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EXECUTIVE SUMMARY

Hanchet, S.M.; Grimes, P.J.; Coombs, R.F. (2002). Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, August–September 2001.

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This paper summarises the results of the sixth acoustic survey of southern blue whiting (SBW) on the Bounty Platform. Three full snapshots of the Bounty Platform were carried out between 18 August and 4 September 2001.

A total of 41 research trawls was made by *Tangaroa* to determine species and size composition of the marks seen during the survey. This is the highest number of trawls carried out on a SBW acoustic survey, and is reflected in improved target identification during this survey. Commercial trawl data were also used to help to determine the main fishing locations. Based on these data and previous experience, SBW marks were initially identified as adult, subadult, and immature fish. These categories were then decomposed to provide estimates of age 1, 2, 3, and 4 plus fish.

During snapshot 1, adult SBW were located on the south of the Bounty Platform in stratum 3. Eleven transects were surveyed in this stratum. The estimate of adult biomass for snapshot 1 was 41 373 t (c.v. = 59%). In snapshot 2, few adult fish were found, but these were again found in stratum 3. The estimate of adult biomass for snapshot 2 was 9698 t (c.v. = 37%). At the start of snapshot 3 most fish were located on the boundary of strata 3 and 4 and so the area was restratified. The estimate of adult biomass for snapshot 3 was 21 671 t (c.v. = 30%). The average of the three snapshots was used to provide the best estimate of adult biomass from this survey and equalled 24 247 t (c.v. = 35%). The decomposed biomass estimate of age 4 plus fish was 21 677 t, which is the lowest in the time series.

Estimates of subadult and immature fish were very consistent between snapshots. The average of the three snapshots was used to provide the best estimate of biomass and equalled 1976 t (c.v. = 11%) for subadult fish and 5046 t (c.v. = 28%) for immature fish. The decomposed biomass estimates were 6010 t for 3 year old fish, 2551 t for 2 year old fish, and 135 t for 1 year old fish. These estimates are below average for the time series and suggest there will be low to moderate recruitment to the fishery over the next few years.

The treatment of the acoustic snapshots from previous surveys of the Bounty Platform was reviewed as part of this study. Two alternative hypotheses were considered. The first hypothesis is that most fish spend most of their year away from the Platform and migrate to the Platform for spawning. The timing of this migration may vary between years, but all fish are on the grounds once spawning has started (there is no evidence of turnover). Under this hypothesis, snapshots with low biomass estimates that have been carried out at the beginning of the survey (and before spawning has started) should be excluded. The alternative hypothesis is that all adult SBW are always present on the Platform for the duration of the survey period. If this hypothesis is true, then all the acoustic snapshots should be averaged to provide the best estimate. The evidence suggests that the first hypothesis is more likely, and this is consistent with the treatment of the snapshots up until the present time. However, we also provide a time series of biomass estimates based on the alternative hypothesis.

1. INTRODUCTION

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

A programme to estimate SBW spawning stock biomass on each fishing ground using acoustic techniques began in 1993. The Bounty Platform, Pukaki Rise, and Campbell Island Rise were each surveyed annually between 1993 and 1995, and the Auckland Islands Shelf was surveyed in 1995 (Hanchet et al. 1994, Hanchet & Ingerson 1996, Ingerson & Hanchet 1996). After the first three annual surveys it was decided to survey these areas less regularly. The Bounty and Pukaki spawning grounds were surveyed in 1997 (Grimes & Hanchet 1999), the Campbell grounds in 1998 (Hanchet et al. 2000b), the Bounty grounds in 1999 (Hanchet & Grimes 2000), and the Campbell and Pukaki grounds in 2000 (Hanchet & Grimes 2001).

The current report stems from an objective carried out under contract to MFish: "To estimate pre-recruit and recruited biomass on Bounty Platform during August and September 2001 using an acoustic survey (SBW2000/01)."

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

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

2. METHODS

2.1 Acoustic survey

2.1.1 Acoustic survey design

Various acoustic survey designs for SBW stocks were investigated by Dunn & Hanchet (1998) and Dunn et al. (2001). These two studies showed that optimal survey design would use proportional sampling, where the underlying distribution of the fish is already known and the sampling effort is proportional to the fish density (see also Thompson & Seber 1998). In the absence of this information, they concluded that two-phase sampling strategies should be used, with up to 20% of stations assigned to the second phase. Information on the distribution of the fish at the time of the survey is available from the location of the fleet and/or the results of the first acoustic snapshot of the area. During the 2001 survey of the Bounty Platform, information from both sources was used to redefine the survey strata and the associated sampling effort.

2.1.2 Stratification and transect allocation

The stratification and allocation used in previous surveys of the Bounty Platform were reviewed by examining the spatial distribution of SBW from historical catch effort data and from previous acoustic surveys. Based on this information, the stratum boundary between strata 1 and 5 was shifted to the north of the Platform to better reflect the pre-recruit fish distribution in the area. Otherwise stratification for the 2001 survey was identical to that used for the 1997 and 1999 surveys (Figure 1).

Initial allocation of phase 1 transects to strata 1 to 5 was carried out using the equation:

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

where: n_i is the number of samples allocated to stratum i of area A_i and variability V_i, and N is the total number of transects in the snapshot. The mean adult acoustic transect density estimates from previous surveys were used as the estimate of variability. The mean was used because this is generally thought to be more precisely known than the variance (Francis 1984).

The allocation of transects to snapshot 1 was similar to that in 1997 and 1999, with a higher allocation in strata 2, 3, and 4 (Table 1). Six phase 2 transects were set aside for allocation during each snapshot to strata which recorded high densities in the first phase. Because of potential problems with fish movement, and to avoid excessive steaming time, the phase 2 transects were carried out whilst phase 1 was in progress. Because density estimates were not available during the survey, the allocation of phase 2 transects was made on an *ad hoc* basis to the stratum where the densest marks were seen during phase 1.

2.1.3 Acoustic snapshots

Snapshot 1 was surveyed anticlockwise from stratum 1 to stratum 5. Dense adult SBW marks were seen only in stratum 3 and so a further six transects were allocated there for phase 2. All the marks were found in transects in the west of stratum 3. The fish appeared to be moving west and into shallow water and it appeared that spawning might be imminent. Snapshot 2 was begun immediately after snapshot 1 had finished, and the area was surveyed clockwise from east to west (i.e., from stratum 5 to stratum 1). The stratification and allocation of transects for snapshot 2 was similar to that of snapshot 1. However, the pre-recruit stratum (stratum 6i) was dropped, as it had only just been surveyed, and a lower weighting was given to stratum 4 as no adult fish were seen there during the first snapshot. During snapshot 2 no dense adult marks were seen, although there were less dense marks in most transects in stratum 3.

At the start of snapshot 3, two Japanese fishing vessels arrived (see also Section 2.2.2). They systematically searched the entire Bounty Platform, particularly focusing on strata 2 to 4, before locating fish and starting fishing on the boundary of strata 3 and 4 (Figure 2). The area was therefore restratified. Strata 3 and 4 were subdivided and a new stratum (stratum 8) placed between them. Dense marks were found in the east of stratum 8 on the night of the 28 August. The following night dense marks were found in stratum 4, and so an additional three phase 2 transects were placed in that stratum. Fishing vessels reported that the fish appeared to be moving to the east, and there was concern that the fish may have been double counted. Therefore, a shorter mini-snapshot of the area encompassing strata 4 and 8 was designed. The aim was to determine whether there was any evidence that the aggregation might be moving east around the Platform. Transects were therefore run only from 240 m out to 360 m (encompassing the main depth range covered by the aggregation during the previous two nights). Thirteen transects were surveyed from east to west starting from the boundary of stratum 4/5 and extending to the boundary of stratum 3/8.

2.1.4 Acoustic transects

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

$$m = 0.5 * L/n$$

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

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

Transects in strata 1 to 5 were surveyed at night because past experience has suggested that acoustic biomass is underestimated using daytime transects on this ground (Hanchet et al. 2000a). Surveying these strata began at 17:15 each evening and continued through to 06:45 each morning. Previous surveys have shown that pre-recruit fish are found mainly to the east of the Bounty Platform, an area with few adult fish (Figure 1, stratum 6i). There is also no evidence that the biomass estimates of pre-recruit fish vary diurnally (Hanchet et al. 2000a). Therefore, in estimating pre-recruit biomass, stratum 5 was divided into strata 5i and 6i. Transects surveyed in stratum 5i (as part of the adult survey) were used to estimate pre-recruit biomass there. Additional transects were carried out during the day in stratum 6i to estimate the pre-recruit biomass. Any of the original "adult" transects falling in stratum 6i were not used for estimating pre-recruit biomass.

In snapshot 1, all phase 1 transects were run from 200 m to 550 m. In snapshots 2 and 3 all transects were run from 200 m to 550 m except the transects in stratum 4 in snapshot 3, which were run from 200 m to 450 m (so that six transects could be completed during the time available). As stated above, in snapshot 4 all transects were run from 240 m to 360 m.

2.1.5 Acoustic equipment and calibration

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

CREST is computer based, using the concept of a software echo sounder. It supports multi-channels which can receive signals from single beam, split beam, dual beam, or other transducer configurations mounted on the ship's hull or in a towed body. Each channel consists of at least a receiver and usually also a transmitter. Each receiver has two broadband, wide dynamic range pre-amplifiers and two 16 bit 'sigma-delta' analog-to-digital converters (ADCs) which feed a digital signal processor (DSP56002). The gains of the two amplifiers differ by a factor of 256 and together they are used to synthesise a 24 bit value. The ADCs have a conversion rate of 100 kHz and the data from these are complex demodulated, filtered, and decimated. The filter is a 100 tap, linear-phase, finite impulse response digital filter with a bandwidth of 1.5 kHz. The filtered data are decimated to 4 kHz and a 20LogR+2αR time-varied gain applied. The results are then shifted to give 16 bit resolution for both the real and imaginary parts of the complex data which are stored for later processing.

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

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

The system was calibrated electrically using a precision microvoltmeter (Rhode & Schwartz URE) and acoustically using a standard sphere. Calibration generally followed the procedures set out by Foote et al. (1987) and Johanesson & Mitson (1983). The standard sphere calibrations used a 38.1 mm ±2.5 μm diameter tungsten carbide sphere, with nominal target strength of –42.4 dB. As for previous surveys (Hanchet & Grimes 2001), acoustic calibrations of both systems were carried out at sea and of the towed system in the deep tank at Greta Point before and after the survey. To calibrate the towed system at sea, the sphere was suspended 20 m below the transducer, on a single nylon line, and calibrated during the current survey in the Marlborough Sounds and during an oreo survey on the Chatham Rise. For the latter the whole assembly was lowered to a depth of about 600 m pausing at 100 m intervals, with data being recorded continuously, allowing the change of system response with depth to be measured. Acoustic calibrations of the hull system were carried out at anchor in the Marlborough Sounds. Three nylon lines were used to suspend the sphere about 30 m under *Tangaroa*. The calibration results are shown in Appendix 1.

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

2.2 Acoustic mark identification and SBW categories

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

2.2.1 *Tangaroa* trawls

Overall, 41 trawls were made to identify targets and collect biological samples. Midwater trawls were made using the NIWA pelagic trawl (headline height ca. 40 m), and bottom trawls were made using the fine mesh orange roughy wing trawl (headline height ca. 4.5 m). All trawls were made with a 40 mm mesh liner in the cod end. Trawls ranged from 5 to 10 minute duration when targeting dense marks, to a maximum of 45 minutes when targeting less dense marks or layers. Most trawls during the biomass part of the survey were carried out during the day. Although this necessitated extra steaming and searching time to find and identify the marks, it proved to be successful and made efficient use of the time available. As in previous years, most of the adult marks were easy to identify, and target identification trawls focused mainly on the less dense pre-recruit SBW marks and other light marks seen in the area. In the past there has been some concern that a single trawl may not be representative of a particular mark type. Therefore, during the 2001 target identification work replicate trawls were carried out in the same general area to determine the spatial and temporal variability of the distribution of the fish in the various aggregations.

The trawls caught a wide range of species, but were dominated by southern blue whiting (Table 2). The next most abundant species were pale ghost shark, banded rattail, ling, and white warehou. The catch rates of SBW are shown in Figure 1. The unscaled length frequency distribution of SBW from each trawl catching reasonable numbers of fish is shown in Figure 3. Pre-recruit marks were found in several areas around the Platform. The size distribution appeared to be slightly different between areas. The categories assigned to the various marks are considered in Section 2.2.3.

A number of trawls were targeted at marks that were not SBW. These included several shallow trawls on very light marks that comprised mainly the oblique banded rattail (*Caelorinchus aspercephalus*) (trawls 11, 21, 24, and 33) and a trawl made in stratum 6i on a dense bottom mark during the day (trawl 13) was mainly found to comprise arrow squid (*Nototodarus sloanii*).

Only five trawls were made in midwater, and these yielded poor catches despite being targeted at dense SBW marks. Bottom trawls made at the same location (either day or night) had much higher catches (see, for example, adjacent trawls 34 & 35, 38 & 39, and 40 & 41).

Separate acoustic recordings were made for trawls using the 12 kHz and 38 kHz hull-mounted transducers. Towards the end of the survey the 12 kHz sounder malfunctioned, and for the last 10 trawls only the 38 kHz record is available.

2.2.2 Commercial trawls

The first vessel started fishing on the Bounty Platform on 26 August, but had problems finding fish. A second vessel arrived on 27 August and together they searched the area for marks. They made moderate catches on 27 August, which improved from 28 to 30 August, but declined again on 31 August and 1 September. By 1 September four vessels were fishing there, and initially they found SBW to the south of the Bounty Platform on the boundary between strata 3 and 4, but the fish and vessels moved gradually east over the next few days (see Figure 2). Fish schools were reported to be dense but only large enough to withstand a single nights fishing. The vessels spent a large amount of time systematically searching each depth range from stratum 1 in the west to stratum 6i in the east. They left the grounds on 1 September after the catches started to decline. The fishing season lasted about 7 days during which the four vessels made 25 trawls and caught about 2300 t of SBW.

2.2.3 Acoustic marks and SBW categories

As mentioned above, dense adult marks were seen in strata 3, 4, and 8 during the acoustic surveying. These marks could be identified as adult SBW both because of their high density and also because of the distinctive characteristics of the pre-spawning and spawning marks. Their identity was confirmed by several *Tangaroa* trawls (trawls 6, 8, 34, 35) and by the location of the commercial trawls. The size distribution of the adult marks was very similar between the commercial data and the research trawls from *Tangaroa*.

Areas of less dense marks were recorded throughout much of the survey area. When the length frequency distributions from the *Tangaroa* trawls made in these areas were compared, they showed remarkably consistent patterns, in both spatial and temporal extent. For example, nine trawls were carried out at depths of 400–500 m in strata 1 and 2. Of these nine trawls, six (trawls 1, 3, 4, 22, 23, 40) caught more than 10 kg of fish (Table 2). They were separated by a distance of about 20 n.miles and were made over a period of 19 days, yet the size distribution of the catch was dominated by a strong mode at 26–27 cm in each case (see Figure 2). Each trawl also had a low proportion of other pre-recruits.

Several other areas of pre-recruit marks were identified. One was in depths of 400–475 m and extended from the eastern half of stratum 2 to the stratum 4/6i boundary. These marks were sampled by trawls 9, 10, 14, 16, 19, 20, 27, and 28 (Figure 2, Table 2). Each trawl had a dominant mode of 3 year old males, but also contained a mixture of other pre-recruit fish. This area of marks was classed as a sub-adult category for the initial analysis to distinguish it from the immature category also found in stratum 2. A third area of marks was located in 480–520 m in stratum 6i. These marks were sampled by trawls 12, 15, 37, and 38. Each trawl had a dominant mode of 3 year old females, and a mixture of other pre-recruits. This area of marks was classed as an immature category for the initial analysis. The fourth group of marks was found in 350–400 m in stratum 1. Only a single trawl was made in this area (trawl 25), and it was dominated by a strong mode of 3 and 4 year old female fish. The mark extended slightly into stratum 2, so to distinguish it from the other categories in this area it was classed as adult. Unlike previous years no marks with only 1 year old juvenile fish were identified. No dense marks were observed which could not be identified. Less dense marks covering a large part of the survey area were generally classified as non-SBW in line with previous acoustic surveys.

The five SBW categories are summarised below, and the corresponding length frequency distributions are given in Figure 4.

1. Immature str 1, 2: Marks in 400–500 m in strata 1 and 2. Mainly 2 year old (trawls 1–5, 22, 23, 40 and 41).
2. Immature str 6i: Marks in 480–520 m in stratum 6i. Mainly 3 year old female (trawls 12, 15, 37, and 38).
3. Subadult str 2, 3, 4: Marks in 400–450 m between strata 2 and 4. Mainly 3 year old male (trawls 9, 10, 14, 16, 19, 20, 27, and 28).
4. Adult str 1, 2: Marks in 350–400 m in strata 1 and 2. Mainly 3 and 4 year old female (trawl 25).
5. Adult str 3, 4, 8: Distinctive marks in 300–450 m in strata 3, 4, and 8. Mainly age 4 plus (trawls 6, 8, 34, 35 and observer data).

2.3 Analysis of acoustic data

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

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

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

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

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

The mean SBW stratum density for each SBW category was multiplied by the area of the stratum to obtain biomass estimates for each stratum which were then summed over all strata to produce an estimate for the snapshot, from the formulae given by Cordue (1991). Biomass estimates were also decomposed into numbers at age, with a plus group at age 4 using the length frequency data given in Figure 4 together with the age-length key derived from the commercial and research tows on the Bounty Platform in 2001 following Hanchet et al. (2000c).

Hanchet & Grimes (2000) concluded that the contribution of other species to the backscattering on the Bounty Platform had little effect on the estimates of adults and only a slight effect on the biomass estimates of the more dispersed schools of juvenile and immature fish. Therefore no allowance has been made for the contribution of other species here.

2.4 Gonad data

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

2.5 Collection of target strength data

In situ target strength (TS) data were collected from SBW marks on five separate occasions. On each occasion the towed body was lowered towards dispersed SBW at dusk or at night and a number of transects were made across the marks with the towed body between 75 and 150 m above the seabed. The size and species composition of the marks was confirmed by trawling before the target strength work had started. TS data were collected on three occasions from adult fish, and on one occasion from each of mainly age 2 fish in stratum 2 (trawls 40 and 41), and mainly age 3 fish in stratum 6i (trawls 37 and 38).

Unfortunately, several problems were encountered during the target strength runs. On two occasions there were equipment malfunctions with either the towed body or tow cable leaking. On the other three occasions the fish moved during or between the passes, either horizontally or vertically, and the data obtained were rather patchy. However, we are confident that some useful results will be obtained from the target strength work carried out during the survey. These data will be examined later in the year as part of project SBW2001/02.

3. RESULTS

3.1 Acoustic biomass estimates

Three full snapshots of the Bounty Platform were carried out between 18 August and 4 September. During snapshot 1, the main aggregation of adult fish was found in stratum 3 on the south of the Bounty Platform (Figure 5, Table 3), and 11 transects were surveyed in this stratum. Of the first five phase 1 transects only the middle transect recorded substantial amounts of fish. Of the six phase 2 transects completed the following night only the three westernmost transects recorded substantial amounts of fish. Two of these transects were close to transects surveyed the previous night, when few fish were recorded. This suggested that the fish were patchily distributed and/or possibly quite mobile. The estimate of adult biomass for snapshot 1 was 41 373 t (c.v. = 59%) (Table 3).

In snapshot 2, few adult fish were found, but these were again mainly in stratum 3 (Figure 6, Table 3). All transects in stratum 3 contained adult fish marks but none were dense. Note that the adult fish recorded from strata 1 and 2 were categorised as adult but were predominantly 3 and 4 year old females. Because no dense marks were seen during the phase 1 transects, no phase 2 transects were surveyed in snapshot 2. The estimate of adult biomass for snapshot 2 was 9698 t (c.v. = 37%) (Table 3).

By the start of snapshot 3 the two commercial fishing vessels had located SBW schools on the boundary of strata 3 and 4 and so the area was restratified and additional transects allocated to stratum 8. When stratum 8 was surveyed most fish were found in the three easternmost transects (Figure 7). The following night dense marks were found in stratum 4, and so an additional three phase 2 transects were placed in that stratum. Adult SBW were found in only two of the westernmost transects of stratum 4 (Figure 7). The estimate of adult biomass for snapshot 3 was 21 671 t (c.v. = 30%) (Table 3).

Fishing vessels reported that the fish appeared to be moving to the east, and there was concern that some of the fish in snapshot 3 may have been double counted (once in stratum 8 and again in stratum 4). Therefore, the following night a short snapshot of the area encompassing the main aggregation in strata 4 and 8 was surveyed (Figure 8). The aim was to determine the approximate length of the aggregation, and to determine whether there was any evidence that it was moving east around the Platform. Dense adult SBW marks were found on only three of the easternmost transects. No fish were found in the area where they had been seen the previous two nights. However, the adult biomass estimate of snapshot 4 was only 4326 t (c.v. = 49%).

Estimates of subadult fish were very consistent between snapshots, ranging from 1327 t to 2304 t, and were also precise with c.v.s ranging from 13 to 24%. Estimates of immature fish were also reasonably consistent between snapshots, ranging from 3735 t to 6023 t. However, they were less precise, with c.v.s ranging from 55 to 96%.

Decomposed biomass estimates are summarised for each snapshot in Table 4. Strata 5 and 5i were not surveyed in snapshot 3, so values for these strata in snapshot 3 were assumed to be the average of snapshots 1 and 2.

3.2. Gonad data

The timing of spawning on the Bounty Platform in 2001 was difficult to determine precisely. Gonads were examined sporadically during the survey from 18 August to 6 September (Table 5a). Few running ripe fish were caught, but it was evident that by 3 September most fish had already spawned. Only two commercial vessels carried observers this year, both from 27 August to 1 September (Table 5b). However, the results from the two vessels were slightly different. One vessel caught running ripe fish on 27 and 29 August, whereas the second vessel caught running ripe fish only on 30 August. Overall, it appears that the main spawning on the Bounty Platform was from 27 to 31 August.

Data were also examined for evidence of turnover. Fish examined at the beginning of the survey had not spawned because ovaries were still large and contained no residual ovulated eggs. Spawning took place during snapshots 2 and 3, and the percentage of spent fish increased only on 1 September. Although there was an increase in maturing fish on 1 September (Table 5b), it appears that these fish had already spawned one batch of eggs because this increase coincided with an increase in stage 8 fish from the *Tangaroa* samples (Table 5a). There was therefore no evidence of turnover from the gonad data.

4. DISCUSSION

4.1 Treatment of acoustic snapshots

Decisions on which snapshots to use for the various years in the time series have generally been made by consensus within the Middle Depths Working Group. During the 2002 stock assessment rounds several members of the Working Group questioned the basis for some of these decisions. We examine the reasoning behind the approach used in the past and go on to generate two time series of abundance indices of adults based on two alternative hypotheses.

In the first hypothesis some proportion of the fish is not always present on the Platform for the duration of the survey period. Under this scenario most of the fish spend the non-spawning period away from the Platform and then migrate to the Platform for spawning. The timing of this migration may vary between years, but all fish are on the grounds once spawning has started. Under this scenario in some years fish are on the grounds at the beginning of the survey, but in other years they may not be present until part way through the survey. Therefore, **snapshots with low biomass estimates** that have been carried out at the beginning of the survey (and before spawning has started) should be excluded on the basis that the fish are not yet on the grounds and therefore not available to the survey. A more objective approach would be to exclude **all snapshots** that were carried out before spawning had started. However, if the latter approach were used it would lead to the exclusion of several more snapshots (including the initial ones from 1997 and 2001 and both from 1999), and such a restrictive criterion does not appear warranted.

The alternative hypothesis is that all adult SBW are always present on the Platform for the duration of the survey period. If this hypothesis is true, then all the acoustic snapshots are equally likely to survey the fish, and so they should all be averaged to provide the best estimate.

Commercial catch data appear to support hypothesis 1. During the 1980s and 1990s there was some fishing outside the spawning season on the Campbell and Pukaki grounds, but virtually none outside the spawning season on the Bounty Platform (Hanchet 1993). In 1992, the year when 60 000 t of fish were removed from the Bounty Platform, several vessels tried fishing the grounds during three periods in May and July making 131 trawls. However, catches were small (maximum of 15 t per trawl) and improved only when the vessels returned to the grounds in early August. For example, mean catches from a Japanese vessel increased from about 5 t per trawl in early July to about 100 t per trawl when it returned on 5 August, about 10 days before spawning started.

In 1994 and 1999, commercial vessels also appeared to have problems in finding and catching fish during the period when the initial snapshots were carried out. In 1999, commercial vessels, with experienced skippers and fishing masters, were present on the fishing grounds from 14 August to 6 September. From 14 to 26 August vessels caught only 530 t, whereas on 27 August alone they caught 1320 t, and from then until the end of the season they caught an average of almost 1000 t per day (Hanchet & Grimes 2000). A similar situation occurred in 1994, although fewer vessels were involved.

The limited trawl survey data that exist for the Bounty Platform suggest that at least some adult SBW occur on the Bounty Platform outside the spawning season. Doorspread biomass estimates of almost 35 000 t were reported from a *Shinkai Maru* survey in autumn 1982 and of almost 15 000 t from two surveys by *Amaltal Explorer* in early summer of 1989 and 1990 (Hanchet 1997). However, these surveys tended to have low station densities and the high estimates were often the result of a single trawl. For example, in the 1982 survey about 3.7 t were caught in a 30-minute trawl (van den Broek et al. 1984). The next highest catch was less than 300 kg. These catch rates are consistent with those from the commercial fishing in July 1992 given above, and therefore do not allow us to reject either hypothesis.

There is a further complication that applies to the first acoustic survey carried out in 1993. During that year the fleet appeared to follow an aggregation as it moved around the Platform (Hanchet et al. 1994). Furthermore, the transects carried out in snapshot 1 that would have been most likely to have seen the fish (i.e., those on the main spawning ground in stratum 2) were carried out during the day, and so would have led to an underestimate of biomass in that stratum. Therefore the estimate from snapshot 1 should be rejected under both hypotheses.

The biomass estimates by snapshot are given in Table 6, and are shown in relation to the spawning season in Figure 9. Under hypothesis 1 the first snapshots in 1993, 1994, and 1999 and the second snapshot in 1994 should all be rejected. Under the alternative hypothesis all snapshots from each year are averaged (except snapshot 1 in 1993). The two time series are presented in Table 7a, b.

4.2 Biomass estimates

4.2.1 The 2001 survey

Three main snapshots were carried out during the 2001 survey. The fourth mini-snapshot clearly surveyed only a small part of the main aggregation and should not be considered for biomass estimation. Implications of the snapshot regarding fish movement are considered in Section 4.2.3. The first snapshot was carried out before spawning had started but actually had the highest biomass estimate in the time series. Clearly then, the fish were already on the grounds during the first snapshot. Under either hypothesis given in Section 4.1, the snapshots should therefore be averaged to provide the best overall estimate of adult biomass. The mean biomass estimate of adult SBW from the 2001 survey was 24 247 t (c.v. = 35%). The estimates of subadult and immature fish were very similar between snapshots, and were also averaged equalling 1976 t (c.v. = 11%) and 5046 t (c.v. = 28%) respectively. The corresponding decomposed biomass estimates were 21 677 t for age 4 plus fish, 6010 t for 3 year old fish, 2551 t for 2 year old fish, and 135 t for 1 year old fish (Table 7a).

4.2.2 Comparison with other surveys

The 2001 survey estimate for the sum of the age 4 plus fish is one of the lowest biomass estimates on record under either hypothesis (Table 7a, b). The low biomass estimate of adults from this survey is consistent with the modelling results of Hanchet (2000). His assessment suggested that the 1999 biomass was relatively low, and predicted a further decline as a result of the relatively weak incoming 1996, 1997, and 1998 year classes.

The 2001 survey estimate for the 3 year old fish is about average and that for 1 and 2 year old fish is below average for the time series. This suggests that there will be low to average recruitment to the fishery over the next few years, which is unlikely to allow the stock to rebuild.

4.2.3 The high variability in the 2001 survey

There was a large (4-fold) difference in adult (4+) biomass estimates between the three main acoustic snapshots during the 2001 survey. The c.v. for the adult biomass estimate was 35%, which is higher than the target c.v. of 30%. Several potential reasons for this high within and between snapshot variability were examined including fish movement, target identification, and fish distribution.

There was a clear eastward movement of the aggregation during the course of the survey from the western edge of stratum 3 to the eastern edge of stratum 4. After the mini-snapshot 4 was completed the area was searched for adult marks to carry out target strength work. Adult fish were found only to the northeast of the stratum 4/6i boundary, suggesting that the aggregation had continued moving east. An eastward movement of fish appears to be a common occurrence on the Bounty Platform. Hanchet et al. (1994) documented a large-scale movement of fishing vessels (and presumably also the fish) from the region of stratum 2 around the southern part of the Platform to the east and finally north of the Platform in the 1993 season. Movement of vessels from west to east has occurred in most seasons where there have been several vessels and a reasonably long season covering the spawning and immediate post-spawning period (e.g., 1992, 1993, 1995, etc).

This eastward movement of fish could have contributed to the between-snapshot variability. The two highest snapshots were both carried out from west to east in the same direction as the movement of the fish, but snapshot 2 and the mini-snapshot 4 were against the direction of movement. However, movement is unlikely to have affected the estimates in snapshot 1 because the entire area of the stratum was surveyed in each of phase 1 and 2, and fish would have needed to have moved extremely fast to be surveyed twice in adjacent transects. It is conceivable that fish were moving east as we surveyed in a westward direction in snapshot 2. However, we know from the commercial fishing data that reasonably dense aggregations of fish were on the stratum 3/4 boundaries after stratum 3 had been surveyed. Adult fish marks were also seen on most transects in stratum 3. It is therefore unlikely that the direction of sampling is the reason for the low estimate in snapshot 2. There is some possibility that fish may have moved and been double counted on the successive nights in snapshot 3. However, the main evidence for this comes from mini-snapshot 4, which clearly surveyed only a small proportion of the fish.

A second potential reason for the high between-snapshot variability is errors in target identification. Transects made in snapshot 2 were re-examined, but the only dense marks were very high in the water column. These marks were also present in the other two snapshots and were clearly not adult SBW. The consistency of subadult and immature biomass estimates between snapshots also suggests that there was little misclassification of adults into one or other of these two categories.

A more likely explanation for the high variability is the distribution of the fish. The high spatial and temporal variability, both between adjacent transects and between successive nights, suggested that the fish were patchily distributed and also possibly quite mobile. This was confirmed by the skippers and fishing masters of commercial vessels fishing in the area, who commented that the schools were dense but small and were unable to sustain more than a single night's fishing. Clearly, when fish are very patchily distributed there is a greater chance of missing the densest areas of fish. Almost twice as many transects were surveyed in the main areas of abundance (strata 3 and 4) in snapshots 1 and 3 compared to snapshot 2, and this may have contributed to the difference in biomass between the snapshots. This in itself does not mean that the estimates from any of the snapshots are biased, because all transects still had an equal probability of sampling a dense mark.

The low level of precision and the high between-snapshot variability is possibly a consequence of the low biomass of SBW currently on the Bounty Platform. Once strong year classes have recruited to the fishery, and the biomass has increased, it is expected that the precision of the surveys will improve. Surveys on the Campbell stock, which is substantially larger, have usually had c.v.s of less than 30% (Hanchet et al. 2000b), and recent ones have been less than 20% (Hanchet et al. 2000b, Hanchet & Grimes 2001).

The timing of the 2001 survey was extended to ensure that the fish were surveyed whilst spawning was taking place. This was successful and enabled three snapshots to be completed during the 2001 survey. The time left over at the end of the survey was also useful for obtaining target strength data for pre-recruit fish. We recommend that future surveys continue to start and end several days later, to allow for the variability in the spawning season on the Bounty Platform.

4.3 Mark identification

With six surveys of the Bounty Platform now completed, there is a great deal of certainty in the positive identification of the very dense adult SBW marks that contain most of the SBW biomass. Scientific observer coverage of the commercial fleet also helped to confirm the depths and areas of the adult fish distribution. Research trawling is likely to remain an important tool in the acoustic programme for identifying the size and age composition of SBW in the less dense pre-recruit marks including 1, 2, and immature 3 year old fish.

Only five trawls were made in midwater, and these yielded poor catches despite being targeted at dense SBW marks. Bottom trawls at the same location (either day or night) made much better catches (see for example adjacent trawls 34 & 35, 38 & 39, and 40 & 41). Although the new midwater net is designed for contact with the seabed, much of the Bounty Platform seabed is hard and rough and severe damage or loss of the net is a real possibility if the net is fished hard down on the seabed. The continued use of the bottom trawl in this area is therefore the only real practical option. However, we also recommend some time be spent on the next SBW acoustic survey in trying alternative fishing techniques with the midwater trawl to see if catches can be improved.

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Table 1: Transect allocation for voyage TAN0114. Number of additional phase 2 transects shown in parentheses.

	Number of transects			
	Snapshot 1	Snapshot 2	Snapshot 3	Snapshot 4
Date	18/8/01-24/8/01	24/8/01-29/8/01	29/8/01-04/9/01	04/9/01
Stratum number				
1	4	4	4	–
2	5	5	4	–
3	5 (6)	5	3	–
4	5	3	3 (3)	–
5	2	2	1	–
6i	4	–	4	–
8	–	–	6	13
Total	31	19	27	13

Table 2: *Trawl station details for TAN0114 with catch (kg) of the main species.* Trawl type: BT, bottom, MW, mid-water, * MW trawl on or near bottom, #MW trawl in midwater. Age, age of SBW in years, Ad = adults. CAS, oblique banded rattail; GSP, pale ghost shark; LIN, ling; WWA, white warehou; Total, total catch of all species.

Stn	Date	Lat	Long		Stratum	Min Depth	Max Depth	Age (yrs)	SBW	CAS	GSP	LIN	WWA	Total
1	18-Aug-01	47 43	178 28 E	BT	1	410	430	2/3	125	16	59	24	0	235
2	19-Aug-01	47 36	178 32 E	BT	1	459	487	2/3	4	5	4	0	0	15
3	20-Aug-01	47 58	178 36 E	BT	2	400	402	2/3	25	1	0	0	0	26
4	20-Aug-01	47 59	178 36 E	BT	2	402	410	2/3	36	10	12	4	0	66
5	20-Aug-01	47 59	178 28 E	BT	2	468	508	2	2	14	20	135	0	184
6	21-Aug-01	48 17	179 13 E	BT	3	382	401	Ad	979	29	230	140	0	1400
7	21-Aug-01	48 22	179 20 E	*MW	3	307	375	–	0	0	0	0	0	0
8	22-Aug-01	48 16	179 05 E	BT	3	401	444	Ad	2164	9	175	61	0	2433
9	23-Aug-01	48 21	179 35 E	BT	3	431	454	3/2	4	1	16	0	0	29
10	23-Aug-01	48 21	179 35 E	BT	3	435	457	3/2	130	18	172	17	0	363
11	23-Aug-01	48 13	179 12 E	BT	3	285	311	–	0	63	0	55	1	151
12	24-Aug-01	48 02	179 31 W	BT	6i	497	498	3/2	388	11	10	7	0	457
13	25-Aug-01	48 03	179 45 W	BT	6i	346	385	–	0	4	0	0	1	44
14	25-Aug-01	48 11	179 48 W	BT	4	450	458	3/2	144	12	45	15	0	246
15	25-Aug-01	48 07	179 36 W	BT	4	504	519	3/2	78	10	27	0	0	137
16	26-Aug-01	48 23	179 31 E	BT	3	465	512	3/2/1	26	25	267	11	0	411
17	26-Aug-01	48 19	179 30 E	BT	3	355	404	Ad	2	15	22	27	0	74
18	26-Aug-01	48 21	179 30 E	BT	3	400	439	Ad	1	15	66	26	0	159
19	27-Aug-01	48 04	178 52 E	BT	2	315	366	3/2	375	102	101	76	113	797
20	27-Aug-01	48 05	178 51 E	BT	2	358	360	3/2	787	31	34	45	0	914
21	28-Aug-01	47 52	178 50 E	BT	2	235	278	–	0	192	11	14	0	249
22	28-Aug-01	47 51	178 29 E	BT	1	391	411	2/3	772	0	22	24	0	839
23	28-Aug-01	47 48	178 25 E	BT	1	439	457	2/3	373	6	22	3	0	411
24	29-Aug-01	47 45	178 46 E	BT	1	287	287	–	0	221	0	4	2	254
25	29-Aug-01	47 39	178 40 E	BT	1	361	384	4	731	49	26	9	15	867
26	29-Aug-01	47 26	178 51 E	BT	5	320	389	–	0	2	0	8	0	46
27	31-Aug-01	48 22	179 18 E	BT	3	424	460	3/2	111	15	60	11	0	231
28	31-Aug-01	48 17	179 01 E	BT	3	502	503	3/2	254	8	40	39	0	397
29	31-Aug-01	48 06	178 55 E	BT	2	311	370	–	0	57	4	24	0	115
30	1-Sep-01	48 14	179 44 E	MW	8	135	135	–	0	0	0	0	0	0
31	3-Sep-01	48 05	179 58 E	BT	8	281	293	Ad	3	29	2	3	41	110
32	3-Sep-01	48 01	179 59 W	BT	8	288	292	3/2	2	4	6	2	5	37
33	3-Sep-01	48 01	179 59 E	BT	8	264	289	–	0	371	8	6	0	422
34	3-Sep-01	47 58	179 58 W	*MW	8	287	290	Ad	42	0	0	0	0	42
35	3-Sep-01	47 59	179 59 W	BT	8	282	291	Ad	965	15	11	34	36	1099
36	5-Sep-01	48 06	179 59 E	BT	8	300	325	Ad	1	50	14	49	0	156
37	5-Sep-01	48 03	179 32 W	BT	6i	499	504	3/2	966	0	25	9	0	1036
38	5-Sep-01	48 04	179 32 W	BT	6i	497	503	3/2	35	17	29	0	0	103
39	5-Sep-01	48 07	179 33 W	*MW	6i	488	519	–	0	0	0	0	0	0
40	6-Sep-01	47 50	178 27 E	BT	1	430	457	2/3	1180	72	87	14	0	1413
41	6-Sep-01	47 50	178 26 E	*MW	1	200	440	2	1	0	0	0	0	1
All									10703	1494	1625	895	215	15967

Table 3: Biomass estimate and c.v. by stratum and snapshot of the immature, subadult, and adult SBW categories for the Bounty Platform in 2001. The italicised entries were obtained from the previous snapshot.

Stratum	Area	Immature		Subadult		Adults	
		Biomass	c.v.	Biomass	c.v.	Biomass	c.v.
	(km^2)	(t)	(%)	(t)	(%)	(t)	(%)
Snapshot 1							
1	2 083	876	57	0	-	0	-
2	1 311	2 635	80	420	45	0	-
3	1 624	0	-	219	80	41 373	59
4	2 008	0	-	1 659	29	0	-
5	4 388	-	-	0	-	0	-
5i	1 412	0	-	-	-	-	-
6i	2 976	2 512	98	-	-	-	-
Total	11 414	6 023	54	2 298	24	41 373	59
Snapshot 2							
1	2 083	876	22	0	-	1 579	61
2	1 311	206	99	246	100	190	107
3	1 624	0	-	156	101	7 929	43
4	2 008	0	-	1 902	5	0	-
5	4 388	2 653	73	0	-	0	-
Total	11 414	3 735	53	2 304	13	9 698	37
Snapshot 3							
1	2 083	1 386	53	0	-	510	104
2	1 311	98	85	528	62	0	-
3	941	0	-	560	15	0	-
4	725	0	-	106	99	7 425	60
6i	2 976	3 895	42	-	-	-	-
8	1 572	0		133	72	13 736	34
Total	8 036	5 379	34	1 327	28	21 671	30
Snapshot 4							
8	591	0	-	0	-	4 326	49
Total	591	0	-	0	-	4 326	49
Mean snaps 1-3		**5 046**	**28**	**1 976**	**11**	**24 247**	**35**

Table 4: Decomposed biomass estimates (t) by stratum and snapshot of 1, 2, 3, and 4 year old and over SBW for the Bounty Platform in 2001. Stratum 5 was divided into 5i and 6i for biomass estimates of ages 1—3. The italicised entries were obtained from the mean of the other snapshots.

Snapshot 1

	Age				
Stratum	1	2	3	≥4	Total
1	20	664	128	34	846
2	74	2 086	637	187	2 984
3	6	73	4 767	3 7344	42 190
4	50	363	948	280	1 641
5	-	-	-	0	0
5i	0	0	0	-	0
6i	36	654	1 613	-	2 303
Total	186	3 840	8 093	37 845	49 964

Snapshot 2

	Age				
Stratum	1	2	3	≥4	Total
1	20	711	1421	266	2 418
2	12	216	310	79	617
3	4	39	980	7 179	8 202
4	54	395	1 033	305	1 787
5	42	769	1 894	314	3 019
Total	132	2 130	5 638	8 143	16 043

Snapshot 3

	Age				
Stratum	1	2	3	≥4	Total
1	32	1 063	619	128	1 842
2	18	191	318	94	621
3	16	122	320	95	553
4	2	23	753	5 651	6 429
8	4	38	1 681	12 918	14 641
5	-	-	-	*157*	*157*
5i	*0*	*0*	*0*	-	*0*
6i	56	1 016	2 502	-	3 574
Total	128	2 453	6 193	19 043	27 817
Mean snaps 1—3	**135**	**2 551**	**6 010**	**21 677**	**30 373**

Table 5a: Percentage of females at each gonad stage in *Tangaroa* trawls by date. N, number of fish examined. Gonad stages: 3, ripening; 4, ripe; 5, running ripe; 6, partially spent; 7, spent; 8, reverted (spawned one batch and reverted to ripening stage). (Note immature fish not shown.)

		Gonad stage					
Date	N	3	4	5	6	7	8
18-Aug-01	18	94	0	0	0	6	0
20-Aug-01	15	93	0	0	0	0	0
21-Aug-01	135	97	2	0	0	0	0
22-Aug-01	112	96	4	0	0	0	0
23-Aug-01	80	100	0	0	0	0	0
24-Aug-01	3	100	0	0	0	0	0
25-Aug-01	38	95	5	0	0	0	0
26-Aug-01	10	70	20	0	0	0	0
27-Aug-01	141	99	1	0	0	0	0
28-Aug-01	5	80	20	0	0	0	0
29-Aug-01	28	100	0	0	0	0	0
31-Aug-01	96	85	8	3	2	0	0
3-Sep-01	196	1	10	3	57	10	19
5-Sep-01	8	0	0	0	88	13	0
6-Sep-01	15	0	0	0	0	27	73

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

		Gonad stage				
Date	N	1	2	3	4	5
27-Aug-01	236	17	17	42	23	0
28-Aug-01	126	0	4	94	2	0
29-Aug-01	348	0	7	84	8	0
30-Aug-01	284	1	2	81	16	0
1-Sep-01	139	0	52	7	5	36

Table 6: Timing of snapshots and adult (≥ 3+ fish) biomass estimates (x 10^3 t) from acoustic survey snapshots in relation to the spawning season (>10% running ripe) for each area and year. Bio, biomass. Biomass estimates in bold were used to obtain the best estimate under hypothesis 1.

	Snapshot 1		Snapshot 2		Snapshot 3		Spawning season
	Date	Bio	Date	Bio	Date	Bio	
1993	21–25 Aug	18.0	25–29 Aug	**64.2**			21–29 Aug
1994	15–18 Aug	25.1	18–21 Aug	27.3	21–25 Aug	**59.7**	22–27 Aug
1995	16–22 Aug	**35.1**	27–29 Aug	**39.8**			24–28 Aug
1997	17–23 Aug	**85.1**	23–27 Aug	**39.0**			30–31 Aug
1999	14–19 Aug	16.0	20–28 Aug	**47.7**			1–6 Sep
2001	18–24 Aug	**45.9**	24–28 Aug	**11.8**	29 Aug–4 Sep	**25.2**	27 Aug – 3 Sep

Table 7a: Best estimate of decomposed biomass (t) by survey and age group for the Bounty Platform from 1993 to 2001.

Year	Age 1	Age 2	Age 3	Age ≥4
1993	8 814	6 870	1 410	62 857
1994	94	5 871	32 066	27 672
1995	59 284	4 856	6 658	30 770
1997	1 679	4 144	24 598	37 518
1999	429	745	4 969	42 722
2001	135	2 551	6 010	21 677

Table 7b: Alternative decomposed biomass estimates (t) by survey and age group for the Bounty Platform from 1993 to 2001. (Alternative estimate based on averaging all snapshots.)

Year	Age 1	Age 2	Age 3	Age ≥4
1993	8 814	6 870	1 410	62 857
1994	94	5 871	24 165	13 229
1995	59 284	4 856	6 658	30 770
1997	1 679	4 144	24 598	37 518
1999	429	745	3 505	28 362
2001	135	2 551	6 010	21 677

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

System	Towed body	Hull
Transducer serial no.	28327	23421
3dB beamwidth (°)	7.0×6.9	7.2×7.3
Effective beam angle (sr)	0.0083	0.0091
SL+SRT (dB re 1 V)	61.7	50.4
Transducer depth (m)	20-90	6.5
$20 \log_{10} G$	82.0	91.3

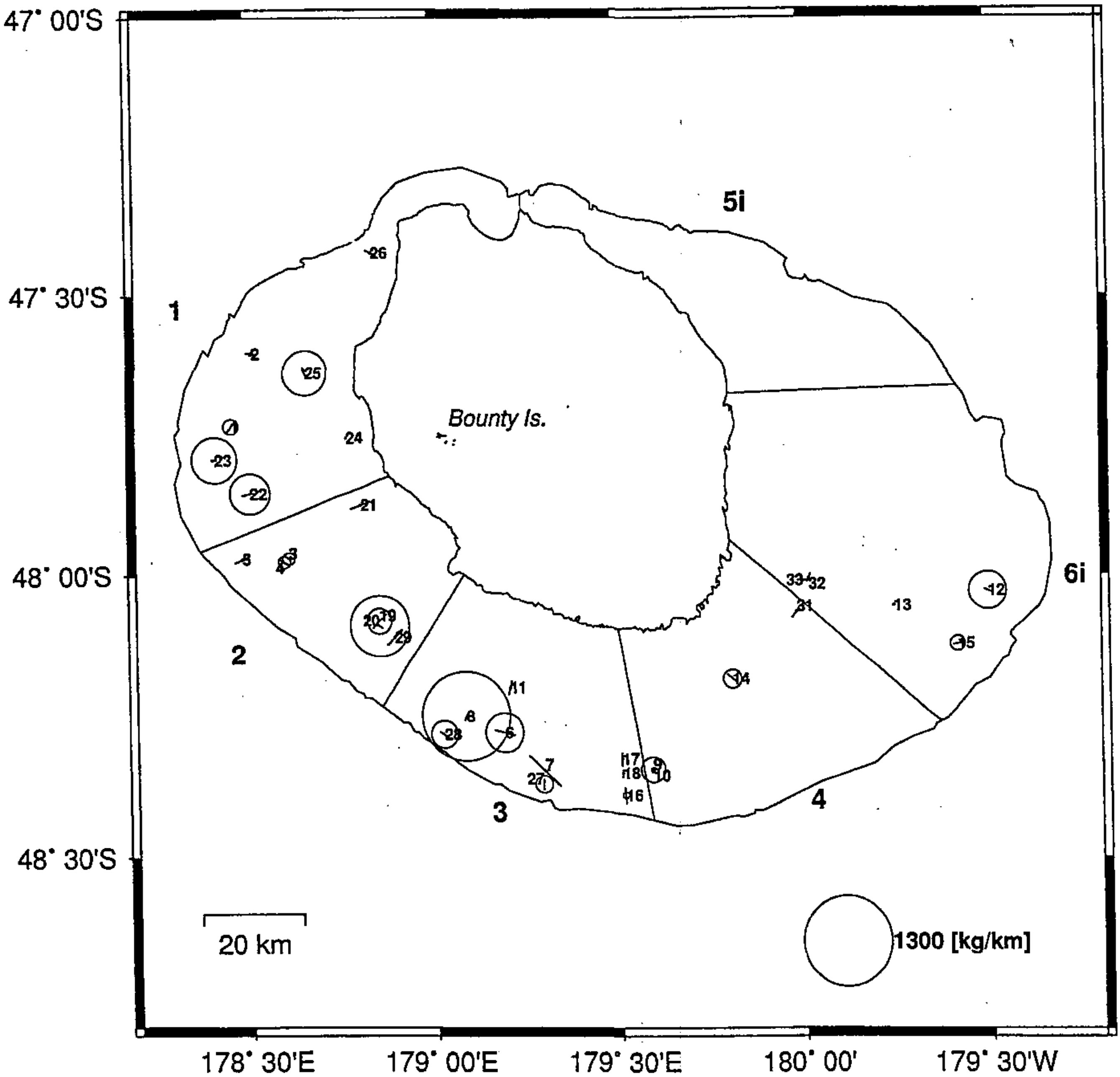

Figure 1: Survey area, stratum boundaries, station numbers and SBW catch rates for research trawls made during TAN0114. Note stratum 5 is the sum of strata 5i and 6i.

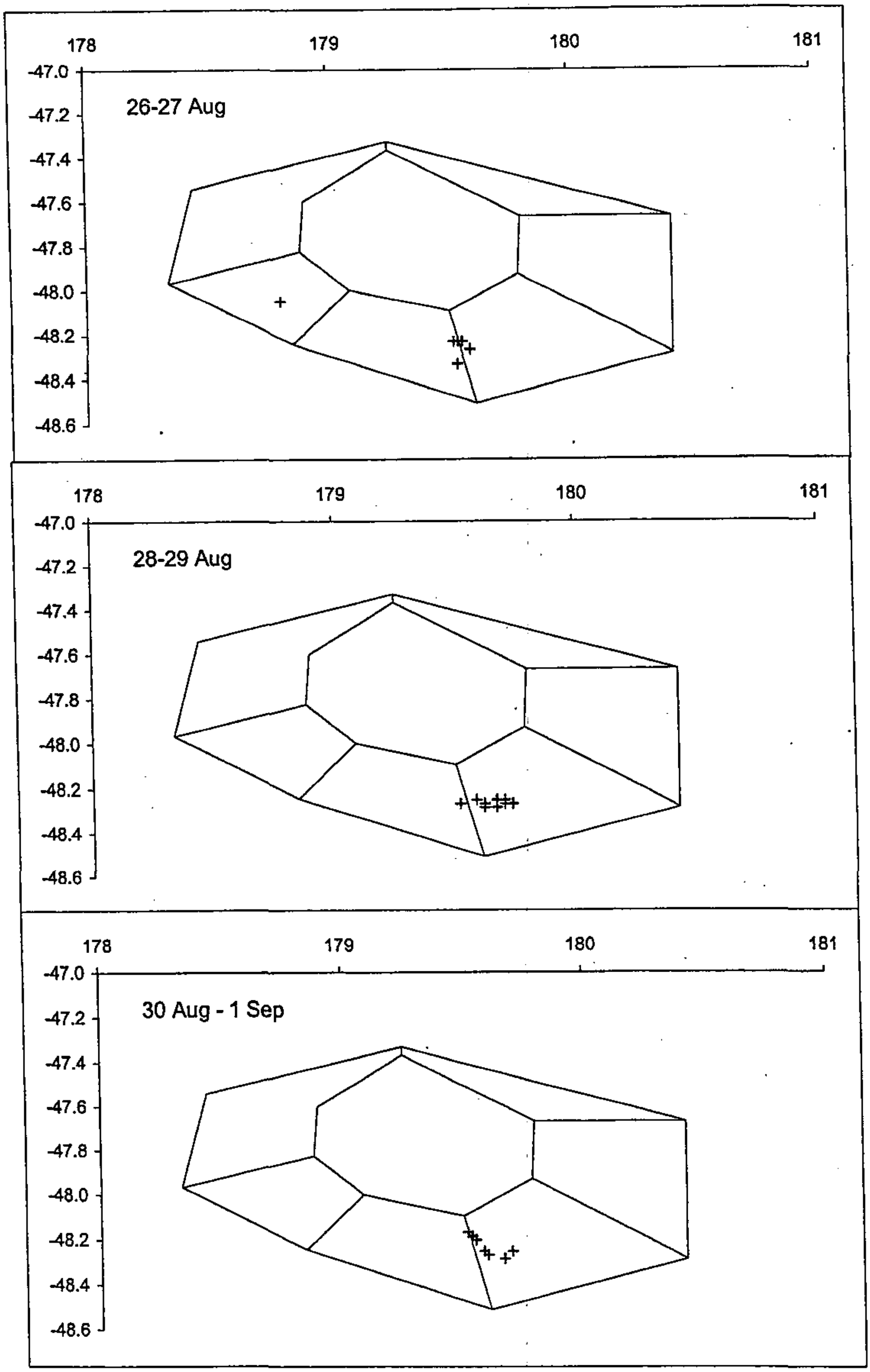

Figure 2: Commercial trawls made from 26 August to 1 September 2001.

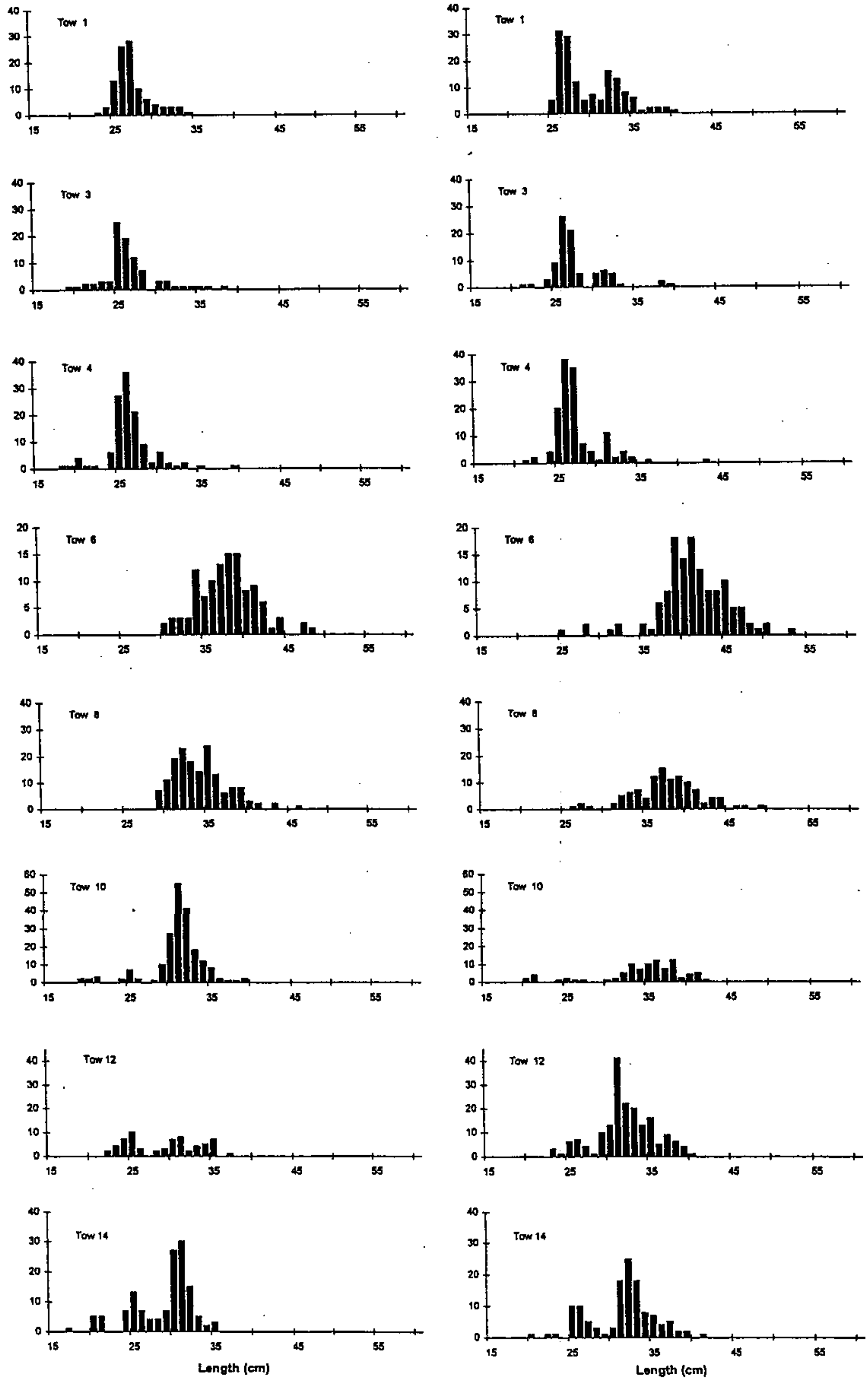

Figure 3: Unscaled length frequency distribution of SBW for *Tangaroa* trawl stations during TAN0114.

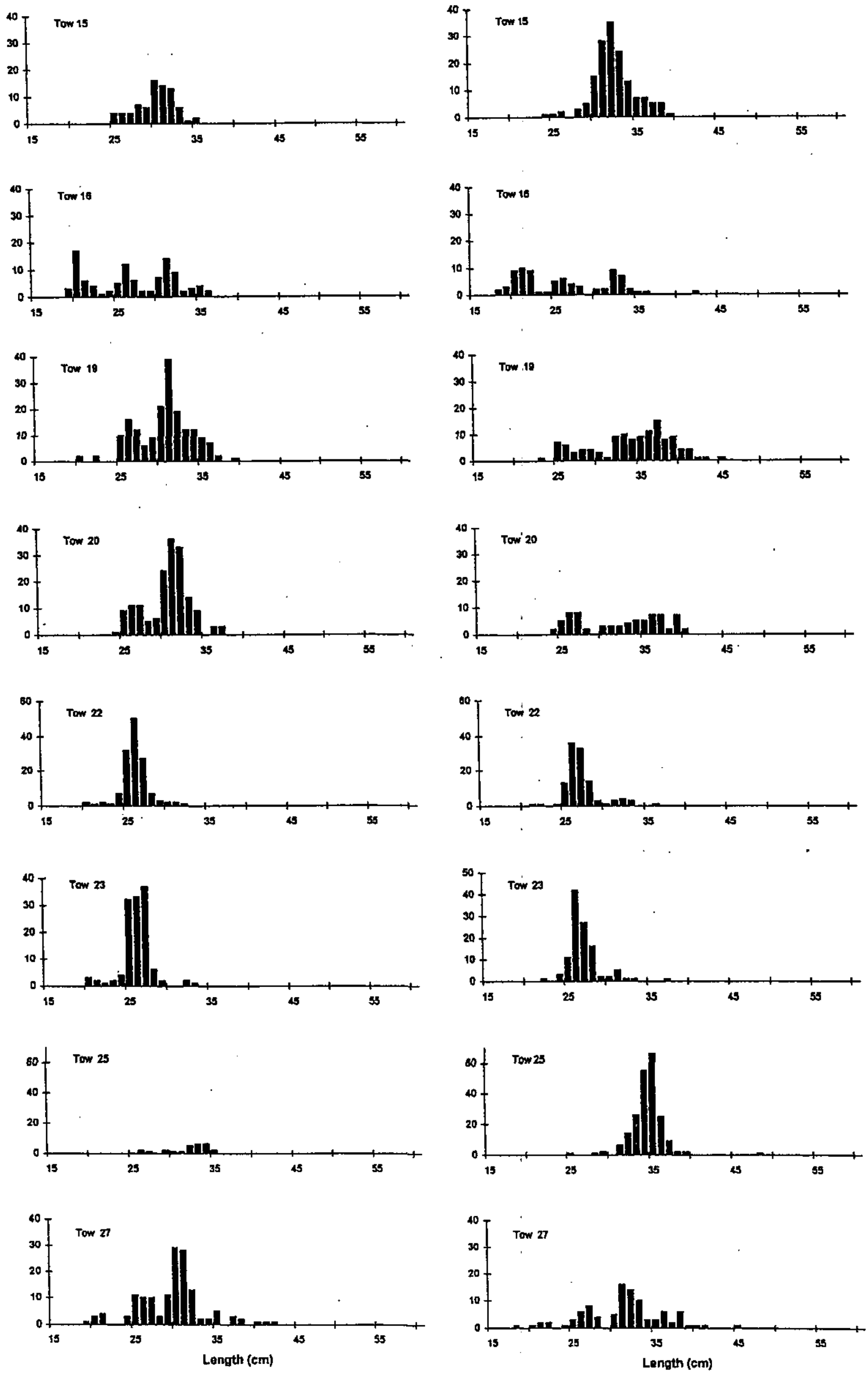

Figure 3: continued.

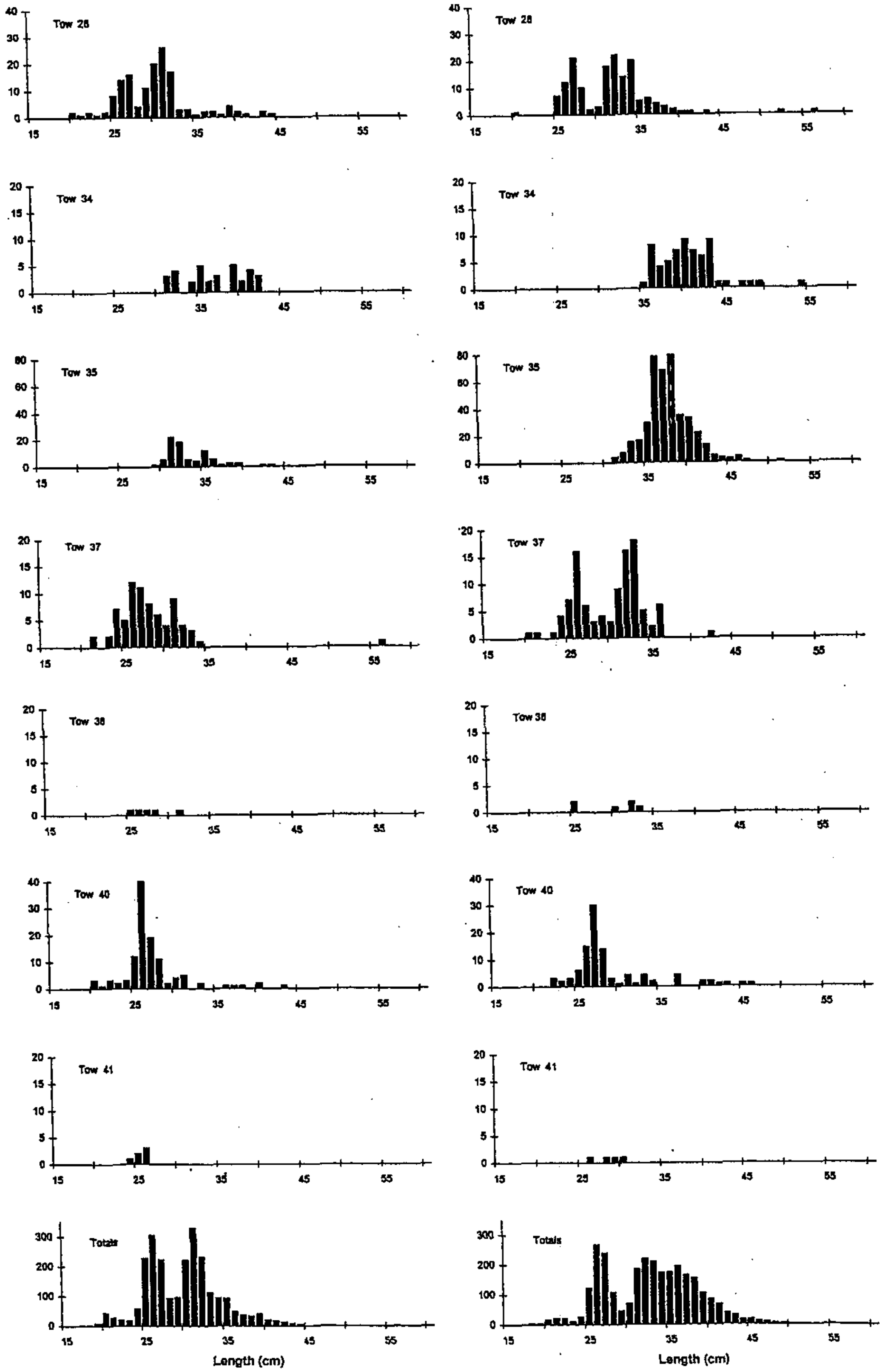

Figure 3: continued.

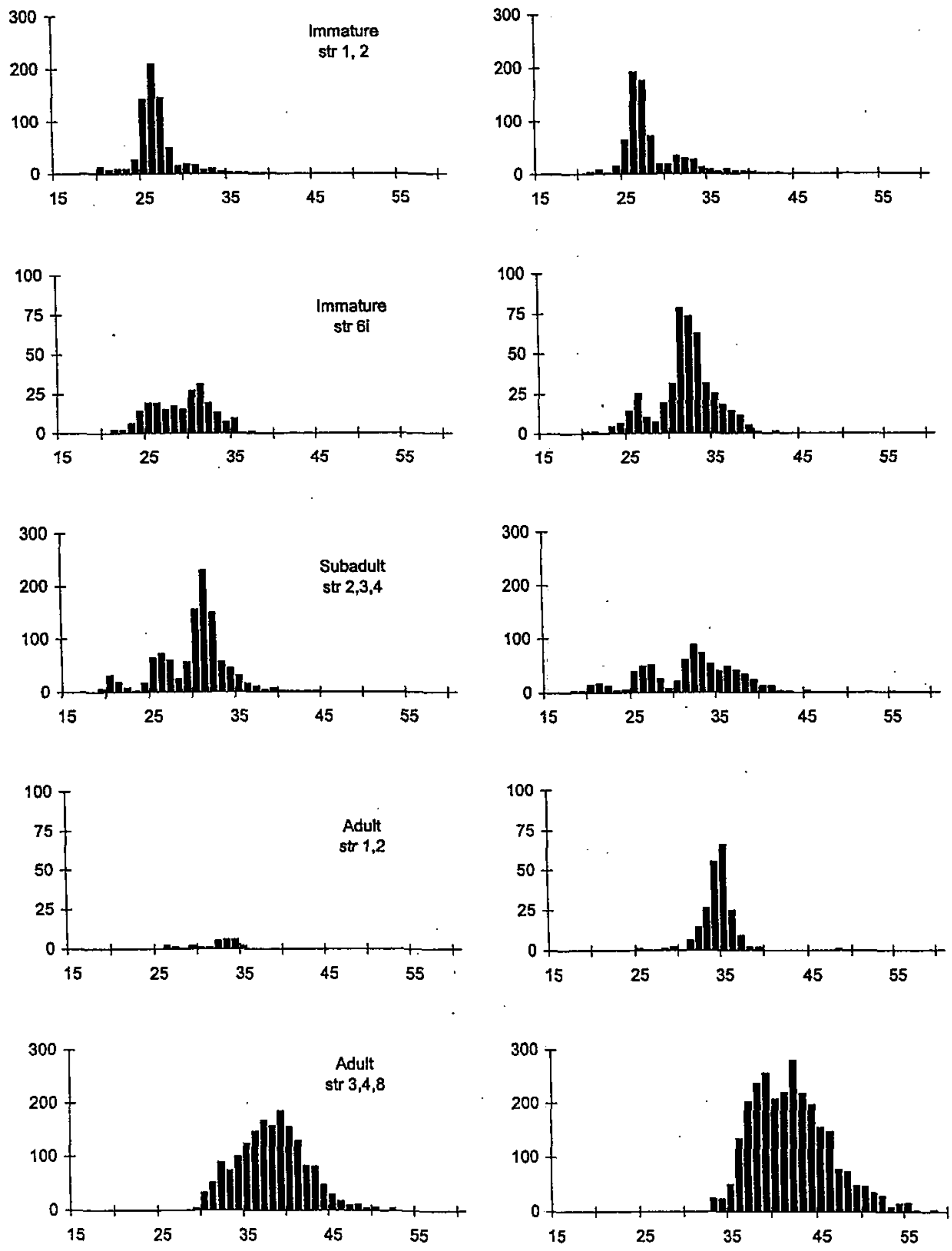

Figure 4: Unscaled length frequency distributions of the SBW categories, and the strata to which they apply.

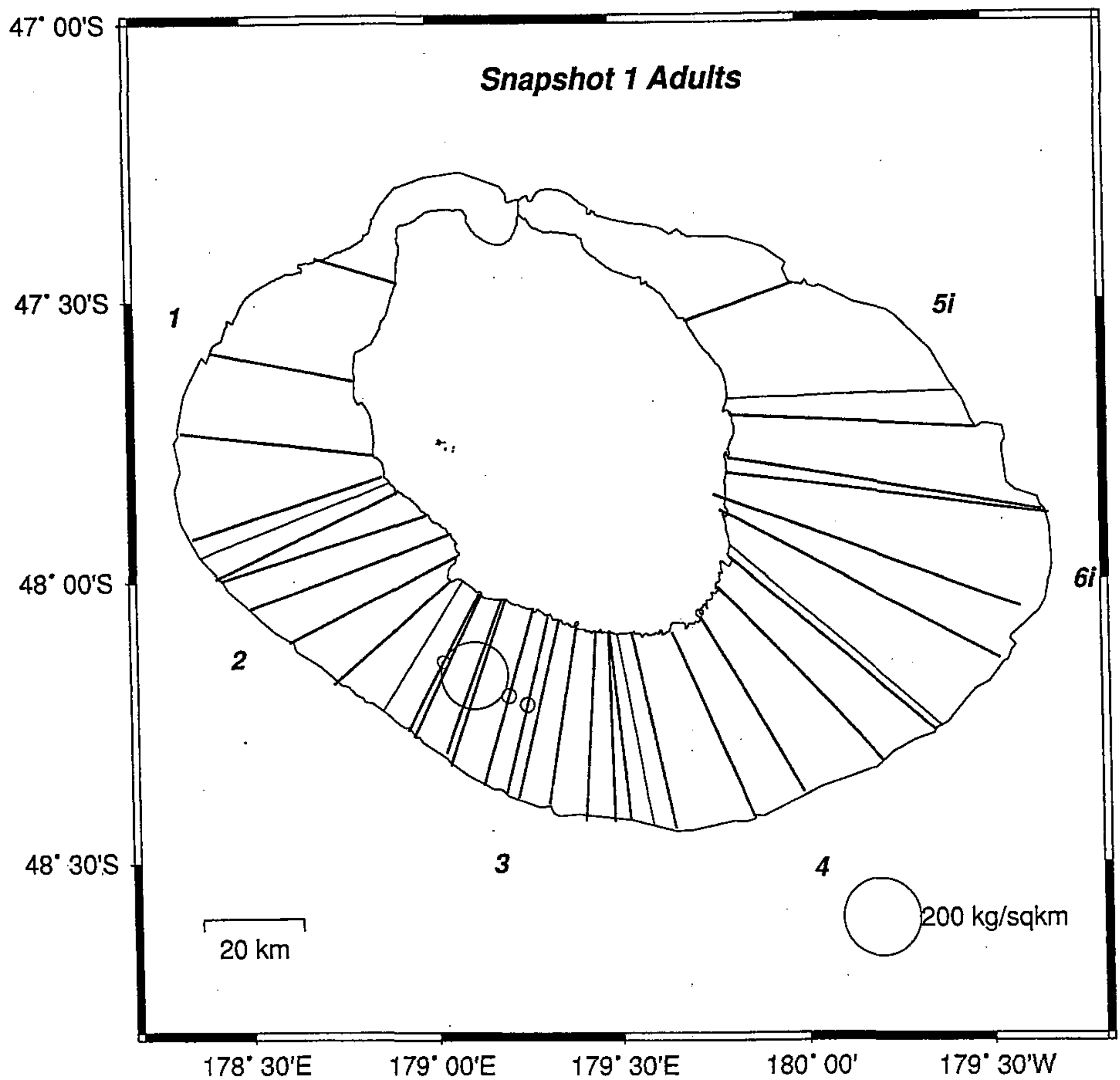

Figure 5: Density estimates of adult southern blue whiting (t. /sq km) by transect for snapshot 1. Note the fish density scale is 10 times higher than in Figures 6 to 8.

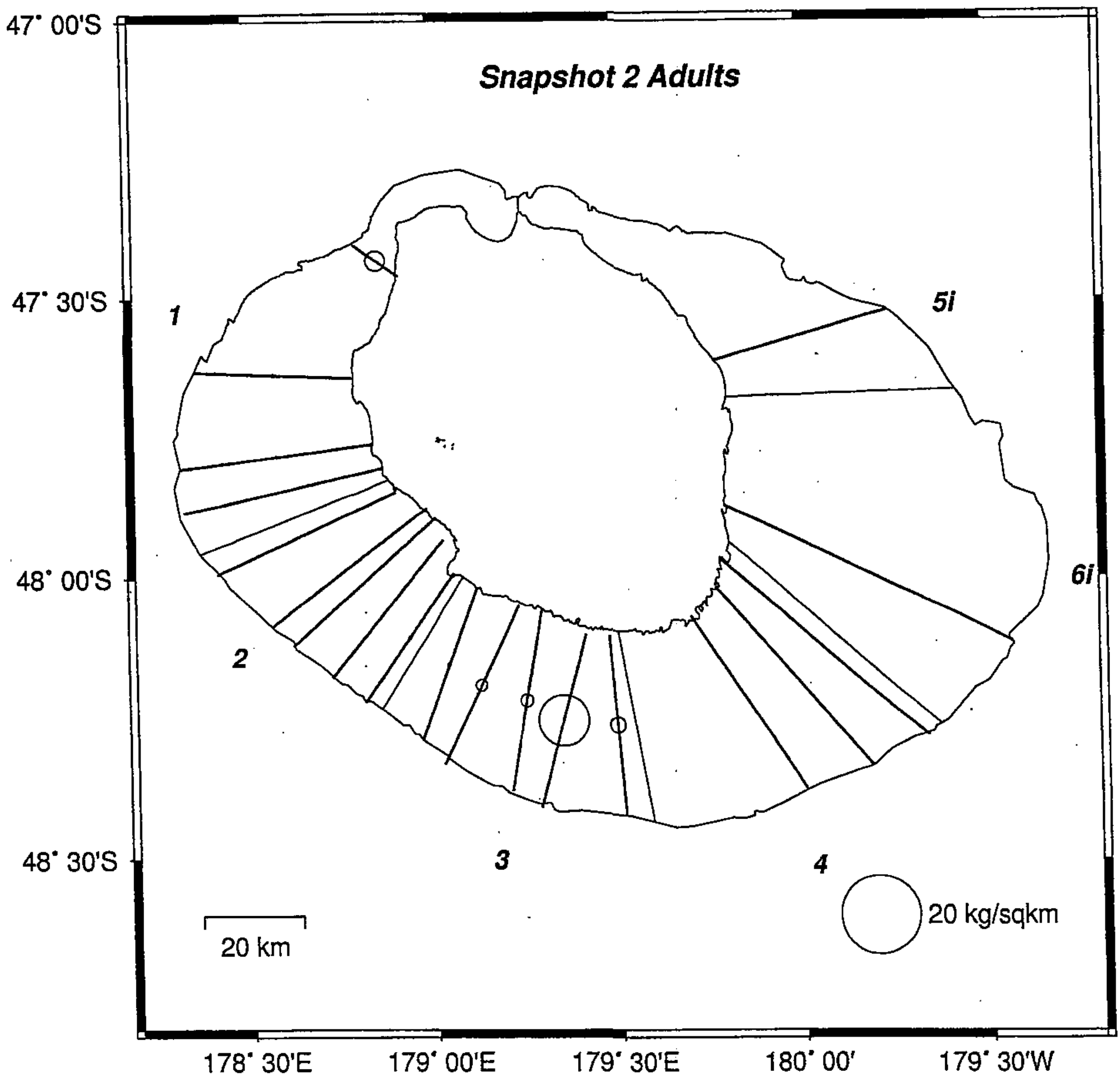

Figure 6: Density estimates of adult southern blue whiting (t. /sq km) by transect for snapshot 2.

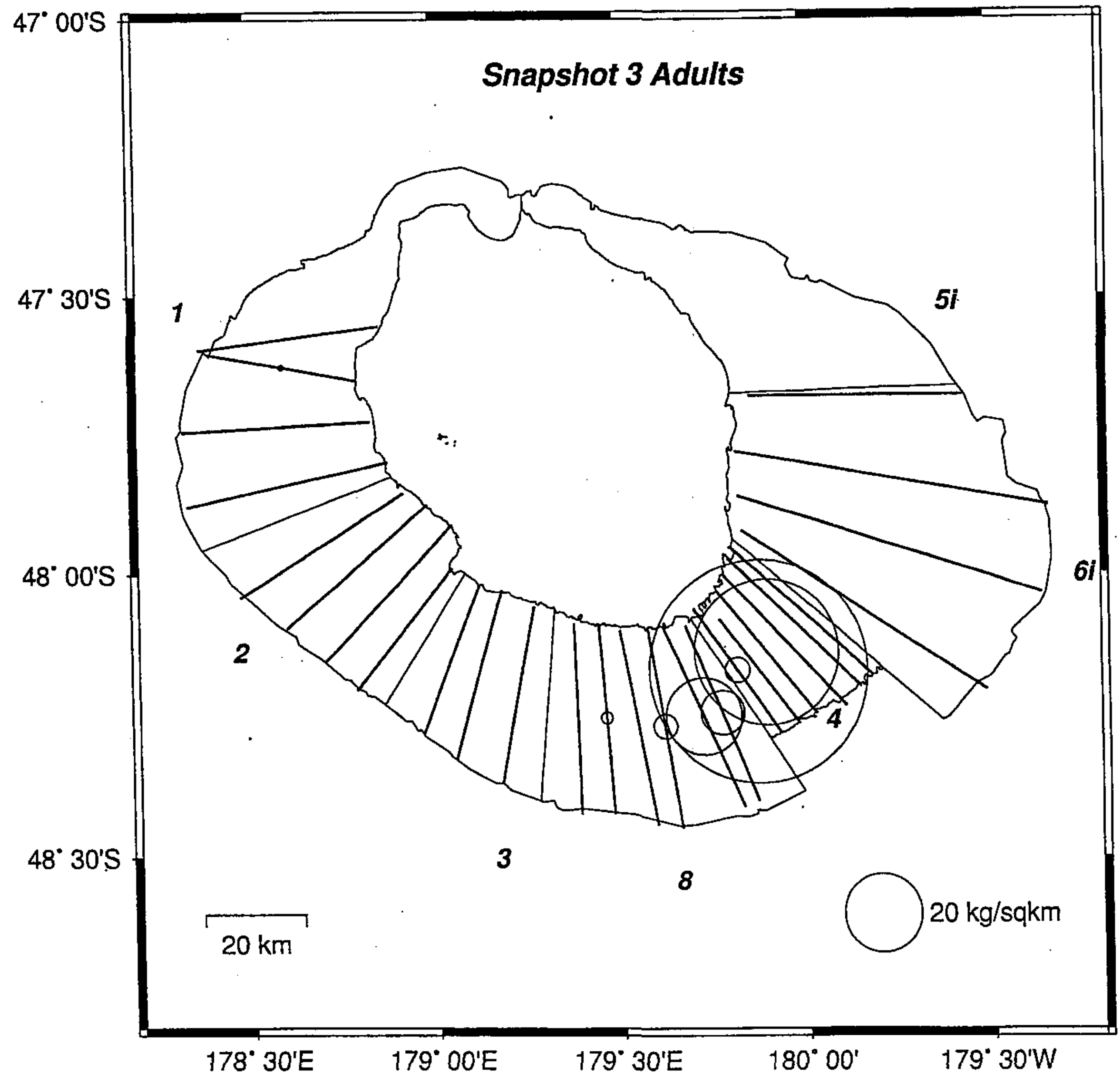

Figure 7: Density estimates of adult southern blue whiting (t. /sq km) by transect for snapshot 3.

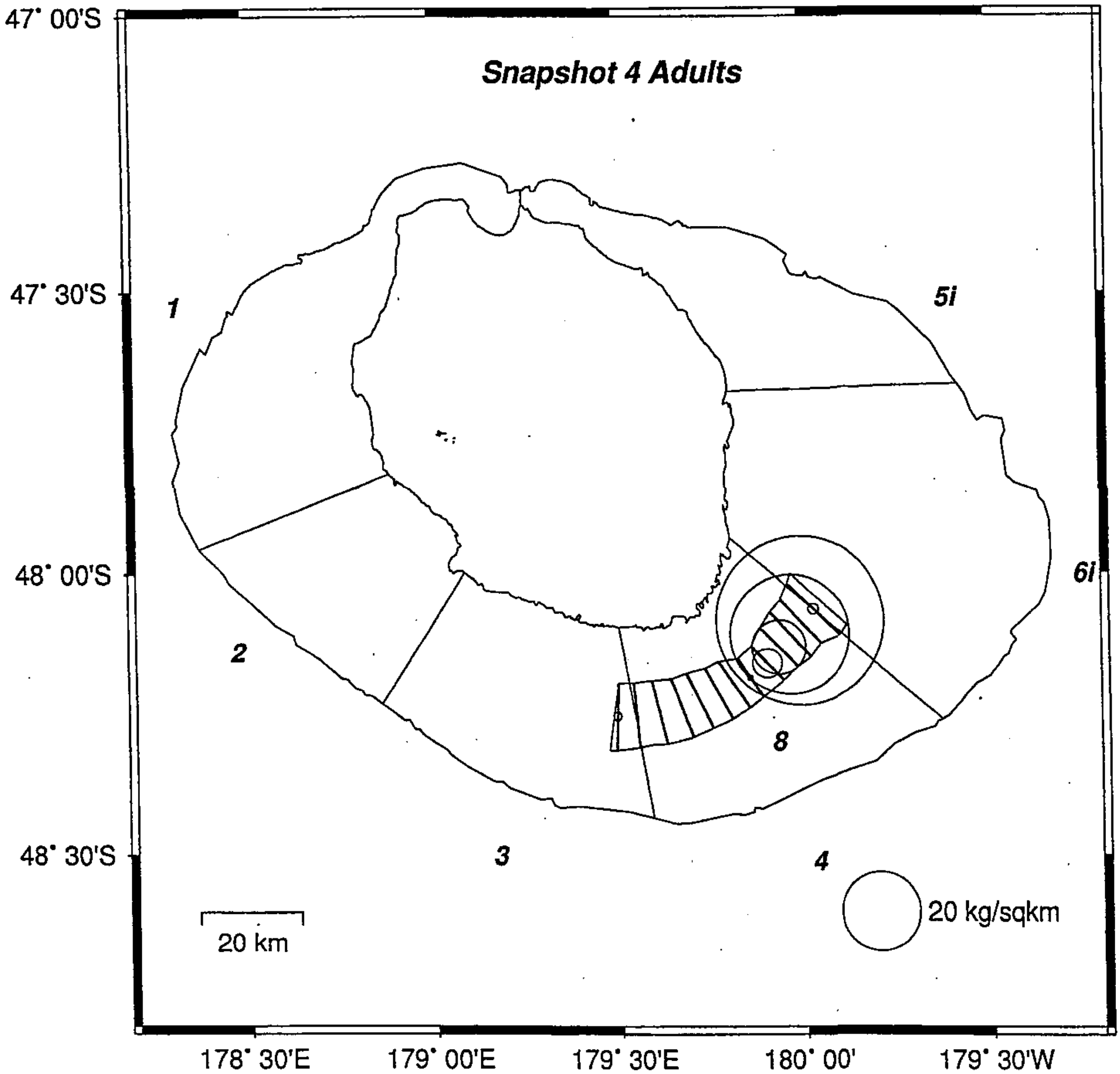

Figure 8: Density estimates of adult southern blue whiting (t. /sq km) by transect for snapshot 4.

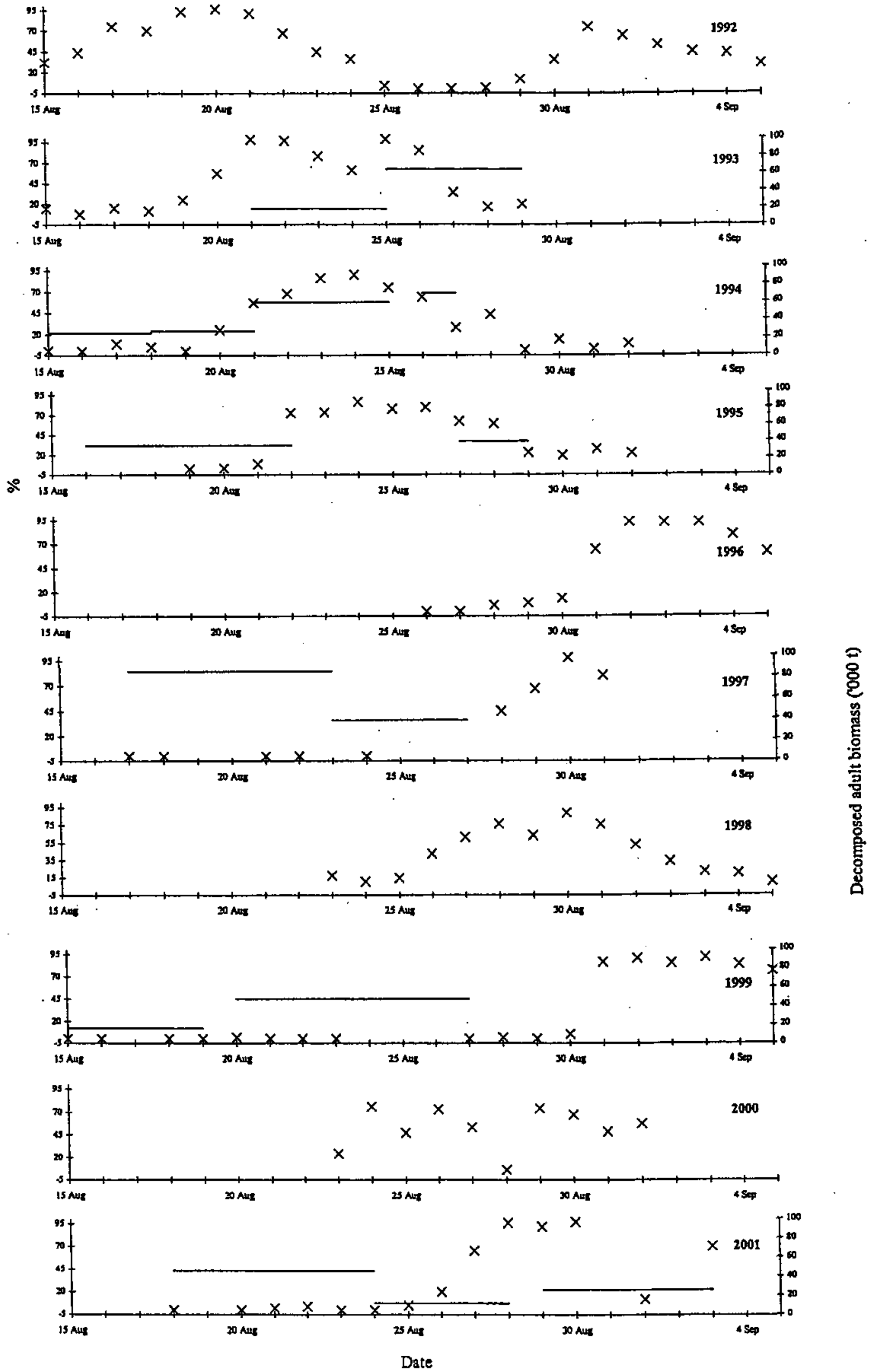

Figure 9: Timing of spawning in relation to the timing and biomass estimates of each of the acoustic snapshots. Percentage ripe and running ripe females (x) and decomposed age >=3+ biomass estimates (solid).