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EXECUTIVE SUMMARY

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This paper summarises the results of the seventh acoustic survey of southern blue whiting (SBW) stocks in subantarctic waters. Two complete acoustic snapshots were carried out on the Campbell Island Rise, and one snapshot was carried out on the Pukaki Rise.

Commercial trawl data were used to help determine the main fishing locations in each area and to assist in the identification of marks. Based on these data, investigative target trawling from *Tangaroa*, and previous experience, SBW marks on the Campbell grounds were mainly identified as adult (mature fish which have recruited to the commercial fishery), immature (mainly 2 year olds, but including some immature 1 and 3 year old fish), or juvenile (1 year old fish). These categories were decomposed to provide estimates of 1, 2, 3, and 4 year old and over fish, as in previous years.

Estimates of adult biomass from each Campbell snapshot were very similar. The mean estimate of adult biomass on the Campbell grounds averaged over both snapshots was 151 300 t (c.v. = 17%). This is lower than the 1998 estimate, but similar to the 1994 and 1995 estimates. The c.v. in the 2000 survey was the lowest recorded in any SBW survey and was partly because of the intensive sampling of the aggregations, and partly because of the dispersed nature of the fish during the second snapshot.

The decomposed Campbell results suggested a continued high biomass of 4 year old and over fish, but generally low numbers of pre-recruits. Estimates of 2 and 3 year olds were the lowest in the 5 year series. Estimates of 1 year olds are thought to be unreliable because these fish probably extend inside 300 m, and there are problems with species identification.

On Pukaki Rise, adult fish were found both by themselves and in mixed schools with pre-recruit fish (mix category), mainly in stratum 4. The biomass estimate of the adult and mixed fish categories were 13 700 t and 18 000 t respectively. The decomposed biomass estimate of 4 year old and over fish was almost 30 000 t, which is consistent with the biomass estimates from surveys carried out in 1993, 1994, and 1997. These estimates of biomass are consistent with the low level of catches reported from this fishery over the past decade. Although the c.v. of the adult biomass estimate was relatively high (38%), it was similar to that obtained from single snapshots during previous surveys of the Pukaki Rise. Furthermore, the c.v. will underestimate the precision in the biomass estimates of the 4 year old and over fish, because these fish were also found in mixed schools with pre-recruits (in the mix and immature categories). Estimates of pre-recruit (1, 2, and 3 year old) fish suggest that these year classes are probably of about average strength. We would therefore predict the biomass to remain reasonably stable over the next few years until a strong year class enters the fishery.

1. INTRODUCTION

The four known spawning grounds for southern blue whiting (SBW) are on the Bounty Platform, Pukaki Rise, Auckland Islands Shelf, and Campbell Island Rise. Spawning occurs on the Bounty Platform from mid August to early September and 3–4 weeks later in the other areas (Hanchet 1998).

A programme to estimate SBW spawning stock biomass on each fishing ground using acoustic techniques began in 1993. The Bounty Platform, Pukaki Rise, and Campbell Island Rise were each surveyed annually between 1993 and 1995, and the Auckland Islands Shelf was surveyed in 1995 (Hanchet et al. 1994, Hanchet & Ingerson 1996, Ingerson & Hanchet 1996). After the first three annual surveys a decision was made to survey these areas less regularly. The Bounty and Pukaki spawning grounds were surveyed in 1997 (Grimes & Hanchet 1999), the Campbell grounds in 1998 (Hanchet et al. 2000b), and the Bounty grounds in 1999 (Hanchet & Grimes 2000).

The current report stems from an objective carried out under contract to MFish: "To estimate pre-recruit and recruited biomass on Campbell Island Rise during September 2000 using an acoustic survey (SBW1999/01)."

The main aim of the acoustic surveys has been to develop a time series of abundance indices of recruited fish (i.e., fish that have recruited into the commercial fishery) for modelling. Because the commercial fishery targets mainly the dense spawning aggregations, the recruited fish are mainly sexually mature. In addition to the spawning fish, pre-recruit fish (immature 1, 2, and 3 year olds) are also found in the survey area. Attempts to quantify pre-recruit biomass in previous surveys by separation into an "immature" (mainly 2 year old fish) category has been problematic due to the occurrence in some years of 2 and 3 year old fish in mixed schools (Hanchet & Ingerson 1996). The problem was resolved by decomposing the SBW categories into numbers at age (Hanchet et al. 2000c).

As in previous years, SBW acoustic marks in the 2000 survey were initially classified into adult (recruited fish), immature (mainly 2 year olds), and juvenile (1 year olds). These categories were then decomposed to provide estimates of 1, 2, 3, and 4 year old and over fish (following Hanchet et al. (2000c).

2. SURVEY DESIGN

2.1 Survey area and transect allocation

2.1.1 Campbell Island Rise

Various acoustic survey designs for SBW stocks were investigated by Dunn & Hanchet (1998). They showed that the optimal survey design would use proportional sampling, where the underlying distribution of the fish is already known and the sampling effort is proportional to the fish density (see also Thompson & Seber 1998). In the absence of this information, they concluded that two-phase sampling strategies should be used, with up to 20% of stations assigned to the second phase. Information on the distribution of the fish at the time of the survey is available from the location of the fleet and/or the results of the first acoustic snapshot of the area. During the 2000 survey of the Campbell Island Rise, information from both sources was used to redefine the survey strata and the associated sampling effort.

The initial stratification used in previous surveys of Campbell Island Rise was reviewed by examining the spatial distribution of SBW from historical catch effort data and from previous acoustic surveys. Based on this information, stratum boundaries were changed slightly to better reflect recent fishing effort and acoustic survey results.

Initial allocation of phase 1 transects was carried out based on the stratification given by Dunn & Hanchet (1998), using the following equation:

$$n_i = NA_iV_i / \sum_{i=1}^{m} A_iV_i \qquad \text{for } m = \text{total number of strata}$$

where:

n_i is the number of samples allocated to stratum i of area A_i and variability V_i, and N is the total number of stations in the snapshot. The proportion of the total number of commercial tows (from 1983 to 1996, and 1990 to 1996) which had been made in each stratum, and also the mean acoustic transect density estimates from previous surveys, were used separately as estimates of variability. (The mean was used because this is generally thought to be more precisely known than the variance (Francis 1984).)

During the 1980s, most fishing effort tended to be focused on the northern strata (particularly 2 and 4), whereas in the 1990s it has been focused more on the southern strata (particularly 5 and 7). The optimal allocation using these two data sets therefore gave somewhat conflicting results. Optimal allocation using the acoustic survey results suggested a higher weighting for strata 2, 3, and 7, but these were based on only four years' data. The final allocation schedule chosen gave most weighting to strata 2 and 7, which have been the most consistent areas of high density, with a slightly higher weighting to stratum 7 on the basis of recent fish distribution.

At the beginning of the survey the commercial fleet was making good catches in 450–480 m in stratum 4. Observers also reported that the fish had almost completed spawning. Typically fish move quickly inshore and then east and south after spawning, so it became important to try and survey the fish before they moved. Stratum 4 was split into shallow (4S) and deep (4D) at the 400 m depth contour (Figure 1). The number of transects in stratum 4S was increased to 6 whilst the number of transects in stratum 4D was increased to 10. Whilst stratum 4D was being surveyed, the fish and commercial vessels rapidly moved shallower into about 425 m. There was concern that the fish may also move east into strata 5 and 6. We therefore dropped the proposed transects in the deeper strata 3N and 3S, and instead concentrated on transects in strata 5 and 6. Transects surveyed at the southern end of stratum 3S and at the northern ends of strata 5 and 6 had few SBW marks. Over the next few days the fleet appeared to follow the aggregation as it moved east through strata 5 and 6 (see also Section 2.2.2), so the approach appears justified.

Transect allocation for snapshot 2 in the northern area was similar to that planned originally for snapshot 1. (During snapshot 2 there was no vessel information for the northern area because all vessels were working in strata 5 and 7). However, towards the end of the snapshot the weather deteriorated, and it was not possible to complete the planned transects in strata 2 and 3N. Instead we returned to the Pukaki Rise, where additional target strength data were collected.

In snapshot 1, the densest marks in the southern area were found on a single transect in stratum 7. This stratum already had eight transects, and it was considered that there would be little gain from allocating further phase 2 transects there. Marks were also seen at the southern end of stratum 6. Based on the location of the marks from snapshot 1, several changes were made for snapshot 2 (Figure 2). Stratum 7 was divided into north (7N) and south (7S) at 53° S. Stratum 7S was further divided into shallow (7Ss) and deep (7Sd) at 425 m depth. Stratum 6 was divided into two strata (6N and 6S), at 52° 40' S. When transects were carried out in stratum 6S, marks extended east of the 6S stratum boundary outside the survey area, so the stratum boundary was extended out to 171° 25'E. The final allocation used for both snapshots is shown in Table 1.

During both snapshots, transects extended from 300 m to the stratum boundary. There is no evidence for a strong diel difference in SBW backscatter (Hanchet et al. 2000a), so transects were carried out during day and night.

2.1.2 Pukaki Rise

The stratification and allocation of transects on the Pukaki Rise was initially based on the historic commercial catch and effort data, and previous acoustic survey data, which gave a higher weighting to strata 2 and 3 (Figure 3). However, at the beginning of the survey the commercial fleet was making good catches in stratum 4, so the number of transects there was increased from four to eight (Table 1). Transects were run from 250 to 450 m. There is no evidence for a strong diel difference in SBW backscatter (Hanchet et al. 2000a), so transects were carried out during day and night.

2.1.3 Acoustic transects

The random parallel transect design of Jolly & Hampton (1990) was used in all strata with transects being run perpendicular to the depth contours, i.e., from shallow to deep water or vice versa. The mid position of each transect was randomised for each snapshot. The minimum distance between transects varied amongst strata, and was calculated as follows:

$$m = 0.5 * L/n$$

where m is minimum distance, L is length of stratum, and n is number of transects.

Thus, the minimum distance was large enough to ensure that no large areas were left unsurveyed within each stratum, as in previous surveys (Ingerson & Hanchet 1996, Grimes & Hanchet 1999). At times the direction of transects was altered to allow the survey to continue despite poor weather conditions. Minimum distances of 2 n. mile between the end of one transect and the start of the next reduced spatial correlation between transects in such instances.

2.1.4 Calibration

The acoustic data were collected with NIWA's Computerised Research Echo Sounder Technology (*CREST*) (Coombs 1994, 2000).

CREST is computer based, using the concept of a "software echo sounder". It supports multi-channels which can receive signals from single beam, split beam, dual beam, or other transducer configurations mounted on the ship's hull or in a towed body. Each channel consists of at least a receiver and usually also a transmitter. Each receiver has two broadband, wide dynamic range pre-amplifiers and two 16 bit "sigma-delta" analogue-to-digital converters (ADCs) which feed a digital signal processor (DSP56002). The gains of the two amplifiers differ by a factor of 256 and together they are used to synthesise a 24 bit value. The ADCs have a conversion rate of 100 kHz and the data from these are complex (quadrature) demodulated, filtered, and decimated. The filter is a 100 tap, linear-phase, finite-impulse response digital filter with a bandwidth of 1.5 kHz. The filtered data are decimated to 4 kHz and a

20LogR+2αR time-varied gain applied. The results are then shifted to give 16-bit resolution for both the real and imaginary parts of the complex data which are stored for later processing.

For this survey, data were collected using both hull and towed body mounted transducers. In the towed system the transducer, transmitter, and receiving electronics were all mounted in the towed body which was towed at speeds of from 5 to 10 knots and at depths of between 20 and 90 m. The digital data from the receiver were transmitted via the tow cable to a control computer on *Tangaroa* where they were combined with position and transect information and stored. For hull transducers the whole system was mounted on *Tangaroa*.

The transmitter is a switching type with a nominal power output of 2 kW rms. The transmitted frequency was 38.156 kHz for the towed system and 38.000 kHz for the hull. The transmitted pulse length was 1 ms, the effective pulse length 0.78 ms, and the time between transmits 3 s for all systems. The hull transducer was a Simrad model 38-7, 38 kHz, single beam type and the towed transducer a Simrad model ES38DD, 38 kHz, split-beam type, with a depth rating of 1500 m.

The system was calibrated electrically using a precision microvoltmeter (Rhode & Schwartz URE) and acoustically using a standard sphere. Calibration generally followed the procedures set out in Foote et al. (1987) and Johannesson & Mitson (1983). The standard sphere calibrations used a 38.1 mm ±2.5 μm diameter tungsten carbide sphere, with a nominal target strength of –42.4 dB. Acoustic calibrations of the towed system were carried out in the deep tank at Greta Point before and after the survey and at sea. For the latter the sphere was suspended from the towed body, 20 m below the transducer, on a single nylon line. At-sea calibrations were carried out both at anchor at Campbell Island and on orange roughy surveys on the Chatham Rise. For the latter the whole assembly was lowered to a depth of about 600 m pausing at 100 m intervals, with data being recorded continuously, allowing the change of system response with depth to be measured. Acoustic calibrations of the hull system were carried out at anchor at Campbell Island and in the Marlborough Sounds. Three nylon lines were used to suspend the sphere about 30 m under *Tangaroa*. The calibration results are given in Appendix 1.

Data were also collected at 12 kHz on the hull system, but this was not calibrated nor used in the biomass estimate.

2.2 Acoustic mark identification

Acoustic mark identification was based on targeted research trawls using *Tangaroa*, on an examination of the location of trawls made by the commercial fleet, and on experience gained from earlier acoustic surveys.

2.2.1 Research trawls

A total of 24 bottom trawls and 3 midwater trawls were carried out to determine species and size composition of the marks (Table 2). Trawls 1–5 and 27 were made on the Pukaki Rise and trawls 6–26 were made on the Campbell Island Rise. Midwater trawls were made using a new pelagic trawl (headline height ca. 40 m), whilst bottom trawls were made using the fine-mesh orange roughy wing trawl (headline height ca. 5 m). All trawls were made with a 40 mm mesh liner in the codend. Trawls ranged from 5 to 10 minute duration when targeting dense marks, up to a maximum of 45 minutes when targeting less dense marks or layers. The location of these trawls is shown in Figures 1 and 2, and the SBW size distribution in Figure 4.

Trawling on the Pukaki Rise was mainly aimed at identifying the marks seen in shallow water, which were not being fished by commercial vessels. As in previous years, trawls caught either mainly 2 year olds or a mixture of 2 year olds and adults.

Trawling on the Campbell grounds focused on targeting marks in a range of depths from 300 m out to 600 m, which were not being fished by the commercial fleet. A number of trawls were made between 300 and 425 m in each of the shallow strata to help identify the marks seen in the shallow waters. Trawling showed that these marks comprised mainly pre-recruit SBW, silverside, small scaled nototheniid, smooth rattail, and javelinfish (Table 2). Age 1 SBW were mainly found between 300 and 400 m, whilst age 2 SBW were found between 380 and 425 m. A distinctive silverside layer, occurring slightly off the bottom during the day, was also common in this depth range. During snapshot 2, a series of trawls were also made in deeper water (over 420 m) to identify some of the deeper more dispersed marks. These caught a range of other species in particular ling and javelinfish (Table 2).

2.2.2 Commercial trawls

Vessels started fishing on the Pukaki Rise on 2 September and continued through until 7 September. Most trawling was carried out in stratum 4, but several trawls were also made in strata 3 and 5 (Figure 5). Most of the fish were still in the pre-spawning phase throughout this period (Hanchet Unpubl. results.). The size distribution of SBW in the commercial catch on Pukaki Rise is shown in Figure 6.

Vessels started fishing on the Campbell Island Rise on 7 September and continued through until 4 October. During snapshot 1, all vessels fished spawning and post-spawning fish in stratum 4D, taking a total catch of 5400 t. On 13 September, vessels moved southeast into strata 3S and 6 and eventually ended up slightly outside the survey area (see Figure 5). The following day a total of 22 tows made outside the survey area yielded a total catch of only 400 t. Vessels then moved southwest and south searching for fish. During snapshot 2 most fishing was carried out in strata 5 and 7. A second spawning event took place from 17 to 25 September. The size distribution of SBW in the commercial catch on the Campbell Island Rise was similar to that from trawls made on adult marks by *Tangaroa* (Figure 6).

2.2.3 Acoustic marks and SBW categories

Campbell

The size distributions from the research and commercial tows were used to assign the main SBW marks seen during the survey into the following categories:

1. Characteristic marks in shallow water 300–400 m: 1 year old SBW.
2. Characteristic marks in 390–430 m: mainly 2 year old SBW.
3. Some shallow marks in 400–430 m: mix of 2 year old and adult SBW.
4. Dense marks greater than 430 m: mainly adult SBW.

There was a range of marks in depths of 300–400 m in several strata: some were hard down on the bottom during the day and others formed a continuous layer slightly off the bottom during the day. Although eight trawls were carried out in this depth range, there was still considerable uncertainty over the mark identification. The layer occurring slightly off the bottom during the day was assumed to comprise mainly silversides (e.g., Table 2, trawls 18 and 19). At night this layer dispersed slightly but essentially remained as a continuous layer in the bottom 20–30 m. The bottom marks hard down during the day were assumed to comprise 100% juvenile (1 year old) SBW. This is probably an overestimate because some trawls also caught reasonable proportions of other species (e.g., Table 2, trawls 7, 8, and 12). At night the juvenile SBW marks moved up into the water column and appeared as small dispersed schools extending up to 50 m off the bottom.

As in previous years reasonably extensive marks were found throughout the survey area in depths of 390–430 m. Trawling showed that these marks usually comprised immature (mainly 2 year old) SBW (e.g., Figure 4, tows 9, 17, 21, 25). At night they had a similar appearance to the "juvenile" marks, although they tended to be somewhat denser. The bycatch of other species in these "immature" marks was typically a lot lower than in the "juvenile" marks (Table 2).

In some areas the marks in depths of 390–430 m included substantial numbers of adults (e.g., Figure 4, tows 6, 15, 16). The proportion of 2 year olds to adults was quite variable between trawls. For the purposes of the analysis, these "immature/adult" marks were initially included in the "adult" biomass category. However, for the decomposition analysis they were treated as a separate group. The size distribution of the group used for the decomposition was assumed to be the sum of the length frequency from the three trawls. The bycatch of other species in these "immature/adult" marks was similar to the immature marks (Table 2).

Two main areas containing adult fish were found during the survey. The first area was located almost entirely in stratum 4D in depths of 450–500 m during snapshot 1. These marks were the target of the commercial vessels at the time. Therefore, these marks were all assumed to be adult SBW, and the observer commercial LF data were assumed to be representative of these marks. The second area of dense marks were found in the southern area on the boundary of strata 6 and 7. Two trawls by *Tangaroa* caught a mixture of 2 year old and adults (Figure 4, tows 10 and 11), but several trawls made by commercial vessels shortly afterwards caught mainly adult SBW. There was little difference in the size distribution of fish from commercial vessels between the northern and southern grounds, so the adult marks from both areas were assigned the same scaled observer length frequency (Figure 6).

During snapshot 2, adult SBW marks were mainly confined to the southern strata 6 and 7. The marks were generally more dispersed than those seen in snapshot 1. During the day the marks were reasonably hard down, whilst at night they formed a diffuse layer up to about 100 m above the bottom. Although the fish were spawning their second batch of eggs as we surveyed strata 5 and 6N, we saw no typical spawning marks. Because of the diffuse nature of the marks seen during snapshot 2, it is possible that they included significant amounts of backscatter from non SBW targets. Few *Tangaroa* trawls were carried out on these marks, so the observed trawls were analysed for bycatch. A plot of the bycatch by day from all observed trawls suggests that the proportion of other species was extremely low until the end of the season (Figure 7).

No dense marks were observed which could not be identified. A large extent of moderately dense marks at the southern edge of the survey in 500–600 m appeared to comprise mainly javelinfish (Table 2, tow 14). Less dense marks covering a large part of the survey area were generally classified as non-SBW in line with previous acoustic surveys.

Pukaki Rise

The size distributions from the research and commercial tows were used to assign the main SBW marks seen during the survey into the following categories.

1. Characteristic marks in 250–400 m: mainly 2 year old SBW.
2. Some shallow marks in 400–430 m: adult SBW.
3. Dense marks in 350–400 m in stratum 4: mix of adult and 2 year old SBW.

The densest marks were found in stratum 4, in depths of 400–430 m, and were classified as adults because they were being fished by the commercial fleet. Dense marks in strata 3 and 4 in these depths were decomposed using the size frequency of the commercial catch (see Figure 6). Adult marks elsewhere were decomposed using the size frequency from *Tangaroa* trawl 2 (see Figure 4).

Dense marks were also found in depths of 330–400 m in stratum 4. Few commercial trawls were carried out that shallow, but research trawls 3, 4, and 5 all caught various amounts of adult and 2 year old SBW (see Figure 4). For the purposes of the analysis they were divided into two SBW categories: 'immature' and 'mix'. The deeper marks tended to be denser and were classified as 'mix', and were decomposed using the size frequency from trawl 3. The shallower and less dense marks in stratum 4, and around the rest of the Pukaki Rise, were classified as 'immature', and were decomposed using the combined size frequency from trawls 1 and 4.

2.3 Analysis of acoustic data

The average areal acoustic backscattering on each transect was calculated using standard echo integration (Burczynski 1979) of the SBW marks identified from echograms. To calculate the mean SBW density for each stratum, the mean areal backscattering was multiplied by the mean weight per fish and divided by the mean backscattering cross section (per fish). Target strength-fish length and fish weight-fish length relationships (male, female, and average) were used together with the length frequencies to estimate the mean weight and mean backscattering cross section in each area.

The abundance indices in previous surveys were turned into absolute estimates using the target strength-fish length relationship used for blue whiting in the Northern Hemisphere by Monstad et al. (1992). Recent studies on gadoids in the Northern Hemisphere (Rose 1998) have suggested a higher target strength (similar slope but higher intercept) (Figure 8). *In situ* target strength data collected during the 1998 and 2000 southern blue whiting acoustic surveys agree with the recent Northern Hemisphere relationship (Dunford 2001). Preliminary results from recent swimbladder modelling studies suggest a higher target strength, and possibly also steeper slope, than the Northern Hemisphere studies (Figure 8). The target strength-fish length relationship used in previous years was retained in the current analysis because it is not yet known which alternative relationship is most likely.

The weight-length relationships, which apply to spawning fish, were taken from Hanchet (1991). The target strength–fish length relationship

$$TS = 21.8 \log_{10} FL - 72.8$$

was used, where TS is target strength (dB re 1 μPa at 1m) and FL is fork length in centimetres (see Grimes & Hanchet (1999) for further details).

The mean SBW stratum density for each SBW category was multiplied by the area of the stratum to obtain biomass estimates for each stratum which were then summed over all strata to produce an estimate for the snapshot, from the formulae given by Cordue (1991). Biomass estimates were also decomposed into numbers at age, with a plus group at age 4 using the length frequency data together with the age-length key derived from the commercial and research tows on the Campbell Island Rise and Pukaki Rise in 2000 following Hanchet et al. (2000b). The length distribution for each of the

SBW categories is discussed in Section 2.2.3. No allowance has been made for the contribution of other species to the backscattering assigned to the SBW categories.

2.4 Gonad data

Staging data for female fish (using the five stage system given by Hanchet (1998)) were recorded by scientific observers on each ground during the season. Data were examined to define spawning times on each ground and to determine whether there was any evidence of turnover. Turnover would be occurring if large numbers of fish had spawned and left the area during the survey or before it began, or if new fish arrived on the ground during the survey or after it had ended. The gonad data were therefore examined to determine whether large numbers of spent fish were present in the area before or during the survey, or if there was a large increase in spent fish followed by an increase in ripening fish (i.e., fish which had not already spawned that year) during the survey or after it had been completed.

3. RESULTS

3.1 Acoustic biomass estimates

3.1.1 Campbell Island Rise

The results of the two snapshots completed on the Campbell Island Rise are shown in Table 3 and Figure 9. During snapshot 1, adults were found on both the northern and southern grounds in approximately equal numbers. The most important stratum on the northern ground for adults was stratum 4D with a biomass of 74 400 t (c.v. = 36%). The most important stratum on the southern ground for adults was stratum 7 with a biomass of 41 700 t (c.v. = 75%). The overall snapshot biomass was 151 300 t (c.v. = 28%). Less dense marks of immature fish were seen around much of the survey area with the densest marks in stratum 5, resulting in an immature biomass estimate of 2300 t (c.v. = 46%). Few marks of only juvenile fish were encountered and these were mainly in strata 2 and 7. The juvenile biomass estimate was 1440 t (c.v. = 57%).

During snapshot 2, the adults were more widespread in the southern ground occurring in strata 7Sd, 7N and 6S (see Figure 9). The highest biomass was in stratum 6S, which had a biomass of 89 000 t (c.v. = 25%). However, an additional 45 000 t was recorded in the various sub-strata in stratum 7. Very few fish extended north into strata 4, 5, and 6N. The final estimate for snapshot 2 was 151 400 t (c.v. = 18%). This biomass estimate is almost identical to the value obtained for snapshot 1. Slightly more immature fish were encountered in the second snapshot and these were mainly in strata 4 and 5, resulting in an immature biomass estimate of 7300 t (c.v. = 27%). Again, few juvenile fish were seen and these were mainly in stratum 2, 4, and 5. The juvenile biomass estimate was 1600 t (c.v. = 57%).

The decomposed biomass estimates by age class are shown in Table 4.

3.1.2 Pukaki Rise

Most of the adult fish were found in stratum 4, where the fleet was fishing (Table 5, Figure 10). The adult biomass estimate was only 13 700 t (c.v. = 38%). However, the biomass of the mix category (which also comprised mainly adult fish) in stratum 4 was 18 000 t (c.v. = 74%). Immature fish were found all around the Rise, but the highest densities and greatest biomass was in stratum 4. The immature biomass estimate was 5200 t (c.v. = 62%). The decomposed biomass estimates by age class are given in Table 6.

3.2 Gonad data

Spawning started very early on the Campbell Island Rise in 2000. The first fish were caught on the northern ground on 7 September, and were in a range of gonad stages indicating that spawning was already underway (Table 7). The first spawning finished by 9 September, because by then most fish had reverted back to the ripe or ripening stage and a small percentage were spent. Over the next week, 60–80% of the fish had reverted to stage 2, 10–15% were spent, and only 1–5% were running ripe. Fish sampled from outside the survey area on 14 September had similar gonad stages to others sampled on adjacent days. The first sample of fish from on the southern ground were caught by *Tangaroa* on 12 September (Table 8). At this time the fish were in a wide variety of gonad stages, indicating that most fish in the southern area had already spawned at least some of their eggs. By 14 September most fish had reverted to the maturing stage (note stage 8 on *Tangaroa* is equivalent to observer stage 2).

The second spawning started on 17 September and coincided with a marked increase in catch rates by the vessels, which were now fishing in the central part of stratum 5. Vessels remained fishing this area until 19 September. After a short break due to bad weather, vessels resumed fishing slightly further to the south on the boundary between strata 5 and 7N. They made good catch rates and caught spawning fish in this area until 25 September. At the end of the second spawning about 50–60% of the fish were spent/resting, and the remainder had again reverted to the maturing stage. This is the first indication that some SBW may spawn three batches of eggs.

The data were examined for evidence of turnover. The first snapshot was completed on both grounds before the fish had finished their first spawning and started to disperse. After the first spawning was finished the percentage of spent fish fluctuated considerably between 5 and 20%, with slightly lower values from 15 to 17 September. However, this decline also coincided with a change in fishing location. During this period there was little active spawning and the percentage of ripening fish remained reasonably constant suggesting that there was no substantial turnover of spent fish leaving the grounds. During the second spawning the percentage of spent fish increased to 50–60% and stayed reasonably constant at that level. Although there was an increase in the proportion of maturing fish during mid and late September, observers reported that these fish had already spawned. There was therefore no evidence of turnover from the gonad data.

Fish were sampled on the Pukaki Rise from 3 to 7 September. During this period most fish were in the ripening stage, with less than 10% spawning (Table 7). This suggests that the first main spawning event had not yet begun. (We define spawning as more than 10% of the fish with running ripe eggs.) The fish were sampled again on 27 September. At this stage most fish had reverted to the ripening stage, suggesting that the first spawning was over but that the second spawning had not yet begun.

4. DISCUSSION

4.1 Biomass estimation

4.1.1 Campbell Island Rise

The 2000 season was unusual in that it was the earliest spawning on record. The acoustic survey and fishery started on 7 September, which is similar to previous years, but by this time the first spawning of the northern aggregation was well under way. By moving quickly, and dropping some of the transects in the deeper strata, we surveyed aggregations on both northern and southern spawning grounds before the first spawning was over and the fish had started to disperse. We are therefore reasonably confident of the results of the first snapshot.

However, there are several questions regarding our confidence in the results of the second snapshot.

Firstly, was the whole adult population within the survey area during the second snapshot? At the start of the second snapshot fish were caught by the fleet outside the survey area to the east of stratum 6. However, catches and catch rates were poor, and the school was fished for only one day, suggesting it did not contain significant quantities of fish. There was also no strong evidence from gonad staging data for any substantial turnover of the population. Lastly, there was no evidence of substantial amounts of fish in strata 2 and 3 which were not surveyed during the second snapshot. It appears then that most of the population was still in the survey area during the second snapshot.

Secondly, was the survey area itself adequately surveyed during the second snapshot? When the second snapshot survey was being planned it appeared that most fish were in the southern portions of strata 6 and 7, and most transects were allocated to these strata. In addition, the number of transects in stratum 5 was increased from three to five, to reflect the increase in historical fishing in this stratum after the first spawning is over. During the surveying, as anticipated, most of the fish were found in strata 6S, 7N and 7Sd. However, relatively few fish were seen in the centre and south of stratum 5, where most of the commercial fishing was carried out from 16 to 21 September. Part of the mismatch between the fishing and the acoustic surveying may be due to the difference in timing. Whilst commercial vessels were fishing in stratum 5 we were surveying strata 7N and 7Sd. As we moved north into stratum 5 on 20 September the vessels moved south and fished along the stratum 5/7N boundary. It is therefore possible that fish had either dispersed and moved south out of stratum 5 by the time we surveyed the area, or that the level of sampling effort was not high enough to pick them up.

Thirdly, because fish were more dispersed in the second snapshot was there more of a problem with species mix? Only a limited amount of research trawling was carried out on the adult marks seen during the second snapshot. These marks were dominated by SBW (70–95%) but had reasonable amounts of rattails and javelinfish. Commercial vessels using a larger mesh size and probably fishing denser aggregations had minimal bycatch during this period (under 1%). In 1998, the possible contribution of other species to the total backscatter was calculated to be 8000 t (about 10%) and this correction applied to the second snapshot survey biomass estimate (Hanchet et al. 2000b). Because of the different systems used in the 2000 survey between snapshots 1 and 2, a similar approach was not attempted for the 2000 survey. Corrections for species mix have been applied to acoustic surveys for oreos (Doonan et al. 2000). However, this approach requires considerably more research trawl data than is available from the 2000 survey. So although it is likely that the adult biomass is overestimated, this cannot currently be quantified.

In conclusion, the results of the second snapshot should be treated with some caution. Given the potential problems with snapshot 2, it is surprising that the biomass was so similar to snapshot 1. Perhaps any problems caused by fish leaving the area or being under sampled were offset by the inclusion of a higher proportion of other species in the acoustic backscatter.

The results of the five acoustic surveys of the Campbell grounds are given in Table 9. The 2000 biomass is lower than the 1998 estimate, but similar to the 1994 and 1995 estimates. The c.v. in the 2000 survey was the lowest recorded in any SBW survey and was partly because of the intensive sampling of the aggregations, and partly because of the dispersed nature of the fish during the second snapshot. The decomposed Campbell results suggest a continued high biomass of 4 year old and over fish, but generally low numbers of pre-recruits. Estimates of 2 and 3 year olds were the lowest in the 5 year series. Estimates of 1 year olds are thought to be unreliable because these fish probably extend inside 300 m, and there are problems with species identification.

The comparability of the 2000 survey to previous surveys needs some consideration. In the previous acoustic surveys of the Campbell stock the first spawning did not start until mid September (Hanchet et al. 2000c). In each survey the first snapshot on the northern ground and both snapshots of the southern ground were completed before spawning had started. The second snapshot of the northern ground was either carried out before spawning (1993), whilst spawning was in progress (1994, 1995), or immediately post-spawning (1998). Hanchet et al. (2000c) noted that in the first three surveys the biomass estimates increased between the two snapshots, but in the fourth it declined slightly. However, they considered that this probably reflected sampling precision rather than any systematic change in abundance, and concluded that the results of the two snapshots should be averaged to provide the best estimate. In the 2000 survey there was no pre-spawning biomass estimate on either ground. So the estimate obtained from the 2000 survey may be biased upwards compared to the best estimates obtained from previous years.

To get some idea of the effect this might have on the 2000 survey estimate, we examined the differences between the two snapshots in the previous surveys (in Hanchet et al. 2000c). Estimates changed by +26%, +40%, +17%, and -3% for the four surveys respectively. The average increase between snapshots 1 and 2 is therefore about 20%. If this was applied to the snapshot 1 estimate from the 2000 survey it would result in a drop in biomass of about 10%.

In the 2001 SBW assessment, the Middle Depths Working Group (MDWG) agreed to use the average of snapshots 1 and 2 as the best estimate of biomass from the 2000 acoustic survey. We see no strong reason to change that decision. However, we believe that the estimate from the first snapshot is more comparable to estimates of biomass from the second snapshots of previous surveys. This would lead to a slight upward bias (perhaps of the order of 10%) in the 2000 acoustic survey estimate relative to previous surveys. *It is recommended that this be considered by the* MDWG before the next SBW assessment is carried out.

4.1.2 Pukaki Rise

All previous surveys of the Pukaki Rise have been carried out between 29 August and 6 September (Hanchet et al. 2000c), and most snapshots were carried out before spawning had started. The timing of the 2000 survey in relation to spawning was very similar to that of previous surveys, and the biomass estimates should therefore be comparable to those surveys.

The biomass estimate of 4 year old and over fish from the 2000 survey was almost 30 000 t, which is consistent with the biomass estimates from surveys carried out in 1993, 1994, and 1997 (Table 10). The reason for the very low 1995 survey estimates is unknown, but the survey was carried out about a week before spawning started, and most of the fish might have arrived late on the grounds that year. All estimates of biomass are consistent with the low level of catches reported from this fishery over the past decade.

Although the c.v. of the adult biomass estimate was relatively high (38%), it was similar to that obtained from single snapshots during previous surveys of the Pukaki Rise. Furthermore, the c.v. will underestimate the precision in the biomass estimates of the 4 year old and over fish, because these fish were also found in mixed schools with pre-recruits (in the mix categories). As discussed by Hanchet et al. (2000c), more trawls are necessary before the precision of the decomposed biomass estimates can be obtained using bootstrapping.

Estimates of pre-recruit (1, 2, and 3 year old) fish were about average for the 2000 survey. This suggests that these three year classes are probably about average strength. We would therefore predict the biomass to remain reasonably stable over the next few years until a strong year class enters the fishery.

4.2 Target strength

There is additional uncertainty over these biomass estimates due to uncertainty over target strength. *In situ* target strength work carried out during the 1994, 1998, and 2000 SBW acoustic surveys and theoretical modelling studies suggest a steeper slope than that currently assumed (see Section 2.3 and Figure 8). This would affect the use of the Campbell surveys in a relative sense because the biomass of smaller fish (in the 1994 and 1995 surveys) would have been underestimated whilst the biomass of larger fish (in the 1993, 1998, and 2000 surveys) would have been overestimated. It would have less impact on the Pukaki Rise surveys. It is planned to collect further *in situ* target strength data in the 2001 survey of the Bounty Platform.

4.3 Mark identification

With seven surveys now completed, there is a great deal of certainty to the positive identification of the very dense adult SBW marks that contain most of the SBW biomass. Good scientific observer coverage of the commercial fleet also helped to confirm the depths and areas of fish distribution. Trawling is likely to remain an important tool in the acoustic programme for the following reasons:

1. distinguishing less dense adults marks from pre-recruit marks in areas where they occur in similar depths;
2. identifying the size and age composition of SBW in the less dense pre-recruit marks including 1, 2, and immature 3 year old fish;
3. separating other species such as silversides, rattails and other small schooling midwater fish such as lanternfish and pearlside from the moderately dense schools of pre-recruit SBW when they are in the shallower part of their depth range and close to the bottom;
4. establishing species mix proportions away from the dominant heavy SBW marks, particularly in post-spawning aggregations.

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Table 1: Transect allocation during voyage TAN0009 in snapshots 1 and 2.

Stratum number	Stratum area	Number of transects	
	Km^2	Snapshot 1	Snapshot 2
Pukaki Rise			
Date		4/9/00-7/9/00	
1	676	6	–
2	1 247	8	–
3	813	5	–
4	1 147	8	–
5	1 765	3	–
Total	5 648	30	
Campbell Island Rise			
Date		8/9/00-13/9/00	13/9/00-26/9/00
2	3 154	5	1
3N	2 342	1	2
3S	1 013	1	3
4	2 690	–	5
4S	690	6	–
4D	2 000	10	–
5	3 029	3	5
6	4 711	5	–
6N	2 550	–	4
6S	4 014	–	10
7	4 217	8	–
7N	1 899	–	4
7Sd	1 771	–	10
7Ss	502	–	4
Total	–	39	48

Table 2: Trawl station details for TAN0009 with catch (kg) of the main species. Trawl type: BT, bottom; MW, mid-water; * MW trawl on bottom; #MW, trawl 70-100 m off bottom. Age, age of SBW in years, Ad = adults. LIN, ling; JAV, javelinfish; SSI, silverside; SCD, small scaled nototheniid; CAS, smooth rattail; Total, total catch of all species.

Station	Date	Lat	Long	Trawl type	Stra-tum	Min Depth	Max Depth	Age (yrs)	Catch (kg) SBW	LIN	JAV	SSI	SCD	CAS	Total
1	5-Sep-00	49 33	171 53	BT	3	375	383	2	98	17	3	4	0	4	155
2	6-Sep-00	49 20	171 19	BT	1	371	376	2, Ad	366	50	3	4	0	48	578
3	7-Sep-00	49 25	172 13	BT	4	349	354	Ad	234	0	0	2	0	6	249
4	7-Sep-00	49 25	172 07	BT	4	330	338	2, 3	983	3	0	8	5	1	1034
5	7-Sep-00	49 27	172 10	*MW	4	340	354	2, 3	22	17	0	4	0	<1	48
6	9-Sep-00	51 35	169 50	BT	2	415	429	2, Ad	198	62	42	2	4	11	335
7	9-Sep-00	51 37	169 49	BT	2	362	400	1	96	0	2	77	267	19	693
8	9-Sep-00	51 39	169 43	BT	2	332	350	1	497	0	0	28	57	8	594
9	11-Sep-00	51 58	170 42	BT	5	438	440	2	185	8	1	1	0	3	218
10	12-Sep-00	53 12	170 50	BT	6	461	461	2, Ad	258	6	3	6	0	6	300
11	12-Sep-00	53 12	170 51	#MW	6	350	390	Ad	12	0	0	0	0	0	77
12	13-Sep-00	53 10	170 01	BT	7	306	330	1	118	0	1	2	0	26	158
13	14-Sep-00	53 14	171 13	*MW	6S	446	447	Ad	29	0	<1	4	0	<1	34
14	19-Sep-00	53 23	170 39	BT	7Sd	563	564	-	1	243	535	1	0	4	894
15	19-Sep-00	53 04	170 25	BT	7Ss	420	422	Ad	227	1	4	1	0	6	243
16	19-Sep-00	52 60	170 24	BT	7Ss	422	425	2, Ad	184	1	15	3	0	46	256
17	21-Sep-00	52 14	170 23	BT	5	390	390	2	430	0	0	2	4	12	457
18	22-Sep-00	52 02	170 24	BT	5	300	340	-	0	0	0	134	18	64	224
19	22-Sep-00	52 01	170 27	BT	5	345	360	1	<1	0	<1	53	1	7	72
20	22-Sep-00	51 59	170 33	BT	5	399	403	1	10	0	<1	31	13	24	106
21	22-Sep-00	51 57	170 37	BT	5	420	434	2	313	57	3	4	1	26	436
22	22-Sep-00	52 03	170 45	BT	5	447	464	Ad	279	138	42	17	0	13	629
23	25-Sep-00	51 34	170 28	BT	4	449	487	Ad	60	0	126	33	0	8	344
24	25-Sep-00	51 40	170 21	BT	4	450	460	Ad	112	236	57	25	0	8	553
25	25-Sep-00	51 44	170 17	BT	4	412	425	2	190	9	8	10	14	8	272
26	25-Sep-00	51 54	170 15	BT	4	300	333	1	<1	0	0	24	22	41	90
27	27-Sep-00	49 27	172 09	BT	4	362	362	2, Ad	455	66	<1	2	2	2	557
Total catch									5 358	915	847	481	403	400	9 606

Table 3: Biomass estimate and c.v. by stratum and snapshot of adult, immature (mainly 2 year old), and juvenile (mainly 1 year old) SBW, for the Campbell Island Rise in 2000. The italicised entries were obtained from the previous snapshot.

		Adults		Immature		Juvenile	
Stratum	Area (km^2)	Biomass (t)	c.v. (%)	Biomass (t)	c.v. (%)	Biomass (t)	c.v. (%)
Snapshot 1							
2	3 154	11 276	56	0	–	601	61
3N	2 342	0	–	0	–	0	–
3S	1 013	1 079	–	0	–	0	–
4D	2 000	74 408	36	158	100	0	–
4S	690	868	76	253	64	107	75
5	3 029	7 968	60	1 704	60	0	–
6	4 711	14 048	60	0	–	0	–
7	4 217	41 677	75	185	66	732	101
Total	21 156	151 324	28	2 300	46	1 440	57
Snapshot 2							
2	3 154	–	–	*0*	–	*601*	*61*
3N	2 342	0	–	0	–	0	–
3S	1 013	0	–	0	–	0	–
4	2 690	5 424	21	4 014	38	434	71
5	3 029	8 860	27	2 431	45	470	105
6N	2 550	3 824	36	0	–	0	–
6S	4 014	88 918	25	0	–	0	–
7N	1 899	22 004	28	614	101	14	95
7Sd	1 771	17 654	78	0	–	0	–
7Ss	502	4 690	45	246	72	80	92
Total	22 964	151 374	18	7 305	27	1 599	43
Mean		**151 349**	**17**	**4 803**	**23**	**1 520**	**35**

Table 4: Decomposed biomass estimates (t) by stratum and snapshot of 1, 2, 3, and 4 year old and over SBW for the Campbell Island Rise in 2000. The italicised entries were obtained from the previous snapshot.

Stratum	Area (km²)	Ages 1	2	3	≥ 4
Snapshot 1					
2	3 154	370	2 117	501	8 280
3N	2 342	–	–	–	–
3S	1 013	–	–	–	–
4D	2 000	0	1 944	4 186	67 738
4S	690	68	262	53	808
5	3 029	10	1 779	490	7 642
6	4 711	0	340	791	12 811
7	4 217	446	1 206	2 326	37 619
Total	21 156	894	7 648	8 347	134 898
Snapshot 2					
2	3 154	*370*	*2 117*	–	–
3N	2 342	0	0	0	0
3S	1 013	0	0	0	0
4	2 690	292	3 878	362	5 173
5	3 029	304	2 493	534	8 226
6N	2 550	0	93	215	3 485
6S	4 014	0	2 150	5 006	81 034
7N	1 899	12	1 104	1 249	20 115
7Sd	1 771	0	401	932	15 088
7Ss	502	50	1 036	196	3 205
Total	22 964	1 028	13 272	8 494	136 326
Mean		**961**	**10 460**	**8 421**	**135 612**

Table 5: Biomass estimate and c.v. of adult and immature SBW by stratum for the Pukaki Rise.

Stratum	Area (km²)	Adults Biomass (t)	Adults c.v. (%)	Mix Biomass (t)	Mix c.v. (%)	Immature Biomass (t)	Immature c.v. (%)
1	676	1 678	38	0	–	318	72
2	1 247	247	99	0	–	0	–
3	813	1 780	101	0	–	815	91
4	1 147	10 016	48	18 039	74	4 027	78
5	1 765	0	–	0	–	0	–
Total	5 648	13 721	38	18 039	74	5 160	62

Table 6: Decomposed biomass estimates of 1, 2, 3, and 4 year old and over SBW for the Pukaki Rise in 2000.

Stratum	Area (km^2)	1 (t)	2 (t)	3 (t)	≥4 (t)
1	676	4	765	214	655
2	1 247	0	92	32	105
3	813	10	689	215	1 766
4	1 147	44	5 722	5 116	22 405
5	1 765	0	0	0	0
Total	5 648	58	7 268	5 577	24 931

Table 7: Percentage of females at each gonad stage from observer data by area and date. n, number of fish examined. Gonad stages: 1, immature/resting; 2, ripening; 3, ripe; 4, running ripe; 5, spent (see also Hanchet 1998).

		Gonad stage				
Date	n	1	2	3	4	5
Campbell Island Rise						
7-Sep-00	210	1	38	44	0	17
8-Sep-00	165	2	4	57	32	5
9-Sep-00	306	1	46	42	6	5
10-Sep-00	747	3	68	9	2	19
11-Sep-00	630	2	63	23	4	8
12-Sep-00	455	3	64	17	2	14
13-Sep-00	485	2	71	15	3	9
14-Sep-00	380	4	69	13	2	12
15-Sep-00	717	3	82	9	2	4
16-Sep-00	642	4	75	9	5	7
17-Sep-00	776	4	62	16	14	5
18-Sep-00	939	13	15	32	25	16
19-Sep-00	979	10	6	22	43	19
20-Sep-00	59	24	2	46	8	20
21-Sep-00	1 381	15	8	16	29	32
22-Sep-00	1 464	11	9	12	21	47
23-Sep-00	449	17	8	16	15	45
24-Sep-00	938	12	12	16	27	33
25-Sep-00	792	10	24	13	11	41
28-Sep-00	417	18	30	9	1	43
29-Sep-00	675	17	29	9	5	41
30-Sep-00	502	11	22	10	1	56
1-Oct-00	181	13	22	8	6	52
Pukaki Rise						
3-Sep-00	687	1	81	10	7	0
4-Sep-00	308	1	60	32	6	0
5-Sep-00	418	1	90	6	2	0
6-Sep-00	290	0	82	13	4	0

Table 8: Percentage of females at each gonad stage in *Tangaroa* trawls by area and date. PR, Pukaki Rise; CIR, Campbell Island Rise. n, number of fish examined. Gonad stages: 3, ripening; 4, ripe; 5, running ripe; 6, partially spent; 7, spent; 8, reverted (spawned one batch and reverted to ripening stage).

Date	Area	n	Gonad stage					
			3	4	5	6	7	8
6-Sep-00	PR	79	82	10	5	0	0	3
7-Sep-00	PR	170	90	9	1	0	0	0
9-Sep-00	CIR	30	17	17	53	0	3	10
11-Sep-00	CIR	18	33	0	22	0	44	0
12-Sep-00	CIR	261	3	0	15	44	19	20
14-Sep-00	CIR	29	0	0	7	0	7	86
19-Sep-00	CIR	130	0	0	7	9	19	65
22-Sep-00	CIR	167	1	0	4	3	72	20
25-Sep-00	CIR	165	0	0	1	12	82	5
27-Sep-00	PR	105	1	6	6	15	17	55

Table 9: Biomass estimates (t) by survey and age group for the Campbell Island Rise. The analysis was initially carried out on SBW categories, which were then decomposed using age frequency data. The decomposed estimates for 1993-1995 are not directly comparable to the SBW category estimates because of additional changes in target identification. SSB, spawning stock biomass.

SBW category estimates

Year	1yo		2yo		Adult (SSB)	
	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.
1993	–	–	89 600	23	18 500	21
1994	–	–	22 400	38	161 400	36
1995	–	–	19 800	25	121 100	30
1998	1 300	52	13 000	20	171 500	18
2000	1 520	35	4 800	23	151 300	17

Decomposed estimates

	1yo	2yo	3yo	4yo+
1993	1 817	71 902	14 781	24 033
1994	329	12 259	139 552	28 841
1995	0	11 176	23 228	130 535
1998	2 283	13 142	28 022	167 668
2000	961	10 460	8 421	135 612

Table 10: Biomass estimates (t) by survey and age group for the Pukaki Rise. The analysis was initially carried out on SBW categories, which were then decomposed using age frequency data. The decomposed estimates for 1993-1995 are not directly comparable to the SBW category estimates because of additional changes in target identification. SSB, spawning stock biomass.

SBW category estimates

Year	Immature (2yo)		Mix		Adults (SSB)	
	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.
1993	26 300	20	–	–	*49 800	24
1994	200	–	–	–	*39 000	45
1995	30	–	–	–	12 800	18
1997	3 100	12	–	–	31 000	35
2000	5 160	62	*18 039	74	13 721	38

* Includes some immature 2 or 3 yr old fish.

Decomposed estimates

Year	1yo	2yo	3yo	4yo+
1993	578	26 848	9 315	31 152
1994	8	1 193	6 364	35 969
1995	0	102	775	11 743
1997	22	2 838	864	34 086
2000	64	3 035	2 065	29 446

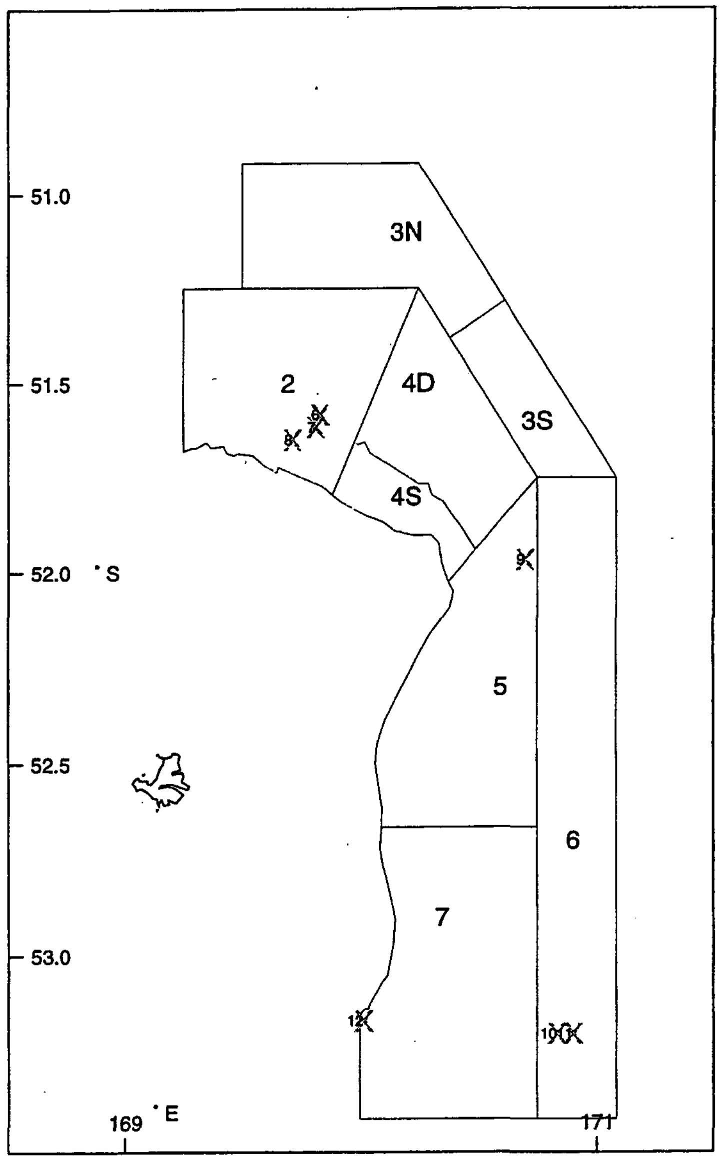

Figure 1: Survey area, stratum boundaries and location of trawls in snapshot 1 on Campbell Island Rise during TAN0009.

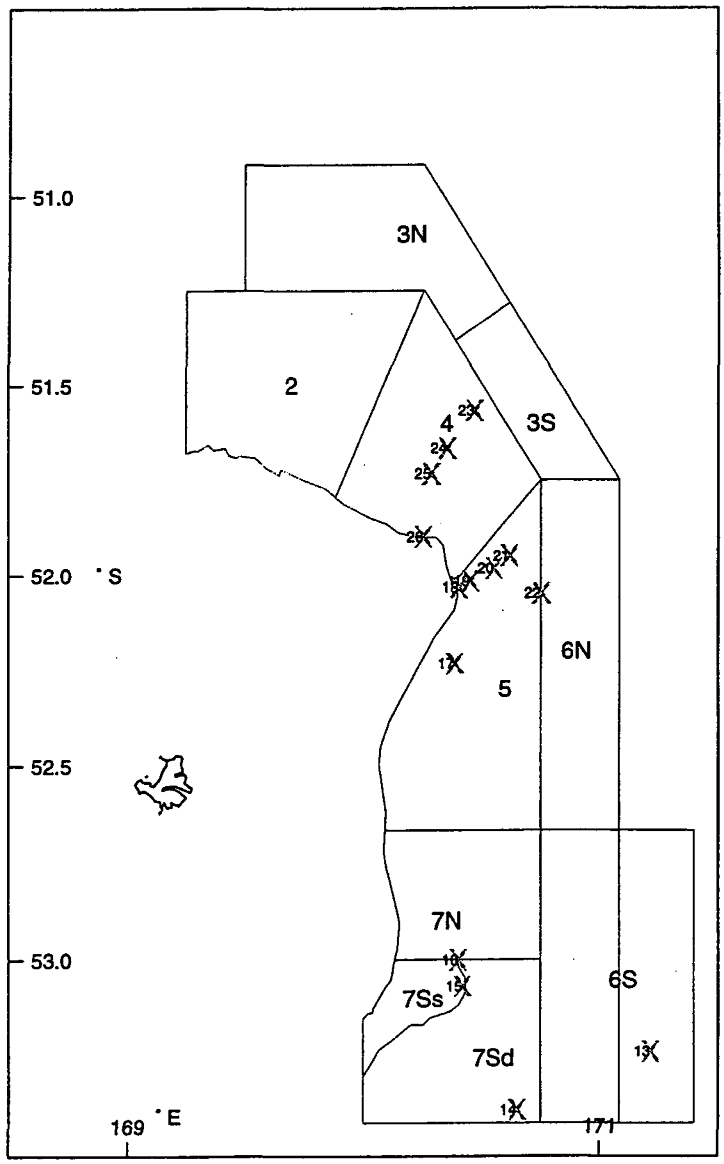

Figure 2: Survey area, stratum boundaries and location of trawls in snapshot 2 on Campbell Island Rise during TAN0009.

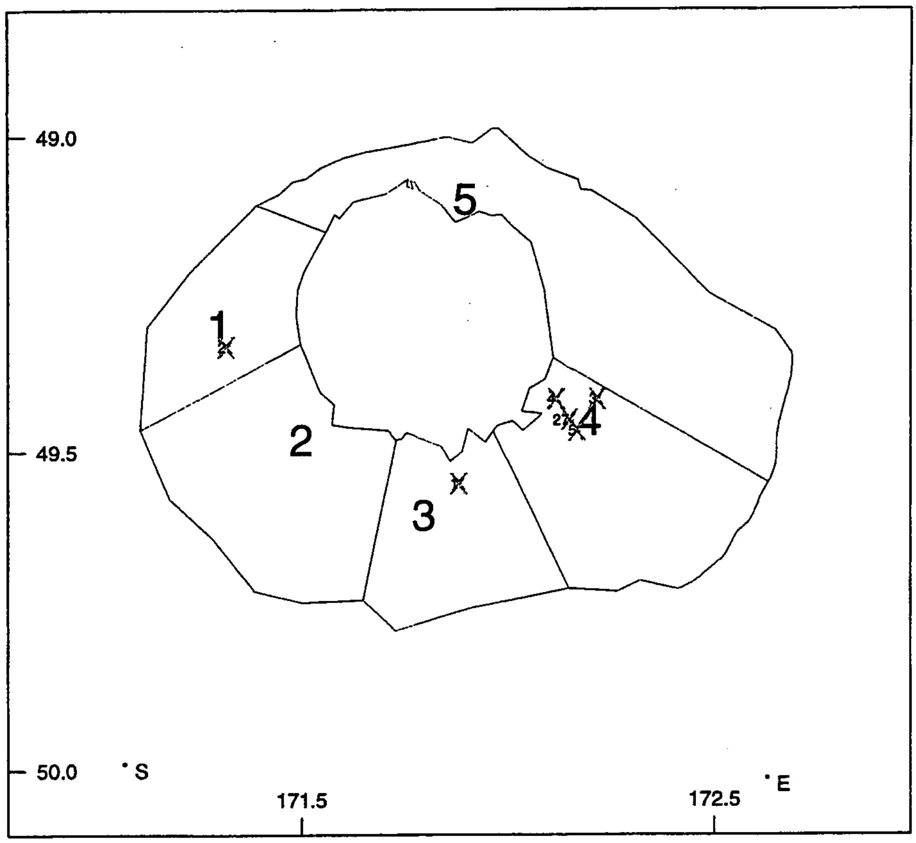

Figure 3: Survey area and stratum boundaries and location of trawls made on Pukaki Rise during TAN0009.

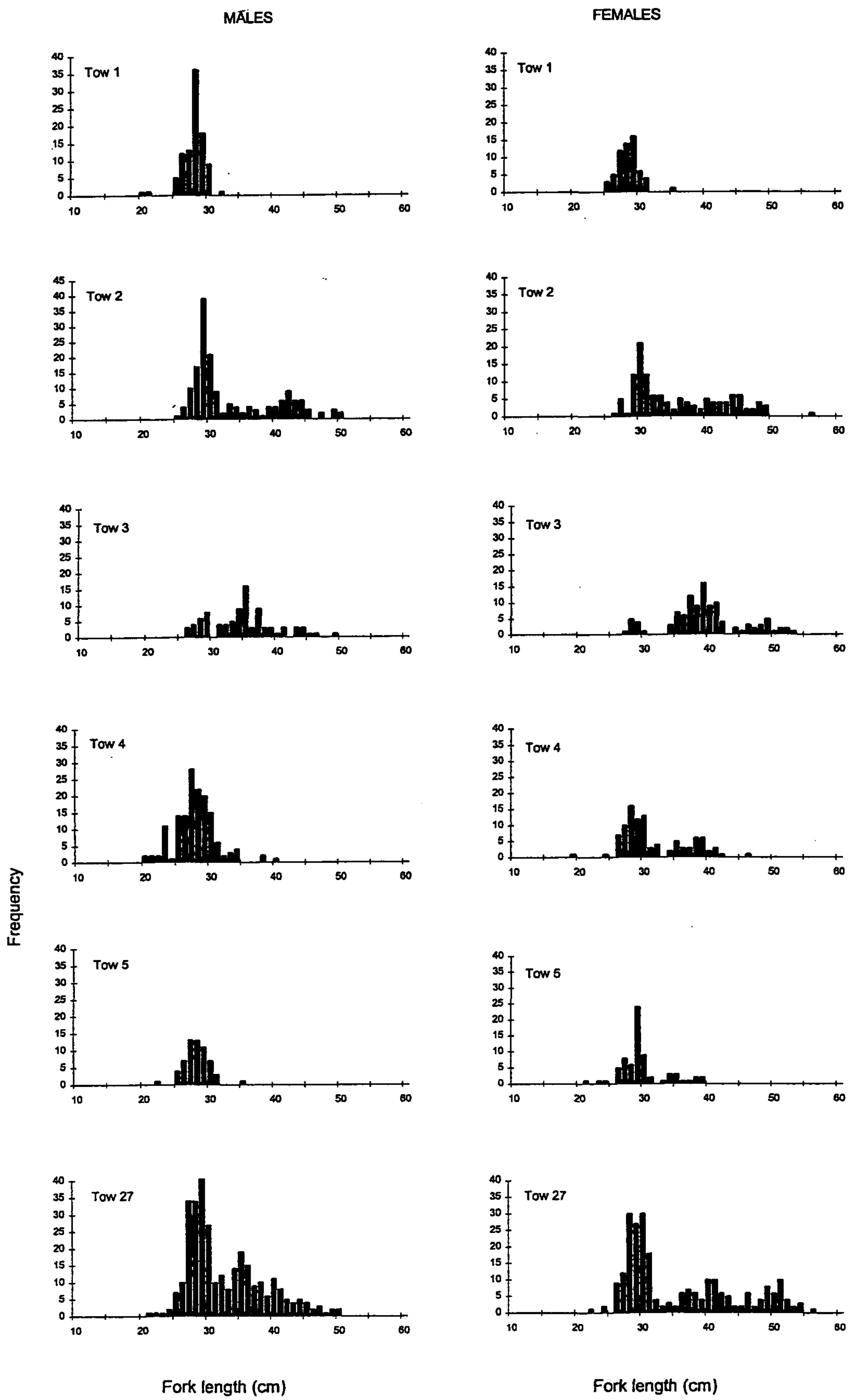

Figure 4: Unscaled length frequency distributions of male and female SBW for each trawl station. Tows 1 to 5 and 27 from Pukaki Rise, and tows 6 to 26 from Campbell Island Rise.

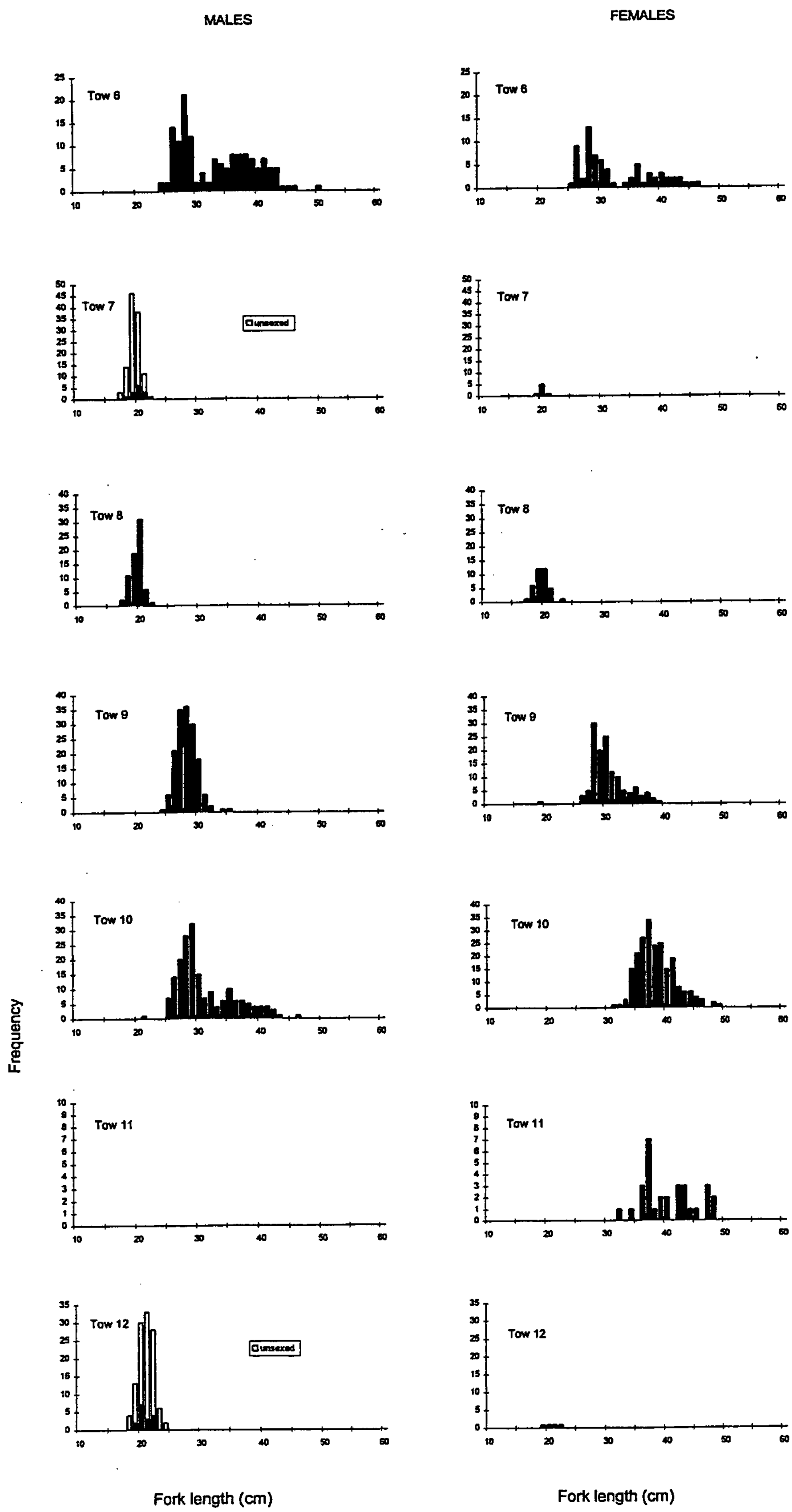

Figure 4 continued:

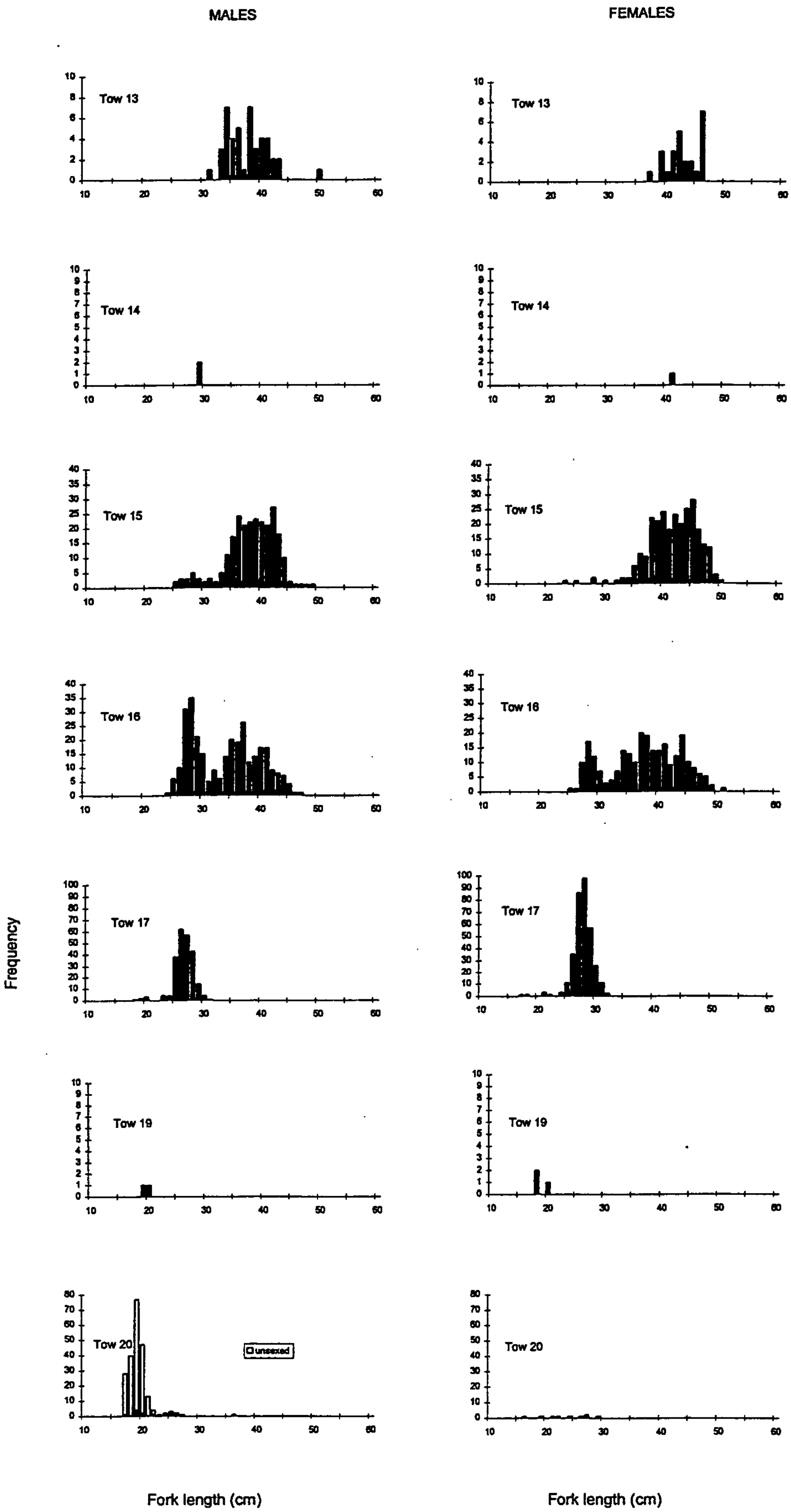

Figure 4 continued:

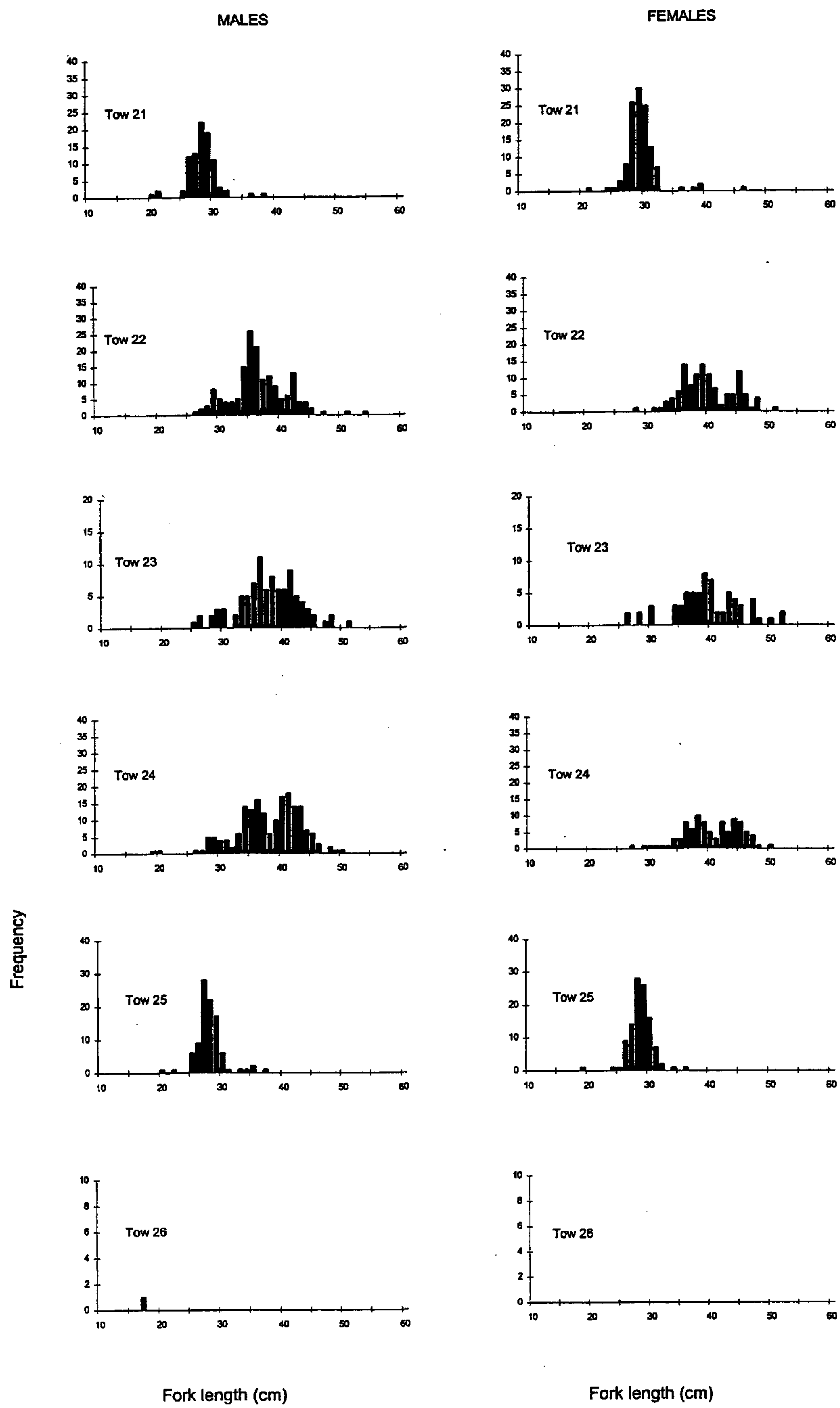

Figure 4 continued:

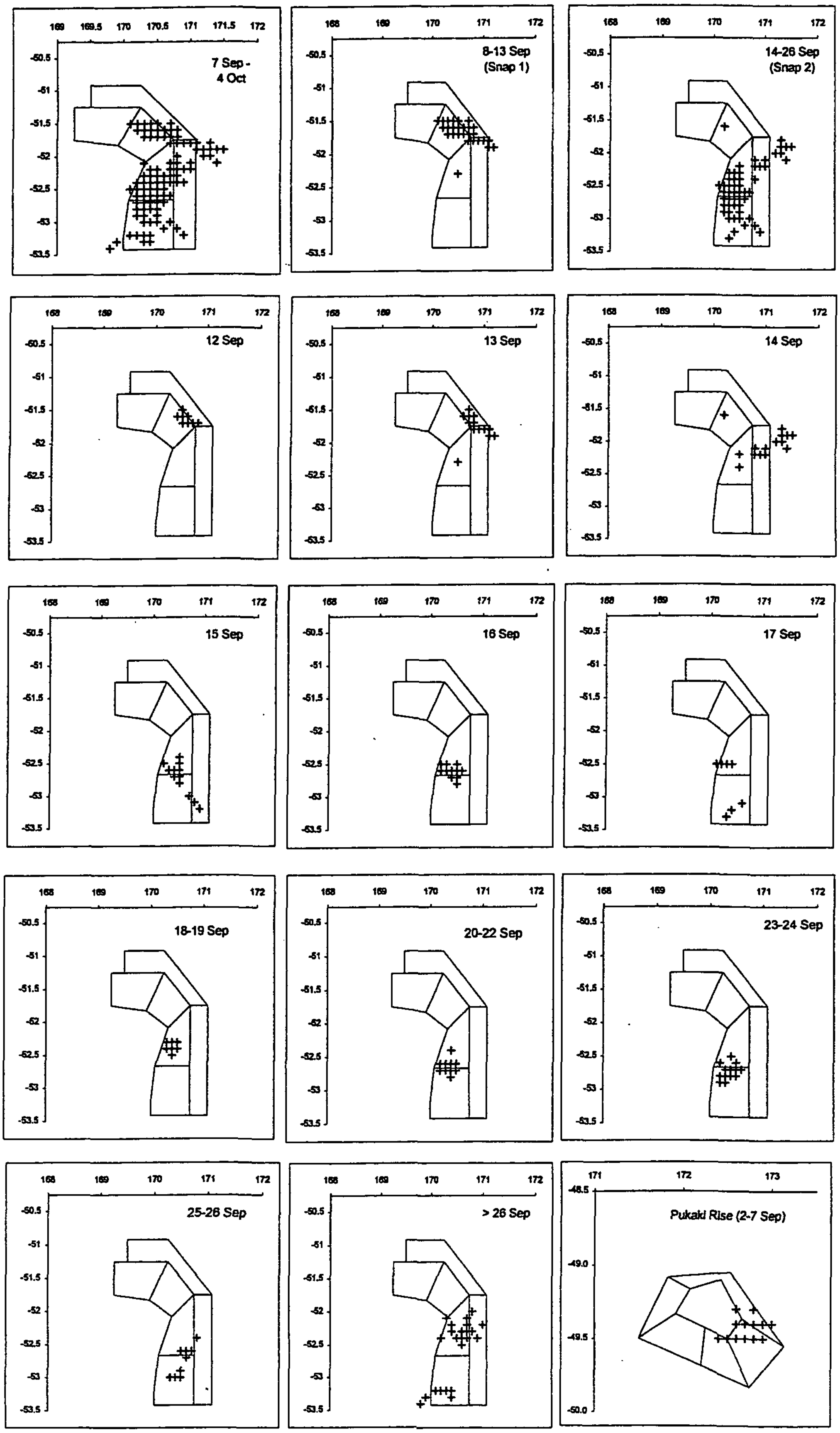

Figure 5: Location of commercial trawls on Campbell Island Rise and Pukaki Rise in 2000.

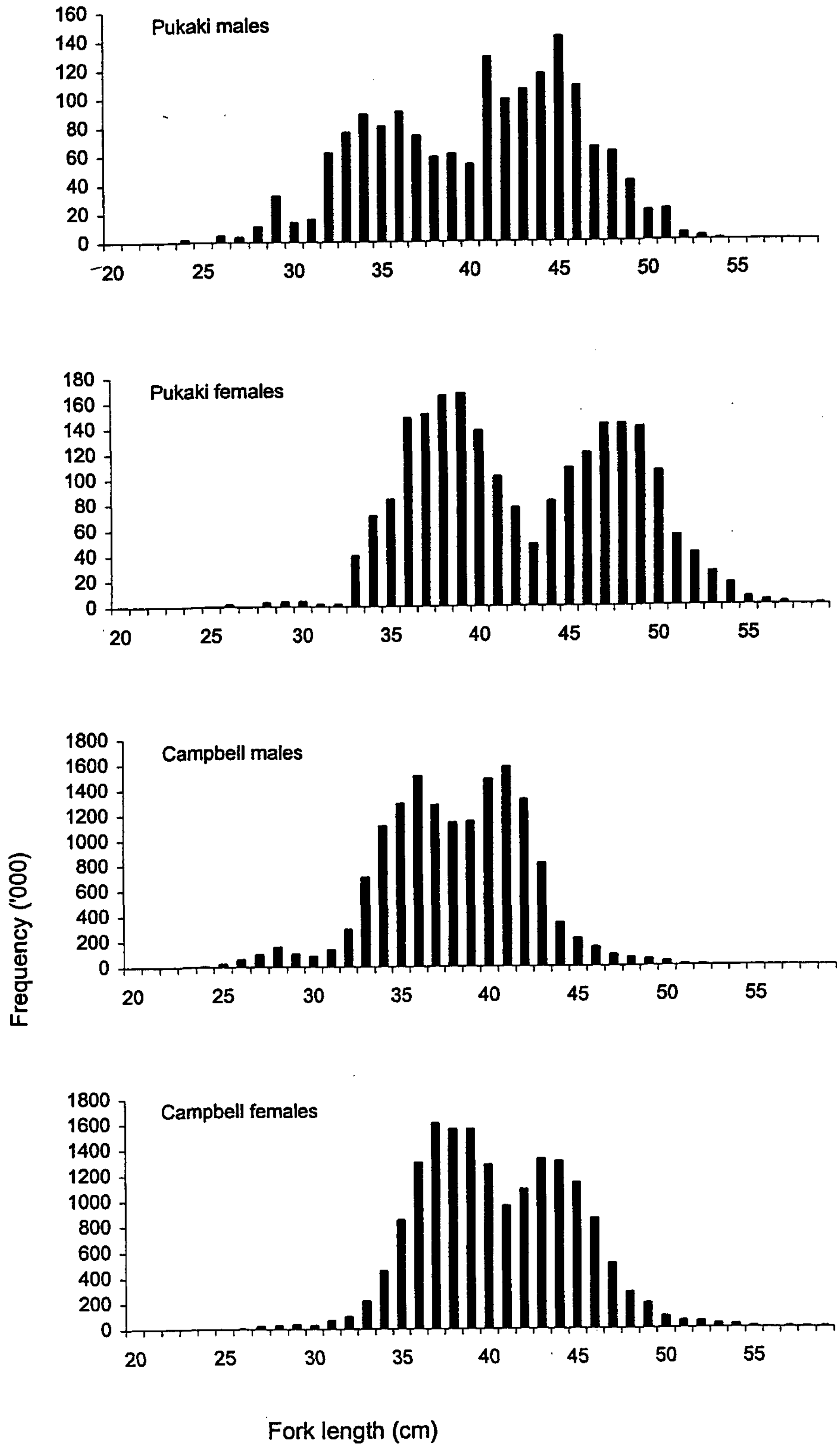

Figure 6: Scaled length frequency distributions for observer data from the Campbell Island Rise and Pukaki Rise in 2000.

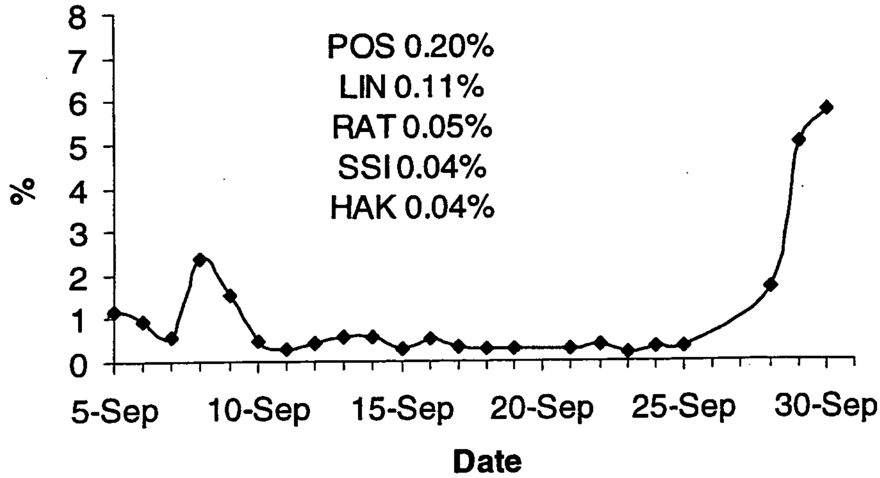

Figure 7: Daily % bycatch recorded by observers in the commercial SBW fishery for the 2000 season, together with % season bycatch for the top five species: POS, porbeagle shark; LIN, ling; RAT, rattail; SSI, silverside; HAK, hake.

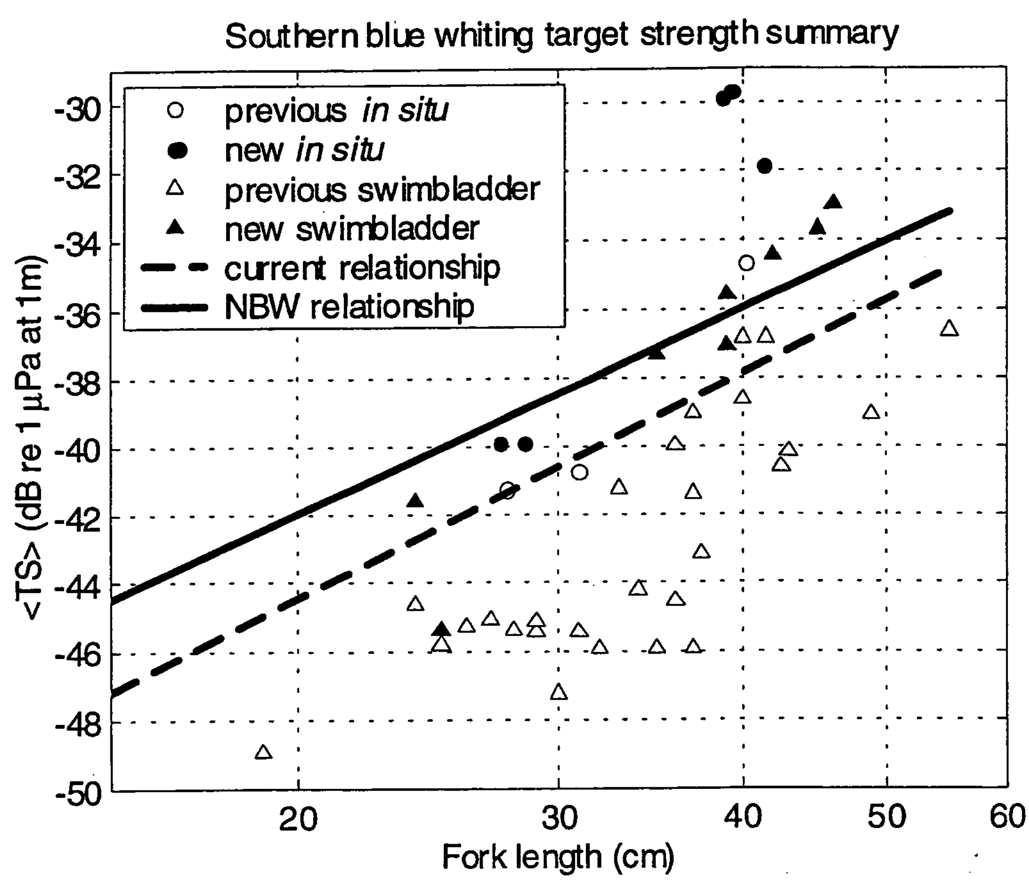

Figure 8: Southern blue whiting target strength summary from Dunford (2001).

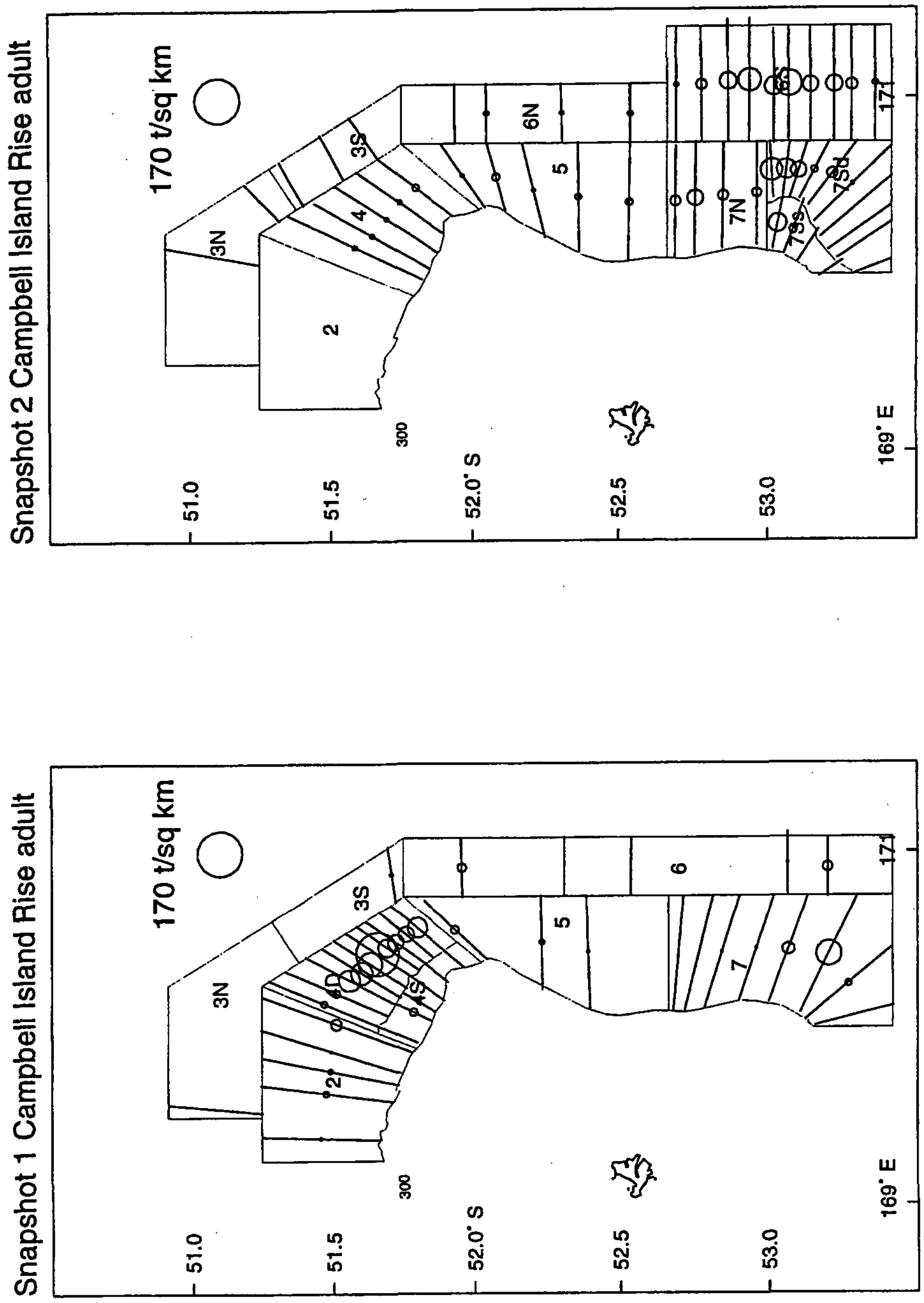

Figure 9: Density estimates of adult southern blue whiting by transect for snapshots 1 (left) and 2 (right) on the Campbell Island Rise.

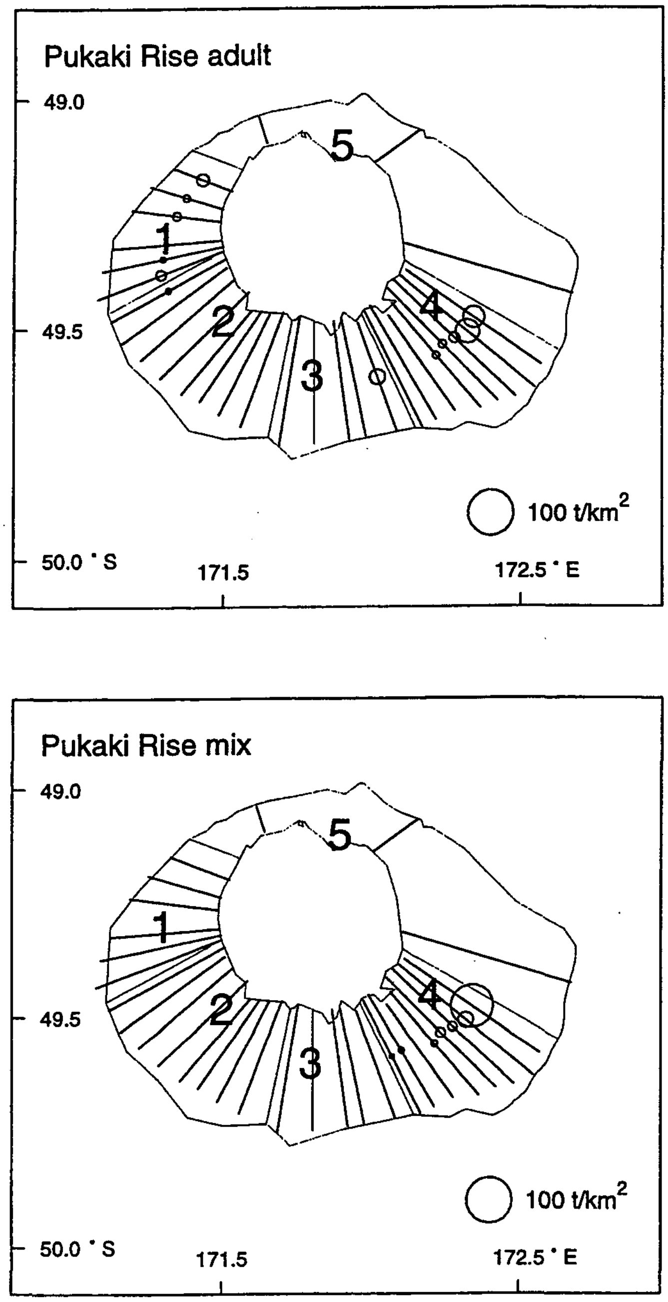

Figure 10: Density estimates of adult (top) and 'mix' (bottom) SBW by transect for the Pukaki Rise.

Appendix 1: Calibration data for the systems used. *G* is the gain of the system at a range of 1 m. Note, a small number of transects with the hull system were carried out at reduced power (SL+SRT = 44.4 dB re 1 V).

System	Towed body	Hull
Transducer serial no.	28327	23421
Nominal 3dB beamwidth (°)	7.0	7.3
Effective beam angle (sr)	0.0083	0.0091
SL+SRT (dB re 1 V)	61.7	50.4
Transducer depth (m)	20-90	6.5
$20 \log_{10} G$	82.0	91.3