggests that similar processes are affecting the two areas. This hypothesis will be investigated further in 2009–10 as part of the MFish project ENV2009/04.

As in 2001–07 female hoki that were macroscopically staged as spent (stage 7) during the 2008 Sub-Antarctic survey tended to have lower LCI (average LCI = 2.54%, n = 32) than resting (stage 2) females (average LCI = 2.92%, n = 620). This suggests that fish that have recently spawned may have lower condition than fish that either spawned earlier or did not spawn. A similar pattern was observed for male hoki in 2005 (O'Driscoll & Bagley 2006b), 2006 (O'Driscoll & Bagley 2008), and 2007 (Bagley et al. 2009), but not in 2001–04 or 2008. In 2008, the average LCI for male hoki that were partially spent or spent (stages 6–7) (n = 50) was the same as the average LCI of 2.50% for resting (stage 2) males (n = 270).

Gonad samples were taken from 705 female hoki and preserved in 10% buffered formalin. These are available for histological examination to estimate proportion spawning (Grimes & O'Driscoll 2006).

3.8 Acoustic results

A total of 235 acoustic data files (97 trawl files and 138 steam files) was recorded during the 2008 survey. Data quality was generally good, but deteriorated during periods of bad weather. About 11% of the acoustic files were considered too noisy to be analysed quantitatively (Table 12).

Mark types were similar to those described for previous surveys (O'Driscoll 2001, O'Driscoll & Bagley 2003a, 2003b, 2004, 2006a, 2006b, 2008, Bagley et al. 2009). The frequency of occurrence in 2008 of each of the seven mark categories is given in Table 13. Surface layers were observed in 82% of daytime echograms and 98% of night echograms in 2008 (Table 13). The identity of organisms in these surface layers is unknown because no tows have been targeted at the surface in this region. Acoustic scattering is probably contributed by a number of pelagic zooplankton (including gelatinous organisms such as salps) and fish. Pelagic schools and layers were also common and likely contain mesopelagic fish species such as pearlsides (*Maurolicus australis*) and myctophids, which are important prey of hoki. Bottom layers, which are associated with a mix of demersal fish species, were observed in 59% of day steam files, 36% of overnight steams, and 45% of trawl files in 2008 (Table 13). As in previous years (O'Driscoll 2001, O'Driscoll & Bagley 2006b, Bagley et al. 2009), bottom schools were occasionally observed during the day in 300–600 m water depth, and these were often associated with catches of southern blue whiting in the bottom trawl (e.g., Figure 15).

Pelagic and bottom layers tend to disperse at night, to form pelagic and bottom clouds respectively. In previous surveys cloud marks were detected more often in night recordings. However, in 2008, dispersed cloud marks were frequently observed in daytime recordings during trawls and while steaming (Table 14). The increase in dispersed marks in 2008 was associated with an increase in total backscatter (i.e., backscatter throughout the water column) from the 92 trawl files which were integrated (Table 14). Data from the other five trawl recordings were not included in the quantitative analysis because the acoustic data were too noisy (three files) or because the accompanying bottom trawl was not considered suitable for biomass estimation (two files). Total acoustic backscatter in 2008 was 33% higher than in 2007 and the highest in the four survey's where this has been calculated (Table 14). Likewise, the backscatter from the bottom 10 m was 67% higher in 2008 than that in 2007, and was the highest in the series. This was consistent with the high total trawl catch rates recorded in 2008 (Table 14).

There was a weak positive correlation between acoustic backscatter and trawl catch rates (Figure 16). Trawl catch rates were more strongly correlated with total acoustic backscatter from bottom-referenced marks than with backscatter from the bottom 10 m only (Figure 16). This suggests that the trawl may be vertically herding fish from more than 10 m above the bottom. Weak, but significant, positive correlations between backscatter and catches have been observed in surveys in 2000, 2001, 2003, 2005, and 2007 (O'Driscoll 2002, O'Driscoll & Bagley 2004, 2006b, Bagley et al. 2009), but not in 2002, 2004, or 2006 (O'Driscoll & Bagley 2003b, 2006a, 2008).

Acoustic methods are unlikely to provide alternative abundance estimates for demersal species in the Sub-Antarctic because of the relatively low fish densities and mixed species composition. However, we believe it is useful to continue to collect acoustic data to monitor other components of the ecosystem (especially mesopelagic fish) and to aid in the interpretation of trawl survey results. A more extensive analysis of mesopelagic acoustics in the Sub-Antarctic from this and previous surveys will be carried out in 2009–10 as part of MFish project ENV200904. Analysis of analogous acoustic data from the Chatham Rise trawl survey series has already led to development of a time-series of abundance estimates for diurnally migrating mesopelagic fish (O'Driscoll et al. 2009). Comparison of acoustic data from the two regions suggests that there is 2–5 times more total backscatter on the Chatham Rise (38–59 $m^2 km^{-2}$, Stevens et al. 2009) than in the Sub-Antarctic (9–16 $m^2 km^{-2}$, Table 14).

3.9 Hydrological data

Temperature profiles were available from 98 CTD casts. Surface (5 m depth) temperatures ranged between 7.1 and 13.1 °C (Figure 17), while bottom temperatures were between 4.6 and 11.4 °C (Figure 18). Bottom temperature decreased with depth, with lowest bottom temperatures recorded from water deeper than 900 m on the margins of the Campbell Plateau. Highest surface and bottom temperatures were at Puysegur. As in previous years, there was a general trend of increasing water temperatures towards the north and west (Figures 17–18).

The average surface temperature in 2008 of 9.4 °C was similar to that observed in 2007 (9.5 °C), and within the range of average surface temperatures observed in 2002–06 (8.8–10.3 °C). In general there is a negative correlation between surface temperature and depth of the thermocline (Figure 19), with cooler surface temperatures in years when the thermocline is deep (e.g., 2003), and warm surface temperatures when there is a shallow mixed layer (e.g., 2002). O'Driscoll & Bagley (2006b) hypothesised that the depth of the thermocline is related to the amount of surface mixing and extent of thermal stratification, with shallower mixed layers in those years with warmer, more settled weather. As in 2007, the thermocline in 2008 was at about 80–150 m, which is average for this time of year (e.g., Figure 19). Average bottom temperatures in 2008 (6.9 °C) were within the range of average temperatures observed in 2002–07 (6.7–7.0 °C). However, at some locations (e.g., Figure 19), bottom temperatures were the lowest observed. It is difficult to compare temperatures with those observed on Sub-Antarctic surveys before 2002 because temperature sensors were uncalibrated.

4. DISCUSSION

There was a very large (threefold) increase in estimates of hoki abundance between the 2006 and 2007 trawl surveys (Bagley et al. 2009). This increase was confirmed by the 2008 survey, but could not be fitted by the stock assessment model in 2009. Bagley et al. (2009) explored two possible explanations for the sharp rise in 2007: 1) recruitment of hoki to the Sub-Antarctic from the Chatham Rise; 2) a change in trawl survey catchability between 2006 and 2007. Neither hypothesis could be discounted, but there was more supporting evidence for a change in trawl catchability (Bagley et al. 2009). Hoki increased across all age classes in 2007, which was not consistent with the hypothesis of recruitment from the Chatham Rise which mainly occurs at ages 3–7 (Livingston et al. 2002). The age frequency observed in 2008 (see Figure 11) was consistent with the age frequency in 2007. Biomass estimates in core strata for 11 of the 12 major species also increased from 2006 to 2007, which supported the hypothesis that there was a change in catchability between these two surveys (Bagley et al. 2009). There was no consistent increase or decrease in abundance of core species between 2007 and 2008, with 5 of 12 species decreasing and 7 species increasing (see Figure 6). It is still not clear whether catchability was unusually high in 2007–08 or unusually low in 2006.

Any apparent changes in trawl survey catchability were not related to changes in gear or gear performance. The trawl has been within consistent specifications throughout the time series (see Table 4). Bagley et al. (2009) found that unstandardised commercial catch rates of hoki during the survey period also increased considerably from 2006 to 2007, suggesting that the change in hoki catchability was not restricted to the research survey. Total acoustic backscatter from bottom marks in 2007–08 was also higher than that observed in 2006 (see Table 14), which was consistent with the higher trawl catches.

5. CONCLUSIONS

The hoki biomass was similar to the 2007 estimate of 46 005 t, confirming the large increase from 2006 (14 747 t). The survey methodology was consistent with previous years and it is still not clear whether catchability was unusually high in 2007–08 or unusually low in 2006. Despite the large increase in the estimated hoki biomass in the past two surveys the 2008 estimate is still much less than the biomass observed in the Sub-Antarctic in the early 1990s. The hoki age frequency observed in 2008 was consistent with the age frequency in 2007. In 2008, modes at age 6 for males and females, and at age 8 for females, showed progression of the 2002 and 2000 year-classes, observed at ages 5 and 7 in 2007.

Biomass estimates for hake and ling for all strata in 2008 were slightly lower that those recorded in 2007, by 12% and 14% respectively. However, the estimate of hake biomass from core 300–800 m strata was much lower than in 2007 because almost half of the hake biomass in 2008 was in stratum 25 (800– 1000 m) at Puysegur.

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Table 1: Stratum areas, depths, and number of successful biomass stations from the November–December 2008 Southland and Sub-Antarctic trawl survey. Stratum boundaries are shown in Figure 1, and station positions are plotted in Figure 2.

Stratum	Name	Depth (m)	Area (km^2)	Proposed phase 1 stations	Completed phase 1 stations	Completed phase 2 stations
1	Puysegur Bank	300–600	2 150	4	4	
2	Puysegur Bank	600–800	1 318	4	4	
3a	Stewart-Snares	300–600	4 548	5	5	
3b	Stewart-Snares	300 -600	1 556	4	4	
4	Stewart-Snares	600–800	21 018	4	4	2
5a	Snares-Auckland	600–800	2 981	5	4	
5b	Snares-Auckland	600–800	3 281	4	4	
6	Auckland Is.	300–600	16 682	4	4	
7	South Auckland	600–800	8 497	3	3	
8	N.E. Auckland	600–800	17 294	4	4	
9	N. Campbell Is.	300–600	27 398	6	6	
10	S. Campbell Is.	600–800	11 288	3	3	
11	N.E. Pukaki Rise	600–800	23 008	4	4	3
12	Pukaki	300–600	45 259	7	7	
13	N.E. Camp. Plateau	300–600	36 051	3	3	1
14	E. Camp. Plateau	300–600	27 659	3	3	
15	E. Camp. Plateau	600–800	15 179	3	3	
25	Puysegur Bank	800–1 000	1 928	4	4	4
26	S.W. Campbell Is.	800–1 000	31 778	3	3	
27	N.E. Pukaki Rise	800–1 000	12 986	3	3	
28	E. Stewart Is.	800–1 000	8 336	4	4	2
Total			**320 159**	**84**	**83**	**12**

Table 2: EK60 transceiver settings and other relevant parameters. Values in bold were calculated from the calibration on 30 May 2008.

Parameter					
Frequency (kHz)	18	38	70	120	200
GPT model	GPT-Q18(2)-S 1.0 00907205c476	GPT-Q38(4)-S 1.0 00907205c463	GPT-Q70(1)-S 1.0 00907205ca98	GPT-Q120(1)-S 1.0 009072058148	GPT-Q120(1)-S 1.0 009072058148
GPT serial number	652	650	674	668	692
GPT software version	050112	050112	050112	050112	050112
ER60 software version	2.1.2	2.1.2	2.1.2	2.1.2	2.1.2
Transducer model	Simrad ES18-11	Simrad ES38	Simrad ES70-7C	Simrad ES120-7C	Simrad ES200-7C
Transducer serial number	2080	23083	158	477	364
Transmit power (W)	2000	2000	1000	500	300
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Transducer peak gain (dB)	**22.96**	**25.81**	**26.43**	**26.17**	**24.96**
Sa correction (dB)	**-0.81**	**-0.57**	**-0.35**	**-0.36**	**-0.25**
Bandwidth (Hz)	1570	2430	2860	3030	3090
Sample interval (m)	0.191	0.191	0.191	0.191	0.191
Two-way beam angle (dB)	–17.0	–20.60	–21.0	–21.0	–20.70
Absorption coefficient (dB/km)	2.67	9.79*	22.79	37.44	52.69
Speed of sound (m/s)	1494	1494	1494	1494	1494
Angle sensitivity (dB) alongship/athwartship	13.90/13.90	21.90/21.90	23.0/23.0	23.0/23.0	23.0/23.0
3 dB beamwidth (º) alongship/athwartship	**10.8/10.8**	**7. 0/7.0**	**6.6/6.6**	**6.5/6.6**	**6.8/6.9**
Angle offset (º) alongship/athwartship	**0.0/0.0**	**0.0/0.0**	**0.0/0.0**	**0.0/0.0**	**0.0/0.0**
Calibration RMS deviation (dB)	**0.26**	**0.16**	**0.25**	**0.35**	**0.39**

* Acoustic densities were calculated with an absorption coefficient of 8.0 dB km^{-1} so that these would be comparable to earlier results from the CREST acoustic system.

Table 3: Survey tow and gear parameters (recorded values only). Values are number of tows (n), and the mean, standard deviation (s.d.), and range of observations for each parameter.

	n	Mean	s.d	Range
Tow parameters				
Tow length (n.miles)	95	2.99	0.12	2.07–3.05
Tow speed (knots)	95	3.5	0.06	3.3–3.6
Gear parameters (m)				
300–600 m				
Headline height	37	6.9	0.22	6.6–7.5
Doorspread	37	114.1	5.10	103.8–125.4
600–800 m				
Headline height	38	6.9	0.21	6.4–7.3
Doorspread	35	116.3	4.78	104.6–125.3
800–1000 m				
Headline height	20	6.9	0.25	6.2–7.3
Doorspread	20	116.9	5.04	109.7–128.3
All stations 300–1000 m				
Headline height	95	6.9	0.22	6.2–7.5
Doorspread	92	115.5	5.05	103.8–128.3

Table 4: Comparison of doorspread and headline measurements from all surveys in the summer *Tangaroa* time-series. Values are the mean and standard deviation (s.d.). The number of tows with measurements (n) and range of observations is also given for doorspread.

	Doorspread (m)					Headline height (m)	
Survey	*n*	mean	s.d.	min	max	mean	s.d.
1991	152	126.5	7.05	106.5	145.5	6.6	0.31
1992	127	121.4	6.03	105.0	138.4	7.4	0.38
1993	138	120.7	7.14	99.9	133.9	7.1	0.33
2000	68	121.4	5.22	106.0	132.4	7.0	0.20
2001	95	117.5	5.19	103.5	127.6	7.1	0.25
2002	97	120.3	5.92	107.0	134.5	6.8	0.14
2003	13	123.1	3.80	117.3	129.7	7.0	0.22
2004	85	120.0	6.11	105.0	131.8	7.1	0.28
2005	91	117.1	6.53	104.0	134.4	7.2	0.22
2006	85	120.5	4.82	104.0	129.7	7.0	0.24
2007	94	114.3	7.43	97.5	130.8	7.2	0.23
2008	92	115.5	5.05	103.8	128.3	6.9	0.22

Table 5: Biomass estimates, coefficients of variation, and catch of the 20 species with highest catch weights in the 2008 Sub-Antarctic trawl survey. Estimates are from successful biomass stations for all strata combined. Biomass estimates from 2007 (from Bagley et al. 2009) are shown for comparison.

		2008 (TAN0813)			2007 (TAN0714)		
	Species	Catch	Biomass	c.v.	Catch	Biomass	c.v.
Species	code	(kg)	(t)	(%)	(kg)	(t)	(%)
Hoki	HOK	12 789	48 340	14	15 672	46 003	16
Javelinfish	JAV	9 111	48 659	15	2 691	12 066	12
Ling	LIN	6 501	22 879	10	5 477	26 492	8
Hake	HAK	3 420	2 355	16	2 012	2 662	15
Silver warehou	SWA	2 256	4 122	55	349	514	38
Black oreo	BOE	1 942	7 848	49	433	2 674	72
Shovelnosed dogfish	SND	1 839	910	26	381	261	32
Pale ghost shark	GSP	1 658	10 098	13	2 119	13 107	11
Southern blue whiting	SBW	1 416	15 219	14	966	8 165	24
Ridge-scaled rattail	MCA	1 295	11 198	37	1 098	8 544	19
Spiny dogfish	SPD	1 207	3 096	19	1 590	3 589	17
Longnose velvet dogfish	CYP	1 089	1 780	19	924	2 176	26
Deepwater spiny dogfish	CSQ	949	813	26	338	1 154	25
White warehou	WWA	935	2 209	40	1 450	1 707	61
Glass sponge	HYA	748	7 490	33	348	4 095	59
Smooth oreo	SSO	555	1 150	58	211	862	50
Baxter’s lantern dogfish	ETB	555	2 269	21	431	2 583	20
Oliver’s rattail	COL	555	2 663	16	281	1 587	32
Ribaldo	RIB	491	910	16	327	1 086	13
Arrow squid	NOS	428	396	36	1 753	2 161	86
Total catch (all species)		56 156			44 748		

Table 6: Estimated biomass (t) and coefficients of variation (%, below in parentheses) of the 12 major species by stratum. Species codes are given in Appendix 2. Subtotals are provided for core strata (1–15) and core + Puysegur 800–1000 m (Strata 1–25).

Stratum	HOK	LIN	HAK	BOE	GSH	GSP
1	1 371	2 320	37	0	89	4
	(62)	(57)	(66)		(42)	(100)
2	528	180	109	0	0	5
	(38)	(35)	(66)			(63)
3a	1 662	757	68	0	12	161
	(42)	(49)	(88)		(82)	(100)
3b	711	165	42	0	107	0
	(52)	(55)	(83)		(40)	
4	3 802	1 858	185	2 679	0	1 304
	(30)	(26)	(29)	(88)		(34)
5a	313	136	120	0	2	63
	(24)	(28)	(38)		(100)	(55)
5b	444	310	103	0	0	382
	(6)	(19)	(37)			(19)
6	797	257	22	0	753	0
	(29)	(43)	(100)		(45)	
7	1 979	423	30	0	0	110
	(54)	(51)	(100)			(45)
8	7 964	2 206	72	0	0	660
	(9)	(9)	(63)			(22)
9	4 148	2 309	20	0	102	887
	(20)	(25)	(100)		(94)	(35)
10	484	286	0	0	0	119
	(54)	(38)				(23)
11	6 704	744	240	30	0	362
	(59)	(42)	(81)	(63)		(30)
12	3 594	4 233	26	0	0	2 514
	(50)	(8)	(100)			(22)
13	7 978	3 594	0	0	0	1 848
	(49)	(29)				(42)
14	1 246	2 296	0	0	63	819
	(30)	(37)			(100)	(67)
15	3 255	757	0	0	0	97
	(59)	(55)				(21)
Subtotal (strata 1–15)	**46 980**	**22 831**	**1 074**	**2 709**	**1 128**	**9 335**
	(14)	**(10)**	**(23)**	**(87)**	**(32)**	**(13)**
25	508	36	1 088	0	0	7
	(43)	(57)	(24)			(29)
Subtotal (strata 1–25)	**47 488**	**22 867**	**2 162**	**2 709**	**1 128**	**9 342**
	(14)	**(10)**	**(17)**	**(87)**	**(32)**	**(13)**
26	0	0	0	0	0	455
						(51)
27	473	0	21	2 994	0	34
	(45)		(100)	(100)		(45)
28	379	12	172	2 145	0	267
	(53)	(90)	(52)	(21)		(23)
Total (All strata)	**48 340**	**22 879**	**2 355**	**7 848**	**1 128**	**10 098**
	(14)	**(10)**	**(16)**	**(49)**	**(32)**	**(13)**

Table 6 (cont): Estimated biomass (t) and coefficients of variation (%, below in parentheses) of the 12 major species by stratum. Species codes are given in Appendix 2. Subtotals are provided for core strata (1–15) and core + Puysegur 800–1000 m (Strata 1–25).

Stratum	JAV	LDO	RIB	SBW	SPD	WWA
1	33	14	8	0	465	361
	(35)	(47)	(100)		(62)	(100)
2	36	11	33	0	0	37
	(20)	(11)	(17)			(69)
3a	524	27	0	0	98	16
	(62)	(30)			(17)	(68)
3b	4	16	0	0	218	72
	(64)	(42)			(39)	(54)
4	2 830	17	84	0	154	122
	(40)	(100)	(50)		(22)	(65)
5a	115	9	37	0	3	84
	(16)	(58)	(9)		(100)	(93)
5b	513	2	24	1	13	0
	(27)	(100)	(20)	(100)	(48)	
6	0	0	123	73	85	0
			(21)	(38)	(100)	
7	1 487	0	130	0	6	0
	(34)		(30)		(100)	
8	8 135	68	74	3	106	48
	(30)	(59)	(43)	(58)	34)	(59)
9	3 881	41	13	602	570	1 248
	(74)	(98)	(100)	(37)	(42)	(65)
10	1 107	0	133	0	0	0
	(15)		(55)			
11	7 137	17	100	561	39	0
	(34)	(69)	(59)	(100)	(55)	
12	5 221	238	0	8 517	374	106
	(56)	(30)		(13)	(26)	(87)
13	8 608	190	0	3 136	494	105
	(49)	(76)		(46)	(52)	(65)
14	2 496	55	0	2 223	454	0
	(62)	(96)		(41)	(76)	
15	3 441	108	22	103	13	0
	(40)	(81)	(100)	(100)	(100)	
Subtotal (strata 1–15)	**45 568**	**813**	**781**	**15 219**	**3 092**	**2 199**
	(16)	**(25)**	**(18)**	**(14)**	**(19)**	**(40)**
25	594	2	107	0	0	0
	(16)	(82)	(38)			
Subtotal (strata 1–25)	**46 162**	**815**	**888**	**15 219**	**3 092**	**2 199**
	(16)	**(25)**	**(16)**	**(14)**	**(19)**	**(40)**
26	0	0	0	0	0	0
27	1 646	0	10	0	0	0
	(15)		(100)			
28	851	0	12	0	4	10
	(44)		(64)		(65)	(63)
Total (All strata)	**48 659**	**815**	**910**	**15 219**	**3 096**	**2 209**
	(15)	**(25)**	**(16)**	**(14)**	**(19)**	**(40)**

Table 7: Time series of biomass estimates of hoki and hake for core 300–800 m strata and for all surveyed strata from Sub-Antarctic trawl surveys.

		Core strata (300–800 m)		All strata (300–1000 m)	
		Biomass	c.v. (%)	Biomass	c.v. (%)
HOKI	Summer series				
	1991	80 285	7		
	1992	87 359	6		
	1993	99 695	9		
	2000	55 663	13	56 407	13
	2001	38 145	16	39 396	15
	2002	39 890	14	40 503	14
	2003	14 318	13	14 724	13
	2004	17 593	11	18 114	12
	2005	20 440	13	20 679	13
	2006	14 336	11	14 747	11
	2007	45 876	16	46 003	16
	2008	46 980	14	48 340	14
	Autumn series				
	1992	67 831	8		
	1993	53 466	10		
	1996	89 029	9	92 650	9
	1998	67 709	11	71 738	10
HAKE	Summer series				
	1991	5 553	44		
	1992	1 822	12		
	1993	2 286	12		
	2000	2 194	17	3 103	14
	2001	1 831	24	2 360	19
	2002	1 293	20	2 037	16
	2003	1 335	24	1 898	21
	2004	1 250	27	1 774	20
	2005	1 133	20	1 624	17
	2006	998	22	1 588	17
	2007	2 188	17	2 622	15
	2008	1 074	23	2 355	16
	Autumn series				
	1992	5 028	15		
	1993	3 221	13		
	1996	2 026	12	2 825	12
	1998	2 506	18	3 898	16

Table 7 cntd: Time series of biomass estimates of ling for core 300–800 m strata and for all surveyed strata from Sub-Antarctic trawl surveys.

		Core strata (300–800 m)		All strata (300–1000 m)	
		Biomass	c.v. (%)	Biomass	c.v. (%)
LING	Summer series				
	1991	24 085	7		
	1992	21 368	6		
	1993	29 747	12		
	2000	33 023	7	33 033	7
	2001	25 059	7	25 167	6
	2002	25 628	10	25 635	10
	2003	22 174	10	22 192	10
	2004	23 744	12	23 794	12
	2005	19 685	9	19 755	9
	2006	19 637	12	19 661	12
	2007	26 486	8	26 492	8
	2008	22 831	10	22 879	10
	Autumn series				
	1992	42 334	6		
	1993	33 553	5		
	1996	32 133	8	32 363	8
	1998	30 776	9	30 893	9

Table 8: Numbers of fish for which length, sex, and biological data were collected; - no data.

	Length frequency data				Length-weight data	
	No. of fish measured			No. of	No. of	No. of
Species	Total †	Male	Female	samples	fish	samples
Alfonsino	1	1	0	1	1	1
Arrow squid	437	265	171	31	284	30
Banded rattail	3 057	392	358	46	741	23
Baxter's lantern dogfish	459	231	228	32	401	32
Bigeye cardinalfish	79	0	0	1	0	0
Black cardinalfish	47	18	14	5	47	5
Black oreo	1 428	745	682	12	266	12
Bollons's rattail	190	81	109	10	87	9
Brown chimaera	2	2	0	1	2	1
Dark ghost shark	405	230	175	17	326	17
Deepwater spiny dogfish	134	66	68	18	134	18
Finless flounder	18	12	6	1	18	1
Four-rayed rattail	842	26	45	10	93	4
Frostfish	1	1	0	1	1	1
Gemfish	1	0	1	1	1	1
Giant chimaera	1	1	0	1	1	1
Giant stargazer	68	15	53	18	68	18
Hake	1 124	306	818	47	1 075	47
Hapuku	1	0	1	1	1	1
Hoki	7 298	2 745	4 552	90	1 390	80
Humpback rattail	3	0	3	1	3	1
Javelinfish	9 491	349	1 561	77	1 625	54
Ling	2 156	1 162	994	80	1 085	72
Longnose velvet dogfish	248	63	185	16	232	16
Longnosed chimaera	89	48	41	30	89	30
Lookdown dory	127	54	73	42	127	42
Lucifer dogfish	146	75	71	7	34	5
Notable rattail	81	0	0	1	0	0
Oblique banded rattail	1 117	46	363	21	424	14
Oliver's rattail	2 295	62	129	19	423	10
Orange roughy	218	100	117	14	193	14
Owston's dogfish	9	5	4	1	9	1
Pale ghost shark	1 130	567	563	74	963	74
Pale toadfish	1	0	0	1	1	1
Ray's bream	22	10	11	10	22	10
Red cod	104	65	39	7	104	7
Ribaldo	284	75	209	42	256	42
Ridge-scaled rattail	668	381	287	30	361	29
Rough skate	15	7	8	8	15	8
Scampi	7	4	3	2	7	2
School shark	7	7	0	3	7	3
Sea perch	14	9	5	4	14	4
Seal shark	10	3	7	3	10	3
Shovelnosed dogfish	188	96	92	13	188	13
Silver dory	308	199	109	2	60	2
Silver warehou	415	192	223	8	102	8
Silverside	1 333	532	582	32	691	29
Small banded rattail	61	13	14	3	0	0
Smallscaled cod	14	6	8	1	14	1
Small-scaled slickhead	306	171	135	7	199	7
Smooth oreo	485	249	236	15	139	15
Smooth skate	9	4	5	8	9	8

Table 8 cont: Numbers of fish for which length, sex, and biological data were collected.

	Length frequency data				Length-weight data	
	No. of fish measured			No. of	No. of	No. of
Species	Total †	Male	Female	Samples	fish	samples
Southern blue whiting	2 757	1 213	1 467	29	664	29
Spiky oreo	153	99	54	1	44	1
Spiny dogfish	576	160	416	52	345	52
Two saddle rattail	50	0	0	1	0	0
White rattail	23	13	10	4	23	4
White warehou	405	253	152	26	224	26
Widenosed chimaera	50	28	22	14	50	14

†Total is sometimes greater than the sum of male and female fish because the sex of some fish was not recorded.

Table 9: Length-weight regression parameters* used to scale length frequencies for the 12 major species.

	Regression parameters				Length	
Species	a	b	r^2	n	range (cm)	Data source
Black oreo	0.035164	2.8534	.85	264	23.2 – 37.8	TAN0813
Dark ghost shark	0.002961	3.1840	.96	325	34.4 – 68.5	TAN0813
Javelinfish	0.001638	3.0866	.94	1 625	18.2 – 56.4	TAN0813
Hake	0.002492	3.2457	.97	1 075	44.2 – 124.2	TAN0813
Hoki	0.005024	2.8712	.98	1 390	34.6 – 109.5	TAN0813
Ling	0.001300	3.2877	.98	1 083	36.7 – 126.2	TAN0813
Lookdown dory	0.027480	2.9624	.97	127	16.7 – 54.0	TAN0813
Pale ghost shark	0.013396	2.7913	.97	963	25.9 – 83.8	TAN0813
Ribaldo	0.006827	3.1033	.97	255	29.0 – 72.2	TAN0813
Southern blue whiting	0.003715	3.1505	.99	664	17.2 – 57.3	TAN0813
Spiny dogfish	0.000486	3.5033	.94	344	55.9 – 97.5	TAN0813
White warehou	0.066312	2.6922	.97	223	29.5 – 60.3	TAN0813

* $W = aL^b$ where W is weight (g) and L is length (cm); r^2 is the correlation coefficient, n is the number of samples.

Table 10: Numbers of hoki, hake, and ling at each reproductive stage*.

	Hoki		Hake		Ling	
Reproductive stage	Male	Female	Male	Female	Male	Female
1	897	990	183	497	176	199
2	1 601	3 404	36	117	244	635
3	7	34	11	143	175	26
4	4	1	25	6	516	111
5	1	0	35	3	8	2
6	198	5	14	7	25	0
7	15	92	2	45	2	0
Total staged	2 723	4 526	306	818	1 146	973

*See Appendix 1 for description of gonad stages.

Table 11: Average liver condition index (LCI) and somatic condition factor (CF) for hoki sampled during Sub-Antarctic trawl surveys 2001–08.

	LCI		CF	
Year	Male	Female	Male	Female
2001	2.58	3.12	2.61	2.57
2002	2.37	2.74	2.63	2.60
2003	2.36	2.93	2.62	2.60
2004	2.71	3.25	2.63	2.59
2005	3.01	3.15	2.75	2.68
2006	2.66	2.98	2.71	2.70
2007	3.03	3.22	2.70	2.68
2008	2.53	2.69	2.72	2.67

LCI = liver weight (g) / gutted weight (g) x 100
CF = gutted weight (g) / (length (cm))^3 x 1000

Table 12: Quality of acoustic data collected during trawl surveys in the Sub-Antarctic between 2000 and 2008. The quality of each recording was subjectively categorised as "good", "marginal" or "poor" based on the appearance of the 38 kHz echograms (see appendix 2 of O'Driscoll & Bagley (2004) for examples).

Survey	Number of recordings	% of recordings Good	Marginal	Poor
2000 (TAN0012)	234	57	21	22
2001 (TAN0118)	221	65	20	15
2002 (TAN0219)	202	78	12	10
2003 (TAN0317)	169	37	25	38
2004 (TAN0414)	163	61	25	14
2005 (TAN0515)	197	75	16	9
2006 (TAN0617)	195	46	25	29
2007 (TAN0714)	194	63	16	20
2008 (TAN0813)	235	61	28	11

Table 13: Percentage occurrence of the seven acoustic mark types classified by O'Driscoll (2001) in trawl surveys of the Sub-Antarctic between 2000 and 2008. Several mark types were usually present in the same echogram. *n* is the number of acoustic files examined.

				Pelagic marks			Bottom marks		
Acoustic file	Survey	*n*	Surface layer	School	Layer	Cloud	Layer	Cloud	School
Day steam	2000 (TAN0012)	90	93	71	63	6	58	17	11
	2001 (TAN0118)	85	91	71	72	41	54	26	12
	2002 (TAN0219)	72	92	72	75	19	79	19	14
	2003 (TAN0317)	64	94	56	53	47	67	30	13
	2004 (TAN0414)	49	82	63	55	43	69	31	12
	2005 (TAN0515)	75	91	77	73	63	67	59	16
	2006 (TAN0617)	73	88	53	67	37	30	34	3
	2007 (TAN0714)	65	94	74	57	43	43	52	12
	2008 (TAN0813)	74	86	80	59	74	59	89	19
Night steam	2000 (TAN0012)	36	97	22	14	33	17	67	3
	2001 (TAN0118)	26	100	23	19	85	38	85	8
	2002 (TAN0219)	23	100	13	13	96	39	91	0
	2003 (TAN0317)	22	95	14	14	86	32	73	0
	2004 (TAN0414)	22	95	14	23	68	36	95	0
	2005 (TAN0515)	23	100	61	44	100	57	91	4
	2006 (TAN0617)	24	96	33	42	75	13	83	4
	2007 (TAN0714)	24	100	42	33	83	38	96	0
	2008 (TAN0813)	64	98	19	20	72	36	83	3
Trawl	2000 (TAN0012)	108	90	50	52	23	37	20	10
	2001 (TAN0118)	110	81	60	62	32	35	26	15
	2002 (TAN0219)	108	91	60	59	32	41	31	15
	2003 (TAN0317)	83	86	37	53	28	46	25	4
	2004 (TAN0414)	92	63	47	48	29	38	33	10
	2005 (TAN0515)	99	85	65	60	55	38	52	6
	2006 (TAN0617)	95	67	40	54	29	29	25	1
	2007 (TAN0714)	105	78	53	41	43	39	30	10
	2008 (TAN0813)	97	78	56	45	69	45	69	9

Table 14: Average trawl catch (excluding benthic organisms) and acoustic backscatter from tows where acoustic data quality was suitable for echo integration for Sub-Antarctic surveys between 2000 and 2008. All tows were conducted during daylight. Only bottom-referenced regions were integrated in 2000–04.

Survey	Number of recordings	Trawl catch (kg km^{-2})		Average acoustic backscatter (m^2 km^{-2})		
		Mean	Median	Bottom 10 m only	All bottom marks	Entire echogram
2000 (TAN0012)	100	697	590	0.502	3.37	–
2001 (TAN0118)	101	779	567	0.506	2.90	–
2002 (TAN0219)	96	726	443	0.657	4.08	–
2003 (TAN0317)	48	568	351	0.622	2.50	–
2004 (TAN0414)	80	1 031	393	0.484	1.77	–
2005 (TAN0515)	87	691	457	0.623	2.40	14.88
2006 (TAN0617)	69	543	436	0.475	1.89	8.80
2007 (TAN0714)	75	833	525	0.541	3.45	12.06
2008 (TAN0813)	92	939	747	0.905	3.17	16.02

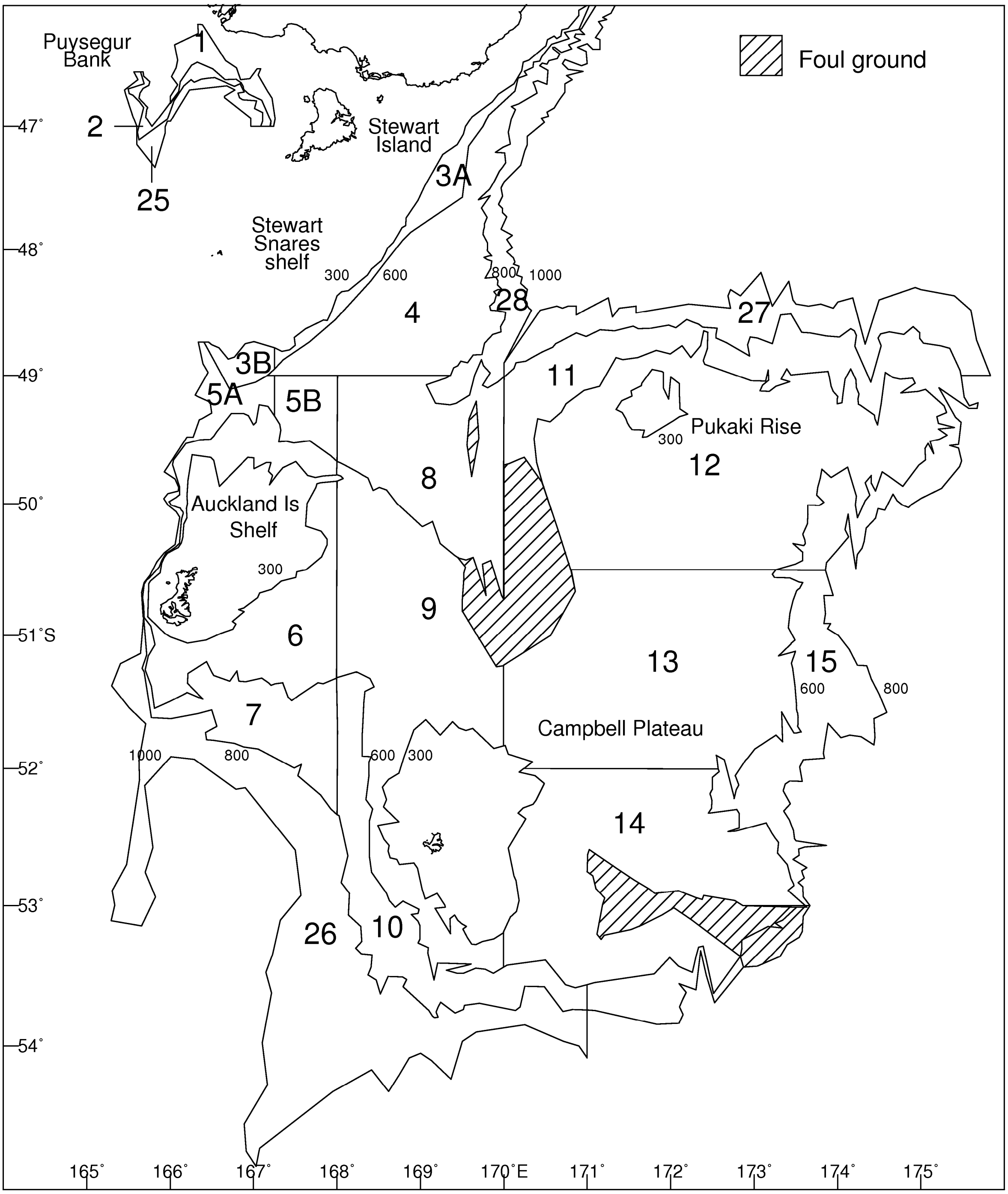


Figure 1: Stratum boundaries for the November–December 2008 Southland and Sub-Antarctic trawl survey.

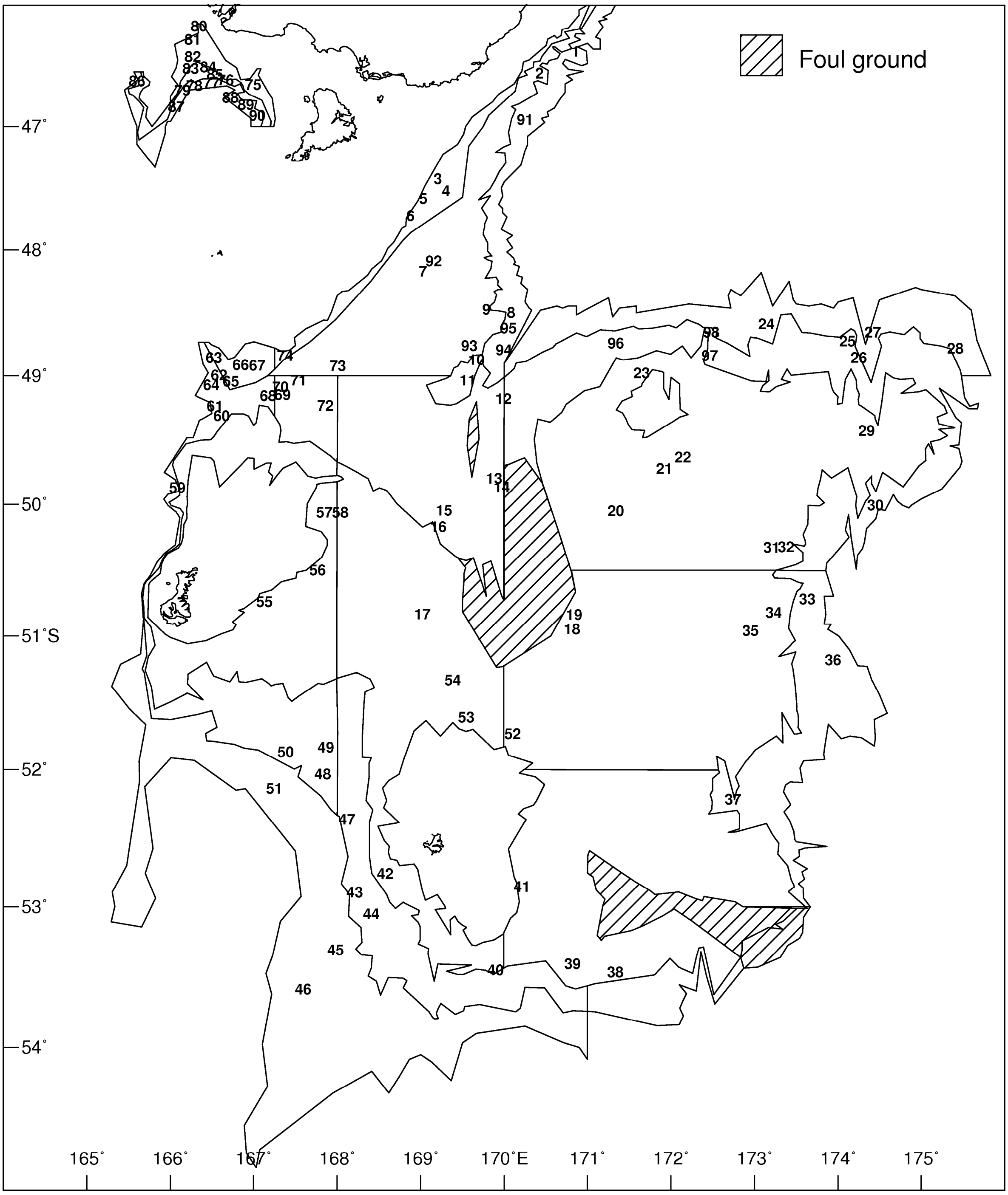


Figure 2: Map showing start positions of all bottom trawls (including unsuccessful stations) from the November–December 2008 Southland and Sub-Antarctic trawl survey.

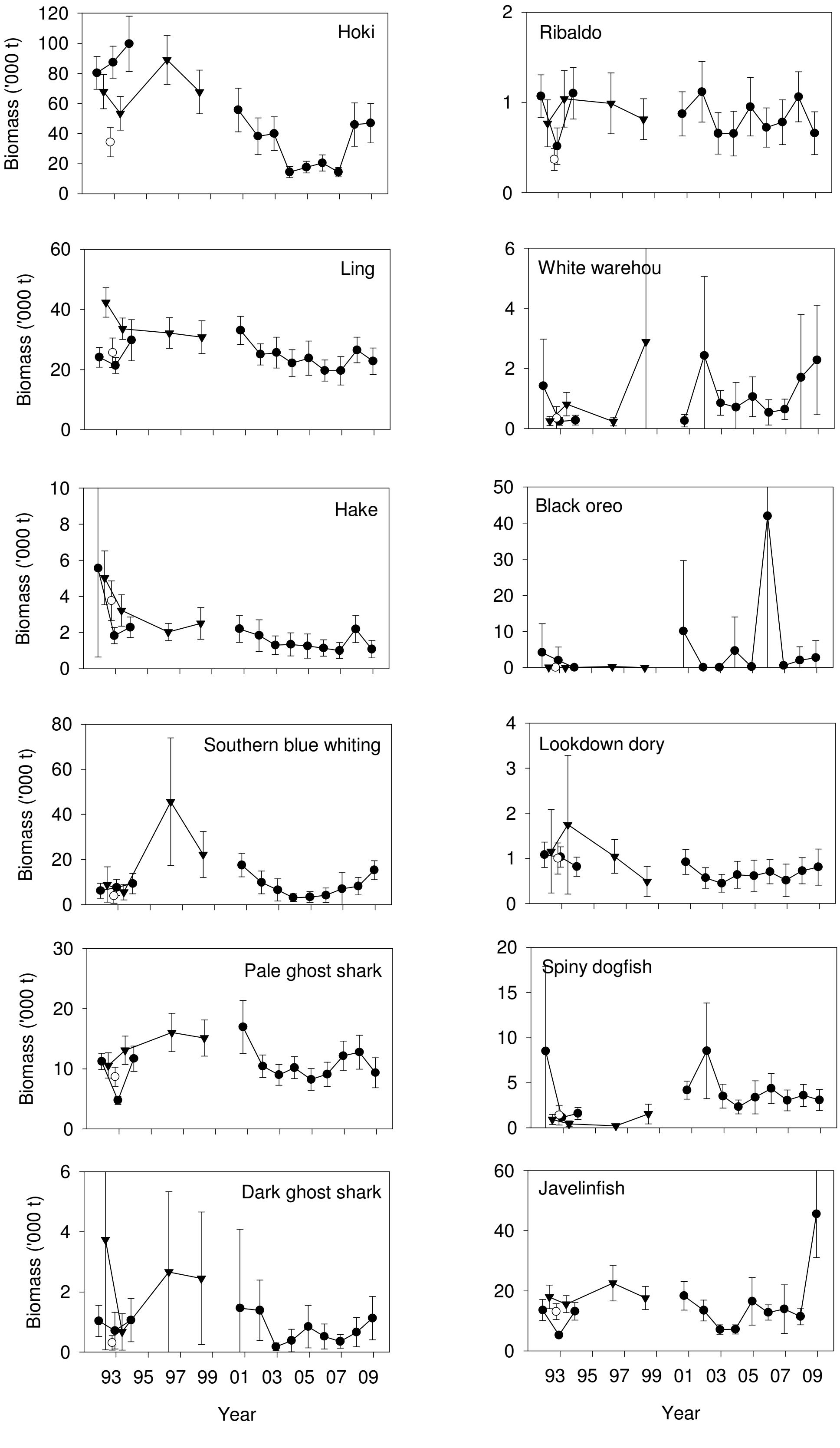


Figure 3: Trends in biomass (± 2 standard errors) of major species in the core 300–800 m strata in all Sub-Antarctic trawl surveys from *Tangaroa*. Solid circles show the summer time series and solid triangles the autumn time series. The open circle shows biomass from a survey of the same area in September–October 1992.

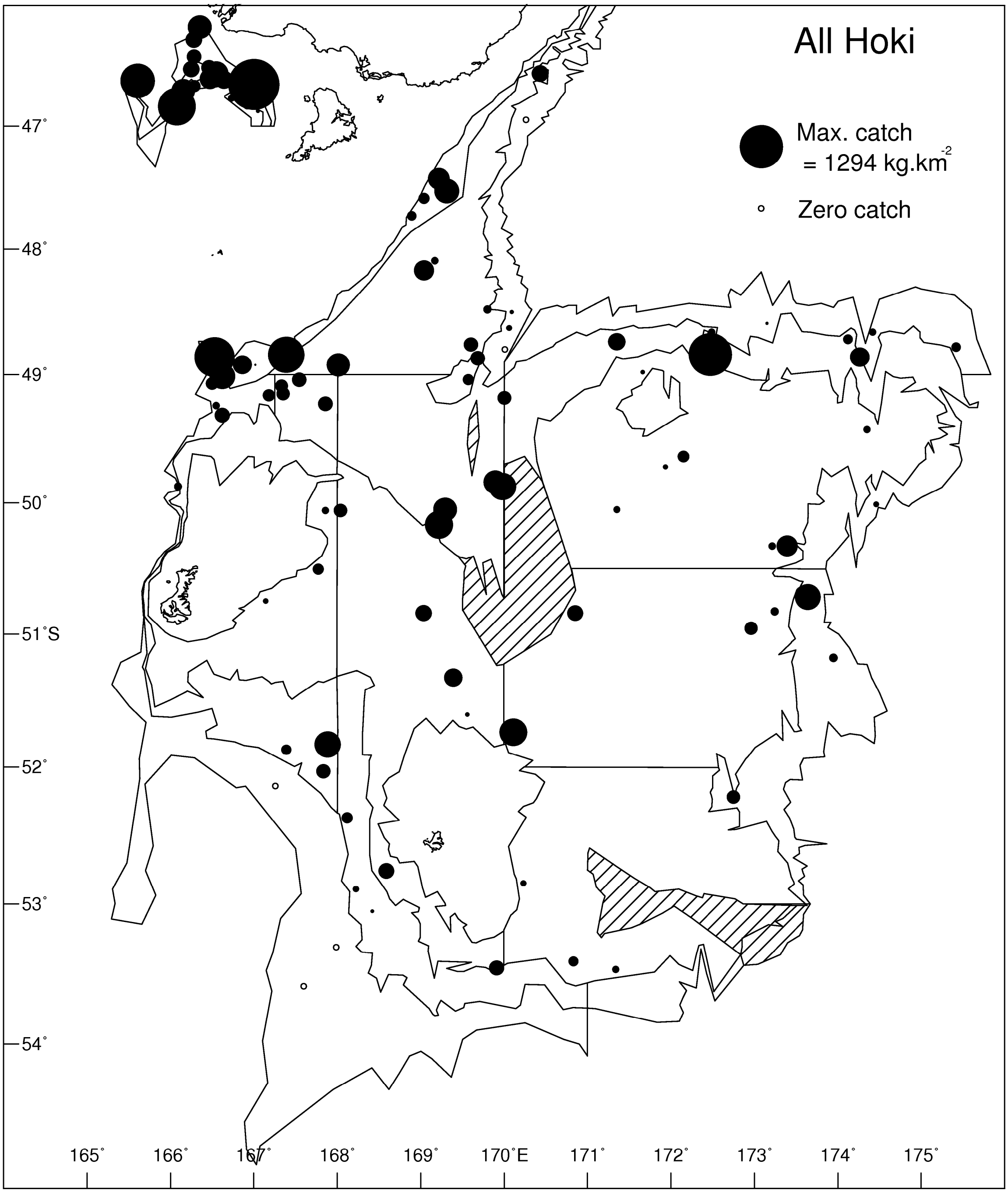


Figure 4a: Distribution and catch rates of all hoki in the summer 2008 trawl survey. Circle area is proportional to catch rate.

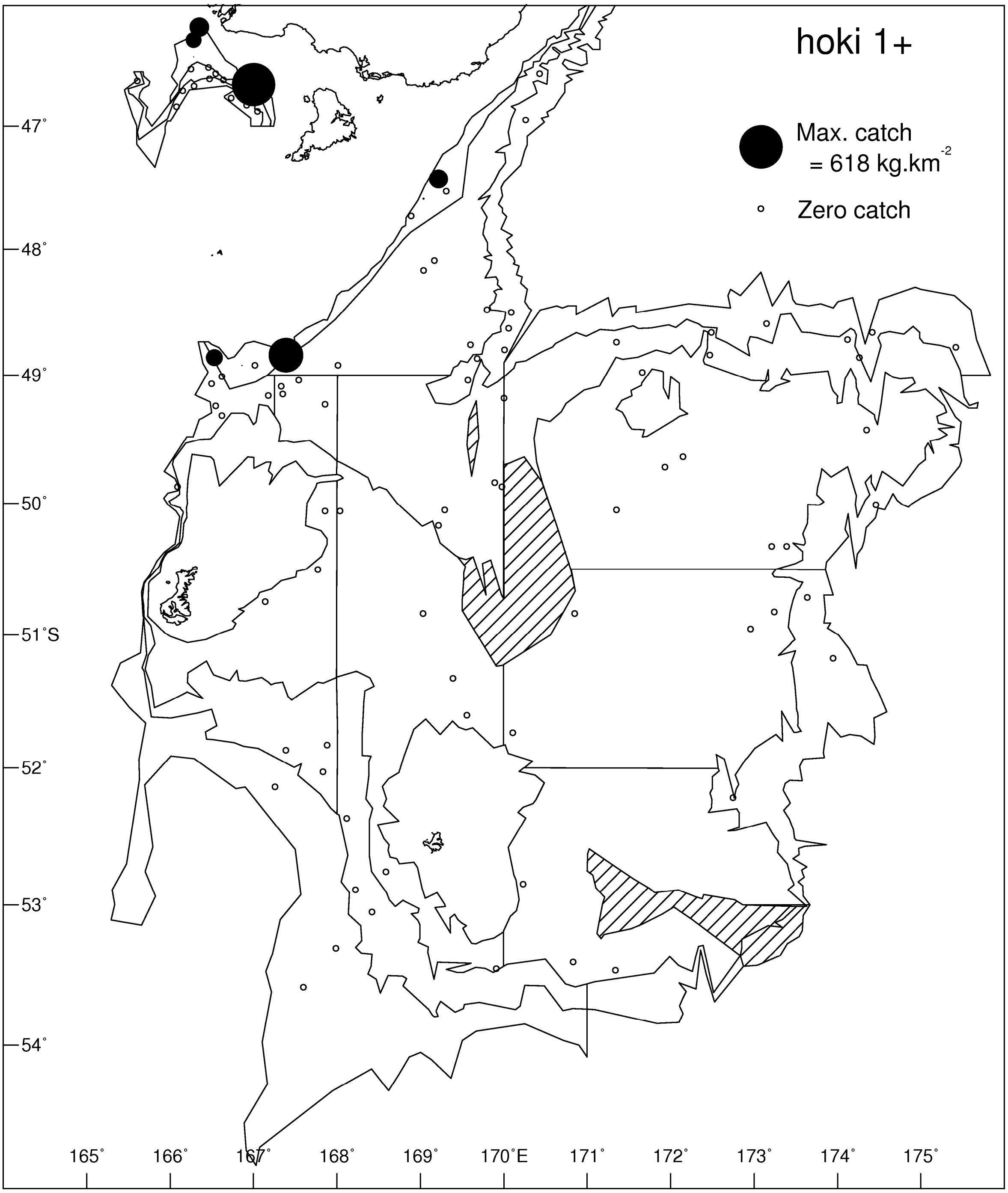


Figure 4b: Distribution and catch rates of 1+ (<45 cm) hoki in the summer 2008 trawl survey. Circle area is proportional to catch rate.

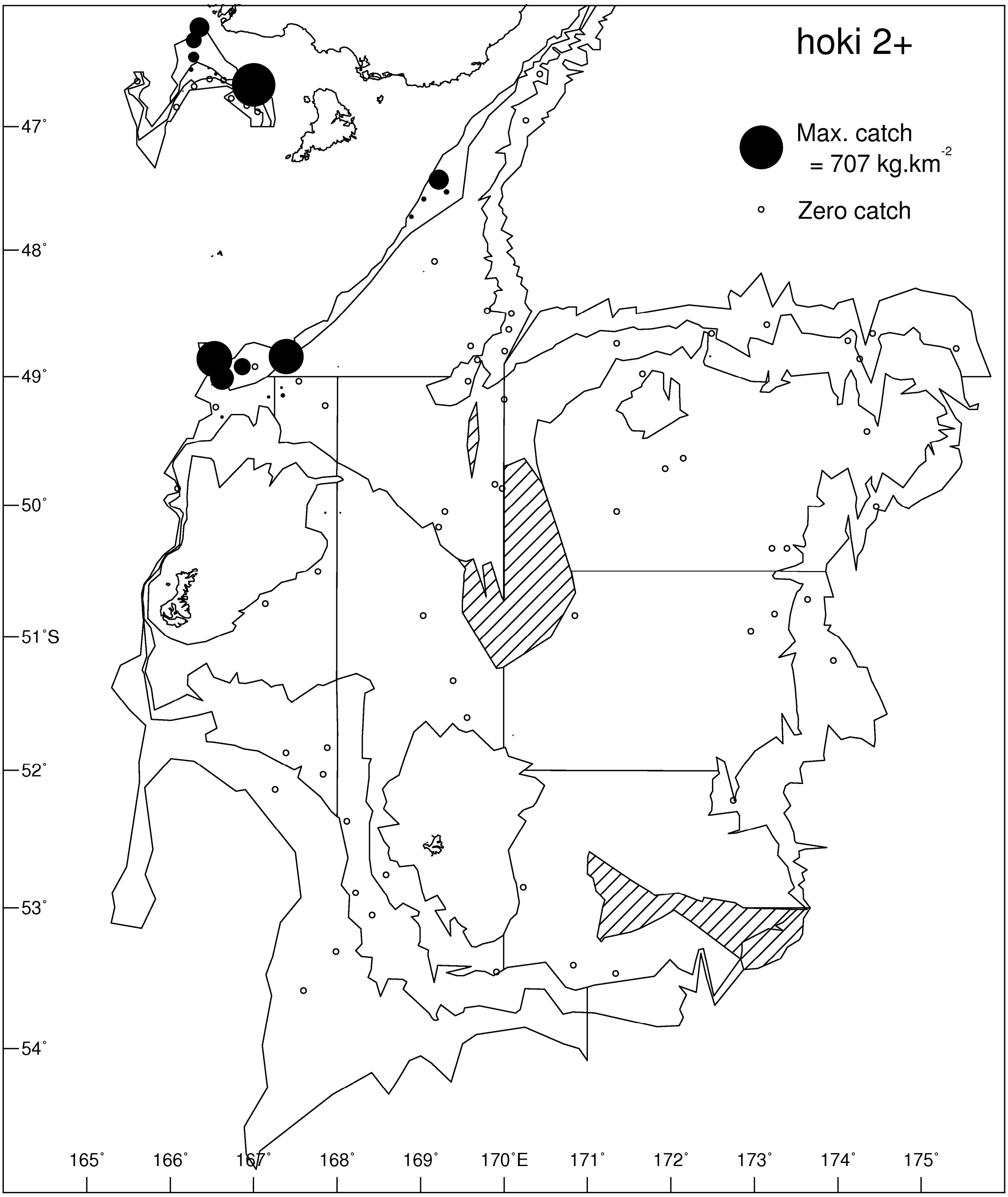


Figure 4c: Distribution and catch rates of 2+ (45–57 cm) hoki in the summer 2008 trawl survey. Circle area is proportional to catch rate.

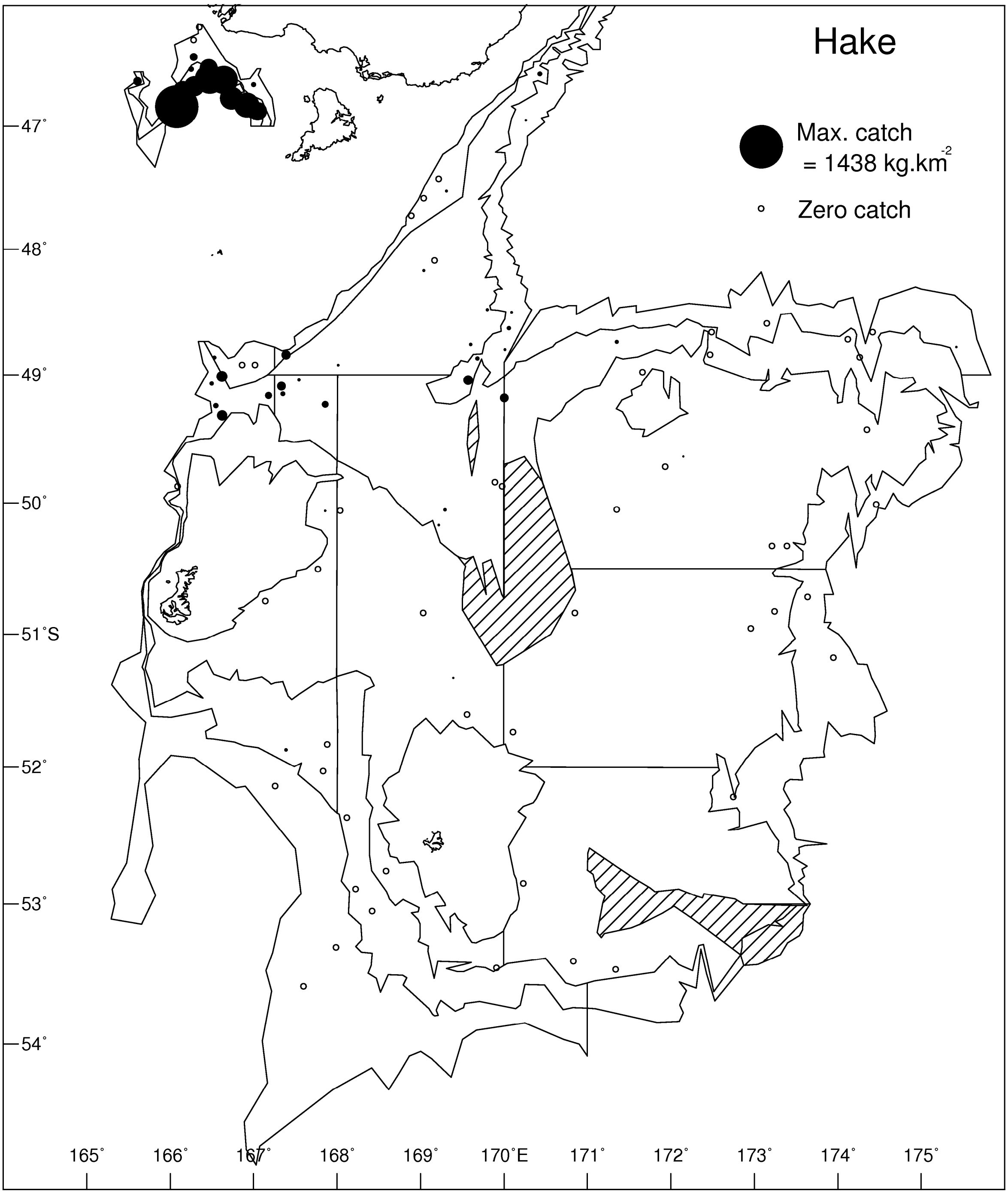


Figure 5: Distribution and catch rates of hake in the summer 2008 trawl survey. Circle area is proportional to catch rate.

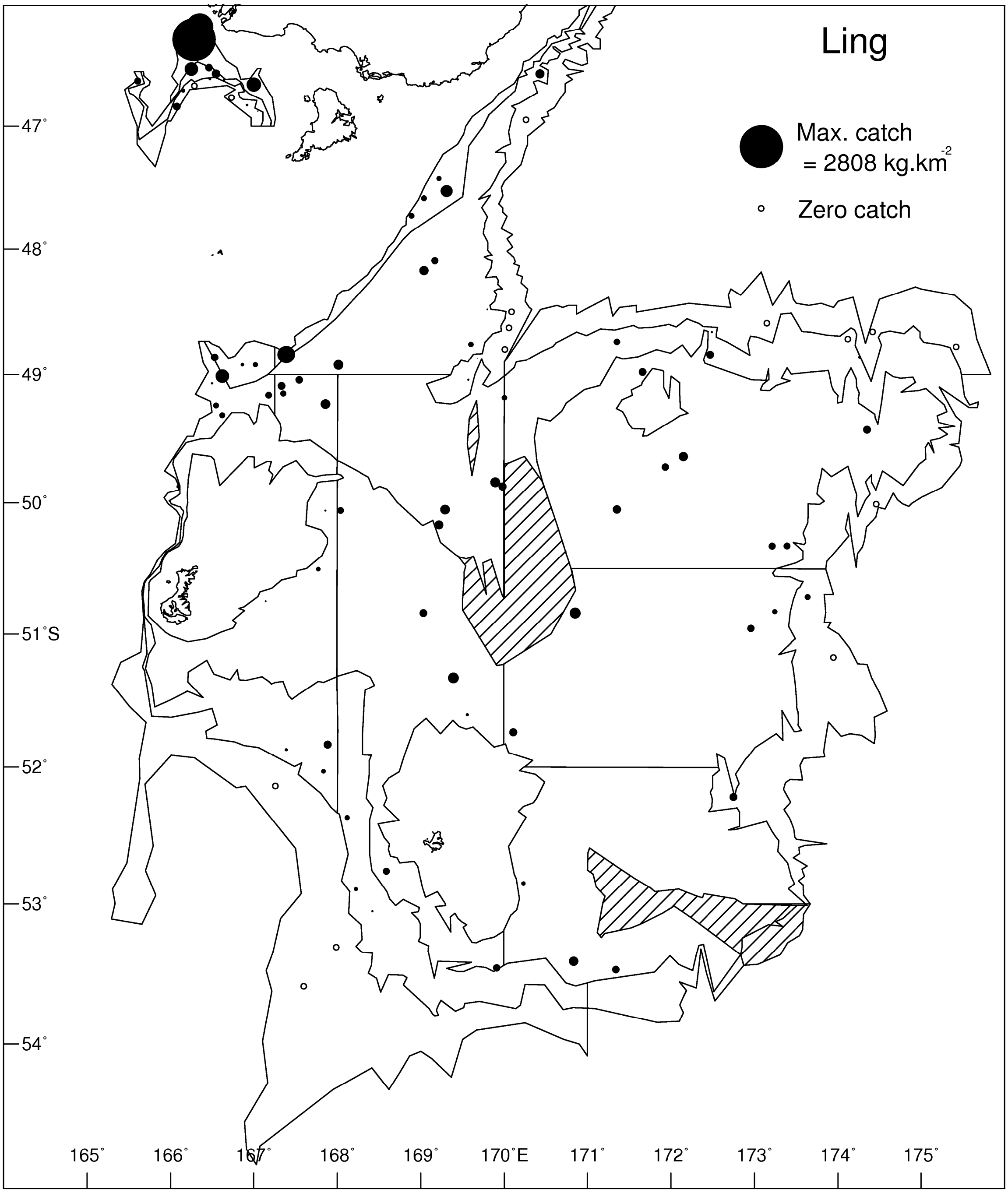


Figure 6: Distribution and catch rates of ling in the summer 2008 trawl survey. Circle area is proportional to catch rate.

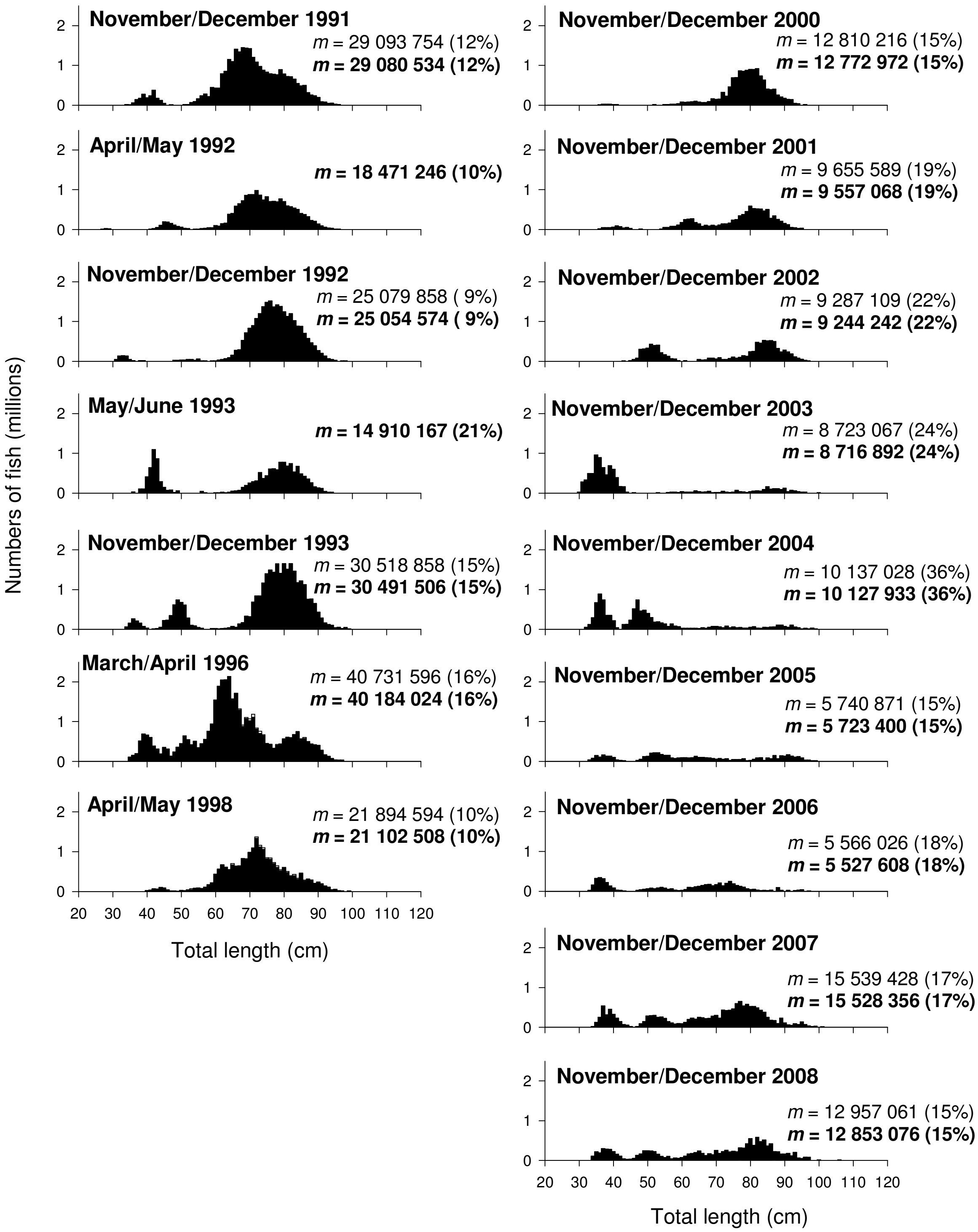


Figure 7a: Scaled length frequency for male hoki from all Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all strata as white bars. Because few hoki were caught outside core strata, white bars are very small. Numbers (*m* values) above are for all strata and below (in bold) for core strata with c.v.s in parentheses.

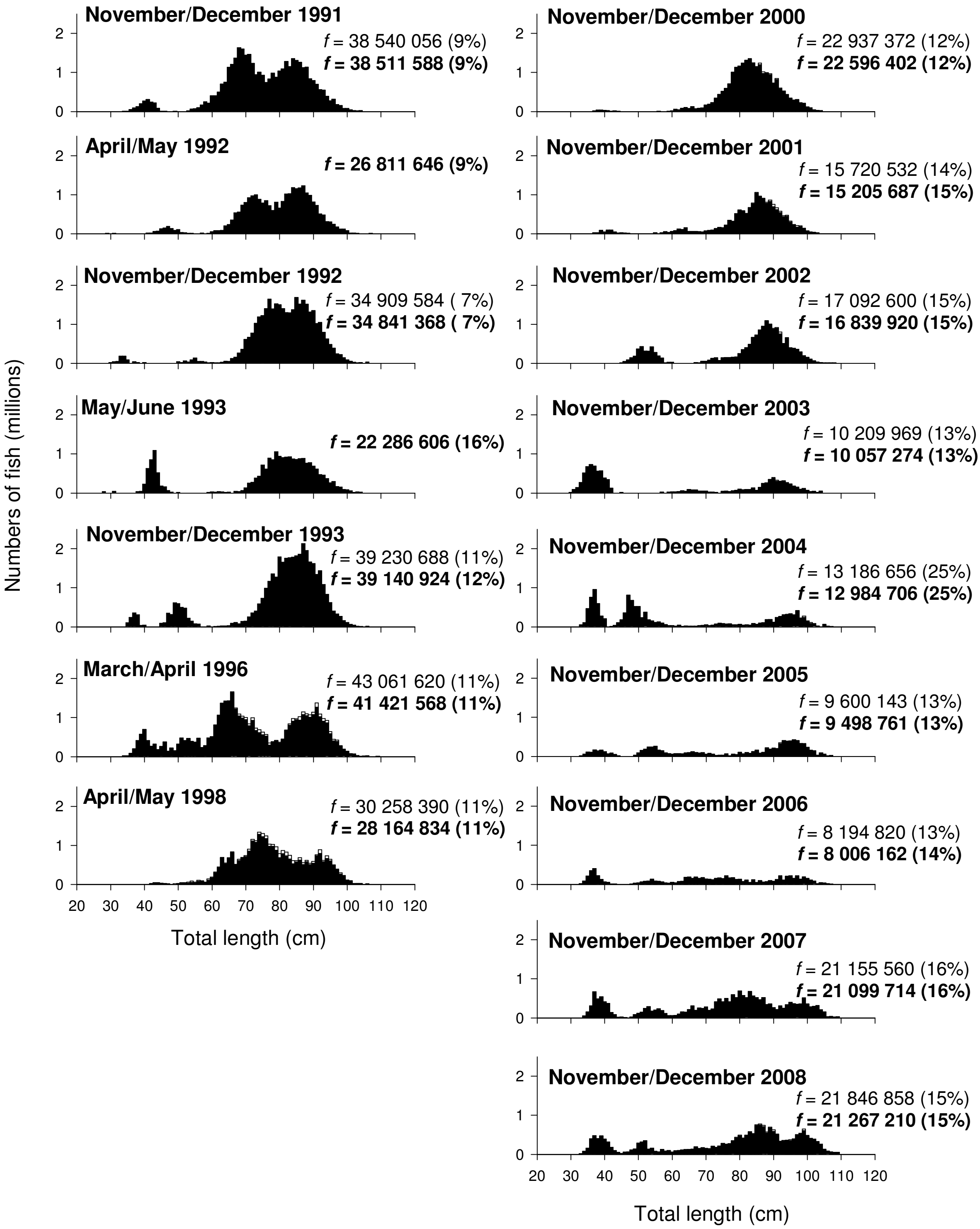


Figure 7b: Scaled length frequency for female hoki from all Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all strata as white bars. Because few hoki were caught outside core strata, white bars are very small. Numbers (*f* values) above are for all strata and below (in bold) for core strata with c.v.s in parentheses.

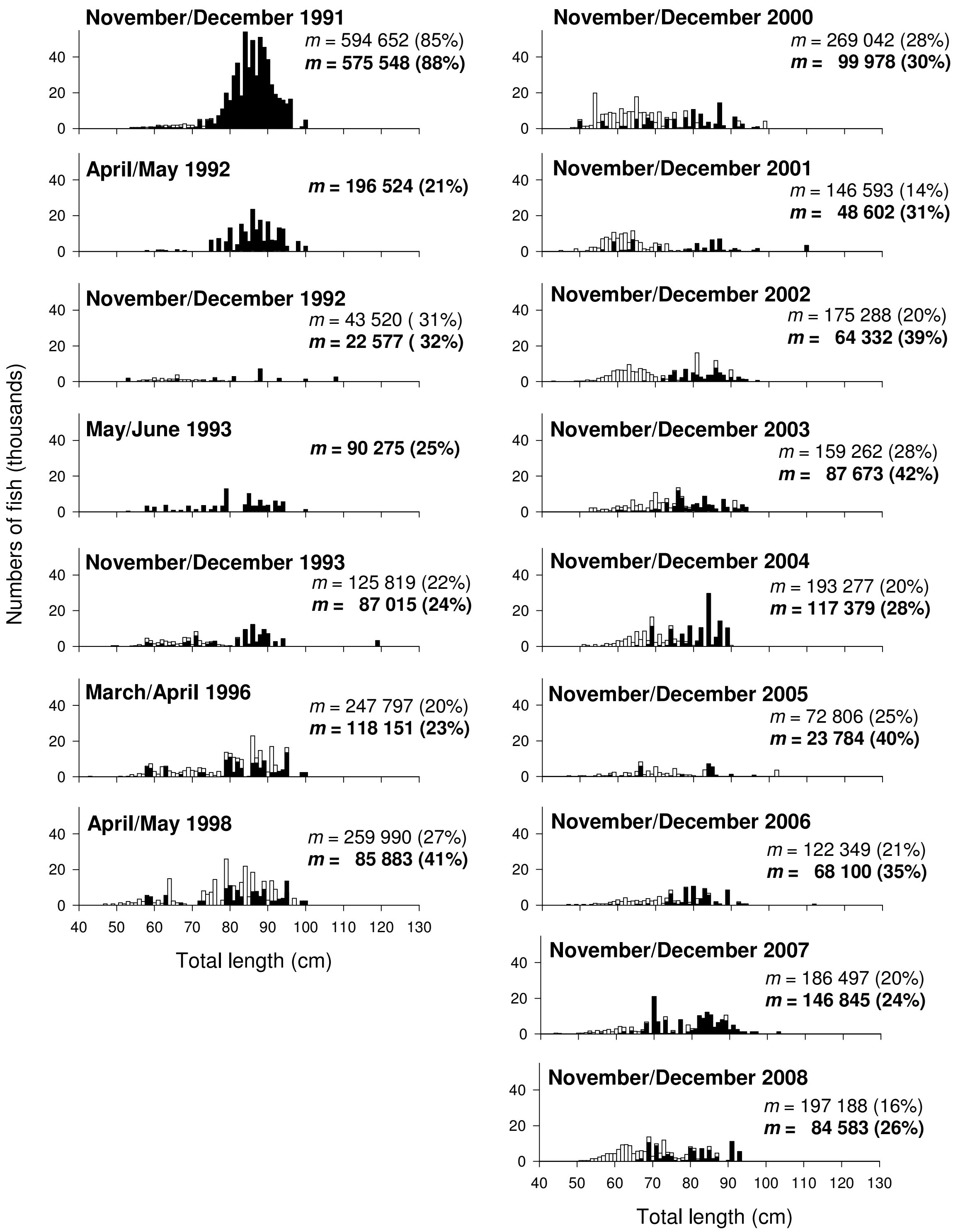


Figure 8a: Scaled length frequency for male hake from all Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all strata as white bars. Numbers (*m* values) above are for all strata and below (in bold) for core strata with c.v.s in parentheses.

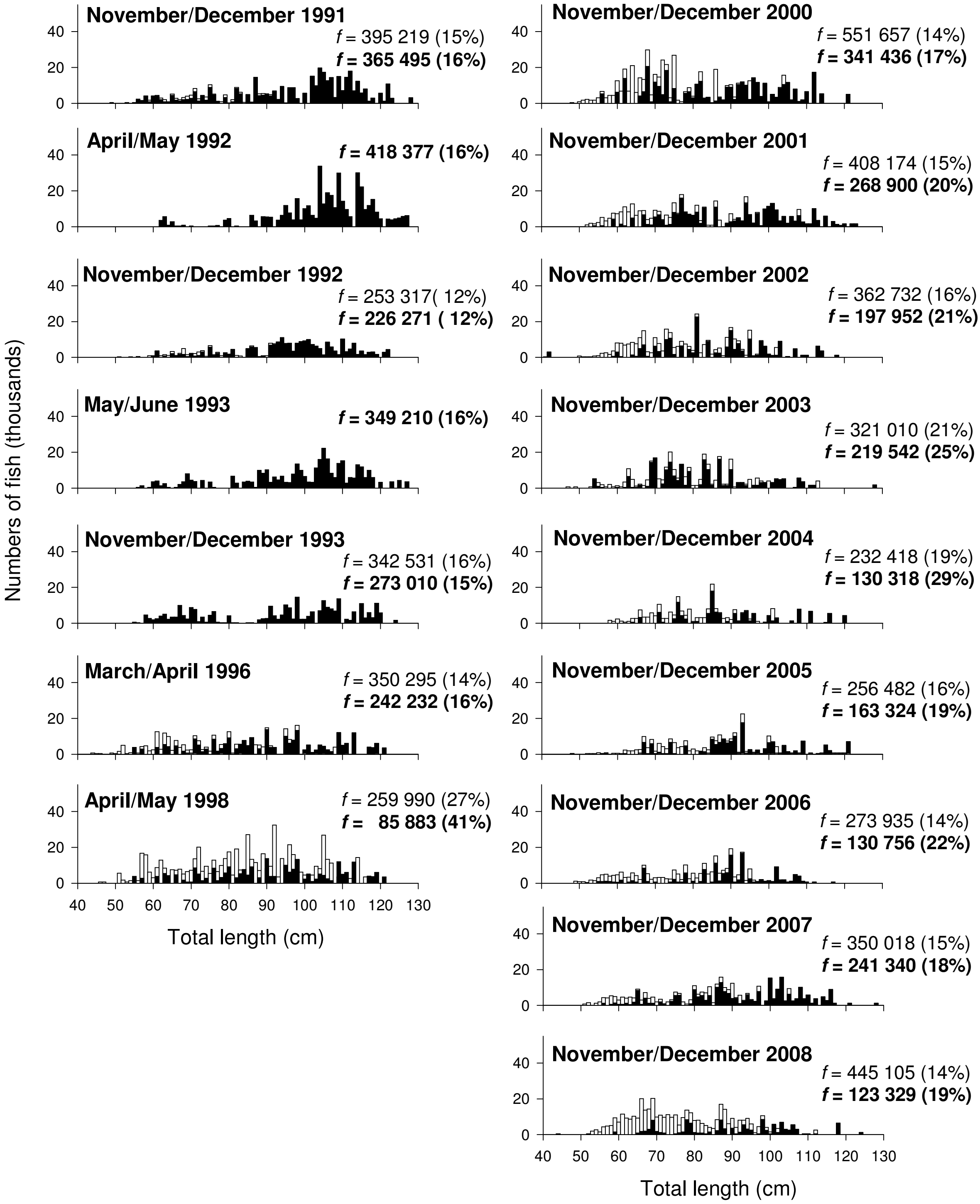


Figure 8b: Scaled length frequency for female hake from all Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all strata as white bars. Numbers (*f* values) above are for all strata and below (in bold) for core strata with c.v.s in parentheses.

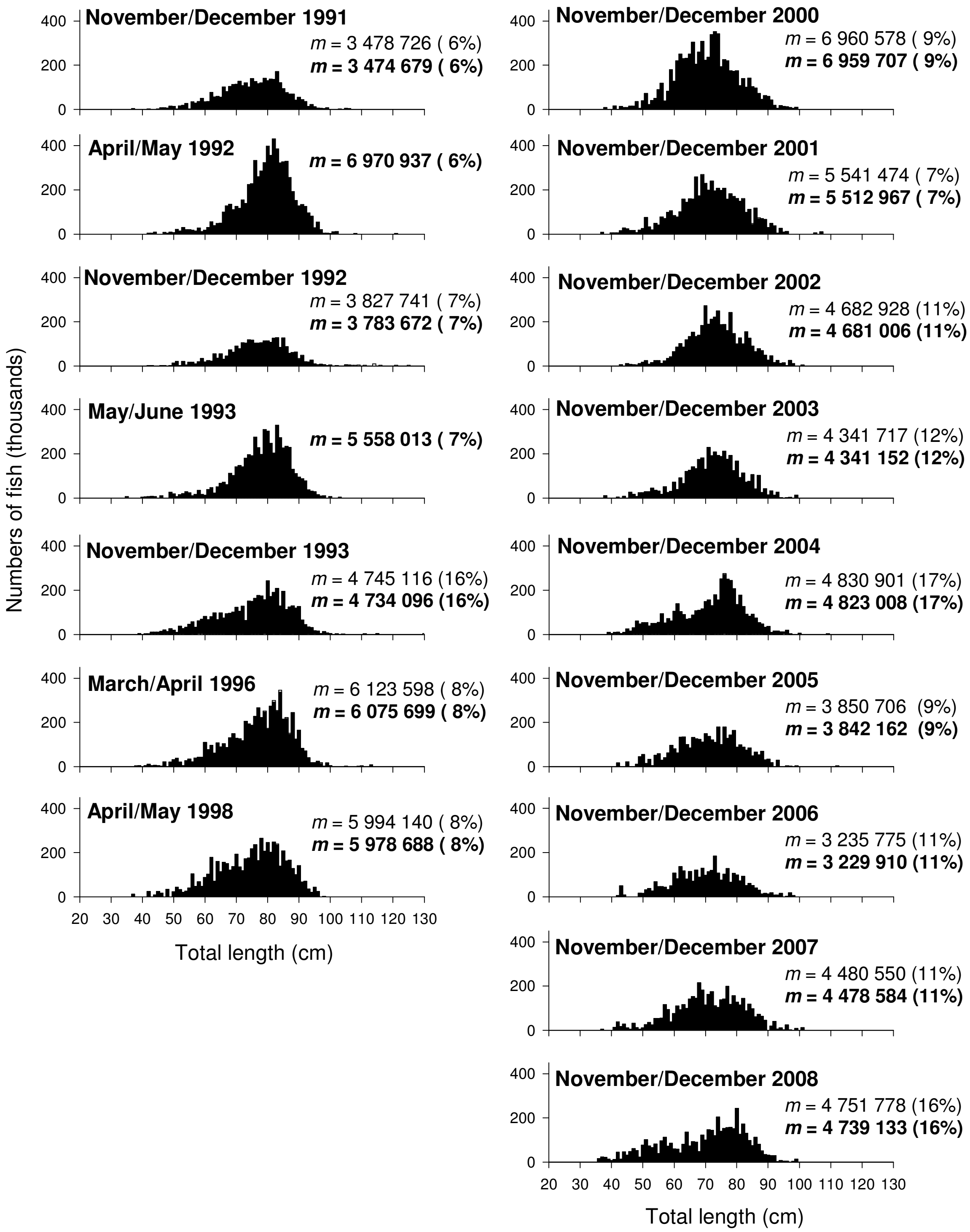


Figure 9a: Scaled length frequency for male ling from all Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all strata as white bars. Because few ling were caught outside core strata, white bars are very small. Numbers (*m* values) above are for all strata and below (in bold) for core strata with c.v.s in parentheses.

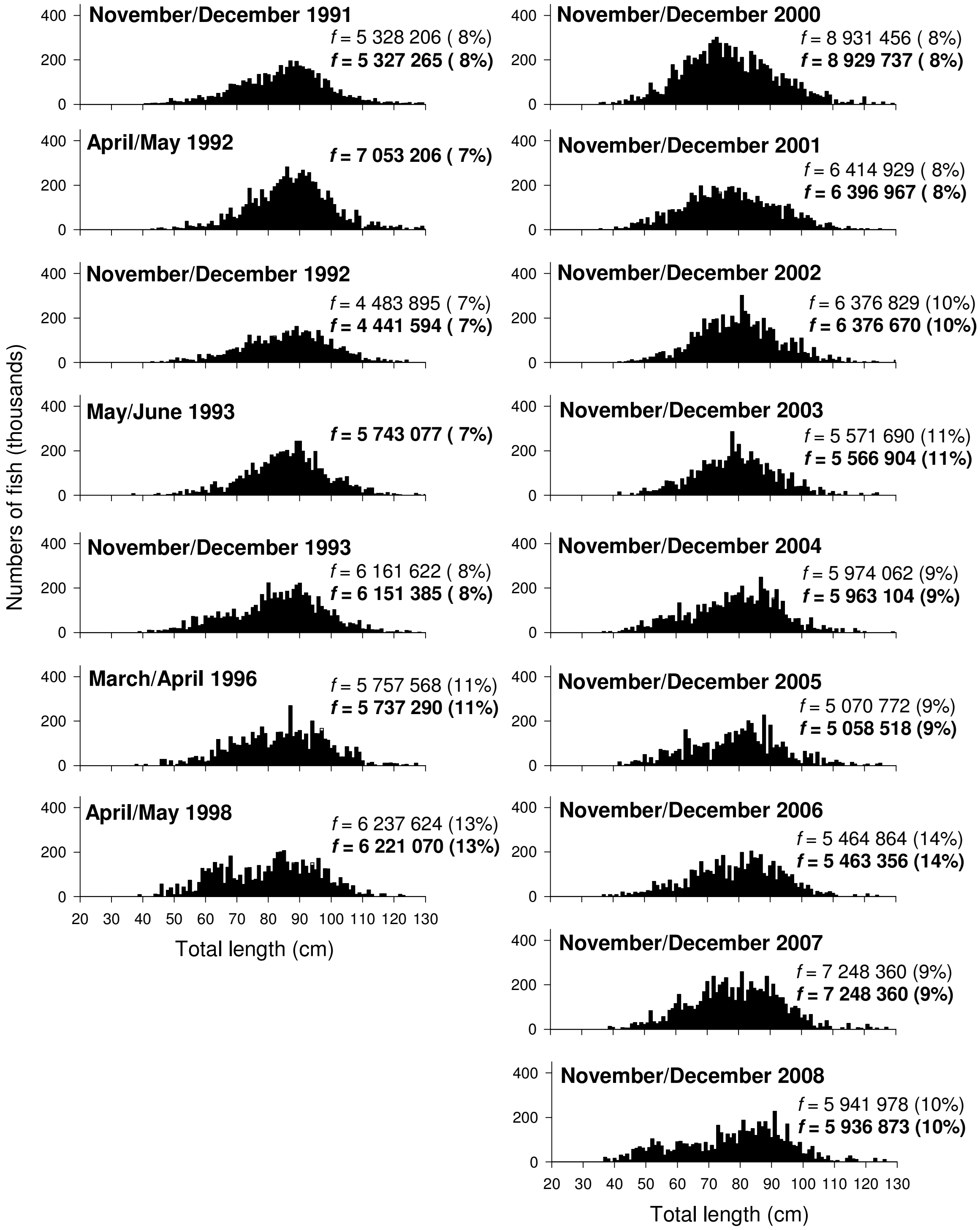


Figure 9b: Scaled length frequency for female ling from all Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all strata as white bars. Because few ling were caught outside core strata, white bars are very small. Numbers (*f* values) above are for all strata and below (in bold) for core strata with c.v.s in parentheses.

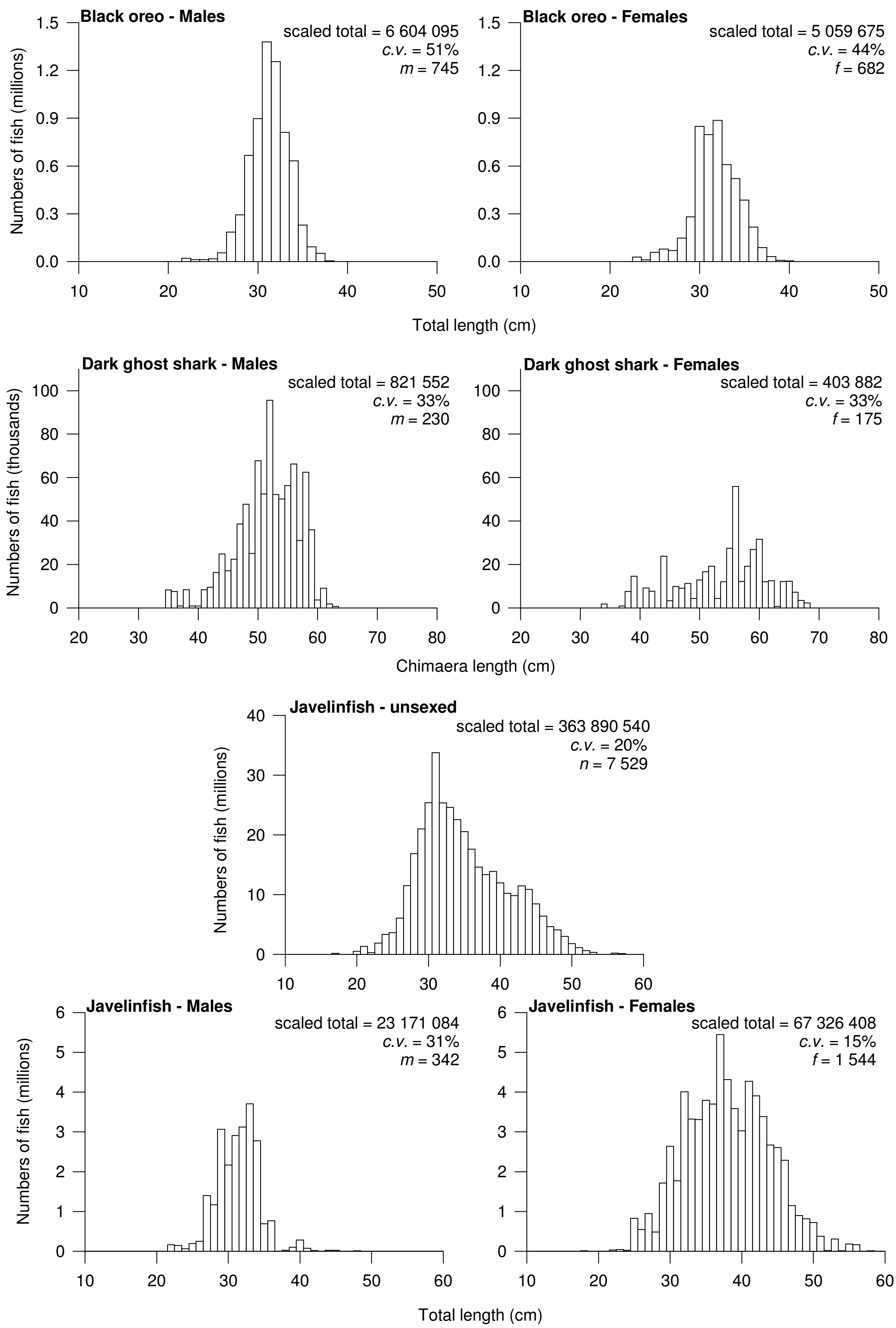


Figure 10: Length frequency distributions by sex of other major species in the November–December 2007 survey. Scaled total is the estimated total number of fish in the surveyed area, c.v. is the coefficient of variation, *m*, *f*, and *n* values are the number of fish measured.

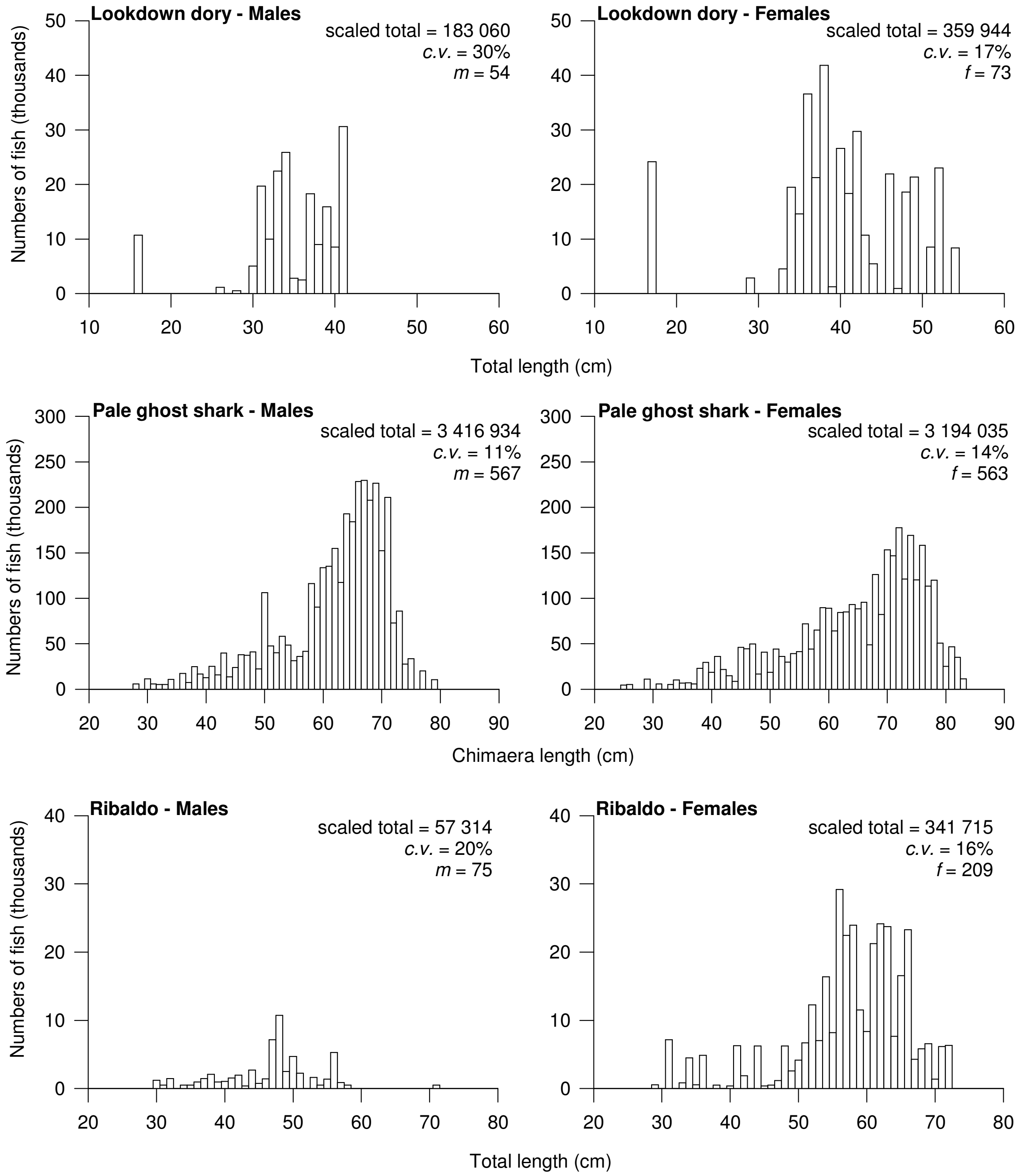


Figure 10 cont: Length frequency distributions by sex of other major species in the November–December 2007 survey. Scaled total is the estimated total number of fish in the surveyed area, c.v. is the coefficient of variation, *m* and *f* values are the number of fish measured.

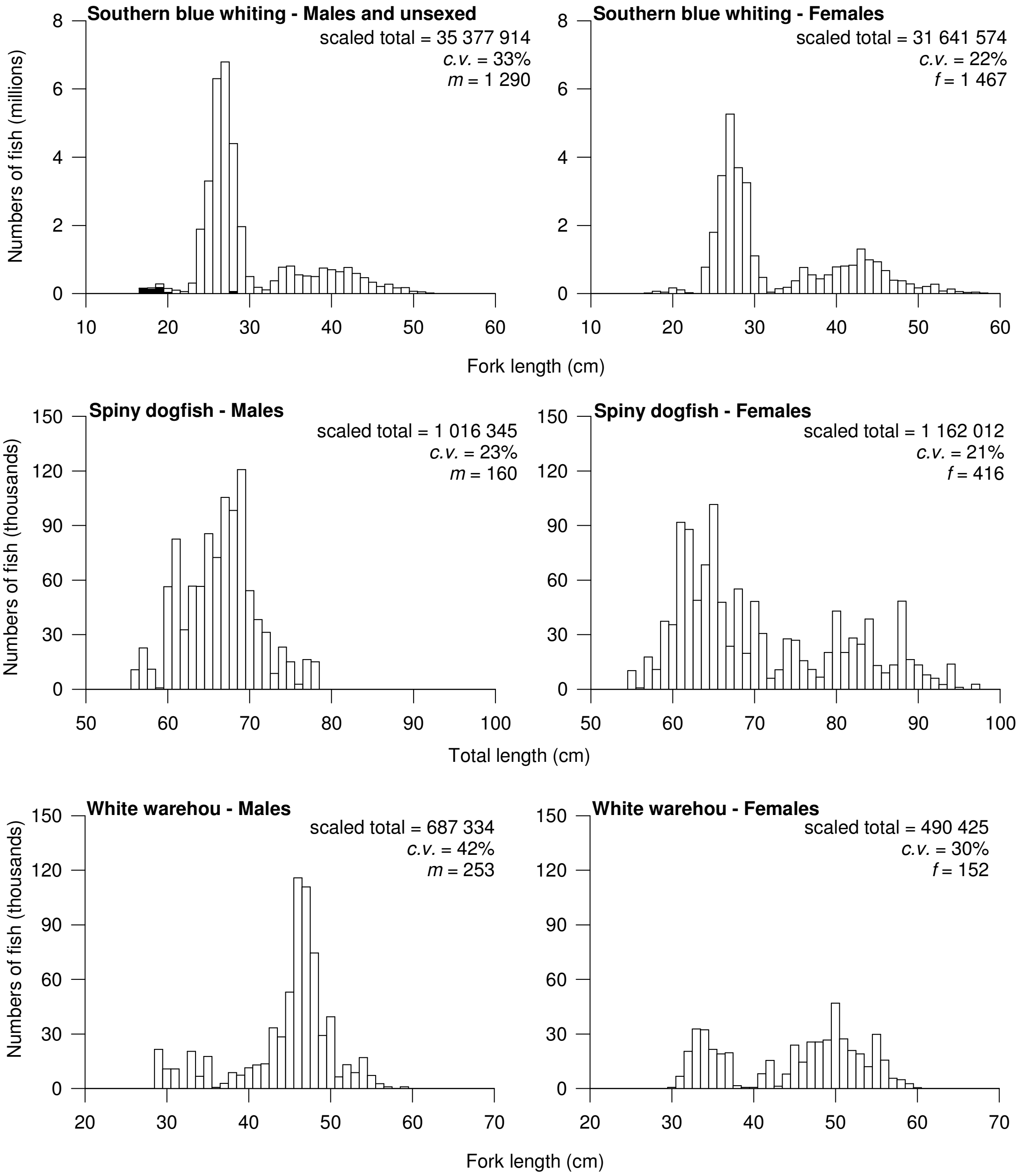


Figure 10 cont: Length frequency distributions by sex of other major species in the November–December 2007 survey. Scaled total is the estimated total number of fish in the surveyed area, c.v. is the coefficient of variation, *m* and *f* values are the number of fish measured. Black bars are unsexed fish.

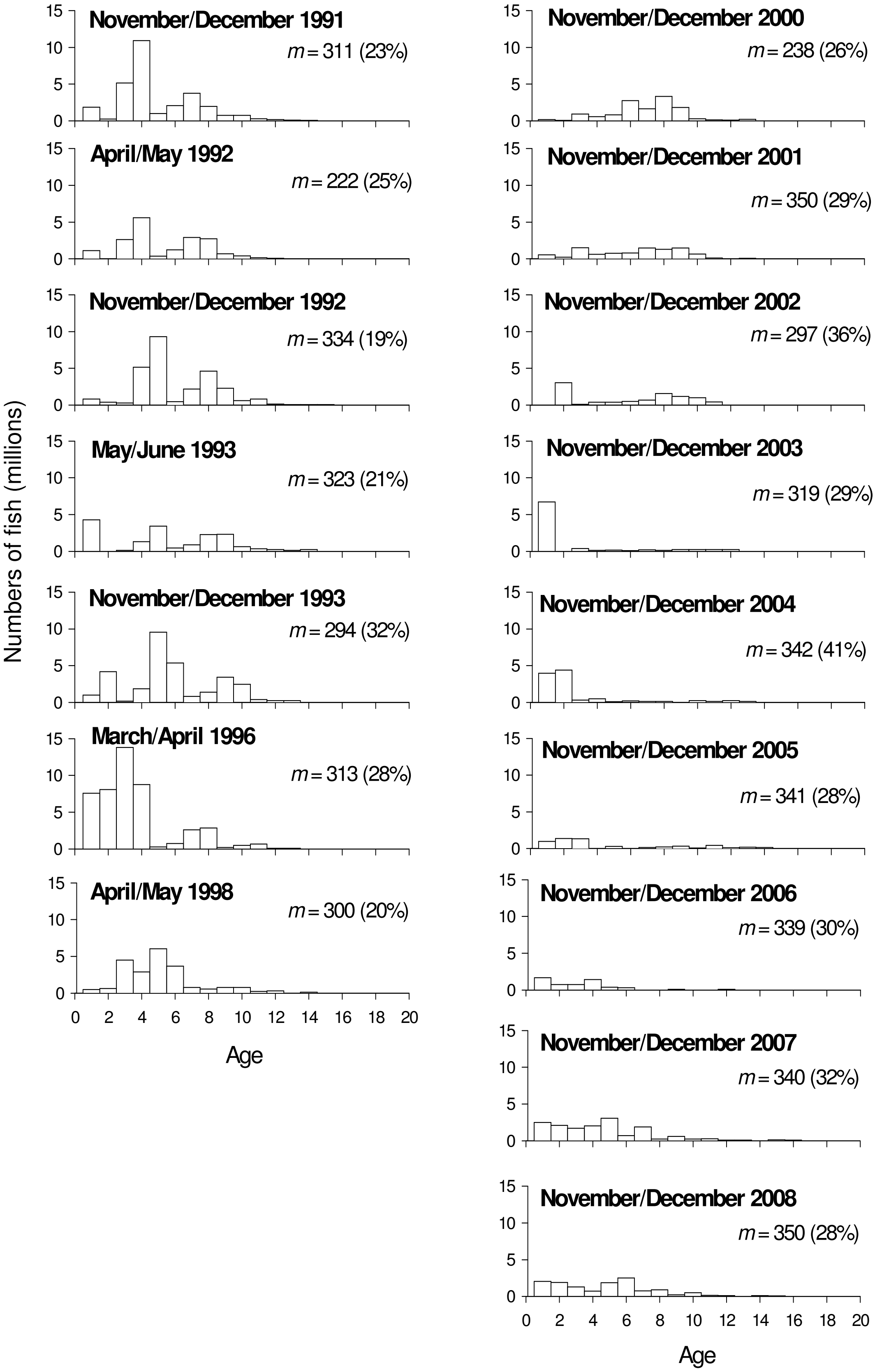


Figure 11a: Scaled age frequency for male hoki from all Sub-Antarctic *Tangaroa* trawl surveys for the core 300–800 m survey area. Number of fish aged (*m* values) are given with c.v.s in parentheses.

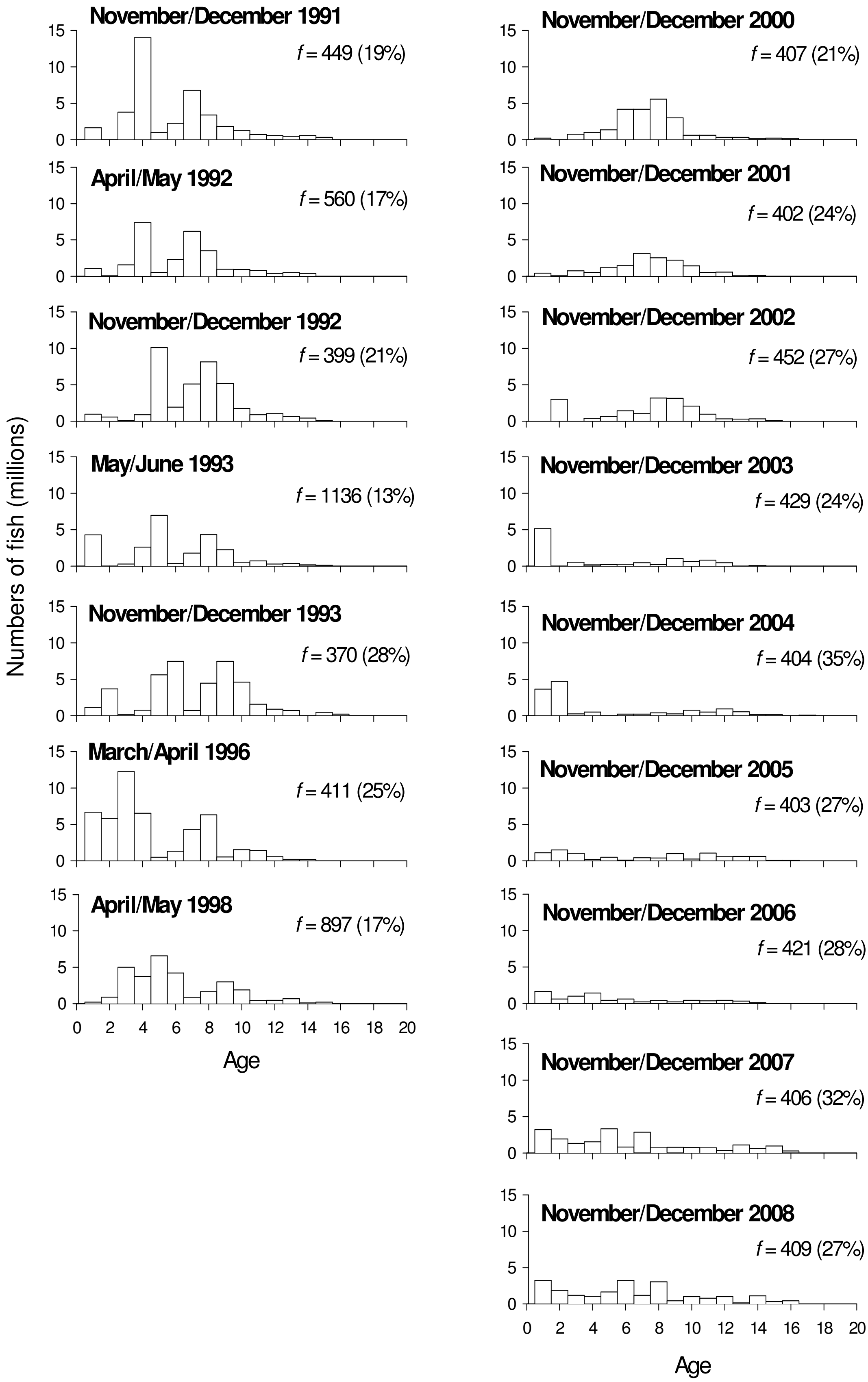


Figure 11b: Scaled age frequency for female hoki from all Sub-Antarctic *Tangaroa* trawl surveys for the core 300–800 m survey area. Number of fish aged (*f* values) are given with c.v.s in parentheses.

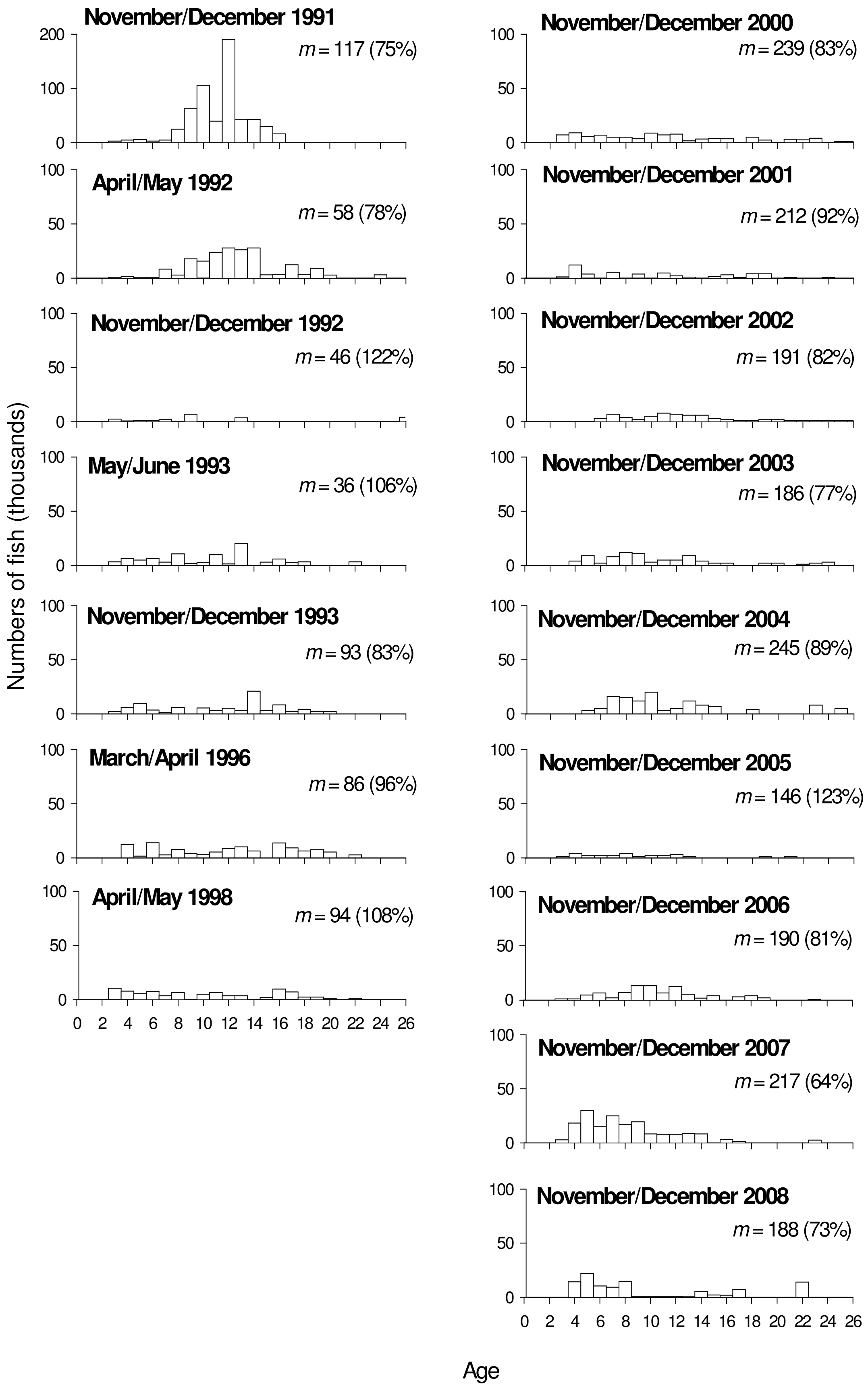


Figure 12a: Scaled age frequency for male hake from all Sub-Antarctic *Tangaroa* trawl surveys for the core 300–800 m survey area. Number of fish aged (*m* values) are given with c.v.s in parentheses.

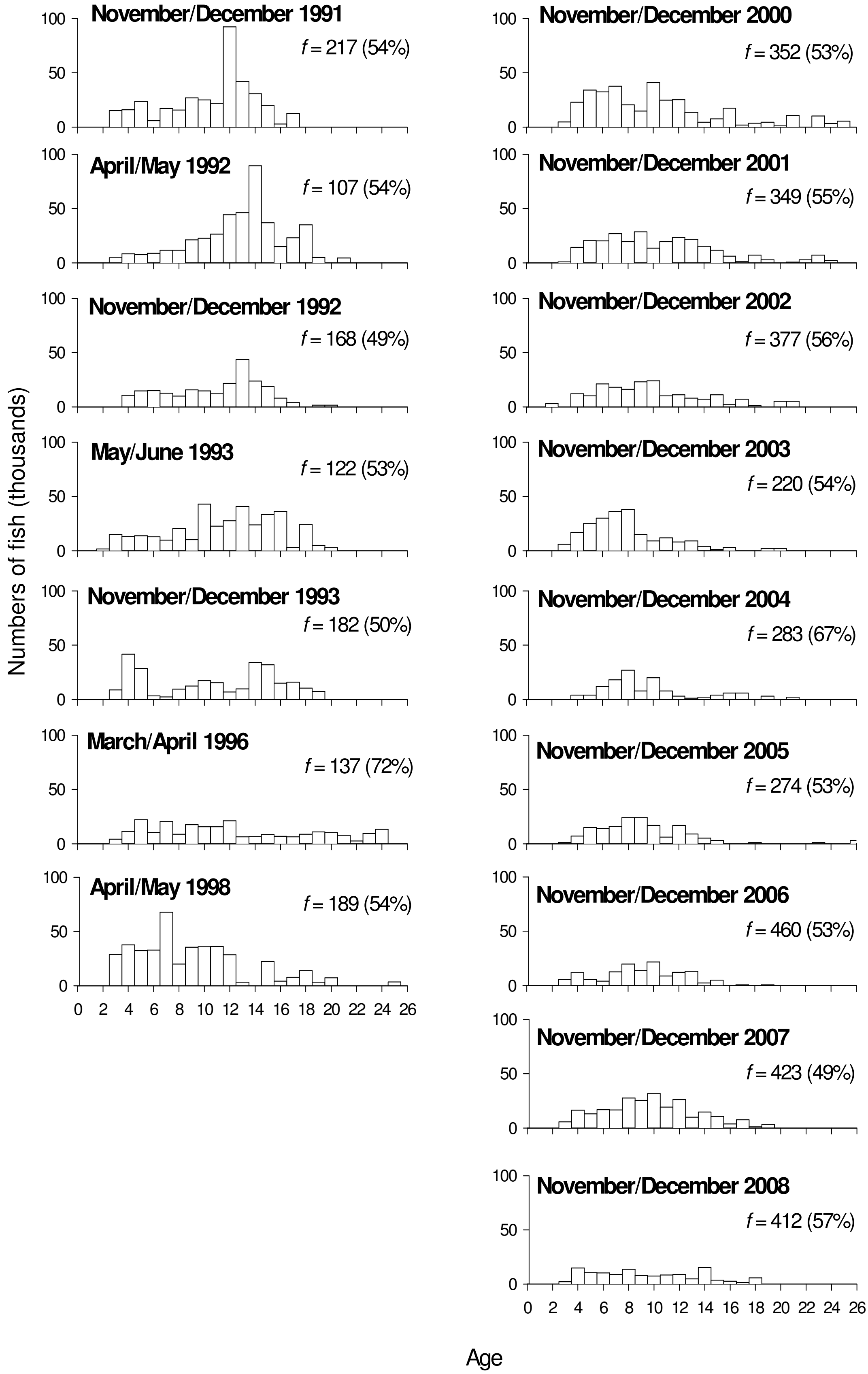


Figure 12b: Scaled age frequency for female hake from all Sub-Antarctic *Tangaroa* trawl surveys for the core 300–800 m survey area. Number of fish aged (*f* values) are given with c.v.s in parentheses.

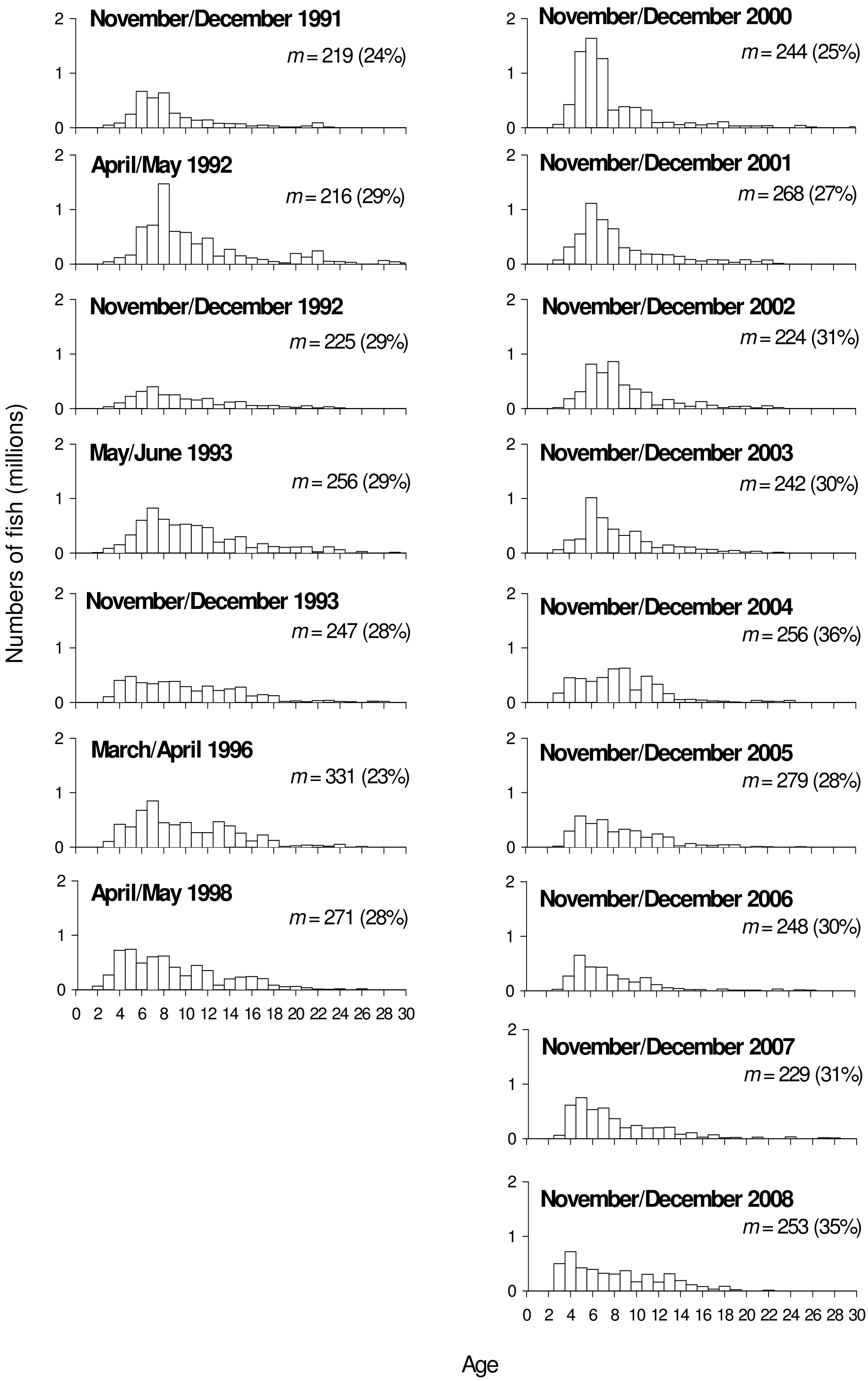


Figure 13a: Scaled age frequency for male ling from all Sub-Antarctic *Tangaroa* trawl surveys for the core 300–800 m survey area. Number of fish aged (*m* values) are given with c.v.s in parentheses.

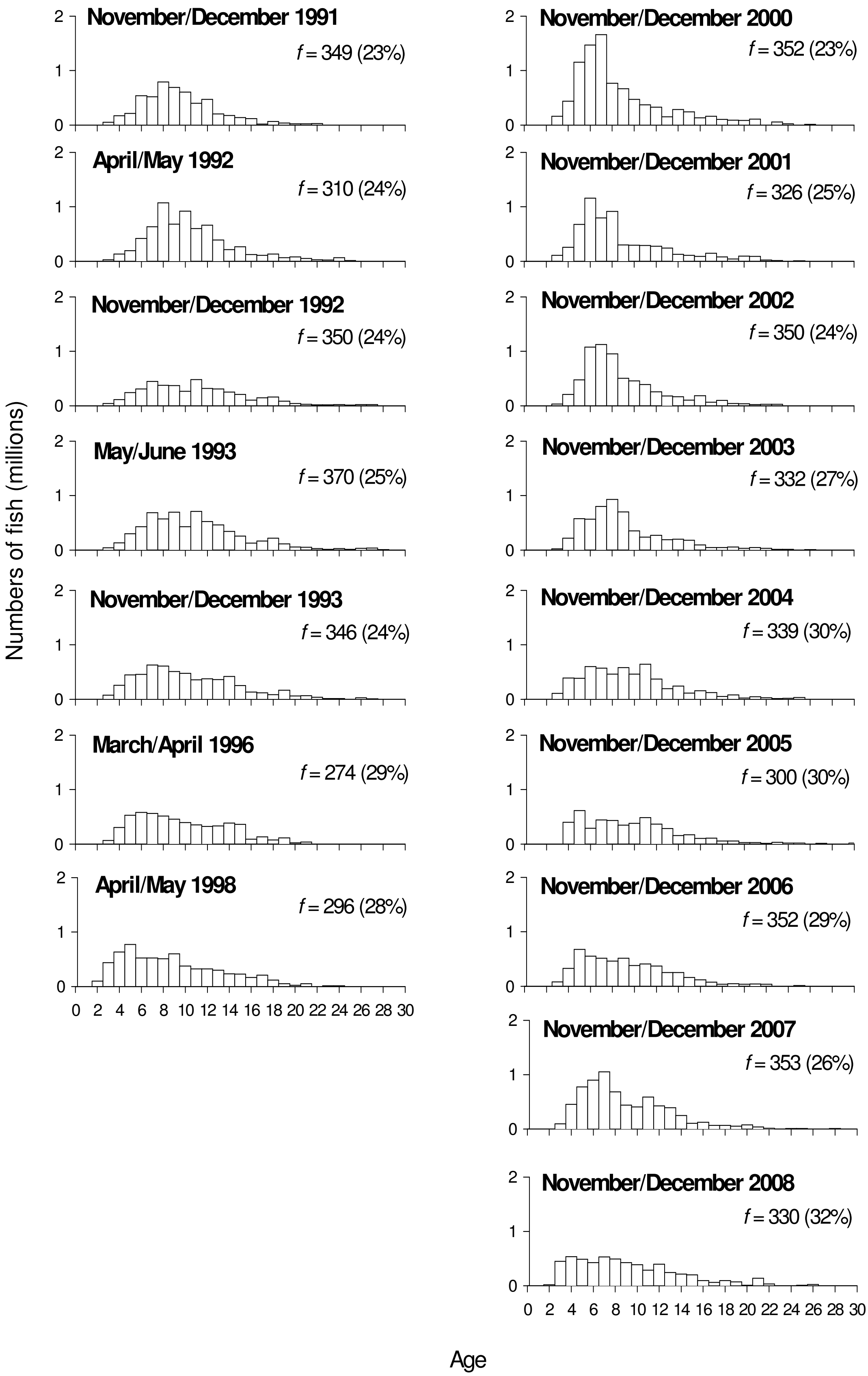


Figure 13b: Scaled age frequency for female ling from all Sub-Antarctic *Tangaroa* trawl surveys for the core 300–800 m survey area. Number of fish aged (*f* values) are given with c.v.s in parentheses.

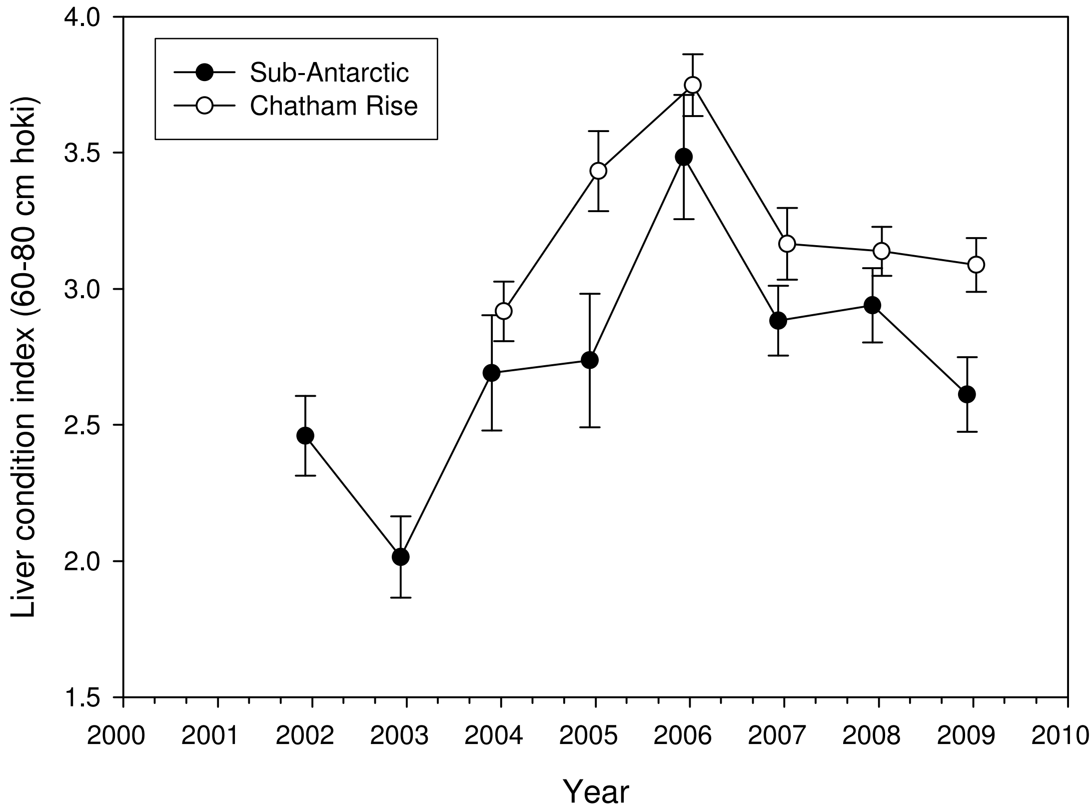


Figure 14: Mean liver condition (+/- 2 standard errors) for 60–80 cm hoki in the Chatham Rise and Sub-Antarctic trawl surveys.

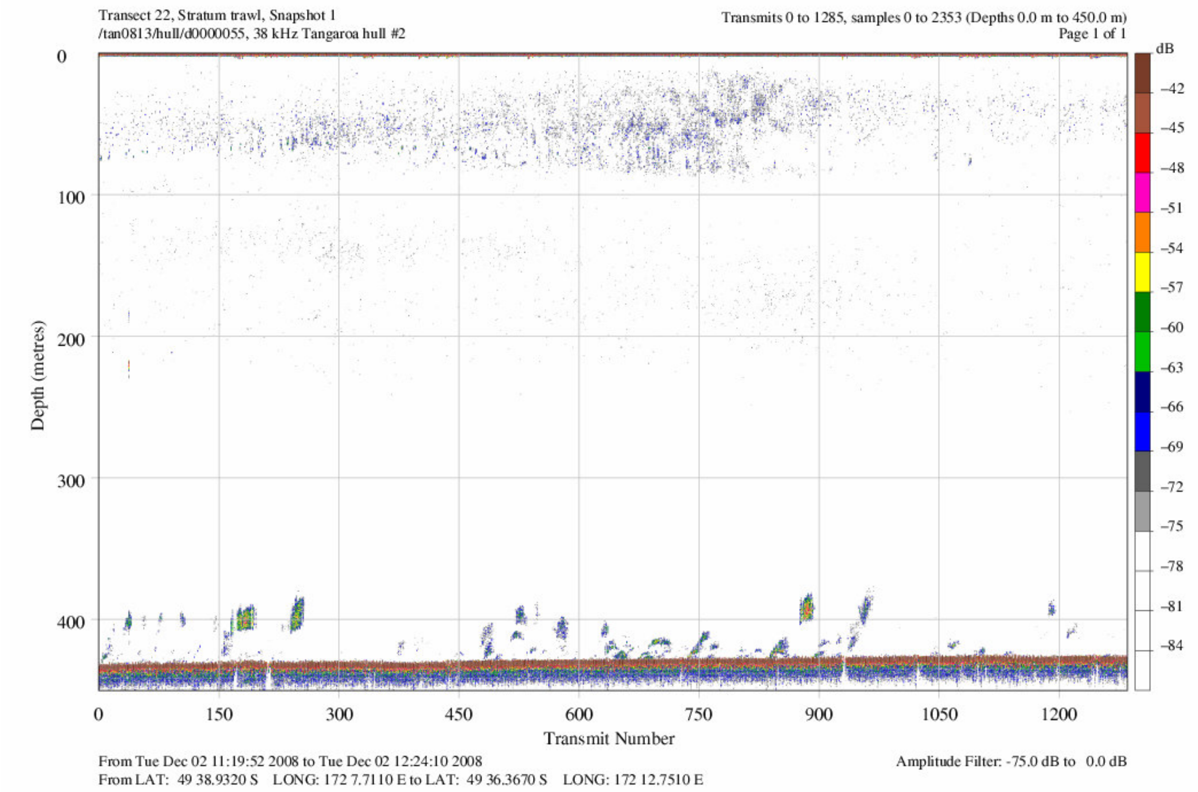
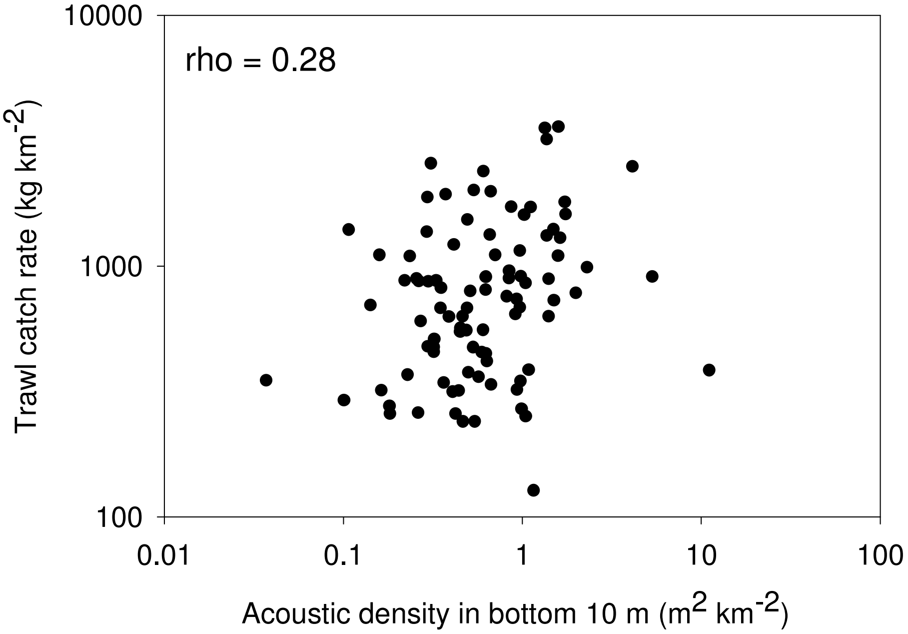


Figure 15: Acoustic echogram (38 kHz) collected during tow 22 on the Pukaki Rise (stratum 12) showing bottom schools. The trawl caught 190 kg of southern blue whiting.



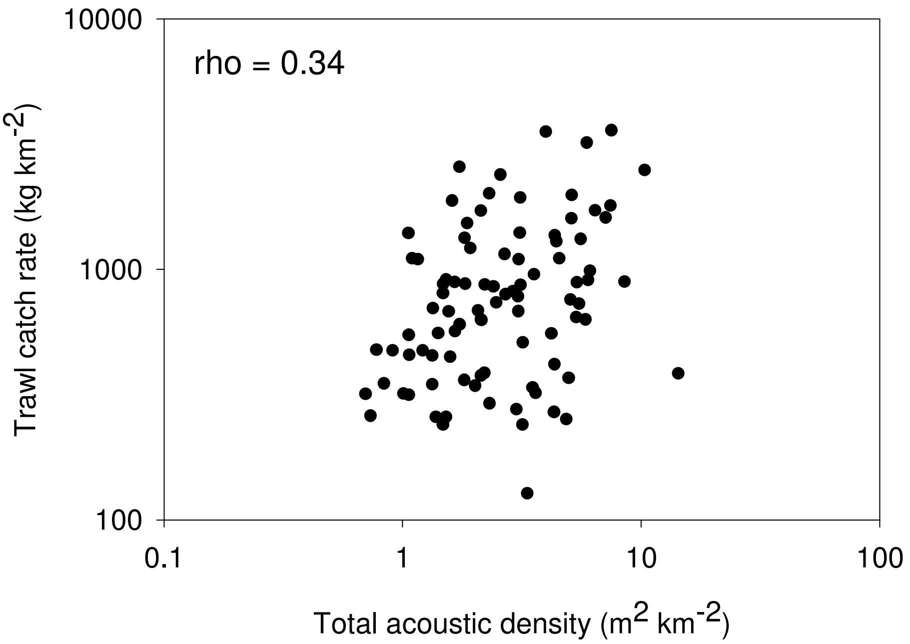


Figure 16. Relationship between total trawl catch rate (all species excluding benthic invertebrates) and acoustic backscatter recorded during the trawl in the Sub-Antarctic in 2008. Rho values are Spearman's rank correlation coefficients.

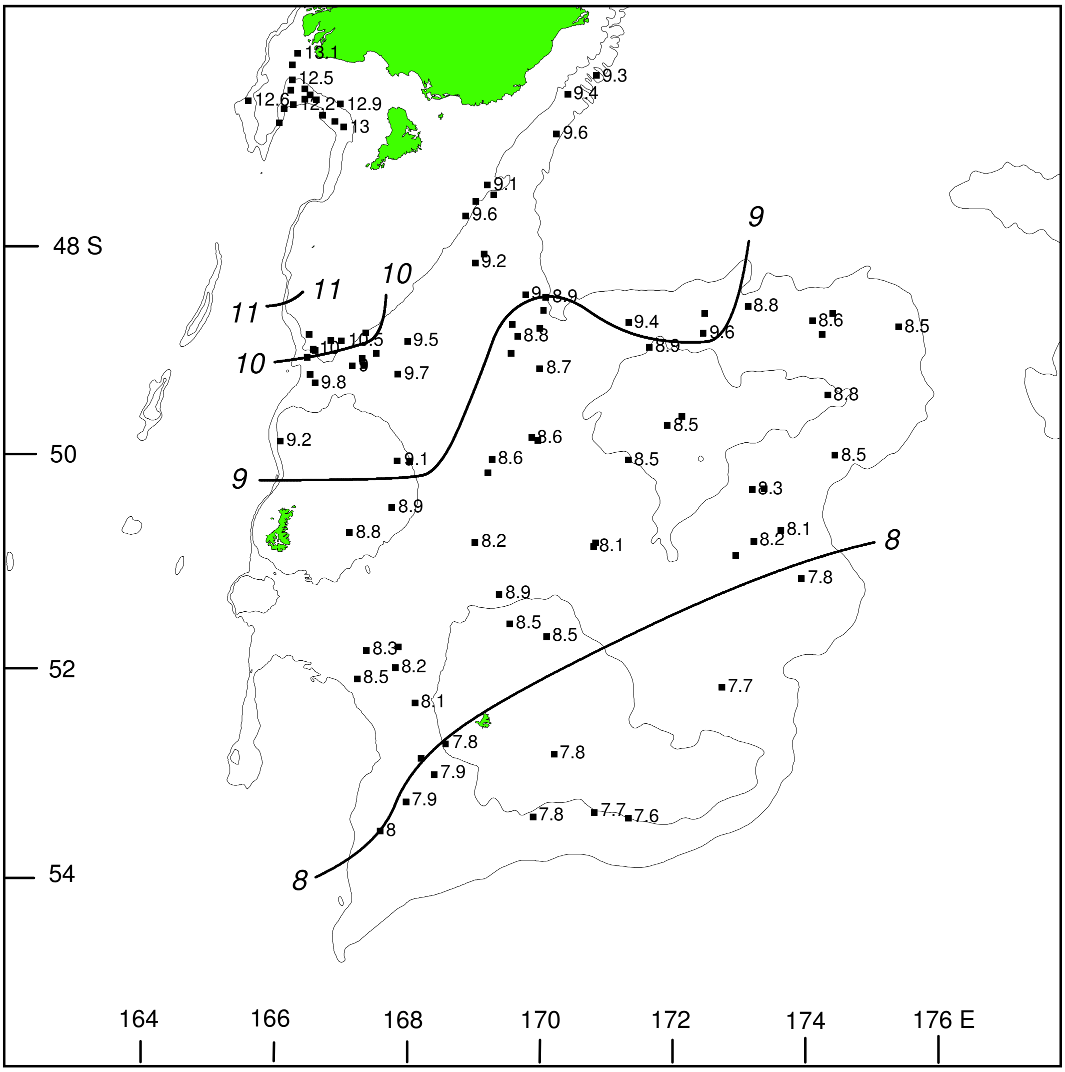


Figure 17: Surface water temperatures (°C). Squares indicate station positions. Not all temperatures are labelled where two or more stations were close together. Contours show isotherms estimated by eye.

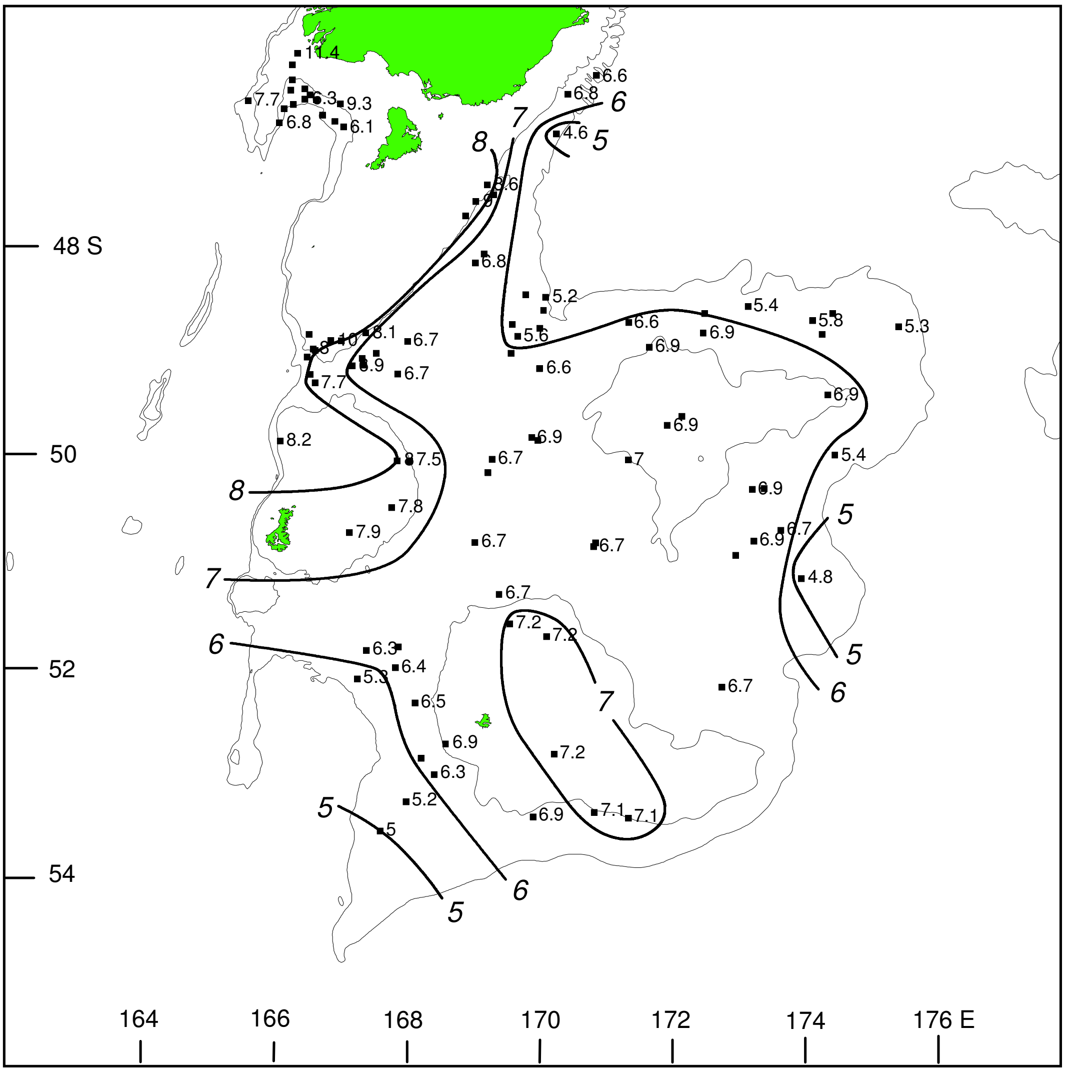


Figure 18: Bottom water temperatures (°C). Squares indicate station positions. Not all temperatures are labelled where two or more stations were close together. Contours show isotherms estimated by eye.

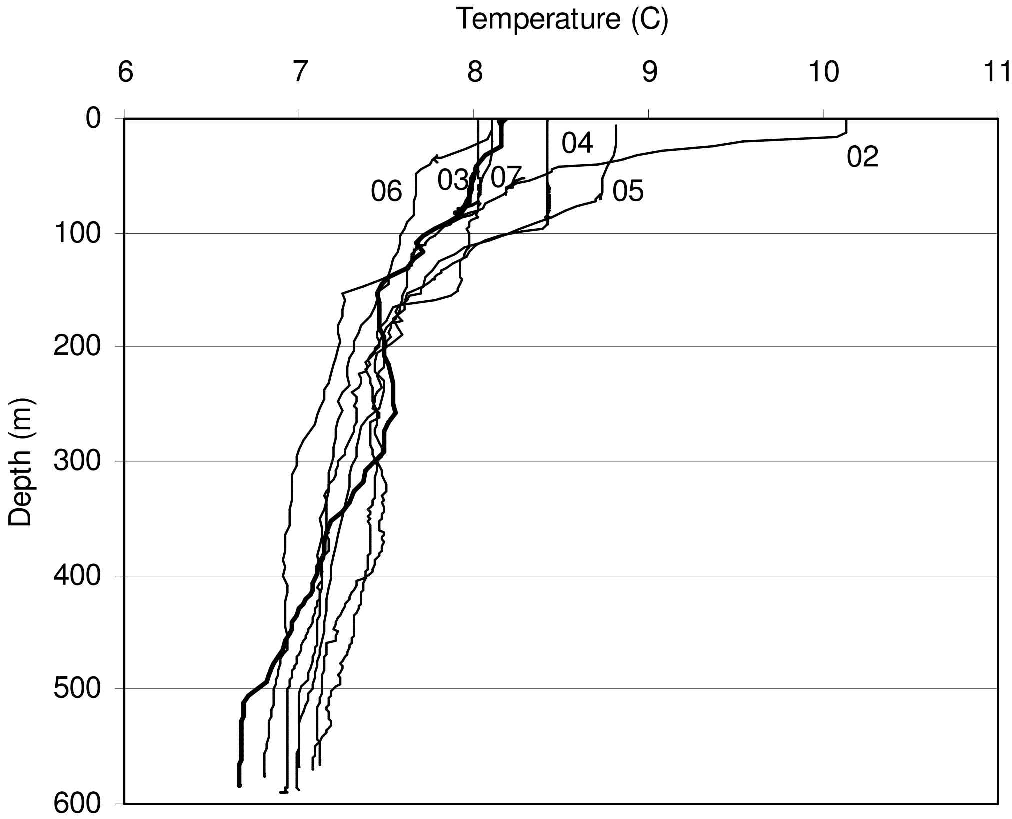


Figure 19: Comparison of vertical profiles of temperature from the net-mounted CTD on tows in stratum 9 at approximately 50 45’ S and 169 00’ E in 2002 (TAN0219 station 54, on 6 December), 2003 (TAN0317 station 45, on 29 November), 2004 (TAN0414 station 54, on 14 December), 2005 (TAN0515 station 42, on 6 December), 2006 (TAN0617 station 33, on 5 December), 2007 (TAN0714 station 40, on 7 December), and 2008 (TAN0813 station 17, on 30 November). The profile from 2008 is the bold line. Labels on the other lines indicate the year (i.e., 2002 is ‘02’).

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 thin and flabby; white or transparent.	Ovaries are developed, but no developing eggs are visible.
3	Ripening	Testes 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.

Appendix 2: Scientific and common names, species codes and occurrence (Occ.) of fish, squid, and other organisms. Note species codes, particularly invertebrates are continually updated on the database following this and other surveys.

Scientific name	Common name	Species code	Occ.
Porifera	unspecified sponges	ONG	5
Hexactinellida: glass sponges			
Hyalascus sp.	floppy tubular sponge	HYA	28
Geodiidae			
Geodinella vestigifera	ostrich egg sponge	GVE	3
Crellidae			
Crella incrustans	orange frond sponge	CIC	2
Hymedesmiidae			
Phorbas spp.	grey fibrous massive sponge	PHB	5
Tetillidae			
Tetilla leptoderma	furry oval sponge	TLD	4
Cnidaria			
Hydrozoa	unidentified hydroid	HDR	1
Scyphozoa	unspecified jellyfish	JFI	4
Anthozoa			
Actiniaria	unspecified sea anemones	ANT	1
Actiniidae			
Bolocera spp	smooth deepsea anemone	BOC	1
Actinostolidae	deepsea anemone	ACS	15
Alcyoniidae			
Hormathiidae	warty deepsea anemone	HMT	12
Hexacorallia	unspecified coral	COU	3
Paragorgiidae			
Paragorgia aborea	bubblegum coral	PAB	1
Ascidiacea	unspecified sea squirt	ASC	1
Tunicata			
Thaliacea	unspecified salps	SAL	4
Salpidae			
Pyrosoma atlanticum		PYR	6
Mollusca			
Gastropoda: gastropods			
Capulidae			
Malluvium calcareum	cap limpet	MCC	3
Ranellidae			
Fusitron magellanicus		FMA	7
Volutidae	unspecified volute	VOL	3
Cephalopoda: squid and octopus	unspecified squid	SQX	3
Teuthoidea: squids			
Histioteuthidae			
Histioteuthis spp	violet squid	VSQ	8
Ommastrephidae			
Nototodarus sloanii	arrow squid	NOS	32
Todarodes filippovae	Antarctic flying squid	TSQ	19
Onychoteuthidae			
Moroteuthis ingens	warty squid	MIQ	67
M. robsoni	warty squid	MRQ	8

Appendix 2: (Continued)

Scientific name	Common name	Species code	Occ.
Octopoda: Octopus			
Octopodidae			
Benthoctopus spp.	deepwater octopus	BNO	2
Enteroctopus zealandicus	yellow octopus	EZE	2
Graneledone spp.	deepwater octopus	DWO	7
Opisthoteuthididae		OSQ	1
Opisthoteuthis spp.	umbrella octopus	OPI	3
Crustacea			
Malacostraca			
Dendrobranchiata/Pleocyemata			
Caridea			
Campylonotidae			
Camplyonotus rathbonae	sabre prawn	CAM	5
Nematocarcinidae			
Lipkius holthuisi	omega prawn	LHO	38
Oplophoridae			
Acanthephyra spp.		ACA	1
Oplophorus spp.	deepwater prawn	OPP	1
Pasiphaeidae			
Pasiphaea aff. tarda	deepwater prawn	PTA	7
Palinura			
Polychelidae			
Polycheles spp.	deepsea blind lobster	PLY	3
Nephropidae: clawed lobsters			
Metanephrops challengeri	scampi	SCI	2
Anomura	unidentified crab	CRB	3
Lithodidae			
Lithodes cf *longispinus*	long-spined king crab	LLT	4
Lithodes murrayi	southern stone crab	LMU	5
Neolithodes brodiei	Brodie's king crab	NEB	3
Paralomis zelandica	prickly king crab	PZE	2
Majidae			
Jacquinotia edwardsii	giant spider crab	GSC	4
Leptomithrax garricki	Garrick's masking crab	GMC	2
Portunidae			
Nectocarcinus bennetti	smooth red swimming crab	NCB	1
Paguridae			
Sympagurus dimorphus	hermit crab	SDM	2
Colossendeidae			
Colossendeis spp.	giant sea spiders	PYC	1
Echinodermata			
Asteroidea	unspecified asteroid	ASR	3
Asteriidae			
Cosmasterias dyscrita	cat's foot star	CDY	1
Pseudechinaster rubens		PRU	1
Sclerasterias mollis	cross-fish	SMO	1
Astropectinidae			
Dipsacaster magnificus	magnificent sea-star	DMG	13
Psilaster acuminatus	geometric star	PSI	2
Proserpinaster neozelanicus		PNE	2

Appendix 2: (Continued)

Scientific name	Common name	Species code	Occ.
Benthopectinidae			
Benthopecten spp.		BES	1
Echinasteridae			
Henricia compacta		HEC	3
Goniasteridae			
Ceramaster patagonicus	pentagon star	CPA	16
Hippasteria trojana	trojan star	HTR	21
Lithosoma novaezelandiae	rock star	LNV	7
Mediaster sladeni	Sladen's star	MSL	1
Pillsburiester aoteanus		PAO	9
Radiasteridae			
Radiaster gracilis		RGR	2
Solasteridae			
Crossaster japonicus	sun star	CJA	5
Solaster torulatus	chubby sun-star	SOT	2
Zoroasteridae			
Zoroaster spp	rat-tail star	ZOR	26
Echinoidea	unspecified sea urchin	ECH	1
Regularia			
Cidaridae			
Goniocidaris umbraculum	umbrella urchin	GOU	4
Echinothuriidae, Phormosomatidae	unspecified Tam O'Shanter urchin	TAM	31
Echinothuriidae	unspecified Tam O'Shanter urchin	ECT	4
Echinidae			
Gracilechinus multidentatus	deepsea kina	GRM	1
Ophiuroidea			
Gorgonocephalidae			
Gorgonocephalus sp	gorgons head basket-star	GOR	1
Holothuroidea	unspecified sea cucumbers	HTH	27
Aspidochirotida			
Synallactidae			
Bathyplotes moseleyi		BAM	5
Pseudostichopus mollis		PMO	13
Elasipodida			
Laetmogonidae			
Pannychia moseleyi		PAM	1
Chondrichthyes			
Triakidae: smoothhounds			
Galeorhinus galeus	school shark	SCH	3
Squalidae: dogfishes			
Centrophorus squamosus	deepwater spiny dogfish	CSQ	20
Centroscymnus coelolepis		CYL	4
C. crepidater	longnose velvet dogfish	CYP	23
C. owstoni	smooth skin dogfish	CYO	6
C. plunketi	Plunket's shark	PLS	4
Deania calcea	shovelnose dogfish	SND	14
Etmopterus baxteri	Baxter's dogfish	ETB	41
E. lucifer	lucifer dogfish	ETL	50
Scymnorhinus licha	seal shark	BSH	14
Squalus acanthias	spiny dogfish	SPD	55
Oxynotidae: rough sharks			
Oxynotus bruniensis	prickly dogfish	PDG	2

Appendix 2: (Continued)

Scientific name	Common name	Species code	Occ.
Scyliorhinidae: cat sharks			
Apristurus spp	deepsea catsharks	APR	7
Halaelurus dawsoni	Dawson's catshark	DCS	7
Torpedinidae: electric rays			
Typhlonarke spp.	numbfish	BER	1
Rajidae: skates			
Bathyraja shuntovi	longnosed deepsea skate	PSK	3
Dipturus innominata	smooth skate	SSK	8
D. nasuta	rough skate	RSK	9
Notoraja spp	bluntnosed skate	BTH	3
Notoraja asperula	smooth deepsea skate	BTA	18
N. spinifera	prickly deepsea skate	BTS	6
Chimaeridae: chimaeras, ghost sharks			
Chimaera sp	brown chimaera	CHP	1
Chimaera lignaria	giant chimaera	CHG	1
Hydrolagus bemisi	pale ghost shark	GSP	79
H. novaezelandiae	dark ghost shark	GSH	17
Rhinochimaeridae: longnosed chimaeras			
Harriotta raleighana	longnose chimaera	LCH	32
Rhinochimaera pacifica	widenose chimaera	RCH	15
Osteichthyes			
Notacanthidae: spiny eels			
N. sexspinis	spineback	SBK	44
Synaphobranchidae: cutthroat eels			
Diastobranchus capensis	basketwork eel	BEE	18
Congridae: conger eels			
Bassanago bulbiceps	swollenheaded conger	SCO	35
B. hirsutus	hairy conger	HCO	32
Gonorynchiformes: sandfish			
Gonorynchus forsteri & *greyi*	sandfish	GON	2
Argentinidae: silversides			
Argentina elongata	silverside	SSI	37
Bathylagidae: deepsea smelts			
Bathylagus antarcticus	deepsea smelt	BAA	3
Nansenia spp.	deepsea smelt	NAN	2
Alepocephalidae: slickheads			
Alepocephalus australis	small-scaled brown slickhead	SSM	10
Platytroctidae: tubeshoulders			
Persparsia kopua	tubeshoulder	PER	2
Chauliodontidae: viperfishes			
Chauliodus sloani	viperfish	CHA	6
Stomiidae: scaly dragonfishes			
Stomias spp	scaly dragonfish	STO	2
Astronesthidae: snaggletooths			
Species not identified	snaggletooth	AST	1
Malacosteidae: loosejaws			
Species not identified	loosejaw	MAL	1
Idiacanthidae: black dragonfishes			
Idiacanthus sp	black dragonfish	IDI	2
Sternoptychidae: hatchetfishes			
Argyropelecus gigas	giant hatchetfish	AGI	1
Photichthyidae: lighthouse fishes			
Photichthys argenteus	lighthouse fish	PHO	22

Appendix 2: (Continued)

Scientific name	Common name	Species code	Occ.
Paralepididae: barracudinas			
Magnisudis prionosa	barracudina	BCA	1
Myctophidae: lanternfishes			
Species not identified	lanternfish	LAN	2
Diaphus sp.		DIA	2
Gymnoscopelus spp.	lanternfish	GYM	4
G. piabilis	lanternfish	GYP	1
Lampadena spp.	lanternfish	LPD	1
Lampanyctodes hectoris	lanternfish	LHE	2
Lampanyctus spp.	lanternfish	LPA	4
Protomyctophum spp.	lanternfish	PRO	1
Moridae: morid cods			
Antimora rostrata	violet cod	VCO	7
Notophycis marginata	dwarf cod	DCO	3
Halargyreus johnsoni	Johnson's cod	HJO	14
Lepidion microcephalus	small-headed cod	SMC	10
Mora moro	ribaldo	RIB	42
Pseudophycis bachus	red cod	RCO	8
Tripterophycis gilchristi	grenadier cod	GRC	1
Gadidae: true cods			
Micromesistius australis	southern blue whiting	SBW	30
Merlucciidae: hakes			
Lyconus sp		LYC	4
Macruronus novaezelandiae	hoki	HOK	93
Merluccius australis	hake	HAK	47
Macrouridae: rattails, grenadiers			
Caelorinchus aspercephalus	oblique-banded rattail	CAS	41
C. biclinozonalis	two saddle rattail	CBI	1
C. bollonsi	Bollons's rattail	CBO	17
C. fasciatus	banded rattail	CFA	75
C. innotabilis	notable rattail	CIN	26
C. kaiyomaru	Kaiyomaru rattail	CKA	17
C. matamua	Mahia rattail	CMA	16
C. oliverianus	Oliver's rattail	COL	50
C. parvifasciatus	small-banded rattail	CCX	6
C. supernasutus	supanose rattail	CFX	1
Coryphaenoides dossenus	humpback rattail	CBA	13
C. serrulatus	serrulate rattail	CSE	16
C . subserrulatus	fourrayed rattail	CSU	33
Lepidorhynchus denticulatus	javelinfish	JAV	89
Macrourus carinatus	ridge-scaled rattail	MCA	33
Mesobius antipodum	black javelinfish	BJA	4
Nezumia namatahi	squashed face rattail	NNA	1
Trachyrincus aphyodes	white rattail	WHX	11
Trachyrincus longirostris	unicorn rattail	WHR	1
Ventrifossa nigromaculata	blackspot rattail	VNI	22
Ophidiidae: cusk eels			
Genypterus blacodes	ling	LIN	83
Trachichthyidae: roughies			
Hoplostethus atlanticus	orange roughy	ORH	14
H. mediterraneus	silver roughy	SRH	7
Paratrachichthys trailli	common roughy	RHY	2
Diremidae: discfishes			
Diretmus argenteus	discfish	DIS	3

Appendix 2: (Continued)

Scientific name	Common name	Species code	Occ.
Anoplogastridae: fangtooth			
Anoplogaster cornuta	fangtooth	ANO	1
Berycidae: alfonsions			
Beryx splendends	alfonsino	BYS	1
Zeidae: dories			
Capromimus abbreviatus	capro dory	CDO	2
Cyttus novaezealandiae	silver dory	SDO	5
C. traversi	lookdown dory	LDO	43
Macrorhamphosidae: snipefishes			
Centriscops humerosus	banded bellowsfish	BBE	4
Scorpaenidae: scorpionfishes			
Helicolenus spp.	sea perch	SPE	4
Oreosomatidae: oreos			
Allocyttus niger	black oreo	BOE	14
Neocyttus rhomboidalis	spiky oreo	SOR	4
Pseudocyttus maculatus	smooth oreo	SSO	16
Congiopodidae: pigfishes			
Alertichthys blacki	alert pigfish	API	1
Congiopodus coriaceus	deepsea pigfish	DSP	2
Hoplichthyidae: ghostflatheads			
Hoplichthys haswelli	deepsea flathead	FHD	4
Psychrolutidae: toadfishes			
Neophrynichthys angustus	pale toadfish	TOP	11
N. latus	dark toadfish	TOD	2
Psychrolutes sp	blobfish	PSY	4
Percichthyidae: temperate basses			
Polyprion oxygeneios	hapuku	HAP	1
Apogonidae: cardinalfishes			
Epigonus lenimen	bigeye cardinalfish	EPL	8
E. telescopus	black cardinalfish	EPT	6
Bramidae: pomfrets			
Brama brama	Ray's bream	RBM	15
B. australis	southern Ray's bream	SRB	1
Nototheniidae: ice cods			
Paranotothenia microlepidota	smallscaled cod	SCD	1
Uranoscopidae: armourhead stargazers			
Kathetostoma giganteum	giant stargazer	STA	18
Percophidae: opalfishes			
Hemerocoetes spp	opalfish	OPA	2
Gempylidae: snake mackerels			
Rexea solandri	gemfish	SKI	1
Trichiuridae: cutlassfishes			
Lepidopus caudatus	frostfish	FRO	1
Centrolophidae: raftfishes, medusafishes			
Centrolophus niger	rudderfish	RUD	7
Icichthys australis	ragfish	RAG	1
Schedophilus huttoni		SUH	1
Seriolella caerulea	white warehou	WWA	26
S. punctata	silver warehou	SWA	8
Tubbia tasmanica		TUB	1
Bothidae: lefteyed flounders			
Arnoglossus scapha	witch	WIT	2
Neoachiropsetta milfordi	finless flounder	MAN	31

Appendix 3: Scientific and common names of benthic invertebrates formally identified following the voyage.

NIWA No.	Cruise/Station No	Phylum	Class	Order	Family	Genus	Species
48104	TAN0813/29	Crustacea	Malacostraca	Decapoda	Majidae	*Teratomaia*	*richardsoni*
48113	TAN0813/83	Crustacea	Malacostraca	Decapoda	Majidae	*Teratomaia*	*richardsoni*
48108	TAN0813/53	Bryozoa	Gymnolaemata	Cheilostomata	Bitectiporidae	*Bitectipora*	*retepora*
48108	TAN0813/53	Bryozoa	Gymnolaemata	Cheilostomata	Chaperiidae	*Chaperiopsis (Clipeochaperia)*	*funda*
48108	TAN0813/53	Bryozoa	Gymnolaemata	Cheilostomata	Smittinidae	*Parasmittina*	*aotea*
48109	TAN0813/57	Bryozoa	Gymnolaemata	Cheilostomata	Celleporidae	*Celleporina*	*sinuata*
48109	TAN0813/57	Bryozoa	Gymnolaemata	Cheilostomata	Smittinidae	*Hippomonavella*	*flexuosa*
48109	TAN0813/57	Bryozoa	Gymnolaemata	Cheilostomata	Celleporidae	Lagenipora(?)	
48109	TAN0813/57	Bryozoa	Gymnolaemata	Cheilostomata	Microporellidae	*Microporella*	*agonistes*
48109	TAN0813/57	Bryozoa	Gymnolaemata	Cheilostomata	Bitectiporidae	*Parkermavella*	*punctigera*
48109	TAN0813/57	Bryozoa	Gymnolaemata	Cheilostomata	Bitectiporidae	*Parkermavella*	*virago*
48109	TAN0813/57	Bryozoa	Gymnolaemata	Cheilostomata	Bitectiporidae	Schizomavella(?)	
50288	TAN0813/57	Bryozoa	Gymnolaemata	Cheilostomata	Microporellidae	*Microporella*	*agonistes*
50289	TAN0813/57	Bryozoa	Gymnolaemata	Cheilostomata	Smittinidae	*Hippomonavella*	*flexuosa*
50290	TAN0813/57	Bryozoa	Gymnolaemata	Cheilostomata	Bitectiporidae	*Parkermavella*	*virago*
50291	TAN0813/57	Bryozoa	Gymnolaemata	Cheilostomata	Celleporidae	*Celleporina*	*sinuata*
50292	TAN0813/57	Bryozoa	Gymnolaemata	Cheilostomata	Bitectiporidae	*Parkermavella*	*punctigera*
48105	TAN0813/34	Urochordata	Ascidiacea [Tunicates]	Enterogona Aplousobranchia	Polyclinidae	Synoicum	
47848	TAN0813/56	Cnidaria	Anthozoa	Actiniaria			
47868	TAN0813/56	Cnidaria	Anthozoa	Actiniaria	Isanthidae		
47869	TAN0813/42	Cnidaria	Anthozoa	Actiniaria			
47871	TAN0813/56	Cnidaria	Anthozoa	Actiniaria			
47872	TAN0813/68	Cnidaria	Anthozoa	Actiniaria	Hormathiidae		
47873	TAN0813/56	Cnidaria	Anthozoa	Actiniaria	Hormathiidae		
48100	TAN0813/23	Cnidaria	Anthozoa	Gorgonacea	Acanthogorgiidae	Acanthogorgia	
48107	TAN0813/53	Cnidaria	Hydrozoa	Anthoathecata	Stylasteridae	Errina	
48117	TAN0813/93	Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	Anthomastus	
48098	TAN0813/3	Echinodermata	Asteroidea	Velatida	Korethrasteridae	*Peribolaster*	*lictor*
48110	TAN0813/58	Echinodermata	Asteroidea	Paxillosida	Radiasteridae	*Radiaster*	*gracilis*
48111	TAN0813/58	Echinodermata	Holothuroidea (Class)	Aspidochirotida	Synallactidae	*Bathyplotes*	*moseleyi*
48112	TAN0813/69	Echinodermata	Asteroidea	Forcipulatida	Asteriidae	*Perissasterias*	*monacantha*
48116	TAN0813/93	Echinodermata	Asteroidea	Valvatida	Goniasteridae	*Mediaster*	*arcuatus*
48119	TAN0813/45	Echinodermata	Asteroidea	Valvatida	Goniasteridae	*Pillsburiaster*	*aoteanus*

Appendix 3: (continued)

NIWA No.	Cruise/Station No	Phylum	Class	Order	Family	Genus	Species
48099	TAN0813/5	Porifera	Demospongiae	Poecilosclerida	Latrunculiidae	*Latrunculia*	*millerae*
48101	TAN0813/23	Porifera	Demospongiae	Poecilosclerida	Coelosphaeridae	*Lissodendoryx*	*bifacialis*
48102	TAN0813/23	Porifera	Demospongiae	Astrophorida	Geodiidae	*Geodia*	*regina*
48103	TAN0813/23	Porifera	Demospongiae	Astrophorida	Pachastrellidae	*Poecillastra*	*laminaris*
48106	TAN0813/43	Porifera	Demospongiae	Spirophorida	Tetillidae	Cinachyrella	
48114	TAN0813/91	Porifera	Demospongiae	Spirophorida	Tetillidae	Cinachyrella	
48115	TAN0813/86	Porifera	Demospongiae	Astrophorida	Geodiidae	Pachymatisma	
48118	TAN0813/87	Porifera	Demospongiae	Astrophorida	Geodiidae	Pachymatisma	
48120	TAN0813/16	Porifera	Demospongiae	Poecilosclerida	Coelosphaeridae	Lissodendoryx	
52586	TAN0813/23	Porifera	Demospongiae	Spirophorida	Tetillidae	*Craniella*	*neocaledoniae*