New Zealand Fisheries Assessment Research Document 96/18

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

J. K. V. Ingerson & S. M. Hanchet
NIWA
PO Box 14-901
Wellington

September 1996

Ministry of Fisheries, Wellington

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

J.K.V. Ingerson & S.M. Hanchet

N.Z. Fisheries Assessment Research Document 96/18. 29 p.

1. Executive summary

This paper summarises the results of the third acoustic survey of southern blue whiting stocks in subantarctic waters. Two complete acoustic snapshots were carried out on the Bounty Platform, Pukaki Rise, Auckland Islands Shelf, and Campbell Island Rise. Pre-spawning fish were surveyed during the first snapshots on the Bounty Platform, Auckland Islands Shelf, and Campbell Island Rise, and during both snapshots on the Pukaki Rise. Spawning and post-spawning fish were surveyed during the second snapshots on the Bounty Platform, Auckland Islands Shelf, and Campbell Island Rise.

Commercial trawl data were used to determine the main fishing locations in each area and to assist in the identification of marks. Based on these data, and investigative target trawling from *Tangaroa*, southern blue whiting marks were identified as adult (sexually mature), immature (2 and 3 year old sexually immature fish), or juvenile (1 year olds).

Strong diurnal differences in acoustic backscattering were again recorded on the Bounty Platform. Attempts were therefore made to survey the main strata in this area entirely at night, as it is believed that the night-time biomass estimates are more reliable and accurate.

Adult biomass estimates were highest on the Campbell Island Rise at about 121 100 t (*c.v.* = 30%). Estimated adult biomass on Bounty Platform was 35 200 t (*c.v.* = 24%), on Pukaki Rise 12 800 t (*c.v.* = 18%), and on the Auckland Islands Shelf 7800 t (*c.v.* = 34%). There was no evidence of turnover and estimates of target strength are available, so these biomasses can be regarded as absolute.

2. Introduction

A programme to estimate southern blue whiting (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, carried out in 1994, were documented by Hanchet & Ingerson (1996a), and were used in the stock assessment in 1995 (Hanchet & Ingerson 1995). The third survey in the time series was carried out in August and September 1995 and the results used in stock assessment in 1996 (Hanchet & Ingerson 1996b).

Although the main aim of the survey was to estimate the spawning stock biomass of SBW, each area included at least part of the range of non-recruited fish. Modelling suggests that a small proportion (less than 10%) of fish recruit to the fishery at age 2, a larger but variable

proportion (on average about 50%) recruit at age 3, and that fish are fully recruited at age 4 (Hanchet & Haist 1994). Therefore, for the purposes of this report adults are defined as sexually mature fish (which would spawn that year), immature fish are defined as 2 and 3 year old fish which are sexually immature and would not spawn that year, and juvenile fish are defined as 1 year old fish.

The objectives of the acoustic surveys were as follows.

(1) To develop a time series of relative abundance indices for juvenile, immature, and adult SBW on the Bounty Platform, Pukaki Rise, Auckland Islands Shelf, and Campbell Island Rise.

(2) To estimate the absolute abundance of SBW on the Bounty Platform, Pukaki Rise, Auckland Islands Shelf, and Campbell Island Rise.

This paper summarises the results of the 1995 acoustic survey of SBW stocks. Estimates of biomass and their coefficients of variation (*c.v.*s) are provided, where possible, for juvenile, immature, and adult fish on the Bounty Platform, Pukaki Rise, Auckland Islands Shelf, and Campbell Island Rise.

3. Survey design

3.1 Survey area and transect allocation

3.1.1 Main survey

The acoustic survey was carried out from *Tangaroa* in August and September 1995. Stratification and allocation of transects to strata on the Bounty Platform, Pukaki Rise, and Campbell Island Rise were based on the results of the 1993 and 1994 surveys, and on the location of the fleet during the 1995 season. The Auckland Islands Shelf area was being surveyed for the first time, and initial stratification was based on the historical location of commercial tows. This was modified for snapshot 2 to reflect the location of the fleet during the 1995 season. Five strata were surveyed on the Bounty Platform, four on the Pukaki Rise, three on the Auckland Islands Shelf, and seven on the Campbell Island Rise (Figure 1).

Two acoustic snapshots were completed on each of the four main fishing grounds. The stratum area and number of transects by stratum by snapshot for each of the areas are given in Table 1.

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 but was large enough to ensure no large areas were left unsurveyed within each stratum (Jolly & Hampton 1990, Simmonds *et al.* 1992). Zig-zag transects were used occasionally to maximise the area covered for a given transect length (Simmonds *et al.* 1992), and at other 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.

In general, transects ran from a specified minimum depth (which was area specific) to either the edge of the stratum boundary or to a maximum depth, whichever came first. The bottom depth never exceeded 600 m, and in most transects was less. Thus, transects on the Bounty Platform ran from a bottom depth of 200 m to the edge of the stratum boundary. Transects on the Pukaki Rise ran from 250 m and on the Campbell Island Rise from 330 m to the edge of the stratum boundary. During snapshot 1 on the Auckland Islands Shelf, the transects ran from 300 m to the stratum boundary, but in snapshot 2 the inshore depth became 420 m.

3.1.2 Fleet strata and high density strata

When time permitted, an adaptive survey approach was used in an attempt to gain more precise estimates of high density adult aggregations. Smaller areas of high adult fish density were surveyed further by creating new strata encompassing the aggregation and allocating several random transects within the new strata. The boundaries of the aggregation were ascertained by a combination of examining the densities of fish observed during the background survey, movements of commercial vessels during the previous 12–24 hours, and by carrying out preliminary transects through the aggregation. If during the course of surveying a high density stratum the fish appeared to extend beyond these boundaries, the stratum was altered accordingly.

On the Bounty Platform, a high density stratum was surveyed at night during snapshot 1, and another was surveyed at night during snapshot 2. On the Campbell Island Rise one high density stratum was surveyed during snapshot 1. Three high density strata were surveyed during snapshot 2, the largest of the three at night. The two smaller strata surveyed were both largely within the area surveyed by the first high density stratum, and one was surveyed during the day and the other at night. No high density strata were surveyed on either the Pukaki Rise or the Auckland Islands Shelf.

3.2 Acoustic mark identification

This survey was the third in the time series, and there is now much more certainty regarding the identification of fish marks. The observer coverage of the commercial fleet during the 1995 season was comprehensive, so it was unnecessary for *Tangaroa* to carry out many target identification tows. Of the eight tows that were carried out, four were on the Pukaki Rise, two on the Auckland Islands Shelf, and one each on the Bounty Platform and Campbell Island Rise. Catch rates in the commercial fishery for each area were examined for the periods during and outside the snapshots to assist in fish mark identification, and length frequency data collected by observers were used to determine the size of the fish being caught. Based on the results of both the research and the commercial tows, SBW marks were assigned as adult, immature, or juvenile.

On the Bounty Platform juveniles, were mainly confined to shallower depths of 200–250 m and their marks could usually be separated from the adult marks on the basis of depth and area

alone. Additionally, a trawl by *Tangaroa* confirmed a large area of marks in depths of 350–450 m in strata 3 and 4 to be juvenile SBW. Dense marks in the south of the area (strata 2 and 3) were fished by the commercial fleet, confirming them to be adult SBW.

On the Pukaki Rise, one midwater and three bottom trawls were carried out by *Tangaroa*. No juvenile or immature fish were found, and all large marks were confirmed as adult SBW.

Two trawls were carried out by *Tangaroa* on the Auckland Islands Shelf. The first was targeting a midwater mark in depths of 330–360 m on the western boundary of stratum 2 during snapshot 1, and the other was targeting a layer in 400–420 m in stratum 2. No SBW were caught in either tow. Denser marks in deeper water (480–520 m) were fished by the commercial fleet and confirmed as adult SBW.

On the Campbell Island Rise, immature fish were always in shallower water than adults (usually less than about 400 m) and could be distinguished from adults on the basis of depth alone. In addition, a trawl by *Tangaroa* on a mark in 400 m caught a sample of immature SBW. Dense marks in strata 3 and 7 were fished by the commercial fleet, and confirmed as adult SBW.

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, the mean areal backscattering of each stratum 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 (*see* Hanchet & Ingerson 1996a for details). Adult SBW were assumed to have the length distribution caught by the commercial fishery for that particular area (Hanchet & Ingerson 1996b). Strata on Campbell Island Rise were divided into two groups, north (strata 1–4) and south (strata 5–7), because length-frequency data were different for each area. Based on trawling data, immature fish were estimated to have a mean length of about 28 cm on the Campbell Island Rise, and 1 year old fish on the Bounty Platform were estimated to have a mean length of 16 cm.

The acoustics data were analysed in two ways: (i) excluding the fleet stratum and (ii) including the fleet stratum. In (i) 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). In (ii) the area of the fleet stratum was calculated and the transects completed in that stratum were analysed as in (i) above. The areas of the original strata which included the fleet stratum in their boundaries were correspondingly reduced in size. Any portions of the original transects which passed through the fleet stratum were removed from the analysis, and the average areal backscattering and biomass for the remaining area of the original strata recalculated. The day and night fleet stratum transects were analysed separately to determine whether there were diurnal differences in the backscattering estimates.

3.4 Gonad data

Staging data for female fish (using the five stage system given by Hanchet (1993)) were recorded by scientific observers on each ground during the season. These data were examined to define spawning times on each ground and to determine whether there was any evidence of turnover. Turnover would be detected 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.

4. Results

4.1 Acoustic biomass estimates

4.1.1 Bounty Platform

The results of the two snapshots completed on Bounty Platform are shown in Tables 2a and 2b and Figure 2. During snapshot 1, the aggregations of fish seen in strata 1 and 2 were surveyed during the day as well as at night. As on the previous surveys in 1993 and 1994, there were large differences in transect density between day and night (Table 2b). Daytime transects appeared to greatly underestimate biomass, so only the night-time estimates have been used.

During snapshot 1, adults were mainly confined to stratum 2 (*see* Table 2a, Figure 2). The two transects at the western end of stratum 2 had much higher densities than the eastern two, and this is reflected in the high *c.v.* of 58% on the estimated biomass of 21 900 t. Few adult SBW were seen in the rest of the survey area: however large marks of juvenile fish were seen in strata 3 and 4, resulting in a juvenile biomass estimate of 93 300 t (*c.v.* = 37%).

A high density stratum (stratum 8) was added into stratum 2 in an attempt to gain a more precise estimate of the adult biomass seen there during the background transects. The boundaries were chosen on the basis of the marks seen during both daytime and night-time transects. Transect densities from stratum 8 are shown in Figure 2. The westernmost transect had a very high density, resulting in a high stratum *c.v.* of 44%. The overall adult biomass estimates for snapshot 1 were 24 100 t (*c.v.* = 52%) using the background transects only, and 34 400 t (*c.v.* = 36%) if stratum 8 was included.

By the time snapshot 2 was completed several days later, the large aggregation seen in snapshot 1 was moving east. Fish marks were seen in the two easternmost transects of stratum 2, both in shallow and in deep water (Figure 3). The biomass estimate of 30 600 t from this stratum had a high *c.v.* of 61%. A high density stratum (stratum 8) was surveyed which covered both the area of the marks seen in stratum 2 and also a part of stratum 3. Unfortunately, the fish extended even further east than was envisaged and it is clear that this snapshot would have underestimated the biomass of the shallow aggregation. The overall estimates for snapshot 2 were 30 600 t (*c.v.* = 61%) for stratum 2 alone, and 36 000 t (*c.v.* = 33%) if stratum 8 was included.

The best overall estimate of biomass is considered to be the mean of the two snapshot estimates (including both the high density strata), 35 200 t (*c.v.* = 24%).

4.1.2 Pukaki Rise

Results of the two snapshots completed on Pukaki Rise are shown in Table 3 and Figure 4. In both snapshots, SBW marks were found around the southern part of the Rise, with the densest marks and most biomass in strata 2 and 3. Snapshot 1 gave a biomass estimate of 10 700 t (*c.v.* = 18%), and the second snapshot a slightly higher biomass estimate of 14 800 t (*c.v.* = 28%). No dense marks were seen in any of the strata, so no high density strata were added. The two snapshot estimates were averaged to give a mean biomass of 12 800 t (*c.v.* = 18%).

4.1.3 Auckland Islands Shelf

Two broad bands of fish were seen during snapshot 1; one through the middle of the three strata in depths of 420–460 m, and another along the outer boundary in 480–520 m. The transect densities were very even in stratum 1, but more variable in the other two strata (Figure 5). The overall biomass from the snapshot was estimated to be 4400 t (*c.v.* = 23%) (Table 4).

Snapshot 2 was carried out 2 weeks later, after the completion of both snapshots on the Campbell Island Rise. While steaming across the area to the southeast of stratum 3 to begin snapshot 2, apparent SBW marks were seen in depths of about 520 m. Scientific observers aboard one of the commercial vessels confirmed that these marks were being targeted successfully for SBW. As a result, the entire survey area was moved to the east to ensure that these marks were adequately sampled (*see* Figure 5). The biomass estimates from all strata were higher than in snapshot 1, and the overall estimate from snapshot 2 was 7800 t (*c.v.* = 34%). Because of the problems with the depth being sampled, it is considered that snapshot 2 gave the best estimate of biomass for this ground (*see* Table 4).

4.1.4 Campbell Island Rise

Adult fish were found on both northern and southern grounds during each snapshot. In snapshot 1, fish on the northern ground were mainly in a large aggregation within stratum 3. A high density stratum (stratum 8), extending slightly beyond the eastern boundary of stratum 3 was placed around this aggregation (Figure 6). Despite the increased number of transects the *c.v.* was higher in the high density stratum than in the background survey (Table 5). The aggregation was 30 n. miles long and up to 10 n. miles wide and the estimated biomass was 53 200 t in the background survey and 75 300 t when stratum 8 was included. Fish on the southern ground were in a single aggregation seen in the last two transects of stratum 7 (Figure 6).

The biomass estimate for both grounds using the background strata alone was 78 600 t (*c.v.* = 36%), and 102 700 t (*c.v.* = 38%) including stratum 8 (*see* Table 5).

During snapshot 2, stratum 9 was surveyed with zig-zag transects, but no SBW were found. The aggregation on the southern ground was still in stratum 7, but was seen in four of the eight transects (Figure 7). The estimate of biomass for stratum 7 was 82 200 t (*c.v.* = 65%). The fish on the northern ground were seen on two transects in stratum 3, and on one transect

in stratum 4 (near the boundary with stratum 3). The first two transects in stratum 2 were surveyed to determine the western extent of the fish aggregations, but neither of these transects showed any fish. Therefore, surveying of stratum 2 was postponed while a high density stratum (stratum 8) was surveyed near the dense marks seen in strata 3 and 4 (*see* Figure 7). However, only two aggregations were seen in stratum 8, and these were in the same place as the aggregations surveyed by the transects in the background survey of stratum 3. It therefore appeared that the original biomass estimate of stratum 3 was biased upwards because two of the four transects just happened to pass through the main schools in the stratum. The aggregation seen originally in stratum 4 was not seen during stratum 8.

The next day, two more high density strata (strata 8d and 8n) were placed around the two aggregations seen in each of strata 3 and 8 (*see* Figure 7). The two estimates were 6300 t and 18 500 t respectively, which, when summed, were similar to the stratum 8 estimate of 22 500 t, but were considerably lower and more precise than the original background estimate from stratum 3. It appeared from the echotraces that neither stratum 8 nor stratum 8n surveyed the main aggregation originally seen in stratum 4. It was seen while turning between two transects in stratum 8, and would not need to have moved much further to avoid being surveyed in stratum 8n. When the first two transects in stratum 2 were resurveyed after the completion of the high density strata, fish marks were seen that had not been in evidence previously. As the main aggregations in strata 3 and 4 appeared to have dispersed immediately after the high density survey, it is believed that the fish now seen in stratum 2 had already been surveyed in strata 3 and 4, and so the first two transects in stratum 2 were not included in the biomass estimates.

For the reasons outlined above it is believed that the best estimate of biomass for the northern aggregation in snapshot 2 comes from the sum of the biomasses of stratum 4, stratum 8n, and stratum 8d, i.e. 139 600 t (*c.v.* = 44%).

There was no reason to suspect that either snapshot under-estimated or over-estimated the biomass, so they were averaged to give a best estimate of 121 000 t (*c.v.* = 30%).

Immature fish were surveyed in both snapshots. A considerable proportion of the immature biomass in snapshot 1 was from stratum 5 (*see* Table 5), and the estimate for snapshot 1 was 21 200 t (*c.v.* = 25%). Stratum 5 was not surveyed in snapshot 2, so the estimate was much lower (8700 t, *c.v.* = 21 %). The best estimate from both snapshots comes from adding the stratum 5 biomass in snapshot 1 to the average of the biomass estimates from the two snapshots for the other strata, giving a mean of 19 800 t (*c.v.* = 20%).

4.2 Fleet movement

On the Bounty Platform the activities of the commercial fleet were centred around the area in stratum 2 where the highest fish densities were seen during the background survey (Figure 8). The fleet then moved to the east during the course of snapshot 2, fishing two aggregations; one in about 250 m and the other in 400 m. After snapshot 2 was completed, fishing took place in stratum 3, although the catch rates were low. At the end of the season (in late September) a few tows were made in strata 1 and 2.

On the Pukaki Rise most of the fishing effort was in strata 2 and 3, although there did not appear to be any areas of high fish density (Figure 9). The larger catch rates in stratum 2 were made in mid September, well after the survey had been completed.

Commercial trawls on the Auckland Islands Shelf confirmed that the area of highest fish density was on the outer boundary of stratum 2 (snapshot 1), which in snapshot 2 became the middle of stratum 2. Two unsuccessful tows were made in shallow water early in the season (Figure 10).

On the Campbell Island Rise during snapshot 1, most fishing was conducted in stratum 3 (Figure 11). Several vessels also fished the southern aggregation in stratum 7, with moderate success. In snapshot 2, the fishery concentrated on the northern ground, largely in the area of the aggregation surveyed in stratum 8n. After the acoustic snapshots were completed some fishing continued on the southern ground, although by this time the fish had moved outside the boundary of stratum 7. The northern aggregation had dispersed immediately after the surveying of stratum 8n, and some tows were made in strata 1, 2, 4, and 5, before most of the vessels abandoned the grounds. However, some vessels continued to fish in stratum 5 and 7 until the middle of October. The catch in both the northern and southern grounds was dominated by 4 year old mature fish.

4.3 Gonad data

The gonad data provided no evidence of turnover on any of the grounds. 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 1993). Evidence for this occurring in 1995 can be seen in an increase in the proportion of stage 2 fish (Table 6). Scientific observers have noted that these stage 2 fish often exhibit evidence of previous spawning, and so are not new fish entering the grounds to spawn for the first time.

The main spawning on the Bounty Platform was from 24 to 28 August, slightly later than usual. Although no verification was possible, the proportion of stage 2 fish observed in late August suggests that the fish may have spawned again in early September.

The timing of spawning on the Pukaki Rise could not be determined, but would have started on or about 18 September. The precise timing of spawning on the Auckland Islands Shelf also could not be determined, although from the percentage of spent fish it appears that spawning would have started about 14–15 September.

The timing of spawning on the Campbell Island Rise was slightly earlier than in the last 2 years. On the northern ground the main spawning was from 13 to 16 September, and the proportion of stage 2 fish in late September suggests that a second spawning may have taken place in early October. On the southern ground, spawning would probably have been from about 16 to 20 September because spawning and spent fish were caught on 19 September, when the first observed vessels arrived.

5. Discussion

5.1 Biomass estimation by area

5.1.1 Bounty Platform

Attempts were made during snapshot 1 to survey strata 1 and 2 during the day. However, as in all the surveys to date, densities were very much lower than at night, and at times no fish marks were visible at all. Some possible reasons for these day-night differences in apparent fish density 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.

Several attempts were made to observe the change in distribution of the fish from night to day. Large dispersed clouds of SBW that stretched some tens or hundreds of metres off the bottom were observed over the period of dawn. The fish were seen to descend to the sea floor, and subsequently became impossible to distinguish from the echo returned from the sea bed. It also appeared that some of the fish formed very dense, and apparently extremely mobile, schools. It was not possible to stay in contact with such schools. It is unlikely that such schools were actively avoiding the vessel, even though some of the low frequency noise would undoubtedly penetrate many hundreds of metres (G. Macaulay, NIWA, pers. comm.) Several studies have investigated the avoidance reaction of fish to vessels, although most of these studies have concentrated on fish near the surface or in water less than 100 m deep (Olsen *et al.* 1983, Aglen 1994). The avoidance reaction by fish at depths greater than 200 m has also been shown to be negligible (Ona & Godø 1990). Even if some avoidance reaction of SBW was occurring at depths of 350–400 m, their movement would also be unlikely to take them beyond the width of the acoustic beam. It may therefore be that the schools are moving quickly, and their size and density may lessen the chance of their being detected by this survey method.

The survey was further hampered by bad weather and the loss of 7 days from the survey due to the loss of the towbody. The main aggregation on the Bounty Platform was surveyed on four occasions. All four estimates were similar, ranging from 24 000 t to 34 000 t in snapshot 1 and 30 000 to 36 000 t in snapshot 2. However, it is known that fish extended beyond the stratum boundaries in snapshot 2, probably leading to an underestimate of the biomass during that snapshot. The mean estimate from the two snapshots gives an overall biomass of 35 200 t and a *c.v.* of 24%.

The adult biomass estimate in 1995 is lower than both the 1993 and 1994 estimates (Table 7). However, the biomass in both 1993 and 1994 may have been overestimated through double-counting (Hanchet & Ingerson 1996a), and the 1995 biomass may have been an underestimate for the reasons mentioned above. The huge estimated biomass of juveniles (93 300 t) suggests the possible emergence of a very strong year class, although the estimate is based on the results of only one snapshot.

5.1.2 Pukaki Rise

Both snapshots on the Pukaki Rise were carried out well before the fish started spawning. The season was very poor for the commercial fleet, and no dense areas of fish were found until the middle of September. The best estimate of biomass for the area was 12 800 t (*c.v.* = 18%). Because of the timing of the 1995 survey in relation to the timing of spawning it is likely that this is an underestimate. It is clearly much lower than estimates from both the 1993 and 1994 surveys (*see* Table 7). The strong 1991 year class was expected to substantially increase the adult biomass in 1995, but instead does not yet appear to have recruited to the Pukaki Rise fishery.

5.1.3 Auckland Islands Shelf

As this was the first attempt to survey the Auckland Islands Shelf using the acoustic technique there was some uncertainty over the suitability of the stratum boundaries. Initially, these were based on the distribution and catch rates of tows in the commercial fishery during the preceding years. However, at the beginning of snapshot 2 it became clear that SBW were distributed deeper than in previous years and so the stratum boundaries were extended into deeper water. Therefore the biomass from snapshot 1 is believed to be an underestimate and the best estimate, 7800 t (*c.v.* = 34%), is considered to be from snapshot 2. This is believed to be a reasonable estimate for this ground as it encompassed the main aggregations and was made at the peak of spawning. It is also consistent with the low level of catch historically taken from this ground.

5.1.4 Campbell Island Rise

Parts of the northern aggregation were surveyed on five occasions. The estimates ranged from 55 200 t to 89 800 t. The values used in the best estimates (59 000 and 77 300 t) lie in the middle of this range. Unfortunately the southern aggregation was surveyed only twice, resulting in quite different estimates of 23 500 t and 82 200 t with high *c.v.*s. It will be important in the future to survey each of the main aggregations several times to improve the precision and accuracy of the survey results.

There were significant changes in fish behaviour between the two snapshots. In snapshot 1, the fish were in one very large aggregation, which appeared to be at least 30 n. miles long by up to 10 n. miles wide. This is the largest such aggregation seen during any of the surveys. This then appeared to split into several smaller, denser schools once spawning began, but the fish appeared to stay largely within the same area, unlike in previous surveys when the fish schools were more mobile.

The three acoustic surveys to date showed a large increase in biomass from 1993 to 1994, but a slight decrease in 1995. Modelling results suggested that the biomass in 1995 should have been higher than in 1994 as fish from the 1991 year class continued to recruit to the fishery, and growth of that year class continued to be greater than loss through natural mortality. However, *c.v.*s from both the 1994 and 1995 surveys are high, and the 95% confidence intervals on the biomass estimates overlap.

The estimated biomass of immature fish from the 1995 survey was similar to that from the 1994 survey but was much lower than from the 1993 survey. It is too early to know whether the survey will provide useful recruitment indices, but the results so far are consistent with the catch-at-age data from the fishery.

6. Conclusions

With three surveys now having been completed, there is a great deal more certainty to the positive identification of SBW marks. Good scientific observer coverage of the commercial fleet also aided in confirmation of the depths and areas of fish distribution. Very few target identification tows needed to be carried out by *Tangaroa*, and this is likely to continue in future surveys, especially given the difficulties of deploying and retrieving the acoustic towed body in heavy weather.

The Bounty Platform continues to be the hardest area to survey. Fish there are highly aggregated, extremely mobile, and show marked diurnal differences in acoustic backscattering. The timing of the survey and the need to survey all the major spawning aggregations was also demonstrated by the surveys of the other three areas. Future surveys will need to address these issues.

The high density stratum approach did not improve the precision of the biomass estimates as much as in previous surveys. Simulation work is planned for before the next survey in an attempt to determine the advantages (if any) of the high density stratum method, and the sources of any possible bias.

7. Acknowledgments

We thank the scientific staff who assisted on the survey and also the officers and crew of *Tangaroa* for their helpful cooperation. Also thanks to scientific observers Darryl Morrow, Richard Win, Bruce King, and Robert Hales for passing on fishing information during the course of the survey.

8. References

Aglen, A. 1994: Sources of error in acoustic estimation of fish abundance. *In*, Ferno, A. & Olsen, S. (Eds.), Marine fish behaviour in capture and abundance estimation, pp. 107–133. Fishing News International Books, Oxford.

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.

Hanchet, S. M. 1993: Southern blue whiting (*Micromesistius australis)* fishery assessment for the 1993–94 fishing year. N.Z. Fisheries Assessment Research Document. 93/17. 56 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., 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. & 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.

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.

Olsen, K., Angell, J., Pettersen, F., & Lovik, A. 1983: Observed fish reactions to a surveying vessel with special reference to herring, cod, capelin and polar cod. *FAO Fisheries Report 300*: 131–138.

Ona, E. & Godø, O. R. 1990: Fish reaction to trawling noise: The significance for trawl sampling. *Rapport et Proces-Verbaux des Reunions du Conseil International pour l'Exloration de la Mer,* 189: 159–166.

Simmonds, E. J., Williamson, N. J., Gerlotto, F., & Aglen, A. 1992: Acoustic survey design and analysis procedure: a comprehensive review of current practice. *ICES Cooperative Research Report No. 187.* 127 p.

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

Stratum	Stratum area (km^2)	Number of transects: Snapshot 1	Number of transects: Snapshot 2
Bounty Platform		16–22 August	27–29 August
1n	1 466	4	–
2	2 750[1] 2300[2]	5	6
3	2 500	4	–
4	1 953	3	–
5	1 306	5	–
8	475[1] 950[2]	11	8
Pukaki Rise		30 Aug–1 Sept	1–2 September
1	703	4	4
2	1 949	8	8
3	837	4	4
4	326	4	–
Campbell Island Rise		7–13 September	14–19 September
1	2 250	5	–
2	3 437	8	6
3	2 824[1] 2 336[2]	6	4
4	2 700	5	3
5	4 247	3	–
7	3 500	8	8
8	580[1] 960[2]	7	10
8d	48	–	8
8n	270	–	13
9	1 922	–	5
Auckland Islands Shelf		5–7 September	19–21 September
1	617[1] 1 167[2]	3	3
2	1 220[1] 1 972[2]	5	5
3	1 232[1] 1 075[2]	3	3

[1] Snapshot 1
[2] Snapshot 2

Table 2a: Stratum area (km^2) and biomass by stratum and snapshot for the Bounty Platform for night-time strata only. Strata with an H refer to the high density stratum survey. n, night strata; d, day strata

			Biomass (t)			
Snapshot	Stratum	Stratum area	Adults	*c.v.* (%)	Juveniles	*c.v.* (%)
1	1n	1 466	2 200	31	0	–
	2	2 750	21 900	58	0	–
	2H	2 275	8 400	93	0	–
	3	2 500	3 600	96	19 700	96
	4	1 953	0	–	73 500	39
	8Hn	475	20 200	44	0	–
Total (excluding H)			24 100	52	93 300	37
Total (including H)			34 400	36	–	–
2	2	2 300	30 600	61	0	–
	2H	1 580	1 200	46	0	–
	8H	950	34 800	34	0	–
Total (excluding H)			30 600	61	0	–
Total (including H)			36 000	33	0	–
Adult best estimate						
Snapshot 1 (including 8H)			34 400	36		
Snapshot 2 (including 8H)			36 000	33		
Total			**35 200**	**24**		
Juvenile best estimate						
Snapshot 1					93 300	37

Table 2b: Comparison of day and night biomass estimates fron strata on the Bounty Platform

			Biomass (t)	
Snapshot	Stratum	Stratum area	Adults	*c.v.* (%)
1	1d	1 466	1 200	99
	1n	1 466	2 200	31
	8Hd	475	4 700	36
	8Hn	475	20 200	44

Table 3: Stratum area (km^2) and biomass by stratum and snapshot for the Pukaki Rise

Snapshot	Stratum	Stratum area	Biomass (t) Adults	*c.v.* (%)
1	1	703	890	37
	2	1 949	5 400	25
	3	837	4 400	31
	4	326	0	–
Total			10 700	18
2	1	703	220	24
	2	1 949	7 300	40
	3	837	7 300	41
Total			14 800	28
Best estimate				
Total			**12 800**	**18**

Table 4: Stratum area (km^2) and biomass by stratum and snapshot for the Auckland Islands Shelf

Snapshot	Stratum	Stratum area	Biomass (t) Adults	*c.v.* (%)
1	1	617	1 800	10
	2	1 220	2 100	43
	3	1 232	490	77
Total			4 400	23
2	1	1 167	2 000	31
	2	1 972	5 100	51
	3	1 075	700	41
Total			7 800	34
Best estimate				
Snapshot 2			**7 800**	**34**

Table 5: Stratum area (km^2) and biomass by stratum and snapshot for the Campbell Island Rise. Strata with an H refer to the high density stratum surveys, and the subscript separates them

Snapshot	Stratum	Stratum area	Biomass (t) Adults	*c.v.* (%)	Immatures	*c.v.* (%)
1	1	2 250	0	–	0	–
	2	3 437	0	–	2 800	34
	3	2 824	53 200	44	0	–
	3H	2 284	1 900	96	0	–
	4	2 700	2 000	61	5 300	30
	5	4 247	0	–	9 638	50
	7	3 500	23 500	69	3 500	30
	8H	580	75 300	48	0	–
	9		Not surveyed			
Total (excluding H)			78 600	36	21 200	25
Total (including H)			102 700	38	21 200	25
2	1		Not surveyed			
	2	3 400	0	–	3 800	44
	3	2 336	55 600	63	0	–
	$3H_1$	1 566	100	88	0	–
	$3H_2$	2 153	200	88	0	–
	4	2 700	34 200	88	2 600	22
	$4H_1$	2 590	32 800	88	2 600	22
	$4H_2$	2 565	32 500	88	2 600	22
	5		Not surveyed			
	7	3 500	82 200	65	2 300	19
	$8(H_1)$	960	22 500	85	0	–
	$8d(H_2)$	48	6 300	23	0	–
	$8n(H_2)$	270	18 500	20	0	–
	9	1 922	0	–	0	–
Total (excluding H_1 and H_2)			171 900	41	8 700	21
Total (including H_1)			137 600	46	8 700	21
Total (including H_2)			139 600	44	8 700	21
Best estimate						
Snapshot 1 (including H)			102 700	38	21 200	25
Snapshot 2 (including H_2)			139 600	44	8 700	21
Total			**121 100**	**30**	**19 800**	**20**

Table 6: 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 *et al.* 1994)

		Gonad stage				
Date	n	1	2	3	4	5
Auckland Islands Shelf						
19-Sep-95	346	17	62	7	2	12
20-Sep-95	326	16	59	3	1	22
21-Sep-95	116	35	34	1	2	28
23-Sep-95	80	0	48	3	3	48
24-Sep-95	106	2	67	3	3	25
Bounty Platform						
19-Aug-95	378	0	97	2	0	0
20-Aug-95	171	0	96	4	0	0
21-Aug-95	240	0	91	9	0	0
22-Aug-95	292	0	27	72	1	0
23-Aug-95	381	5	22	69	4	0
24-Aug-95	398	3	11	65	21	0
25-Aug-95	573	5	17	60	17	0
26-Aug-95	326	1	18	46	33	1
27-Aug-95	307	3	32	56	7	2
28-Aug-95	351	2	38	48	11	1
29-Aug-95	379	13	56	20	3	8
30-Aug-95	302	0	79	12	7	1
31-Aug-95	104	3	69	17	10	1
Pukaki Rise						
3-Sep-95	82	1	96	2	0	0
4-Sep-95	86	3	94	2	0	0
5-Sep-95	211	12	87	1	0	0
6-Sep-95	192	22	73	5	0	0
15-Sep-95	300	0	93	6	1	0
16-Sep-95	190	0	81	18	1	0
17-Sep-95	75	0	68	31	1	0
Northern Campbell Island Rise						
8-Sep-95	387	0	100	0	0	0
9-Sep-95	587	0	100	0	0	0
10-Sep-95	505	1	96	3	0	0
11-Sep-95	667	1	86	13	0	0
12-Sep-95	612	0	24	75	1	0
13-Sep-95	686	0	5	82	12	0
14-Sep-95	617	1	3	30	64	1
15-Sep-95	484	4	6	40	43	7
16-Sep-95	529	9	30	10	41	10
17-Sep-95	446	12	39	11	9	29
18-Sep-95	216	23	43	0	3	31
27-Sep-95	118	1	49	31	7	13
28-Sep-95	97	51	41	5	0	3
Southern Campbell Island Rise						
5-Sep-95	59	0	100	0	0	0
6-Sep-95	132	1	98	1	0	0
7-Sep-95	154	0	100	0	0	0
19-Sep-95	455	3	15	25	37	20
20-Sep-95	170	12	36	28	14	10
21-Sep-95	198	0	38	23	8	31
25-Sep-95	204	41	34	7	2	16

Table 7: Summary of biomass estimates in t x 10^3 (and *c.v.*s) for each area, and category of SBW for the 1993, 1994, and 1995 acoustic surveys

	Adult (mature)			Immature (mostly 2)			Juvenile (age 1)		
Area	1993	1994	1995	1993	1994	1995	1993	1994	1995
Campbell Island	18.5 (21)	161.4 (36)	121.1 (30)	89.6 (23)	22.4 (38)	19.8 (20)	0	0	0
Bounty Platform	94.6 (46)	55.0 (22)	35.2 (24)	5.9 (43)	15.8 (87)	0	7.2 (46)	0.2 (80)	93.3 (37)
Pukaki Rise	49.8 (24)	39.0* (45)	12.8 (18)	26.3 (20)	0	0	0	0	0
Auckland Is.	-	-	7.8 (24)	-	-	0	-	-	0

* Includes some immature 3 yr old fish.

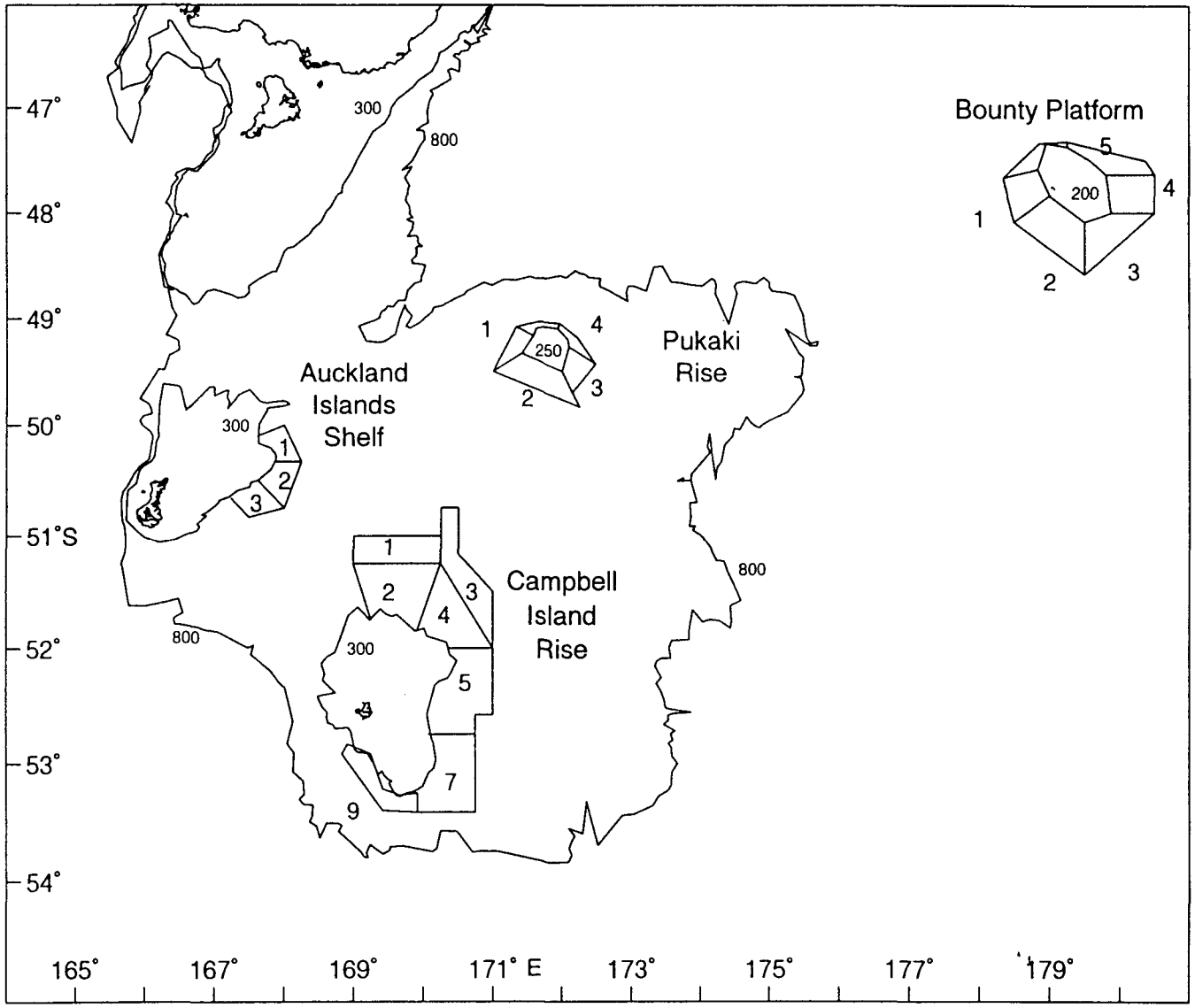
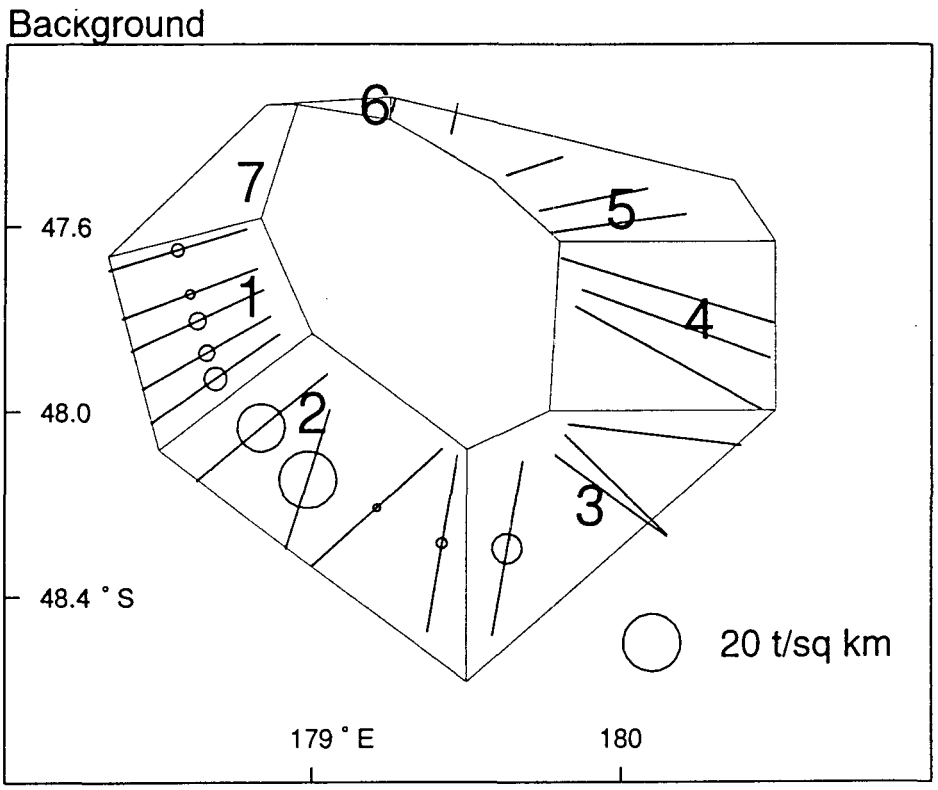


Figure 1: Strata numbers and boundaries surveyed during SBW acoustic survey TAN9510.



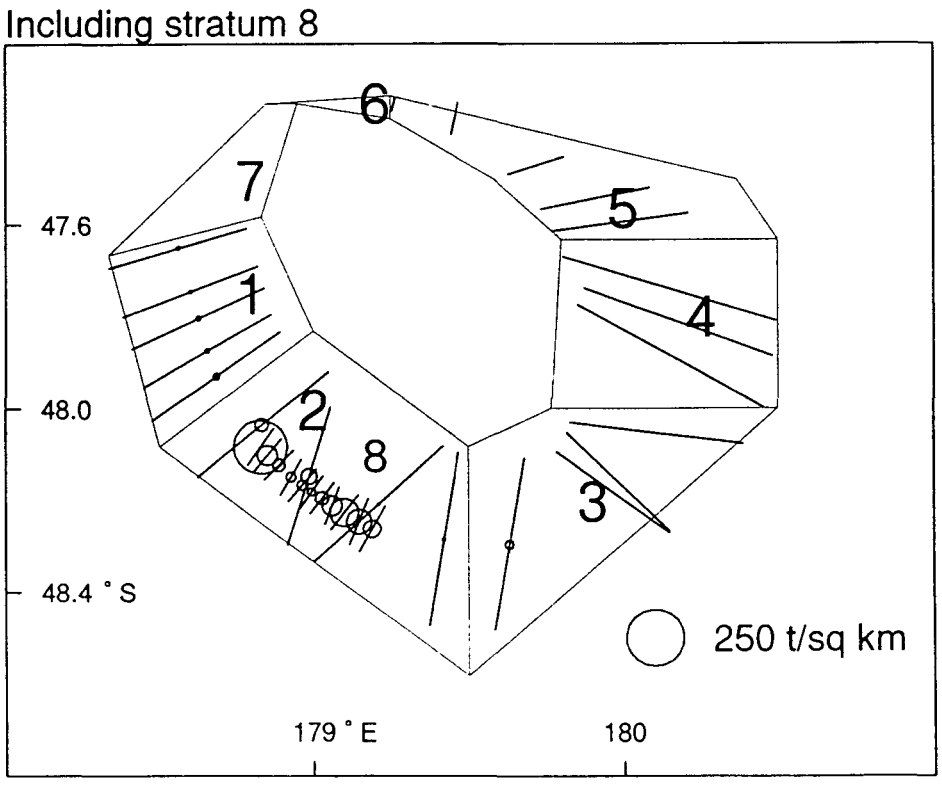


Figure 2: Density estimates of adults (t/sq km) by transect during snapshot 1 on the Bounty Platform.

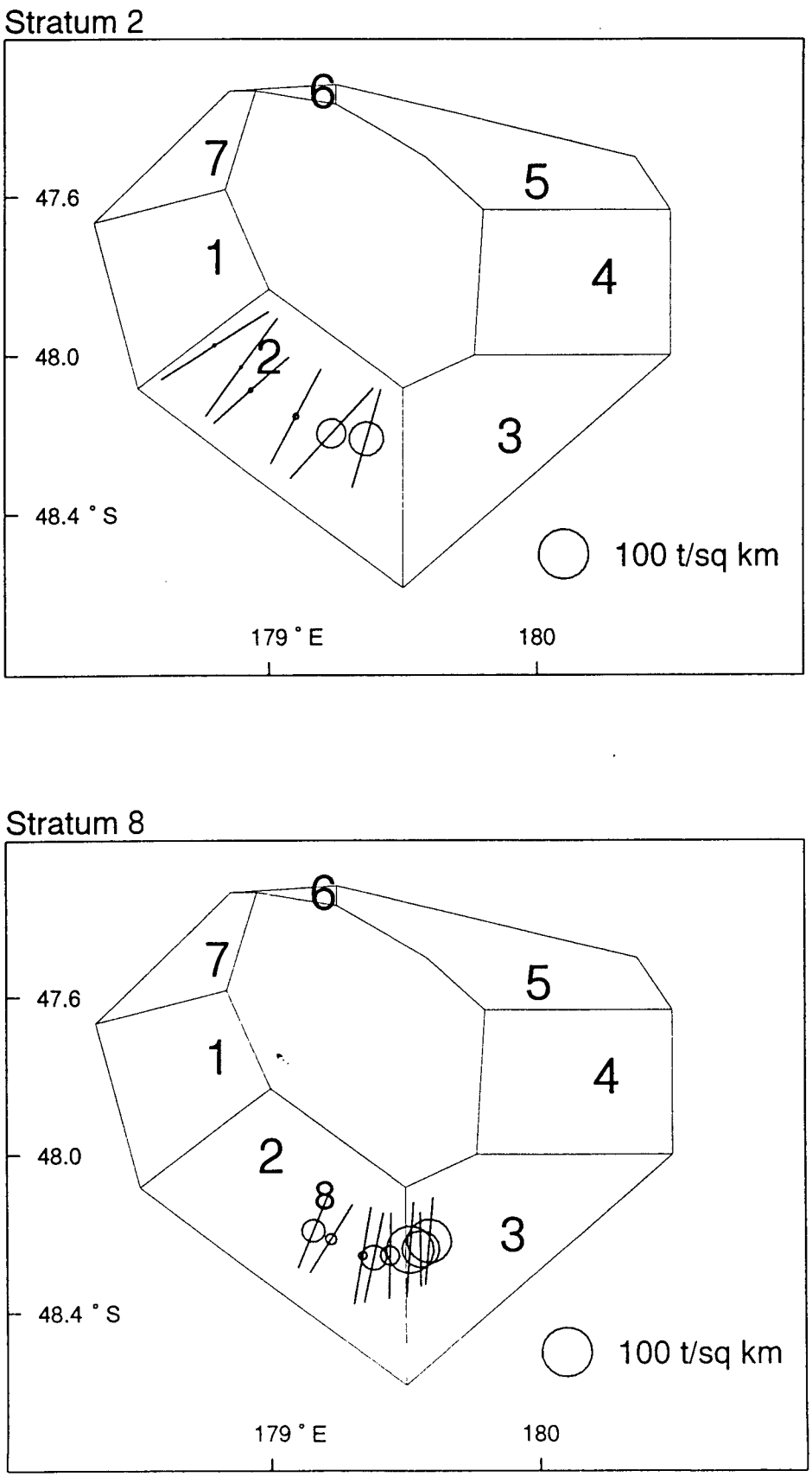
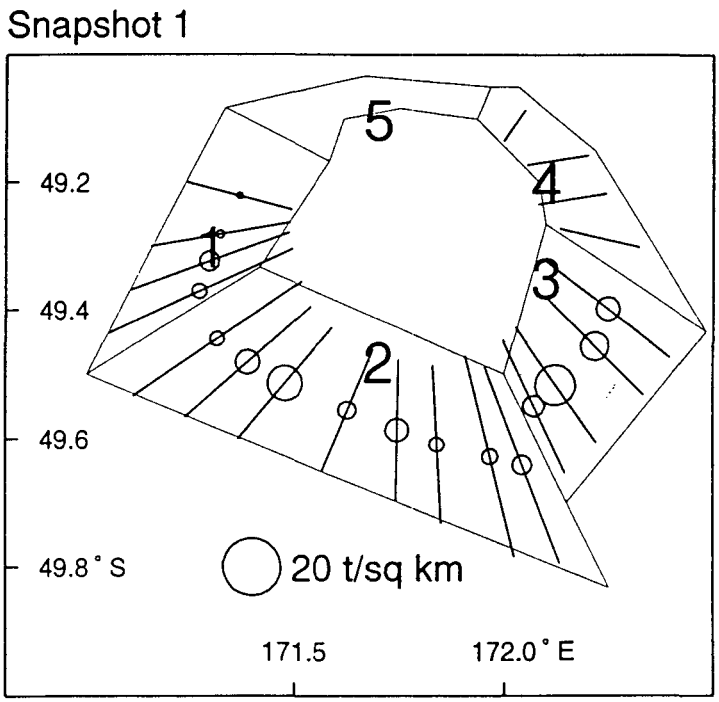


Figure 3: Density estimates of adults (t/sq km) by transect during snapshot 2 on the Bounty Platform.



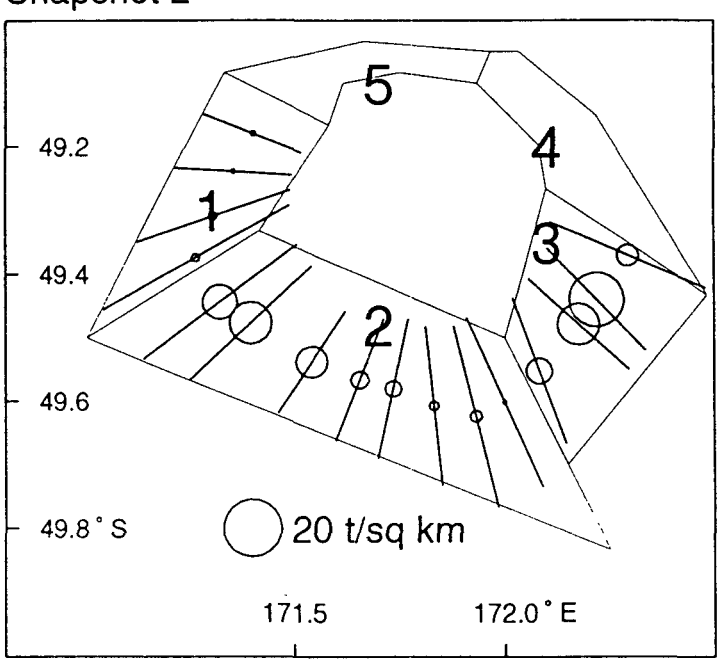


Figure 4: Density estimates of adults (t/sq km) by transect for both snapshots on the Pukaki Rise.

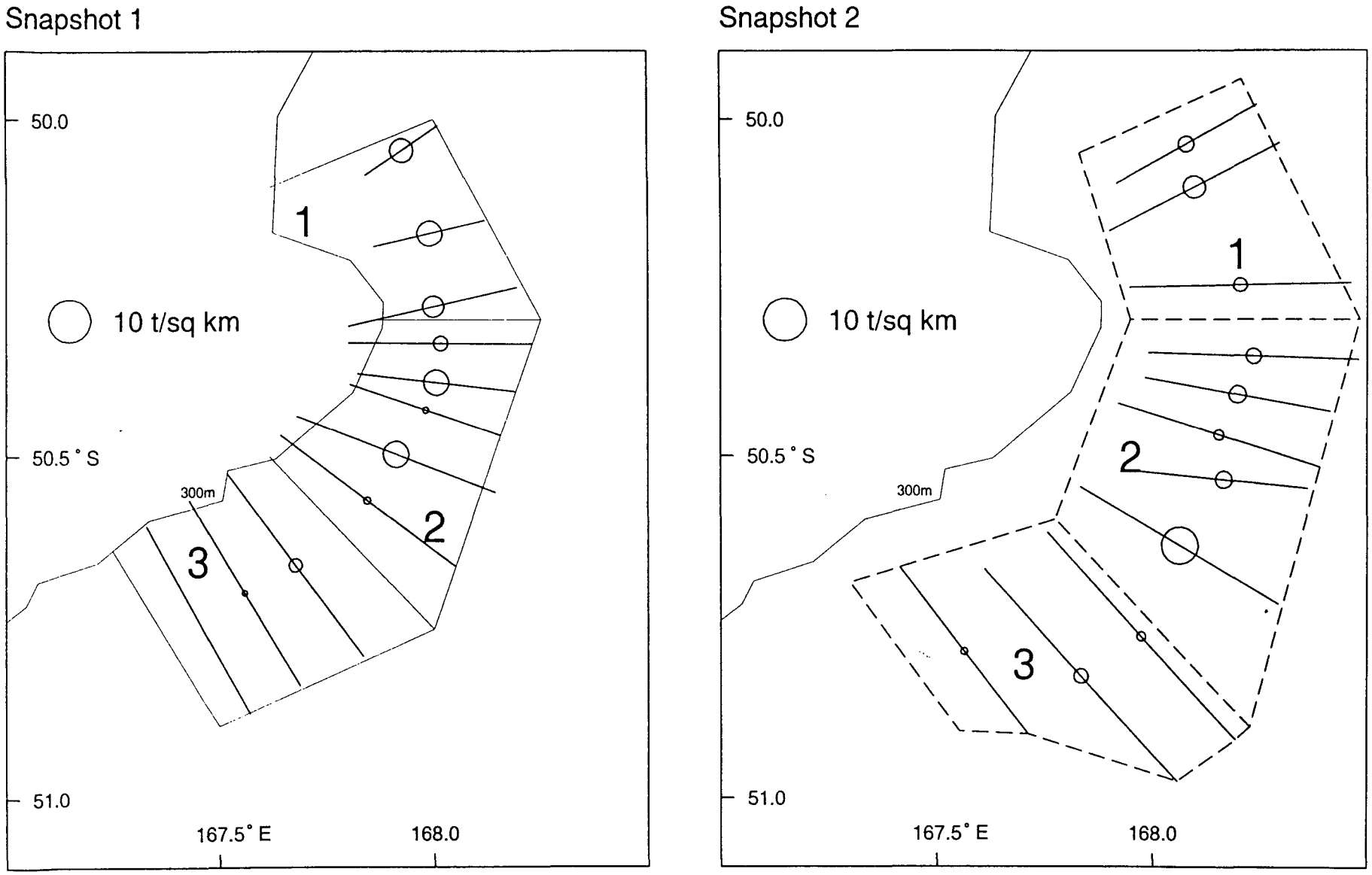


Figure 5: Density estimates of adults (t/sq km) by transect for both snapshots on the Auckland Islands Shelf. The dashed lines indicate the new strata positions in snapshot 2 after the survey area was moved into deeper water.

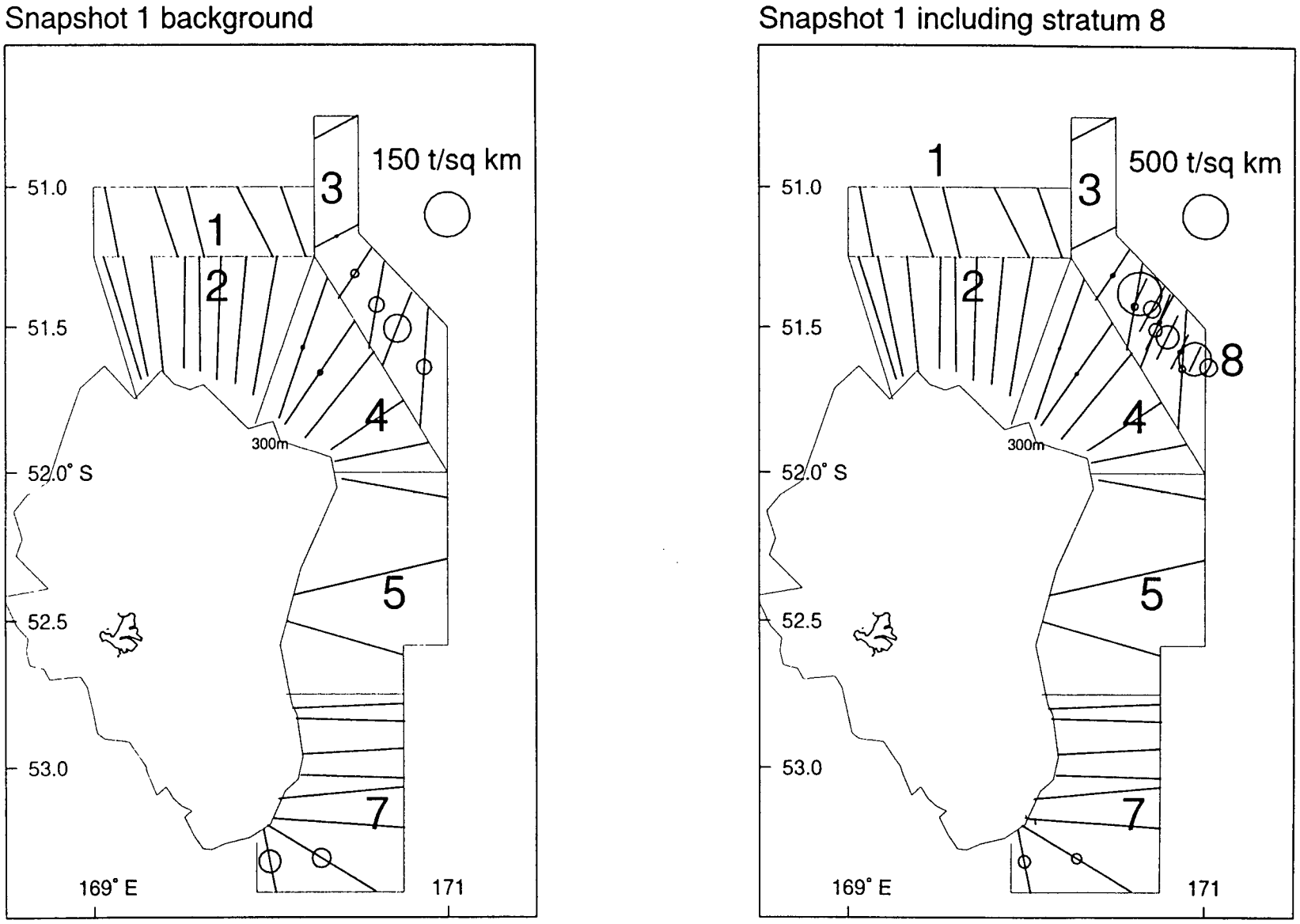


Figure 6: Density estimates of adults (t/sq km) by transect for snapshot 1 on the Campbell Island Rise.

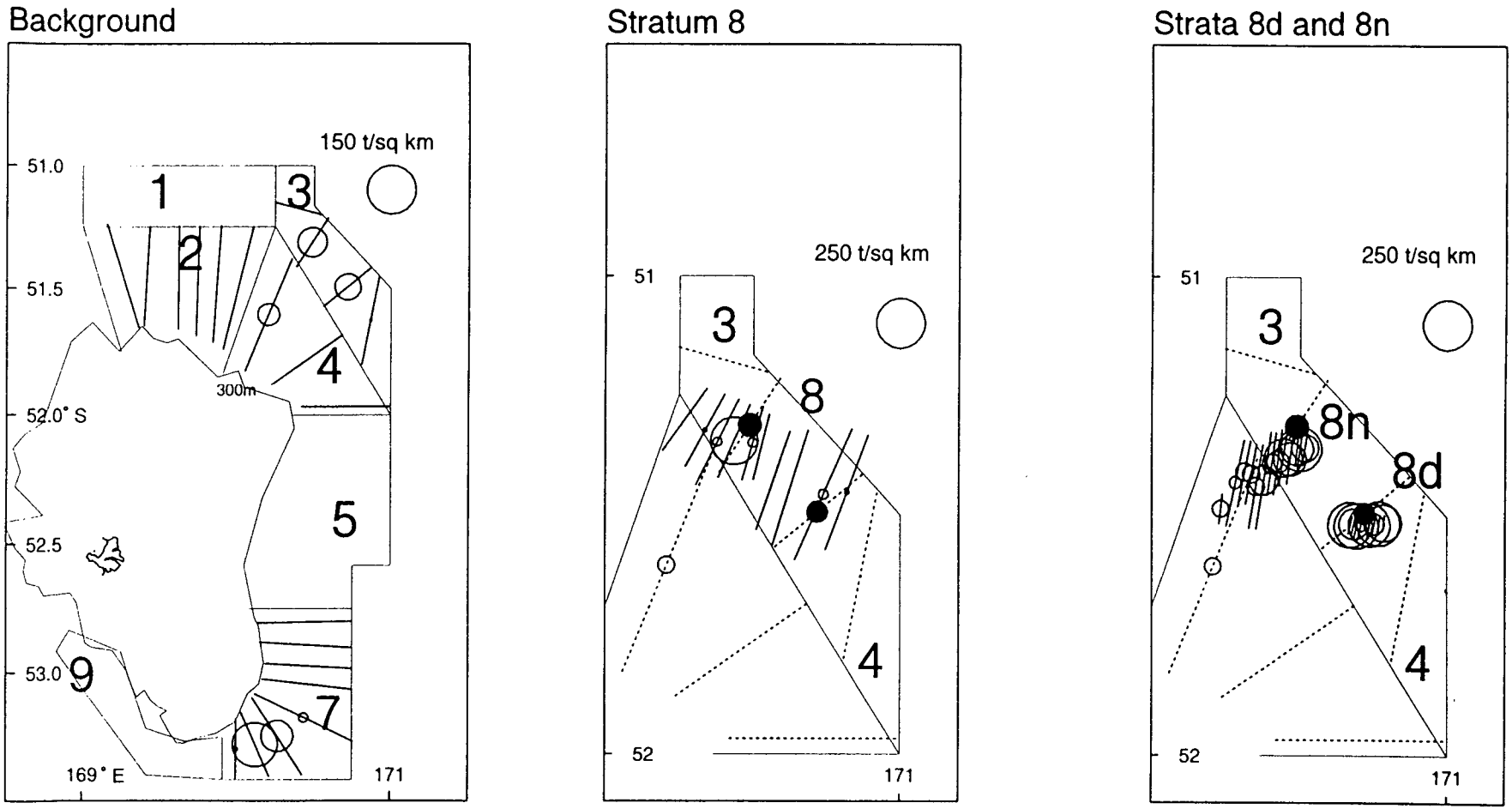


Figure 7: Density estimates of adults (t/sq km) by transect for snapshot 2 on the Campbell Island Rise. The dashed lines and filled circles represent transect positions and fish densities from the background survey.

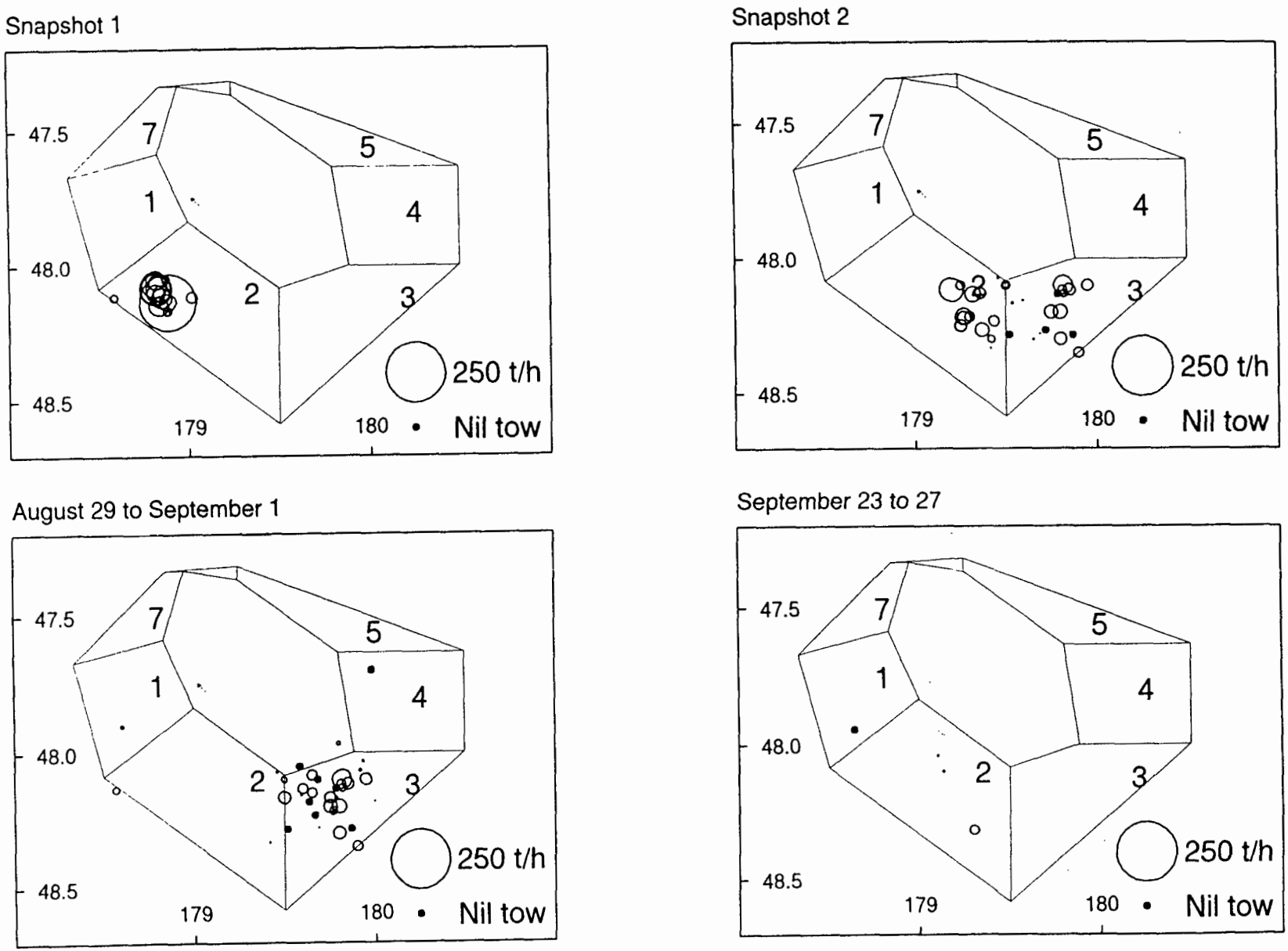


Figure 8: Catch rates (t/h) of all commercial tows made on the Bounty Platform during the 1995 season.

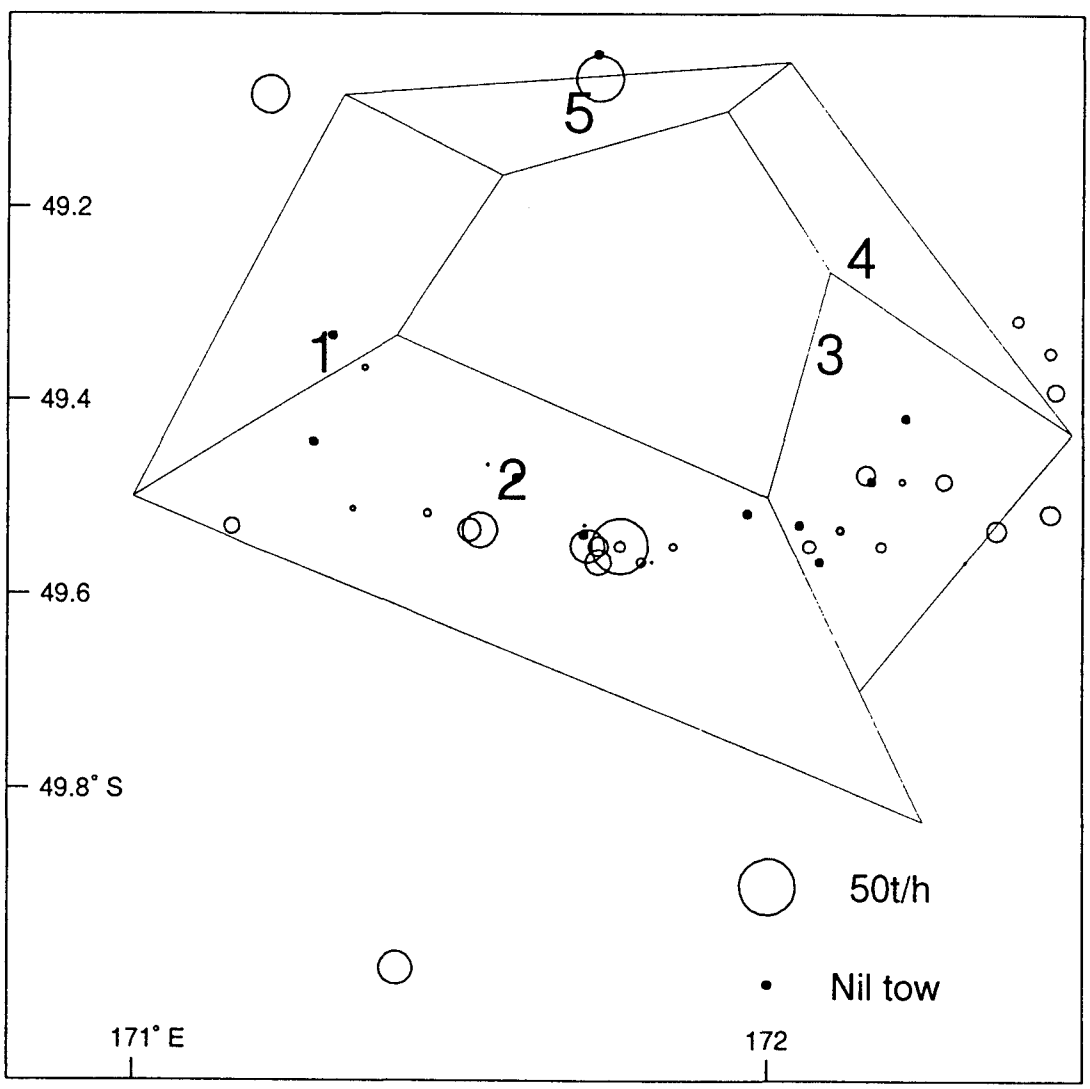


Figure 9: Catch rates (t/h) of all commercial tows made on the Pukaki Rise during the 1995 season.

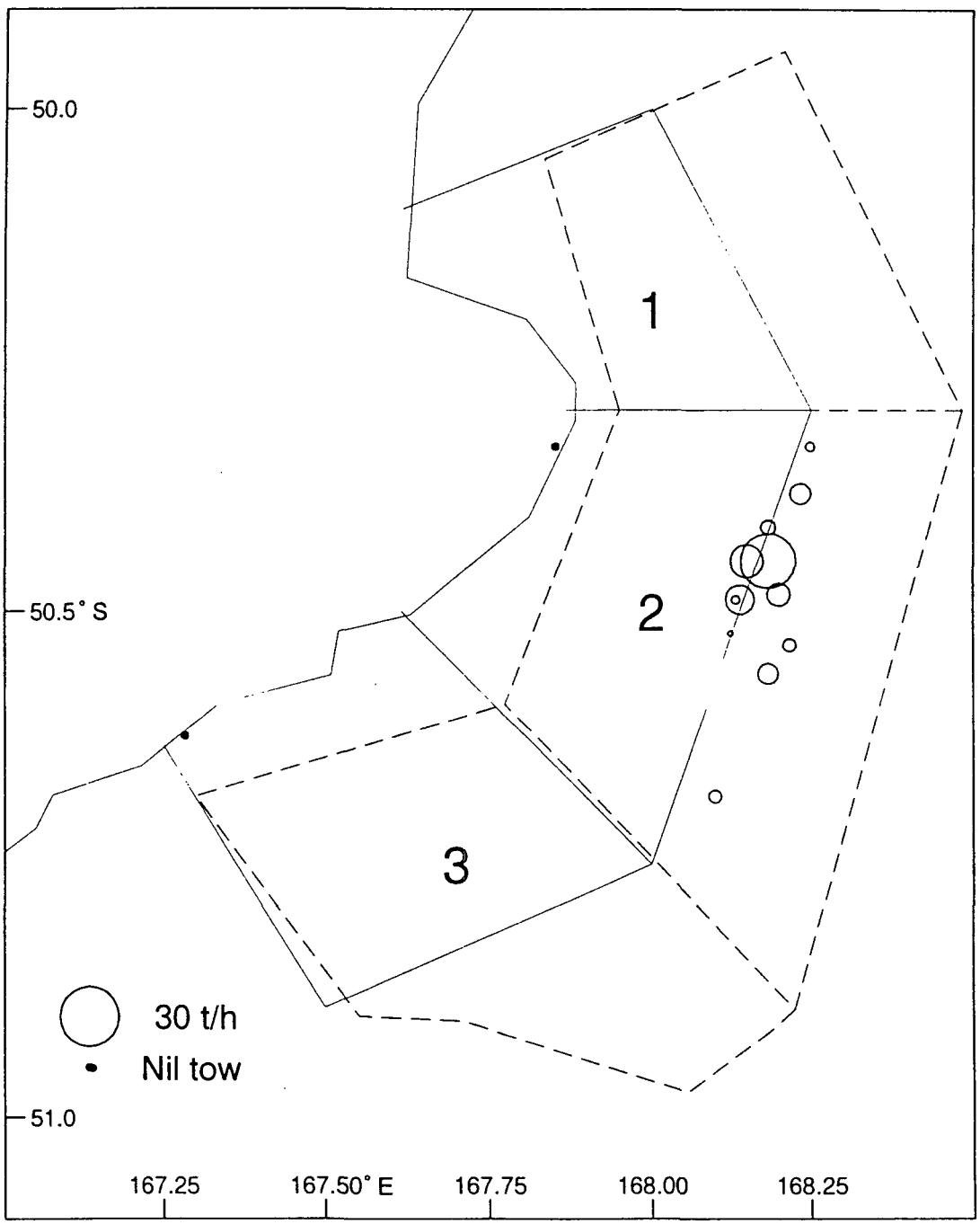


Figure 10: Catch rates (t/h) of all commercial tows made on the Auckland Islands Shelf during the 1995 season. The dashed lines indicate the new strata positions in snapshot 2 after the survey area was moved into deeper water.

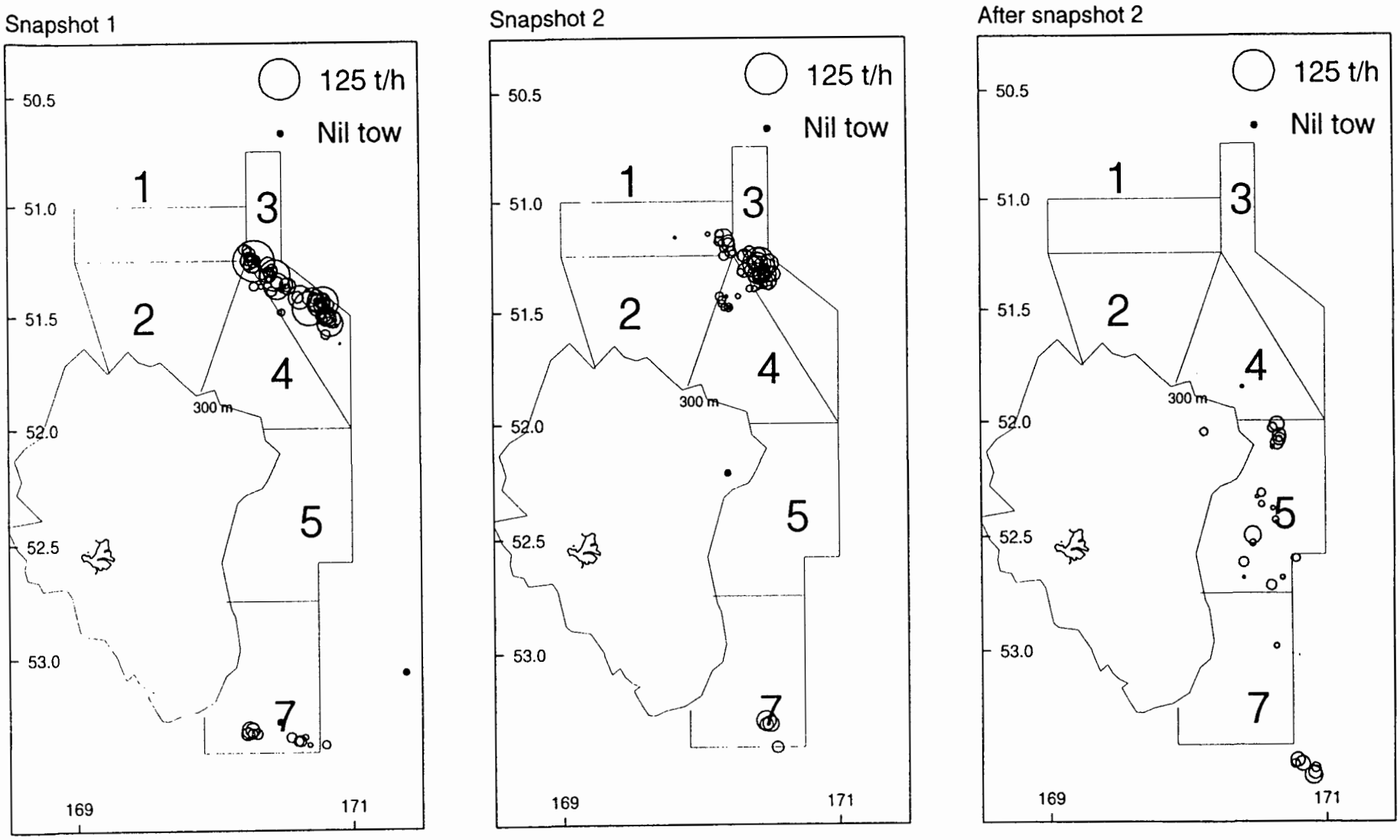


Figure 11: Catch rates (t/h) of all commercial tows made on the Campbell Island Rise during the 1995 season.