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Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform and Pukaki Rise, August-September 1997

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Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform and Pukaki Rise, August-September 1997

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1. Executive summary

This paper summarises the results of the fourth acoustic survey of southern blue whiting (SBW) stocks in subantarctic waters. Two complete acoustic snapshots were carried out on the Bounty Platform and Pukaki Rise. The timing of the surveys was excellent as the fish on each ground started to spawn during the second snapshot.

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 were initially identified as adult (mainly mature fish which have recruited to the commercial fishery), immature (mainly 2 year olds, but including some immature 3 year old fish), or juvenile (1 year old fish).

Preliminary estimates of adult biomass on the Bounty Platform averaged 58 000 t (*c.v.* = 36%). However, this estimate was considered to be inaccurate because it included a large proportion of immature 3 year old fish from the strong 1994 year class. The adults were therefore redefined to include all fish greater than or equal to 3 years old. The estimates of all three SBW categories were recalculated by stratum based on the weight of each SBW category in the length frequency sample from that stratum. The revised biomass estimate for the 1997 survey was 64 600 t. The results of the 1994 survey were also adjusted in the same way. These revised estimates should be regarded as provisional until the decomposition has been carried out more rigorously.

Estimated adult biomass on the Pukaki Rise was very similar between snapshots, averaging 31 000 t (*c.v.* = 35%). This is considered to be the best estimate so far available because it is the first time that spawning has been in progress, and the first where there has been little problem over species identification. It is recommended that results of the earlier surveys of the Pukaki Rise be re-examined, species identification reviewed, and where necessary the biomass estimates decomposed into the appropriate SBW categories.

2. 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 (Figure 1). Spawning occurs in the Bounty Platform from mid August to early September and 3–4 weeks later in the other areas (Hanchet 1998a).

A programme to estimate SBW spawning stock biomass on each fishing ground using acoustic techniques began in 1993. The results of the first survey were documented by

Hanchet *et al.* (1994) and were used in the stock assessment for that year (Hanchet & Haist 1994). The results of the second survey, in 1994, were documented by Hanchet & Ingerson (1996a), and were used in the stock assessment in 1995 (Hanchet & Ingerson 1995). The results of the third survey, in 1995, were documented by Ingerson & Hanchet (1996), and the results used in the 1996 stock assessment (Hanchet & Ingerson 1996b).

After the first three annual surveys it was decided to survey these areas biannually. The Bounty and Pukaki spawning grounds were surveyed in August and September 1997. It is intended to survey Auckland and Campbell grounds in 1998.

The current report stems from two objectives carried out under contractual arrangements with MFish.

1. To estimate biomass on Bounty Platform and Pukaki Rise during August and September 1997 using an acoustic survey (MDBW02),
2. To estimate pre-recruit and spawning biomass on Bounty Platform and Pukaki Rise from data collected during the 1997 acoustic survey (SBW9701).

The main aim of the acoustic surveys has been to develop a time series of abundance indices of recruited fish (i.e., fish which 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, and for modelling purposes the maturity and selectivity ogives are assumed to be synonymous. Modelling of the stocks suggests that less than 10% of the fish recruit to the fishery at age 2, a larger but variable proportion (ranging from 10 to 50 %) recruit at age 3, and that fish are fully recruited at age 4 (Hanchet 1998b). 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 "immature" (mainly 2 year old fish) and "juvenile" (1 year old fish) categories has been problematic due to the occurrence in some years of 1, 2, and 3 year old fish in mixed schools (Hanchet *et al.* 1994, Hanchet & Ingerson 1996a).

As in previous years, SBW acoustic marks in the current survey were therefore initially classified into adults (recruited fish), immatures (mainly 2 year olds), and juveniles (1 year olds). However, preliminary results for the Bounty Platform were unsatisfactory because all three categories included a large proportion of immature 3 year old fish from the strong 1994 year class. This was a problem because the adult index included fish which had not recruited to the fishery, and the estimate of immature fish comprised mainly 3 year old fish, and was therefore not consistent with earlier surveys. To be more accurate, and make better and fuller use of the data, the adult biomass on the Bounty Platform was redefined to include all fish 3 years or more old, and the estimates of 1 and 2 year olds and the results of the earlier surveys were adjusted accordingly.

Although no attempt was made to redefine the biomass estimates of adults and pre-recruits for the Pukaki Rise, it is acknowledged that problems exist with the estimates from earlier surveys. It is recommended that the definition of adult biomass on the Pukaki Rise also be re-examined and the appropriate analyses be carried out before the next survey and assessment of this stock.

3. Survey design

3.1 Survey area and transect allocation

3.1.1 Main survey

The suitability of various acoustic survey designs for SBW stocks was investigated by Dunn & Hanchet (1998). They examined several approaches, including the use of conventional stratified surveys and adaptive or two-phase survey designs using simulation studies. They showed that a two-phase sampling strategy (Francis 1984) was of benefit in acoustic surveys of the Bounty Platform, but not of the Pukaki Rise. Use of the two-phase methodology on the Bounty Platform led to a halving of the mean squared error, but introduced bias of up to 15%. Similar estimates of bias were obtained for the Pukaki Rise, but with much smaller reduction in mean squared error. Biases associated with the informal two-phase design used in previous acoustic surveys of SBW could not be assessed. They concluded that two-phase sampling strategies should be used for future acoustic surveys of SBW, with up to 20% of stations assigned to the second phase.

The stratification and allocation used in previous surveys of the Bounty Platform and Pukaki Rise were also reviewed by Dunn & Hanchet (1998) who examined 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 the usual fishing grounds. Allocation of phase 1 transects was based on the proportion of the total number of commercial tows (from 1990 to 1996) which had been made in each stratum. (At the time the allocation calculations were made the stratum areas were not available.)

On the Bounty Platform, stratum 2 was identified as having consistently higher catch rates, and so the allocations were adjusted to reflect this (Table 1). Four phase 2 transects were set aside for allocation during each snapshot to strata which recorded high densities in the first phase. Because of potential problems with fish movement, and to avoid excessive steaming time, the phase 2 transects were carried out whilst phase 1 was in progress. Because neither density estimates nor stratum areas were available during the survey the allocation of phase 2 transects was made on an *ad hoc* basis to the stratum where the densest marks were seen during phase 1. During both snapshots, dense marks were seen in stratum 2, and so the phase 2 transects were completed immediately after that stratum had been surveyed in phase 1. Transects in strata 1–5 were surveyed at night because past experience has suggested that acoustic biomass is underestimated using daytime transects on this ground. Transects made during the day in stratum 1 were for comparison only and not used in the estimation of biomass. Surveying began at about 1730 and continued through to about 0700 each morning.

Previous surveys have shown that pre-recruit fish are found mainly to the east of the Bounty Platform, an area with few adult fish (Figure 2, stratum 6i). There is also no evidence that the biomass estimates of the pre-recruit fish vary diurnally. Therefore, in estimating pre-recruit biomass, stratum 5 was divided into strata 5i and 6i. Transects surveyed in stratum 5i (as part of the adult survey) were used to estimate pre-recruit biomass there. Additional transects were

carried out during the day in stratum 6i to estimate the pre-recruit biomass. Any of the original "adult" transects falling in stratum 6i were not used for estimating pre-recruit biomass.

Transects on the Bounty Platform ran from a bottom depth of 200 m to the edge of the stratum boundary (usually about 550 m depth). The outer edge of the boundary was determined from the maximum depth fished historically by the fleet in each of the strata. Due to time constraints and inclement weather, transects in strata 3, 4, and 6i made at the end of snapshot 2 were run into 300 m.

On the Pukaki Rise, the stratification and allocation were very similar to those used in previous surveys. Stratum 2 was identified as having consistently higher catch rates, and so the allocation of phase 1 transects was adjusted to reflect this (*see* Table 1). Based on the marks seen during snapshot 1, the phase 1 allocation was adjusted slightly for snapshot 2. Acoustic transects were carried out day and night, between depths of 250 and 450 m. No phase 2 transects were surveyed.

The random parallel transect design of Jolly & Hampton (1990) was used in most 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 following previous surveys (Ingerson & Hanchet 1996). At times the direction of transects was altered to allow the survey to continue despite poor weather conditions. A minimum distance of 2 n. miles between the end of one transect and the start of the next reduced spatial correlation between transects in such instances.

3.1.2 High density and day time strata

To continue investigations into the reason for diurnal differences in biomass estimates an area of high adult density was surveyed during the day on the Bounty Platform. The highest adult fish density was encountered during both snapshots in the southwest portion of stratum 2 during the night time. During the second snapshot a boundary was put around the marks seen during the night and the aggregation was surveyed again during the day at a slower speed of 6 knots, with the towbody lower in the water column, to improve bottom definition. The area surveyed during the day was labelled stratum 8d (Figure 3).

3.2 Acoustic mark identification and SBW categories

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 previous experience gained from earlier acoustic surveys.

Bounty Platform

Eight trawls were carried out on the Bounty Platform using *Tangaroa* to identify marks seen whilst carrying out acoustic transects (Table 2). The length frequency distribution of SBW caught in these tows is shown in Figure 4. Apart from SBW the main catch in these tows was pale ghost shark (*Hydrolagus* sp.), and rattails (mainly *Caelorinchus aspercephalus*).

Only about 20 commercial tows were carried out on the Bounty Platform in 1997, of which 8 were observed. Most commercial tows were made immediately after the acoustic survey was completed on spawning aggregations in strata 2 and 3. The size distribution from the research and commercial tows were used to assign the main SBW marks seen during the survey into the categories used in previous surveys: juvenile (1 year olds), immature (mainly 2 year olds, but including some immature 3 year olds), and adult (mainly mature fish which have recruited into the commercial fishery).

Light marks in the north of stratum 1 were predominantly immature 3 year old fish (tow 1) and were assigned immature. Heavy marks in 400–520 m in stratum 2 were assumed to be adult fish on the basis of tows 3 and 7, on the location of the commercial fishing after the snapshot was completed, and on the density and size of the marks (which formed a loose aggregation up to 5 n.miles wide and up to 10 n.miles long). Some light marks within stratum 2 were considered to be mainly immature 2 and 3 year old fish on the basis of tow 2, and assigned immature. (Although some 1 and 4 year old fish were also caught during tow 2, these fish were disregarded in the initial analysis). No trawling was carried out in stratum 3 and light marks seen there were again assumed to be 2 and 3 year old fish and assigned immature.

Heavy marks found in stratum 4 in 400–520 m during snapshot 1 were shown to comprise mainly 3 and 4 year old fish (tow 4). Although the trawl contained a small proportion of 1 and 2 year olds and many of the 3 year old female fish were immature, the mark was assigned to the adult category. Similar marks were found slightly deeper and further north in snapshot 2, and were also assumed to be adults. An area of less dense marks in 350–430 m in the north of stratum 4 and in stratum 6i was considered to be a mixture of 1, 2, and 3 year old fish on the basis of tow 6 and assigned immature fish. No SBW marks were identified in stratum 5.

Preliminary results for each of the categories based on the above analysis were inaccurate because all three categories included a large proportion of immature 3 year olds. This was unsatisfactory because:
(i) The adult (recruited) biomass estimates included immature 3 year old fish, which would not have recruited to the fishery.
(ii) The immature category (ostensibly of mainly 2 year old fish) included a large proportion of immature 3 year olds.
(iii) The strength of the 1994 year class (3 year olds) was not being indexed effectively.

The acoustic survey covered the entire Bounty Platform area, and so fish of all ages should be fully available to the acoustic gear. Therefore, to make fuller use of the data the adult biomass on the Bounty Platform was redefined to include all fish 3 or more years old (3+). To do this

properly would require re-examining the marks on a transect by transect basis, assigning a length frequency distribution and hence target strength distribution to that mark, and then decomposing the resulting biomass by age class. It was not possible to complete this process in the time available. Instead, the mean biomass estimate for each stratum was decomposed into 1, 2, and 3+ fish on the basis of the weight of each SBW category in the length frequency sample from that stratum.

In effect, most of the biomass in strata 1, 2, and 4 were added to the new 3+ category, and the biomass from stratum 6i and the north of stratum 4 was assumed to be 10% age 1, 40% age 2, and 50% age 3+.

Preliminary examination of the results of the earlier surveys suggested that in the 1994 survey immature 3 year old fish had been included with the immature 2 year old biomass in strata 3 and 4. The results of that survey were adjusted by assuming 60% of the biomass in those strata by weight were 3 year old fish.

Pukaki Rise

Three trawls were carried out on the Pukaki Rise using *Tangaroa* to identify marks seen whilst carrying out acoustic transects (*see* Table 1). The length frequency distribution of fish caught in these tows is shown in Figure 4. Apart from tow 9, the targeted tows failed to hit dense marks, and the catches included about 300 kg of silverside, and small numbers of hoki, hake, ling, pale ghost shark, and spiny dogfish. The bycatch from tow 9 was mainly hoki, hake, and ling and equalled about 10% of the total catch for that tow.

About 35 commercial tows were carried out on the Pukaki Rise in 1997, of which 25 were observed. About half the tows were made during and immediately after snapshot 2 of the acoustic survey, and the remainder were made at the end of September. The commercial tows in early September caught predominantly SBW. The size distribution from the research and commercial tows were used as guidelines to assign the main SBW marks seen during the survey into the categories used in previous surveys: immature (mainly 2 year olds), and adult (mainly mature fish which have recruited into the commercial fishery).

During the first snapshot, light marks were seen in most transects in strata 2 and 3 in depths of 350–410 m. No trawls were carried out, but based on previous experience these were assumed to be adult SBW. During the second snapshot, dense night-time marks were seen on three transects in strata 2 and 3, again in 350–410 m. The dense marks were typical SBW spawning marks, and were fished intensively by the commercial fleet over the next few days. Although three bottom trawls were carried out near the marks during the day and caught some fish ranging from 28–50 cm, most were immature (28–35 cm) (tows 9–11). However, none of the tows hit dense marks on the bottom, and most of the catch in tow 9 was taken from a mark which extended up to 20–30 m off the bottom.

Lighter marks (some with a high vertical extent) occurred in stratum 4 in 380–430 m during both snapshots. A number of tows were made by commercial vessels in stratum 4 and the southern end of stratum 5 at the end of September which caught almost exclusively 2 year old

fish. Therefore, these marks were assigned immature. Dense marks in stratum 5 were seen in snapshot 1. Although no trawls were made on this mark, they were dense marks located hard down on the bottom and were assumed to be adult SBW.

No attempt was made to redefine the adult and pre-recruit biomass estimates for the Pukaki Rise and it is acknowledged that problems also exist with estimates from some of the earlier surveys. It is recommended that the definition of adult biomass be re-examined and the appropriate re-analysis be carried out before the next survey and assessment of this stock, planned for 1999.

3.3 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 weight-length relationships, which apply to spawning fish, were taken from Hanchet (1991). The following target strength-fork length relationship was used,

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

where TS is target strength in decibels and FL is fork length in centimetres (*see* Hanchet *et al.* 1994 for further details). The same relationship was used for acoustic surveys of blue whiting in the Northern Hemisphere (Monstad *et al.* 1992). The relationship is derived from target strength measurements of individual fish made by Nakken & Olsen (1977), which were later re-analysed by Foote (1980), and has been further modified in line with field observations (T. Monstad, Institute of Marine Research, Bergen, Norway, pers. comm.). Split beam and deconvolution estimates of the target strength of small SBW (under 35 cm) from New Zealand waters are in good agreement with the Northern Hemisphere relationship (McClatchie *et al.* 1998).

Adult SBW were assumed to have the length distribution caught by the commercial fishery, except for stratum 4 in the Bounty Platform which contained a high proportion of 3 year olds so, *Tangaroa* data were used for that area (tow 4 Figure 4). The length frequency distributions for immature and juvenile fish were taken from the *Tangaroa* tows. On the Bounty Platform, the mean lengths of immature fish were 31 cm in strata 1 and 2, and 25 cm in stratum 6i, and mean length of juvenile fish was 19 cm. The mean length of immature fish on Pukaki Rise was 25 cm.

No allowance has been made for the contribution of other species to the backscattering assigned to the SBW categories.

In the acoustics analysis the mean SBW stratum density 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 in Cordue (1991).

3.4 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. For the period before the commercial fleet arrived (17 to 24 August) *Tangaroa* samples were used. 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 either spawned and left the area before the survey began, or if new fish arrived on the ground after the survey had ended. The gonad data were therefore examined to determine whether large numbers of spent fish were present in the area before the survey began (and which might have subsequently left the area), or if there was a large increase in spent fish followed by an increase in maturing fish (i.e., fish which hadn't already spawned that year) after the survey had been completed.

4. Results

4.1 Acoustic biomass estimates

4.1.1 Bounty Platform

The preliminary results of the two snapshots completed on the Bounty Platform are shown in Tables 3a and 3b and Figures 2, 5, and 6. During snapshot 1, adults were mainly confined to strata 2 and 4 in 400–520 m (*see* Table 3a, Figure 5). The estimated biomass was 78 200 t (*c.v.* = 49%), with most (53 000 t) in stratum 4. Few adult SBW were seen in the rest of the survey area. Less dense marks of immature fish were seen in 400–450 m around much of the survey area with the densest marks in strata 4 and 6i, resulting in an immature biomass estimate of 14 600 t (*c.v.* = 69%). Few marks of only juvenile fish were encountered and these were in strata 1 and 2.

During the second snapshot the adults were again confined to strata 2 and 4. The estimated biomass was 36 800 t (*c.v.* = 43%) with 25 000 t in stratum 2. Less immature fish were encountered in the second snapshot and these were mainly in strata 1 and 6i. Again few juvenile fish were encountered and these were in stratum 1.

Revised estimates of adult (3+), immature (2 year old), and juvenile (1 year old) biomass are given by stratum in Table 3b.

A high density stratum (stratum 8d) within stratum 2 was created for comparison of night/day adult biomass estimates. The boundaries were chosen on the basis of the marks seen during night-time transects. Transect densities from stratum 8d are shown in Figure 3. The total day time biomass for 8d (1300 t) represents only 5% of the night time biomass for stratum 2 (Table 3c).

4.1.2 Pukaki Rise

Results of the two snapshots completed on Pukaki Rise are shown in Table 4 and Figures 7 and 8. In the first snapshot, SBW marks were found around the southern half of the Rise in strata 2, 3, 4, and the southern portion of 5. The densest marks and most biomass were in stratum 5. Snapshot 1 gave an adult biomass estimate of 32 450 t (*c.v.* = 41%). During the second snapshot, dense night time spawning marks were seen on 3 transects in strata 2 and 3 in 350–410 m. Snapshot 2 gave an adult biomass estimate of 30 112 t (*c.v.* = 57%).

During snapshot 1, immature fish were encountered in all strata but the greatest density was in stratum 4. The immature biomass for the first snapshot was 4600 t (*c.v.* = 14%), of which 3400 t were in stratum 4. During the second snapshot less immature fish were encountered and the biomass estimate was 1700 t (*c.v.* = 23%). The distribution was similar to that during the first snapshot with most fish in stratum 4, and small numbers of fish occurring in all other strata except stratum 5.

No juvenile fish were encountered in either snapshot.

4.2. Gonad data

The main spawning on the Bounty Platform started on 29 August. Increasing numbers of ripe and running ripe fish were seen on 30 and 31 August but no spent and only a few immature/resting fish were present indicating that this was the first spawning (*see* Table 5).

The timing of spawning on the Pukaki Rise may have been a little earlier than usual, in contrast to the Bounty Platform. Spawning was under way by 2 September with mainly ripening, ripe, or running ripe fish present in equal proportions (*see* Table 5). A second spawning event was also fished by commercial vessels from 25 to 27 September. A high proportion of spawning and spent fish were noted on 25 September with only a few ripening or ripe fish. On the following 2 days the proportion of spawning and spent fish tapered off, no more ripening or ripe fish were present, and an increasing proportion of fish were in stage 1 (immature/resting). A second spawning event 10–14 days after the main spawning has been noted previously on both the Bounty Platform and the Campbell Island Rise (Hanchet 1998a).

There was no evidence of turnover on either ground from the gonad data.

4.3. Previous acoustic surveys

The results of the re-analysis of the 1994 survey of the Bounty Platform are shown in Table 6.

5. Discussion

5.1 Biomass estimation by area

5.1.1 Bounty Platform

The main aggregation on the southwest side of the Bounty Platform (stratum 2) was surveyed twice. This aggregation appeared relatively stable at night over both snapshots. However, the large aggregation containing a higher proportion of 3 year old fish in the southeast (stratum 4) appeared more mobile and in hindsight the sampling density in this large stratum was too low. No significant amounts of fish were found beyond the stratum boundaries, although on at least two occasions dense schools were seen in stratum 4 while steaming between transects.

The timing of the survey was reasonably good this year because the fish were already aggregated and the survey was carried out immediately before spawning. There is no reason to suspect that either snapshot estimate is biased, so the snapshots were averaged to give the best estimate. The revised adult biomass estimate was 64 600 t.

The adult (3+) biomass estimate in 1997 is similar to the 1994 estimate (Table 6). The adult biomass in 1993 is thought to have been overestimated through double-counting (Hanchet *et al.* 1994, Hanchet 1998b). The 1995 biomass is thought to have been an underestimate as fish extended beyond the stratum boundaries, and not all strata were surveyed during the second snapshot (Ingerson & Hanchet 1996, Hanchet 1998b).

The mean biomass estimates of immature and juvenile fish were about 2000 t and 620 t respectively.

As in all the surveys to date, adult densities observed during the day were very much lower than at night. Some possible reasons for these differences were discussed by Hanchet & Ingerson (1996a). They considered that lateral avoidance, changes in fish density distribution, and bottom shadowing were the most likely reasons for these differences.

This is the first attempt to decompose the SBW acoustic biomass estimates into the various age categories. Because of time constraints it was not possible to carry this out in a rigorous manner and so the revised estimates from the current analysis should still be regarded as preliminary. It is recommended the appropriate re-analysis be carried out before the next survey and assessment of this stock, planned for 1999.

No allowance has been made for the contribution of other species to the backscattering assigned to the SBW categories. The bycatch of other species in the commercial fishery is negligible (Hanchet *et al.* 1994), and it is considered that the contribution of other species to the acoustic backscattering from the dense adult SBW marks would be negligible. Species mix is likely to be a greater problem for the less dense juvenile and immature marks. However, these are used as relative abundance indices in the modelling.

5.1.2 Pukaki Rise

Both snapshots gave similar biomass results overall, but the strata in which the biomass mainly occurred were different. In snapshot 1 a dense aggregation was encountered in one transect to the east of the Pukaki Rise in the southern portion of stratum 5. In snapshot 2, dense night-time spawning aggregations were surveyed to the southwest in strata 2 and 3, where the commercial fleet operated. It is suspected that adult fish resident to the east of the Pukaki Rise (well outside the survey area) migrate west towards stratum 5, and then south towards strata 2 and 3. It is therefore possible that the aggregation encountered in stratum 5 in snapshot 1, was then surveyed 5 days later in snapshot 2 on the recognised spawning ground in strata 2 and 3.

There is no reason to suspect that either snapshot estimate is biased, so the snapshots were averaged to give the best estimate. The mean biomass estimate from the two snapshots was 31 282 t (*c.v.* = 35%). It should be noted that this estimated *c.v.* reflects sampling error. Other sources of uncertainty (e.g., target strength, target identification, calibration, etc) were not quantified.

The 1997 survey estimate is higher than the 1995 estimate (*see* 6) which was thought to be an underestimate because the survey was carried out well before spawning had started (Hanchet 1998b). It is lower than the 1993 and 1994 survey estimates (*see* 6), where there is some doubt over the target identification (Hanchet 1998b). In the 1993 survey, the adult biomass was over-estimated because of the inclusion of immature 2 year olds with the adult biomass (Hanchet *et al.* 1994). In the 1994 survey, the adult biomass was over-estimated because of the inclusion of immature 3 year olds with the adult biomass (Hanchet & Ingerson 1996a). It is believed that the 1997 estimate is the most reliable estimate to date because it is the first time that the Pukaki Rise has been surveyed whilst spawning has been in progress, and the first where there has been virtually no problem of inclusion of immature SBW or other species in the adult biomass.

No juvenile fish (1 year olds) were encountered in either snapshot, and it is suspected that on the Pukaki Rise they inhabit shallower water.

No attempt was made to redefine the adult and pre-recruit biomass estimates for the Pukaki Rise and it is acknowledged that some problems exist with the estimates available from previous surveys. It is recommended that to make better use of the data the definition of adult biomass be re-examined and the appropriate re-analysis be carried out before the next survey and assessment of this stock, planned for 1999.

No allowance has been made for the contribution of other species to the backscattering assigned to the SBW categories. The bycatch of other species in the commercial fishery is negligible (Hanchet *et al.* 1994), and it is considered that the contribution of other species to the acoustic backscattering from the dense adult SBW marks would be negligible. Species mix is likely to be a greater problem for the less dense immature marks, however, these are used as relative abundance indices in the modelling.

5.2 Mark identification

With four 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 aided in confirmation of 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 the small schooling midwater fish such as the common lanternfish (*Lampanectodes hectoris*) and pearlside (*Maurolicus muelleri*) 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 marks which are easily identified as SBW.

Case 1 is a particular problem on the Pukaki Rise where pre-recruit and adults are usually found in similar depths. During the day, the adult marks tend to be denser and hard down on the bottom, but during the night, when fish are pre-spawning, the two categories are harder to separate. In these cases it will always be necessary to carry out tows for a positive identification and to collect a length frequency distribution. On the Bounty Platform, spawning adults tend to be in different strata from the pre-recruit fish.

Case 2 is a problem on both grounds. There appear to be no consistent differences between marks comprising immature 1, 2, and 3 year old SBW, and it will always be necessary to carry out tows for a positive identification and to collect a length frequency distribution.

Case 3 is more difficult as a single sampling device will not sample such different sized species quantitatively, the targets are mobile, and there are no data available from the commercial fleet. The most practical approach may be to devote some time to categorising these types of marks, following any changes in their appearance and location especially over the 2 hours around dawn and dusk; then target each mark type with appropriate trawls to establish their identity. This would require setting time aside at the appropriate time of the day.

Case 4 is only resolvable by doing more background trawls. This uncertainty is, however, unlikely to significantly affect the overall biomass result.

Very few target identification tows were carried out by *Tangaroa* in 1997 and these were mainly to resolve instances of case 1 and 2. On the Bounty Platform, tows were usually carried out during the day leaving the night-time to acoustic transects. A prolonged period of marginal weather slowed progress through the acoustic transects which left less time for trawling, especially on the Pukaki Rise. In future more time should be set aside to ensure progress continues to be made in resolving these uncertainties.

5.3 Survey design

The two-phase sampling strategy used for the 1997 survey appeared to be moderately successful, although the target *c.v.* of 30% for adult biomass was slightly exceeded in both areas. On the Bounty Platform, inclusion of four second phase transects in stratum 2 during both snapshots reduced the *c.v.*s and would have helped in obtaining the consistent biomass estimates between snapshots. In contrast, in stratum 4 the initial number of transects was low, biomass estimates from the two snapshots were quite different, and the *c.v.*s were high. Inclusion of second phase transects in stratum 4 would undoubtedly have helped provide more consistent biomass estimates between snapshots, and would have reduced the *c.v.*s. Despite the slight increase in bias (Dunn & Hanchet 1998), it is recommended that future surveys have a greater proportion of transects allocated to the second phase.

The change in stratification and allocation of transects also proved to be reasonably successful, and should be retained for future surveys. Dunn & Hanchet (1998) identified two areas of reasonably high commercial catch rates on the Bounty Platform (in stratum 2 and 4), where aggregations were found during the 1997 survey. The aggregation in stratum 4 was dominated by young fish, and this may be a preferred spawning ground for first time spawners. A similar occurrence has been noted for the Campbell Island stock by Hanchet (1998a).

The stratification on the Pukaki Rise may still need some refinement. If fish are moving on to the Rise from the east then one would expect consistently higher transect densities in the east of the survey area before the spawning starts. (This may not necessarily be reflected in the catch rates from the commercial fishery - which tend to fish there during the spawning season). Because the acoustic surveys may sometimes be carried out before the fish start spawning the stratum 4 boundary should be moved north towards 49° 15'S to encompass such pre-spawning aggregations in future.

6. Recommendations

1. Review the target identifications that have been used in previous surveys of these grounds.
2. Redefine the definition of adults on the Pukaki Rise.
3. Decompose SBW categories where marks comprise fish from more than one category.
4. Carry out more tows to get better data on the size composition of marks.
5. Carry out a higher percentage of phase 2 transects.
6. Move the stratum Pukaki 4/5 boundary north to ensure better sampling of pre-recruit schools.

7. Acknowledgments

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8. References

Burczynski, J. 1979: Introduction to the use of sonar systems for estimating fish biomass. *FAO Fisheries Technical Paper No. 191.* 89 p.

Cordue, P. L. 1991: Hoki acoustic biomass indices for the west coast South Island 1988, 1989, and 1990. N.Z. Fisheries Assessment Research Document 91/11. 31 p.

Dunn, A. & Hanchet, S.M. 1998: Two-phase acoustic survey designs for southern blue whiting on the Bounty Platform and the Pukaki Rise. *NIWA Technical Report* 28. 29 p.

Foote, K.G. 1980: Averaging of fish target strength functions. Journal of the Acoustics Society of America 67 (2): 504–515.

Francis, R.I.C.C. 1984: An adaptive survey for stratified random trawl surveys. *New Zealand Journal of Marine and Freshwater Research 18*: 175–194.

Hanchet, S.M. 1991: Southern blue whiting fishery assessment for the 1991–92 fishing year. N.Z. Fisheries Assessment Research Document 91/7. 48 p.

Hanchet, S.M. 1998a: A review of southern blue whiting (*M.australis*) stock structure. N.Z. Fisheries Assessment Research Document 98/8. 28 p.

Hanchet, S.M. 1998b: Southern blue whiting (*M.australis*) stock assessment for the Bounty Platform and Pukaki Rise for 1998 and 1999. N.Z. Fisheries Assessment Research Document 98/32. 33 p.

Hanchet, S. M., Chatterton, T. D., & Cordue, P. L. 1994: Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, Pukaki Rise, and Campbell Island Rise, August-September 1993. N.Z. Fisheries Assessment Research Document 94/23 38 p.

Hanchet, S.M., & Haist, V. 1994: Southern blue whiting (*Micromesistius australis*) fishery assessment for the 1994–95 fishing year. N.Z. Fisheries Assessment Research Document 94/22. 41 p.

Hanchet, S. M. & Ingerson, J. K. V. 1995: Southern blue whiting (*Micromesistius australis*) fishery assessment for the 1994–95 fishing year. N.Z. Fisheries Assessment Research Document 95/20. 37 p.

Hanchet, S. M. & Ingerson, J. K. V. 1996a: Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, Pukaki Rise, and Campbell Island Rise, August-September 1994. N.Z. Fisheries Assessment Research Document 96/3. 28 p.

Hanchet, S. M. & Ingerson, J. K. V. 1996b: Southern blue whiting (*Micromesistius australis*) fishery assessment for the 1995–96 fishing year. N.Z. Fisheries Assessment Research Document 96/12. 34 p

Ingerson, J. K. V. & Hanchet, S. M. 1996: Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, Pukaki Rise, Auckland Islands Shelf, and Campbell Island Rise, August-September 1995. N.Z. Fisheries Assessment Research Document 96/18. 29 p.

Jolly, G. M. & Hampton, I. 1990: A stratified random transect design for acoustic surveys of fish stocks. *Canadian Journal of Fisheries and Aquatic Sciences 47*: 1282–1291.

McClatchie, S., Macaulay, G., Hanchet, S., Coombs, R.F. 1998: Target strength of southern blue whiting (*M.australis*) using swimbladder modelling, split beam and deconvolution. *ICES Journal of Marine Science 55:* 482-493.

Monstad, T., Borkin, I. & Ermolchev, V. 1992: Report of the joint Norwegian-Russian acoustic survey on blue whiting, spring 1992. *ICES C.M. 1992/H:6, Pelagic Fish Committee.* 26 p.

Nakken, O. & Olsen, K. 1977: Target strength measurements of fish. *Rapports et Process-verbaux des Reunions. Conseil International pour l'Exploration de la Mer 170:* 52–69.

Table 1: Stratum areas and numbers of transects per snapshot for each spawning ground. For stratum boundaries *see* Figure 1. d, day strata

Stratum	Stratum area (km^2)		Number of transects			
			Snapshot 1		Snapshot 2	
	Snapshot 1	Snapshot 2	Phase 1	Phase 2	Phase 1	Phase 2
Bounty Platform			17–23 August		23–27 August	
1d	1 319	1 319	3	–	–	–
1	1 319	1 319	3	–	3	–
2	1 308	1 308	7	4	7	4
3	1 857	1 163	4	–	4	–
4	2 643	1 956	4	–	4	–
5	4 952	4 360	3	–	3	–
6i	2 761	2 169	4		4	
Total			28	4	25	4
Pukaki Rise			29–31 August		2–5 September	
1	676	676	3	–	3	–
2	1 247	1 247	7	–	6	–
3	813	813	4	–	4	–
4	1 147	1 147	3	–	4	–
5	1 765	1 765	3	–	3	–
Total			20	0	20	0

Table 2: Trawl station details for TAN9710. Ages present in the sample. All trawls (except station 5 which was a mid-water trawl) were made using the orange roughy wing trawl. *, burst window

Stn.	Stratum	Area	Date	Start position		Depth of gear		SBW	Ages
				Latitude	Longitude	Start	Finish	(kg)	
1	1	Bounty	17 Aug 97	47 40.7	178 31.1	410	430	350	3
2	2	Bounty	18 Aug 97	47 58.2	178 26.0	518	512	86	mainly 1&3
3	1/2	Bounty	18 Aug 97	47 53.2	178 23.2	514	464	1130*	≥ 5
4	4	Bounty	21 Aug 97	48 19.7	179 52.1	483	473	240*	mainly 3&5
5	4	Bounty	21 Aug 97	48 18.3	179 55.2	458	468	0	–
6	6i	Bounty	18 Aug 97	47 59.9	179 40.1	420	425	89	1, 2&3
7	2	Bounty	24 Aug 97	48 05.5	178 45.3	431	430	40	≥ 5
8	3	Bounty	26 Aug 97	48 14.7	179 13.6	331	404	0	–
9	2	Pukaki	02 Sep 97	49 27.8	171 24.7	388	333	338*	mainly 2
10	3	Pukaki	03 Sep 97	49 32.9	171 58.8	385	320	41	mainly 2
11	3	Pukaki	05 Sep 97	49 35.3	171 55.2	390	387	80	mainly 2

Table 3a: Stratum area (km²), preliminary biomass, and *c.v.* by stratum and snapshot for the Bounty Platform for night-time strata only; for immature and juvenile estimates stratum 5 was subdivided into 5i and 6i (see text for details)

		Adults		Immature		Juvenile	
Stratum	Area	Biomass (t)	c.v. (%)	Biomass (t)	c.v. (%)	Biomass (t)	c.v. (%)
Snapshot 1							
1	1 319	2 216	82	273	111	185	110
2	1 308	23 049	67	154	100	44	98
3	1 857	75	99	0	0	0	0
4	2 643	52 902	66	8 491	99	0	0
5	4 952	0	0	-	-	-	-
5i	2 191	-	-	0	0	0	0
6i	2 761	-	-	5 660	99	0	0
Total	14 840	78 242	49	14 578	69	229	91
Snapshot 2							
1	1 319	0	0	1 211	112	178	97
2	1 308	25 044	48	41	99	0	0
3	1 163	102	91	575	102	0	0
4	1 956	11 638	89	89	96	0	0
5	4 360	0	0	-	-	-	-
5i	2 191	-	-	0	0	0	0
6i	2 169	-	-	2 591	50	0	0
Total	12 275	36 784	43	4 507	44	178	97
Best estimate		Adults		Immature		Juvenile	
Total		57 513	36	9 543	54	204	67

Table 3b: Revised biomass estimates (t) by stratum for the Bounty Platform (both snapshots combined)

Stratum	Adult (3+)	Immature	Juvenile
1	1 788	59	185
2	24 125	16	25
3	347	29	0
4	36 291	256	13
5i	0	0	0
6i	2 081	1 645	400
Total	64 632	2 005	623

Table 3c: Comparison of day and night biomass estimates from strata on the Bounty Platform

			Adult	
Snapshot	Stratum	Stratum area	Biomass (t)	*c.v.* (%)
2	8d	193	1 300	63
	2	1 308	25 044	48

Table 4: Stratum area (km^2) and biomass by stratum and snapshot for the Pukaki Rise

			Adults		Immature	
	Stratum	Area	Biomass (t)	*c.v.* (%)	Biomass (t)	*c.v.* (%)
Snapshot 1						
	1	676	0	80	441	34
	2	1 247	2 944	26	339	99
	3	813	3 398	46	252	59
	4	1 147	1 785	94	3 436	14
	5	1 765	24 324	54	146	137
Total		5 648	32 451	41	4 614	14
Snapshot 2						
	1	676	0	0	27	0
	2	1 247	15 143	71	101	100
	3	813	14 969	89	51	99
	4	1 147	0	0	1 494	25
	5	1 765	0	0	0	0
Total		5 648	30 112	57	1 673	23

Best estimate	Adults (t)	*c.v* (%)	Immature (t)	*c.v* (%)
Total	31 282	35	3 144	12

Table 5: Percentage of females at each gonad stage from *Tangaroa* and 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
Bounty Platform						
17-Aug-97	87	91	9	0	0	0
18-Aug-97	220	31	68	1	0	0
21-Aug-97	135	43	53	4	0	0
22-Aug-97	197	98	2	0	0	0
24-Aug-97	41	10	85	5	0	0
28-Aug-97	173	1	55	44	1	0
29-Aug-97	332	0	33	58	9	0
30-Aug-97	318	1	1	60	38	0
31-Aug-97	61	5	15	67	13	0
Pukaki Rise						
2-Sep-97	237	0	32	31	35	2
3-Sep-97	551	1	36	51	11	1
4-Sep-97	483	2	6	77	13	2
5-Sep-97	185	3	27	34	34	2
6-Sep-97	502	8	12	55	21	4
7-Sep-97	61	95	2	3	0	0
25-Sep-97	81	40	1	7	28	23
26-Sep-97	136	77	0	0	7	15
27-Sep-97	86	93	0	0	2	5

Table 6: Revised mid-season estimates of adult and pre-recruit biomass (t) from acoustic surveys on Bounty Platform and Pukaki Rise. SSB, spawning stock biomass

	Bounty Platform			Pukaki Rise	
Year	Adults (3+)	Age 2	Age 1	Adults (SSB)	Age 2
1993	94 600	5 900	7 200	*49 800	26 300
1994	64 000		200	*39 000	200
1995	35 200	0	93 300	12 800	30
1997	64 600	2 000	620	31 000	3 100

* Includes some immature 2 or 3 yr old fish.

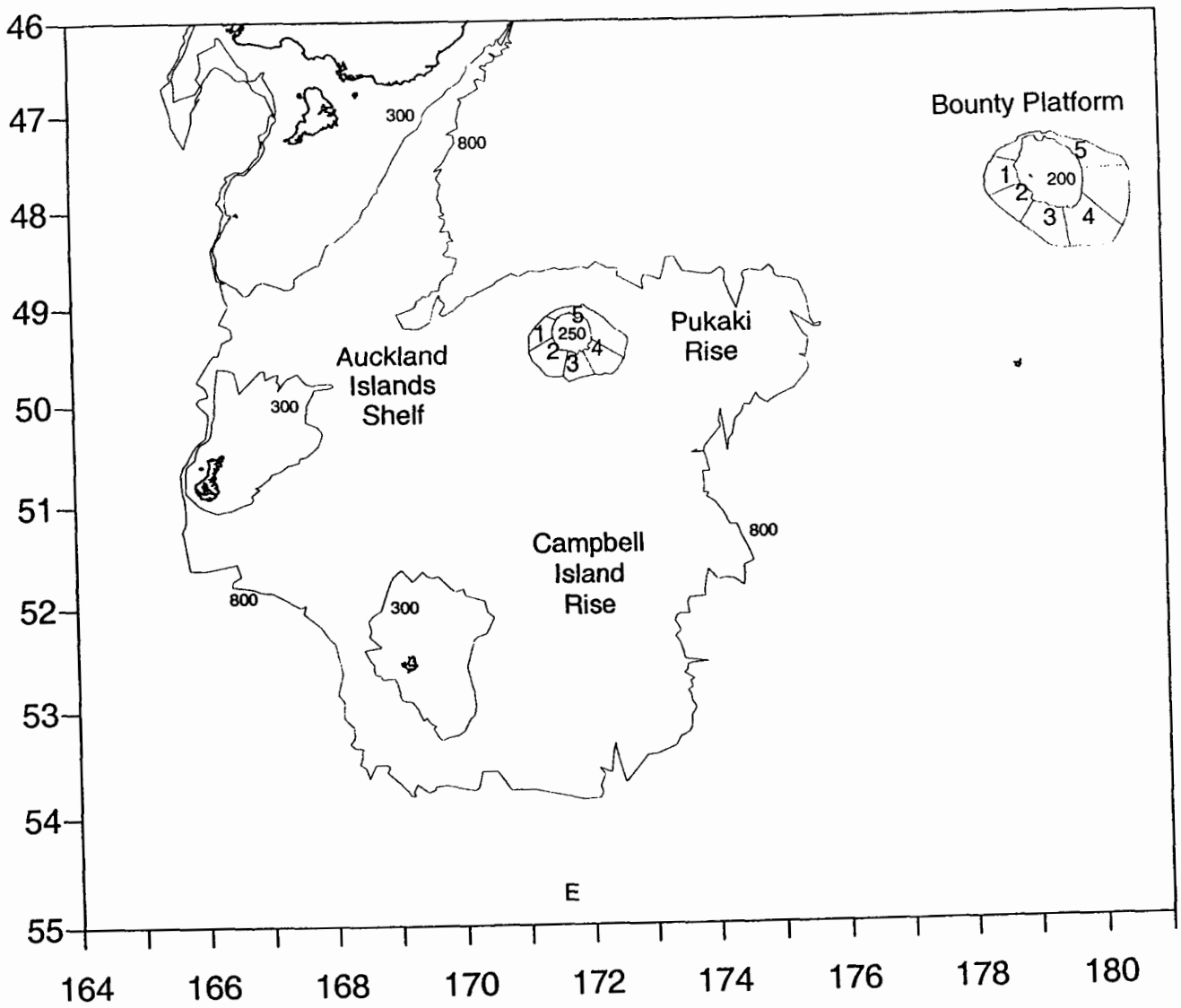
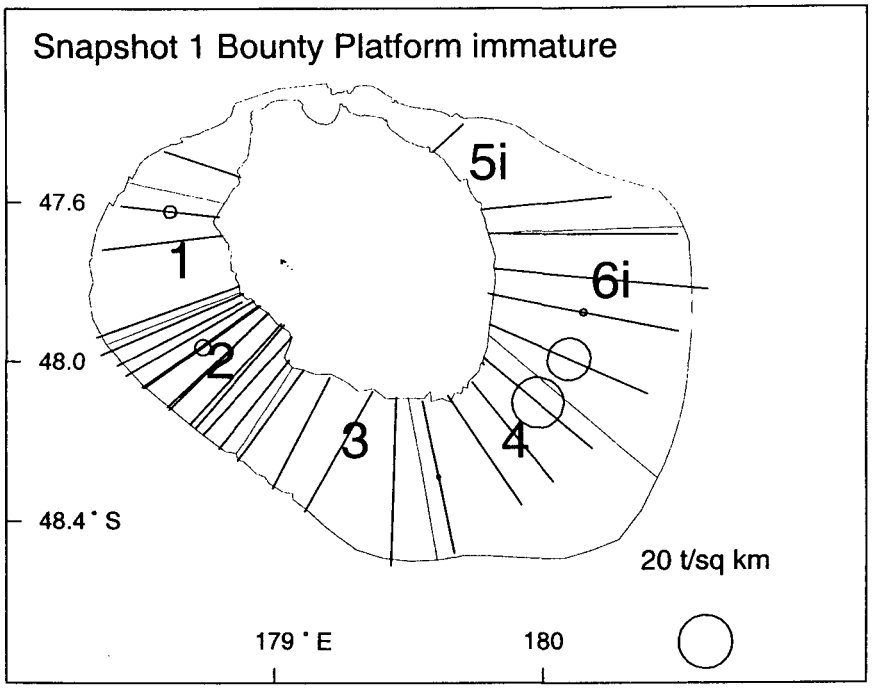


Figure 1:Survey area and stratum boundaries for TAN9710.



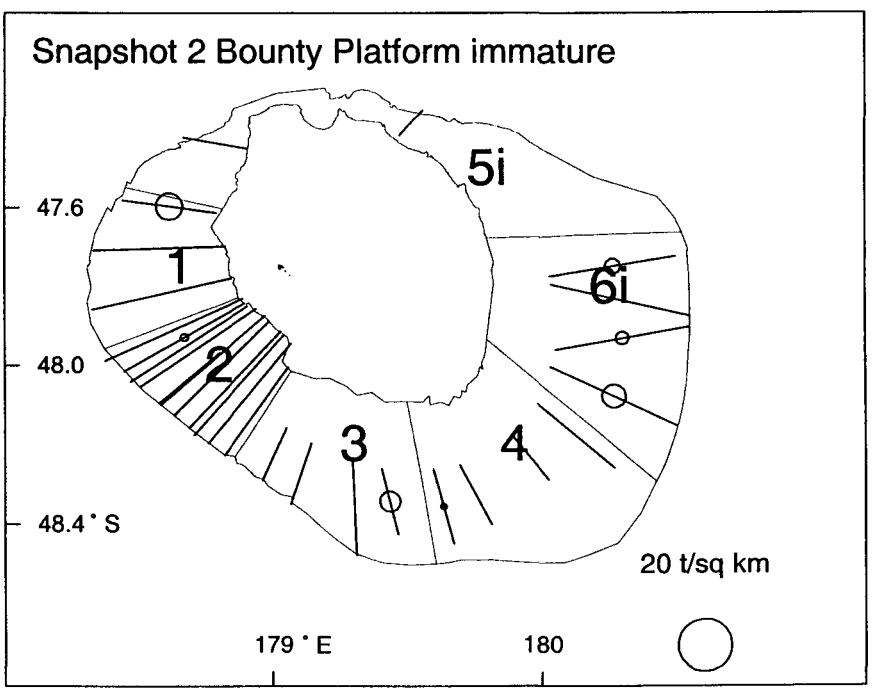


Figure 2: Density estimates of immature southern blue whiting (t. km^{-2}) by transect for snapshots 1 and 2 on the Bounty Platform.

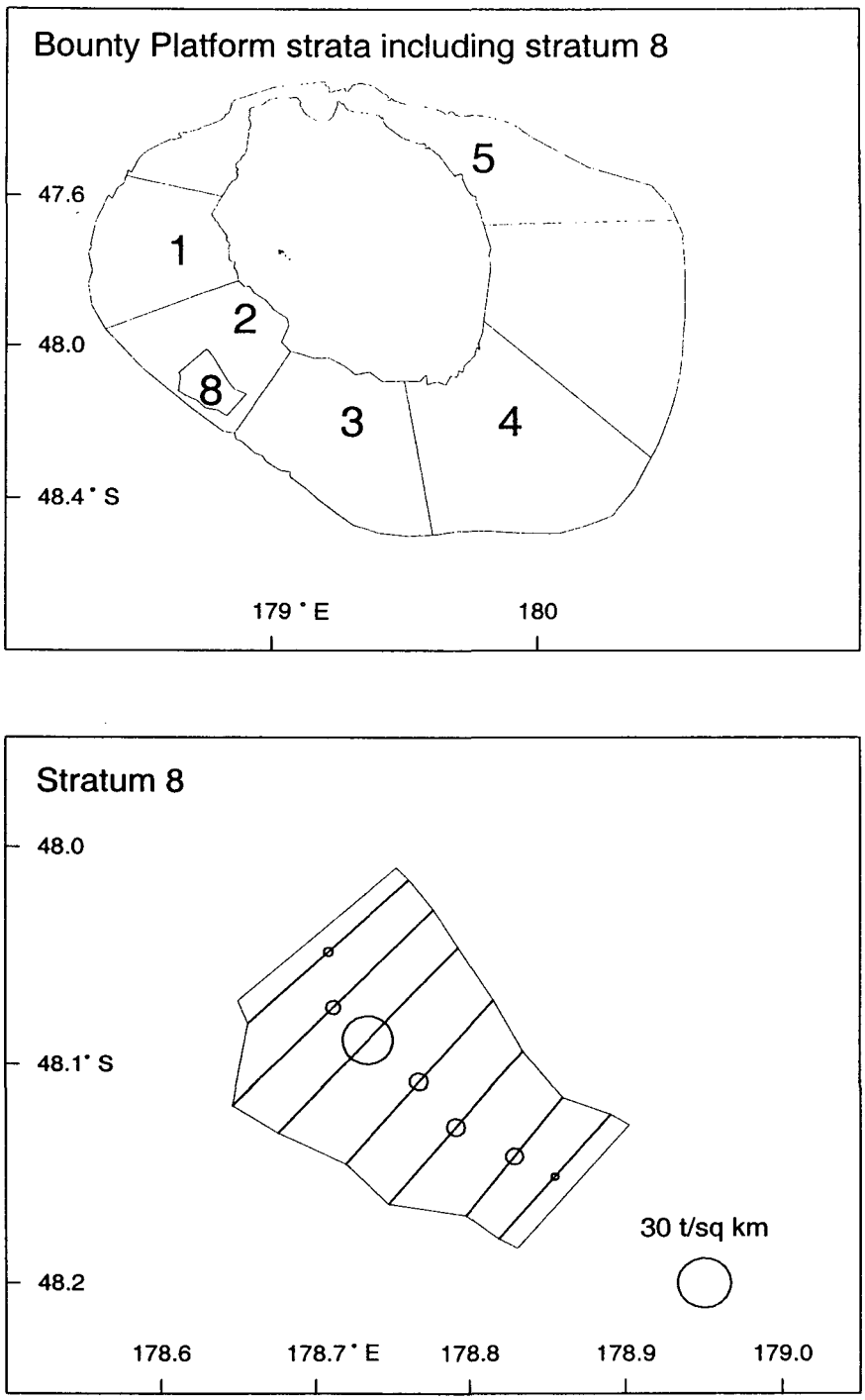


Figure 3: Bounty Platform showing location of stratum 8, the daytime high density stratum, and the five adult strata. Density estimates of adult southern blue whiting (t. km^{-2}) by transect are given for stratum 8.

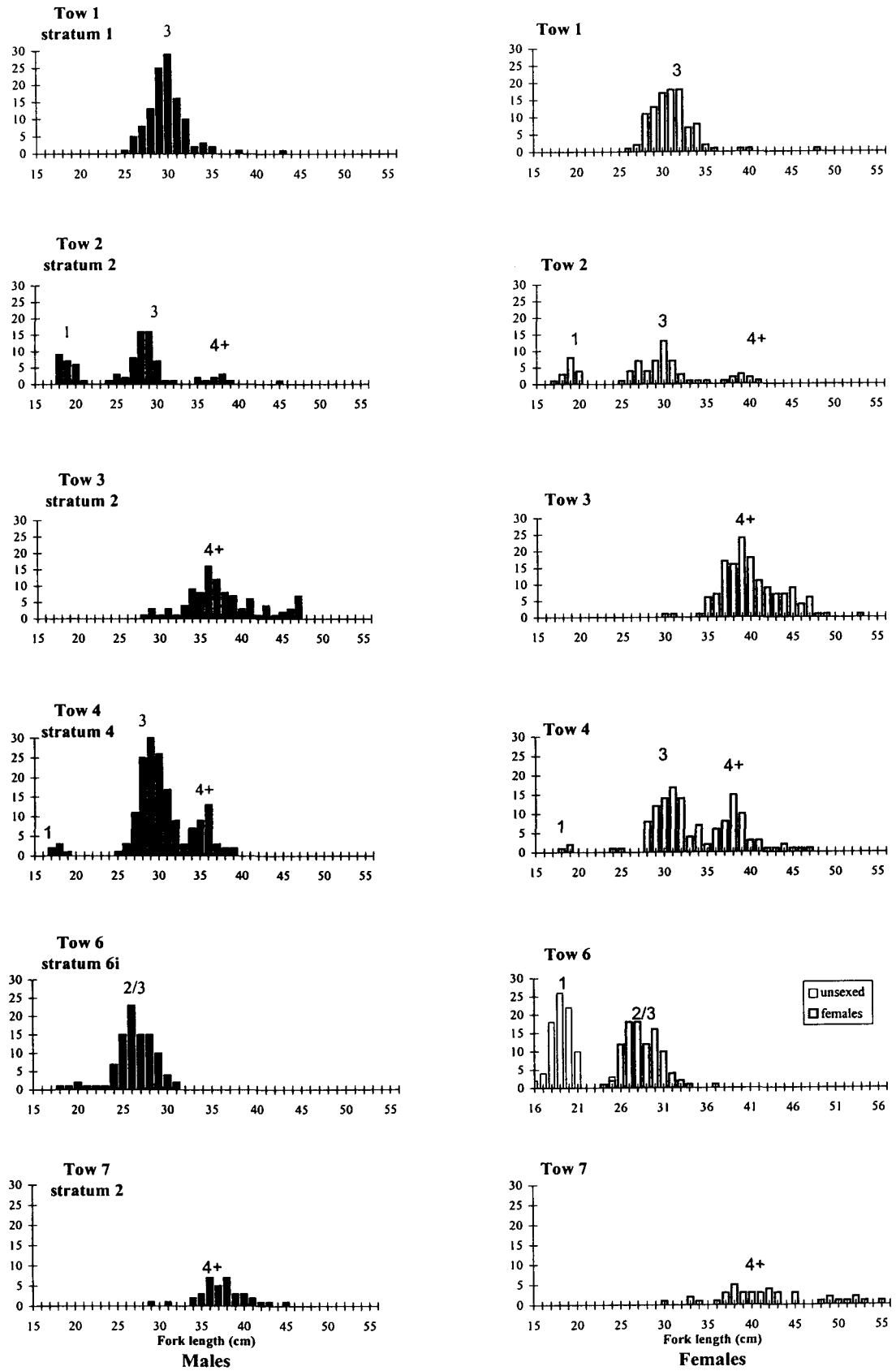


Figure 4: Unscaled length frequency distributions of southern blue whiting for each *Tangaroa* trawl station and for observer data collected on the Bounty Platform and Pukaki Rise during the 1997 spawning season.
Modal lengths of strong year classes are shown.

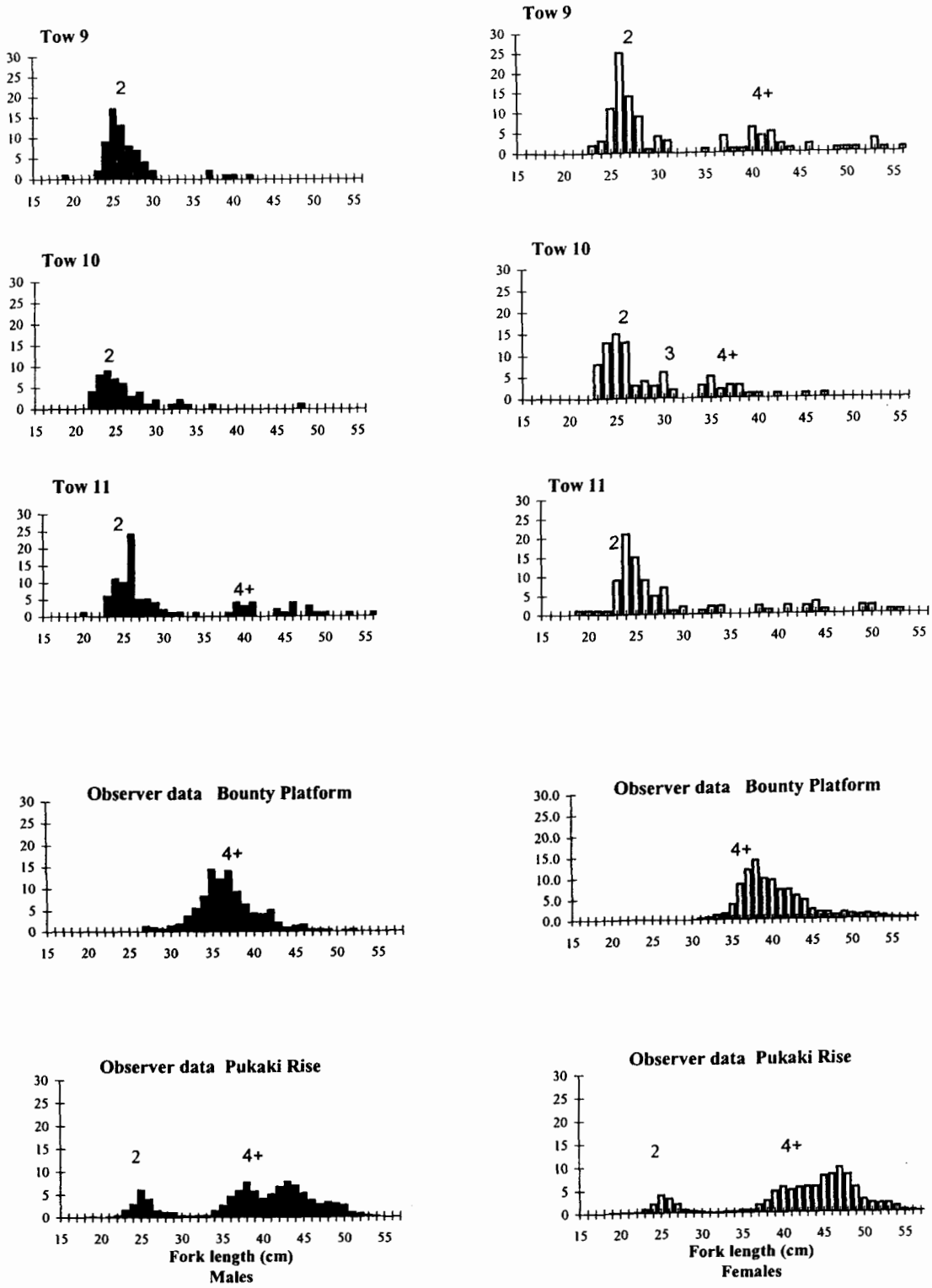
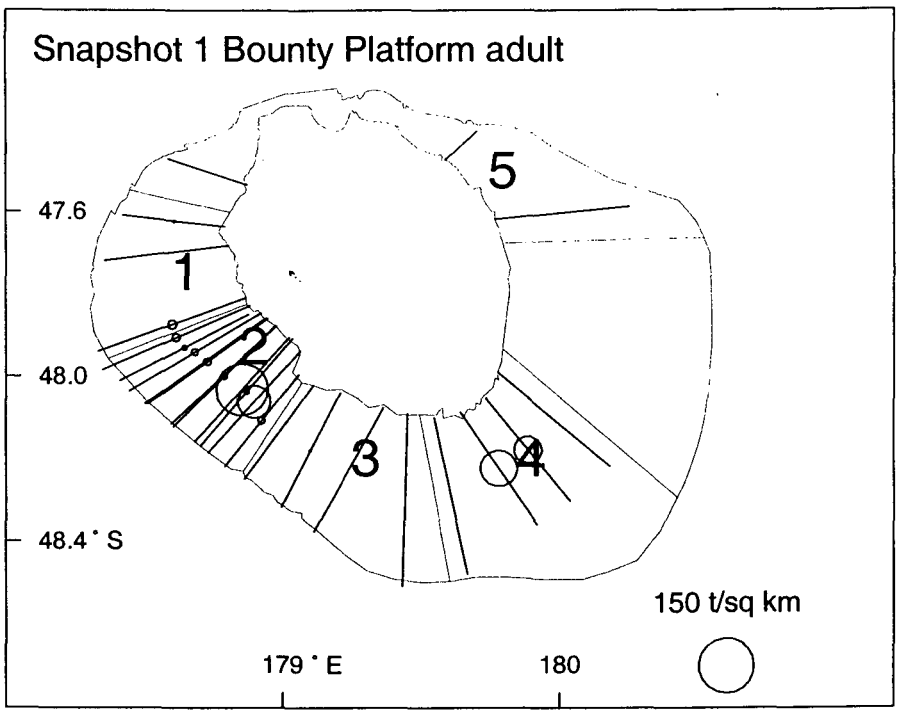


Figure 4: *continued*



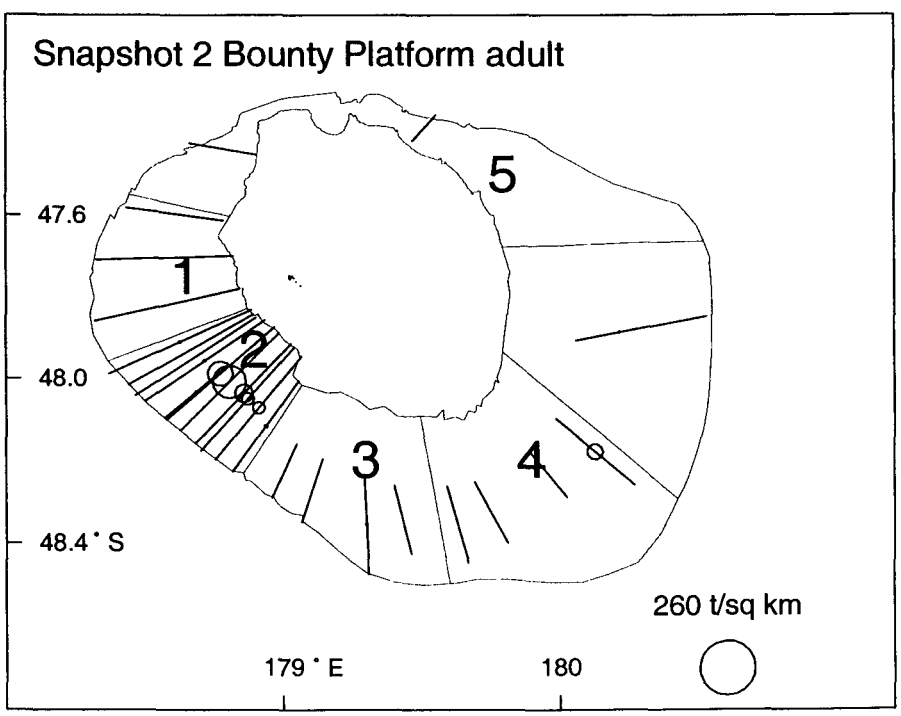


Figure 5: Density estimates of adult southern blue whiting (t. km^{-2}) by transect for snapshots 1 and 2 on the Bounty Platform.

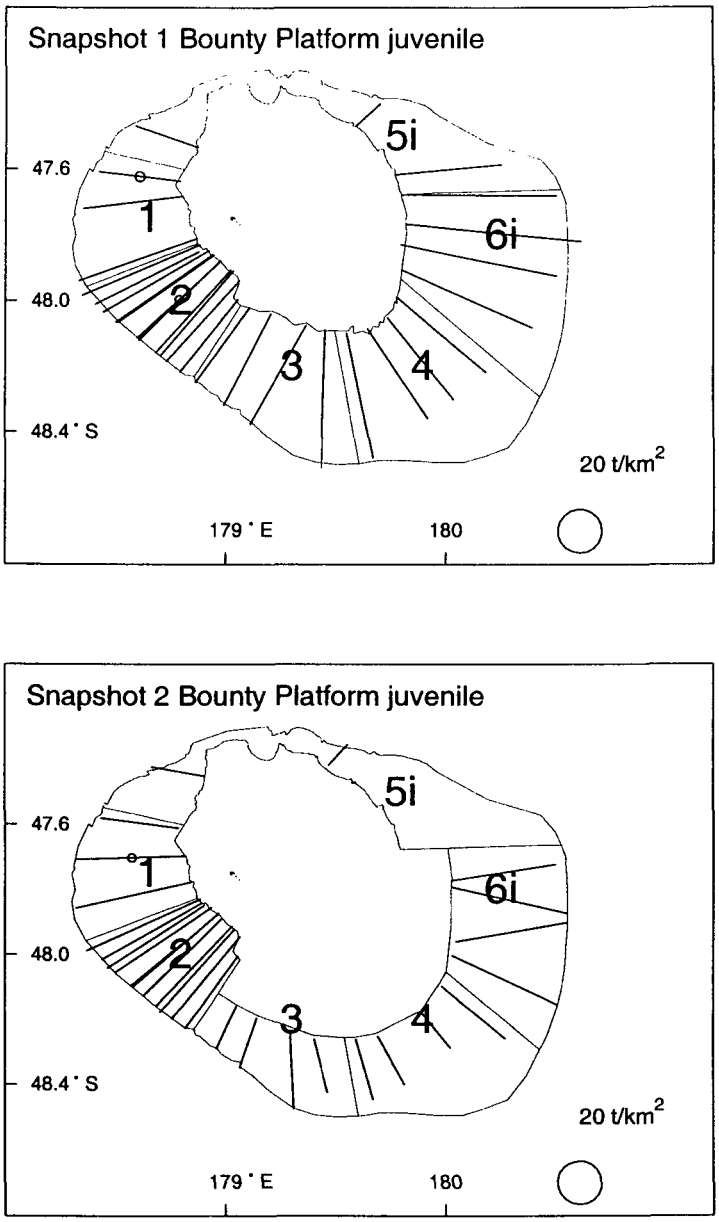


Figure 6: Density estimates of juvenile southern blue whiting (t. km^{-2}) by transect for snapshots 1 and 2 on the Bounty Platform.

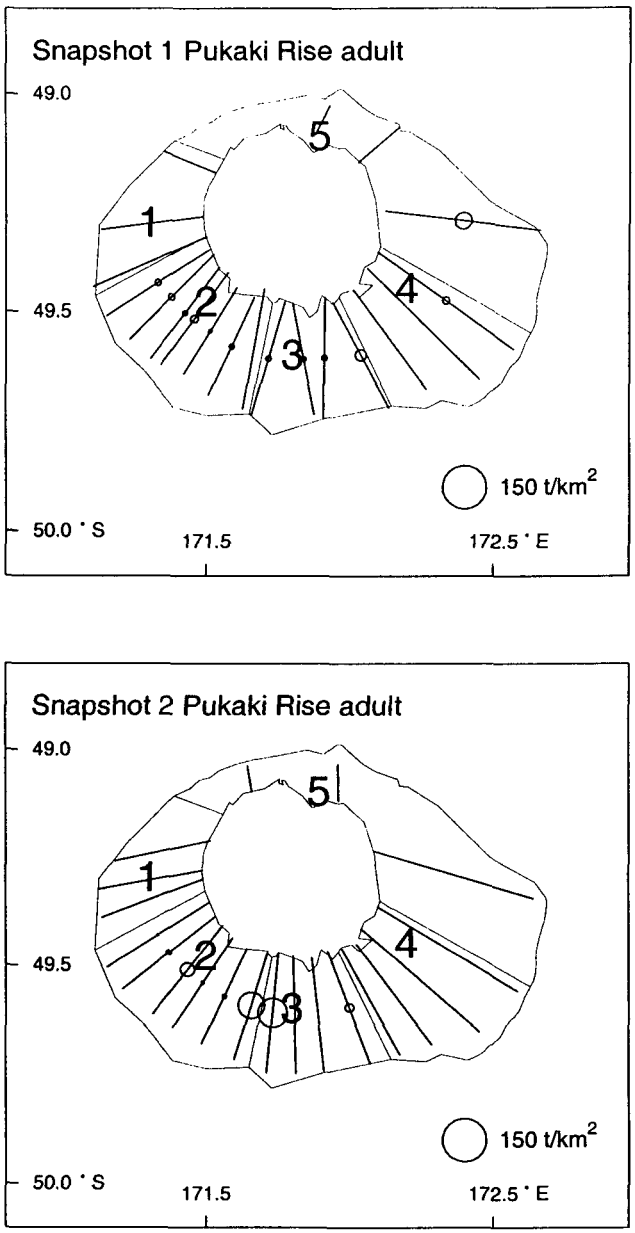
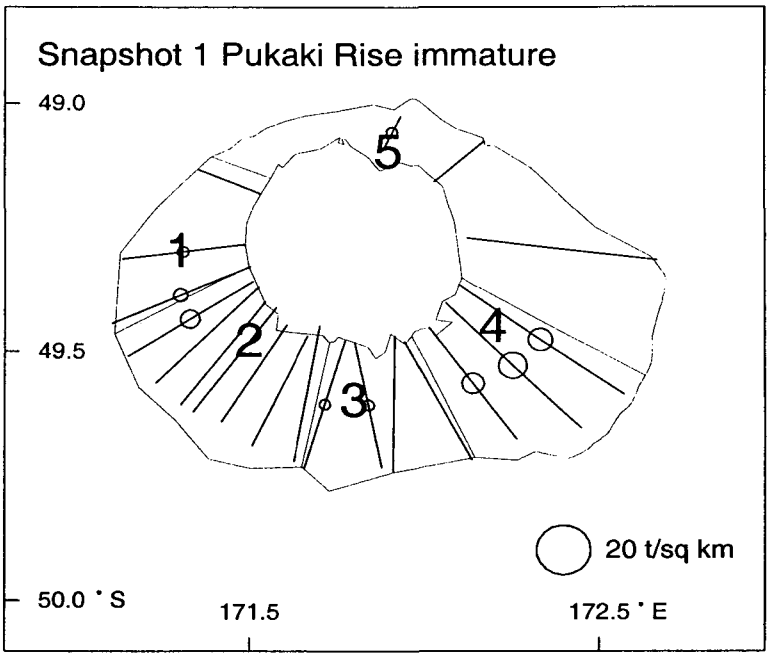


Figure 7: Density estimates of adult southern blue whiting (t. km^{-2}) by transect for snapshots 1 and 2 on the Pukaki Rise.



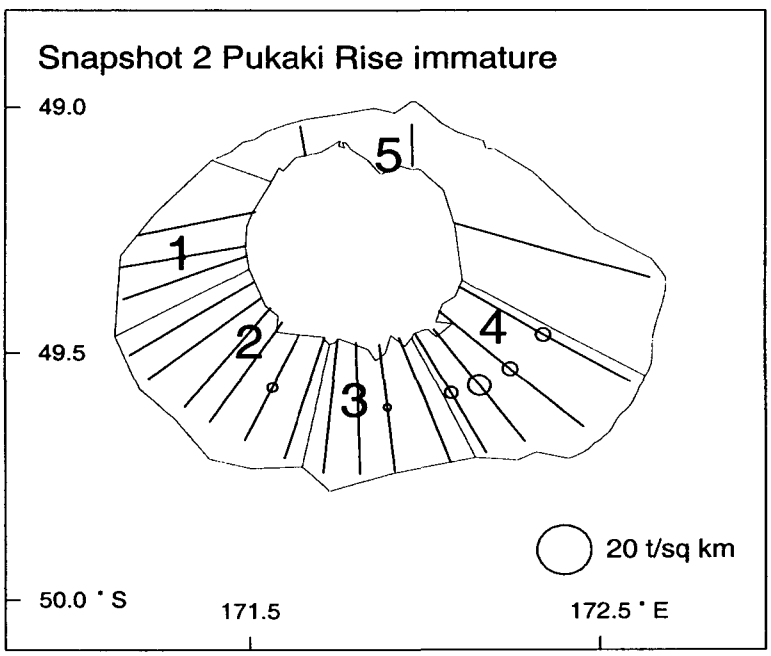


Figure 8: Density estimates of immature southern blue whiting (t. km^{-2}) by transect for snapshots 1 and 2 on the Pukaki Rise.