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Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, Pukaki Rise, and Campbell Island Rise, August-September 1993

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1. Executive summary

This paper summarises the results of an acoustic survey of stocks of southern blue whiting in subantarctic waters. Two acoustic snapshots were carried out on each of the Bounty Platform, Pukaki Rise, and Campbell Island Rise. Fish on the Bounty Platform were spawning, whereas fish in the other areas were pre-spawning.

Commercial trawl data were examined to determine the main fishing locations within each area and help in the interpretation of marks. Based on this analysis, and the results of targeted research tows on *Tangaroa*, marks were classified into seven categories: definite adults, probable adults, possible adults, definite immatures/juveniles, probable immatures/juveniles, possible immatures/juveniles, and others (definitely not southern blue whiting).

Commercial trawl data and reproductive data collected by scientific observers were analysed to determine whether turnover of fish was occurring during the period of the snapshots. There was no evidence of turnover on the Campbell Island Rise or the Pukaki Rise. However, on the Bounty Platform there was some evidence to suggest a large-scale anticlockwise movement of fish around the Platform which meant that fish were not counted during the first snapshot and possibly double-counted in the second snapshot.

Estimates of total adult biomass (i.e., the sum of definite, probable, and possible adults) were similar for the Bounty Platform and Pukaki Rise at 60 000–100 000 t. Total adult biomass was slightly lower on the Campbell Island Rise at 50 000 t. None of the differences between areas were significant. Biomass estimates of immature fish (mainly 2 year olds) were very high on the Campbell Island Rise and Pukaki Rise, suggesting that the 1991 year class is relatively strong. The biomass of the 1991 year class on the Bounty Platform could not be estimated, but the 1992 year class there also seems to be reasonably strong.

2. Introduction

Landings of southern blue whiting (SBW) have increased considerably in recent years, peaking at 75 000 t in August-September 1992. (This is part of the 1991–92 fishing year which runs from 1 October to 30 September). A 32 000 t catch limit was introduced for the first time in the 1992–93 fishing year and this resulted in a catch of 27 700 t. There is great uncertainty about the current biomass and sustainable yields of all three stocks (Hanchet 1993, Hanchet & Haist 1994).

During the 1980s, landings were taken mainly from the Campbell Island stock, and a time series of catch-at-age and CPUE indices have been developed for this stock. Historical biomass and fishing mortalities have been estimated for this stock using Virtual Population Analysis (VPA) and separable Sequential Population Analysis (sSPA) and are now reasonably

well known. However, current biomass is highly sensitive to the CPUE data used for tuning the models, and is only poorly estimated (Hanchet 1993, Hanchet & Haist 1994). Because both CPUE and catch-at-age data sets are collected from the commercial fishery they can give misleading results, e.g., if selection patterns are markedly different from year to year. It is therefore important to develop a time series of relative abundance indices which are independent of the fishery.

Since 1990, fishing effort and landings have increased on the Bounty Platform and Pukaki Rise, and in 1991–92 almost 60 000 t was taken from the Bounty Platform. Because there has been no consistent fishery on the Bounty Platform we do not have a long enough time series of CPUE data or catch-at-age data on which to base an assessment. At present we have little idea of stock size or potential yields from this stock. In the longer term it is planned to assess both the Pukaki Rise and the Bounty Platform stocks using catch-at-age models, and catch-at-age data are currently being collected for both these stocks for this purpose. In the shorter term an alternative method for stock assessment was required. By carrying out the survey whilst fish were aggregated in each area at the same time of year it was envisaged that the relative abundance in each area could be estimated. Estimates of current biomasses and yields could then be drawn by analogy with the Campbell Island Rise stock.

This paper summarises the results of the 1993 acoustic survey of southern blue whiting stocks. Estimates of biomass and their *c.v.*s are provided where possible for immature and adult fish on the Bounty Platform, Pukaki Rise, and Campbell Island Rise.

3. Survey design

3.1 Survey area and transect allocation

An acoustic survey of the SBW stocks on the Bounty Platform, Pukaki Rise, and Campbell Island Rise was carried out by *Tangaroa* in August and September 1993. Stratification and allocation of transects were initially based on the historical distribution of commercial catches on these grounds from 1986 to 1992. During the survey additional strata were included to ensure a more complete coverage of each spawning ground. Six main strata were surveyed on the Bounty Platform, five on the Pukaki Rise and seven on the Campbell Island Rise (Figures 1–5). In addition, a high density fleet stratum (stratum 8) was surveyed twice during snapshot 2 on Bounty Platform (once during the day and again at night) (Figure 3). Two high density fleet strata were surveyed during snapshot 1 on the Campbell Island Rise (Figure 6). The first (stratum 8dn) was surveyed twice (once during the day and again at night), whilst the second (stratum 8e) was surveyed only once. A fleet stratum (stratum 8) was also surveyed in the second snapshot on the Campbell Island Rise (*see* Figure 5). The boundaries of the fleet stratum were based on the position of most vessels in the fleet over a 12–24 hour period immediately before the stratum was surveyed. On each occasion the fleet stratum was surveyed whilst the wide-area acoustic snapshot was in progress.

Two acoustic snapshots were completed in each area. The stratum area and number of transects by stratum by snapshot are listed in Table 1, and the transect locations are shown in Figures 2 to 6. Except for stratum 9 on the Campbell Island Rise, the parallel transect survey design of Jolly & Hampton (1990) was used in each stratum with transects being run at right angles to the depth contours, i.e., from shallow to deep water or vice versa. The start

position of each transect was randomised for each snapshot, but the minimum distance between transects was large enough to ensure no large areas were left unsurveyed within each stratum following Jolly & Hampton (1990) and Simmonds *et al.* (1992). In stratum 9, zig-zag transects were used because this stratum was being surveyed in an exploratory context and a zig-zag maximises the area covered for a given transect length (Simmonds *et al.* 1992).

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 maximum bottom depth never exceeded 600 m, but in most transects was less than this. Thus, transects on the Bounty Platform were from a bottom depth of 200 m to the edge of the stratum boundary: similarly transects on the Pukaki Rise were from 250 m and on the Campbell Island Rise from 300 m. On the Bounty Platform, few marks were seen in deep water during the first snapshot, therefore in snapshot 2 all transects were surveyed out to a bottom depth of 500 m only. For a similar reason in snapshot 2 on the Campbell Island Rise, transects in strata 2 and 4 were shortened to survey the depth range 330–520 m.

Stratum areas were calculated by joining up the start and/or finish positions of the transects with the stratum boundary and calculating the total enclosed area. Stratum areas were smaller for some strata in snapshot 2 for the reasons outlined above.

3.2 Layer identification

Due to problems with trawl gear and bad weather only 28 midwater tows were made by *Tangaroa* during the survey (Appendix 1). As insufficient data were collected from this work to comprehensively identify all targets, tow by tow data from the commercial fishery were also examined. Catch rates in the fishery for the duration of the two snapshots, and for the period outside the snapshot, were plotted separately for each area. In addition, commercial catch rates were compared between depths. Based on the results of both the research and the commercial tows, marks were assigned to one of the following seven categories: definite adults, probable adults, possible adults, definite immatures/juveniles, probable immatures/juveniles, possible immatures/juveniles, and "others" (definitely not SBW). The juvenile fish were defined as 1 year old fish (mainly < 20 cm FL) and the immature fish were defined as immature 2 and 3 year olds (mainly 20–30 cm FL).

Marks were classified as definite adults when they were on the main fishing ground in the correct area and depth range. They were classified as probable adult when they were in the right depth range, but not in the main fishing ground whilst the snapshot was taking place, and as possible adult when the marks were in deeper water (out to a certain depth) or in an area not fished by the fleet during the season.

Marks were classified as immature or juvenile fish only when it was reasonably certain that they were not adult fish. On the Bounty Platform juveniles were mainly confined to shallower depths of 200–300 m and could usually be separated from the adult marks on the basis of depth and area alone. However, the depth and location of immature and adult fish overlapped and most research tows outside stratum 2 caught a mixture of these two categories. For the analysis these marks were all assigned possible adult: this will overestimate the total adult biomass.

No juvenile fish were caught on the Pukaki Rise so estimates for this category are not presented. The distribution of immature and adult fish overlapped on the Pukaki Rise so they had to be distinguished by the shape of the marks and their location. Using this method most marks could be identified as either predominantly adults or predominantly immature fish, but the remainder were assigned as possible adults on the basis that they contained at least some adult fish. Once again the total adult biomass category will be slightly overestimated.

No juvenile fish were caught on the Campbell Island Rise so estimates for this category are not given. On the Campbell Island Rise immature fish were always in shallower water than adults and could be distinguished from adults on the basis of depth alone.

Most juvenile and immature marks were classed in the probable category since they were usually not verifed through trawling. Marks were classified as "other" when they were either in very deep water (the depth was area dependent), or were obvious scattering layers of salps, natant decapods or mesopelagic fish (usually in midwater).

3.3 Analysis

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. 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. The same relationship is 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.).

The length of SBW used in the relationship depended on the marks and the area concerned. Adult fish marks were assumed to have the length distribution caught by the commercial fishery for that particular area (*see* Hanchet & Haist 1994). Immature fish marks were assumed to have a mean length of about 28 cm on the Campbell Island Rise and 24 cm on the Pukaki Rise: juvenile fish marks were assumed to have a mean length of 16 cm on the Bounty Platform, based on commercial and research length frequency data.

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, using 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 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 were then recalculated.

The day and night fleet stratum transects were analysed separately to determine whether there were diurnal differences in the backscattering estimates.

As preliminary analysis showed that several of the categories had a low biomass, for the final estimates only four combined categories have been presented. These are (i) definite and probable adult biomass; (ii) total adult biomass (i.e., the sum of definite, probable, and possible adult biomasses); (iii) definite and probable immature (or on the Bounty Platform, juvenile) biomass; (iv) total adult and immature/juvenile biomass (i.e., the sum of definite, probable, and possible adult and immature/juvenile biomasses).

3.3 Gonad data

Biological data were examined to determine whether there was any evidence of turnover on each of the grounds. Turnover would be important 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. Gonad stage (using the eight stage system given in Appendix 2) and weight were recorded for a sample of 40–200 male and female fish collected on each tow from *Tangaroa*. Staging data for female fish (using the five stage system given in Appendix 3) were also recorded by scientific observers on each ground during the season.

4. Results

4.1 Acoustic biomass estimates

Biomass estimates by stratum and category for each snapshot on the Bounty Platform excluding the fleet stratum (stratum 8) are shown in Table 2, and the density estimates for the total adults category in Figure 2. Biomass estimates of most categories were similar between the two snapshots except for stratum 1, where the snapshot 2 biomass of total adults was three times that in snapshot 1. Four of the five transects had higher densities in snapshot 2 than in snapshot 1. Two research tows were made on the marks in stratum 1, one in each snapshot, and both caught a mixture of adult and immature fish. An unknown, but probably small, proportion of the total adult biomass in both snapshots would have been immature fish.

Biomass estimates for the Bounty Platform including the fleet stratum (stratum 8) are shown in Table 3 and the density estimates for stratum 8 in Figure 3. The inclusion of the fleet stratum on the Bounty Platform made a large difference to the adult biomass estimates. The biomass estimate of definite and probable adults increased by over 50% from 27 000 t to 42 000 t, and its *c.v.* from 27% to 49%, and the estimate of total adults increased by about 20%

from 71 000 t to 86 000 t and its *c.v.* from 28% to 32%. Figure 2 shows that the increased biomass and *c.v.* resulted from a single transect in the centre of the fleet stratum which recorded a very high density of SBW. The density estimates for two of the other transects surveyed in stratum 8 were 32 and 44 t. km^{-2} and were comparable to the other two densest transects surveyed in stratum 1. The other two transects surveyed in stratum 8 were quite low.

The biomass estimates were calculated using the average of the day and night transects. Using only the night transects would give considerably higher biomass estimates. A biomass of over 46 000 t (*c.v.* = 83%) was estimated from the night fleet stratum by itself compared to only 1650 t (*c.v.* = 24%) during the day (bottom Table 3). However, for reasons seen later, it may not be desirable to use only the results of the night fleet stratum with that of the rest of snapshot 2 because of the risk of double counting.

Biomass estimates by stratum and category for each snapshot on the Pukaki Rise are shown in Table 4, and the density estimates for the total adults category in Figure 4. Snapshot totals were similar for each category between snapshots, although there was a substantial shift in total adult biomass from stratum 1 in snapshot 1 to stratum 2 in snapshot 2. Some of the research tows made in stratum 2 and 3 caught both immature fish and adults, so the total adult biomass estimate will include an unknown immature biomass component.

Biomass estimates by stratum and category for each snapshot on the Campbell Island Rise, excluding the fleet stratum (stratum 8), are shown in Table 5, and the density estimates for the total adults category in Figure 5. Total biomass estimates of most categories were again similar between the two snapshots, although there was a substantial reduction in total adult biomass in stratum 2 in the second snapshot.

Biomass estimates for the Campbell Island Rise including the fleet stratum (stratum 8) are shown in Table 6 and the density estimates for stratum 8 in Figure 6. The inclusion of the fleet stratum in snapshot 1 on the Campbell Island Rise increased the biomass estimate of the two adult categories by 10–20% and substantially decreased their *c.v.*s. The day and night fleet stratum biomass estimates (bottom Table 6) were very similar, indicating there was little diurnal difference in adult biomass estimates. In snapshot 2 the inclusion of the fleet stratum made little difference to the biomass estimates or their *c.v.*s.

4.2 Fleet movement

On Bounty Platform the pattern of fishing was quite different between the snapshot period and the rest of the season (Figures 7 and 8). As there were also marked differences within the snapshot period, the data were examined in more detail. Vessel positions and catch rates are shown at 2-day intervals in Figure 9. The fleet began fishing on 10 August in depths of 400–500 m on the outer boundary of stratum 2. The fleet followed the shelf edge in an easterly and then northerly direction arriving in stratum 5 on 21 August. Reasonably good catch rates were made throughout this period and the fish were of a similar size in all strata. The fleet continued to move north over the next few days but lost contact with the fish near stratum 6 on 24 August. The fleet dispersed during 25 and 26 August searching for fish. Some vessels moved back clockwise around the Platform, but had no success there. Other vessels continued anticlockwise around the Platform towards stratum 2. The first vessels

arrived in stratum 2 on 25 August but made only poor catches there. The rest of the fleet arrived on 26 August and the fishing improved that night and over the next few days. Most vessels made better catches and catch rates at night than during the day. However, some vessels also made good catches during the day.

On the Pukaki Rise very little fishing had been carried out before snapshot 1 began. During both snapshots vessels were fishing and searching throughout strata 1–3 (Figure 10). After the survey ended fishing focussed on the northwest end of stratum 2 (Figure 11).

On the Campbell Island Rise only limited fishing, mainly in strata 4 and 7, was carried out before the snapshot began. During both snapshots vessels mainly fished in stratum 4 and in the east of stratum 2 (Figure 12). After the survey finished vessels moved further west into stratum 2 (Figure 13).

4.3 Gonad data

Gonad data from the observers are shown in Table 7, and from *Tangaroa* in Table 8 (for further details *see* Hanchet & Haist (1994). On the Bounty Platform fish caught between 10 and 20 August showed a steady maturing of gonads. The first running ripe fish were picked up in stratum 5 on August 21 and spawning would have started shortly afterwards. Between 21 and 24 August most fish in stratum 5 were either ripe or running ripe, although one sample on 24 August comprised mainly fish which had already spawned one batch and had reverted to the maturing stage. On 26 August (now in stratum 2) most fish were still either ripe or running ripe, and some observers commented that some of the ripe fish had already spawned before. Most fish examined on *Tangaroa* on 27 August were classified as partially spent (stage 6), and the remainder were either running ripe or had reverted to the maturing stage. By 28 August observers reported about 50% of the fish had reverted to the maturing stage.

On the Pukaki Rise the main spawning started on 7 September, just after the survey was completed. About 30% of fish were spawning on 8 September, and spawning probably would have continued until at least 10–12 September.

On the Campbell Island Rise the main spawning started on 21 September, again just after the survey was completed. Reasonable numbers of ripe fish were caught in early to mid September, but these fish were mainly small and probably did not constitute the main spawning group.

4.4 Bycatch

The weight and percentage by weight of bycatch species from all observed tows during the snapshots are tabulated for each area in Table 9. The weight of the bycatch was less than 0.05% in each area. Even if the target strengths for these species are much larger than for SBW they are unlikely to significantly affect the overall results.

5. Discussion

5.1 Biomass estimation by area

Before the acoustic snapshot results can be are used as estimates of biomass the possibility of fish movement during the snapshots needs to be considered, particularly for the Bounty Platform where there were large differences in biomass between the two snapshots, and between the day and night fleet strata. If some of these differences were due to fish movement, it will affect the way the acoustic results should be treated.

Bounty Platform

As was discussed above, during the early part of the season the fleet moved gradually anticlockwise around the Bounty Platform, from stratum 2 to stratum 6, maintaining reasonable catch rates as they went (*see* Section 4.2 and Figure 9). There are two possible explanations for this movement: (i) there was a single large fish aggregation moving anticlockwise around the Platform, or (ii) there were a number of smaller aggregations distributed all around the Platform. If the latter, then we would have expected to see at least some sign of them them in strata 3 to 6 during the two acoustic snapshots. However, the transect density estimates and biomass estimates for those strata were very low (Figure 2, Table 2). Furthermore, the commercial vessels which returned to strata 3 and 4 on 25–26 August got mainly zero tows (Figure 9). Lastly, the length frequency and gonad staging data collected by the observers were reasonably consistent throughout the period, which again may be more indicative of a single aggregation. It is therefore considered more likely that there was a single large aggregation of fish migrating around the Platform. Based on the average position of the fleet in each 2-day period in Figure 9 the movement of this aggregation is estimated to be about 7 – 10 n. miles per day.

The situation after 24 August is less clear. As stated above, the fleet appeared to lose the fish after 24 August, some vessels searching strata 3 and 4 to the east and some searching strata 7 and 1 to the west. They eventually found good marks in stratum 2 in the evening of 26 August and made good catch rates there over the next few days. So did the aggregation continue to move around the shelf ending up in stratum 2, or were the stratum 2 fish a different aggregation altogether?

There is some evidence from the acoustic data that the fish continued to migrate around the shelf into stratum 2. The stratum 1 biomass, surveyed during the night of 25 August, was three times higher during the second snapshot than on the first (Table 2), with four out of the five transect densities being higher (Figure 2). The stratum 8 biomass estimate, surveyed during the night of 26 August, was about 25 times higher than it had been during the day (Table 3). Both these differences would be consistent with a movement of the fish down the western side of the Platform and into stratum 8 by the night of 26 August. Observer length frequency and gonad staging data were also consistent between the two sampling dates, which may again indicates a single aggregation. However, the evidence is rather tenuous. The *c.v.*s on these biomass estimates are all very large so that the observed differences are non-significant and could easily be due to chance. Furthermore, results from the second acoustic survey in 1994 also showed large diurnal differences in the densities of spawning fish marks on three separate occasions, which could not be accounted for purely by fish movement. So

even if the point estimates in the fleet stratum were true, the differences in biomass may not necessarily be due to a large-scale migration of fish into the area.

When more surveys have been carried out movements of pre-spawning and spawning adult SBW on the Bounty Platform may become a little clearer. For the present analysis, the results have been treated assuming (i) movement had occurred, and (ii) no movement occurred.

Under the movement hypothesis the results of snapshot 1 were discounted because the main aggregation was not surveyed. The results of snapshot 2 (including the fleet stratum) were also considered invalid because the fish would have been double counted – once in stratum 1 and then again at night in the fleet stratum. This leaves the results of snapshot 2 (excluding the fleet stratum) as the only reliable estimates of biomass in this area (i.e., snapshot 2 in Table 2).

Under the no movement hypothesis consideration needs to be given as to the treatment of the two snapshots and the day and night fleet strata. Averaging the two snapshots and averaging the day and night fleet strata may underestimate the true biomass, but are consistent with a no movement hypothesis. Using only the results of the second snapshot together with the night fleet strata, on the other hand, could overestimate biomass. Both estimates are presented in the final summary table, as they provide a range of point estimates of biomass.

Total adult biomass estimates were similar for the movement and no movement hypotheses (Table 10), and ranged from about 60 000 to 70 000 t. However, when only the nightime transects were used for the fleet stratum the total adult biomass was about 110 000 t. The total adult biomass will be slightly overestimated on the Bounty Platform as the immature fish marks could not be clearly distinguished from adult marks in most strata (except the fleet strata).

Although the biomass of immature fish on the Bounty Platform could not be estimated, the biomass of 1 year olds was about 9000 t, which, given an average weight of 30 g, equates to about 300 million fish. This would make it a very strong year class.

Pukaki Rise

Fleet movements and fish behaviour on the Pukaki Rise appear more straightforward. Although snapshots on the Pukaki Rise were made during the pre-spawning period, spawning started the day after the last snapshot was completed. Biomass estimates of most categories were very similar between snapshots. There was a slight shift in biomass from the southern end of stratum 1 in snapshot 1 to the northern end of stratum 2 in snapshot 2, but this should not have introduced bias into the results. After the survey most vessels continued to fish in the north of stratum 2 where the most consistent marks had been seen during snapshot 2. It is therefore unlikely that significant turnover had taken place and so the results of the two snapshots were averaged (Table 10). Total adult biomass was estimated to be 60 000 t and immature biomass was 30 000 t. As on the Bounty Platform, the total adult biomass is probably overestimated because of the mix with immature fish.

Campbell Island Rise

Both snapshots on the Campbell Island Rise were carried out in the pre-spawning period and spawning started shortly after the survey ended. The fleet remained in essentially the same position during both snapshots, but afterwards moved further to the west of stratum 2 where only light marks were seen during the survey. The evidence suggests that the school being fished in stratum 4 had moved west into stratum 2 to spawn. The results of the two snapshots from Table 6 were therefore averaged to give a mean plateau height estimate for each category (*see* Table 10). Definite and probable adult biomass was estimated to be 25 000 t and total adult biomass was 48 000 t.

Using a separable Sequential Population Analysis (sSPA) Hanchet & Haist (1994) estimated the 1993 mid-season spawning biomass of the Campbell Island Rise stock to be 34 000 t with a 90% confidence interval of 18 000–72 000 t. The acoustic point estimate for definite and probable adults is lower than the sSPA point estimate, but the acoustic point estimate of total adults is higher than the sSPA point estimate. Both lie within the 90% confidence interval from the model.

Estimates of immature fish biomass on the Campbell Island Rise were about double those of the adults. This is consistent with the occurrence of large numbers of 1 and 2 year old fish of the 1991 year class on the Campbell Plateau reported during trawl surveys in 1992 and 1993 respectively (Hanchet & Haist 1994). However, the magnitude of the estimate is surprising. A 2 year old fish weighs on average about 100 g, so a biomass of 87 000 t equates to about 870 million fish. The largest recruitment of 2 year olds in this stock, predicted from the sSPA, is about 140 million fish (Hanchet & Haist 1994), so this acoustic result may need to be treated with caution.

5.2 Comparison of biomass between areas

Estimates of definite and probable adult biomass were not significantly different between all three areas, and ranged from 25 000 t on the Campbell Island Rise to 64 000 t on the Bounty Platform (*see* Table 10). Estimates of total adult biomass (i.e., the sum of definite, probable, and possible adults) were also not significantly different between areas, and ranged from 48 000 t on the Campbell Island Rise to 109 000 t on the Bounty Platform. Given the large *c.v.*s on these estimates it is difficult to draw strong conclusions regarding the relative sizes of the different stocks of adult SBW. Furthermore, it should be remembered that the distribution of immature SBW overlapped with the adults on the Bounty Platform and the Pukaki Rise so some of the biomass attributed to possible adults on both grounds should have been included in the immature fish biomass. The data indicated that this year class is exceptionally strong on the Campbell Island Rise, and if it is also strong on the other two areas it could substantially influence their biomasses estimates.

6.1 Conclusions

Although there was a great deal of uncertainty about layer identification in each of the areas the following preliminary conclusions can be reached.

1. The 1992–93 adult biomass on the Bounty Platform is at least as large as, and possibly larger than, that on each of the Campbell Island Rise and the Pukaki Rise.

2. The densest marks in the entire survey were found in a single large aggregation in the main spawning ground on the Bounty Platform, which was estimated to be 47 000 t (*c.v.* = 83%) (assuming a target strength-fish length relationship derived for blue whiting in the Northern Hemisphere).

3. The 1992–93 adult biomass on the Pukaki Rise was at least as large as that on the Campbell Island Rise. There was greater uncertainty regarding the Pukaki Rise biomass estimate as it was difficult to completely separate adult marks from immature fish marks on this ground.

4. There is a large biomass of mainly 2 year old fish (1991 year class) on the Campbell Island Rise and the Pukaki Rise (and possibly also on the Bounty Platform) which should recruit into the fisheries in 1993–94 and 1994–95.

7. Acknowledgments

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Table 1: Stratum areas and numbers of transects per snapshot (snap) for each spawning ground. For stratum boundaries *see* Figures 1-6. (– stratum not surveyed during that snapshot, so there was no stratum area)

Stratum	Stratum area (km^2) Snap 1	Snap 2	Number of transects Snap 1	Snap 2
Bounty Platform				
1	1 466	1 433	5	5
2	2 754	2 511	6	6
3	2 479	1 967	4	4
4	1 953	1 953	3	3
5	1 306	817	5	5
7	691	536	3	3
8	–	306	0	10
Pukaki Rise				
1	703	703	2	4
2	1 949	1 949	8	8
3	837	837	5	4
4	326	326	0	3
5	220	220	0	3
Campbell Island Rise				
1	4 500	4 500	5	0
2	3 437	2 716	6	4
3	2 900	2 900	0	0
4	2 839	2 742	3	3
5	4 247	4 247	3	2
6	2 618	2 618	3	3
7	3 580	3 580	6	6
8dn	774	–	11	0
8e	544	–	5	0
8	–	1803	0	3
9	1922	1922	0	7

Table 2: Number of transects, stratum area, and biomass (t) of four different categories of SBW (southern blue whiting) by stratum and snapshot for the Bounty Platform, 21–29/8/93. Def., definite; Prob., probable; Juv., juvenile; Imm., immature

Stratum	Snap–shot	Stratum area	No. of tran–sects	Def. + Prob. Adult	Total Adult	Def. + Prob. Juv.	Total Adult + Imm+Juv
1	1	1 466	5	3 995	16 737	0	16 966
	2	1 433	5	11 558	51 842	0	51 901
2	1	2 754	6	11 270	11 923	171	12 196
	2	2 511	6	9 531	11 244	536	11 835
3	1	2 479	4	27	82	6 057	6 176
	2	1 967	4	852	2 106	5 443	7 636
4	1	1 953	3	6 313	7 297	1 434	8 737
	2	1 953	3	4 291	5 235	4 341	9 634
5	1	1 306	5	285	407	332	749
	2	817	5	434	492	0	506
7	1	691	3	0	56	0	61
	2	536	3	0	238	0	238
Total	1	10 486	26	21 890	36 502	7 995	44 885
(*c.v.*)				(55)	(32)	(49)	(28)
Total	2	9 164	26	26 666	71 157	10 320	81 750
(*c.v.*)				(27)	(28)	(49)	(25)

Table 3: Number of transects, stratum area, and biomass (t) of four different categories of SBW by stratum and snapshot for the Bounty Platform 21–29/8/93 including stratum 8. (Stratum 8 estimated as mean of day and night transects.) Abbreviations are explained in Table 2

Stratum	Snap–shot	Stratum area	No. of tran–sects	Def. + Prob. Adult	Total Adult	Def. + Prob. Juv.	Total Adult + Imm+Juv
1	1	1 466	5	3 995	16 737	0	16 966
	2	1 433	5	11 558	51 842	0	51 901
2	1	2 754	6	11 270	11 923	171	12 196
	2	2 205	6	364	2 197	471	2 716
8	2	306	10	24 101	24 101	0	24 101
3	1	2 479	4	27	82	6 057	6 176
	2	1 967	4	852	2 106	5 443	7 636
4	1	1 953	3	6 313	7 297	1 434	8 737
	2	1 953	3	4 291	5 235	4 341	9 634
5	1	1 306	5	285	407	332	749
	2	817	5	434	492	0	506
7	1	691	3	0	56	0	61
	2	536	3	0	238	0	238
Total	1	10 486	26	21 890	36 502	7 995	44 885
(*c.v.*)				(55)	(32)	(49)	(28)
Total	2	9 164	36	41 600	86 211	10 254	96 732
(*c.v.*)				(49)	(32)	(49)	(29)
Biomass of stratum 8 night and day transects separately							
8 Night	2	306	5	46 550	46 550	0	46 550
8 Day	2	306	5	1 651	1 651	0	1 651

Table 4: Number of transects, stratum area, and biomass estimates (t) of four different categories of SBW by stratum and snapshot for the Pukaki Rise 31/8/93–6/9/93. Totals include strata 1–3 only. Abbreviations are explained in Table 2

Stratum	Snap–shot	Stratum area	No. Tran–sects	Def. + Prob Adult	Total Adult	Def. + Prob. Imm.	Total Adult + Imm.
1	1	703	2	10 419	35 630	4 500	35 635
	2	703	4	3 473	4 104	2 143	6 361
2	1	1 949	8	25 383	26 821	23 835	50 762
	2	1 949	8	37 637	41 326	32 941	74 302
3	1	837	5	4 350	6 712	842	7 603
	2	837	4	4 887	5 101	1 502	6 610
4	1	–	0	Not surveyed			
	2	326	3	0	4 120	0	4 120
5	1	–	0	Not surveyed			
	2	220	3	0	531	0	531
Total	1	3 887	15	40 151	70 164	24 682	95 000
(*c.v.*)				(37)	(28)	(31)	(22)
Total	2	3 887	22	45 997	50 531	36 586	87 273
(*c.v.*)				(32)	(28)	(37)	(22)

Table 5: Number of transects, stratum area, and biomass estimates (t) of four different categories of SBW by stratum and snapshot for the Campbell Island Rise, 6–19/9/93. Totals exclude stratum 9. Abbreviations are explained in Table 2

Stratum	Snap–shot	Stratum area	No. of tran–sects	Def. + Prob. Adult	Total Adult	Def. + Prob. Imm.	Total Adult + Imm.
1	1	4 500	5	0	0	0	0
	2	4 500	0		not surveyed		
2	1	3 437	6	13 905	15 347	6 642	22 851
	2	2 716	4	1 693	3 142	7 906	11 268
4	1	2 839	3	8 074	8 389	11 765	20 785
	2	2 742	3	7 749	7 987	20 620	29 051
5	1	4 247	3	1 324	15 018	63 017	78 035
	2	4 247	2	6 326	7 047	47 048	54 095
6	1	2 618	3	0	5 225	0	5 225
	2	2 618	3	0	4 794	0	4 794
7	1	3 580	6	550	10 578	8 395	19 480
	2	3 580	6	5 472	14 269	19 033	35 184
9	1	1 922	0		not surveyed		
	2	1 922	7	0	13 421	3 264	18 161
Total	1	23 000	27	23 853	54 558	84 819	146 377
(*c.v.*)	1			(38)	(19)	(37)	(22)
Total	2	22 485	25	21 239	37 866	94 608	135 019
(*c.v.*)	2			(45)	(23)	(28)	(21)

Table 6: Number of transects, stratum area, and biomass estimates (t) of four different categories of SBW by stratum and snapshot for the Campbell Island Rise, 6–19/9/93, with stratum 8 included (average of day/night). Totals exclude stratum 9. Biomass of stratum 8 from only day and only night transects also given. Abbreviations are explained in Table 2

Stratum	Snap–shot	Stratum area	No. of tran–sects	Def. + Prob. Adult	Total Adult	Def. + Prob. Imm.	Total Adult + Imm.
1	1	4 500	5	0	0	0	0
	2	4 500	0		not surveyed		
2	1	3 173	6	2 546	3 874	4 058	8 688
	2	1 863	4	631	1 586	4 858	6 594
4	1	1 966	3	937	1 161	3 227	4 829
	2	1 791	3	4 968	5 123	6 557	11 934
8dn	1	774	11	8 698	8 698	2 269	10 967
8e	1	544	5	15 015	15 015	2 243	17 258
8	2	1803	3	2 637	3 118	16 657	19 774
5	1	3 998	3	1 326	15 018	63 017	78 035
	2	4 445	2	6 326	7 675	47 048	54 723
6	1	2 618	3	0	5 225	0	5 225
	2	2 618	3	0	4 794	0	4 794
7	1	3 580	6	595	10 578	0	5 225
	2	3 580	6	5 472	14 269	19 033	35 184
9	1	1 922	0		not surveyed		
	2	1 922	7	0	13 421	3 264	18 161
Total	1	23 000	27	29 115	59 569	83 210	144 483
(*c.v.*)	1			(23)	(14)	(38)	(22)
Total	2	22 485	25	20 032	36 564	94 153	133 003
(*c.v.*)	2			(47)	(23)	(28)	(21)
Biomass of stratum 8 night and day transects separately							
8 Night	1	774	7	9 696	9 696	2 112	11 808
8 Day	1	774	4	7 701	7 701	2 410	10 110

Table 7: Percentage of females at each gonad stage from observer data by area and date. BP, Bounty Platform; PR, Pukaki Rise, CI, Campbell Island Rise; AI, Auckland Island. *See* Appendix 3 for a description of the gonad staging system.

Area	Date		Gonad stage				
		Total	1	2	3	4	5
BP	10AUG93	86	0	100	0	0	0
BP	11AUG93	189	0	100	0	0	0
BP	12AUG93	344	1	99	0	0	0
BP	13AUG93	229	0	100	0	0	0
BP	14AUG93	184	0	100	0	0	0
BP	15AUG93	580	1	84	14	0	0
BP	16AUG93	552	1	91	7	0	0
BP	17AUG93	521	2	83	15	0	0
BP	18AUG93	430	0	89	11	0	0
BP	19AUG93	582	10	65	25	0	0
BP	20AUG93	277	0	43	57	0	0
BP	21AUG93	511	0	2	47	51	0
BP	22AUG93	435	0	3	90	7	0
BP	23AUG93	311	0	2	74	25	0
BP	24AUG93	262	0	21	41	35	3
BP	26AUG93	449	0	2	91	7	0
BP	28AUG93	378	0	49	29	17	4
BP	29AUG93	178	0	72	11	9	8
PR	07AUG93	80	96	4	0	0	0
PR	25AUG93	98	35	64	1	0	0
PR	26AUG93	55	40	58	2	0	0
PR	28AUG93	61	7	93	0	0	0
PR	30AUG93	40	20	80	0	0	0
PR	31AUG93	80	16	80	4	0	0
PR	02SEP93	254	35	63	1	1	0
PR	03SEP93	387	3	89	7	0	0
PR	04SEP93	318	0	85	14	1	0
PR	05SEP93	144	0	2	88	9	1
PR	06SEP93	360	0	2	94	4	0
PR	07SEP93	288	0	1	88	10	0
PR	08SEP93	368	0	6	63	30	1
PR	09SEP93	62	15	40	31	15	0
CI	28AUG93	110	0	100	0	0	0
CI	29AUG93	119	0	100	0	0	0
CI	30AUG93	87	0	100	0	0	0
CI	31AUG93	140	0	100	0	0	0
CI	01SEP93	319	36	60	4	0	0
CI	09SEP93	181	2	75	23	1	0
CI	10SEP93	269	0	98	1	0	0
CI	11SEP93	264	0	88	12	0	0
CI	12SEP93	148	2	86	11	0	0
CI	13SEP93	96	2	98	0	0	0
CI	14SEP93	72	0	81	19	0	0
CI	18SEP93	214	0	96	3	0	0
CI	19SEP93	334	0	80	19	1	0
CI	20SEP93	214	1	59	33	7	0
CI	21SEP93	76	0	49	32	20	0
CI	22SEP93	235	0	16	60	22	1
CI	23SEP93	159	0	13	36	50	1
CI	24SEP93	212	1	2	75	19	3
CI	25SEP93	141	2	2	40	51	4
CI	26SEP93	59	2	10	27	19	42
AI	15SEP93	66	0	2	95	3	0
AI	16SEP93	73	0	0	40	60	0
AI	17SEP93	35	0	20	46	31	3
AI	18SEP93	90	0	28	41	27	4

Table 8: Percentage of male and female fish at each gonad stage, by area for *Tangaroa* survey, August - September 1993. The gonad staging system is described in Appendix 2. BP, Bounty Platform; PR, Pukaki Rise, CI, Campbell Island Rise.

			Gonad stage							
Area	Date	Total	1	2	3	4	5	6	7	8
Males										
BP	21–27 Aug	322	20	0	0	10	14	54	2	–
PR	3–6 Sep	341	18	0	6	73	1	2	0	–
CI	7–10 Sep	240	5	0	2	91	1	1	0	–
Females										
BP	21–27 Aug	294	23	0	11	1	9	43	2	11
PR	3–6 Sep	309	22	1	61	11	1	2	0	2
CI	7–10 Sep	249	9	0	89	1	0	0	0	1

Table 9: Weight of southern blue whiting and weight and percentage by weight of the main bycatch species from observed vessels in the southern blue whiting fishery (15/8/93 – 30/9/93). BP, Bounty Platform; PR, Pukaki Rise; CI, Campbell Island Rise; n, number of observed tows.

		SBW	Hake		Hoki		Ling	
Area	n	(t)	(t)	%	(t)	%	(t)	%
BP	70	4 971	0	0	0	0	0.16	0.00
PR	42	1 976	0.38	0.02	0.18	0.01	0.29	0.01
CI	49	2 516	0.92	0.02	0.06	0.01	0.19	0.01

Table 10: Summary of mean plateau biomass estimates (and *c.v.*s) for each area, for each category of SBW. Values for Bounty Platform (1) are the estimates from snapshot 2 only (Table 5) (i.e., assuming movement); for Bounty Platform (2) are the average of the two snapshots from Table 6 (with the day and night fleet stratum transects averaged), (i.e., assuming no movement); for Bounty Platform (3) are the results of snapshot 2 from Table 6 with only the night fleet stratum transects (i.e., assuming no movement); for Pukaki Rise are the average of the two snapshots from Table 7; for Campbell Island are the average of the two snapshots from Table 4. Abbreviations are explained in Table 2.

Area	Def. + Prob. adult	Total adult	Def. + Prob. imm	Def. + Prob. juv	Total adult + imm + juv
Bounty Platform (1)	26 666	71 157	–	10 320	81 750
	(27)	(28)		(49)	(25)
Bounty Platform (2)	31 745	61 356	–	9 124	70 809
	(37)	(24)		(35)	(22)
Bounty Platform (3)	64 049	108 660	–	10 254	119 181
	(62)	(40)		(49)	(37)
Pukaki Rise	43 074	60 348	30 789	–	91 137
	(24)	(20)	(25)		(16)
Campbell Island	24 574	48 067	88 681	–	138 743
	(24)	(12)	(23)		(15)

Appendix 1. Station details for TAN9308. Gear dep., depth of gear (groundrope) at beginning (Beg) and end of tow; Bot. dep., depth of bottom at beginning (Beg) and end of tow. SBW weight, weight of southern blue whiting (SBW) in the catch in kg. SBW size: ad = > 2 years old, (> 30 cm); imm = 2 years old, (20–30 cm); juv = 1 year old, (< 20 cm). BP, Bounty Platform; PR, Pukaki Rise, CI, Campbell Island Rise.

Station	Area	Date	Lat (S)		Long		Gear dep. Beg	Gear dep. end	Bot. dep. Beg	Bot. dep. end	SBW weight	SBW size
1	BP21	Aug 93	480564	S	1784855	E	398	349	399	360	0.0	–
2	BP22	Aug 93	475618	S	1784027	E	349	220	358	346	24.1	juv/ad
3	BP22	Aug 93	480900	S	1784403	E	508	360	521	367	0.0	–
5	BP23	Aug 93	480751	S	1794747	E	215	217	223	227	666.5	juv
7	BP24	Aug 93	474984	S	1793976	W	381	376	387	384	15.7	imm
8	BP24	Aug 93	473233	S	1795082	E	370	314	391	325	2.4	imm
10	BP25	Aug 93	472261	S	1785129	E	395	273	424	364	0.0	–
12	BP25	Aug 93	473993	S	1783433	E	278	368	376	376	14.2	imm/ad
13	BP26	Aug 93	480736	S	1785465	E	339	329	349	346	1.2	ad
14	BP26	Aug 93	480544	S	1785433	E	290	290	315	300	9.8	ad
15	BP27	Aug 93	475979	S	1785534	E	220	306	244	309	198.7	ad
16	BP27	Aug 93	480293	S	1785379	E	260	283	280	303	86.0	ad
20	PR	3 Sep 93	492371	S	1712350	E	168	350	350	350	584.8	ad
21	PR	4 Sep 93	492479	S	1712186	E	223	313	372	338	15.9	ad/imm
22	PR	4 Sep 93	492650	S	1713154	E	211	232	294	342	2971.8	ad
24	PR	5 Sep 93	493384	S	1715756	E	203	255	382	306	30.8	imm/ad
25	PR	5 Sep 93	493689	S	1720092	E	400	430	420	432	16.1	ad/imm
26	PR	5 Sep 93	492978	S	1720178	E	286	263	316	294	0.5	imm
27	PR	5 Sep 93	492841	S	1720396	E	232	283	262	283	69.7	imm/ad
28	PR	6 Sep 93	493306	S	1713590	E	360	290	388	330	157.2	imm
30	CI	7 Sep 93	511371	S	1690387	E	180	239	545	556	0.0	–
31	CI	7 Sep 93	510945	S	1690558	E	371	350	555	555	0.0	–
32	CI	7 Sep 93	510926	S	1690753	E	540	534	550	536	0.0	–
34	CI	8 Sep 93	511618	S	1694234	E	540	520	540	530	0.0	–
35	CI	8 Sep 93	513286	S	1700076	E	443	411	470	412	0.7	ad
36	CI	10 Sep 93	514440	S	1700891	E	350	410	391	411	81.9	imm
37	CI	10 Sep 93	513740	S	1701911	E	448	446	462	476	251.9	ad
39	CI	10 Sep 93	513979	S	1703617	E	360	390	475	494	254.1	ad

Appendix 2. Gonad staging system used on TAN9308.

STAGE			
1	IMMATURE	F.	Ovaries translucent, white and small (about 2 cm long). No eggs present.
		M.	Testes thin translucent ribbons, almost undetectable.
2	RESTING	F.	Ovaries elongate and pale in colour. No eggs visible to naked eye.
		M.	Testes partially lobed, but still threadlike.
3	MATURING	F.	Ovaries creamy white and firm, with opaque eggs.
		M.	Testes multilobed, opaque to white in colour with no milt extrudable.
4	MATURE	F.	At least one clear hyaline egg visible through ovary wall. Ovary considerably enlarged and speckled.
		M.	Testes with large creamy white lobes. Only small amount of milt extrudable.
5	RUNNING RIPE	F.	Clear (ovulated) eggs freely extrudible either from vent or cut ovary. At least 10% of the eggs in the ovary should be in this stage.
		M.	Milt easily extrudible and free–running when pressed.
6	PARTIALLY SPENT	F.	Ovary bloodshot and partiallu deflated. Vitellogenic, hyaline, and some ovulated eggs present (see also stage 8).
		M.	Testes brownish at edges, bloodshot and thin. Some milt extruded with pressure.
7	SPENT	F.	Ovary bloody, flaccid and dark red/purple. Ovary wall often thickened. A few residual opaque or ovulated eggs may be present.
		M.	Testes usually brownish, thin and straggly with no extrudible milt.
8	REVERTED	F.	Ovary bloodshot and partially deflated. Mainly vitellogenic eggs, but a few ovulated eggs also present.

Appendix 3: Female SBW gonad staging system used by observers.

1. IMMATURE/RESTING

Ovary very small and white, no eggs visible.

2. RIPENING

Ovary creamy white. White (opaque) eggs barely visible. No clear (hyaline) eggs present in egg mass. Fish which have already spawned this season may have a few clear (ovulated) eggs present in centre of ovary.

3. RIPE

At least one clear (hyaline) egg present in egg mass. Ovary considerably enlarged, swollen and speckled. In fish which have already spawned this season the ovary may become purplish and have a few (<10%) clear (ovulated) eggs in its centre.

4. RUNNING RIPE

Clear (ovulated) eggs freely extrudible either from vent or cut ovary. Eggs should flow freely and smoothly off the surface of a knife. At least 10% of eggs in the ovary should be in this state.

5. SPENT

Ovary bloody, flaccid and dark red/purple. Ovary wall often thickened. Up to 100 residual opaque (white) or ovulated (clear) eggs may be present, depending on size of fish.

Note:

Some fish may have already spawned some eggs this season as evidenced by occurrence of a few disclike ovulated eggs in centre of ovary. Record ovary as stage 2 or 3 depending on absence or presence of clear (hyaline) eggs in the egg mass.

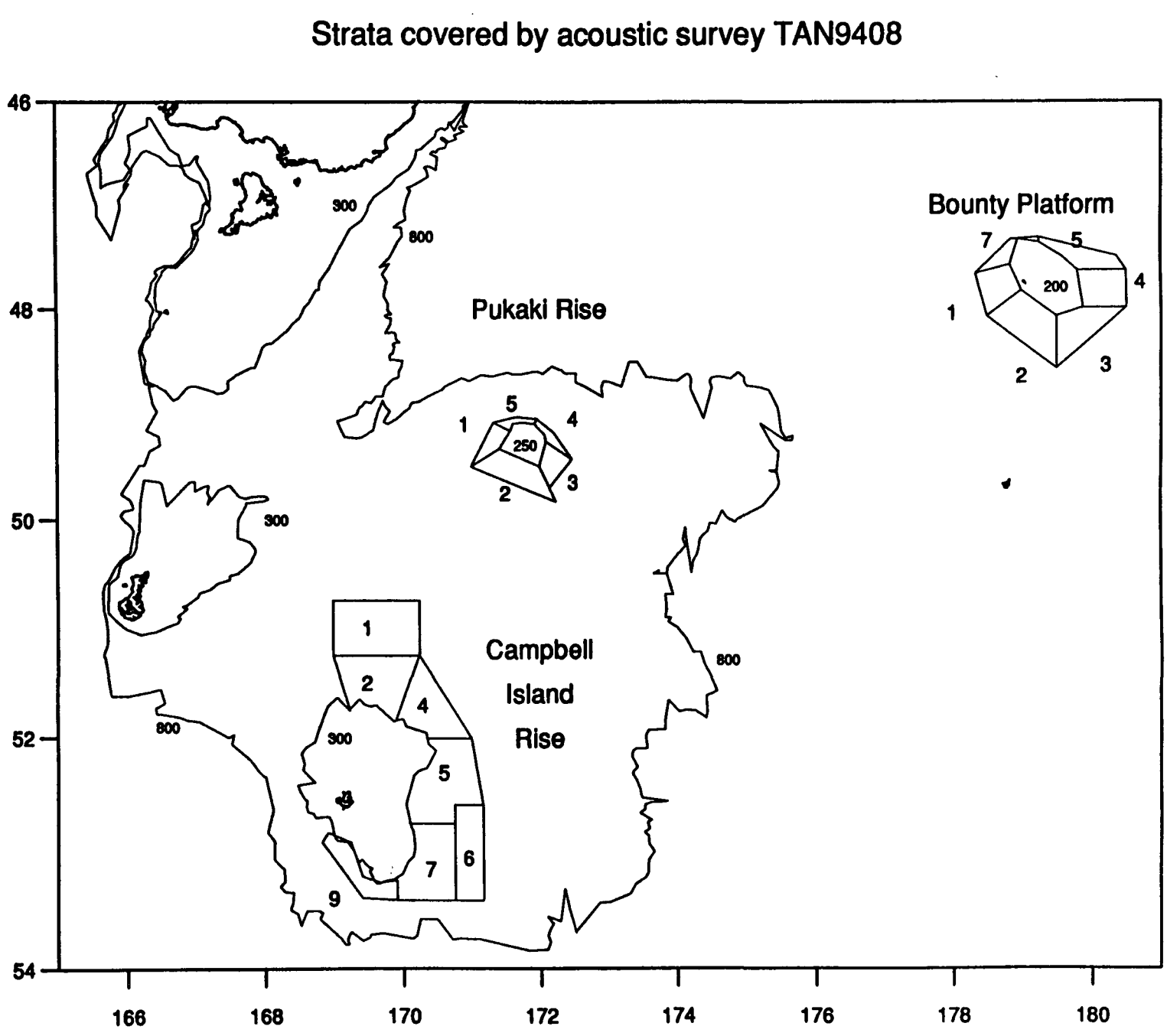
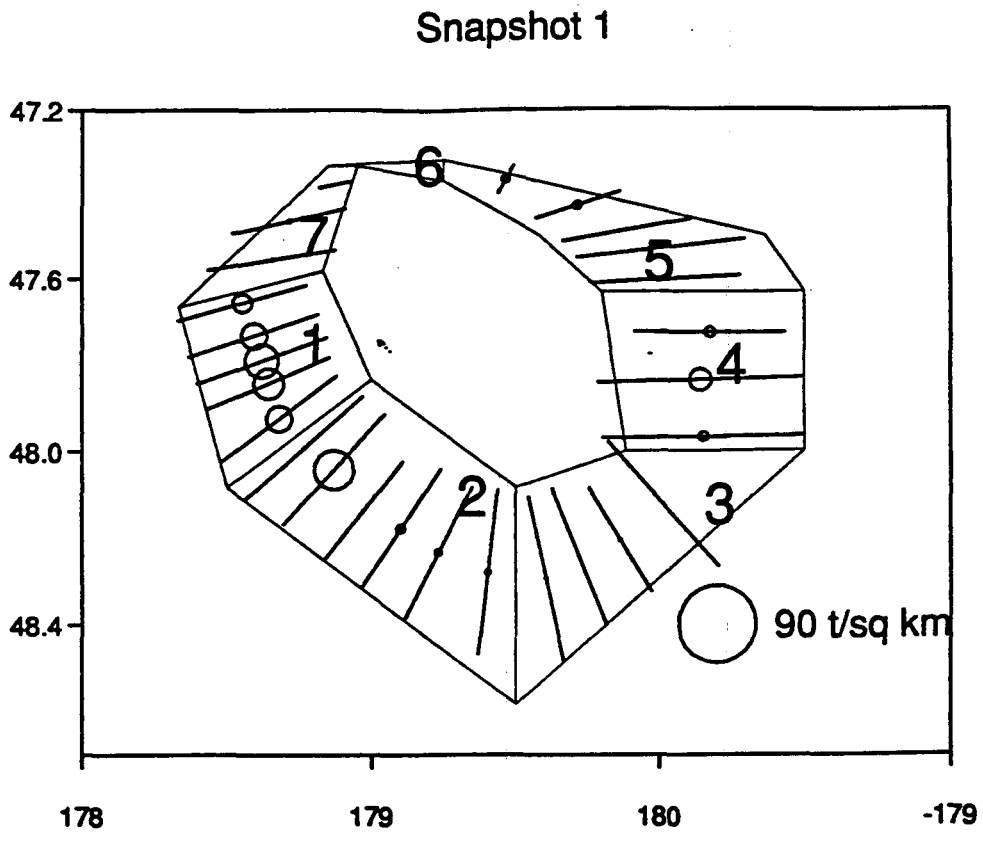


Figure 1. Strata numbers and boundaries surveyed during acoustic survey TAN9308.



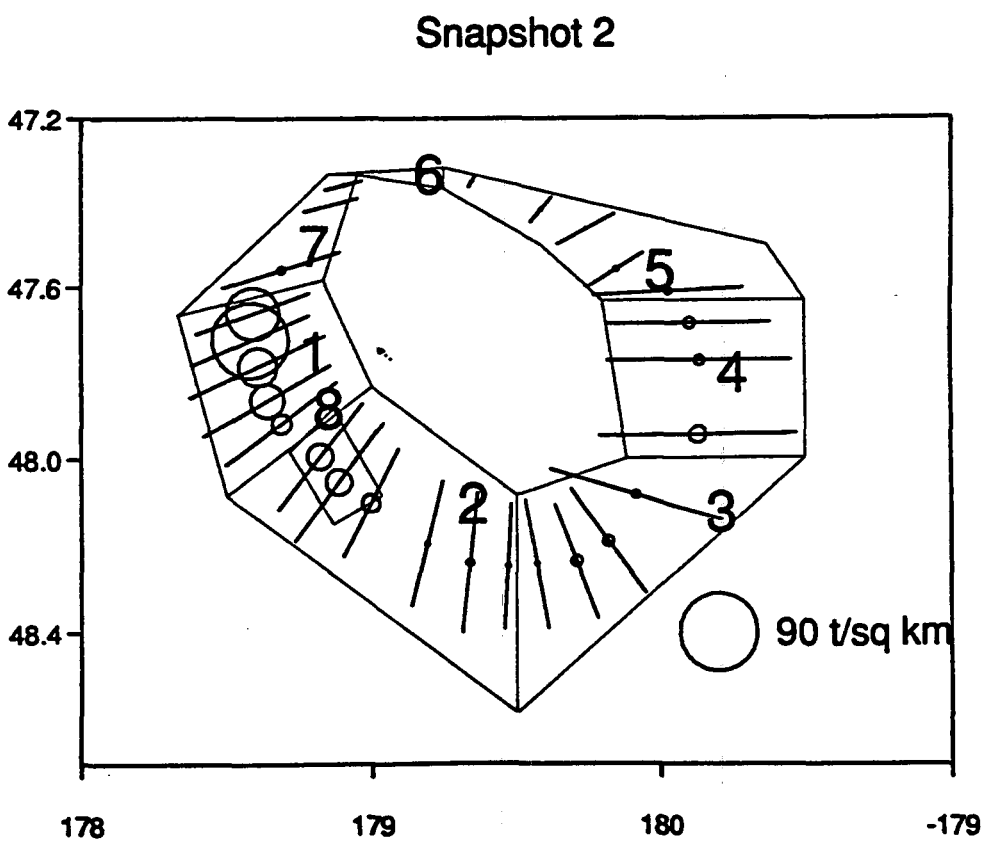


Figure 2. Density estimates of total adults (t. km^{-2}) by transect for each acoustic snapshot on the Bounty Platform (note stratum 8 transects not plotted). Snapshot 1, 21-25 Aug; Snapshot 2, 25-29 Aug.

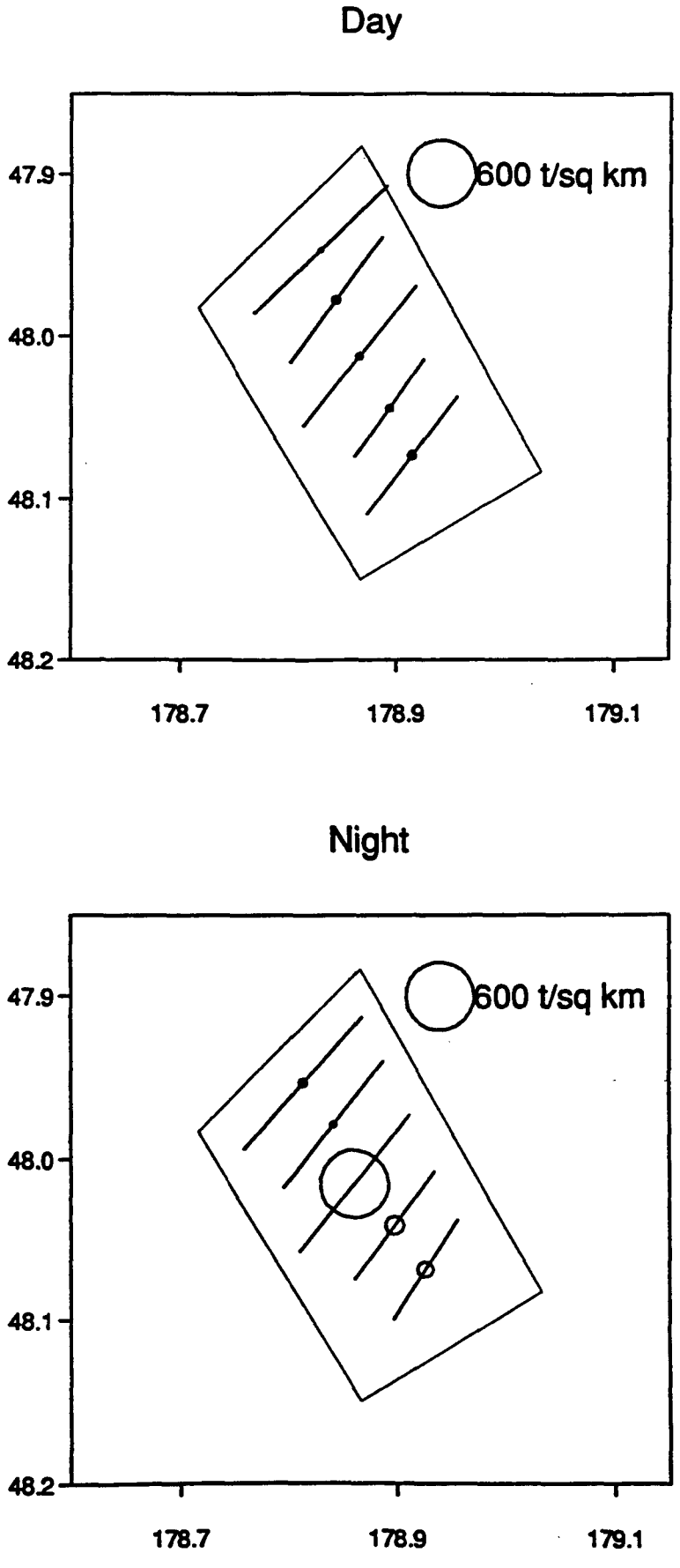


Figure 3. Density estimates of total adults (t. km^{-2}) by transect for the day and night fleet stratum on the Bounty Platform on 26/27 Sep, 11:00-04:30.

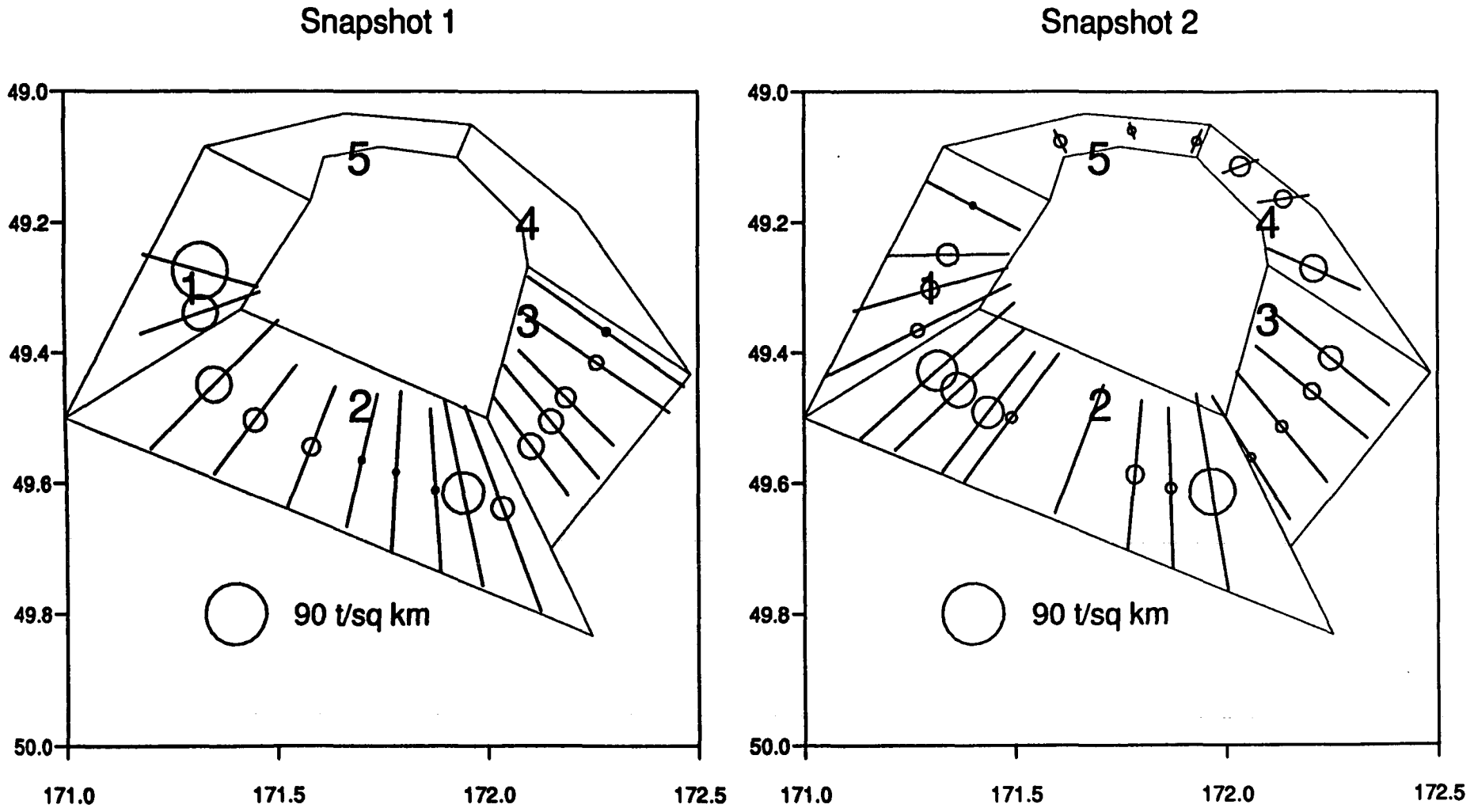


Figure 4. Density estimates of total adults (t. km^{-2}) by transect for each acoustic snapshot on the Pukaki Rise. Snapshot 1, 31 Aug - 1 Sep; Snapshot 2, 3-6 Sep.

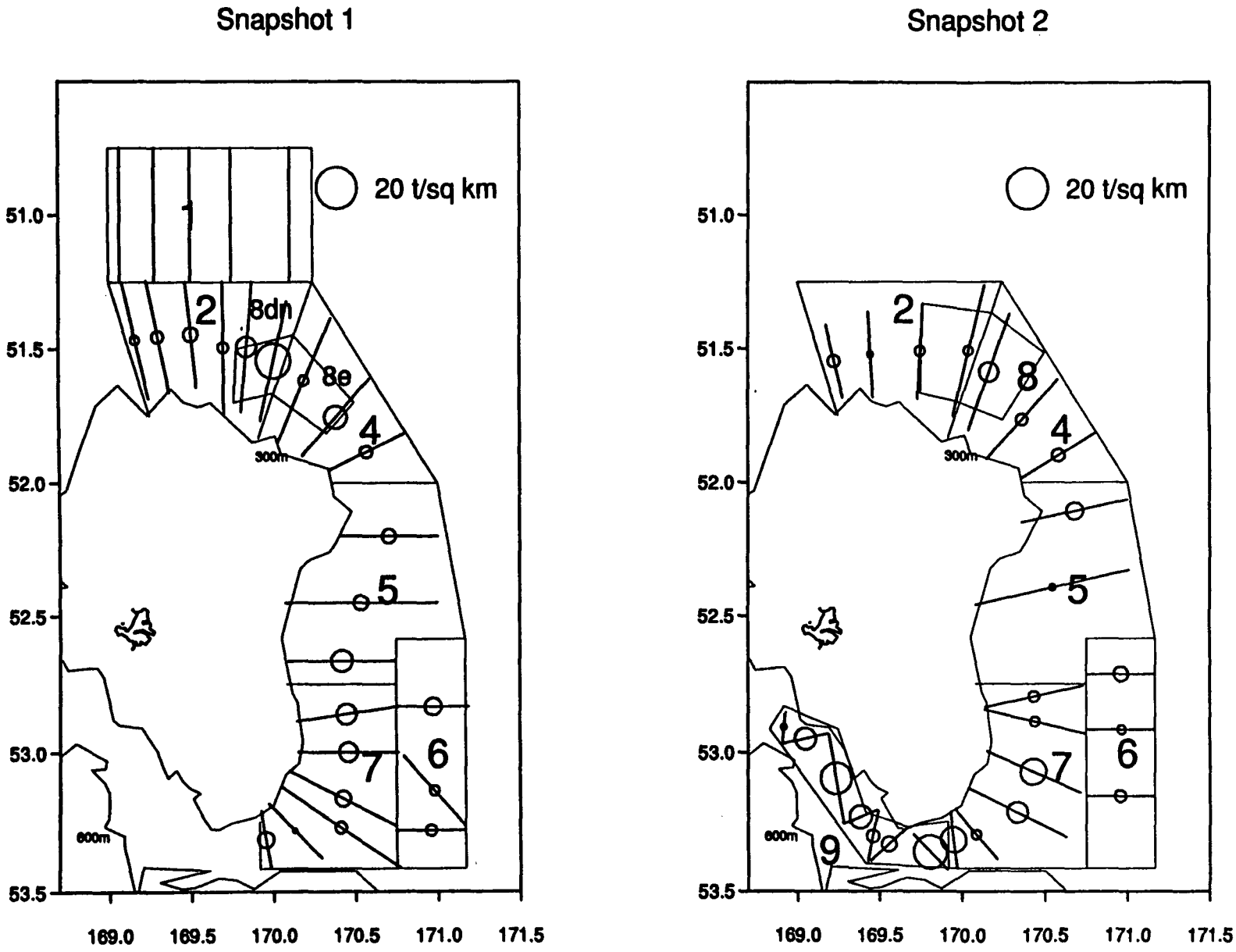
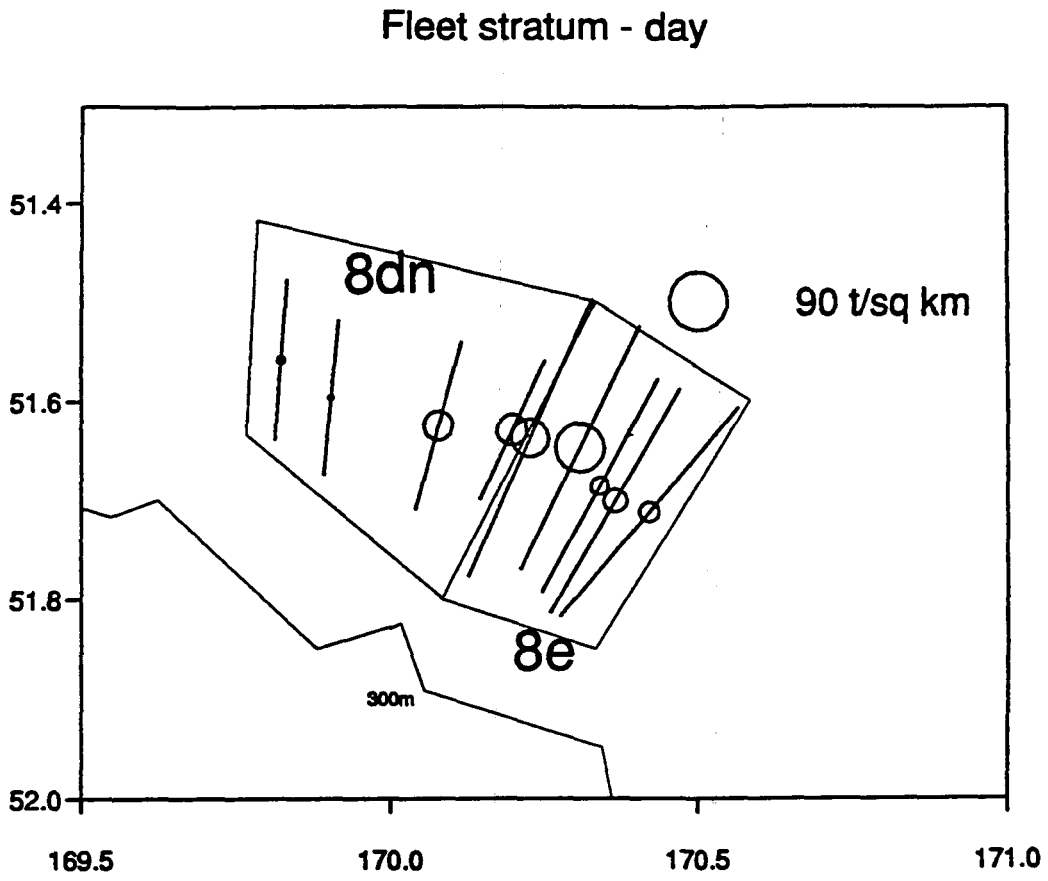


Figure 5. Density estimates of total adults (t. km^{-2}) by transect for each acoustic snapshot on the Campbell Island Rise (note stratum 8 transects not plotted). Snapshot 1, 6-12 Sep; Snapshot 2, 12-19 Sep.



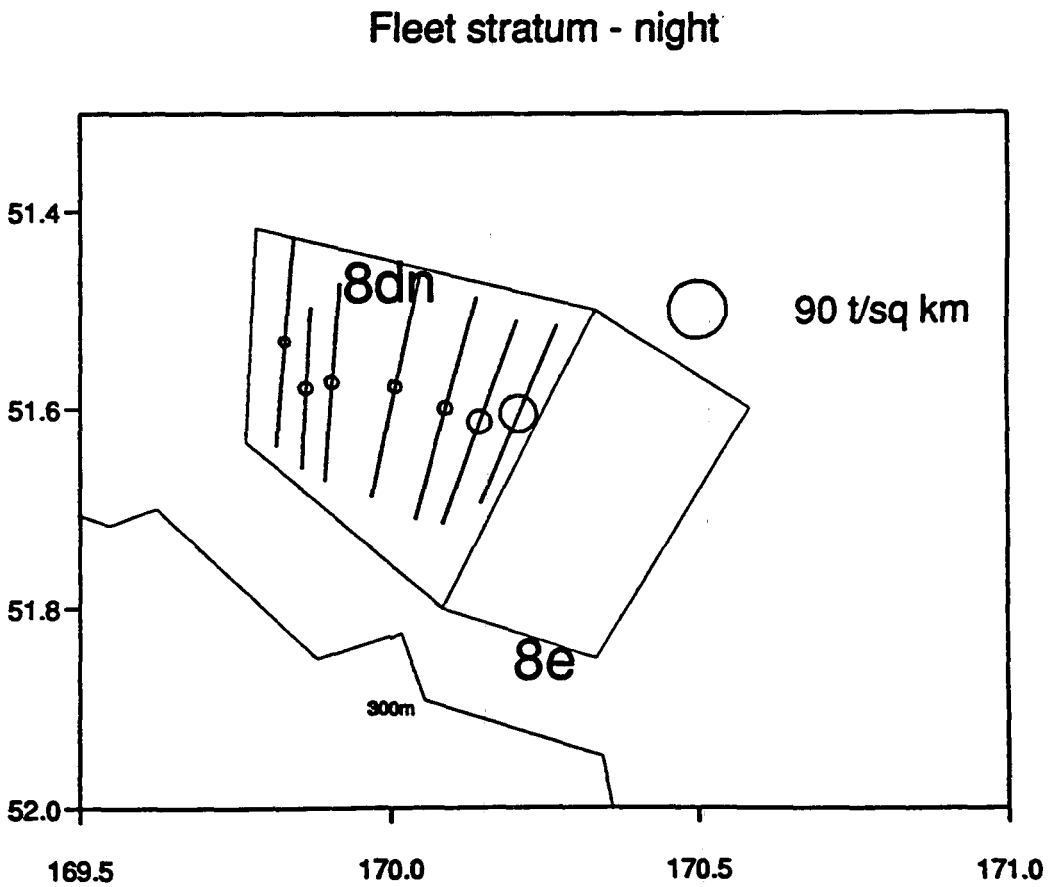


Figure 6. Density estimates of total adults (t. km^{-2}) by transect for the night and day fleet stratum on the Campbell Island Rise on 8/9 Sep, 18:30-17:30.

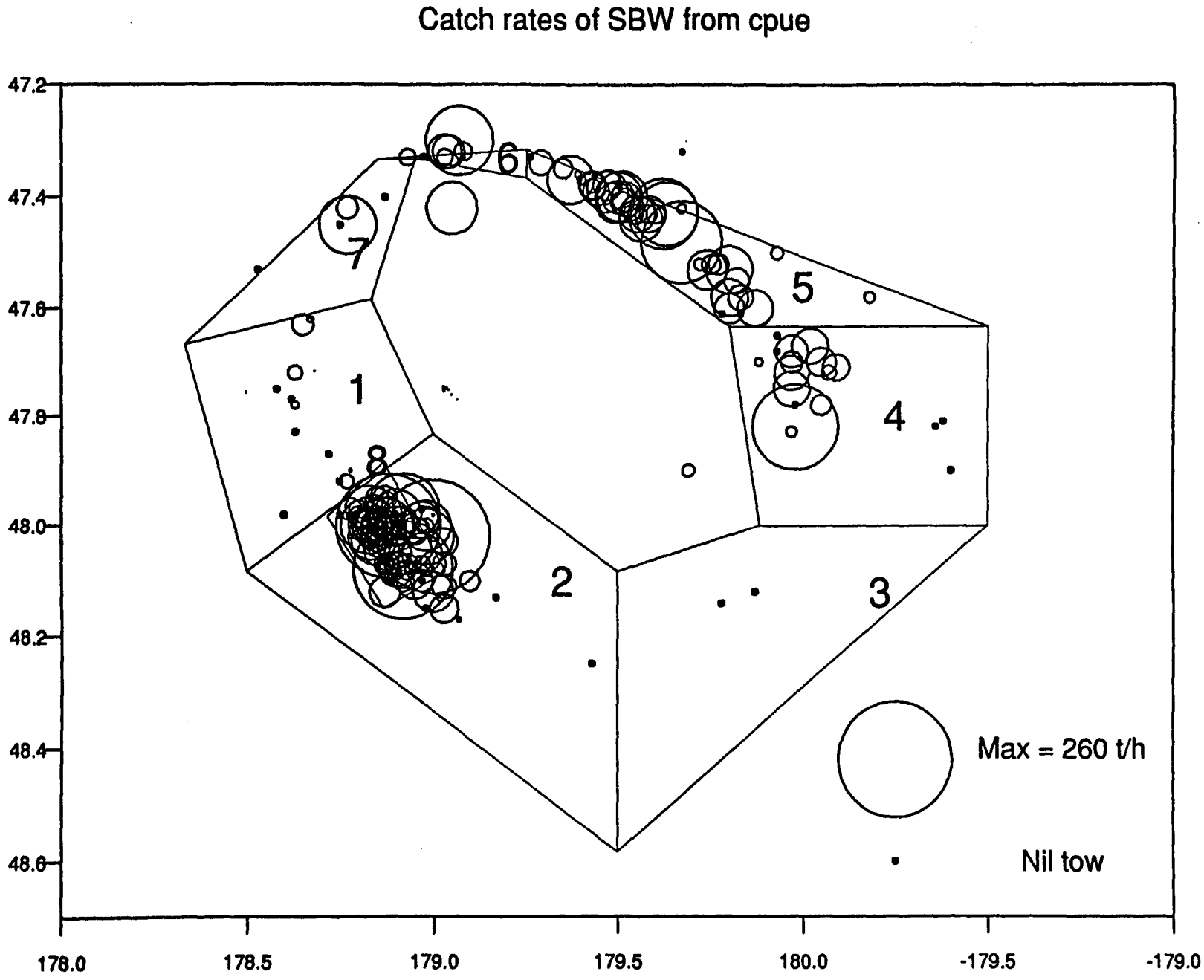


Figure 7. Catch rates (t. h^{-1}) of all commercial tows made on the Bounty Platform during the period of the acoustic snapshots (21/8/93 – 29/8/93).

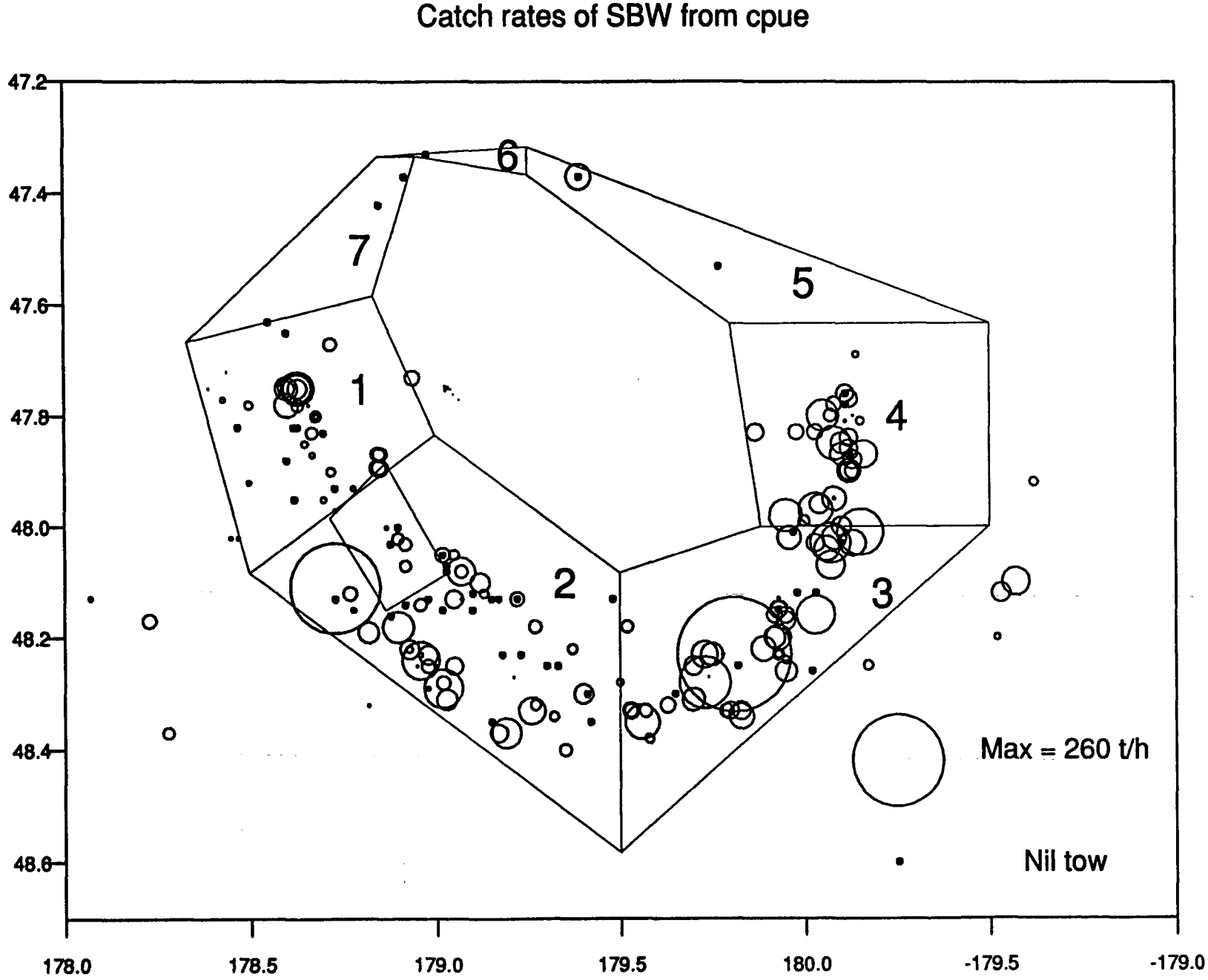


Figure 8. Catch rates (t. h^{-1}) of all commercial tows made on the Bounty Platform outside the snapshot period during August 1993.

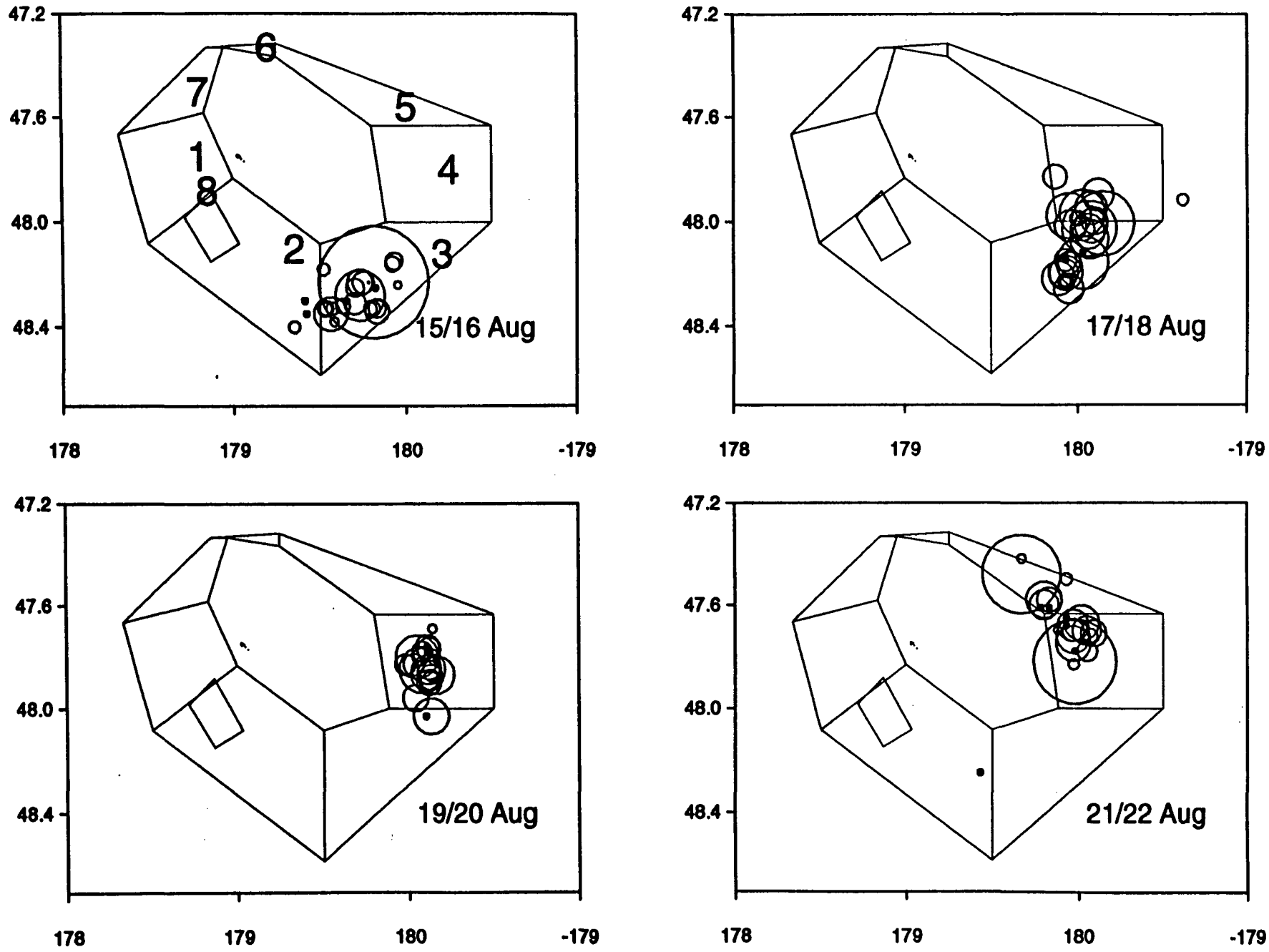


Figure 9. Catch rates (scaled to a maximum of 200 t. h^{-1}) and nil catches (•) of all commercial tows made on the Bounty Platform during the period (15/8/93 – 30/8/93).

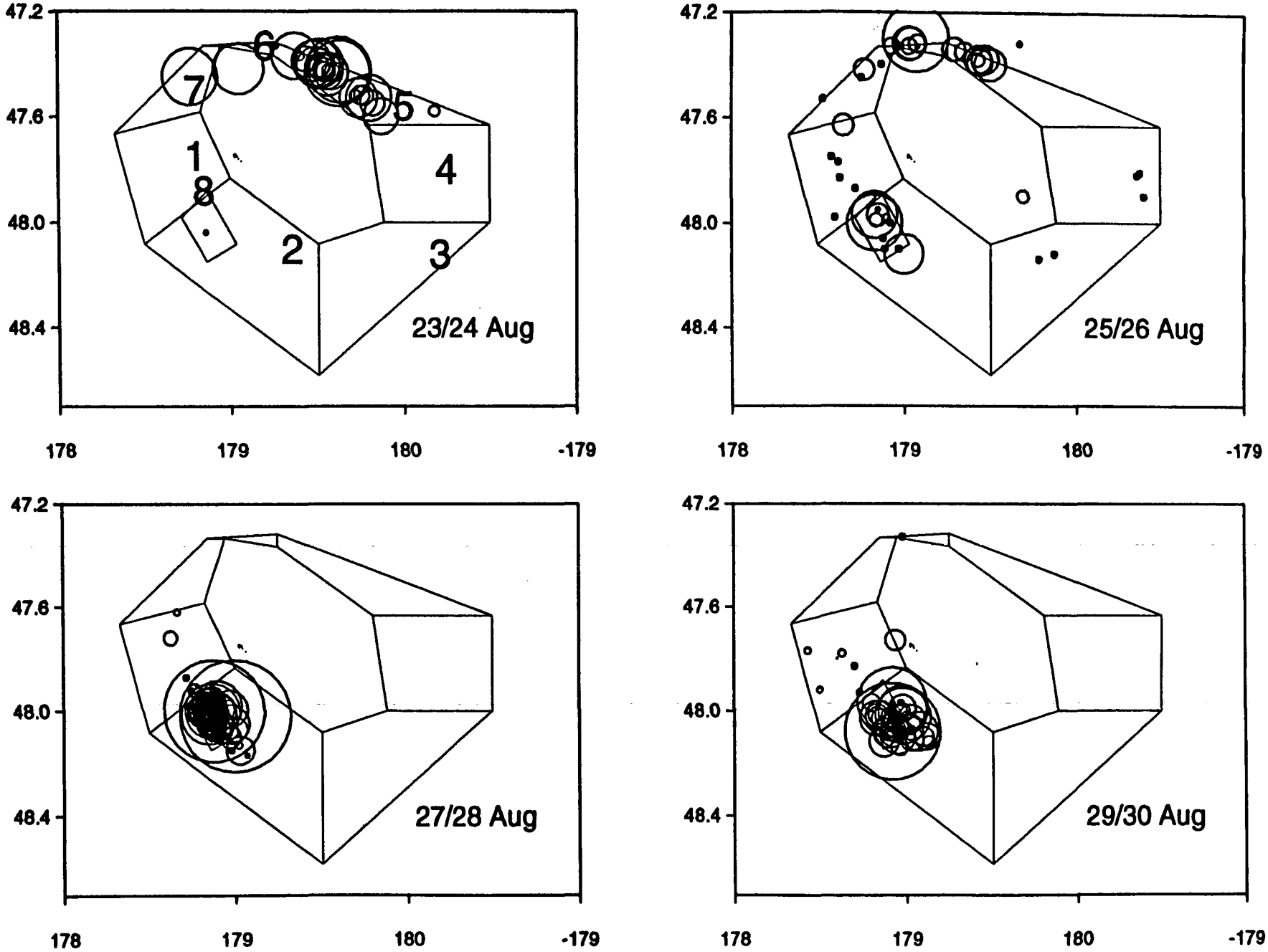


Figure 9. *continued.*

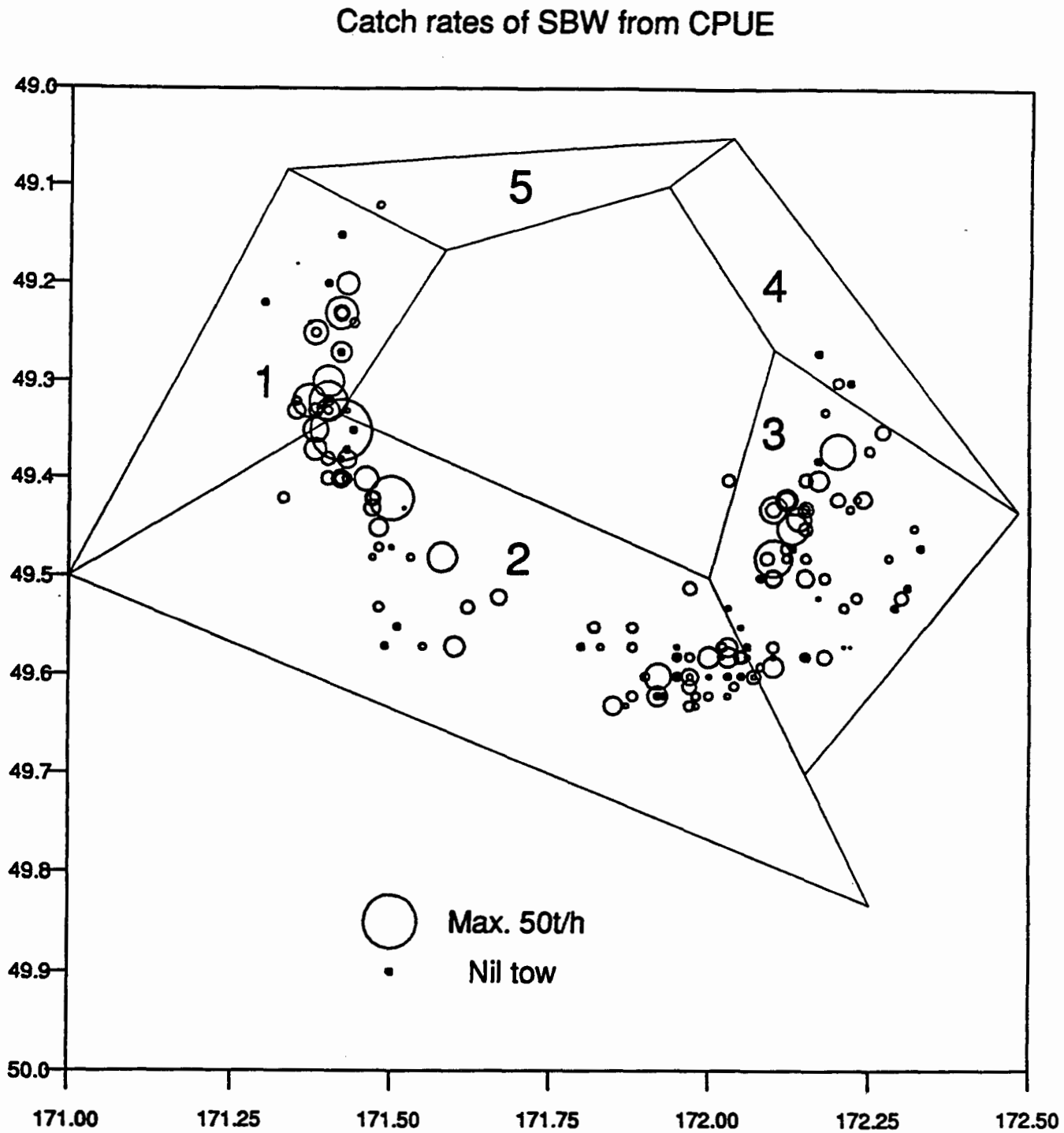


Figure 10. Catch rates ($t.h^{-1}$) of all commercial tows made on the Pukaki Rise during the period of the acoustic snapshots (31/8/93 – 6/9/93).

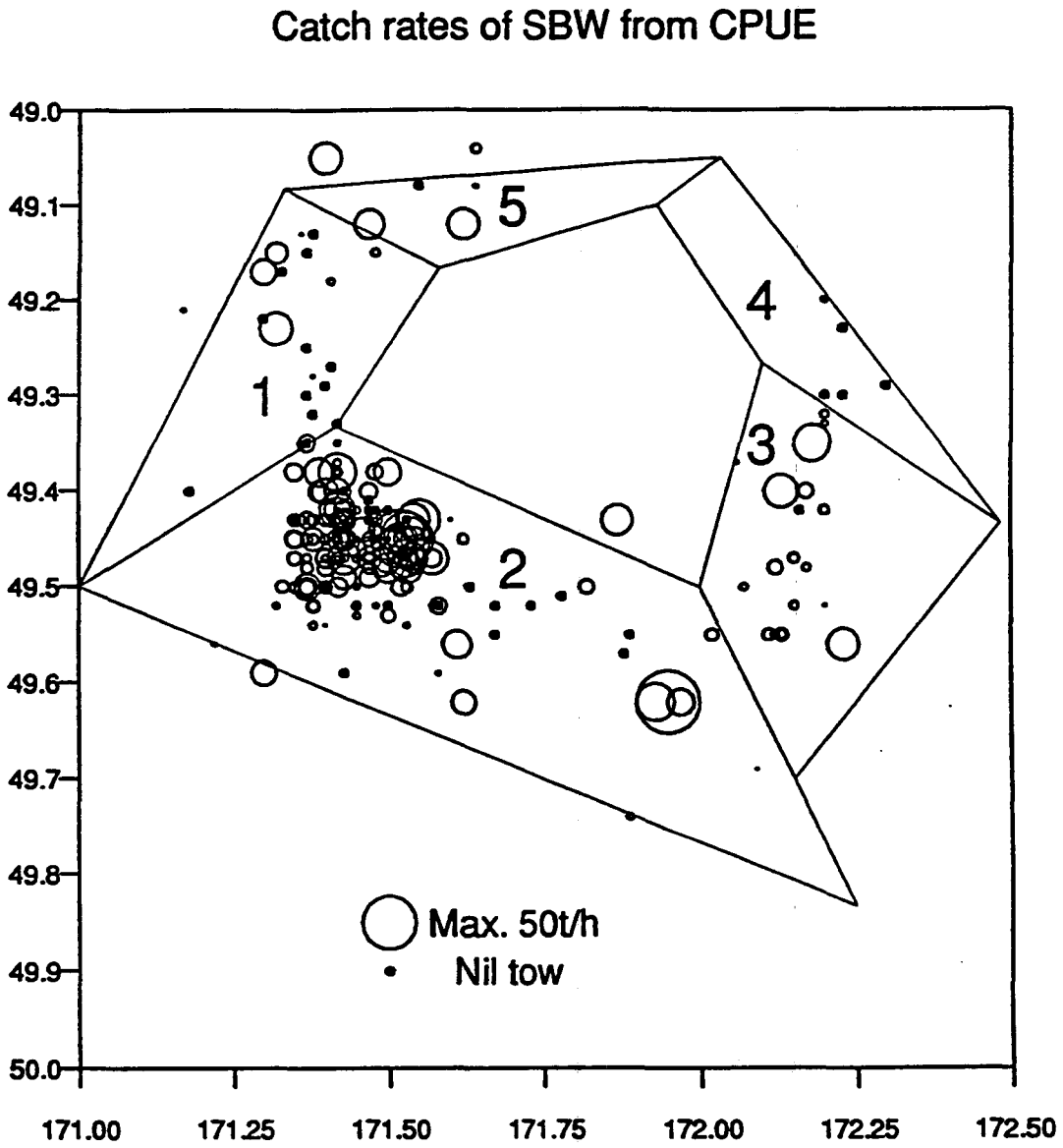


Figure 11. Catch rates ($t.h^{-1}$) of all commercial tows made on the Pukaki Rise outside the snapshot period during August and September 1993.

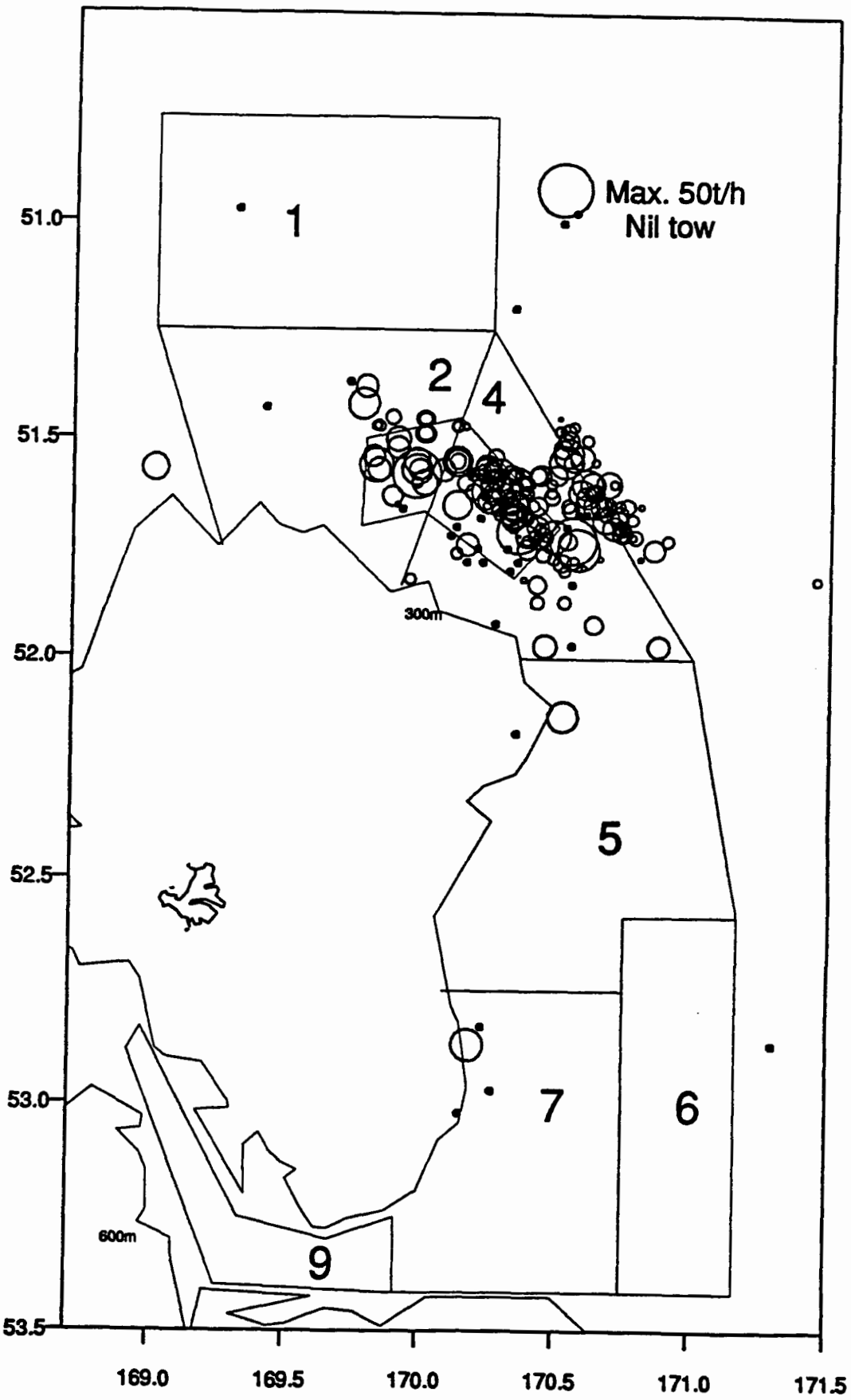


Figure 12. Catch rates ($t.h^{-1}$) of all commercial tows made on the Campbell Island Rise during the period of the acoustic snapshots (6/9/93 – 19/9/93).

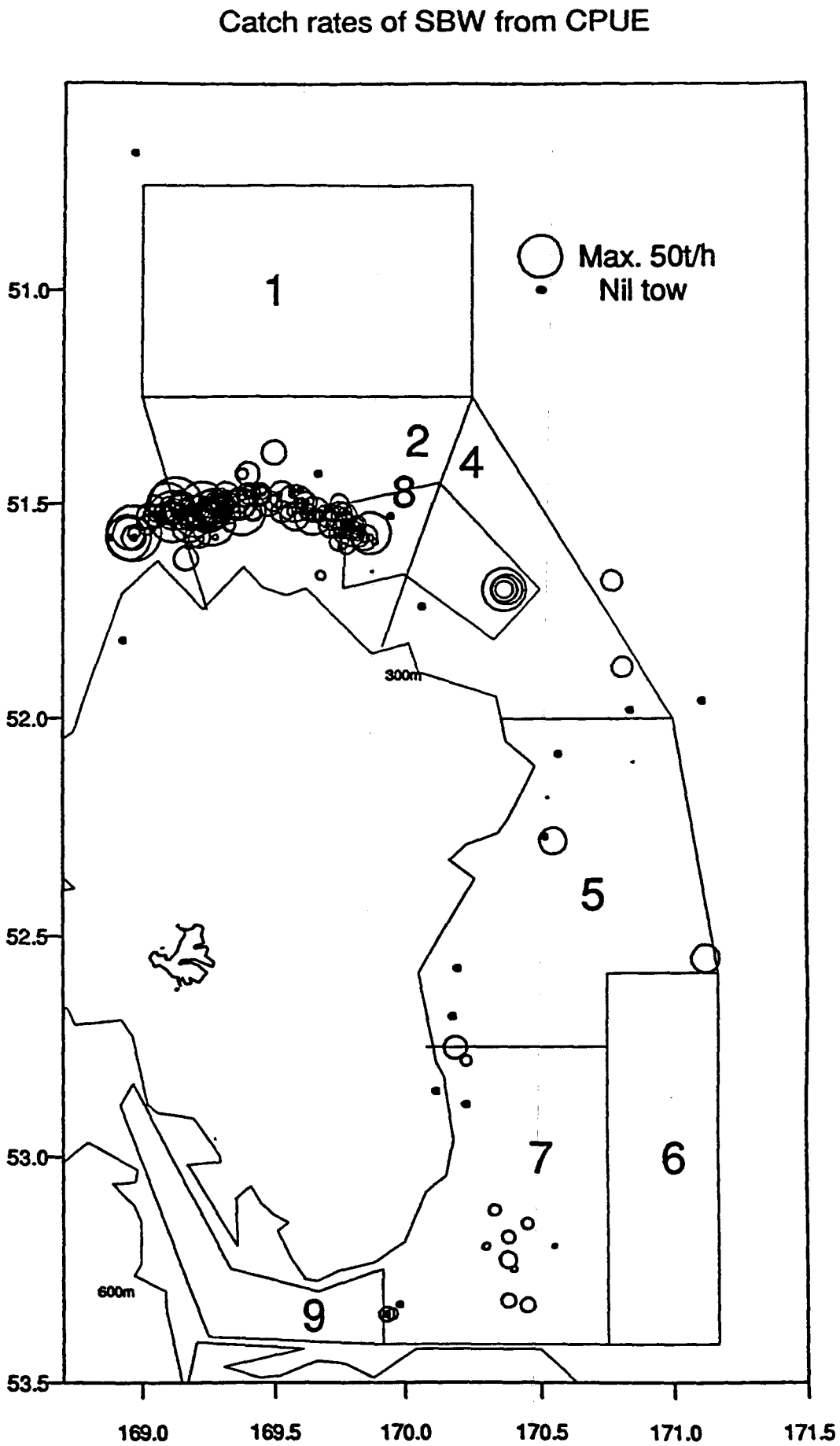


Figure 13. Catch rates ($t.h^{-1}$) of all commercial tows made on the Campbell Island Rise outside the snapshot period during September 1993.