Trawl survey of hoki, hake, and ling in the Southland and Sub-Antarctic areas, November–December 2009 (TAN0911)

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New Zealand Fisheries Assessment Report 2012/05
February 2012

Published by Ministry of Fisheries
Wellington
2012

ISSN 1175-1584 (print)
ISSN 1179-5352 (online)

Bagley, N.W.; O'Driscoll, R.L. (2012).
Trawl survey of middle depth species in the Southland and Sub-Antarctic areas, November–December 2009 (TAN0911).
New Zealand Fisheries Assessment Report 2012/05. 70p.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

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The thirteenth *Tangaroa* summer trawl survey of the Southland and Sub-Antarctic areas was carried out from 24 November to 23 December 2009. Ninety trawls were successfully completed in 21 strata.

Biomass estimates (and c.v.s) for all strata were 66 157 t (16%) for hoki, 22 772 t (10%) for ling, and 1602 t (18%) for hake. The hoki biomass was higher than the 2008 estimate of 48 340 t, continuing the increase from the low of 14 747 t recorded in 2006. The hake estimate from all strata was lower than that in 2008 (2354 t), and the lowest estimate recorded for the summer series for the core strata. The hake biomass in stratum 25 (800–1000 m) at Puysegur was less than half of that observed in 2008 (1088 t in 2008 down to 450 t in 2009). The biomass estimate for ling was very similar to that in 2008 (22 880 t). There was no consistent increase or decrease in the abundance of nine other key species. The estimate for southern blue whiting was over three times higher than that recorded in 2008, and the highest biomass estimate in the summer time series. The biomass of javelinfish was about half of that recorded in 2008 but still the second highest in the summer time series. Estimates for ribaldo, pale ghost shark and spiny dogfish were higher than those recorded in 2008, while lookdown dory, dark ghost shark, white warehou, and black oreo had similar or lower estimates.

The size distribution of hoki was relatively broad, from 35–110 cm. The length and age frequencies for both sexes were dominated by fish between 48 and 58 cm (age 2+). The main age modes showed progression of cohorts from the 2008 survey, with most fish under age 8. A mode at age 9 (2000 year-class) for females in 2008 was still evident, although in reduced numbers. A few larger older hoki (ages 9–17) were present. The age distributions for hake and ling were also broad. Most hake were aged between 4 and 16 years, with a mode between 3 and 5 years. Most ling were between ages 3 and 16. The good recent recruitment of ling reported at ages 3 and 4 in 2008 did not clearly follow through to 2009 in the age frequencies.

Acoustic data were also collected during the trawl survey. Acoustic indices of mesopelagic fish abundance decreased slightly from the previous survey in 2008. There was a weak positive correlation between acoustic density from bottom marks and trawl catch rates in 2009.

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 greatly reduced 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 at over 35 000 t in 1999–00 to 2001–02, declined to a low of about 8000 t in 2006–07, and then increased slowly to 10 000 t in 2008–09 (Ballara et al. 2011). 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 and 2008–09, with a doubling of the western catch limit to 50 000 t (within a total TACC of 110 000 t) for the 2009–10 fishing year. 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 2008–09 were 3415 t (HAK 1, includes the western Chatham Rise) with 2214 t reported from the Sub-Antarctic, 3009 t (LIN 5, Southland), and 3199 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 1991–93 and 2000–09, 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. There was a very large (threefold) increase in estimates of hoki abundance between the 2006 and 2007 trawl surveys (Bagley et al. 2009). The 2008 survey result was similar to 2007 and confirmed the large increase in hoki biomass observed in 2007 (O'Driscoll & Bagley 2009). This increase could not be fitted by the stock assessment model (Francis 2009a, McKenzie & Francis 2009), 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 2008 and gear parameters were consistent with specifications obtained on previous surveys (Bagley et al. 2009, O'Driscoll & Bagley 2009). Despite the large increase in the estimated hoki biomass the 2007–09 estimates were still less than the biomass observed in the Sub-Antarctic in the early 1990s.

The stock status for "western" hoki stock from the 2009 assessment suggested that median estimates of current biomass were 36–39% B_0 and that there was an extended period of poor recruitment from 1995 to 2001 (McKenzie & Francis 2009). The 2009 survey, carried out from 24 November to 23 December 2009 (TAN0911) provided a thirteenth summer estimate of western hoki biomass in time for the 2010 stock 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 MDT2007/01C). 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 previous summer surveys using the *allocate* procedure of Bull et al. (2000) as modified by Francis (2006). Allocation of stations for hoki was based on the 2005–08 surveys, as these best reflect recent changes in hoki abundance. Allocation of stations for hake and ling was based on all surveys from 2000–08. A minimum of three stations per stratum was used. As in previous years, conservative target 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. An additional 5 stations were added outside of the statistical framework because of the need to focus effort on covering the full distributional range of hake age classes. A total of 86 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.

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 in Hurst et al. 1992), with all trawling between 0449 h and 2004 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 minutes 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 *Tangaroa* multi-frequency (18, 38, 70, 120, and 200 kHz) Simrad EK60 echosounders with hull-mounted transducers. All frequencies were calibrated following standard procedures (Foote et al. 1987) on 27 January 2010 in Palliser Bay, at the end of the Chatham Rise trawl survey (Stevens et al. 2011). 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 2416) 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 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 Ministry of Fisheries 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 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 key species. The group of 12 key 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 are caught) is the product of vulnerability, vertical availability, and areal availability. These factors were set at one 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 key 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 751 hoki otoliths, 571 ling otoliths, and 595 hake otoliths were selected from those collected during the trawl survey. Subsamples were obtained by randomly selecting otoliths from 1 cm length bins covering the bulk of the catch and then systematically selecting additional otoliths to ensure that 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 followed the methods applied to recent Sub-Antarctic trawl surveys (e.g., Bagley et al. 2009, O'Driscoll & Bagley 2009) and generalised by O'Driscoll et al. (2011).

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 to compare acoustic backscatter with previous surveys. Acoustic data collected on 38 kHz during each trawl was integrated using custom Echo Sounder Package (*ESP2*) software (McNeill 2001) to calculate the mean acoustic backscatter per square kilometre. The time-series of acoustic indices of mesopelagic backscatter developed by O'Driscoll et al. (2011) were updated. Acoustic data were stratified into three broad sub-areas (O'Driscoll et al. 2011):

1. Puysegur: 165° 00′E – 168° 00′E, 46° 00′S – 48° 00′S
2. West Sub-Antarctic: 165° 00′E – 169° 00′E, 48° 00′S – 54° 00′S

3. East Sub-Antarctic: 169° 00′E – 176° 00′E, 46° 00′S – 54° 00′S

3. RESULTS

3.1 Survey coverage

The trawl survey and acoustic work contracted for this voyage were successfully completed. Weather conditions were moderate to rough for most of the voyage with about four days lost due to unfavourable sea conditions. A further eight hours were lost before the survey started because of a problem with the winch system occurring during a gear trial trawl.

Ninety successful trawl survey stations were completed in 21 strata (Figure 2, Table 1). This total included 85 phase 1 stations and 5 phase 2 stations. One phase 1 station in stratum 3A was unable to be completed due to bad weather.

Two additional stations were completed during phase 1 in strata 6 and 7 of the survey due to variable catches of hoki 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 hoki and increasing the number of hake sampled in strata 4, 6, 7, and 25.

Four stations were considered unsuitable for biomass estimation: station 1 was a gear trial, stations 58 and 69 came fast, and station 85 was targeted to catch more hake for additional otoliths.

Stratum 26, south of Campbell Island, was surveyed this year. Often this stratum is dropped if time is lost due to weather or other factors (as in 2003, 2004 and 2006). As on most previous surveys 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 81 of the 90 tows. Missing doorspread values were estimated from data collected in the same depth range on this voyage. Measured gear parameters in 2009 were within the range of those obtained on other voyages of *Tangaroa* in this area when the same gear was used (Table 4), although mean doorspreads have been slightly lower than earlier surveys since 2007. The new Scantrol winch controller 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 64.2 t was recorded from all trawl stations (63.8 t from valid biomass tows). From the 203 species or species groups caught: 88 were teleosts, 26 elasmobranchs, 9 cephalopods, and 20 crustaceans (Appendix 2). For the key species hoki accounted for 33.6%**,** ling 6.7%, and hake 3.3% of the total catch, while 8.7% of the catch was silver warehou, 7.5 % javelinfish and 7.3% southern blue whiting. 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 key 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 key species are plotted in Figure 3.

Biomass estimates for hoki for all strata in 2009 was 66 157 t. The hoki biomass has increased from the 2007 and 2008 estimates of 46 003 t and 48 340 t respectively, continuing the large increase from 2006 (14 747 t) (Figure 3). The biomass estimates for length ranges corresponding to 1+ (less than 45 cm) and 2+ (45–57 cm) hoki were 527 t (c.v. 54%) and 11 124 t (c.v. 64%) respectively. The biomass of 2+ hoki was seven times higher than the 2008 estimate of 1563 t and mostly taken in two large catches (see Section 3.5). The biomass of fish age 3+ or greater increased to 52 564 t in 2009 from 44 252 t in 2008. Despite the large increases from 2007 the hoki biomass is still much lower than the biomass observed in the Sub-Antarctic in the early 1990s (Table 7).

The hake estimate from all strata was 1602 t, lower than that from 2007 (2622 t) and 2008 (2355 t), and the estimate from core 300–800 m strata (992 t) was the lowest in the summer time series. The hake biomass in stratum 25 at Puysegur (800–1000 m) was 450 t, less than half that observed in 2008 (1088 t) (see Table 6). The estimate of ling biomass in 2009 (22 772 t) was almost identical to the 2008 estimate of 22 879 t.

Five of the nine other key species also increased from 2008 for the total survey area. Most changes were generally small and within the levels of the sampling uncertainty (Figure 3). However, the biomass of southern blue whiting was over three times higher that recorded in 2008, and was the highest biomass recorded in the summer time series. Estimates for some other species such as ribaldo, pale ghost shark and spiny dogfish were higher than those recorded in 2008, while other key species had similar or lower estimates. Although the javelinfish biomass was the second highest in the time series it was only half of the biomass recorded in 2008. Estimates for dark ghost shark, white warehou, and black oreo were lower than 2008 (Figure 3).

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 83 of the 90 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). Two large catches (greater than 5000 kg km^{-2}) were taken: on the eastern Stewart/Snares shelf in stratum 3A; and at Puysegur in stratum 1. Most fish on these two tows were age 2+ (Figure 4c). Catches of small (1+ and 2+) 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 150 kg km^{-2} (Figure 5) while most stations in the east and south of the survey area caught no hake. Ling were caught on all but four stations between 300 and 800 m depth (Figure 6). Both hoki and ling were seldom caught deeper than 800 m. As noted in Section 3.1, no hoki or ling were taken in 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 1662 hoki, 1110 ling, and 784 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 key species are shown in Figure 10.

Hoki length frequencies in 2009 showed a dominant cohort of fish between 45 and 58 cm (age 2+). This year class had the highest numbers of hoki at age 2+ from all the summer time series. The overall length range was similar to the 2008 survey (Figure 7). Modes from about 70–95 cm consisted of fish from the 2002–04 year classes at ages 5–7. The stronger 2002 year-class observed in the 2007 and 2008 surveys followed through in 2009, particularly for females, as did the 2000 year class at age 9 (Figure 11). There were few larger, older hoki of age 10 and above for both sexes. Because of the prevalence of small hoki in 2009, scaled population numbers were higher than recorded in 2008 with over 2.5 times as many males and 1.5 times as many females.

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). There is some evidence of recruitment with higher numbers of hake at age 3 for both sexes and age 4 for females compared with earlier surveys.

The length frequency distribution of ling was broad, with a slight decrease in the numbers of fish under 50 cm for both sexes (see Figure 9). The decrease in smaller fish is also reflected in the age frequencies (Figure 13). The age frequency for ling showed that most fish were between 3 and 16 years old, with the mode at age 6 for males and no clear mode for females (Figure 13). The good recent recruitment of ling reported at ages 3 and 4 in 2008 (O'Driscoll & Bagley 2009) did not clearly follow through to 2009 in the age frequencies.

The length frequency distribution of southern blue whiting caught in 2009 had a strong mode between 29 and 37 cm for both sexes (Figure 10), following on from the strong mode seen in 2008 between 24 and 31 cm (O'Driscoll & Bagley 2009). These are probably fish of age 3 (2006 year-class), a year-class which was estimated as being strong in an acoustic survey of the Campbell Island grounds in August–September 2009 (Gauthier et al. 2011). Black oreo showed higher numbers of small fish (less than 28 cm) than were observed in 2008, with modal lengths of 30 cm for both sexes (see Figure 10). Other points of interest in Figure 10 include: a large mode at 31 cm in the length distribution of unsexed javelinfish (which are probably males - O'Driscoll & Bagley 2009) and a mode at 39 cm for female javelinfish; the continuing high proportion of female ribaldo; the difference in the length frequencies of male and female spiny dogfish; and the few small (less than 40 cm) white warehou caught in 2009.

Gonad stages for hoki, hake, and ling are summarised in Table 10. Immature hoki made up 14% of fish examined, and these were typically fish smaller than 70 cm. Most adult hoki (79%) were in the resting phase. About 5% of female hoki and 10% of male hoki were macroscopically staged as partially spent or spent. Female ling were mostly resting (80%) or immature (12%), but male ling of all gonad stages were recorded, with 43% in spawning condition (ripe and running ripe). Immature stage hake made up 11% of the observations for both sexes. About 12% of male hake were ripe or running ripe, while only one female hake in these stages was recorded.

3.7 Hoki condition indices

Liver and gutted weights were recorded from 1325 hoki in 2009. Hoki condition indices were summarised by O'Driscoll et al. (2011) for summer surveys up to and including 2009. Both liver condition (Table 11) and somatic condition (Table 12) were relatively low in 2009.

Gonad samples were taken from 784 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 319 acoustic data files (91 trawl, 124 day steam, and 104 night-time) was recorded during the 2009 survey. The number of acoustic files while steaming was higher than in previous surveys because the file size was restricted to a maximum of 200 MB in 2009 (i.e., multiple smaller files were created during a steam rather than a single large file). Data quality was good for about half of the time (Table 13), but deteriorated during periods of bad weather. About 20% of the acoustic files were considered too noisy to be analysed quantitatively (Table 13).

Expanding symbol plots of the distribution of total acoustic backscatter from good and adequate quality recordings observed during daytime trawls and night transects are shown in Figure 14. As noted by O'Driscoll et al. (2011), there is a consistent spatial pattern in total backscatter, with highest acoustic densities at Puysegur and on the Stewart-Snares shelf and lowest densities in the southeastern Sub-Antarctic.

Mark types were similar to those described for previous surveys (Table 14). Surface layers were observed in 87% of daytime echograms and 98% of night echograms in 2009 (Table 14). 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 to 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 47% of day steam files, 29% of overnight steams, and 43% of trawl files in 2009 (Table 14). As in previous years (O'Driscoll 2001, O'Driscoll & Bagley 2006b, 2009, Bagley et al. 2009), bottom schools were occasionally observed during the day in 300–600 m water depth, and these were sometimes associated with catches of southern blue whiting in the bottom trawl. 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 (Table 14). However, dispersed cloud marks were also frequently observed in daytime recordings during trawls and while steaming in 2009 (Table 14).

The vertical distribution of acoustic backscatter in 2009 is compared to the average vertical distribution from all years in Figure 15. Diurnal vertical migration was apparent in all years. In 2009, fish occurred throughout the water column during the day, with peaks at around 150 m and 300–600 m (Figure 15). Most of the backscatter at night was concentrated in the upper 200 m (Figure 15). The time-series of day and night estimates of total acoustic backscatter is plotted in Figure 16. As noted by O'Driscoll et al. (2011), night estimates of total backscatter were always higher than day estimates, which may be due to increased noise in night data. Backscatter in the bottom 50 m has been relatively consistent since 2000 (Figure 16).

O'Driscoll et al. (2011) developed a day-based estimate of mesopelagic fish abundance in the Sub-Antarctic by multiplying the total backscatter observed at each daytime trawl station by the estimated proportion of night-time backscatter in the same sub-area and year that was observed in the upper 200 m

(Table 15). The estimated acoustic indices calculated using this method are summarised in Table 16 and plotted in Figure 17 for the entire sub-Antarctic and for the three sub-areas. The mesopelagic indices for the Sub-Antarctic are similar to estimates of total backscatter (see Figure 16) and show a decreasing trend from 2000 to 2006, with an increase in 2007–08. Mesopelagic indices for the whole Sub-Antarctic and the east and west subareas declined slightly in 2009 (Figure 17). Indices from Puysegur showed a more extreme pattern than other subareas and continued to increase in 2009 (Figure 17). Because the station density at Puysegur was disproportionate to its small area (only 1.5% of total Sub-Antarctic area), stratification reduced the influence of the Puyegur subarea on the overall index.

There was a weak positive correlation between acoustic backscatter in the bottom 50 m during the day and trawl catch rates (Figure 18). Weak, but significant, positive correlations between backscatter and catches have been observed in previous surveys in 2000, 2001, 2003, 2005, 2007, and 2008 (O'Driscoll 2002, O'Driscoll & Bagley 2003a, 2004, 2006b, 2009, Bagley et al. 2009), but not in 2002, 2004, or 2006 (O'Driscoll & Bagley 2003b, 2006a, 2008).

3.9 Hydrological data

Temperature profiles were available from 92 CTD casts. Surface (5 m depth) temperatures ranged between 6.9 and 11.7 °C (Figure 19), while bottom temperatures were between 3.8 and 10.4 °C (Figure 20). Bottom temperature decreased with depth, with the lowest bottom temperatures recorded from water deeper than 900 m on the margins of the Campbell Plateau. The 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 19–20).

The average surface temperature in 2009 of 9.0 °C was lower than that observed in 2008 (9.4 °C), but within the range of average surface temperatures observed in 2002–07 (8.8–10.3 °C). In general there is a negative correlation between surface temperature and depth of the thermocline (Figure 21), with cooler surface temperatures in years when the thermocline is deep (e.g., 2003), and warmer 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. However, in 2009, the thermocline was shallow (only about 20 m) with a relatively cool surface temperature (Figure 21). Average bottom temperatures in 2009 (7.0 °C) were within the range of average temperatures observed in 2002–08 (6.7–7.0 °C). 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 biomass increase was sustained in 2008 (O'Driscoll & Bagley 2009), and hoki biomass increased further in 2009.

The series of Sub-Antarctic trawl indices could not be fitted by the stock assessment model in 2009, even when the survey biomass observations were upweighted (McKenzie & Francis 2009). Furthermore, the trawl survey data shows large annual changes in numbers-at-age which cannot be explained by changes in abundance, and are suggestive of a change in catchability for the survey. In 2010, an alternative approach to upweighting was suggested, which assumed that the catchability changed over time (Ministry of Fisheries 2010). This alternative approach was explored in runs in which two catchabilities were fitted for the Sub-Antarctic series, instead of just one, and were found to improve the fit substantially. In one sensitivity run, the catchability in surveys from 2003 to 2006 inclusive was estimated separately from the other years in the series. In another run the catchability from 2007 to 2009 inclusive was estimated separately. In both the sensitivity runs, the current biomass (%B_0) was estimated to be as least as high as the associated base run, but with more uncertainty (Ministry of Fisheries 2010).

Any apparent changes in trawl survey catchability were unlikely to be related to changes in gear or gear performance. The trawl has been within consistent specifications throughout the time series (see Table 4), although average doorspread has decreased slightly (but significantly) since 2007. 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 any change in hoki catchability was not restricted to the research survey. Catches of other species over the same period have not shown the same pattern as hoki, although biomass estimates in core strata for 11 of the 12 key species increased from 2006 to 2007 (see Figure 3), which supports the hypothesis that there was a change in catchability between these two surveys.

5. CONCLUSIONS

The hoki biomass in 2009 was the highest since the resumption of the summer trawl surveys, continuing the increase observed since 2007. The overall abundance was boosted by a very high estimate of 2+ hoki, but abundance of hoki aged 3+ and older also increased from 2008. The survey methodology was consistent with previous years, but it has been suggested that trawl catchability was unusually high in 2007–09 or unusually low in 2003–06 (Ministry of Fisheries 2010). Despite the large increase in the estimated hoki biomass in the past three surveys the 2009 estimate is still less than the biomass observed in the Sub-Antarctic in the early 1990s. The hoki age frequency observed in 2009 was consistent with the age frequency in 2007–08, with progression of modes associated with 2000–05 year-classes.

The hake biomass from all strata was lower than that in 2008 and the lowest estimate recorded for the summer series for the core strata. The biomass estimate for ling was very similar to that in 2008. There was no consistent increase or decrease in the abundance of nine other key species. Acoustic indices of mesopelagic fish abundance decreased slightly from the previous survey in 2008.

6. ACKNOWLEDGMENTS

Thanks to the scientific staff who participated in this voyage, and the master, officers, and crew of *Tangaroa* who contributed to the success of this voyage. Thanks to the scientific staff involved with the otolith preparation and reading of the hake, hoki, and ling otoliths, and Peter Horn for the calculation of the age frequencies. Identification of unidentified organisms taken during the trawl survey was co-ordinated by Sadie Mills, and our thanks to Sadie and the team of experts for the identification of material collected. This work was carried out by NIWA under contract to the Ministry of Fisheries (Research Project MDT2007/01C).Thank you to Peter Horn for reviewing this report.

7. REFERENCES

Bagley, N.W.; O'Driscoll, R.L.; Francis, R.I.C.C.; Ballara, S.L. (2009). Trawl survey of middle depth species in the Southland and Sub-Antarctic areas, November–December 2007 (TAN0714). *New Zealand Fisheries Assessment Report 2009/9*. 63 p.

Ballara, S.L.; O'Driscoll, R.L.; Fu, D. (2011). Catches, size, and age structure of the 2008–09 hoki fishery, and a summary of input data used for the 2010 stock assessment. *New Zealand Fisheries Assessment Report 2011/08.*

Bull, B.; Bagley, N.W.; Hurst, R.J. (2000). Proposed survey design for the Southern Plateau trawl survey of hoki, hake and ling in November-December 2000. Final Research Report to the Ministry of Fisheries for Project MDT1999/01 Objective 1. 31 p. (Unpublished report held by Ministry of Fisheries, Wellington.)

Bull, B.; Dunn, A. (2002). Catch-at-age user manual v1.06.2002/09/12. NIWA Internal Report 114. 23 p. (Unpublished report held in NIWA library, Wellington.)

Chatterton, T.D.; Hanchet, S.M. (1994). Trawl survey of hoki and associated species in the Southland and Sub-Antarctic areas, November–December 1991 (TAN9105). *New Zealand Fisheries Data Report 41*. 55 p.

Coombs, R.F.; Macaulay, G.J.; Knol, W.; Porritt, G. (2003). Configurations and calibrations of 38 kHz fishery acoustic survey systems, 1991–2000. *New Zealand Fisheries Assessment Report 2003/49.* 24 p.

Cordue, P.L.; Ballara, S.L.; Horn, P.L. (2000). Hoki ageing: recommendation of which data to routinely record for hoki otoliths. Final Research Report to the Ministry of Fisheries for Project MOF1999/01 (Hoki ageing). 24 p. (Unpublished report held by Ministry of Fisheries, Wellington.)

Foote, K.G.; Knudsen, H.P.; Vestnes, G.; MacLennan, D.N.; Simmonds, E.J. (1987). Calibration of acoustic instruments for fish density estimation: a practical guide. *ICES Cooperative Research Report 144*. 68 p.

Francis, R.I.C.C. (1981). Stratified random trawl surveys of deep-water demersal fish stocks around New Zealand. *Fisheries Research Division Occasional Publication 32.* 28 p.

Francis, R.I.C.C. (1984). An adaptive strategy for stratified random trawl surveys. *New Zealand Journal of Marine and Freshwater Research 18:* 59–71.

Francis, R.I.C.C. (1989). A standard approach to biomass estimation from bottom trawl surveys. New Zealand Fisheries Assessment Research Document 89/3. 3 p. (Unpublished report held in NIWA library, Wellington.)

Francis, R.I.C.C. (2001). Improving the consistency of hoki age estimation. *New Zealand Fisheries Assessment Report 2001/12.* 18 p.

Francis, R.I.C.C. (2006). Optimum allocation of stations to strata in trawl surveys. *New Zealand Fisheries Assessment Report 2006/23*. 50 p.

Francis R.IC.C. (2009a). Assessment of hoki (*Macruronus novaezelandiae*) in 2008. *New Zealand Fisheries Assessment Report 2009/7*. 80 p.

Francis, R.I.C.C. (2009b). SurvCalc User Manual. 39 p. (Unpublished report held at NIWA, Wellington.)

Gauthier, S.; Fu, D.; O'Driscoll, R.L.; Dunford, A. (2011). Acoustic estimates of southern blue whiting from the Campbell Island Rise, August–September 2009. *New Zealand Fisheries Assessment Report 2011/09, 40 p.*

Grimes, P.J.; O'Driscoll, R.L. (2006). Estimating the proportion of female hoki on the Southern Plateau which spawn each year by microscopic examination of gonad samples. Final Research Report for Ministry of Fisheries Project MDT2003/01 Objective 6. 40 p. (Unpublished report held by Ministry of Fisheries, Wellington.)

Horn, P.L. (1993). Growth, age structure, and productivity of ling, *Genypterus blacodes* (Ophidiidae), in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research 27:* 385–397.

Horn, P.L. (1997). An ageing methodology, growth parameters and estimates of mortality for hake (*Merluccius australis*) from around the South Island, New Zealand. *Marine and Freshwater Research 48:* 201–209.

Horn, P.L.; Sullivan, K.J. (1996). Validated aging methodology using otoliths, and growth parameters for hoki (*Macruronus novaezelandiae*) in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research 30*: 161–174.

Hurst, R.J.; Bagley, N.; Chatterton, T.; Hanchet, S.; Schofield, K.; Vignaux, M. (1992). Standardisation of hoki/middle depth time series trawl surveys. MAF Fisheries Greta Point Internal Report 194. 89 p. (Unpublished report held in NIWA library, Wellington.)

Livingston, M.E.; Bull, B. (2000). The proportion of western stock hoki developing to spawn in April 1998. *New Zealand Fisheries Assessment Report 2000/13.* 20 p.

Livingston, M.E.; Vignaux, M.; Schofield, K.A. (1997). Estimating the annual proportion of nonspawning adults in New Zealand hoki, *Macruronus novaezelandiae. Fishery Bulletin 95*: 99–113.

McKenzie, A.; Francis, R.I.C.C. (2009). Assessment of hoki (*Macruronus novaezelandiae*) in 2009. *New Zealand Fisheries Assessment Report 2009/63*. 43 p.

McNeill, E. (2001). ESP2 phase 4 user documentation. NIWA Internal Report 105. 31 p. (Unpublished report held in NIWA library, Wellington.)

Ministry of Fisheries (2010). Report from the Fisheries Assessment Plenary, May 2010: stock assessments and yield estimates. Ministry of Fisheries. 1158 p.

O'Driscoll, R.L. (2001). Classification of acoustic mark types observed during the 2000 Sub-Antarctic trawl survey (TAN0012). Final Research Report for Ministry of Fisheries Research Project MDT2000/01 Objective 3. 28 p. (Unpublished report held by Ministry of Fisheries, Wellington.)

O'Driscoll, R.L. (2002). Estimates of acoustic:trawl vulnerability ratios from the Chatham Rise and Sub-Antarctic. Final Research Report for Ministry of Fisheries Research Projects HOK2001/02 Objective 3 & MDT2001/01 Objective 4. 46 p. (Unpublished report held by Ministry of Fisheries, Wellington.)

O'Driscoll, R.L.; Bagley, N.W. (2001). Review of summer and autumn trawl survey time series from the Southland and Sub-Antarctic area 1991–1998. *NIWA Technical Report 102.* 115 p.

O'Driscoll, R.L.; Bagley, N.W. (2003a). Trawl survey of middle depth species in the Southland and Sub-Antarctic areas, November–December 2001 (TAN0118). *New Zealand Fisheries Assessment Report 2003/1*. 53 p.

O'Driscoll, R.L.; Bagley, N.W. (2003b). Trawl survey of middle depth species in the Southland and Sub-Antarctic areas, November–December 2002 (TAN0219). *New Zealand Fisheries Assessment Report 2003/46*. 57 p.

O'Driscoll, R.L.; Bagley, N.W. (2004). Trawl survey of hoki, hake, and ling in the Southland and Sub-Antarctic areas, November–December 2003 (TAN0317). *New Zealand Fisheries Assessment Report 2004/49*. 58 p.

O'Driscoll, R.L.; Bagley, N.W. (2006a). Trawl survey of hoki, hake, and ling in the Southland and Sub-Antarctic areas, November–December 2004 (TAN0414). *New Zealand Fisheries Assessment Report 2006/2*. 60 p.

O'Driscoll, R.L.; Bagley, N.W. (2006b). Trawl survey of hoki, hake, and ling in the Southland and Sub-Antarctic areas, November–December 2005 (TAN0515). *New Zealand Fisheries Assessment Report 2006/45*. 64 p.

O'Driscoll, R.L.; Bagley, N.W. (2008). Trawl survey of middle depth species in the Southland and Sub-Antarctic areas, November–December 2006 (TAN0617). *New Zealand Fisheries Assessment Report 2008/30*. 61 p.

O'Driscoll, R.L.; Bagley, N.W. (2009). Trawl survey of middle depth species in the Southland and Sub-Antarctic areas, November–December 2008 (TAN0813). *New Zealand Fisheries Assessment Report 2009/56*. 67 p.

O'Driscoll, R.L.; Hurst, R.J.; Dunn, M.R.; Gauthier, S.; Ballara, S.L. (2011). Trends in relative mesopelagic biomass using time series of acoustic backscatter data from trawl surveys. New Zealand Aquatic Environment and Biodiversity Report No. 76. 99 p.

Stevens, D.W.; O'Driscoll, R.L.; Dunn, M.R.; MacGibbon, D.; Horn, P.L.; Gauthier, S. (2011). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2010 (TAN1001). *New Zealand Fisheries Assessment Report 2011/10*.

Vignaux, M. (1994). Documentation of Trawlsurvey Analysis Program. MAF Fisheries Greta Point Internal Report 225. 44 p. (Unpublished report held in NIWA library, Wellington.)

Table 1: Stratum areas, depths, and number of successful biomass stations from the November–December 2009 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	6	5	
3b	Stewart-Snares	300 -600	1 556	4	4	
4	Stewart-Snares	600–800	21 018	4	4	1
5a	Snares-Auckland	600–800	2 981	5	5	
5b	Snares-Auckland	600–800	3 281	4	4	
6	Auckland Is.	300–600	16 682	3	3	1
7	South Auckland	600–800	8 497	3	3	1
8	N.E. Auckland	600–800	17 294	5	5	
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	6	6	
12	Pukaki	300–600	45 259	6	6	
13	N.E. Camp. Plateau	300–600	36 051	3	3	
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	2
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	
Total			**320 159**	**86**	**85**	**5**

Table 2: EK60 transceiver settings and other relevant parameters. Values in bold were calculated from the calibration on 27 January 2010 (Stevens et al. 2011).

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)	**23.00**	**25.95**	**26.72**	**26.74**	**25.03**
Sa correction (dB)	**-0.76**	**-0.59**	**-0.30**	**-0.35**	**-0.36**
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	**11.0/11.3**	**6.9/6.9**	**6.3/6.4**	**6.1/6.4**	**6.7/6.7**
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)	**0.14**	**0.11**	**0.14**	**0.16**	**0.18**

* 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)	90	2.92	0.24	2.00–3.06
Tow speed (knots)	90	3.5	0.08	3.2–3.6
Gear parameters (m)				
300–600 m				
Headline height	36	7.0	0.20	6.5–7.5
Doorspread	31	113.0	7.65	93.8–122.3
600–800 m				
Headline height	38	6.9	0.19	6.5–7.2
Doorspread	35	118.2	6.19	102.8–129.7
800–1000 m				
Headline height	16	7.1	0.23	6.8–7.6
Doorspread	15	120.3	4.13	113.1–127.4
All stations 300–1000 m				
Headline height	90	7.0	0.21	6.5–7.6
Doorspread	81	116.6	7.07	93.8–129.7

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
2009	81	116.6	7.07	93.8	129.7	7.0	0.21

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

		2009 (TAN0911)			2008 (TAN0813)		
Species	Species code	Catch (kg)	Biomass (t)	c.v. (%)	Catch (kg)	Biomass (t)	c.v. (%)
Hoki	HOK	21 772	66 157	16	12 789	48 340	14
Silver warehou	SWA	5 562	3 620	98	2 256	4 122	55
Javelinfish	JAV	4 785	21 663	16	9 111	48 659	15
Southern blue whiting	SBW	4 686	51 860	75	1 416	15 219	14
Ling	LIN	4 321	22 772	10	6 501	22 879	10
Pale ghost shark	GSP	1 945	15 553	9	1 658	10 098	13
Smooth oreo	SSO	1 942	6 324	86	555	1 150	58
Spiny dogfish	SPD	1 838	4 296	34	1 207	3 096	19
Longnose velvet dogfish	CYP	1 710	2 575	24	1 089	1 780	19
Shovelnosed dogfish	SND	1 637	999	28	1 839	910	26
Hake	HAK	1 534	1 602	18	3 420	2 355	16
Black oreo	BOE	1 289	4 888	52	1 942	7 848	49
White warehou	WWA	1 043	2 093	65	935	2 209	40
Ridge-scaled rattail	MCA	961	7 610	28	1 295	11 198	37
Deepwater spiny dogfish	CSQ	874	1 104	34	949	813	26
Baxter's lantern dogfish	ETB	695	3 008	17	555	2 269	21
Oliver's rattail	COL	655	3 058	24	555	2 663	16
Arrow squid	NOS	636	563	65	428	396	36
Small-scaled brown slickhead	SSM	575	2 587	11	403	2 115	20
Ribaldo	RIB	465	1 255	13	491	910	16
Total catch (all species)		64 202			56 156		

Table 6: Estimated biomass (t) and coefficients of variation (%, below in parentheses) of the 12 key 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	4 998	413	40	0	39	7
	(48)	(14)	(51)		(97)	(74)
2	1 504	107	51	0	0	8
	(29)	(47)	(33)			(34)
3a	9 313	678	40	0	41	130
	(85)	(59)	(37)		(75)	(61)
3b	202	168	24	0	48	3
	(72)	(93)	(100)		(60)	(100)
4	2 870	1 678	175	788	0	1 544
	(40)	(31)	(85)	(99)		(24)
5a	1 149	203	219	0	1	101
	(53)	(28)	(38)		(100)	(51)
5b	530	240	70	0	0	269
	(16)	(27)	(41)			(17)
6	4 472	1 780	74	0	304	213
	(37)	(42)	(67)		(58)	(59)
7	1 511	666	112	0	0	162
	(44)	(37)	(66)			(17)
8	5 784	1 581	60	0	0	736
	(15)	(17)	(100)			(18)
9	11 973	5 039	78	0	0	2 105
	(37)	(33)	(66)			(18)
10	1 721	501	7	0	0	345
	(47)	(52)	(100)			(49)
11	7 283	1 144	41	255	0	464
	(44)	(34)	(100)	(68)		(41)
12	5 290	3 242	0	0	0	4 272
	(41)	(19)				(17)
13	3 333	2 177	0	0	0	1 926
	(43)	(19)				(37)
14	1 841	2 619	0	0	0	836
	(39)	(12)				(7)
15	1 243	477	0	0	0	27
	(24)	(33)				(100)
Subtotal (strata 1–15)	**65 017**	**22 713**	**992**	**1 042**	**433**	**13 147**
	(16)	**(10)**	**(22)**	**(76)**	**(43)**	**(9)**
25	407	30	450	0	0	8
	(38)	(77)	(40)			(43)
Subtotal (strata 1–25)	**65 423**	**22 743**	**1 442**	**1 042**	**433**	**13 155**
	(16)	**(10)**	**(20)**	**(76)**	**(43)**	**(9)**
26	0	0	0	0	0	135
						(59)
27	517	0	53	791	0	63
	(62)		(100)	(50)		(21)
28	217	29	106	3 054	0	200
	(35)	(53)	(46)	(79)		(20)
Total (All strata)	**66 157**	**22 772**	**1 602**	**4 888**	**433**	**13 553**
	(16)	**(10)**	**(18)**	**(90)**	**(43)**	**(9)**

Table 6 (cont): Estimated biomass (t) and coefficients of variation (%, below in parentheses) of the 12 key 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	44	39	4	0	5	674
	(18)	(43)	(100)		(100)	(62)
2	110	8	44	0	0	8
	(48)	(16)	(24)			(58)
3a	224	55	0	0	1 731	51
	(66)	(62)			(78)	(57)
3b	1	4	0	0	450	35
	(59)	(61)			(57)	(74)
4	1 734	0	199	0	107	129
	(24)		(32)		(57)	(54)
5a	81	8	61	0	5	7
	(26)	(35)	(54)		(74)	(61)
5b	601	0	24	0	50	17
	(63)		(62)		(48)	(40)
6	506	170	18	944	321	449
	(67)	(66)	(100)	(82)	(34)	(96)
7	760	13	62	0	4	0
	(33)	(100)	(50)		(100)	
8	2 021	0	186	24	87	0
	(3)		(22)	(73)	(55)	
9	1 916	43	93	2 147	372	706
	(47)	(67)	(68)	(58)	(24)	(60)
10	751	0	150	28	0	0
	(15)		(16)	(100)		
11	5 814	129	142	842	0	16
	(51)	(87)	(51)	(64)		(100)
12	5 079	260	0	44 815	721	0
	(40)	(31)		(86)	(54)	
13	858	92	0	1 672	221	0
	(44)	(100)		(30)	(44)	
14	1 008	0	0	1 367	223	0
	(55)			(32)	(50)	
15	684	0	74	22	0	0
	(41)		(59)	(32)		
Subtotal (strata 1–15)	**19 194**	**820**	**1 056**	**51 860**	**4 296**	**2 093**
	(18)	**(25)**	**(13)**	**(75)**	**(34)**	**(35)**
25	344	2	63	0	0	0
	(36)	(64)	(28)			
Subtotal (strata 1–25)	**19 538**	**822**	**1 120**	**51 860**	**4 296**	**2 093**
	(17)	**(25)**	**(13)**	**(75)**	**(34)**	**(35)**
26	1	0	45	0	0	0
	(40)		(100)			
27	1 737	0	69	0	0	0
	(51)		(82)			
28	348	0	21	0	0	0
	(56)		(100)			
Total (All strata)	**21 663**	**822**	**1 255**	**51 860**	**4 296**	**2 093**
	(16)	**(25)**	**(13)**	**(75)**	**(34)**	**(35)**

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
	2009	65 017	16	66 157	16
	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
	2009	992	22	1 602	18
	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
	2009	22 713	10	22 772	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
Arrow squid	411	223	179	24	8	2
Banded rattail	2 382	-	-	58	1 330	44
Banded stargazer	1	1	-	1	1	1
Basketwork eel	85	6	2	7	10	2
Baxter's lantern dogfish	527	245	281	36	469	34
Bigeye cardinalfish	5	1	4	2	-	-
Black cardinalfish	45	6	7	3	13	1
Black javelinfish	22	7	7	2	22	2
Black oreo	684	329	355	12	391	12
Blackspot rattail	5	-	-	3	5	3
Bluenose	1	-	1	1	1	1
Bollons's rattail	306	106	110	20	200	16
Cape scorpionfish	1	1	-	1	1	1
Dark ghost shark	158	87	71	12	157	11
Dawson’s catshark	2	2	-	2	2	2
Deepsea catshark	3	1	2	2	3	2
Deepwater spiny dogfish	97	47	50	15	93	15
Finless flounder	96	8	12	18	95	17
Four-rayed rattail	1 254	-	-	18	403	12
Gemfish	2	-	2	1	2	1
Giant stargazer	95	12	83	19	87	16
Hairy conger	1	-	-	1	-	-
Hake	735	215	520	44	543	44
Hapuku	2	-	2	2	2	2
Hoki	8 280	3 368	4 908	84	1 734	78
Humpback rattail	3	-	3	3	3	3
Javelinfish	6 807	126	1 546	80	1 293	54
Johnson’s cod	9	4	5	3	8	2
Kaiyomaru rattail	117	-	-	8	40	5
Ling	1 733	842	889	77	1 458	72
Longnose velvet dogfish	483	150	332	23	153	17
Longnosed chimaera	116	69	46	42	107	37
Longnosed deepsea skate	1	1	-	1	1	1
Lookdown dory	144	74	70	35	126	30
Lucifer dogfish	285	146	139	35	109	27
Mahia rattail	9	1	1	4	2	2
Notable rattail	130	-	-	8	87	5
Oblique banded rattail	589	-	-	28	404	21
Oliver's rattail	3 368	-	-	43	1 054	31
Orange roughy	173	91	80	14	131	10
Owston's dogfish	50	29	21	6	45	3
Pale ghost shark	1 213	573	639	74	1 161	70
Plunket’s shark	11	5	6	9	7	6
Prickly dogfish	1	-	1	1	1	1
Ray's bream	9	3	6	3	9	3
Redbait	1	-	1	1	-	-
Red cod	12	8	4	3	12	3
Ribaldo	241	61	180	45	195	41
Ridge-scaled rattail	588	305	278	25	436	25
Rough skate	7	6	1	5	7	5
Rudderfish	6	1	5	5	5	4
School shark	3	1	2	3	3	3

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
Sea perch	74	35	39	5	73	4
Seal shark	35	15	20	13	24	8
Serrulate rattail	37	2	5	9	30	6
Shovelnosed dogfish	301	142	159	14	184	12
Silver dory	154	-	-	2	-	-
Silver warehou	257	119	138	9	110	8
Silverside	757	6	9	27	370	20
Slender smooth-hound	1	-	1	1	1	1
Smallscaled cod	1	-	-	1	1	1
Small-scaled slickhead	330	154	175	10	220	8
Smooth oreo	498	251	246	12	240	8
Smooth skate	11	5	6	7	11	7
Southern blue whiting	2 333	1 011	1 317	29	1 148	29
Southern Ray's bream	17	10	7	7	13	4
Spiky oreo	32	22	10	3	28	2
Spineback eel	86	-	12	14	9	2
Spiny dogfish	713	387	326	45	493	43
Violet cod	43	-	-	2	43	2
Warty squid	125	1	7	26	14	1
White rattail	42	26	10	6	19	4
White warehou	325	239	86	27	297	26
Widenosed chimaera	34	20	14	11	30	9

†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 key species.

	Regression parameters				Length	
Species	*a*	*b*	r^2	*n*	range (cm)	Data source
Black oreo	0.023602	2.9667	0.88	389	22.8 – 37.0	TAN0911
Dark ghost shark	0.004437	3.0871	0.97	157	26.5 – 73.0	TAN0911
Javelinfish	0.000838	3.2598	0.96	1 215	21.5 – 59.4	TAN0911
Hake	0.001976	3.2955	0.97	540	51.9 – 120.8	TAN0911
Hoki	0.004245	2.9062	0.97	1 727	34.3 – 113.8	TAN0911
Ling	0.001358	3.2790	0.97	1 457	38.6 – 142.0	TAN0911
Lookdown dory	0.022312	3.0199	0.94	125	21.4 – 51.0	TAN0911
Pale ghost shark	0.014458	2.7737	0.97	1 154	22.2 – 86.7	TAN0911
Ribaldo	0.005934	3.1520	0.97	195	28.1 – 72.1	TAN0911
Southern blue whiting	0.004819	3.0782	0.95	1 137	27.2 – 56.1	TAN0911
Spiny dogfish	0.001680	3.2070	0.92	492	52.3 – 94.7	TAN0911
White warehou	0.351160	2.2799	0.85	297	33.5 – 60.6	TAN0911

* $W = aL^b$ 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	708	449	59	271	119	103
2	2 317	4 140	125	158	203	714
3	0	48	6	85	51	22
4	1	0	3	0	329	29
5	0	1	5	1	31	8
6	216	3	17	0	96	4
7	113	214	0	4	13	9
Total staged	3 355	4 855	215	519	842	889

*See Appendix 1 for description of gonad stages.

Table 11: Hoki liver condition indices for the Sub-Antarctic and each of the three acoustic strata (see Figure 14 for strata boundaries). From O'Driscoll et al. (2011).

	All areas		East		Puysegur		West	
Survey	Mean	c.v.	Mean	c.v.	Mean	c.v.	Mean	c.v.
2001 (TAN0118)	2.94	1.7	3.45	2.3	2.48	3.8	2.49	2.8
2002 (TAN0219)	2.73	1.8	3.11	2.9	1.99	3.5	2.68	2.6
2003 (TAN0317)	2.76	2.2	3.17	3.4	2.24	5.6	2.55	3.0
2004 (TAN0414)	3.07	2.0	3.45	3.3	2.28	5.9	2.99	2.8
2005 (TAN0515)	3.10	1.6	3.20	2.6	2.27	3.9	3.36	2.4
2006 (TAN0617)	2.88	1.7	3.01	3.4	2.27	4.3	3.02	2.2
2007 (TAN0714)	3.15	1.6	3.42	2.5	2.07	4.5	3.34	2.1
2008 (TAN0813)	2.63	1.6	2.96	2.2	1.87	4.7	2.58	2.6
2009 (TAN0911)	2.49	1.7	2.74	2.5	1.96	5.5	2.34	2.5
All	2.85	0.6	3.16	0.9	2.16	1.5	2.82	0.9

Table 12: Estimated length-weight parameters for hoki from Sub-Antarctic trawl surveys, and derived weight of a 75 cm fish (W(75 cm)), which was used as an index of somatic condition. $W = aL^b$ where W is weight (g) and L is length (cm) . From O'Driscoll et al. (2011).

	LW parameters		W(75 cm)
Survey	a	b	(g)
2000 (TAN0012)	0.005603	2.844446	1208
2001 (TAN0118)	0.005681	2.842391	1214
2002 (TAN0219)	0.004172	2.914928	1219
2003 (TAN0317)	0.003975	2.922135	1198
2004 (TAN0414)	0.003785	2.933285	1197
2005 (TAN0515)	0.005824	2.840234	1233
2006 (TAN0617)	0.004363	2.903530	1214
2007 (TAN0714)	0.004172	2.914241	1215
2008 (TAN0813)	0.005024	2.871200	1215
2009 (TAN0911)	0.004245	2.906240	1195
All			1211

Table 13: Quality of acoustic data collected during trawl surveys in the Sub-Antarctic between 2000 and 2009. 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	0	0	100
2005 (TAN0515)	197	75	16	9
2006 (TAN0617)	195	46	25	29
2007 (TAN0714)	194	63	16	20
2008 (TAN0813)	235	61	28	11
2009 (TAN0911)	319	46	33	20

* There was a problem with synchronisation of scientific and ship's echosounders in TAN0414 (O'Driscoll & Bagley 2006a), so data from this survey were not suitable for quantitative analysis due to the presence of acoustic interference.

Table 14: Percentage occurrence of the seven acoustic mark types classified by O'Driscoll (2001) in trawl surveys of the Sub-Antarctic between 2000 and 2009. 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
	2009 (TAN0911)	124	89	81	52	63	47	70	10
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
	2009 (TAN0911)	104	98	10	11	78	29	70	1
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
	2009 (TAN0911)	91	84	73	51	58	43	52	7

Table 15: Estimates of the proportion of total day backscatter in each stratum and year in the Sub-Antarctic which is assumed to be mesopelagic fish. Estimates were derived from the observed proportion of night backscatter in the upper 200 m with no correction for the surface acoustic deadzone (see O'Driscoll et al. 2011 for details).

	Stratum		
Year	East	Puysegur	West
2000 (TAN0012)	0.64	0.66	0.58
2001 (TAN0118)	0.56	0.39	0.57
2002 (TAN0219)	0.54	0.77	0.60
2003 (TAN0317)	0.60	0.66	0.67
2005 (TAN0515)	0.59	0.38	0.54
2006 (TAN0617)	0.55	0.32	0.56
2007 (TAN0714)	0.56	0.46	0.51
2008 (TAN0813)	0.63	0.58	0.62
2009 (TAN0911)	0.58	0.78	0.63

Table 16: Mesopelagic indices for the Sub-Antarctic. Indices were derived by multiplying daytime estimates of total backscatter by the estimated proportion of night backscatter in the upper 200 m and calculating averages in each area (see Table 15). Unstratified indices were calculated as the unweighted average over all available acoustic data. Stratified indices were obtained as the weighted average of stratum estimates, where weighting was the proportional area of the stratum (Puysegur 1.5% of total area, west 32.6%, east 65.9%).

	Acoustic index (m^2/km^2)									
	Unstratified		East		Puysegur		West		Stratified	
Survey	Mean	c.v.	Mean	c.v.	Mean	c.v.	Mean	c.v.	Mean	c.v.
2000 (TAN0012)	14.1	9	10.8	12	28.8	10	12.6	17	11.6	10
2001 (TAN0118)	13.3	17	9.2	16	29.9	45	13.1	11	10.8	10
2002 (TAN0219)	10.4	12	6.8	13	31.2	28	9.0	7	7.9	8
2003 (TAN0317)	9.8	10	8.1	23	18.9	15	9.2	8	8.6	14
2005 (TAN0515)	8.0	7	7.8	10	6.0	7	8.7	12	8.0	8
2006 (TAN0617)	4.5	6	4.8	10	3.4	13	4.7	9	4.7	7
2007 (TAN0714)	6.4	8	5.7	15	7.3	12	6.2	12	5.9	11
2008 (TAN0813)	9.9	11	7.0	12	13.3	12	12.3	23	8.9	12
2009 (TAN0911)	9.4	11	6.6	12	17.2	13	9.9	21	7.8	11

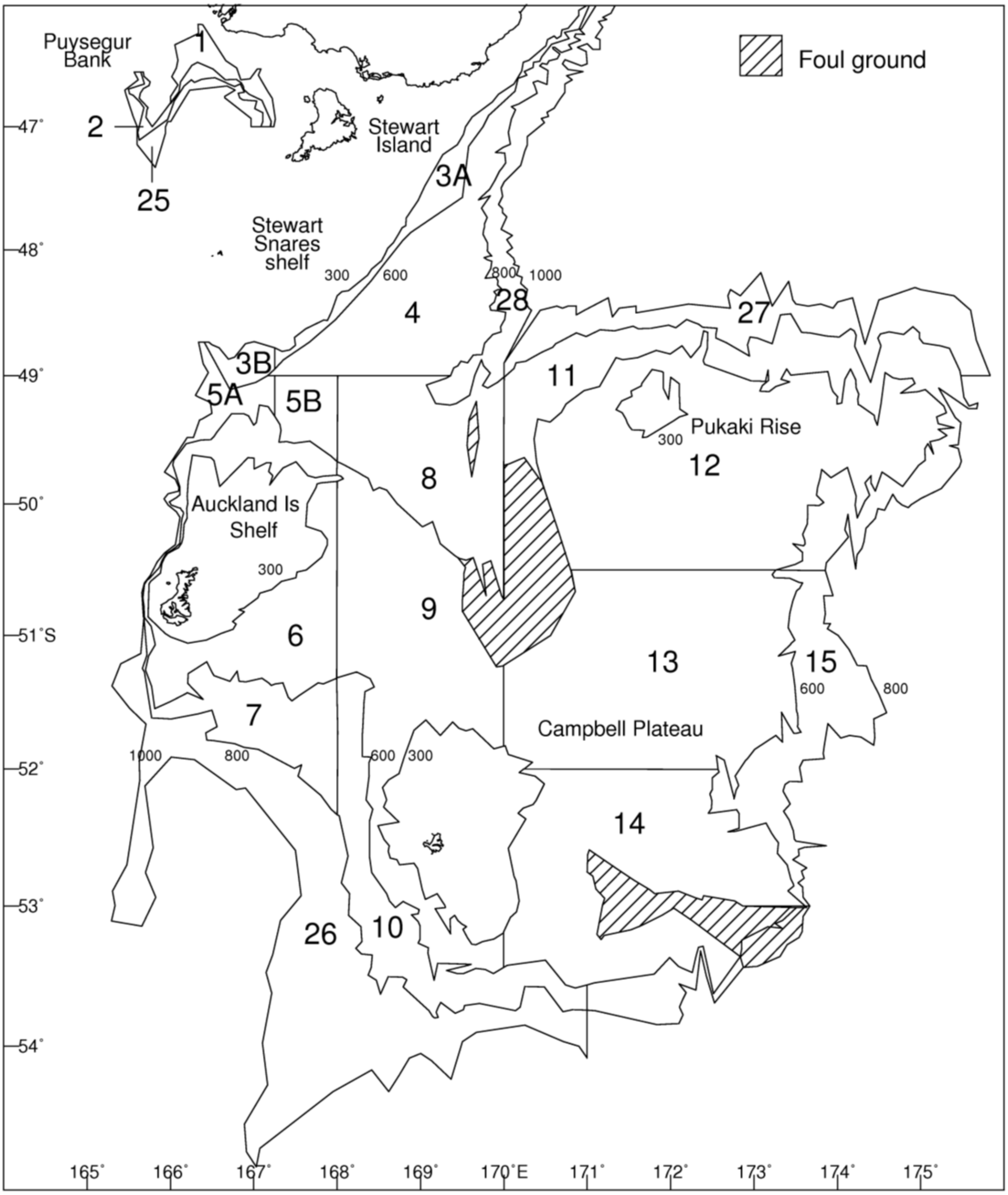


Figure 1: Stratum boundaries for the November–December 2009 Southland and Sub-Antarctic trawl survey.

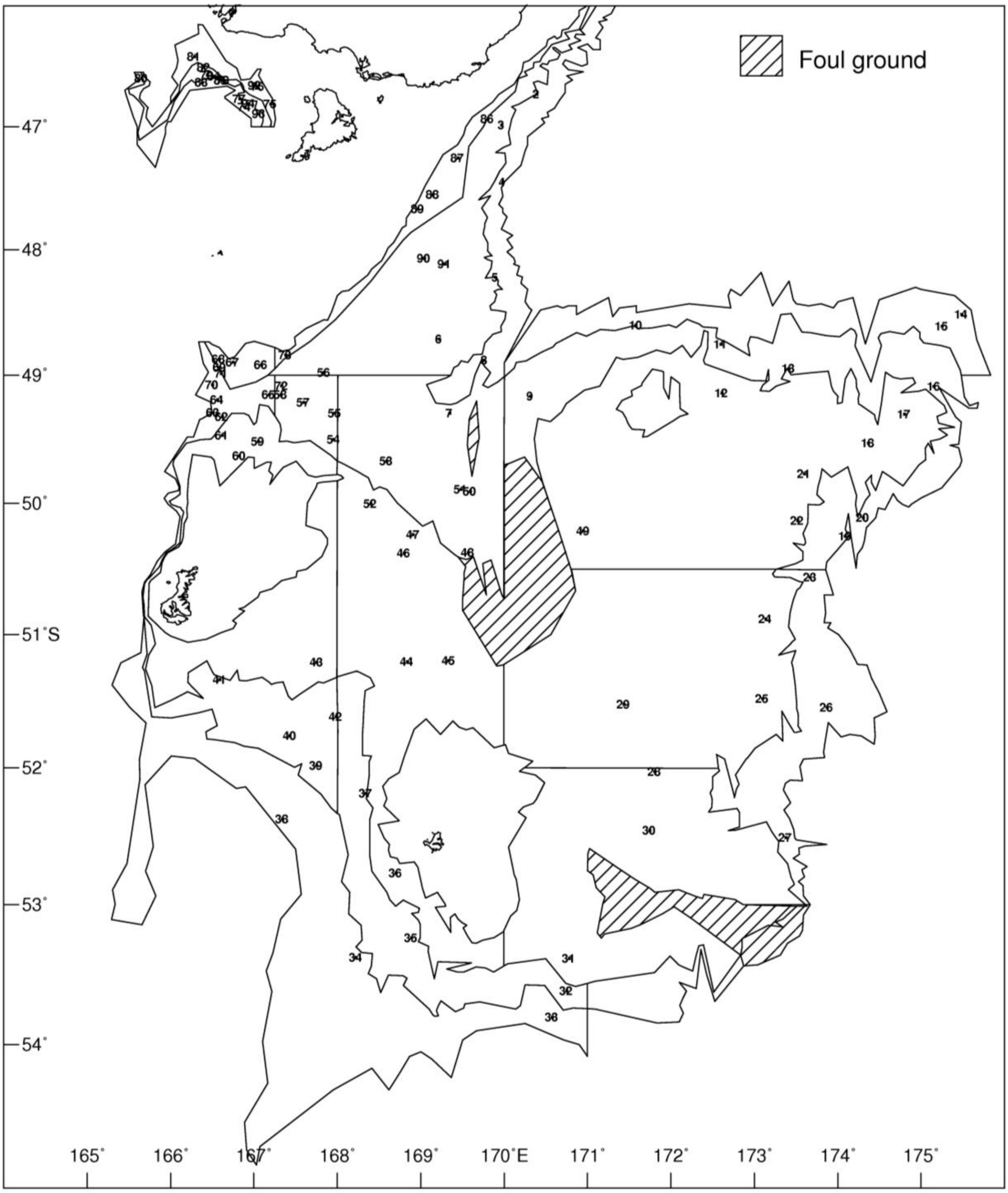


Figure 2: Map showing start positions of all bottom trawls (including unsuccessful stations) from the November–December 2009 Southland and Sub-Antarctic trawl survey.

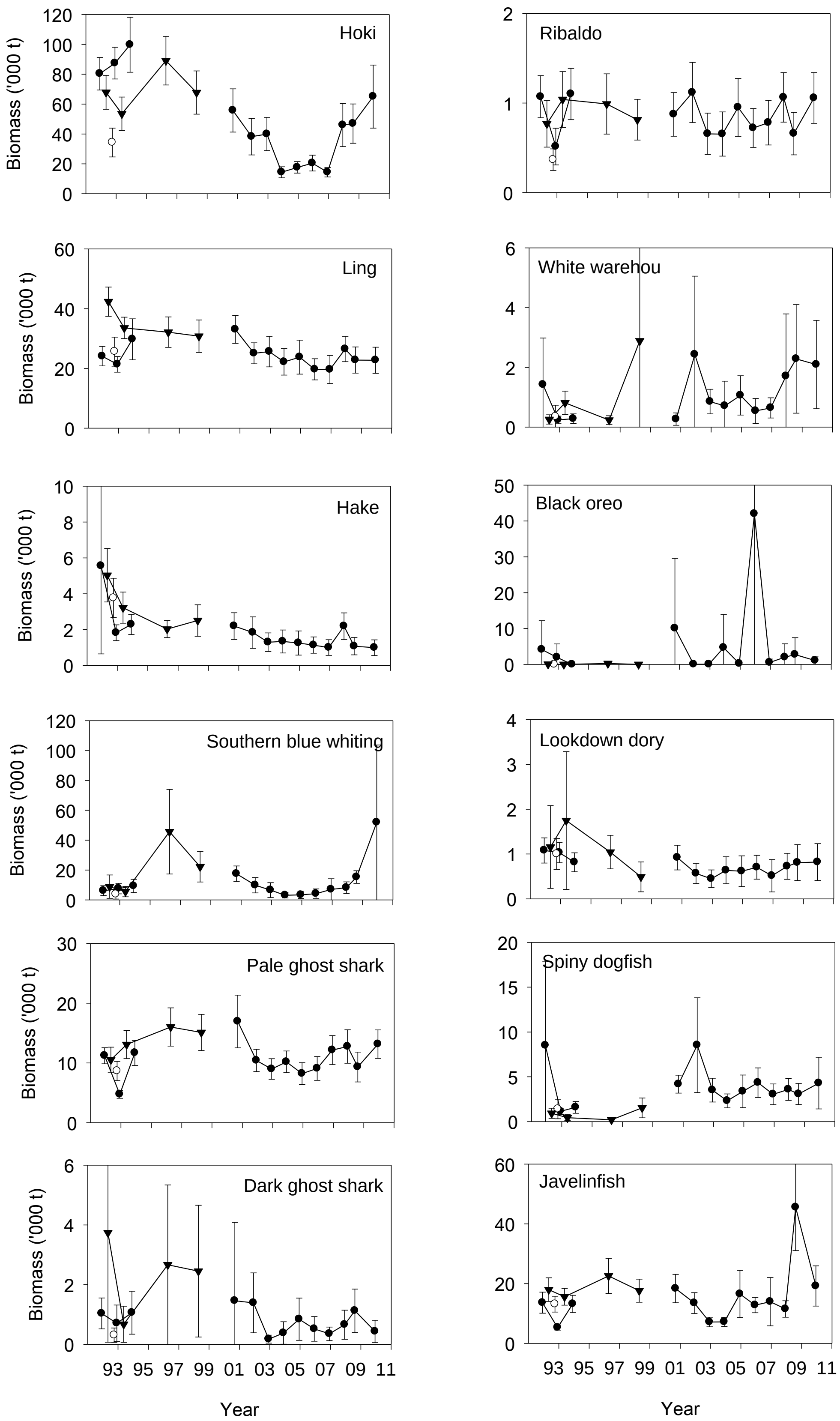


Figure 3: Trends in biomass (± 2 standard errors) of key species in the core 300–800 m strata in all Sub-Antarctic trawl surveys from *Tangaroa*. Solid circles show the summer time series and solid triangles the autumn time series. The open circle shows biomass from a survey of the same area in September–October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

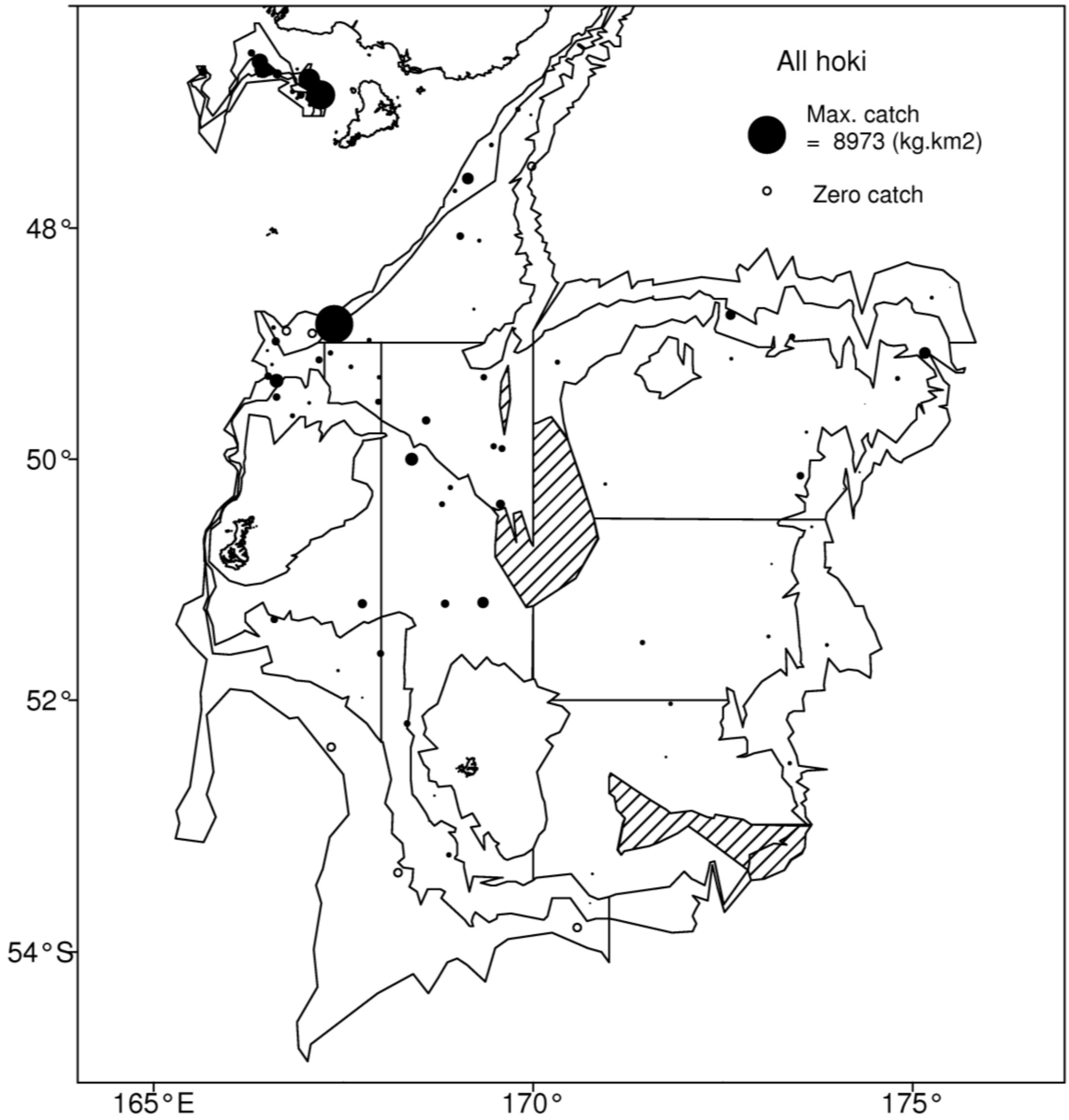


Figure 4a: Distribution and catch rates of all hoki in the summer 2009 trawl survey. Circle area is proportional to catch rate.

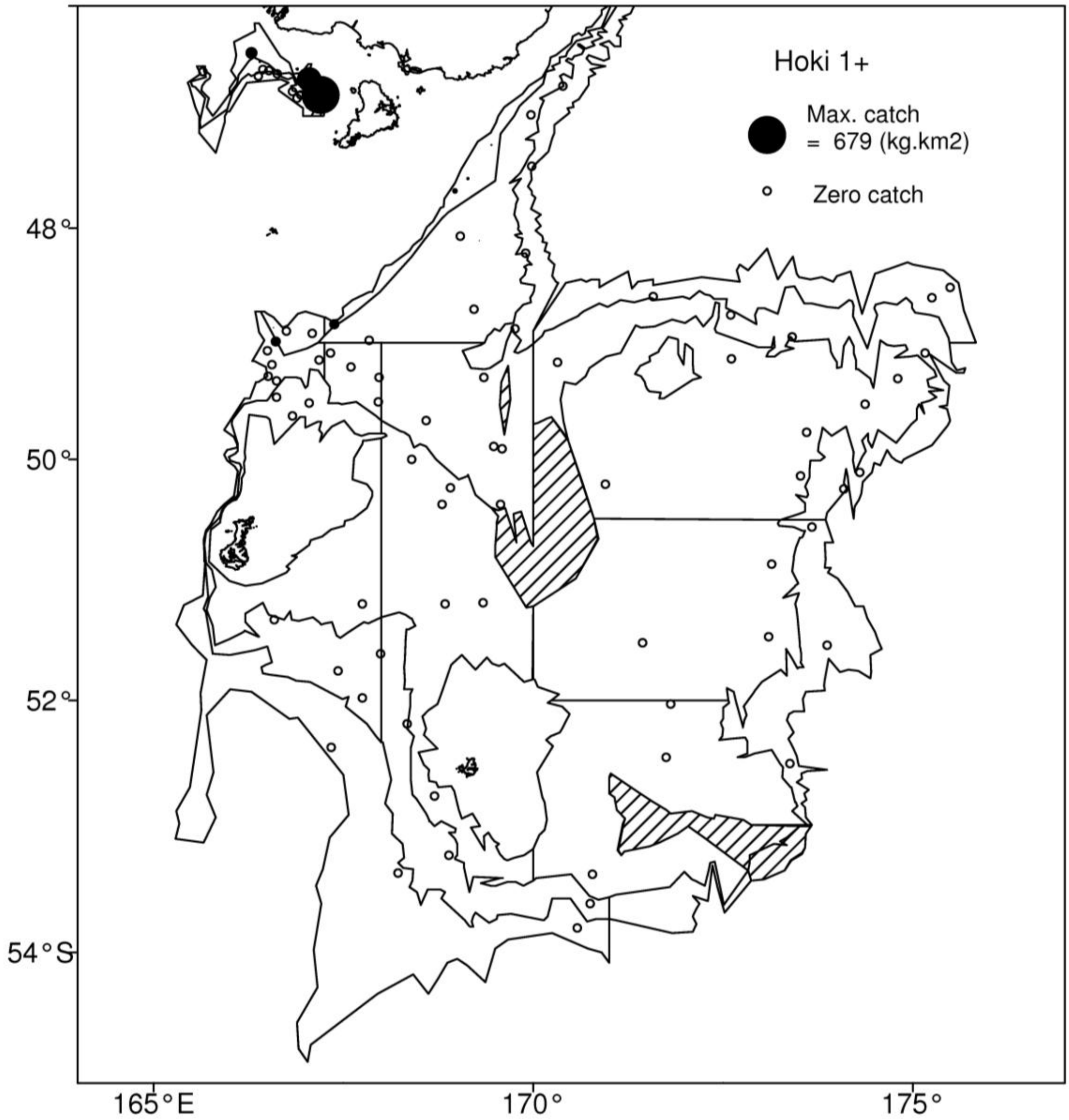


Figure 4b: Distribution and catch rates of 1+ (less than 45 cm) hoki in the summer 2009 trawl survey. Circle area is proportional to catch rate.

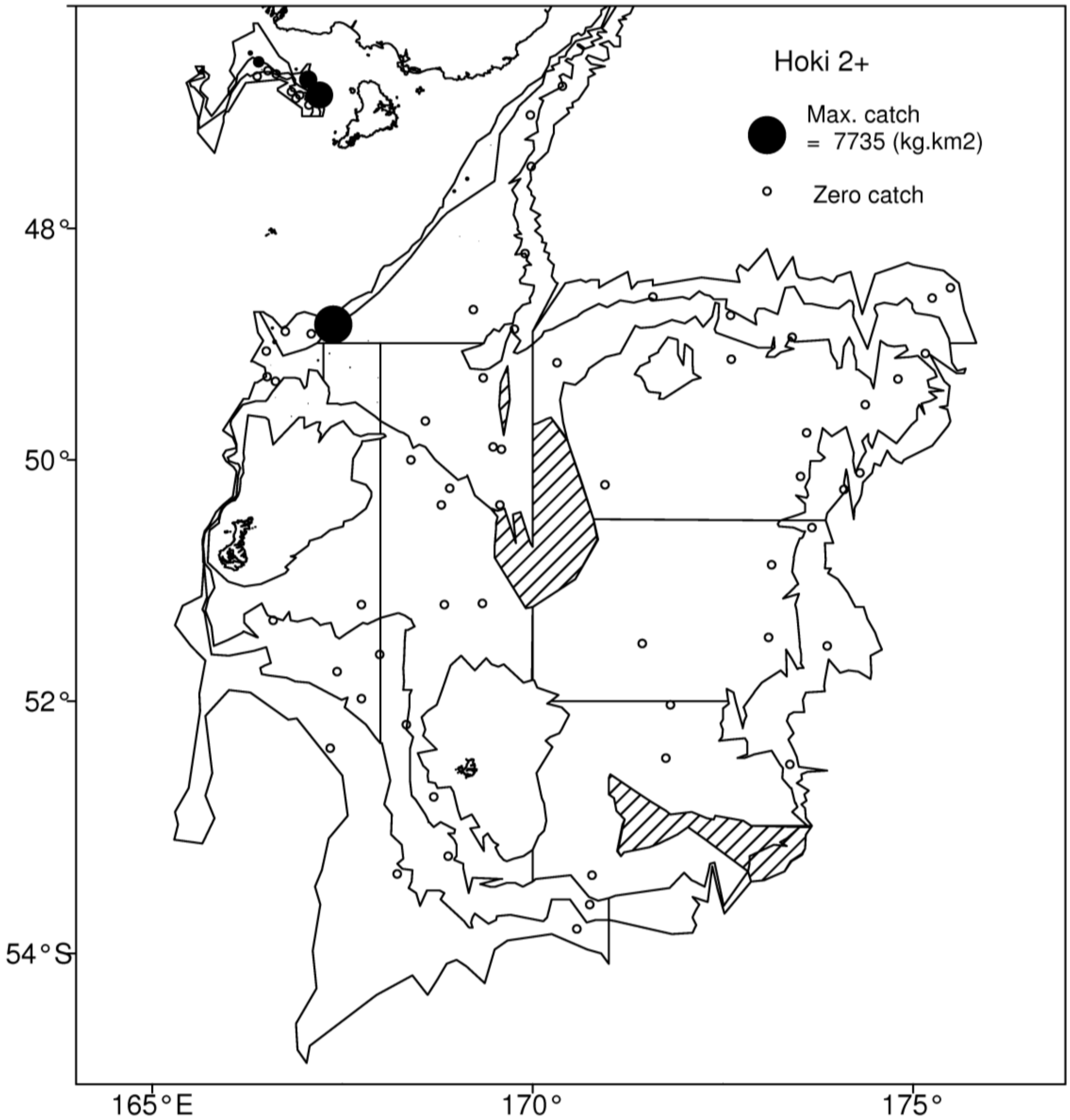


Figure 4c: Distribution and catch rates of 2+ (45–57 cm) hoki in the summer 2009 trawl survey. Circle area is proportional to catch rate.

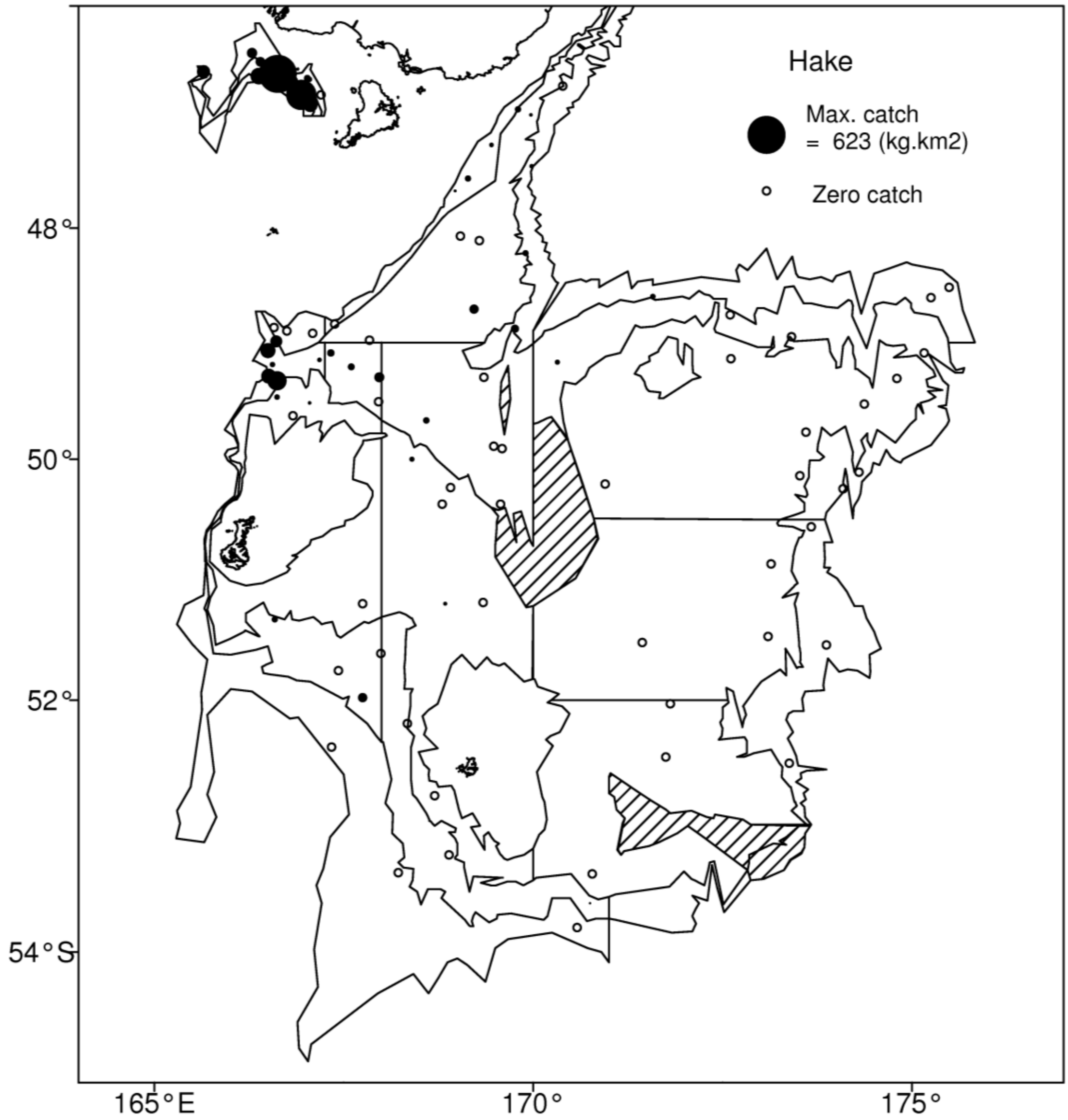


Figure 5: Distribution and catch rates of hake in the summer 2009 trawl survey. Circle area is proportional to catch rate.

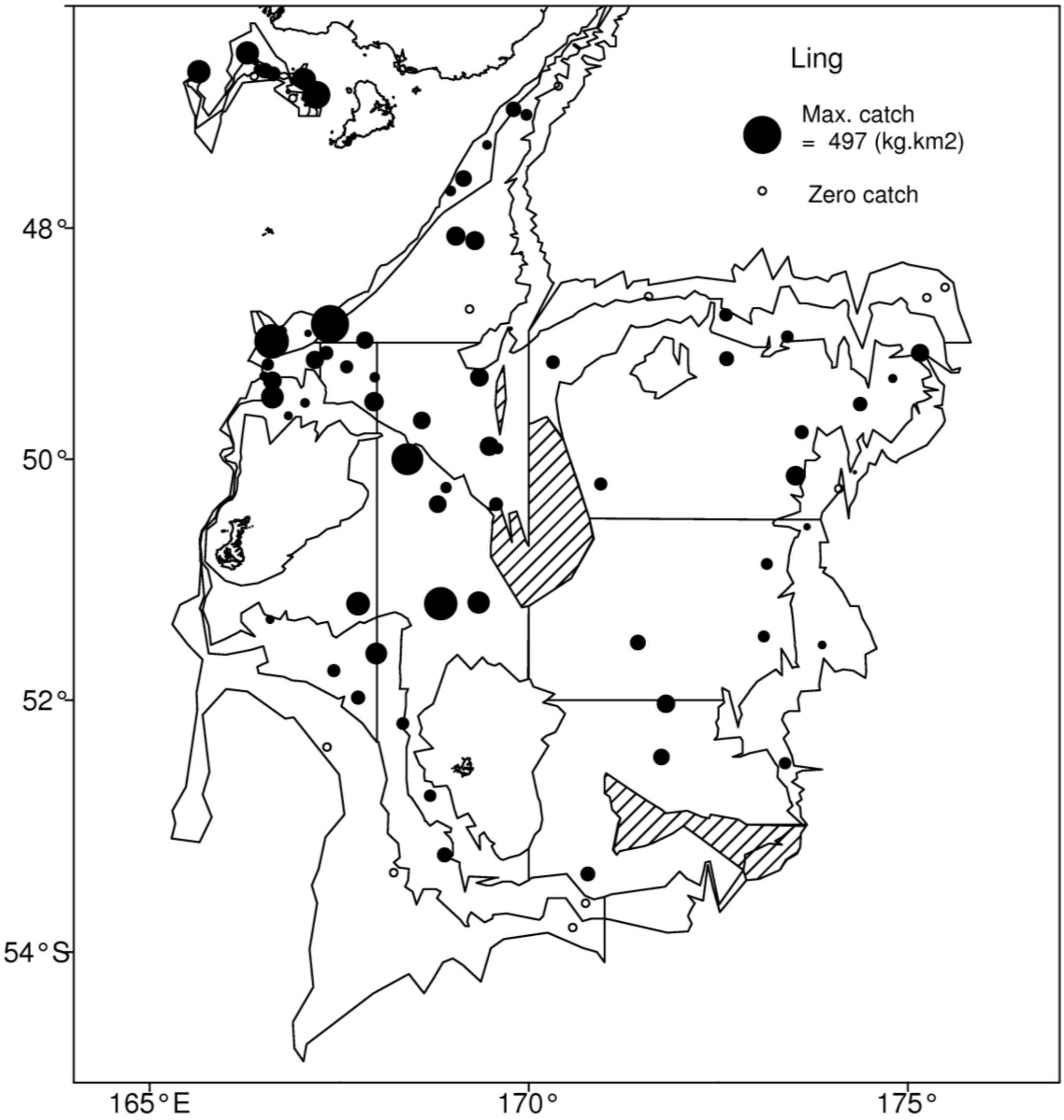


Figure 6: Distribution and catch rates of ling in the summer 2009 trawl survey. Circle area is proportional to catch rate.

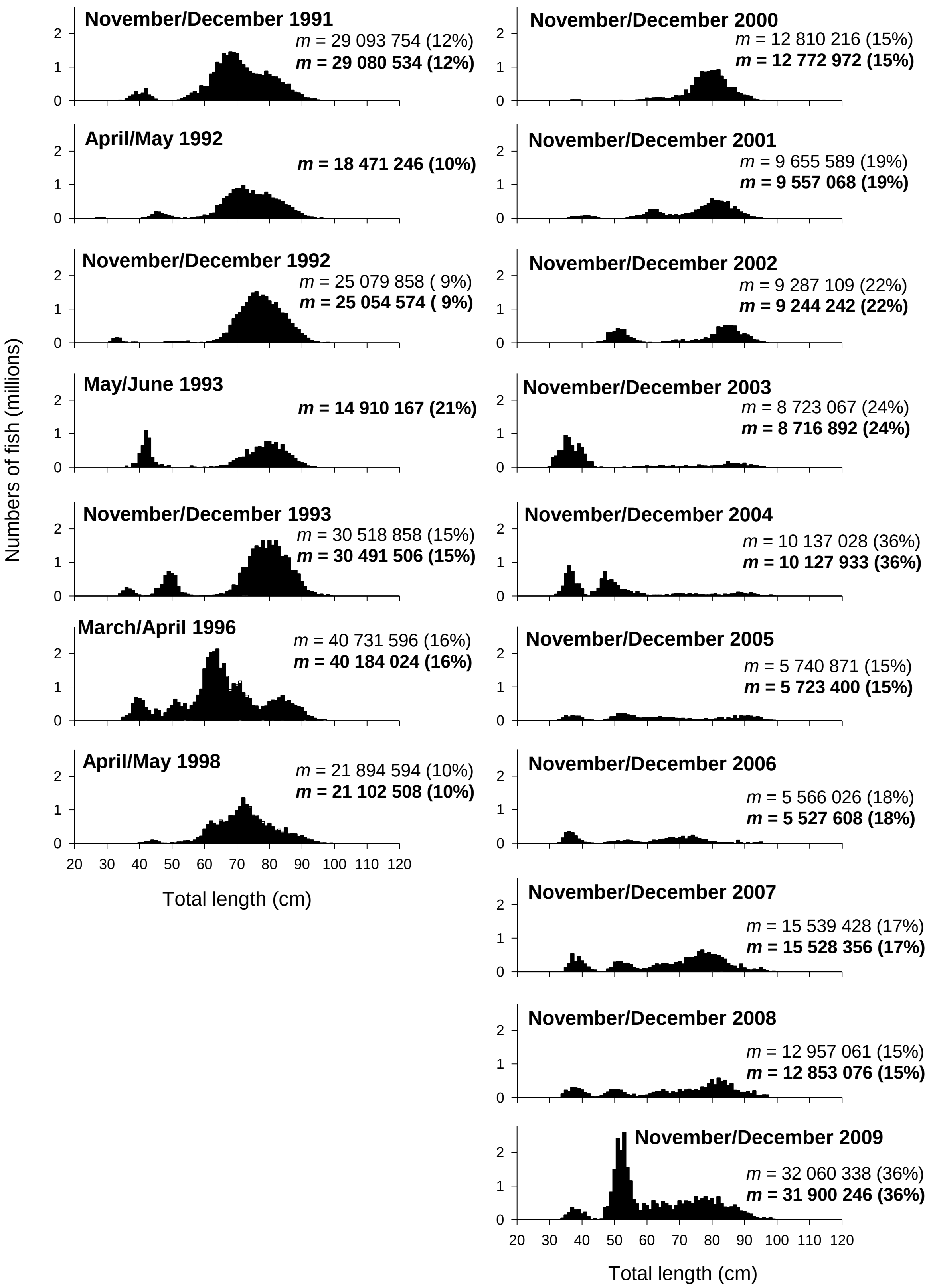


Figure 7a: Scaled length frequency for male hoki from all Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all strata as white bars. Because few hoki were caught outside core strata, white bars are very small. Numbers (*m* values) above are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

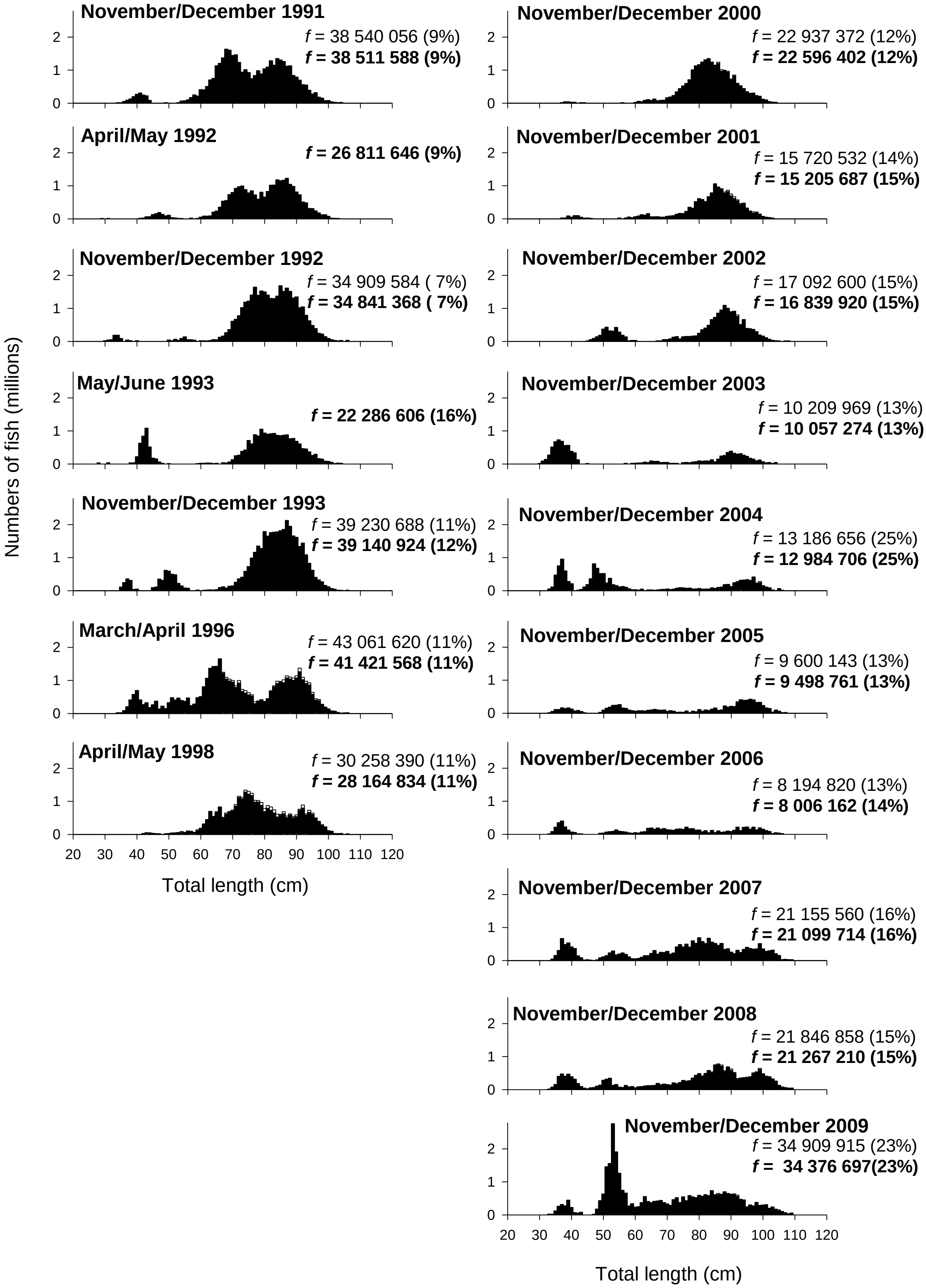


Figure 7b: Scaled length frequency for female hoki from all Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all strata as white bars. Because few hoki were caught outside core strata, white bars are very small. Numbers (*f* values) above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

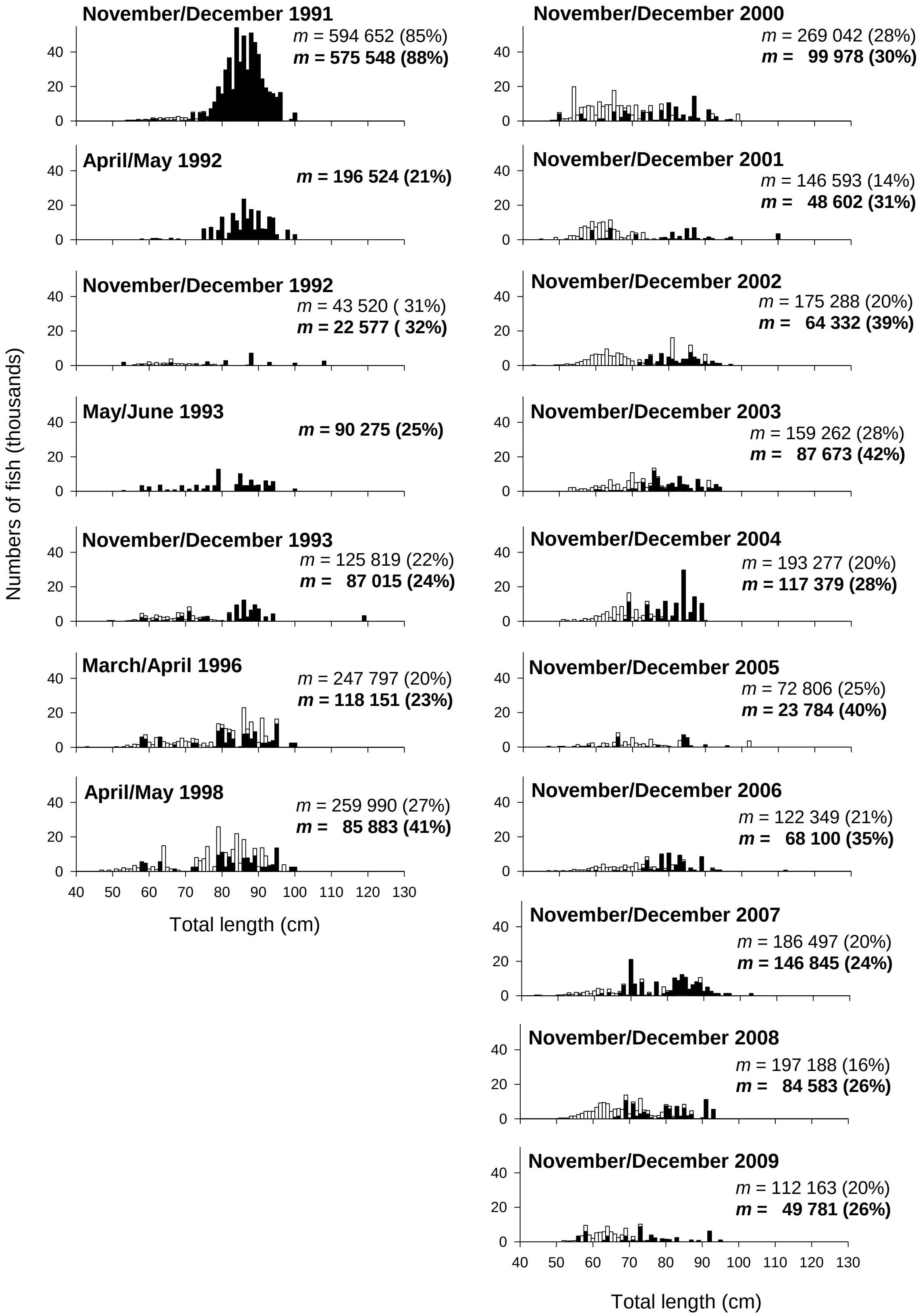


Figure 8a: Scaled length frequency for male hake from all Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all strata as white bars. Numbers (*m* values) above are for all strata and below (in bold) for core strata with c.v.s in parentheses.

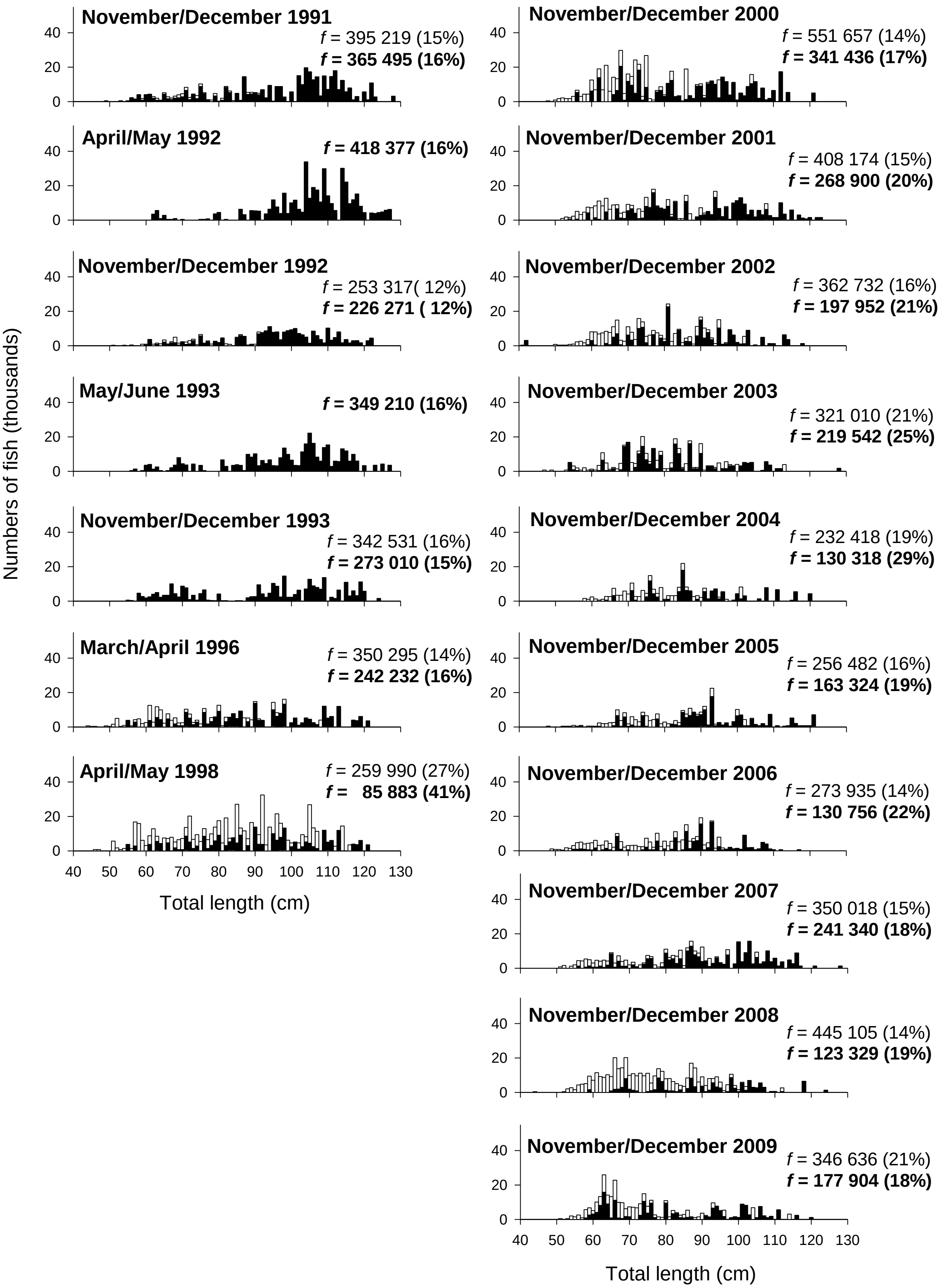


Figure 8b: Scaled length frequency for female hake from all Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all strata as white bars. Numbers (*f* values) above are for all strata and below (in bold) for core strata with c.v.s in parentheses.

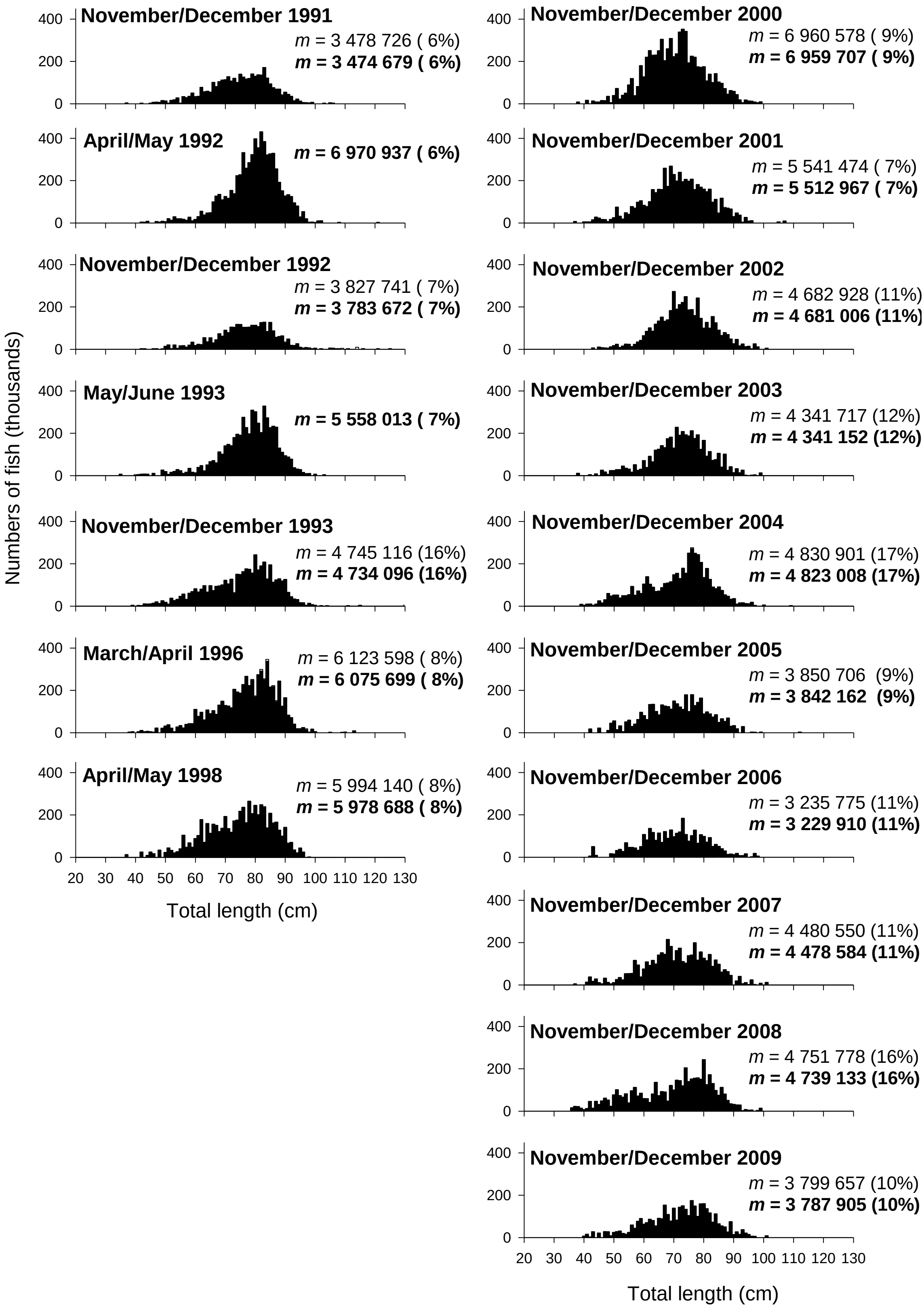


Figure 9a: Scaled length frequency for male ling from all Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all strata as white bars. Because few ling were caught outside core strata, white bars are very small. Numbers (*m* values) above are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

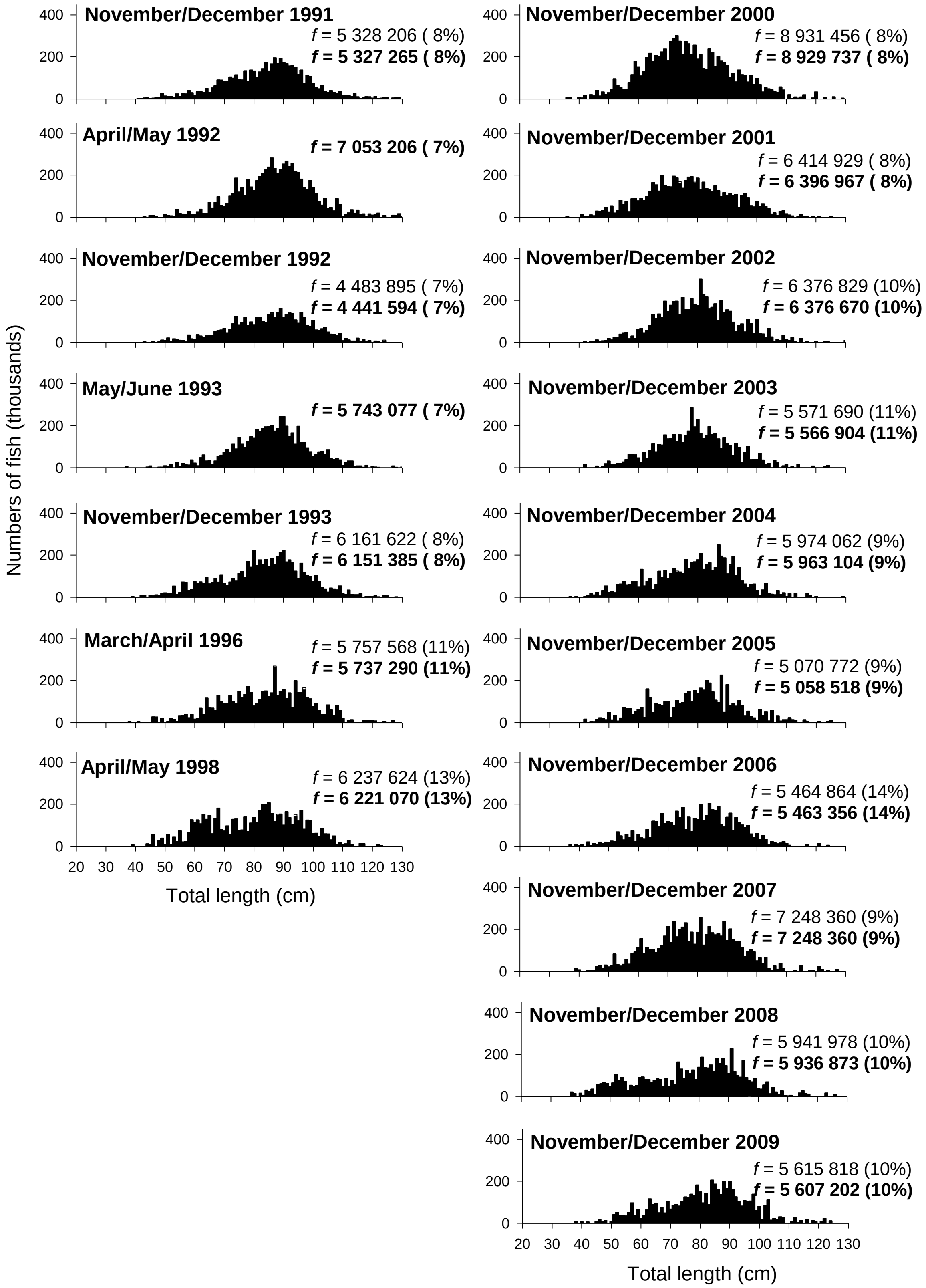


Figure 9b: Scaled length frequency for female ling from all Sub-Antarctic *Tangaroa* trawl surveys. Population numbers for core strata are presented as black bars and for all strata as white bars. Because few ling were caught outside core strata, white bars are very small. Numbers (*f* values) above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

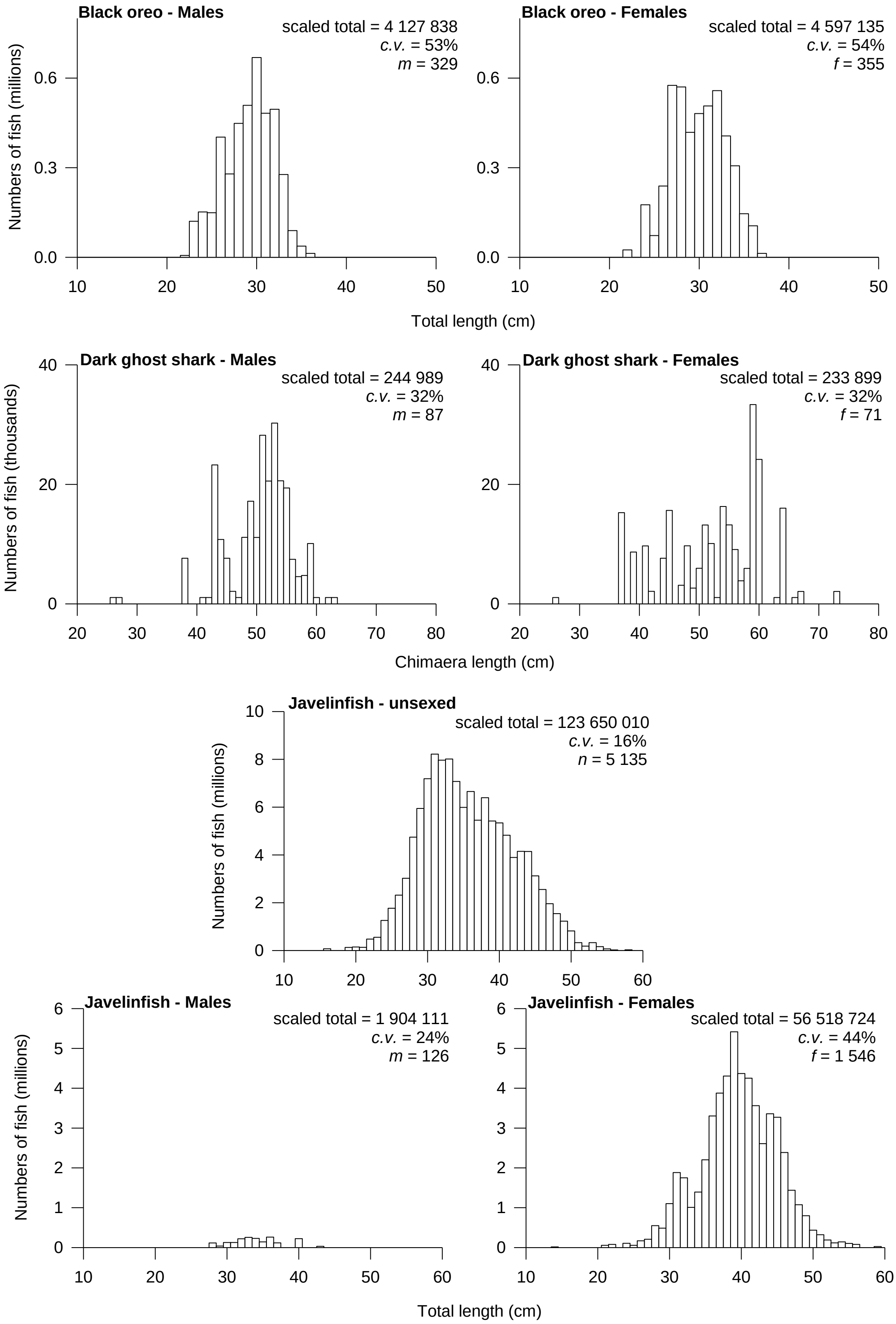


Figure 10: Length frequency distributions by sex of other key species in the November–December 2009 survey. Scaled total is the estimated total number of fish in the surveyed area, c.v. is the coefficient of variation, *m*, *f*, and *n* values are the number of males, females, and unsexed fish measured.

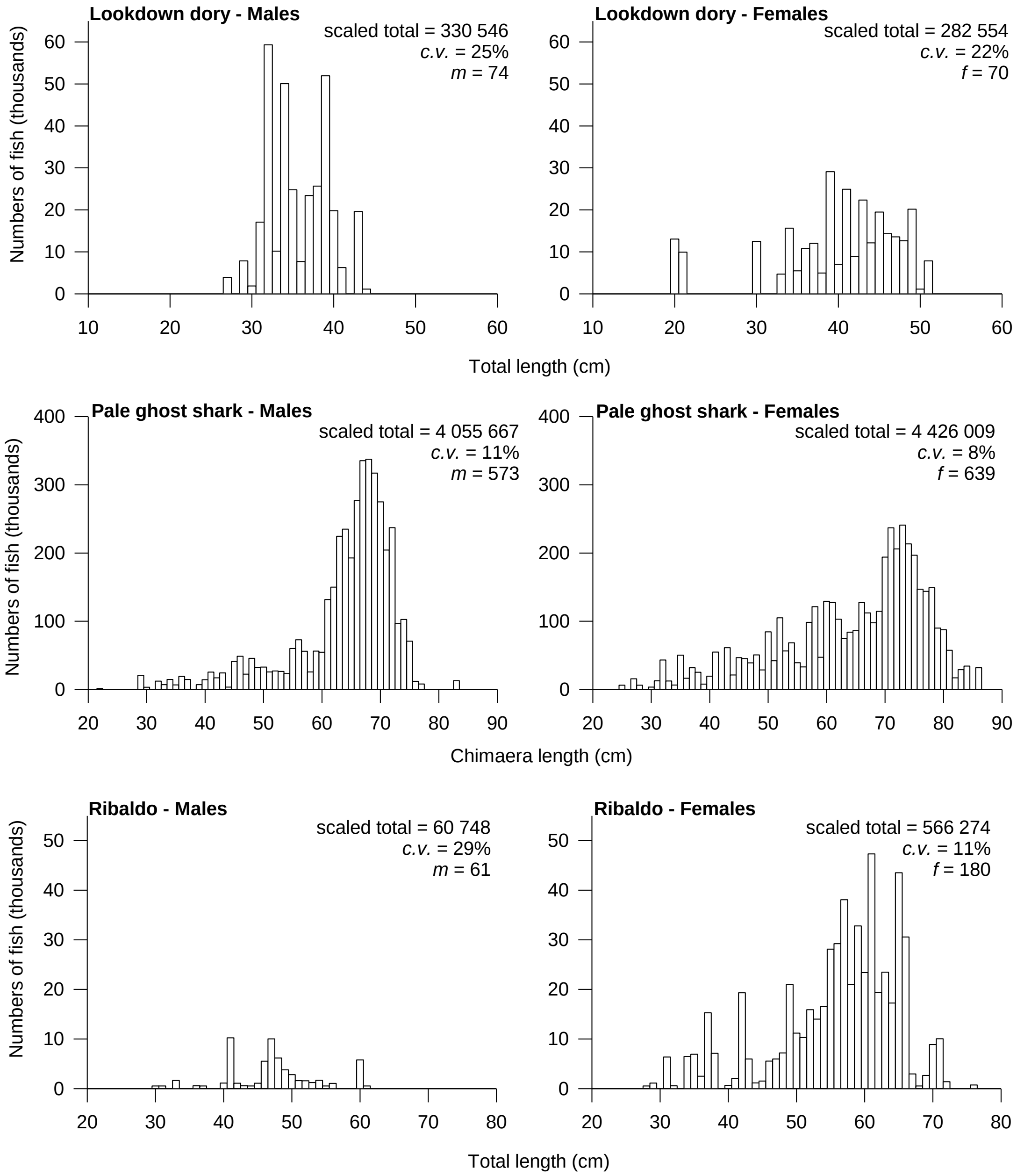


Figure 10 cont: Length frequency distributions by sex of other key species in the November–December 2009 survey. Scaled total is the estimated total number of fish in the surveyed area, c.v. is the coefficient of variation, *m* and *f* values are the number of males and females measured.

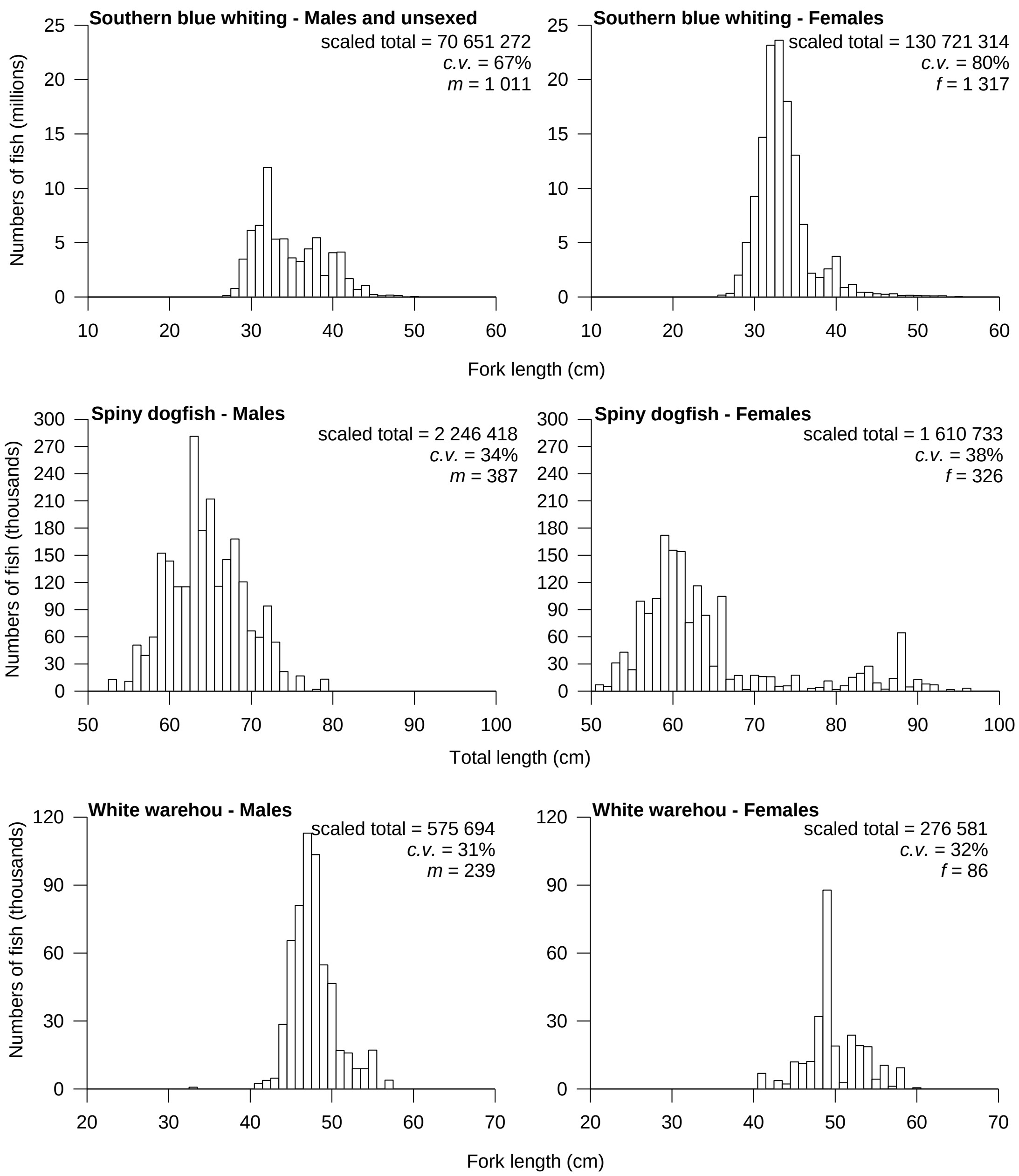


Figure 10 cont: Length frequency distributions by sex of other key species in the November–December 2009 survey. Scaled total is the estimated total number of fish in the surveyed area, c.v. is the coefficient of variation, *m* and *f* values are the number of males and females measured.

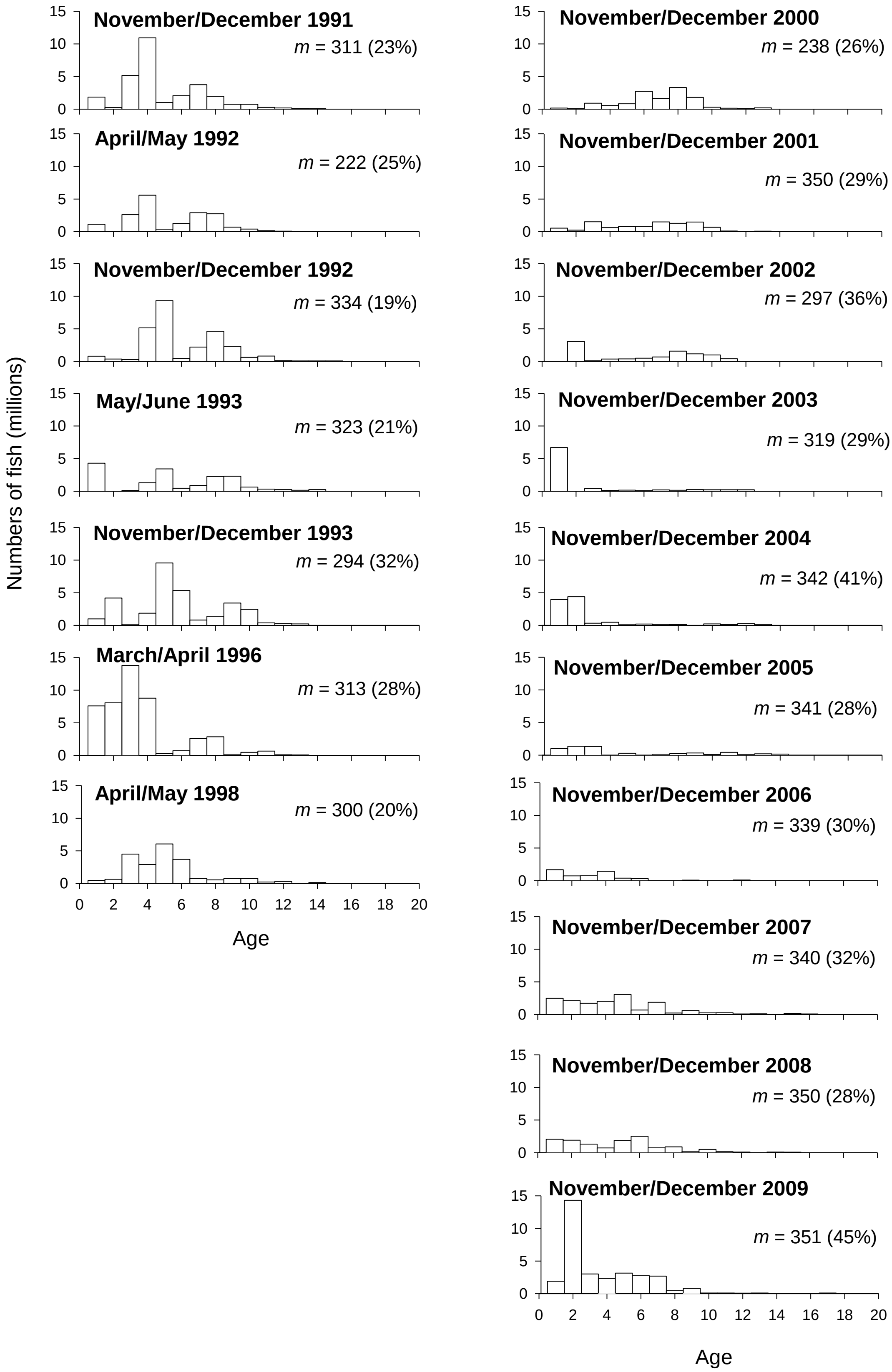


Figure 11a: Scaled age frequency for male hoki from all Sub-Antarctic *Tangaroa* trawl surveys for the core 300–800 m survey area. Number of fish aged (*m* values) are given with c.v.s in parentheses.

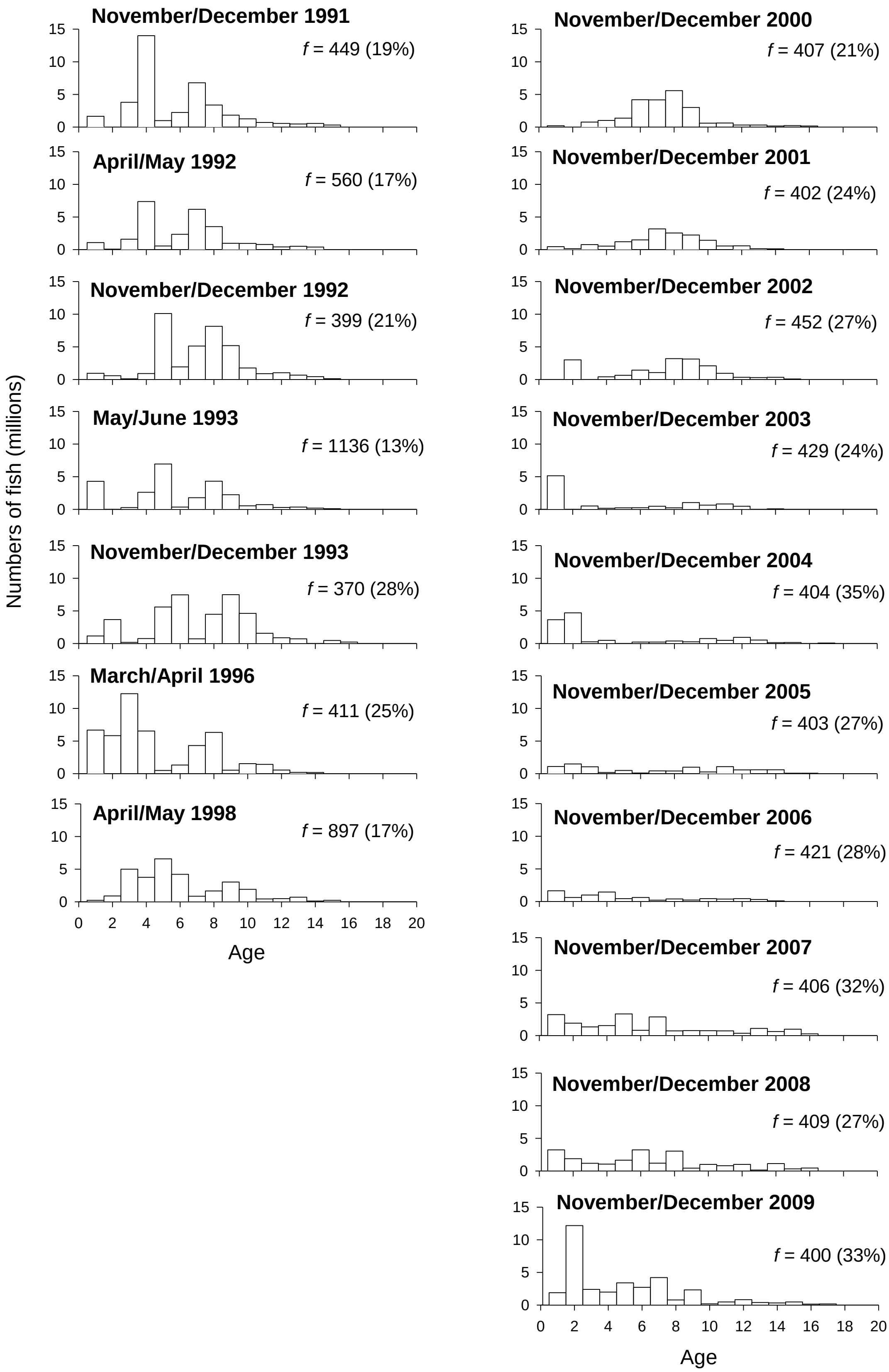


Figure 11b: Scaled age frequency for female hoki from all Sub-Antarctic *Tangaroa* trawl surveys for the core 300–800 m survey area. Number of fish aged (*f* values) are given with c.v.s in parentheses.

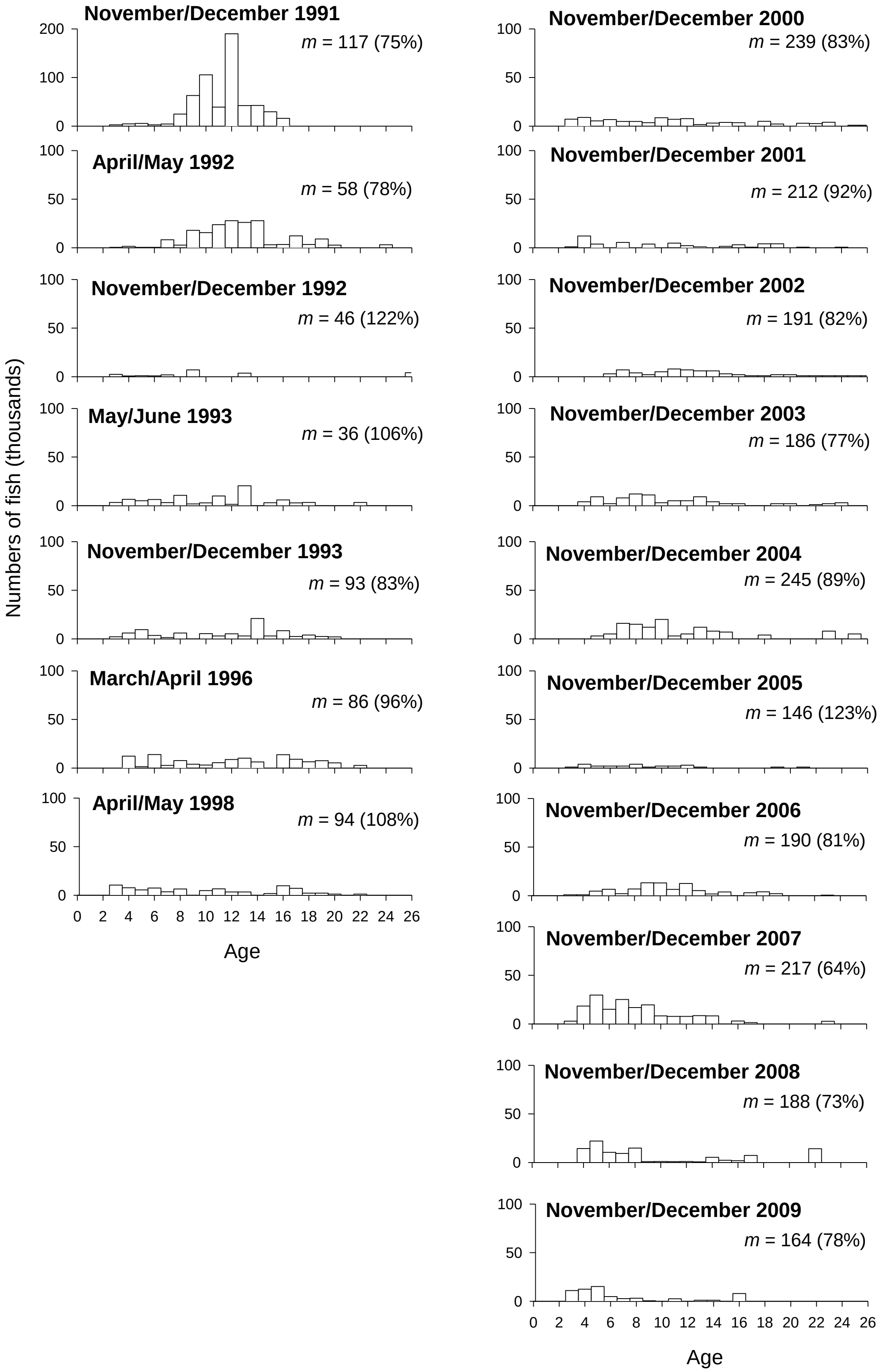


Figure 12a: Scaled age frequency for male hake from all Sub-Antarctic *Tangaroa* trawl surveys for the core 300–800 m survey area. Number of fish aged (*m* values) are given with c.v.s in parentheses.

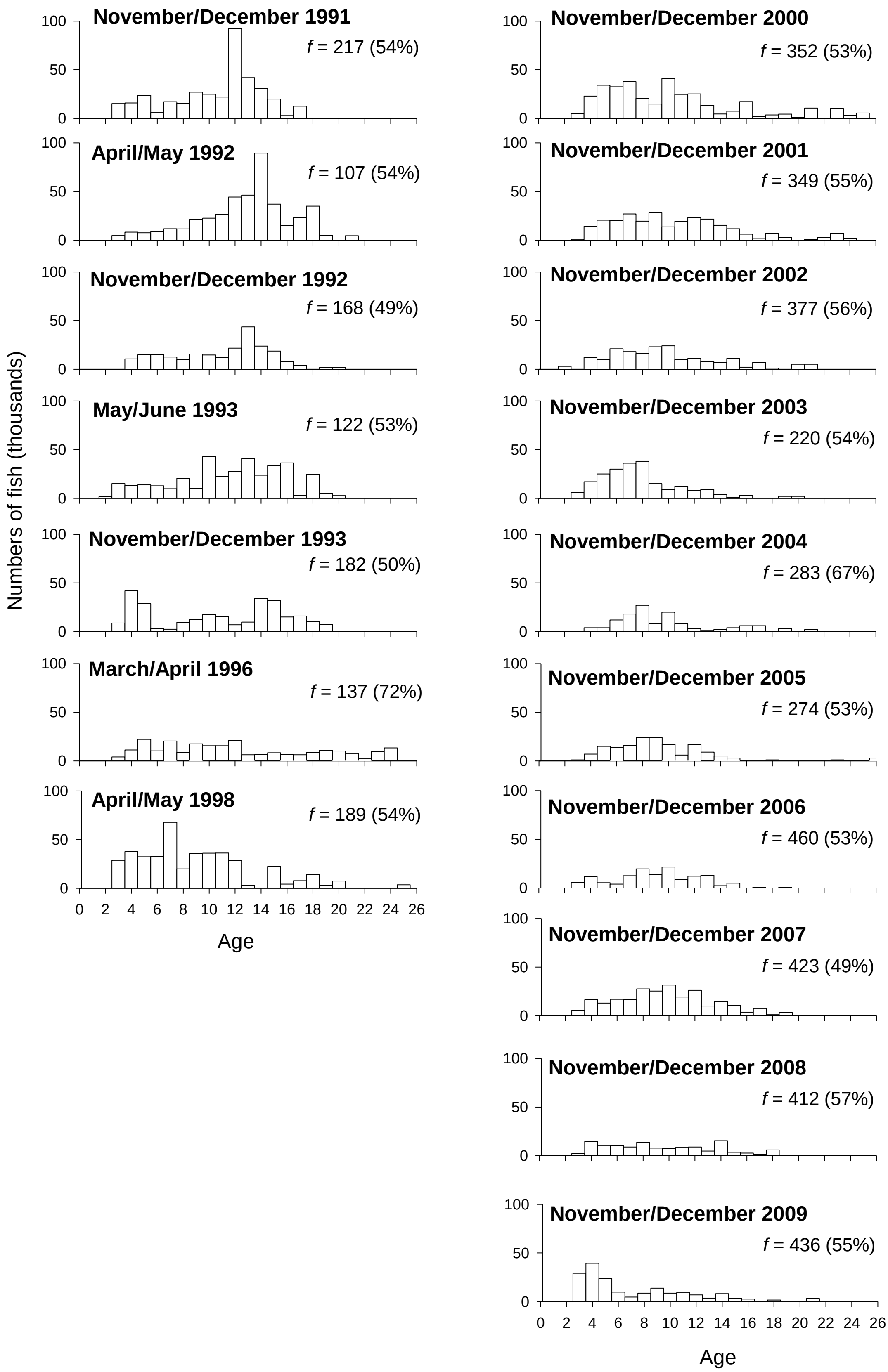


Figure 12b: Scaled age frequency for female hake from all Sub-Antarctic *Tangaroa* trawl surveys for the core 300–800 m survey area. Number of fish aged (*f* values) are given with c.v.s in parentheses.

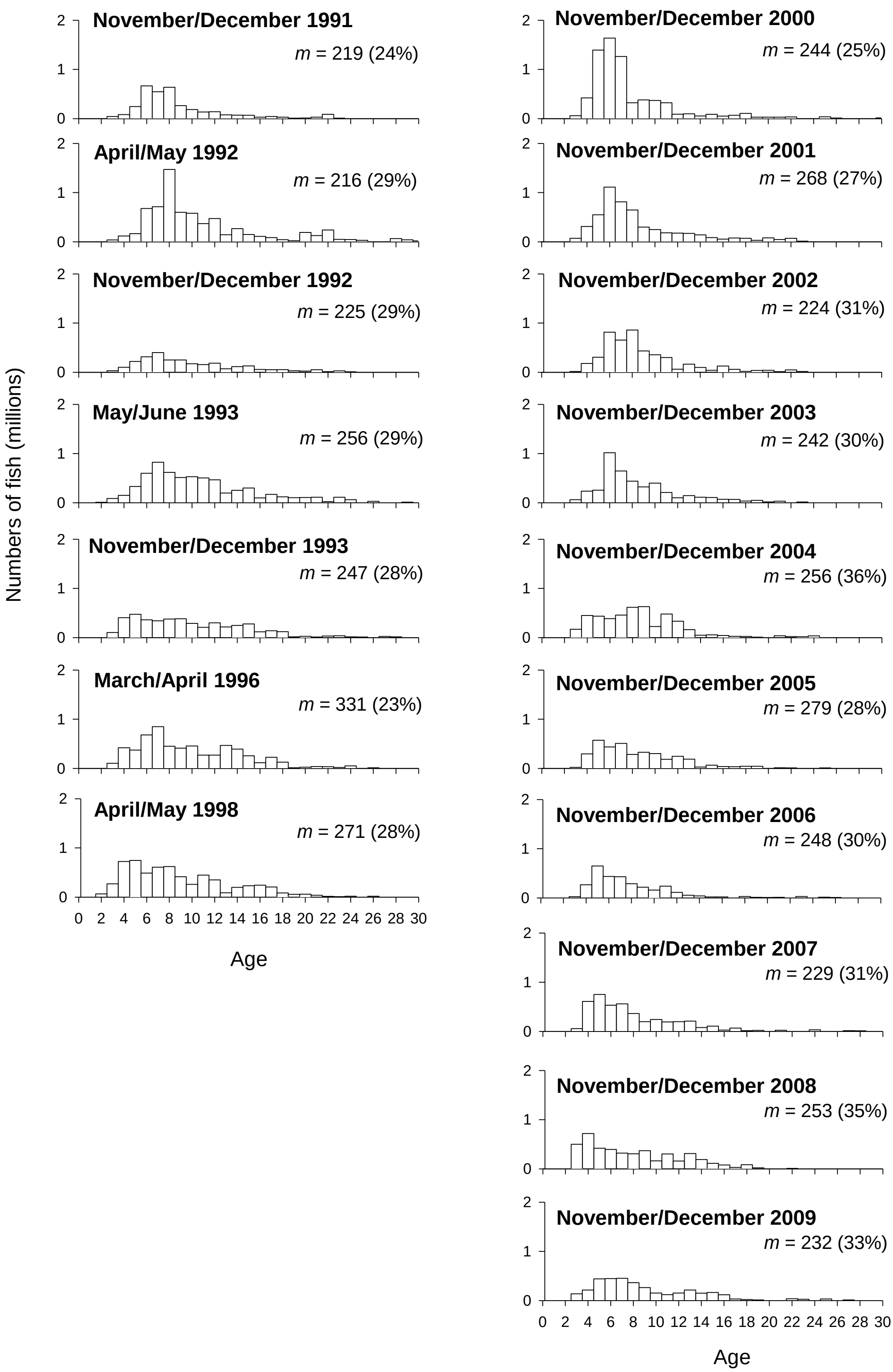


Figure 13a: Scaled age frequency for male ling from all Sub-Antarctic *Tangaroa* trawl surveys for the core 300–800 m survey area. Number of fish aged (*m* values) are given with c.v.s in parentheses.

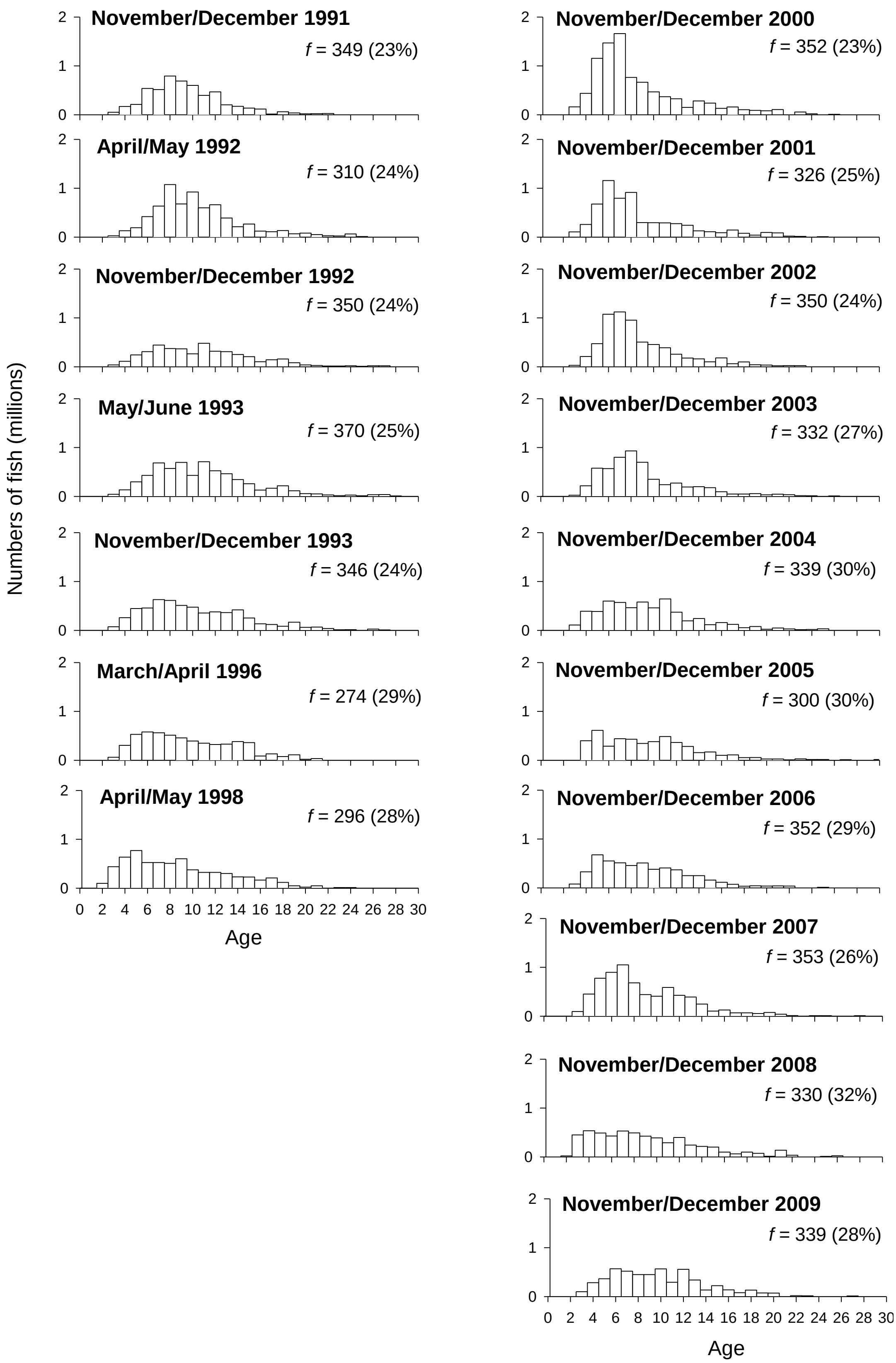


Figure 13b: Scaled age frequency for female ling from all Sub-Antarctic *Tangaroa* trawl surveys for the core 300–800 m survey area. Number of fish aged (*f* values) are given with c.v.s in parentheses.

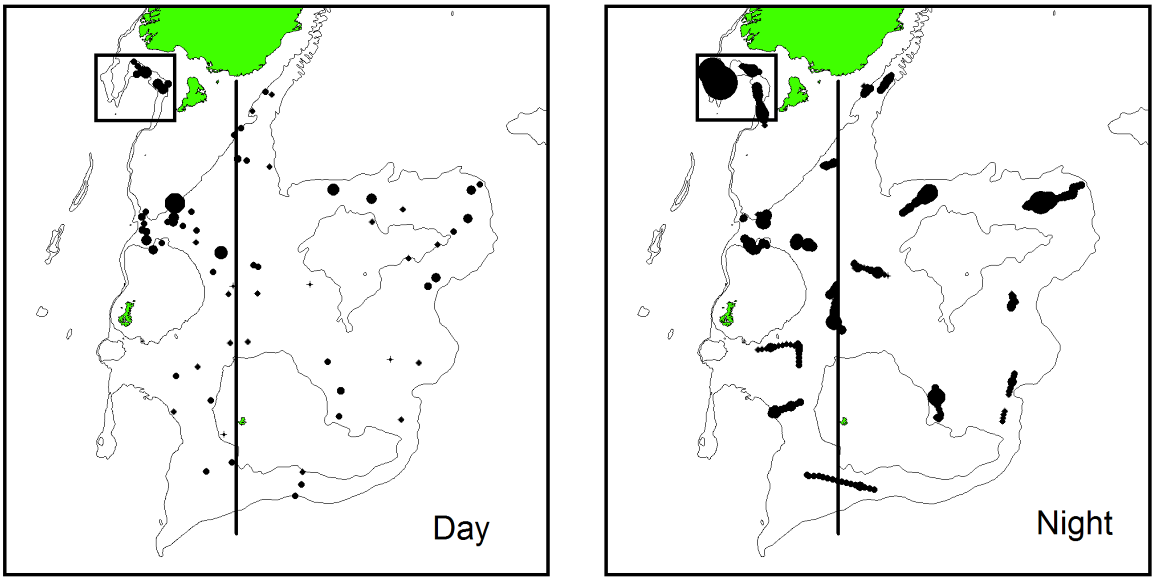


Figure 14: Spatial distribution of total acoustic backscatter in the Sub-Antarctic observed during day trawl stations and night steams. Circle area is proportional to the acoustic backscatter (maximum symbol size = 500 m^2/km^2). Lines separate the three acoustic strata.

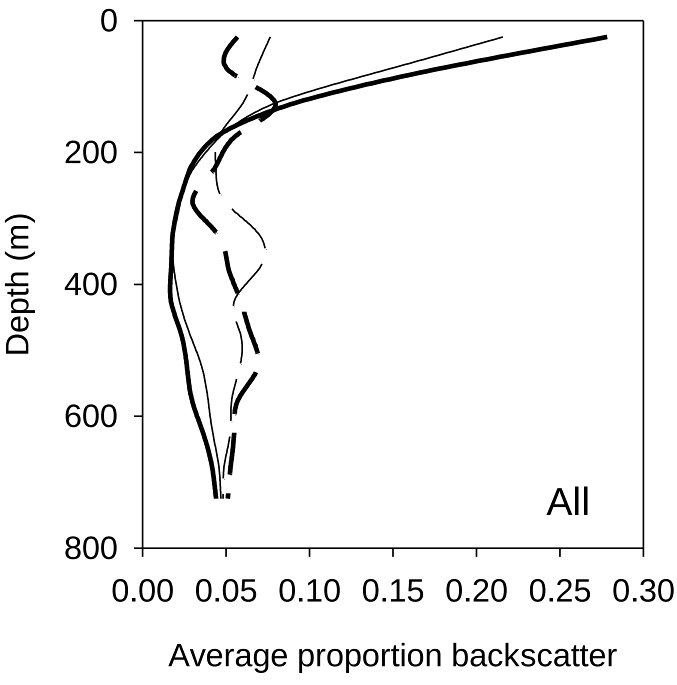


Figure 15: Distribution of total acoustic backscatter integrated in 50 m depth bins on the Sub-Antarctic observed during the day (dashed lines) and at night (solid lines) in 2009 (bold lines), and the average distribution from 2000–09 (thin lines).

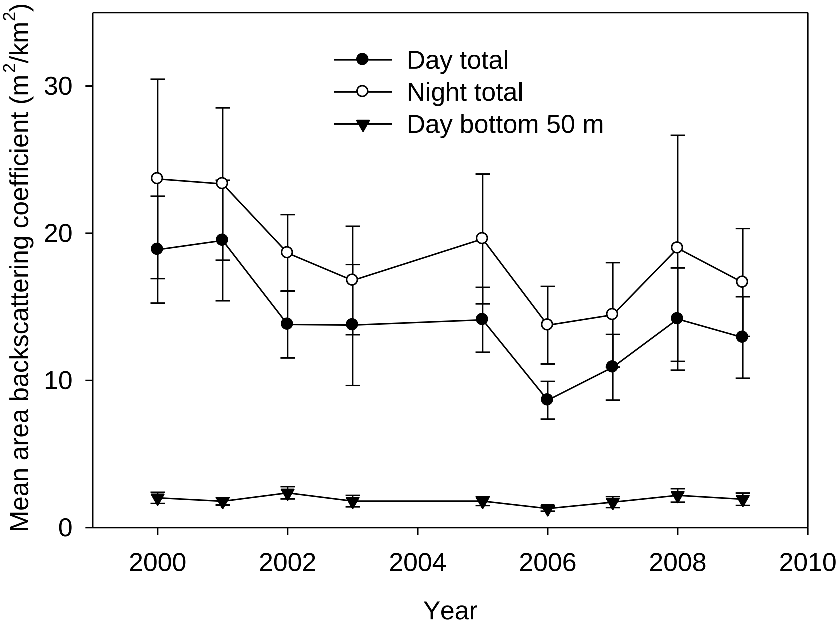


Figure 16: Total acoustic abundance indices for the Sub-Antarctic based on (strata-averaged) mean areal backscatter (sa). Error bars are ± 2 standard errors.

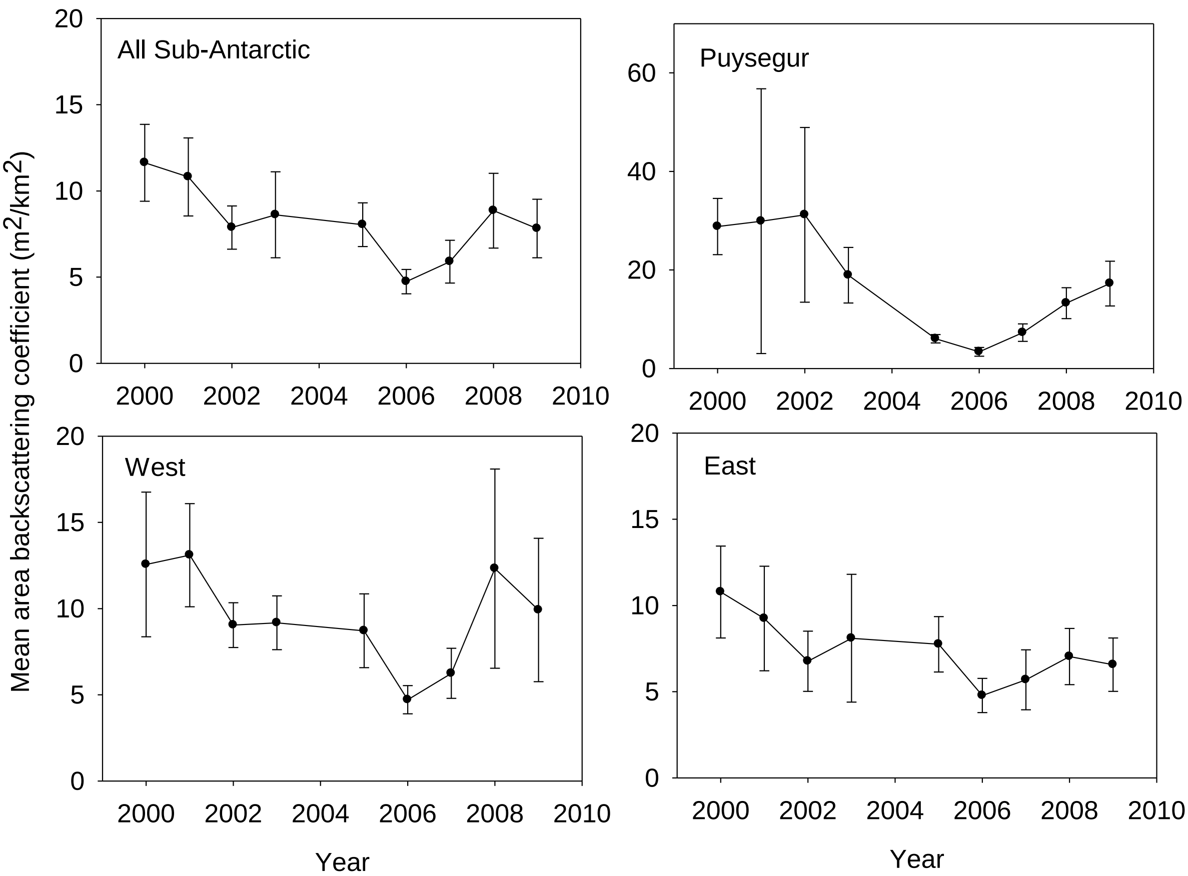


Figure 17: Time-series of mesopelagic indices for the Sub-Antarctic (from Table 16). Panels show indices for the entire Sub-Antarctic and for three sub-areas. Error bars are ± 2 standard errors.

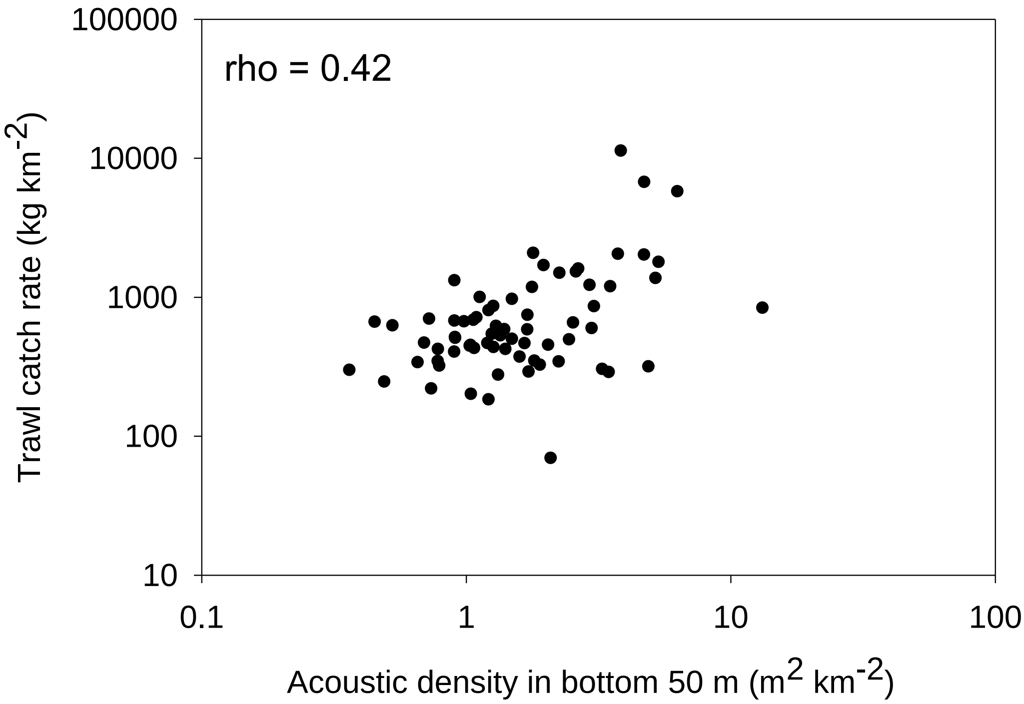


Figure 18: Relationship between total trawl catch rate (all species excluding benthic invertebrates) and acoustic backscatter recorded during the trawl in the Sub-Antarctic in 2009. Rho values are Spearman's rank correlation coefficients.

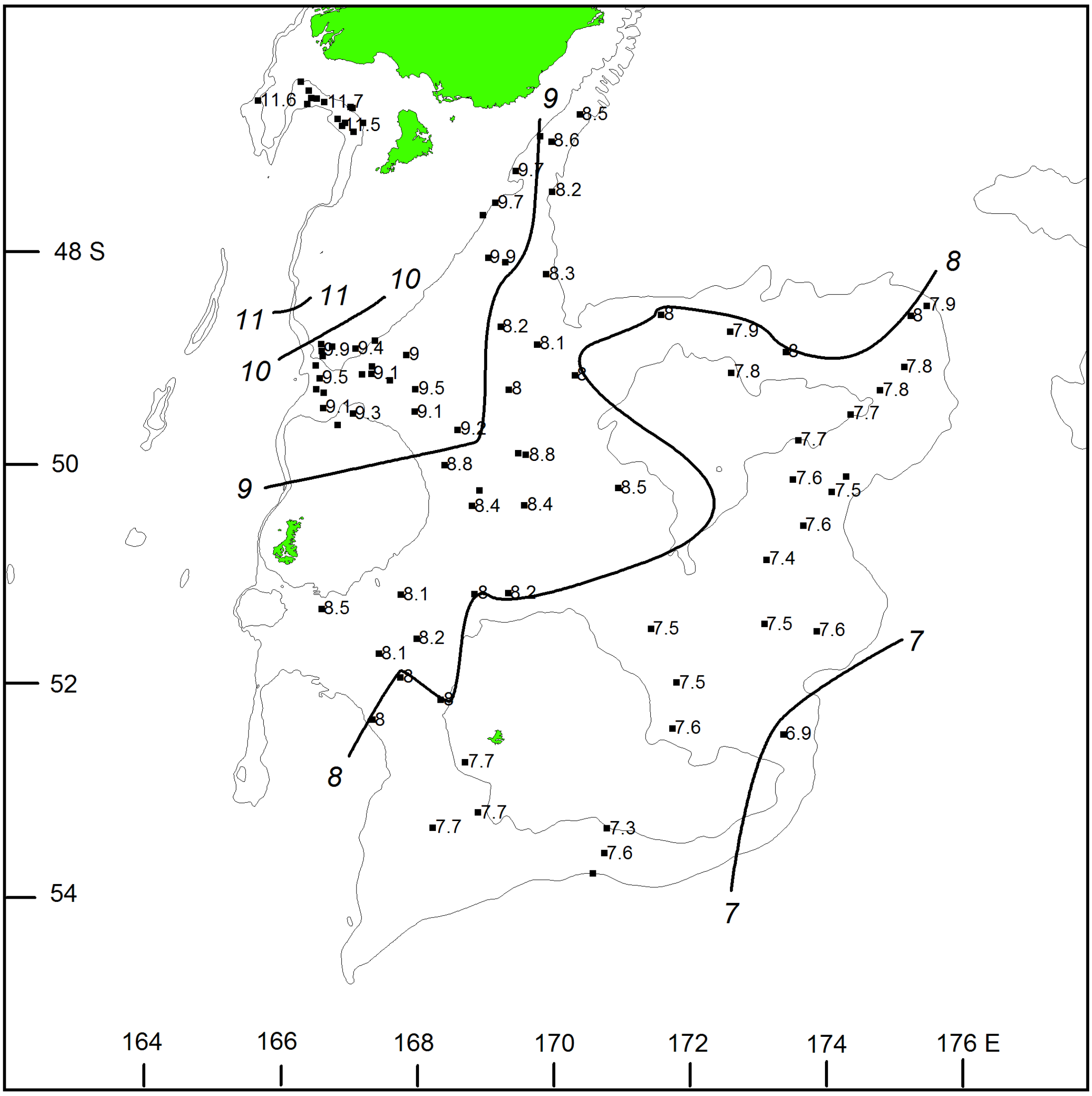


Figure 19: Surface water temperatures (°C). Squares indicate station positions. Not all temperatures are labelled where two or more stations were close together. Contours show isotherms estimated by eye.

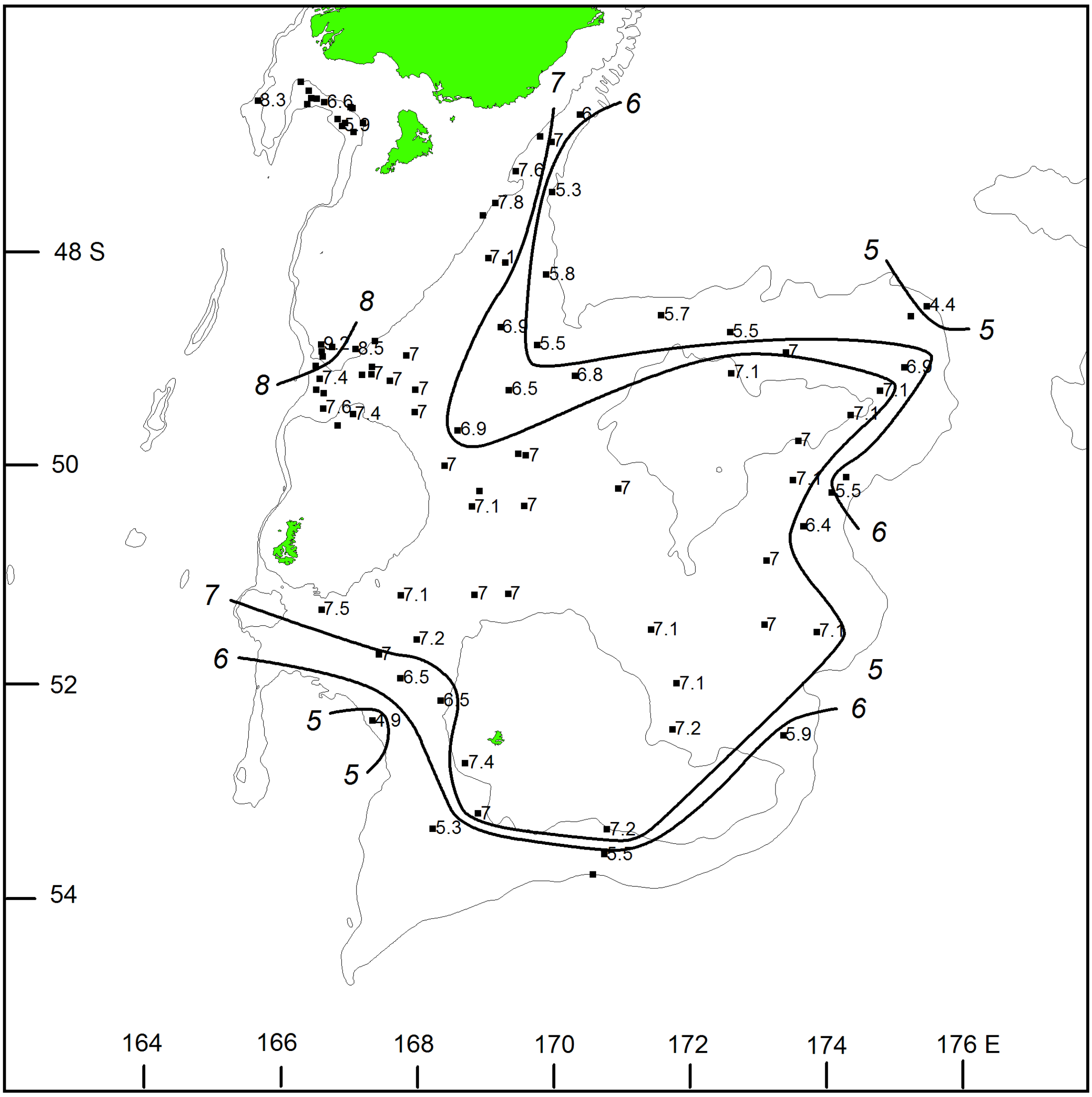
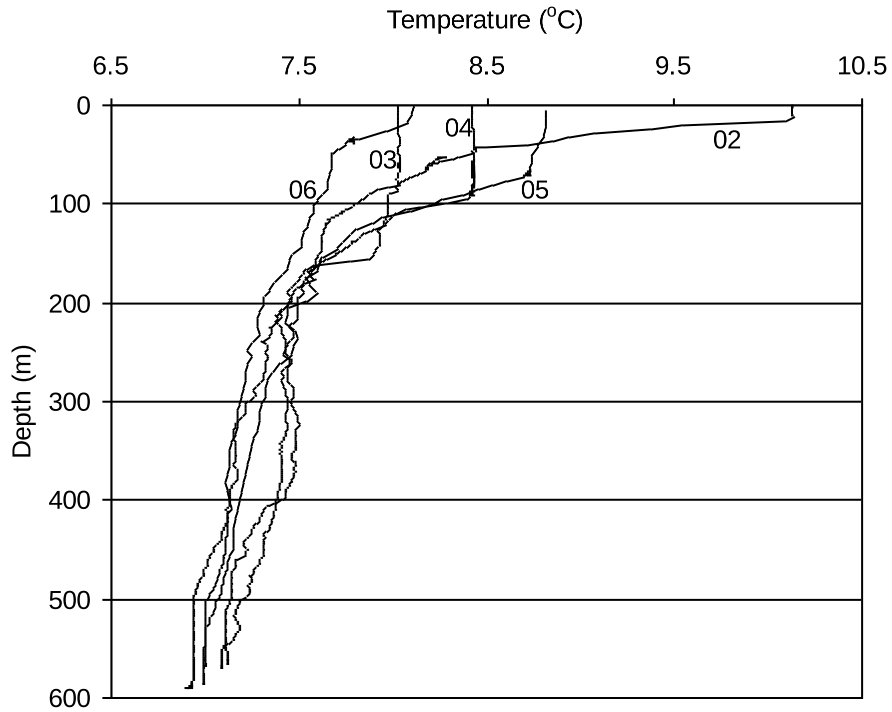


Figure 20: Bottom water temperatures (°C). Squares indicate station positions. Not all temperatures are labelled where two or more stations were close together. Contours show isotherms estimated by eye.



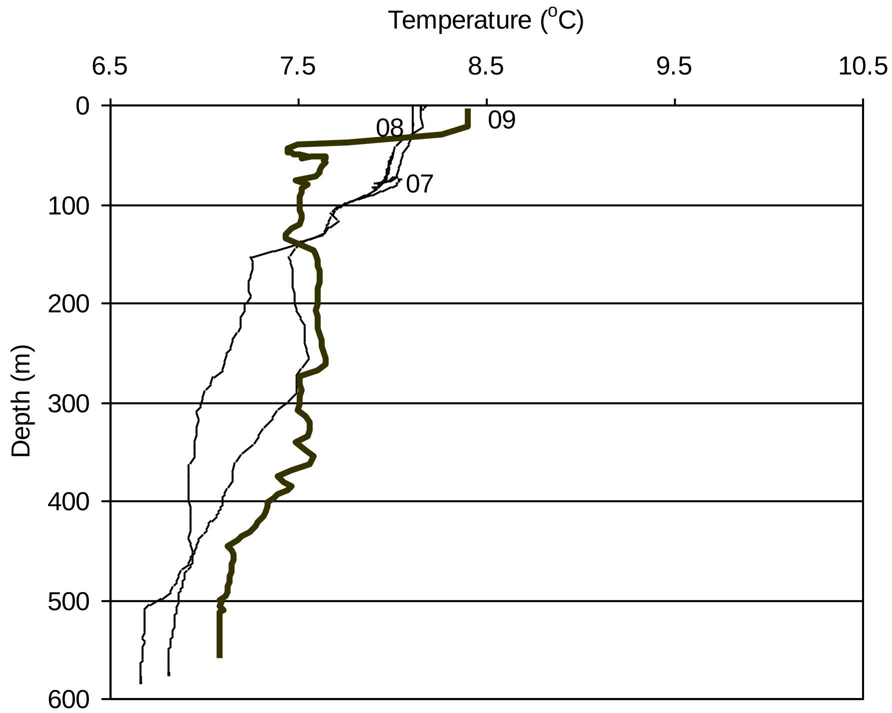


Figure 21: Comparison of vertical profiles of temperature (°C) from the net-mounted CTD on tows in stratum 9 at approximately 50° 45' S and 169° 00' E in 2002 (TAN0219 station 54, on 6 December), 2003 (TAN0317 station 45, on 29 November), 2004 (TAN0414 station 54, on 14 December), 2005 (TAN0515 station 42, on 6 December), 2006 (TAN0617 station 33, on 5 December) (above), 2007 (TAN0714 station 40, on 7 December), and 2008 (TAN0813 station 17, on 30 November). The profile from 2009 (TAN0911 station 46, on 9 December) is the bold red line (below). 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	9
Hexactinellida: glass sponges			
Hyalascus spp.	floppy tubular sponge	HYA	33
Geodiidae			
Geodinella vestigifera	ostrich egg sponge	GVE	1
Suberitidae			
Suberites affinis	fleshy club sponge	SUA	23
Hymedesmiidae			
Phorbas spp.	grey fibrous massive sponge	PHB	2
Tetillidae			
Tetilla leptoderma	furry oval sponge	TLD	4
Demospongiae	siliceous sponges	DSO	1
Cnidaria			
Scyphozoa	unspecified jellyfish	JFI	4
Anthozoa			
Octocorallia			
Alcyonacea	unspecified soft coral	SCO	3
Actiniaria	unspecified sea anemones	ANT	2
Actiniidae			
Bolocera spp.	smooth deepsea anemone	BOC	4
Actinostolidae	deepsea anemone	ACS	31
Alcyoniidae			
Hormathiidae	warty deepsea anemone	HMT	14
Gorgonacea	unspecified coral	GOC	3
Thouarella spp.	bottlebrush corals	THO	2
Caryophylliidae			
Desmophyllum dianthus	crested cup coral	DDI	1
Flabellidae			
Fabellum spp. (*knoxi*)	Flabellum cup corals	ACS	31
Ascidiacea	unspecified sea squirt	ASC	1
Tunicata			
Thaliacea	unspecified salps	SAL	4
Salpidae			
Pyrosoma atlanticum		PYR	1
Mollusca			
Gastropoda: gastropods			
Ranellidae			
Fusitron magellanicus		FMA	10
Volutidae			
Provocator mirabilis	golden volute	GVO	2
Alcithoe wilsonae	volute	AWI	1
Cephalopoda: squid and octopus			
Teuthoidea: squids			
Histioteuthidae			
Histioteuthis spp.	violet squid	VSQ	9
Ommastrephidae			
Nototodarus sloanii	arrow squid	NOS	26
Todarodes filippovae	Antarctic flying squid	TSQ	19

Appendix 2 ctd:

Scientific name	Common name	Species code	Occ.
Onychoteuthidae			
Moroteuthis ingens	warty squid	MIQ	73
M. robsoni	warty squid	MRQ	3
Octopoda: Octopus			
Octopodidae			
Enteroctopus zealandicus	yellow octopus	EZE	1
Graneledone spp.	deepwater octopus	DWO	11
Opisthoteuthididae			
Opisthoteuthis spp.	umbrella octopus	OPI	2
Octopoteuthidae			
Taningia danae	squid	TDQ	1
Crustacea			
Malacostraca			
Dendrobranchiata/Pleocyemata			
Caridea			
Campylonotidae			
Camplyonotus rathbonae	sabre prawn	CAM	4
Nematocarcinidae			
Lipkius holthuisi	omega prawn	LHO	29
Oplophoridae			
Acanthephyra spp.		ACA	5
Oplophorus spp.	deepwater prawn	OPP	1
Pasiphaeidae			
Pasiphaea barnardi	deepwater prawn	PBA	1
Pasiphaea aff. tarda	deepwater prawn	PTA	4
Sergestidae			
Sergestes spp.	Sergestid prawn	SER	1
Lophogastrida			
Gnathophausiidae			
Neognathophausia ingens	giant red mysid	NEI	2
Palinura			
Polychelidae			
Polycheles spp.	deepsea blind lobster	PLY	2
Galatheidae			
Munida spp.	Squat lobster	MNI	1
Anomura			
Lithodidae			
Lithodes cf. *longispinus*	long-spined king crab	LLT	2
Lithodes murrayi	southern stone crab	LMU	7
Neolithodes brodiei	Brodie's king crab	NEB	7
Paralomis zelandica	prickly king crab	PZE	7
Majidae			
Jacquinotia edwardsii	giant spider crab	GSC	1
Teratomaia richardsoni	spiny masking crab	SMK	1
Portunidae			
Nectocarcinus spp.	smooth red swimming crab	NEC	1
Paguridae	unidentified hermit crab	PAG	1
Sympagurus dimorphus	hermit crab	SDM	2
Colossendeidae			
Colossendeis spp.	giant sea spiders	PYC	1

Appendix 2 ctd:

Scientific name	Common name	Species code	Occ.
Echinodermata			
Asteroidea	unspecified asteroid	ASR	7
Brisingidae	Armless stars	BRG	1
Asteriidae			
Cosmasterias dyscrita	cat's foot star	CDY	1
Pseudechinaster rubens		PRU	2
Astropectinidae			
Dipsacaster magnificus	magnificent sea-star	DMG	20
Psilaster acuminatus	geometric star	PSI	7
Proserpinaster neozelanicus		PNE	3
Echinasteridae			
Henricia compacta		HEC	2
Goniasteridae			
Ceramaster patagonicus	pentagon star	CPA	29
Hippasteria trojana	trojan star	HTR	30
Lithosoma novaezelandiae	rock star	LNV	10
Mediaster sladeni	Sladen's star	MSL	1
Pillsburiester aoteanus		PAO	11
Odontasteridae			
Odantaster spp.	tooth-stars	ODT	3
Pterasteridae			
Diplopteraster spp.	starfish	DPP	4
Solasteridae			
Crossaster japonicus	sun star	CJA	6
Solaster torulatus	chubby sun-star	SOT	6
Zoroasteridae			
Zoroaster spp.	rat-tail star	ZOR	34
Crinoidea	sea lilies and feather stars	CRI	1
Echinoidea	unspecified sea urchin	ECN	1
Regularia			
Cidaridae: cidarid urchins			
Goniocidaris parasol	parasol urchin	GPA	5
Echinothuriidae, Phormosomatidae	unspecified Tam O'Shanter urchin	TAM	18
Phormosomatidae			
Phormosoma spp.	Tam O'Shanter urchin	PHM	8
Echinidae			
Gracilechinus multidentatus	deepsea kina	GRM	2
Dermechinus horridus	deepsea urchin	DHO	1
Histocidaridae			
Histocidaris spp.		HIS	1
Spatangidae: heart urchins			
Paramaretia peloria	Microsoft mouse	PMU	1
Ophiuroidea	unspecified brittle star	OPH	1
Gorgonocephalidae			
Gorgonocephalus spp.	gorgons head basket-star	GOR	1
Holothuroidea	unspecified sea cucumbers	HTH	9
Aspidochirotida			
Synallactidae			
Bathyplotes moseleyi		BAM	2
Pseudostichopus mollis		PMO	45

Appendix 2 ctd:

Scientific name	Common name	Species code	Occ.
Chondrichthyes			
Triakidae: smoothhounds			
Galeorhinus galeus	school shark	SCH	3
Squalidae: dogfishes			
Centrophorus squamosus	deepwater spiny dogfish	CSQ	16
Centroscymnus crepidater	longnose velvet dogfish	CYP	25
C. owstoni	smooth skin dogfish	CYO	6
C. plunketi	Plunket's shark	PLS	9
Deania calcea	shovelnose dogfish	SND	15
Etmopterus baxteri	Baxter's dogfish	ETB	37
E. lucifer	lucifer dogfish	ETL	49
Scymnorhinus licha	seal shark	BSH	15
Squalus acanthias	spiny dogfish	SPD	45
Oxynotidae: rough sharks			
Oxynotus bruniensis	prickly dogfish	PDG	3
Lamnidae: mackerel sharks			
Lamna nasus	porbeagle shark	POS	1
Proscylliidae: finback cat sharks			
Gollum attenuatus	slender smoothhound	SSH	1
Scyliorhinidae: cat sharks			
Apristurus spp.	deepsea catsharks	APR	8
Halaelurus dawsoni	Dawson’s catshark	DCS	3
Rajidae: skates			
Bathyraja shuntovi	longnosed deepsea skate	PSK	2
Dipturus innominata	smooth skate	SSK	7
D. nasuta	rough skate	RSK	5
Notoraja spp.	bluntnosed skate	BTH	9
N. asperula	smooth deepsea skate	BTA	7
N. spinifera	prickly deepsea skate	BTS	3
Chimaeridae: chimaeras, ghost sharks			
Chimaera spp.	brown chimaera	CHP	1
Chimaera lignaria	giant chimaera	CHG	1
Hydrolagus bemisi	pale ghost shark	GSP	75
H. novaezelandiae	dark ghost shark	GSH	12
Rhinochimaeridae: longnosed chimaeras			
Harriotta raleighana	longnose chimaera	LCH	46
Rhinochimaera pacifica	widenose chimaera	RCH	11
Osteichthyes			
Notacanthidae: spiny eels			
N. sexspinis	spineback	SBK	44
Synaphobranchidae: cutthroat eels			
Diastobranchus capensis	basketwork eel	BEE	14
Synaphobranchus affinis	grey cutthroat eel	SAF	1
Congridae: conger eels			
Bassanago bulbiceps	swollenheaded conger	SCO	36
B. hirsutus	hairy conger	HCO	30
Serrivomeridae: sawtooth eels			
Serrivomer spp.	sawtooth eel	SAW	1

Appendix 2 ctd:

Scientific name	Common name	Species code	Occ.
Argentinidae: silversides			
Argentina elongata	silverside	SSI	36
Bathylagidae: deepsea smelts			
Bathylagus spp.	deepsea smelt	DSS	4
Alepocephalidae: slickheads			
Alepocephalus australis	small-scaled brown slickhead	SSM	14
Platytroctidae: tubeshoulders			
Persparsia kopua	tubeshoulder	PER	2
Chauliodontidae: viperfishes			
Chauliodus sloani	viperfish	CHA	7
Stomiidae: scaly dragonfishes			
Stomias spp.	scaly dragonfish	STO	1
Astronesthidae: snaggletooths			
Species not identified	snaggletooth	AST	1
Borostomias mononema	snaggletooth	BMO	2
Malacosteidae: loosejaws			
Species not identified	loosejaw	MAL	1
Idiacanthidae: black dragonfishes			
Idiacanthus spp.	black dragonfish	IDI	3
Sternoptychidae: hatchetfishes			
Argyropelecus gigas	giant hatchetfish	AGI	1
Photichthyidae: lighthouse fishes			
Photichthys argenteus	lighthouse fish	PHO	17
Paralepididae: barracudinas	unidentified barracudina	PAL	1
Myctophidae: lanternfishes			
Species not identified	lanternfish	LAN	7
Lampanyctus spp.	lanternfish	LPA	3
Moridae: morid cods			
Antimora rostrata	violet cod	VCO	8
Notophycis marginata	dwarf cod	DCO	5
Halargyreus johnsoni	Johnson’s cod	HJO	14
Lepidion microcephalus	small-headed cod	SMC	9
Mora moro	ribaldo	RIB	45
Pseudophycis bachus	red cod	RCO	4
Gadidae: true cods			
Micromesistius australis	southern blue whiting	SBW	29
Merlucciidae: hakes			
Lyconus sp		LYC	2
Macruronus novaezelandiae	hoki	HOK	84
Merluccius australis	hake	HAK	43
Macrouridae: rattails, grenadiers			
Caelorinchus aspercephalus	oblique-banded rattail	CAS	34
C. bollonsi	Bollons’s rattail	CBO	24
C. fasciatus	banded rattail	CFA	78
C. innotabilis	notable rattail	CIN	17
C. kaiyomaru	Kaiyomaru rattail	CKA	11
C. matamua	Mahia rattail	CMA	7
C. oliverianus	Oliver's rattail	COL	59
C. parvifasciatus	small-banded rattail	CCX	1
Coryphaenoides dossenus	humpback rattail	CBA	4
C. serrulatus	serrulate rattail	CSE	14
C . subserrulatus	fourrayed rattail	CSU	23
Lepidorhynchus denticulatus	javelinfish	JAV	86
Macrourus carinatus	ridge-scaled rattail	MCA	26
Mesobius antipodum	black javelinfish	BJA	2

Appendix 2 ctd:

Scientific name	Common name	Species code	Occ.
Trachyrincus aphyodes	white rattail	WHX	7
Trachyrincus longirostris	unicorn rattail	WHR	2
Ventrifossa nigromaculata	blackspot rattail	VNI	24
Ophidiidae: cusk eels			
Genypterus blacodes	ling	LIN	77
Ceratiidae: seadevils			
Cryptopsaras couesi	seadevil	SDE	1
Regalecidae: oarfishes			
Agrostichthys parkeri	ribbonfish	AGR	1
Trachichthyidae: roughies			
Hoplostethus atlanticus	orange roughy	ORH	14
H. mediterraneus	silver roughy	SRH	5
Paratrachichthys trailli	common roughy	RHY	1
Diremidae: discfishes			
Diretmus argenteus	discfish	DIS	8
Zeidae: dories			
Cyttus novaezealandiae	silver dory	SDO	3
C. traversi	lookdown dory	LDO	35
Macrorhamphosidae: snipefishes			
Centriscops humerosus	banded bellowsfish	BBE	3
Scorpaenidae: scorpionfishes			
Helicolenus spp.	sea perch	SPE	5
Trachyscorpia capensis	Cape scorpionfish	TRS	1
Oreosomatidae: oreos			
Allocyttus niger	black oreo	BOE	12
Neocyttus rhomboidalis	spiky oreo	SOR	4
Pseudocyttus maculatus	smooth oreo	SSO	12
Congiopodidae: pigfishes			
Alertichthys blacki	alert pigfish	API	1
Hoplichthyidae: ghostflatheads			
Hoplichthys haswelli	deepsea flathead	FHD	4
Psychrolutidae: toadfishes			
Neophrynichthys angustus	pale toadfish	TOP	19
Cottunculus nudus	bonyskull toadfish	COT	1
Psychrolutes spp.	blobfish	PSY	4
Percichthyidae: temperate basses			
Polyprion oxygeneios	hapuku	HAP	2
Apogonidae: cardinalfishes			
Epigonus lenimen	bigeye cardinalfish	EPL	3
E. robustus	cardinalfish	EPR	3
E. telescopus	black cardinalfish	EPT	3
Bramidae: pomfrets			
Brama brama	Ray’s bream	RBM	3
B. australis	southern Ray’s bream	SRB	7
Emmelichthyidae: bonnetmouths, rovers			
Emmelichthys nitidus	redbait	RBT	1
Uranoscopidae: armourhead stargazers			
Kathetostoma giganteum	giant stargazer	STA	19
Kathetostoma spp.	banded stargazer	BGZ	1
Gempylidae: snake mackerels			
Rexea solandri	gemfish	SKI	1
Trichiuridae: cutlassfishes			
Benthodesmus elongatus	bigeye scabbard fish	BEN	1
Centrolophidae: raftfishes, medusafishes			
Centrolophus niger	rudderfish	RUD	8

Appendix 2 ctd:

Scientific name	Common name	Species code	Occ.
Hyperoglyphe antarctica	bluenose	BNS	1
Icichthys australis	ragfish	RAG	2
Seriolella caerulea	white warehou	WWA	27
S. punctata	silver warehou	SWA	10
Bothidae: lefteyed flounders			
Arnoglossus scapha	witch	WIT	1
Neoachiropsetta milfordi	finless flounder	MAN	35
Diodontidae: porcupinefishes			
Allomycterus jaculiferus	porcupinefish	POP	1

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

NIWA No.	Voyage/Station No.	Phylum	Class	Order	Family	Genus	Species
60548	TAN0911/55	Arthropoda	Malacostraca	Decapoda	Campylonotidae	*Campylonotus*	*rathbunae*
60549	TAN0911/31	Arthropoda	Malacostraca	Decapoda	Campylonotidae	*Campylonotus*	*rathbunae*
60550	TAN0911/11	Arthropoda	Malacostraca	Decapoda	Polychelidae	*Stereomastis*	*suhmi*
60550	TAN0911/11	Arthropoda	Malacostraca	Decapoda	Polychelidae	*Stereomastis*	*suhmi*
60550	TAN0911/11	Arthropoda	Malacostraca	Decapoda	Polychelidae	*Stereomastis*	*suhmi*
60551	TAN0911/11	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Lithodes*	
60552	TAN0911/15	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Neolithodes*	*brodiei*
60554	TAN0911/19	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Neolithodes*	*brodiei*
60557	TAN0911/78	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Lithodes*	*aotearoa*
60558	TAN0911/78	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Lithodes*	*aotearoa*
60559	TAN0911/78	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Lithodes*	*aotearoa*
60560	TAN0911/78	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Lithodes*	*aotearoa*
60561	TAN0911/78	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Lithodes*	*aotearoa*
60562	TAN0911/66	Arthropoda	Malacostraca	Decapoda	Majidae	*Jacquinotia*	*edwardsii*
60563	TAN0911/66	Arthropoda	Malacostraca	Decapoda	Majidae	*Jacquinotia*	*edwardsii*
60565	TAN0911/5	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Lithodes*	*aotearoa*
60568	TAN0911/24	Arthropoda	Malacostraca	Decapoda	Majidae	*Teratomaia*	*richardsoni*
60569	TAN0911/44	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Paralomis*	*zealandica*
60570	TAN0911/32	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Paralomis*	*zealandica*
60571	TAN0911/31	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Paralomis*	*zealandica*
60572	TAN0911/25	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Paralomis*	*zealandica*
60573	TAN0911/8	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Lithodes*	*aotearoa*
60574	TAN0911/8	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Neolithodes*	*brodiei*
60575	TAN0911/3	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Paralomis*	*zealandica*
60576	TAN0911/2	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Lithodes*	*aotearoa*
60577	TAN0911/4	Arthropoda	Malacostraca	Decapoda	Lithodidae	*Lithodes*	*aotearoa*
61162	TAN0911/35	Arthropoda	Malacostraca	Decapoda	Polychelidae	*Stereomastis*	*suhmi*
68025	TAN0911/5	Arthropoda	Maxillopoda	Rhizocephala	Peltogastridae	*Briarosaccus*	*callosus*
58847	TAN0911/84	Chordata	Ascidiacea [Tunicates]				
61606	TAN0911/57	Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	*Anthomastus*	
61607	TAN0911/91	Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	*Anthomastus*	

NIWA No.	Voyage/Station No.	Phylum	Class	Order	Family	Genus	Species
61608	TAN0911/55	Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	*Anthomastus*	
61611	TAN0911/66	Cnidaria	Anthozoa	Gorgonacea	Primnoidae	*Thouarella*	
61612	TAN0911/65	Cnidaria	Anthozoa	Gorgonacea	Acanthogorgiidae	*Acanthogorgia*	
61613	TAN0911/61	Cnidaria	Anthozoa	Gorgonacea	Acanthogorgiidae	*Acanthogorgia*	
61614	TAN0911/61	Cnidaria	Anthozoa	Gorgonacea	Primnoidae	*Thouarella*	
61609	TAN0911/91	Cnidaria	Anthozoa	Scleractinia	Flabellidae	*Flabellum*	*knoxi*
58836	TAN0911/61	Echinodermata	Asteroidea	Forcipulatida	Asteriidae	*Taranuiaster*	*novaezealandiae*
58833	TAN0911/11	Echinodermata	Asteroidea	Paxillosida	Astropectinidae	*Dipsacaster*	*magnificus*
58837	TAN0911/65	Echinodermata	Asteroidea	Paxillosida	Radiasteridae	*Radiaster*	*gracilis*
58840	TAN0911/25	Echinodermata	Asteroidea	Spinulosida	Echinasteridae	*Henricia*	*compacta*
58830	TAN0911/13	Echinodermata	Asteroidea	Valvatida	Goniasteridae	*Hippasteria*	*phrygiana*
58831	TAN0911/18	Echinodermata	Asteroidea	Valvatida	Goniasteridae	*Hippasteria*	*phrygiana*
58832	TAN0911/16	Echinodermata	Asteroidea	Valvatida	Goniasteridae	*Hippasteria*	*phrygiana*
58835	TAN0911/51	Echinodermata	Asteroidea	Valvatida	Goniasteridae	*Hippasteria*	*phrygiana*
58839	TAN0911/31	Echinodermata	Asteroidea	Valvatida	Goniasteridae	*Lithosoma*	*novaezealandiae*
58841	TAN0911/14	Echinodermata	Asteroidea	Valvatida	Goniasteridae	*Hippasteria*	*phrygiana*
58834	TAN0911/72	Echinodermata	Asteroidea	Velatida	Pterasteridae	*Diplopteraster*	*otagoensis*
58838	TAN0911/45	Echinodermata	Asteroidea	Velatida	Pterasteridae	*Diplopteraster*	*otagoensis*
61627	TAN0911/51	Echinodermata	Echinoidea	Cidaroida	Cidaridae	*Goniocidaris*	*parasol*
61628	TAN0911/13	Echinodermata	Echinoidea	Cidaroida	Cidaridae	*Goniocidaris*	*parasol*
61629	TAN0911/80	Echinodermata	Echinoidea	Cidaroida	Cidaridae	*Histocidaris*	
61626	TAN0911/77	Echinodermata	Echinoidea	Echinoida	Echinidae	*Gracilechinus*	*multidentatus*
61623	TAN0911/61	Echinodermata	Echinoidea	Echinothurioida	Echinothuriidae	*Araeosoma*	
61624	TAN0911/4	Echinodermata	Echinoidea	Echinothurioida	Echinothuriidae	*Hygrosoma*	*luculentum*
61625	TAN0911/48	Echinodermata	Echinoidea	Echinothurioida	Phormosomatidae	*Phormosoma*	*bursarium*
66701	TAN0911/14	Echinodermata	Echinoidea	Echinothurioida	Echinothuriidae	*Hygrosoma*	*luculentum*
66702	TAN0911/19	Echinodermata	Echinoidea	Echinothurioida	Echinothuriidae	*Hygrosoma*	*luculentum*
66703	TAN0911/19	Echinodermata	Echinoidea	Echinothurioida	Echinothuriidae	*Sperosoma*	
66704	TAN0911/51	Echinodermata	Echinoidea	Echinothurioida	Phormosomatidae	*Phormosoma*	*bursarium*
66705	TAN0911/47	Echinodermata	Echinoidea	Echinothurioida	Phormosomatidae	*Phormosoma*	*bursarium*
66706	TAN0911/39	Echinodermata	Echinoidea	Echinothurioida	Phormosomatidae	*Phormosoma*	*bursarium*
66707	TAN0911/27	Echinodermata	Echinoidea	Echinothurioida	Echinothuriidae	*Sperosoma*	

NIWA No.	Voyage/Station No.	Phylum	Class	Order	Family	Genus	Species
66708	TAN0911/23	Echinodermata	Echinoidea	Echinothurioida	Phormosomatidae	*Phormosoma*	*bursarium*
66709	TAN0911/20	Echinodermata	Echinoidea	Echinothurioida	Echinothuriidae	*Hygrosoma*	*luculentum*
66710	TAN0911/61	Echinodermata	Echinoidea	Echinothurioida	Echinothuriidae	*Araeosoma*	
66711	TAN0911/4	Echinodermata	Echinoidea	Echinothurioida	Phormosomatidae	*Phormosoma*	*bursarium*
66712	TAN0911/4	Echinodermata	Echinoidea	Echinothurioida	Echinothuriidae	*Sperosoma*	
66713	TAN0911/4	Echinodermata	Echinoidea	Echinothurioida	Echinothuriidae	*Hygrosoma*	*luculentum*
66714	TAN0911/4	Echinodermata	Echinoidea	Echinothurioida	Echinothuriidae	*Sperosoma*	
61616	TAN0911/35	Echinodermata	Holothuroidea (Class)	Aspidochirotida	Synallactidae	*Bathyplotes*	*sulcatus*
61617	TAN0911/16	Echinodermata	Holothuroidea (Class)	Aspidochirotida	Synallactidae	*Bathyplotes*	*sulcatus*
61618	TAN0911/37	Echinodermata	Holothuroidea (Class)	Aspidochirotida	Synallactidae	*Bathyplotes*	*sulcatus*
61619	TAN0911/59	Echinodermata	Holothuroidea (Class)	Aspidochirotida	Synallactidae	*Bathyplotes*	cf. *moseleyi*
61620	TAN0911/61	Echinodermata	Holothuroidea (Class)	Aspidochirotida	Synallactidae	*?Bathyplotes*	
58842	TAN0911/34	Echinodermata	Ophiuroidea	Euryalinida [aka Phyrynophiurida]	Asteroschematidae	*?Ophiocreas* or *?Astrobrachion*	
61546	TAN0911/5	Echinodermata	Ophiuroidea	Ophiurida	Ophiacanthidae	*Ophiophthalmus*	*relictus*
61604	TAN0911/61	Echinodermata	Ophiuroidea	Ophiurida	Ophiactidae	*Ophiactis*	*abyssicola*
61621	TAN0911/34	Echinodermata	Ophiuroidea	Ophiurida	Ophiacanthidae	*Ophiophthalmus*	*relictus*
61148	TAN0911/51	Mollusca	Bivalvia	Mytiloida	Mytilidae	*Modiolus*	*areolatus*
61610	TAN0911/35	Mollusca	Gastropoda	Neogastropoda	Volutidae	*Alcithoe*	*flemingi*
58846	TAN0911/84	Porifera	Demospongiae	Astrophorida	Geodiidae	*Geodia*	*vestigifera*
58849	TAN0911/80	Porifera	Demospongiae	Astrophorida	Geodiidae	*Pachymatisma*	n. sp. 2 (yellow knobbly tops)
61601	TAN0911/68	Porifera	Demospongiae	Astrophorida	Geodiidae	*Geodia*	regina
61603	TAN0911/61	Porifera	Demospongiae	Astrophorida	Geodiidae	*Pachymatisma*	n. sp. 2 (yellow knobbly tops)
58843	TAN0911/26	Porifera	Demospongiae	Poecilosclerida	Coelosphaeridae	*Lissodendoryx*	n. sp. 1 (crumbly nubbins)
58844	TAN0911/24	Porifera	Demospongiae	Poecilosclerida	Coelosphaeridae	*Lissodendoryx*	n. sp. 1 (crumbly nubbins)
58845	TAN0911/29	Porifera	Demospongiae	Poecilosclerida	Coelosphaeridae	*Lissodendoryx*	n. sp. 1 (crumbly nubbins)
58850	TAN0911/47	Porifera	Demospongiae	Poecilosclerida	Coelosphaeridae	*Lissodendoryx*	n. sp. 1 (crumbly nubbins)
61599	TAN0911/21	Porifera	Demospongiae	Poecilosclerida	Coelosphaeridae	*Lissodendoryx*	n. sp. 1 (crumbly nubbins)
61600	TAN0911/49	Porifera	Demospongiae	Poecilosclerida	Coelosphaeridae	*Lissodendoryx*	n. sp. 1 (crumbly nubbins)
61602	TAN0911/60	Porifera	Demospongiae	Poecilosclerida	Myxillidae	*Myxilla*	n sp. 3 (BoP crumbly encruster)
61605	TAN0911/61	Porifera	Hexactinellida	Lyssacinosida	Rossellidae	*Caulophacus*	cf. *lotifolium*