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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 1994

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1. Executive summary

This paper summarises the results of the second acoustic survey of southern blue whiting stocks in subantarctic waters. Three complete acoustic snapshots were carried out on the Bounty Platform, and two each on the Pukaki Rise and Campbell Island Rise. Prespawning and spawning fish were surveyed on the Bounty Platform and Campbell Island Rise but only prespawning fish were surveyed on Pukaki 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). These were further subdivided into probable and possible categories.

Strong diel differences in acoustic backscattering were recorded whilst fish were spawning on the Bounty Platform and Campbell Island Rise. The reason for this is unclear but may be related to the avoidance of the vessel by the fast-moving daytime schools, or be due to the schools occurring in the bottom blind layer. It is believed that the nighttime biomass estimates are more accurate and these have been used where possible in the analysis.

Adult biomass estimates were highest on the Campbell Island Rise at about 160 000 t (*c.v.* = 34%), of which 15% was from the northern ground and 85% from the southern ground. Estimated adult biomass on Bounty Platform was 55 000 t (*c.v.* = 22%): most of the biomass came from a single large spawning aggregation. The adult biomass estimate on the Pukaki Rise was 39 000 t (*c.v.* = 45%). There was no evidence of turnover and reliable results of target strength work are available, so these estimates are 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 in Hanchet *et al.* (1994) and were used in the stock assessment for that year (Hanchet & Haist 1994). The second survey in the time series was carried out in August and September 1994.

Although the main aim of the survey is to estimate the spawning stock biomass of SBW, the area covered included at least part of the range of non-recruited fish. Modelling suggests that a small proportion (< 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 are as follows.

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

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

This paper summarises the results of the 1994 acoustic survey of SBW stocks. Estimates of relative biomass and their *c.v.*s are provided, where possible, for juvenile, immature, and adult fish on the Bounty Platform, Pukaki Rise, and Campbell Island Rise. The estimates of adult biomass are regarded as absolute because there was no evidence of turnover and reliable estimates of target strength are available. Data from the 1993 survey have been reanalysed as a result of target identification work carried out during the 1994 survey, and the results are also presented.

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 1994. Stratification and allocation of transects was based on the results of the 1993 survey, and the location of the fleet during the 1994 season. Six strata were surveyed on the Bounty Platform, five on the Pukaki Rise, and six on the Campbell Island Rise (Figure 1).

Three acoustic snapshots covering most of the strata were completed on Bounty Platform and two were made in each of the Pukaki Rise and Campbell Island Rise. The stratum area and number of transects by stratum by snapshot are given in Table 1. To better estimate the size of the spawning aggregation on the Bounty Platform, two further snapshots of stratum 2 were carried out. In each of these stratum 2 was divided into three substrata, based on depth, and surveyed both during day and night (*see* Figure 4). A third snapshot, covering a more restricted depth range, was carried out at night on the Pukaki Rise.

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 start 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 on the Campbell Island Rise to maximise the area covered for a given transect length (Simmonds *et al.* 1992). A space of 2 n. miles between the end of one transect and the start of the next ensured independence between transects.

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. On the Bounty Platform, few marks were seen in shallow water during the first snapshot, so in snapshots 2 and 3 transects in some strata were surveyed only from a bottom depth of 230 or 250 m to save time. 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. Stratum areas were calculated by joining end positions of the transects with the stratum boundary and summing the total enclosed area.

3.1.2 Fleet strata and high density strata

Smaller areas were surveyed during some of the snapshots in each area when dense adult marks were seen. Some occurred where the fleet were fishing and were designated fleet strata; others occurred where dense adult SBW marks were seen during the acoustic transects and were designated high density strata. In fleet strata, a boundary was drawn around the area that the fleet had been fishing over the previous 12–24 h. This stratum was then surveyed using the random parallel design. In high density strata, three of the boundaries of the aggregation were ascertained from preliminary zig-zag transects going from shallow to deep water along the shelf, until no more dense marks were seen. Next a group of five parallel transects was randomly drawn so that the mean distance between transects was about 0.5 n. mile. These transects were then surveyed acoustically, continuing shallower or deeper if marks extended beyond the stratum boundaries. The groups of transects were repeated until no more dense marks were seen.

High density strata were surveyed twice during snapshot 3 on the Bounty Platform (once during the day and once at night) (*see* Figure 3), and once in snapshot 1 during the day on the Campbell Island Rise (*see* Figure 6). Fleet strata were surveyed once in the day during snapshot 1 on the Pukaki Rise (*see* Figure 5) and twice during snapshot 2 on the Campbell Island Rise (once during the day and once at night – *see* Figure 7).

3.2 Acoustic mark identification

During the survey 32 tows with the midwater net were made by *Tangaroa*. The tows were a mixture of short tows targeted at dense marks, usually in midwater, which were suspected to be adult SBW, and longer bottom tows targeted at a particular depth range on lighter marks. Tow by tow data from the commercial fishery were also examined. Catch rates in the fishery for the duration of the snapshots, and for the periods outside the snapshots, were plotted separately for each area. Based on the results of both the research and the commercial tows, SBW marks were assigned as adult, immature, or juvenile, and these were further subdivided into probable and possible categories.

Marks were classified as probable adults if they occurred on the main fishing ground. They were classified as possible adult when the marks were in deeper water or in an area not fished by the fleet, or *Tangaroa*, during the survey.

On the Bounty Platform juveniles were mainly confined to shallower depths of 200–250 m and could usually be separated from the adult marks on the basis of depth and area alone. Marks on the west of the Bounty Platform (stratum 1) were not fished by *Tangaroa*, but commercial vessels caught adult fish there. On the east of the Bounty Platform (strata 3, 4, and 5) commercial vessels fishing deeper than 250 m caught mainly immature 2 and 3 year old fish, so these marks were classified as immature.

No 1 or 2 year old fish were caught on the Pukaki Rise. All 3 year old fish caught by *Tangaroa* and in the fishery this year were immature. In most tows they occurred in mixed schools comprising 3 year olds and adults. It was impossible to accurately separate the 3 year old immature fish from the adults, so the 3 year olds were classified as adults and consequently the adult biomass will be overestimated.

No 1 year old 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 (usually less than about 400 m) and could be distinguished from adults on the basis of depth alone.

3.2.1 Reclassification of 1993 marks

The 1993 data were reanalysed to incorporate the improved understanding of acoustic mark identification, and to maintain consistency between the two years. This reduced uncertainty in the 1993 survey results.

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

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

where TS is target strength in decibels and FL is fork length in centimetres (*see* Hanchet *et al.* 1994 for further details). Target strength data on SBW during the survey (Macaulay, NIWA, Wellington, Unpublished results) agreed closely with this relationship.

Adult SBW were assumed to have the length distribution caught by the commercial fishery for that particular area (Hanchet & Ingerson 1995). 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 27 cm on the Bounty Platform, and 1 year old fish 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, 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 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.

As preliminary analysis showed that several of the categories had a low biomass, only four combined categories are presented: (i) probable adult biomass; (ii) total adult biomass (i.e., the sum of probable and possible adult biomasses); (iii) probable immature biomass; and (iv) probable juvenile biomass.

3.3 Gonad data

Staging data for female fish (using the five stage system given by Hanchet *et al.* 1994) 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 three main snapshots completed on Bounty Platform are shown in Table 2 and Figure 2. Adults were confined to strata 1 and 2. Transect densities appeared reasonably consistent in snapshot 1 (*c.v.* = 15%), and the 25 000 t biomass was evenly split between the two strata. In snapshots 2 and 3 transect densities were much more variable, resulting in high *c.v.*s (50–60%) and biomasses of 13 000 t and 27 000 t. Much of the biomass in snapshot 3 is the result of a single transect in stratum 2, which traversed a large spawning mark at night.

Transect densities from the high density stratum are shown in Figure 3 and the biomass results are included in Table 2. There was a 20-fold difference in estimated biomass between day and night. Using the nighttime transects gave a biomass estimate of 55 000 t (*c.v.* = 22%). However, there was some evidence that fish may have moved in the same direction as the stratum was surveyed, which would have resulted in the nighttime biomass being overestimated.

The results of snapshots 4 and 5 are shown in Table 3 and Figure 4. Despite the increased stratification and number of transects the *c.v.*s were still high and the biomass estimates quite variable. There was once again a large difference between day and night, with marks occurring throughout the stratum at night but few were seen during the day. The main aggregation was surveyed in snapshot 4n, but was seen whilst steaming between transects in snapshot 5n. The most reliable biomass estimate is therefore from snapshot 4n which was 49 000 t (*c.v.* = 54%).

4.1.2 Pukaki Rise

Results of the three snapshots completed on Pukaki Rise are shown in Table 4 and Figure 5. SBW marks were found in all strata, with the densest transects and most biomass found in strata 2 and 3. The first two snapshots covered the entire depth range and provided estimates ranging from 49 000 t (*c.v.* = 68%) to 29 000 t (*c.v.* = 32%). The third snapshot had a more restricted depth range, where the fish had previously been seen, but provided a low estimate of only 6000 t.

The fleet stratum was surveyed 2.5 days after the marks were first seen, and at the end of the fishing on the aggregation in that area. No large marks were seen and, given the low biomass, it is likely that the fish had moved elsewhere.

4.1.3 Campbell Island Rise

Results of the two snapshots completed on the Campbell Island Rise are shown in Table 5 and Figure 6. Adult fish were encountered on both northern and southern grounds during each snapshot. In snapshot 1, a small aggregation was found in the northwest corner of stratum 4, and a second, much larger aggregation, was found to the south, on the boundary between strata 5 and 7. During snapshot 2 the southern aggregation was restricted to stratum 7. The northern one was not seen during the main part of the survey. However an aggregation was surveyed as part of the fleet stratum (*see* below) in stratum 1, and it is suspected that this was the same aggregation as had been surveyed during snapshot 1. The two snapshots gave reasonably similar biomass estimates of 137 000 t and 164 000 t, but had high *c.v.*s of 39% and 58% respectively. About 15% of the biomass came from the northern ground and 85% from the southern ground.

The biomass results including stratum 8 are shown in Table 5 and the transect densities are shown in Figure 7. Inclusion of the fleet stratum in snapshot 1 made very little difference to the biomass or *c.v.* of that snapshot. In snapshot 2 the biomass from the nighttime transects was considerably higher than during the day. Inclusion of the nighttime fleet stratum in snapshot 2 increased its biomass to 184 000 t and decreased its *c.v.* to 52%.

4.2 Fleet movement

On the Bounty Platform several vessels began the season fishing in deep water (500–600 m depth) on the edge of stratum 2 (Figure 8). During snapshots 3 to 5 only two vessels were still in the area and these were fishing in depths of 250–350 m in the area of the fleet stratum. After the snapshots were completed the two vessels moved north into stratum 1, where they were joined by several others, and made good catches for a few days. At the end of the season – in late September – several tows were made in stratum 7.

On the Pukaki Rise most of the fishing centred around the fleet stratum during both snapshots (Figure 9). Small schools were also located in strata 1, 2, and 5, but these appeared small as they did not sustain much fishing pressure. Usually only 2 or 3 tows were made on these schools – catching perhaps a total of 100 t – by which time the fish had either been caught or had dispersed. Little fishing was carried out before or after the acoustic snapshots.

On the Campbell Island Rise fishing began on 12 September and focussed initially on the northern ground (Figure 10). Vessels appeared to fish a single aggregation as it moved about 30 n. miles from stratum 4 on 13 September to stratum 1 on 21 September. After the acoustic snapshots were completed all vessels moved to the southern ground and fished there until the end of the season. They caught about 4000 t from the northern ground and about 8000 t from the southern ground. The catch in both areas was dominated by 3 year old mature fish, but the catch on the northern ground had a larger proportion of bigger fish and was fished preferentially.

4.3 Gonad data

Gonad data from the observers are shown in Table 6. There was no evidence of turnover on any of the grounds. On the Bounty Platform fish caught between 12 and 20 August showed a steady maturing of gonads. The first running ripe fish were picked up in stratum 2 on 21 August and spawning would have started shortly after. There were reasonable numbers of spent fish between 25 and 29 August, by which time over 50% of the fish had reverted to the maturing stage.

On the Pukaki Rise no spawning had occurred by 8 September, when the last sample was taken.

On the Campbell Island Rise spawning on the northern ground started on 17 September and continued until 21 September. Spawning did not start on the southern ground until 21 September and continued until 29 September.

5. Discussion

5.1 Diel effects

The results of the 1993 and 1994 day-night comparisons are summarised in Table 7. All six comparisons recorded higher biomasses during the night. Because of the high *c.v.*s only one of these is significantly different. The single day-night comparison for prespawning fish, on the

Campbell Island Rise, showed little difference between day and night. In most other comparisons the differences ranged from 2-fold to almost 30-fold (*see* Table 7). Possible problems with fish movement beyond the stratum boundary during the day and a diurnal inshore/offshore migration might account for part of the differences observed in one or two of the comparisons. However, during most day-night comparisons fish movement was not observed. Furthermore, fish were present during the day because some large catches (> 200 t) were made by commercial vessels using sonar within the fleet stratum during the day. Misund & Aglen (1992) estimated that 35% of midwater schools of herring and sprat, seen ahead of a vessel using a multibeam sonar, avoided the vessel and were not seen on the ships echosounder. Lateral avoidance was about 44% when the vessel was in cruising mode, but 28% when it was in trawling mode (Misund *et al.* 1993). Vessels using sonar in the SBW fishery show quite pronounced changes in direction (up to 45° at a time) apparently to keep track of the schools. Vessels without sonar either did not fish, or made only poor catches and catch rates during the day.

Potential biases due to diurnal differences in acoustic backscattering have been studied (Appenzeller & Leggett 1992, Freon *et al.* 1993, Aglen 1994). Appenzeller & Leggett (1992) found that estimates of pelagic fish abundance in Lake Memphremagog in Quebec, as measured by echo integration, were significantly lower during the day when the fish were aggregated in dense schools. They attributed the lower daytime estimates to acoustic shadowing, and suggested the bias may have been as large as 50%. Freon *et al.* (1993) also found large diurnal differences in acoustic backscattering from a large database comprising mainly small, coastal (continental shelf), tropical pelagic species (mainly Clupeidae and small Carangidae). They attributed the lower daytime backscattering values to lateral avoidance of the vessel by these schools. However, they also believed that changes in density distribution and fish occurring in the bottom blind area may also be important.

The reason for the diel differences in SBW acoustic backscattering is unclear. Some degree of lateral avoidance, particularly by midwater schools, seems quite plausible, and bottom schools may also be missed in the bottom blind area. However, there also appear to be quite pronounced changes in the density distribution of the fish. The schools appear to be much denser during the day than at night. If there were fewer, denser schools during the day then there would be a lower probability of surveying these schools, leading to a substantial underestimation of abundance. It is assumed below that the nighttime comparisons give the most accurate estimates of biomass.

5.2 Biomass estimation by area

5.2.1 Bounty Platform

Snapshots 1 and 2 on the Bounty Platform were carried out during the prespawning period, and snapshots 3 to 5 were carried out whilst fish were spawning. The best estimate of biomass is 55 000 t (snapshot 3, Table 8). Although this may an overestimate due to the double counting of fish, it agrees well with the biomass of 49 000 t estimated in snapshot 4.

The reason for the lower biomasses in snapshots 1 and 2 is unclear. Fish may have been missed by the main survey, which was carried out both during the day and at night, or they may have been outside the survey area.

The adult biomass estimate in 1994 is considerably lower than the 1993 estimate (Table 8). The biomass of the main spawning aggregation in stratum 2 was similar between surveys: 47 000 t in 1993 and 41 000 t in 1994. However, in 1993 an additional 45 000 t was estimated in stratum 1. During that survey there was some doubt over whether these fish then moved around into stratum 2 and were double counted. There is also still some uncertainty over whether the marks in stratum 1 were adult or immature SBW. In the reanalysis it has been assumed that they were adult SBW and were not double counted.

5.2.2 Pukaki Rise

Both snapshots on the Pukaki Rise were carried out before the fish started spawning. The fish distribution was quite patchy, reflecting commercial fishing in the area, and both *c.v.*s were high. The two snapshot estimates were averaged to give a mean biomass of 39 000 t (*c.v.* = 44%) (Table 8). The fleet stratum appeared to be carried out after the fish had left the area and it is therefore not considered appropriate to use this figure as a biomass estimate.

The adult biomass estimates for 1993 and 1994 agree well. Although some immature 3 year olds of the 1991 year class were surveyed during the 1994 survey (and are included in the adult estimate) it is suspected that large numbers may have been located out on the east of the Rise, where they have been recorded during winter trawl surveys (Livingston, NIWA unpubl. data). The adult biomass estimate should show a substantial increase in the 1995 survey when the strong 1991 year class is expected to recruit into the fishery.

5.2.3 Campbell Island Rise

All of the first snapshot and most of the second snapshot on the Campbell Island Rise were carried out before fish started spawning. Both snapshots sampled the two main aggregations on the grounds found by the fleet, and when averaged gave a mean biomass of 161 000 t (*c.v.* = 36%) (Table 8).

The 1994 adult estimate is almost an order of magnitude higher than the adult biomass estimate in 1993. However, a large proportion (> 80 %) of the 1994 biomass comprised 3 year old fish of the 1991 year class. In the 1993 survey the biomass of this year class (as 2 year olds) was estimated to be 90 000 t. In the intervening year the biomass of this year class would have increased by about 17% to 105 000 t (the increase in biomass due to growth outweighing the decrease in numbers due to natural mortality). This figure, combined with the 1993 adult biomass, gives a value of 125 000 t which is in reasonably good agreement with the 1994 estimate.

6. Conclusions

With the improvements in acoustic mark layer identification and the corroboration of the target strength results the acoustic estimates can now be viewed with more confidence than in 1993. Furthermore, although *c.v.*s were high, there was reasonably good agreement between the results of the two surveys. The recruitment of the strong 1991 year class to the Campbell Island fishery means that this stock now has the largest biomass. This biomass is expected to increase next year as more females mature and recruit into the fishery. The Bounty Platform stock has the second highest biomass between 50 000 t and 100 000 t. In the 1995 survey the important strata on the Bounty Platform will be surveyed during day and night, in an effort to reduce any potential diurnal bias. Acoustic estimates are smallest on Pukaki Rise and range from 40 000 to 50 000 t.

7. Acknowledgments

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Table 1: Stratum areas and numbers of transects per snapshot (snap) for each spawning ground. 8d, daytime stratum 8; 8n, nighttime stratum 8. For stratum boundaries *see* Figures 1–7

Stratum	Stratum area (km^2)	Number of transects		
		Snap 1	Snap 2	Snap 3
Bounty Platform				
1	1 466	5	5	4
2	2 754	7	7	7
3	2 479	4	4	3
4	1 953	3	3	2
5	1 306	5	0	0
7	691	3	0	0
8d	107	0	0	12
8n	49	0	0	14
Pukaki Rise				
1	703	4	4	0
2	1 949	7	8	7
3	837	4	4	4
4	326	4	3	0
5	220	5	3	0
8	178	9	0	0
Campbell Island Rise				
1	4 500	3	4	
2	3 437	6	6	
3	2 900	5	0	
4	2 839	4	4	
5	4 247	3	4	
6	2 618	0	0	
7	3 580	6	6	
8	59	9	0	
8d	180	0	11	
8n	158	0	12	
9	1922	0	0	

Table 2: Stratum area (km^2) and biomass of four different categories of southern blue whiting by stratum and snapshot for the Bounty Platform. Strata with an H refer to the high density stratum survey. Prob, probable; Total, probable + possible; Adult, sexually mature; Imm, immature (2 and 3 year old sexually immature); Juv, juvenile (1 year old)

			Biomass (t)			
Snap-shot	Stratum	Stratum area	Prob adult	Total adult	Prob imm	Prob juv
1	1	1 466	12 359	12 359	0	0
	2	2 754	11 133	11 690	0	132
	3	2 479	79	271	8 089	0
	4	1 953	0	0	5 414	0
	5	1 306	0	0	245	0
	7	691	0	35	0	0
	Total	10 629	23 571	24 354	13 747	132
	c.v.		(16)	(16)	(56)	(102)
2	1	1 466	8 434	8 434	0	0
	2	2 754	4 692	4 692	0	457
	3	2 479	0	0	386	0
	4	1 706	0	0	15 517	0
	5	–	–	–	–	–
	7	–	–	–	–	–
	Total	8 358	13 126	13 126	15 903	457
	c.v.		(58)	(58)	(89)	(100)
3	1	1 466	5 344	7 265	0	0
	2	1 823	21 243	21 406	0	0
	2H	1 774	8 896	8 896	0	0
	3	1 692	0	0	83	0
	4	1 800	0	0	15 697	0
	5	–	–	–	–	–
	7	–	–	–	–	–
	8H	49	40 607	40 607	0	0
	Total (excl. H)	7 503	26 588	28 671	15 779	0
	c.v.		(50)	(48)	(87)	–
	Total (incl. H)	7 454	54 690	56 769	15 779	0
	c.v.		(22)	(23)	(87)	–

Table 3: Stratum area (km^2) and biomass of four different categories of southern blue whiting by stratum and snapshot for the Bounty Platform. Abbreviations are explained in Table 2

			Biomass (t)			
Snap-shot	Stratum	Stratum area	Prob adult	Total adult	Prob imm	Prob juv
4d	2/1	379	1 609	1 609	0	0
	2/2	576	4 225	4 225	0	0
	2/3	532	315	315	0	0
	Total	1 487	6 149	6 149	0	0
	c.v.		(72)	(72)	–	–
4n	2/1	379	20 793	20 793	0	0
	2/2	576	26 661	26 661	0	0
	2/3	532	1 347	1 347	–	–
	Total	1 487	48 801	48 801	0	0
	c.v.		(54)	(54)	–	–
5d	2/1	607	23	23	0	0
	2/2	813	8 174	8 174	0	0
	2/3	532	745	745	0	0
	Total	1 852	8 942	8 942	0	0
	c.v.		(94)	(94)	–	–
5n	2/1	607	9 203	9 203	0	0
	2/2	813	10 517	10 517	0	0
	2/3	532	554	554	0	0
	Total	1 852	20 274	20 274	0	0
	c.v.		(53)	(53)	–	–

Table 4: Stratum area (km^2) and biomass of four different categories of southern blue whiting by stratum and snapshot for the Pukaki Rise. Strata with an F refer to the fleet stratum. Abbreviations are explained in Table 2

			Biomass (t)			
Snap-shot	Stratum	Stratum area	Prob adult	Total adult	Prob imm	Prob juv
1	1	703	1 993	2 517	0	0
	2	1 949	40 828	41 410	0	0
	2F	1 771	6 500	6 500	0	0
	3	837	3 172	3 447	0	0
	4	326	2 451	2 831	0	0
	5	220	216	216	0	0
	8F	178	3 341	3 341	0	0
	Total (excl. F)	4 035	48 660	50 421	0	0
	c.v.		(68)	(66)	–	–
	Total (incl. F)	4 035	17 674	18 852	0	0
	c.v.		(22)	(19)	–	–
2	1	703	843	1 653	0	0
	2	1 949	16 168	16 866	0	0
	3	837	9 991	9 991	0	0
	4	326	1 887	1 887	0	0
	5	–	–	–	–	–
	Total	3 815	28 890	30 397	0	0
	c.v.		(32)	(30)	–	–
3	2	813	2 475	2 475	0	0
	3	279	3 397	3 397	0	0
	Total	1 092	5 871	5 871	0	0
	c.v.		(33)	(33)	–	–

Table 5: Stratum area (km^2) and biomass of four different categories of southern blue whiting by stratum and snapshot for the Campbell Island Rise. Strata with an H refer to the high density stratum survey, strata with an F refer to the fleet stratum survey. Abbreviations are explained in Table 2

			Biomass (t)			
Snap-shot	Stratum	Stratum area	Prob adult	Total adult	Prob imm	Prob juv
1	1	4 500	0	0	0	0
	2	3 474	1 792	2 846	429	0
	3	–	0	0	0	0
	4	2 692	20 828	24 730	5 429	0
	4H	2 633	14 218	18 037	5 429	0
	5	4 228	31 268	33 078	871	0
	7	3 349	82 824	87 602	8 541	0
	8H	59	8 219	8 219	0	0
	Total (excl. H)	18 243	136 712	148 260	15 271	0
	c.v.		(39)	(36)	(60)	–
	Total (incl. H)	18 243	138 447	149 910	15 125	0
	c.v.		(37)	(35)	(61)	–
2	1	2 419	0	669	0	0
	1F	2 250	0	0	0	0
	2	3 474	6 496	6 990	16 997	0
	3	–	–	–	–	–
	4	2 692	1 164	2 010	7 271	0
	5	4 228	1 086	1 237	3 012	0
	7	3 349	155 295	158 480	2 445	0
	8F	158	20 374	20 374	0	0
	Total (excl. F)	16 162	164 041	169 387	29 725	0
	c.v.		(58)	(56)	(48)	–
	Total (incl. F)	16 162	184 415	189 092	29 725	0
	c.v.		(52)	(51)	(48)	–

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)

Date	n	Gonad stage 1	2	3	4	5
Bounty Platform						
12AUG94	102	24	75	1	0	0
13AUG94	390	17	82	1	0	0
14AUG94	157	17	83	0	0	0
15AUG94	298	1	99	0	0	0
16AUG94	136	2	98	0	0	0
17AUG94	128	8	84	9	0	0
18AUG94	84	33	62	4	1	0
20AUG94	73	21	55	25	0	0
21AUG94	132	11	32	48	8	0
22AUG94	46	9	24	57	11	0
23AUG94	145	2	8	36	50	3
24AUG94	176	1	5	27	63	5
25AUG94	183	4	10	49	26	11
26AUG94	77	6	22	26	38	8
27AUG94	138	2	41	2	25	30
28AUG94	79	6	34	35	8	16
29AUG94	403	21	56	1	0	22
30AUG94	101	4	82	14	0	0
31AUG94	82	20	78	2	0	0
01SEP94	143	4	87	8	0	0
Pukaki Rise						
02SEP94	76	0	100	0	0	0
03SEP94	364	33	65	1	1	0
04SEP94	291	7	91	1	0	0
05SEP94	429	37	62	0	0	0
06SEP94	147	1	98	1	0	0
07SEP94	376	61	38	1	0	0
08SEP94	69	7	84	7	1	0
14SEP94	117	98	0	2	0	0
Northern Campbell Island Rise						
12SEP94	56	21	77	2	0	0
13SEP94	103	87	13	0	0	0
15SEP94	91	0	74	18	9	0
16SEP94	287	3	66	22	7	1
17SEP94	254	0	43	43	13	0
18SEP94	262	4	29	45	17	6
19SEP94	167	1	2	83	12	2
20SEP94	178	1	3	34	62	1
21SEP94	229	8	3	71	10	8
29SEP94	94	80	6	0	2	12
Southern Campbell Island Rise						
13SEP94	196	35	47	17	1	0
14SEP94	40	13	73	15	0	0
15SEP94	102	24	71	6	0	0
16SEP94	66	27	73	0	0	0
19SEP94	198	39	54	4	3	0
20SEP94	97	35	44	18	3	0
21SEP94	186	19	49	16	10	6
22SEP94	373	33	21	38	8	0
23SEP94	375	39	13	32	11	5
24SEP94	374	32	13	41	12	2
25SEP94	291	12	11	44	15	17
26SEP94	129	18	15	44	19	5
27SEP94	219	17	25	15	23	21
28SEP94	190	24	20	35	5	15
29SEP94	124	18	19	40	15	9
30SEP94	36	8	72	19	0	0

Table 7. Summary of day-night comparisons of biomass estimates

Year	D/N	Spawn/ Presp	Snap#	Stratum Area (km^2)	No. of tran- sects	Biomass (t)	c.v. (%)	Sig
Bounty Platform								
1993	D	S	2	774	5	1 700	24)	NS
1993	N	S	2	774	5	46 600	83)	
1994	D	S	3	107	14	1 700	52)	< 0.05
1994	N	S	3	49	14	40 600	27)	
1994	D	S	4	1 462	18	6 100	72)	NS
1994	N	S	4	1 462	22	48 800	54)	
1994	D	S	5	1 831	14	8 900	94)	NS
1994	N	S	5	1 831	12	20 300	53)	
Campbell Island Rise								
1993	D	P	1	306	4	7 700	66)	NS
1993	N	P	1	306	7	9 700	44)	
1994	D	S	2	180	11	4 300	86)	NS
1994	N	S	2	158	12	20 400	80)	

Table 8: Summary of biomass estimates in t x 10^3 (and *c.v.*s) for each area, and category of SBW for the 1993 and 1994 acoustic surveys. Abbreviations are explained in Table 2

Area	Probable adult 1993	Probable adult 1994	Total adult 1993	Total adult 1994	Probable immature 1993	Probable immature 1994	Probable juvenile 1993	Probable juvenile 1994
Campbell Island	18.5	161.4	33.2	169.8	89.6	22.4	0	0
	(21)	(36)	(15)	(33)	(23)	(38)		
Bounty Platform	94.6	55.0	99.3	56.8	5.9	15.8	7.2	0.2
	(46)	(22)	(44)	(23)	(43)	(87)	(46)	(80)
Pukaki Rise	49.8	39.0	54.9	40.4*	26.3	0	0	0
	(24)	(45)	(22)	(43)	(20)			

* Includes some immature 3 yr old fish.

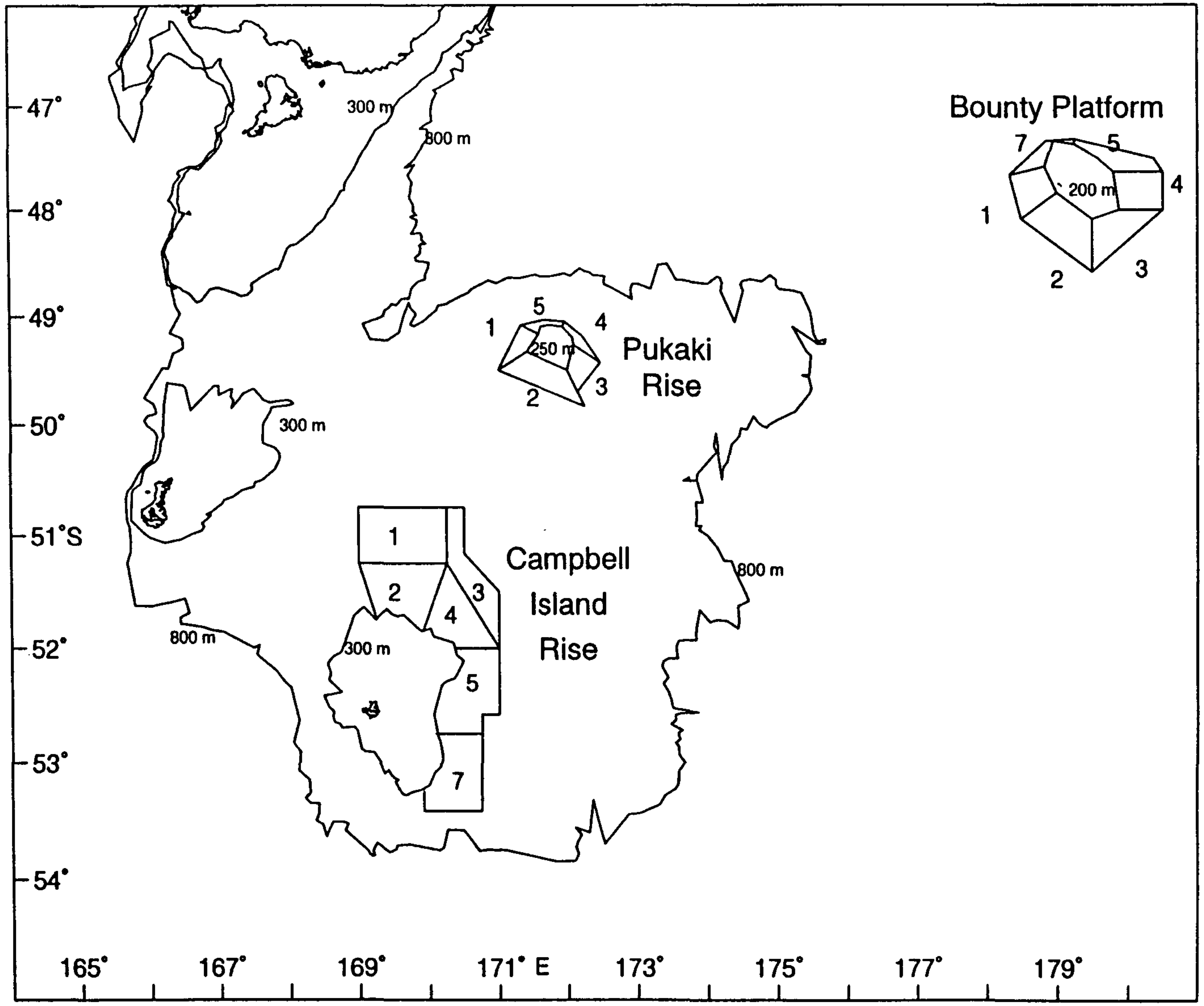

Figure 1: Strata numbers and boundaries surveyed during acoustic survey TAN9408.

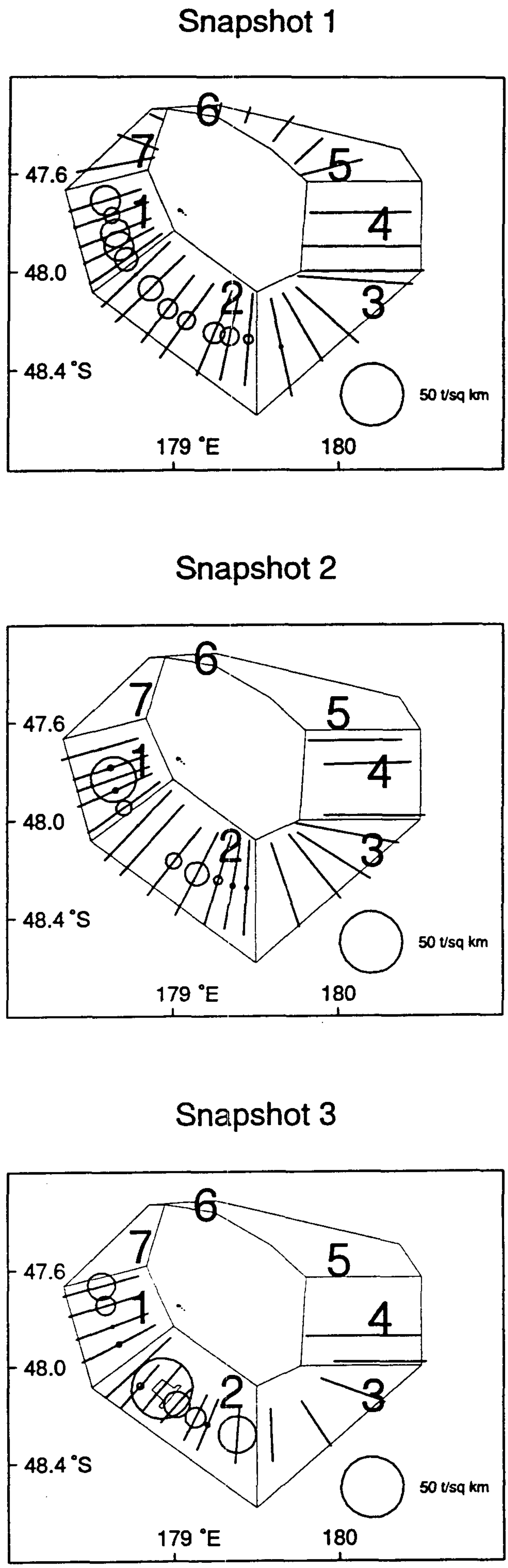

Figure 2: Density estimates of probable adults (t. km^{-2}) by transect for snapshots 1–3 on the Bounty Platform (note stratum 8 transects not plotted), 15/8/94–25/8/94.

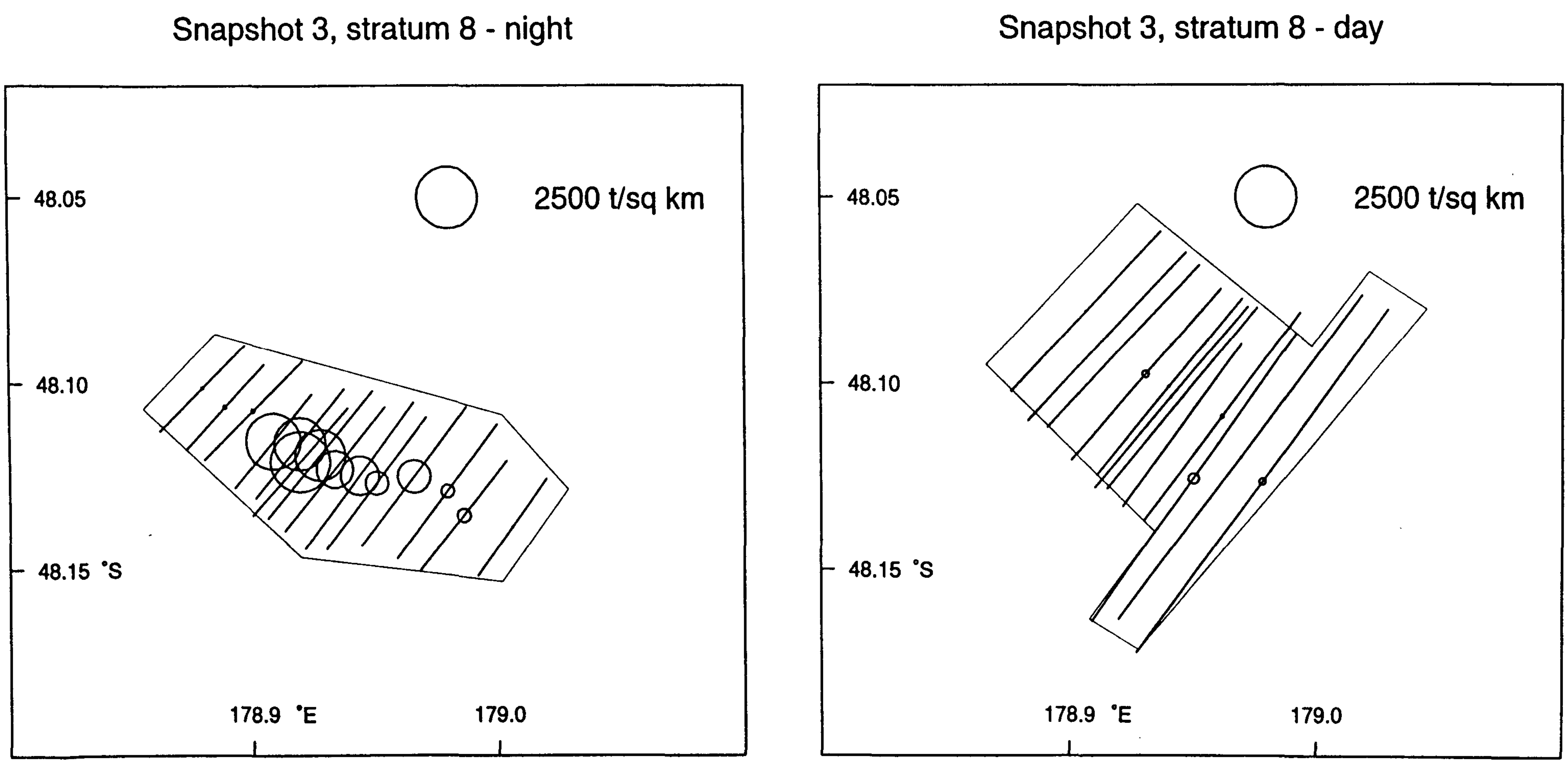

Figure 3: Density estimates of probable adults (t. km^{-2}) by transect for the day and night high density stratum on the Bounty Platform in snapshot 3 (24/8/94).

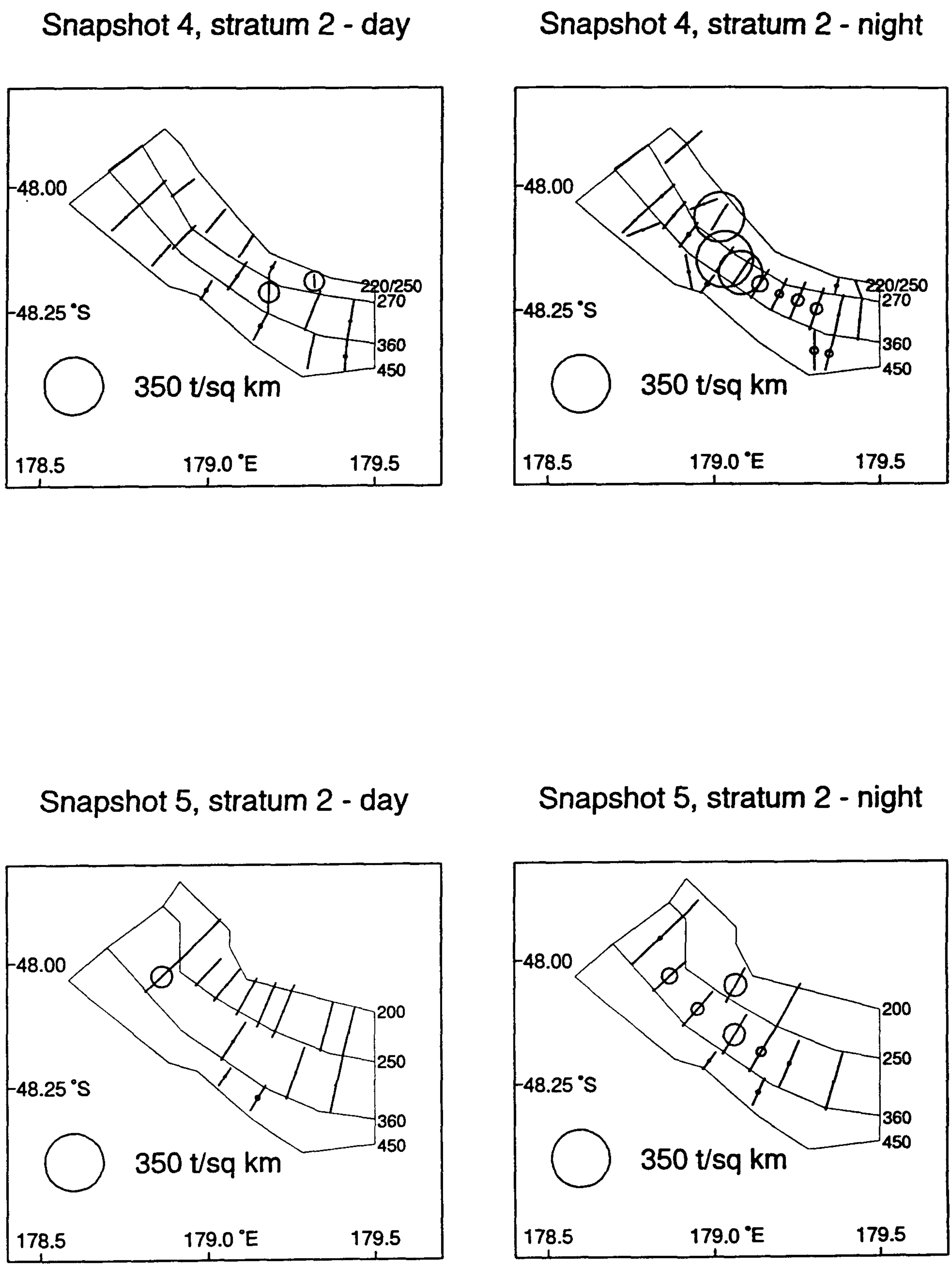

Figure 4: Density estimates of probable adults (t. km^{-2}) by transect in stratum 2 for snapshots 4 and 5 on the Bounty Platform 26/8/94–28/8/94.

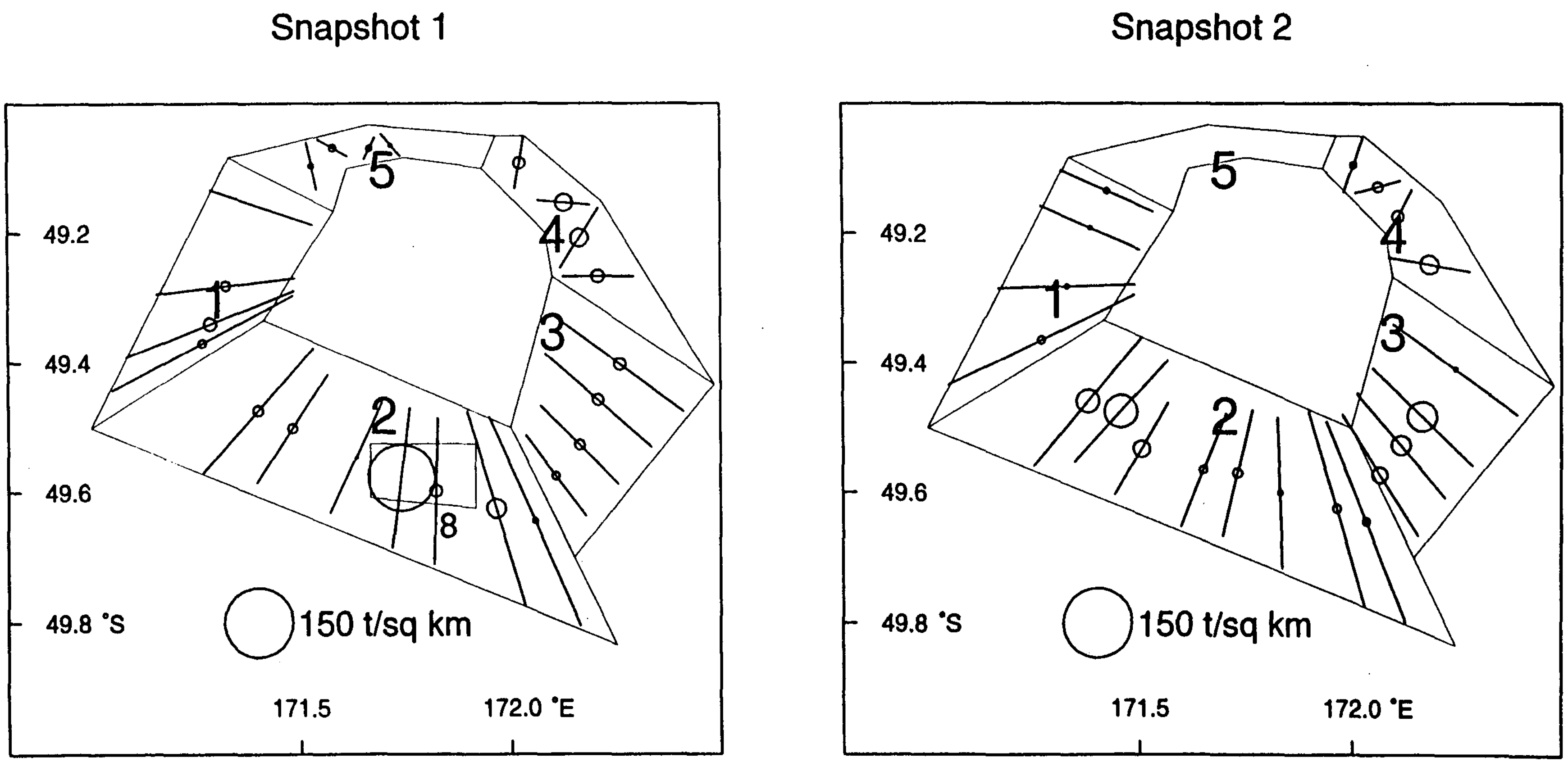

Figure 5: Density estimates of probable adults (t. km^{-2}) by transect for snapshots 1 and 2 on the Pukaki Rise, 31/8/94–10/9/94.

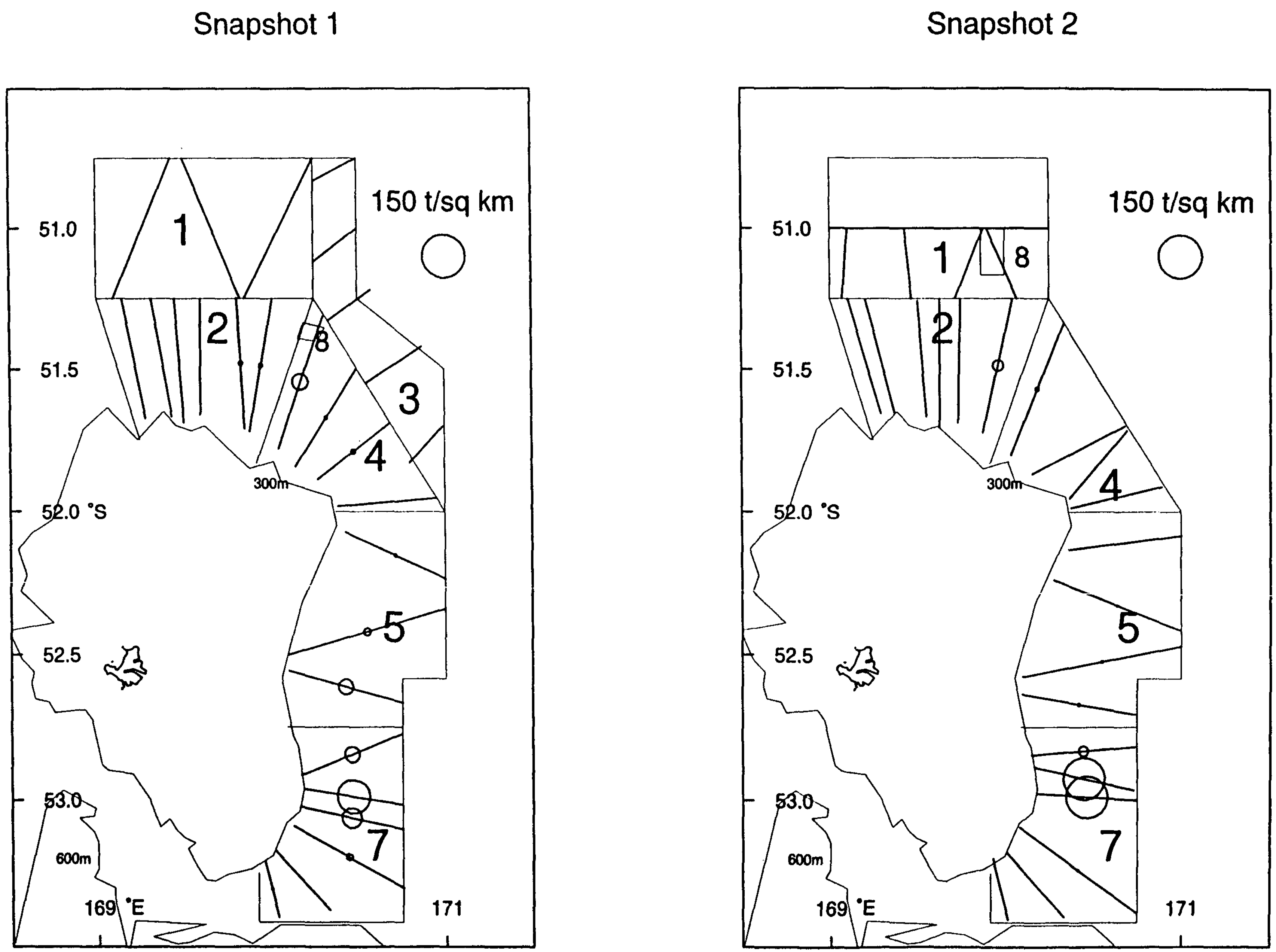

Figure 6: Density estimates of probable adults ($t.\ km^{-2}$) by transect for snapshots 1 and 2 on the Campbell Island Rise (note stratum 8 transects not plotted), 11/9/94–21/9/94.

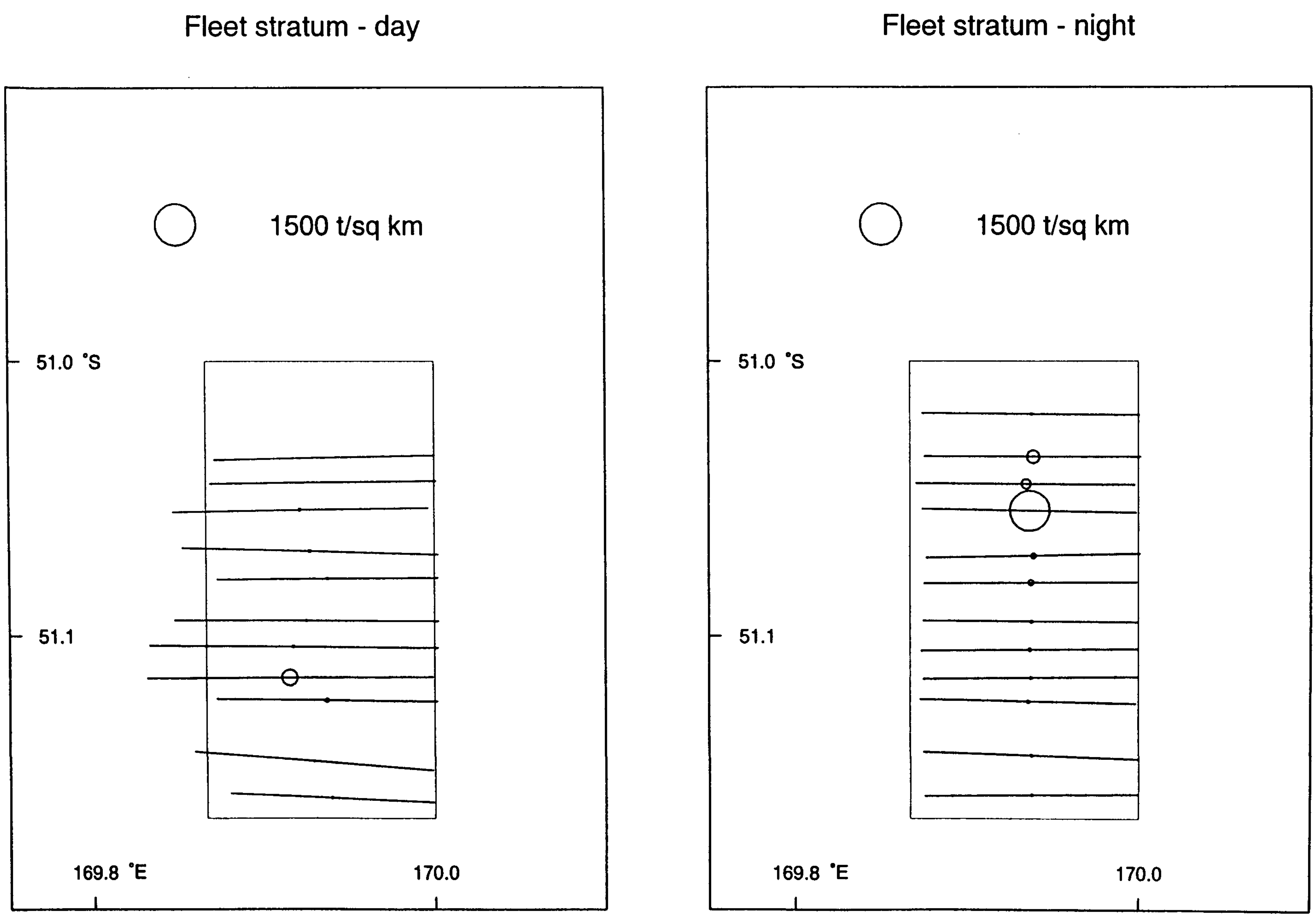

Figure 7: Density estimates of probable adults (t. km^{-2}) by transect for the night and day fleet stratum in snapshot 2 on the Campbell Island Rise.

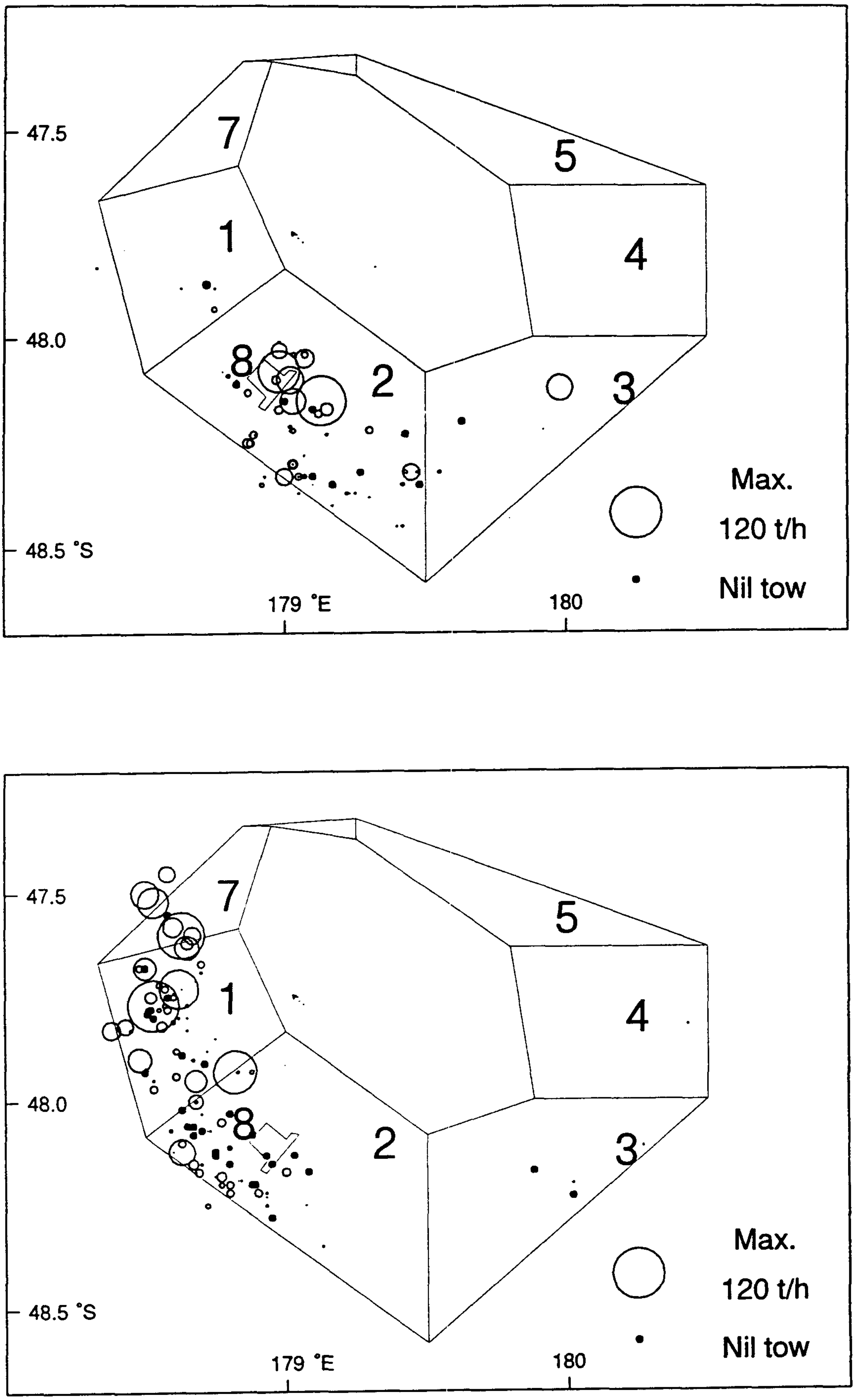

Figure 8: Catch rates (t. h^{-1}) of all commercial tows made on the Bounty Platform during, and outside, the acoustic snapshot period (15/8/94–28/8/94).

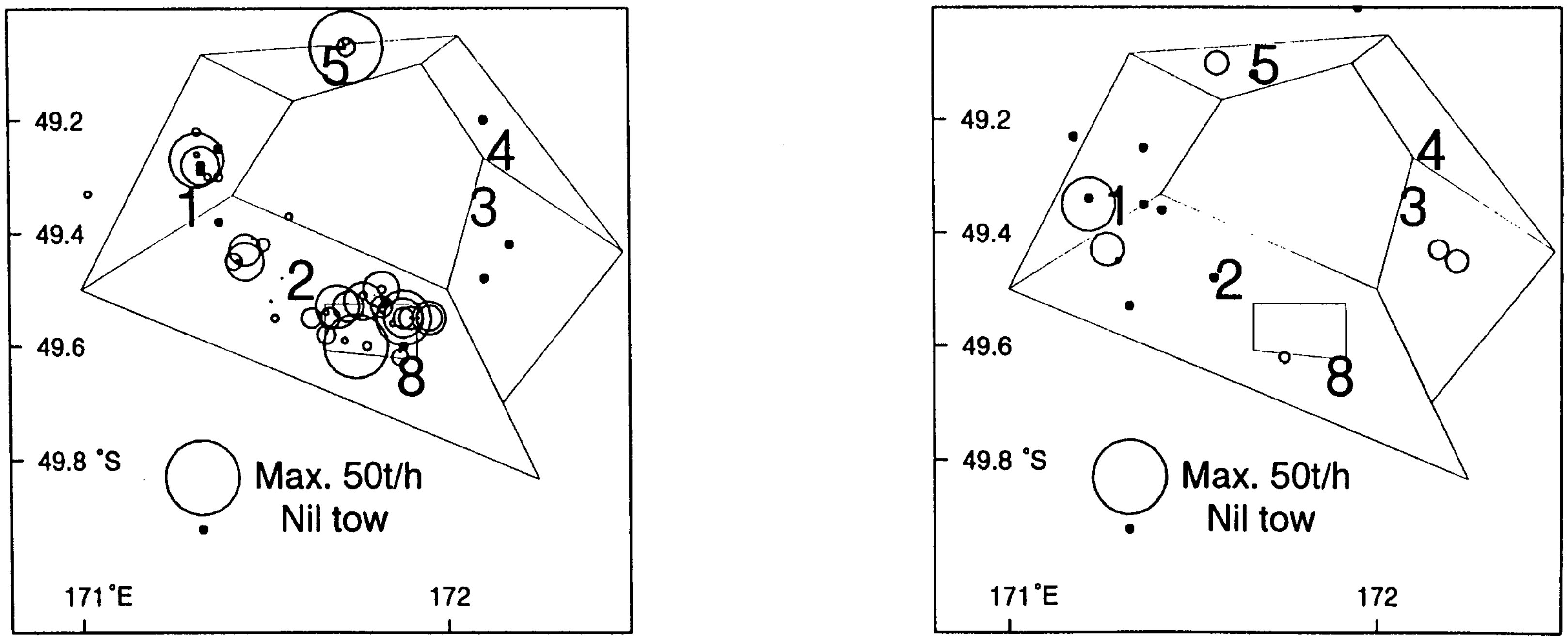

Figure 9: Catch rates ($t.h^{-1}$) of all commercial tows made on the Pukaki Rise during, and outside, the acoustic snapshot period (31/8/94–10/9/94).

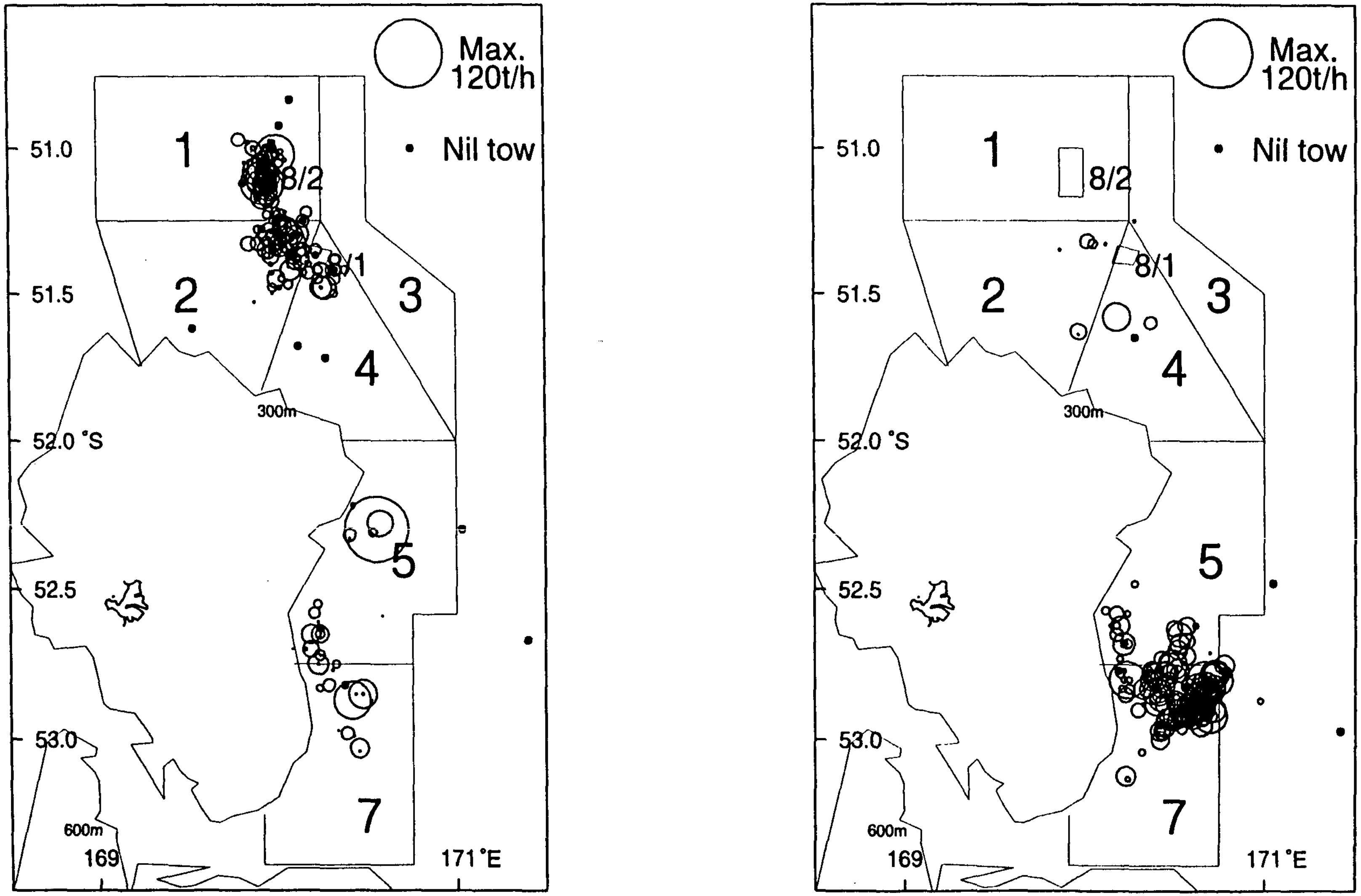

Figure 10: Catch rates (t.h^{-1}) of all commercial tows made on the Campbell Island Rise during the acoustic snapshot period (11/9/94–21/9/94).