MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

ISSN 1175-1584

Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, August 1999

S. M. Hanchet
P. J. Grimes

New Zealand Fisheries Assessment Report 2000/30
September 2000

Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, August 1999

S. M. Hanchet[1]
P. J. Grimes[2]

[1]NIWA
PO Box 893
Nelson

[2]NIWA
PO Box 14 901
Wellington

New Zealand Fisheries Assessment Report 2000/30
September 2000

Published by Ministry of Fisheries
Wellington
2000

ISSN 1175-1584

Citation: Hanchet, S.M. & Grimes, P.J. 2000:
Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*)
from the Bounty Platform, August 1999.
New Zealand Fisheries Assessment Report 2000/30. 25 p.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

Hanchet, S.M. & Grimes, P.J. 2000: Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, August 1999.
***New Zealand Fisheries Assessment Report 2000/30.* 25 p.**

This paper summarises the results of the fifth acoustic survey of southern blue whiting (SBW) on the Bounty Platform. Two acoustic snapshots were completed on the Bounty Platform from 14 to 19 August and 20 to 28 August 1999.

A total of 18 research trawls was made by *Tangaroa* to determine species and size composition of the marks seen during the survey. Commercial trawl data were also used to help determine the main fishing locations and to assist in the identification of marks. Based on these data and previous experience, SBW marks were identified as adult (mainly mature fish which have recruited to the commercial fishery), immature (mainly 3 year old), or juvenile (1 and 2 year old) fish).

Two small areas of adult fish were located on the Bounty Platform during snapshot 1. The first was in the southwest of the survey area in depths of 400–530 m, and was being fished by commercial vessels. The second aggregation was found in the east of the survey area in 400–450 m depth. The estimate of adult biomass for snapshot 1 was 15 340 t (*c.v.* = 32%). In snapshot 2, a large aggregation of adult fish was found in the south of the survey area, in depths of 380–450 m. These marks were the densest seen during the survey. The estimate of adult biomass for snapshot 2 was 45 600 t (*c.v.* = 77%). Spawning was later than usual this year, starting on 1 September, 13 days after snapshot 1 and 4 days after snapshot 2 were completed. Despite being on the grounds from 14 August, commercial vessels failed to make significant catches until 27 August. The estimate from snapshot 1 was particularly low and it was concluded that the fish had not arrived on the grounds when this was completed. Therefore, the second snapshot is assumed to be the best estimate of biomass from this survey.

The biomass estimates of the three southern blue whiting categories were decomposed into numbers of 1, 2, 3, and over 4 year old fish, using the length frequency and age data from the commercial fishery and research trawls. The decomposed biomass estimate of adults (over 4 year old fish) was 42 722 t, which is lower than in 1997, but higher than in 1995, and is consistent with recent patterns of recruitment. The decomposed biomass estimates of 1 and 2 year old fish were 429 t and 745 t respectively, suggesting these are relatively weak year classes and will result in poor recruitment to the fishery over the next two years.

There is considerable uncertainty over the adult biomass estimate from the survey. This was partly due to the late arrival of fish on the grounds, which meant that only the second snapshot could be used for the biomass estimation. Bad weather and the consequent loss of survey time for three of the last five days of the survey also meant that we were unable to allocate more phase 2 stations into stratum 3 where most of the fish were found. It is recommended that future surveys need to start and end several days later, to take account of the apparent change in the spawning season on the Bounty Platform.

1. INTRODUCTION

The four known spawning grounds for southern blue whiting (SBW) are on the Bounty Platform, Pukaki Rise, Campbell Island Rise, and Auckland Islands Shelf. A programme to estimate SBW spawning stock biomass on the first three grounds using acoustic techniques began in 1993 (Hanchet *et al.* 1994). The three grounds were surveyed again in 1994 (Hanchet & Ingerson 1996), and the Auckland Islands Shelf ground was added in 1995 (Ingerson & Hanchet 1996). After the first three surveys it was decided to survey these areas biannually: the Bounty and Pukaki spawning grounds were surveyed in 1997 (Grimes & Hanchet 1999), and the Campbell grounds in 1998 (Hanchet *et al.* 2000a). This report summarises the results of the fifth survey of the Bounty grounds carried out in August 1999.

The current report stems from an objective carried out under contract to MFish: "To estimate pre-recruit and spawning biomass on Bounty Platform during 1999, using an acoustic survey, with a target coefficient of variation (c.v.) of the estimate of 30% (SBW9801)."

The main aim of the acoustic surveys has been to develop a time series of abundance indices of recruited fish (i.e., fish which have recruited into the commercial fishery) for modelling. Because the commercial fishery targets mainly the dense spawning aggregations, the recruited fish are mainly sexually mature. In addition to the spawning fish, pre-recruit fish (immature 1, 2, and 3 year olds) are also found in the survey area. Attempts to quantify pre-recruit biomass in previous surveys by separation into "immature" (mainly 2 year old fish) and "juvenile" (1 year old fish) categories was problematic due to the occurrence in some years of 1, 2, and 3 year old fish in mixed schools (Hanchet *et al.* 1994, Hanchet & Ingerson 1996). This resulted in a further objective to decompose the biomass estimates from these categories into numbers at age (NIWA unpublished results).

As in previous years, SBW acoustic marks in the current survey were therefore initially classified into adult (recruited fish), immature (mainly 3 year olds), and juvenile (1 and 2 year olds). These were then decomposed into numbers at age with a plus group at age 4 using the proportions at age caught in research/commercial trawls.

2. SURVEY DESIGN

2.1 Survey area and transect allocation

2.1.1 Main survey

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

The stratification and allocation used in previous surveys of the Bounty Platform were also reviewed by Dunn & Hanchet (1998) who examined the spatial distribution of SBW from historical catch effort data and from previous acoustic surveys. Based on this information, stratum boundaries were changed slightly to better reflect the usual fishing grounds. Stratification for the 1999 survey was the same as in 1997 (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, with a higher allocation in strata 2 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. Reasonable marks were seen in stratum 4 in snapshot 1 and so a further six transects were allocated there for phase 2.

The design for snapshot 2 was changed slightly, based on the results of snapshot 1. The boundary between stratum 1 and 2 was moved slightly north to encompass marks seen during snapshot 1 and more phase 1 transects were allocated to stratum 4 where marks were seen during the first snapshot. In snapshot 2, marks were seen in stratum 3 and a further six "phase 2" transects were planned there for phase 2. However, due to bad weather only three of these transects could be completed and stratum 5 was dropped.

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.* 2000b). Surveying of 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.* 2000b). 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 in strata 1 to 5 were run from 200 m to 550 m. The phase 2 transects in stratum 4 were run from 300 m to 500 m, and the transects in stratum 6i were run from 250 m to 550 m. In snapshot 2 all transects were run from 250 m to 550 m.

The random parallel transect design of Jolly & Hampton (1990) was used 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 lengthwise axis of stratum, and n is number of transects.

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

2.1.2 Day time transects

To help corroborate marks seen during the night with marks trawled on during the day, several transects were surveyed both during the day and at night.

2.1.3 Acoustic equipment and calibration

Two digital towbodies were used for the routine acoustic transect and target strength work (Appendix 1). Towbody 2 was used for most of the survey until it malfunctioned on 24 August and it was replaced for the rest of the survey by towbody 1. Four terminations were carried out during the survey due to damage to the towbody cable. A vessel speed of about 9 knots was maintained for most transects, although at times this was reduced due to bad weather. For most transects we deployed about 600–700 m of cable and this resulted in a towbody depth of about 80 m when at full speed, and a maximum depth of 150 m at the slowest speed.

The acoustic systems were calibrated with the standard procedure (MacLennan & Simmonds 1992) using a 38.1 mm ± 2.5 µm diameter tungsten carbide sphere with a nominal target strength of –42.4 dB. The towed systems were calibrated before (June 1999) and after (September 1999) the voyage in the deep tank at the NIWA Greta Point laboratories and yielded results that were consistent with previous calibrations.

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 previous experience gained from earlier acoustic surveys.

2.2.1 *Tangaroa* trawls

Eighteen trawl stations were carried out (Figure 1, Table 2). Most trawls were made during daylight hours using the fine meshed orange roughy wing bottom trawl with a 40 mm liner. Trawl 9 was made using the Ymuiden midwater trawl at night. Both nets were fitted with a window of finer mesh which burst when a catch greater than about 2 t was made. Although trawling during the day 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. All the main marks and most minor marks were successfully identified. The length frequency distributions (Figure 2) suggest SBW formed three distinct types of schools comprising different age classes:

(i) Juveniles – mainly 1 and 2 year old fish, 15–30 cm long (tows 15 and 16).
(ii) Immatures – mainly 3 year old fish, 25–35 cm long (tows 8 and 9).
(iii) Adults – mainly adult fish, 30–55 cm long (tows 1, 2, 5, 7, 10, 13, 18).

Reasonably dense marks were seen through much of the survey area in depths of 400–530 m. Trawling showed that these marks were mainly adult fish. The adult schools comprised mainly 5 and 7 year old fish with modes at 35 and 40 cm for males and modes at 37 cm and 42 cm for females respectively (Figure 2). A series of less dense marks in 300–370 m depth were seen in strata 1 to 4. On the basis of trawls 8 and 9, these marks were classed as immature (3 year old) fish. Lighter marks in 400–500 m, usually in midwater and with more vertical extent, were also seen in most strata. On the basis of trawls 15 and 16, these marks were classed as juvenile (1 and 2 year old) fish. Tow 4 caught both juveniles and adults. However, close inspection of the echotrace of the trawl shot suggested the 1 and 2 year old fish were slightly off the bottom. During the night the juveniles appeared in a band between 80 and 150 m above the bottom, whereas the adults appeared to be in the bottom 50 m and kept some contact with the seabed.

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. Several unusual marks seen during the surveying could not be identified, and were classified in an "other" category.

2.2.2 Commercial trawls

A total of 245 commercial tows was carried out on the Bounty Platform in 1999, of which 73 were observed. During snapshot 1 three vessels made reasonable catches on the boundary of strata 1 and 2 taking 500 t from 10 trawls from 15 to 19 August (Figure 3). However, from 20 to 26 August vessels were unable to find reasonable marks, and, despite considerable searching, catches were very poor, totalling only 30 t from 9 trawls. Catches improved markedly on 27 August, with 1300 t taken by five vessels. Catches remained high (1000 t day^{-1}) over the next week as vessels continued fishing in stratum 3 and moved north into strata 4 and 5. Spawning fish were found in strata 3 to 5, and spent fish mainly in strata 4 and 5.

2.3 Analysis of acoustic data

The average areal acoustic backscattering on each transect was calculated using standard echo integration of the marks identified from echograms (Burczynski 1979). 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 (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) (Figure 4). *In situ* target strength data collected during the 1998 SBW acoustic survey agree with the recent Northern Hemisphere relationship

(Macaulay 1999). However, *in situ* data from the 1994 survey agree with the old Northern Hemisphere relationship (McClatchie *et al.* 1998). The *in situ* data collected from both New Zealand surveys, and results of swimbladder modelling studies (McClatchie *et al.* 1998), suggest a steeper slope than the Northern Hemisphere studies (Figure 4). 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 in decibels and FL is fork length in centimetres (*see* Grimes & Hanchet 1999 for further details).

Adult SBW were assumed to have the length distribution caught by the commercial fishery (Hanchet 2000). The length frequency distributions for immature and juvenile fish were taken from the *Tangaroa* tows (*see* Figure 2). The mean SBW stratum density was multiplied by the area of the stratum to obtain biomass estimates for each stratum which were then summed over all strata to produce an estimate for the snapshot, from the formulae given in Cordue (1991). Biomass estimates were also decomposed into numbers at age, with a plus group at age 4 using the length frequency data together with the age-length key derived from the commercial and research tows on the Bounty Platform in 1999.

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

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

3. RESULTS

3.1 Acoustic biomass estimates

Two small areas of adult fish were located on the Bounty Platform during snapshot 1 (Figure 5). The first was in the southwest of the survey area in depths of 400–530 m, and was being fished by commercial vessels. The second aggregation was found in the east of the survey area in 400–450 m depth. Few adult SBW were seen in the rest of the survey area. The estimate of adult biomass for snapshot 1 was 14 600 t (*c.v.* = 32 %) (Table 3). In snapshot 2, a large aggregation of adult fish was found in the south of the survey area, in depths of 380–450 m. These marks were the densest seen during the survey, less dense marks were again present in strata 2 and 4. The estimate of adult biomass for snapshot 2 was 45 600 t (*c.v.* = 77%).

Immature (3 year old) fish were seen in strata 1 and 2 in snapshot 1 and in strata 1, 3, and 4 in snapshot 2 (Figure 6). Biomass estimates were similar between snapshots with 874 t (*c.v.* = 60%) in snapshot 1 and 1527 t (*c.v.* = 39%) in snapshot 2 (Table 3).

Juvenile (1 and 2 year old) fish were seen in all strata in snapshot 1, but only in strata 3 and 4 in snapshot 2 (Figure 7). Biomass estimates were very similar between snapshots with 1009 t (*c.v.* = 56%) in snapshot 1 and 1141 t (*c.v.* = 96%) in snapshot 2 (Table 3).

Biomass estimates of the "other" category were confined to stratum 4, and were 770 t and 293 t in snapshots 1 and 2 respectively.

Decomposed biomass estimates are summarised for each snapshot in Table 4. Strata 5, 5I, and 6I were only partly surveyed in snapshot 2, so values for these strata in snapshot 2 were assumed to be the same as for snapshot 1.

3.2. Gonad data

Observer data showed a rapid change from ripening to ripe to running ripe stages over the period 30 August to 1 September (Table 5). The percentage of running ripe fish remained high until 6 September, when observer coverage finished. There was a slight increase in spent fish towards the end of the spawning period. This suggests that the main spawning on the Bounty Platform was from 1 to 6 September. There was no evidence either from observer data or from samples taken on *Tangaroa* that any significant spawning took place before that date. Increasing numbers of ripe fish were seen on 31 August, but no spent and only a few immature/resting fish were present indicating that this was the first spawning.

There was no evidence of fish spawning and leaving the ground before or during the survey period. There was therefore no evidence of turnover from the gonad data.

4. DISCUSSION

4.1 Biomass estimation

There was a large difference in adult biomass estimates between the two snapshots. Only light adult marks were seen during snapshot 1 and the only dense adult mark was seen on 27 August, towards the end of snapshot 2. Commercial vessels, with experienced skippers and fishing masters, were present on the fishing grounds from 14 August to 6 September. Despite considerable searching, these vessels were unable to obtain good catches until 27 August. 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.

One possible reason for the poor early season catches is the timing of the spawning in 1999. The onset of spawning is variable on the Bounty Platform, ranging from mid to late August (Figure 8). However, in 1999 spawning was the latest on record, starting on 1 September. The commercial fleet aims to fish the different grounds during the spawning season to maximise their CPUE, and this is supported by the strong relationship between the peak in CPUE and the onset of spawning found by

Ingerson & Hanchet (1996). Although there may be a strong relationship between commercial CPUE and the onset of spawning, the relationship is less clear for the biomass estimates from separate snapshots of the acoustic surveys (Figure 8). Pre-spawning biomass estimates were lower than spawning estimates in 1994, but there was no difference between the two in 1995, whilst in 1997, when both snapshots surveyed pre-spawning aggregations, the first snapshot biomass estimate was higher than the second. Until the pre-spawning and spawning behaviour of SBW, and its variation between years, is understood, it is difficult to interpret the different acoustic survey snapshot estimates. It is possible that aggregations were missed by the acoustic survey and also by the commercial vessels during the first snapshot. However, given the experience of the skippers and the amount of searching carried out this seems unlikely. It is therefore concluded that the second snapshot is the best estimate of biomass from this survey.

The decomposed biomass estimate of adults (4 year old and over fish) from snapshot 2 was 42 722 t, which is lower than in 1997, but higher than in 1995 (Table 6). Because of the late spawning in 1999, there is also some concern that the estimate from snapshot 2 may be low. However, estimates of pre-recruits from the 1997 survey were low, and the age structure of the commercial catch in 1999 was dominated by the 1994 year class (NIWA, unpublished results), which had already recruited to the adult biomass by the time of the 1997 survey. The 1999 adult estimate is therefore consistent with the results of the (unpublished results) earlier surveys and recent patterns of recruitment.

There is considerable uncertainty over the adult biomass estimate from the survey. This was partly due to the late arrival of fish on the grounds, which meant that only the second snapshot could be used for the biomass estimation. Bad weather and the consequent loss of survey time for three of the last five days of the survey also meant that we were unable to allocate more phase 2 stations into stratum 3 where most of the fish were found. It is recommended that future surveys start and end several days later to take account of the apparent change in the spawning season on the Bounty Platform.

Estimates of 1 and 2 year old fish were similar between snapshots. There was no reason to suspect that one or other snapshots were more reliable so the two snapshots were averaged to obtain the best estimate of biomass. The decomposed biomass estimates of 1 and 2 year old fish were 429 and 745 t respectively, predicting poor recruitment to the fishery over the next two years.

No allowance has been made for the contribution of other species to the backscattering assigned to the SBW categories. In the dense adult SBW marks fished by the commercial fishery there is very little bycatch (Hanchet *et al.* 1994). In the *Tangaroa* trawls, which tended to be on more dispersed marks, the catch of other species was often equal to, or greater than, the catch of SBW (*see* Table 2). Of the main four species caught, pale ghost shark and white warehou do not have swimbladders and probably have a low target strength compared to SBW. Ling are generally present in low numbers and are typically hard down on the bottom, whilst banded rattail have a restricted depth distribution (most abundant in 300–400 m). It is likely therefore that the contribution of other species to the backscattering would have only a slight effect on the biomass estimates of the more dispersed schools of juvenile and immature fish, and have little effect on the estimates of adults.

4.2 Mark identification

With five surveys of the Bounty Platform now completed, there is a great deal of certainty to the positive identification of the very dense adult SBW marks that contain most of the SBW biomass. Good scientific observer coverage of the commercial fleet also helped to confirm the depths and areas of fish distribution. Trawling is likely to remain an important tool in the acoustic programme for the following reasons:

1. distinguishing less dense adults marks from pre-recruit marks in areas where they occur in similar depths;
2. identifying the size and age composition of SBW in the less dense pre-recruit marks including 1, 2, and immature 3 year old fish;
3. separating the small schooling midwater fish such as the common lanternfish (*Lampanyctodes hectoris*) and pearlside (*Maurolicus muelleri*) from the moderately dense schools of pre-recruit SBW when they are in the shallower part of their depth range and close to the bottom;
4. establishing species mix proportions away from the dominant heavy SBW marks.

5. ACKNOWLEDGMENTS

We are grateful to the scientific staff who assisted on the survey and also the officers and crew of *Tangaroa* for their helpful cooperation. We thank Gavin Macaulay and Mike Beardsell for comments on an earlier draft of the MS and members of the acoustic group for assistance with survey preparation, software and hardware development, data analysis, and calibration of the towbody. We also acknowledge the help of Neil Bagley with the trawl gear, and Brent Wood for estimating stratum areas for each of the grounds. This project was funded by the Ministry of Fisheries project number SBW9801.

6. REFERENCES

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

Cordue, P.L. 1991: Hoki acoustic biomass indices for the west coast South Island 1988, 1989, and 1990. N.Z. Fisheries Assessment Research Document 91/11. 31 p. (Unpublished report held in NIWA library, Wellington.)

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

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

Grimes, P.J. & Hanchet S.M. 1999: Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, and Pukaki, August-September 1997. N.Z. Fisheries Assessment Research Document 99/12. 28 p. (Unpublished report held in NIWA library, Wellington.)

Hanchet, S.M. 1991: Southern blue whiting fishery assessment for the 1991–92 fishing year. N.Z. Fisheries Assessment Research Document 91/7. 48 p. (Unpublished report held in NIWA Library, Wellington).

Hanchet, S.M. 1998: A review of southern blue whiting (*M.australis*) stock structure. N.Z. Fisheries Assessment Research Document 98/8. 28 p. (Unpublished report held in NIWA Library, Wellington).

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

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

Hanchet, S.M., Grimes, P.J., & Bull, B. 2000a: Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Campbell Island Rise, September 1998. *N.Z. Fisheries Assessment Report 2000/9.* 28 p.

Hanchet, S.M., Bull, B., & Bryan, C. 2000b: Diel variation in fish density estimates during acoustic surveys of southern blue whiting. *N.Z. Fisheries Assessment Report 2000/16.* 22 p.

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

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

MacLennan, D.N. & Simmonds, E.J. 1992: Fisheries acoustics. Chapman & Hall, London.

Macaulay, G. 1999: *In situ* target strength of southern blue whiting. Research Progress Report. Unpublished report for the Ministry of Fisheries project SBW9701. (Held by Ministry of Fisheries, Wellington.)

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

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

Rose, G.A. 1998: Review of southern blue whiting acoustic projects for the Ministry of Fisheries, Wellington, NZ. (Unpublished report held by Ministry of Fisheries, Wellington.)

Table 1: Stratum areas and numbers of transects per snapshot for each spawning ground. For stratum boundaries (*see* Figure 1)

Stratum	Stratum area (km^2)		Number of transects: Snapshot 1		Number of transects: Snapshot 2	
	Snapshot 1	Snapshot 2	Phase 1	Phase 2	Phase 1	Phase 2
			14–19 August		20–28 August	
1	1 319	926	3	–	3	–
2	1 308	1 342	7	–	9	–
3	1 857	1 431	3	–	3	3
4	2 643	2 178	4	6	7	–
5	2 191	–	2	–	–	–
6i	2 585	2 585	4		2	
Total			23	6	24	3

Table 2: Trawl station details for TAN9910. SBW catch weight (kg) and age: Ad = adult (> 30cm); 3 = mainly 3 year olds (25–35 cm), 1/2 = 1 and 2 year olds (18–30 cm). Catch weight (kg) of ling (LIN), banded rattail (CAS), pale ghost shark (GSP), and white warehou (WWA). *, burst window and catch estimated on deck. #, rip in lengthener. §, midwater trawl

Stn no.	Date	Latitude	Longitude	Stratum	Gear depth (m) Min	Gear depth (m) Max	SBW Catch	SBW Age	LIN	CAS	GSP	WWA
1	14-Aug-99	47 35.9	178 35.3	1	425	434	406	Ad	0	10	0	0
2	15-Aug-99	48 00.7	178 29.7	2	502	503	188	Ad	180	5	50	0
3#	15-Aug-99	47 40.8	178 33.5	1	336	395	0	–	6	135	45	6
4	16-Aug-99	48 02.3	178 38.2	2	444	447	257	Ad+1/2	200	3	90	0
5*	18-Aug-99	48 11.3	179 58.5	4	404	406	1698	Ad	35	6	105	0
6	18-Aug-99	48 13.9	179 54.2	4	448	456	0	–	30	4	180	0
7	21-Aug-99	47 50.6	178 27.7	1	420	430	29	Ad	70	20	70	2
8	21-Aug-99	47 42.3	178 32.3	1	340	365	129	3	0	125	25	145
9§	21-Aug-99	47 42.5	178 36.6	1	294	340	3	3	25	1	0	0
10	22-Aug-99	48 00.4	178 27.6	2	512	550	5	Ad	15	1	35	0
11	22-Aug-99	47 56.4	178 30.7	2	420	437	0	–	40	35	25	1
12	22-Aug-99	48 02.1	178 40.2	2	418	436	0	–	30	12	10	0
13*	23-Aug-99	48 14.5	179 4.54	3	409	420	2225	Ad	0	10	85	0
14	26-Aug-99	48 18.8	179 30.9	3	350	367	0	–	40	110	30	1
15	26-Aug-99	48 21.5	179 46.4	4	490	492	91	1/2	10	1	260	0
16	28-Aug-99	48 23.0	179 26.4	4	480	500	107	1/2	20	0	140	0
17	28-Aug-99	48 19.2	179 27.7	3	356	372	0	–	240	60	60	0
18*	28-Aug-99	48 19.2	179 29.1	3	375	395	2238	Ad	90	100	150	0

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

Stratum	Area (km²)	Adults Biomass (t)	Adults *c.v.* (%)	Immature Biomass (t)	Immature *c.v.* (%)	Juvenile Biomass (t)	Juvenile *c.v.* (%)	Other Biomass (t)	Other *c.v.* (%)
Snapshot 1									
1	1 319	3 544	76	850	62	76	106	0	0
2	1 308	1 885	53	9	0	174	38	0	0
3	1 857	0	0	0	0	131	98	0	0
4	2 643	8 530	42	0	0	81	66	770	79
5	4 776	1 380	146	–	–	–	–	0	0
5i	2 191	–	–	0	0	0	0	0	0
6i	2 585	–	–	15	99	547	98	0	0
Total		15 340	32	874	60	1 009	56	770	79
Snapshot 2									
1	926	375	95	616	100	0	0	0	0
2	1 342	543	56	0	0	0	0	0	0
3	1 431	43 651	80	827	39	899	120	0	0
4	2 178	1 017	66	84	55	242	64	293	99
6i	2 585	0	0	0	0	0	0	0	0
Total		45 587	77	1 527	39	1 141	96	293	99

Table 4: Decomposed biomass estimates for age 1, 2, 3, and ≥ 4 year old fish by stratum and snapshot for the Bounty Platform; for age 1 and 2 estimates stratum 5 was subdivided into 5i and 6i (see text for details). The italicised entries were obtained from the previous snapshot

Stratum	Area (km²)	Biomass (t) Age ≥ 4	Age 3	Age 2	Age 1
Snapshot 1					
1	1 319	3 336	971	139	20
2	1 308	1 729	184	64	46
3	1 857	27	8	41	34
4	2 643	7 674	757	65	22
5	4 776	1 236	121	–	–
5i	2 191	–	–	3	0
6i	2 585	–	–	158	134
Total		14 002	2 041	470	256
Snapshot 2					
1	926	366	157	21	0
2	1 342	487	48	2	0
3	1 431	39 670	4 475	750	403
4	2 178	963	168	89	64
5	*4 776*	*1 236*	*121*	–	–
5i	*2 191*	–	–	*3*	*0*
6i	*2 585*	–	–	*158*	*134*
Total		42 722	4 969	1 020	601
Best estimate		**42 722**	**4 969**	**745**	**429**

Table 5: Percentage of females at each gonad stage from observer data by 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
14-Aug-99	79	6	94	0	0	0
15-Aug-99	149	4	96	0	0	0
18-Aug-99	72	1	99	0	0	0
19-Aug-99	470	4	96	0	0	0
20-Aug-99	176	5	94	1	0	0
21-Aug-99	54	9	91	0	0	0
22-Aug-99	81	0	100	0	0	0
23-Aug-99	112	1	99	0	0	0
27-Aug-99	660	1	98	0	0	0
28-Aug-99	321	0	98	1	0	0
29-Aug-99	274	0	100	0	0	0
30-Aug-99	275	0	95	5	0	0
31-Aug-99	111	0	14	86	0	0
1-Sep-99	1 039	0	10	70	20	0
2-Sep-99	641	4	9	46	39	2
3-Sep-99	451	3	6	63	28	1
4-Sep-99	500	2	8	49	34	7
5-Sep-99	406	1	12	45	31	10
6-Sep-99	346	2	21	51	14	12

Table 6: Decomposed biomass estimates (t) by survey and age group for the Bounty Platform (NIWA unpublished results)

	1yo	2yo	3yo	4yo+
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

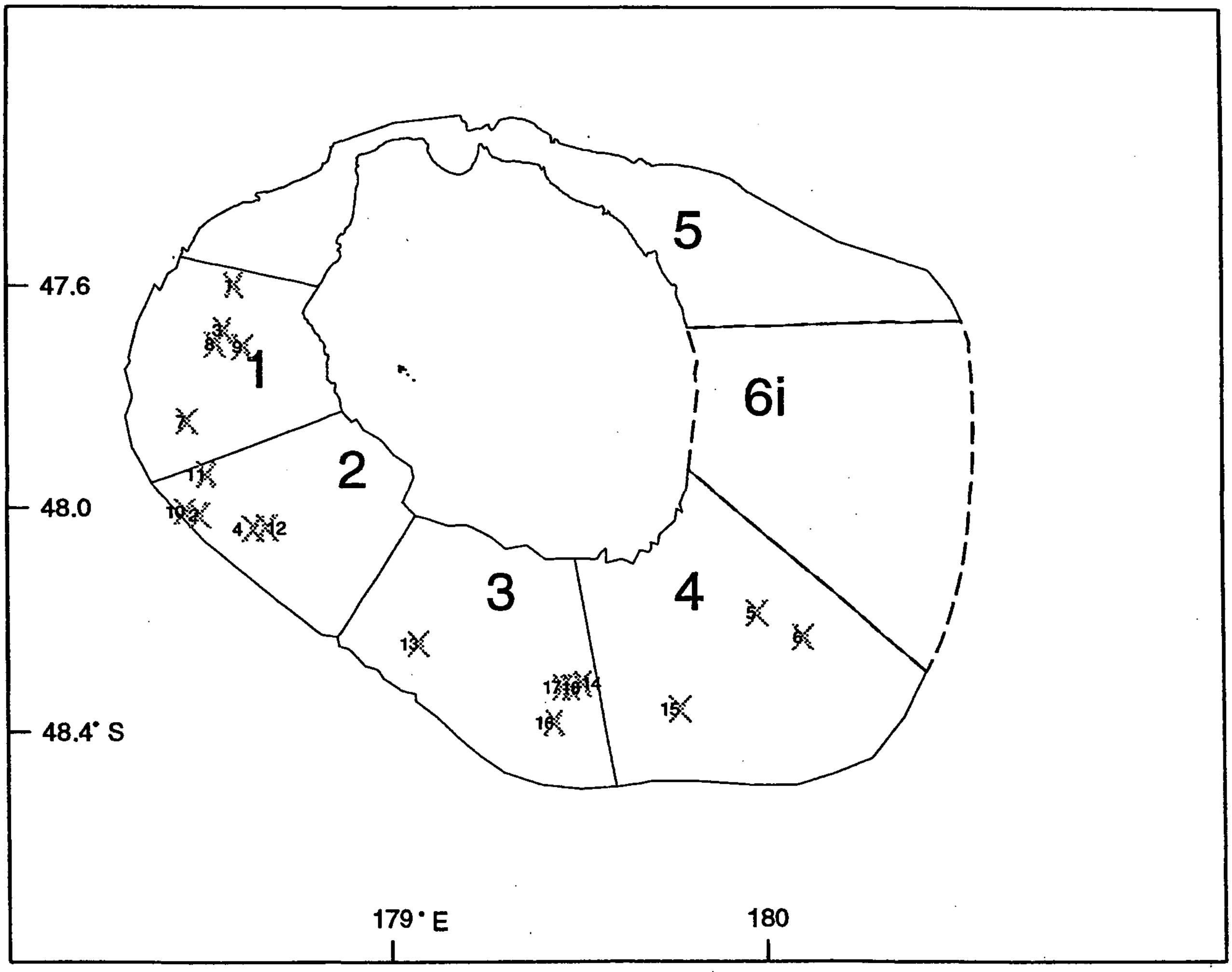


Figure 1: Survey area, stratum boundaries, and location of research trawls for TAN9910. Note stratum 6i is a subset of stratum 5. Depth contours at 200 m and 550 m.

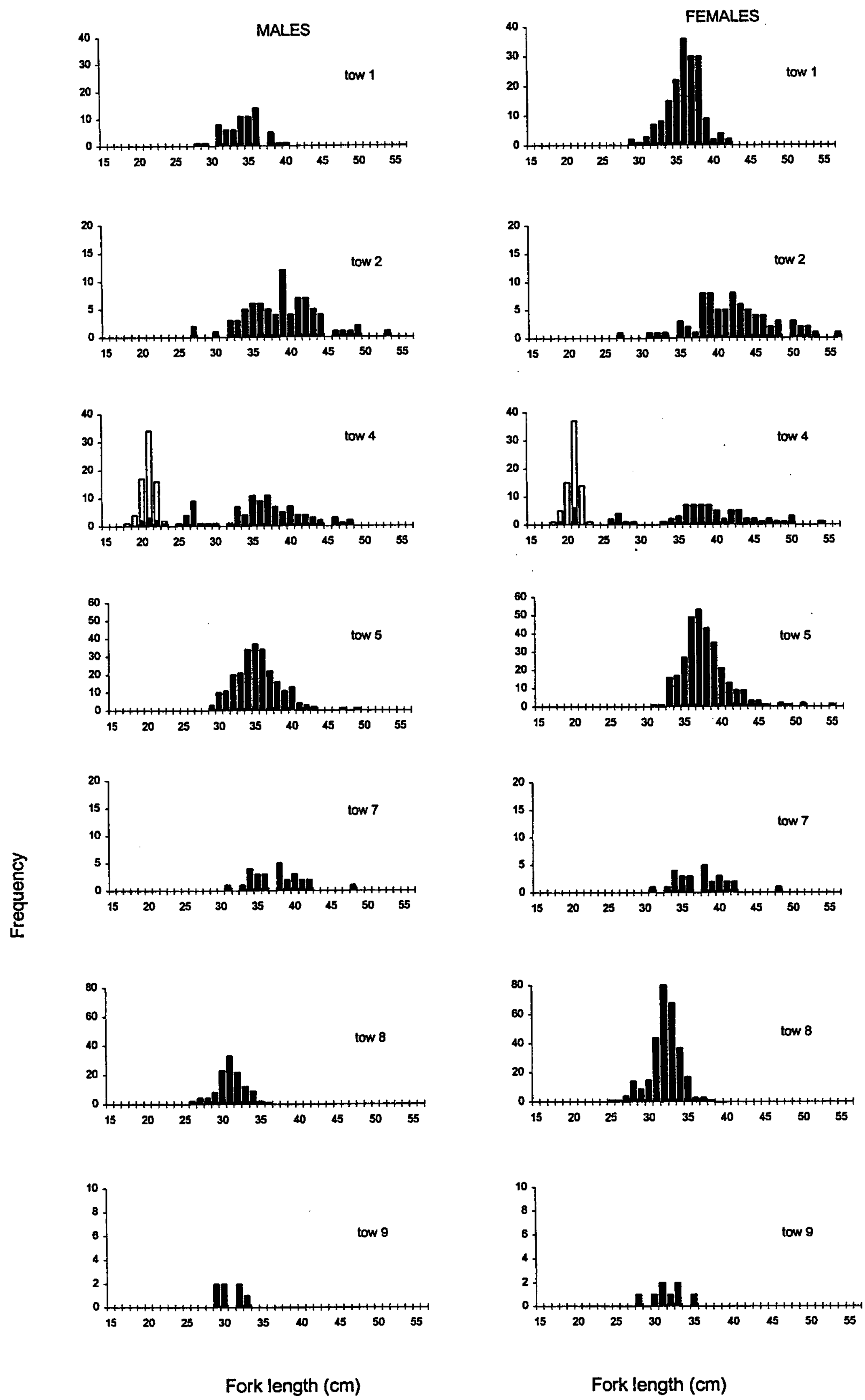


Figure 2: Unscaled length frequency distributions of male and female southern blue whiting for each trawl station. Unsexed fish (unfilled bars) assumed to be 50:50 sex ratio.

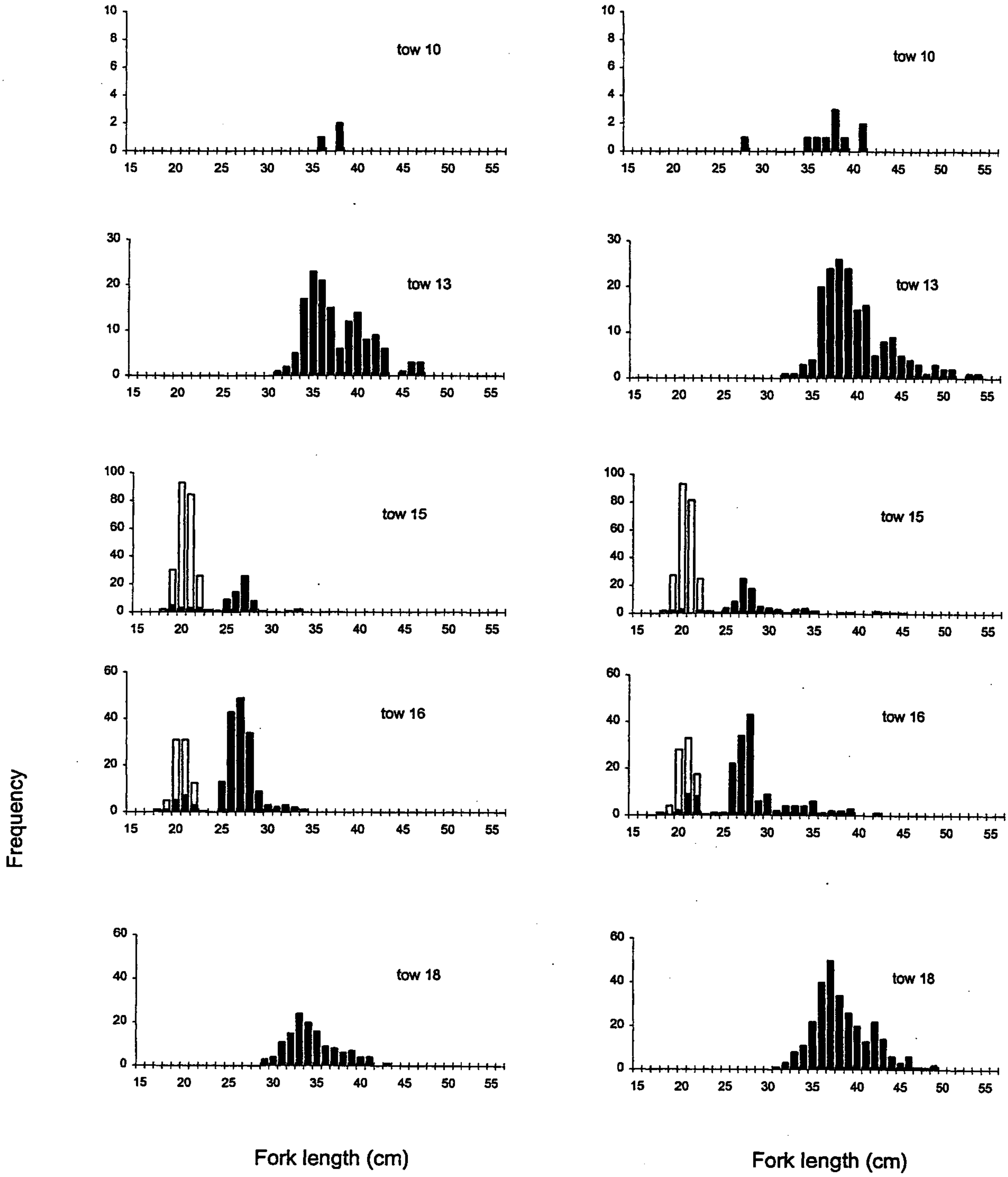


Figure 2: continued

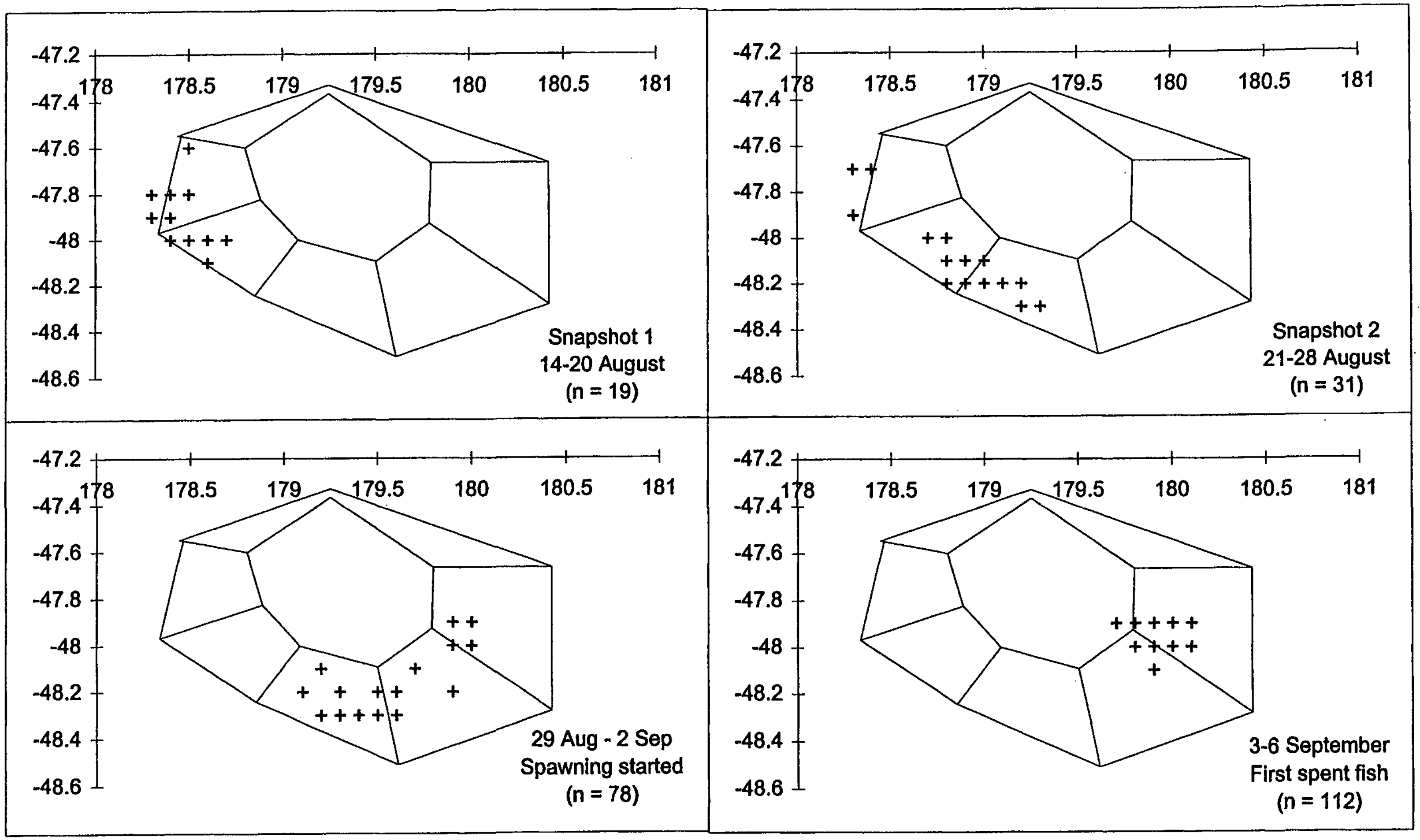


Figure 3: Location of commercial trawls on the Bounty Platform in 1999

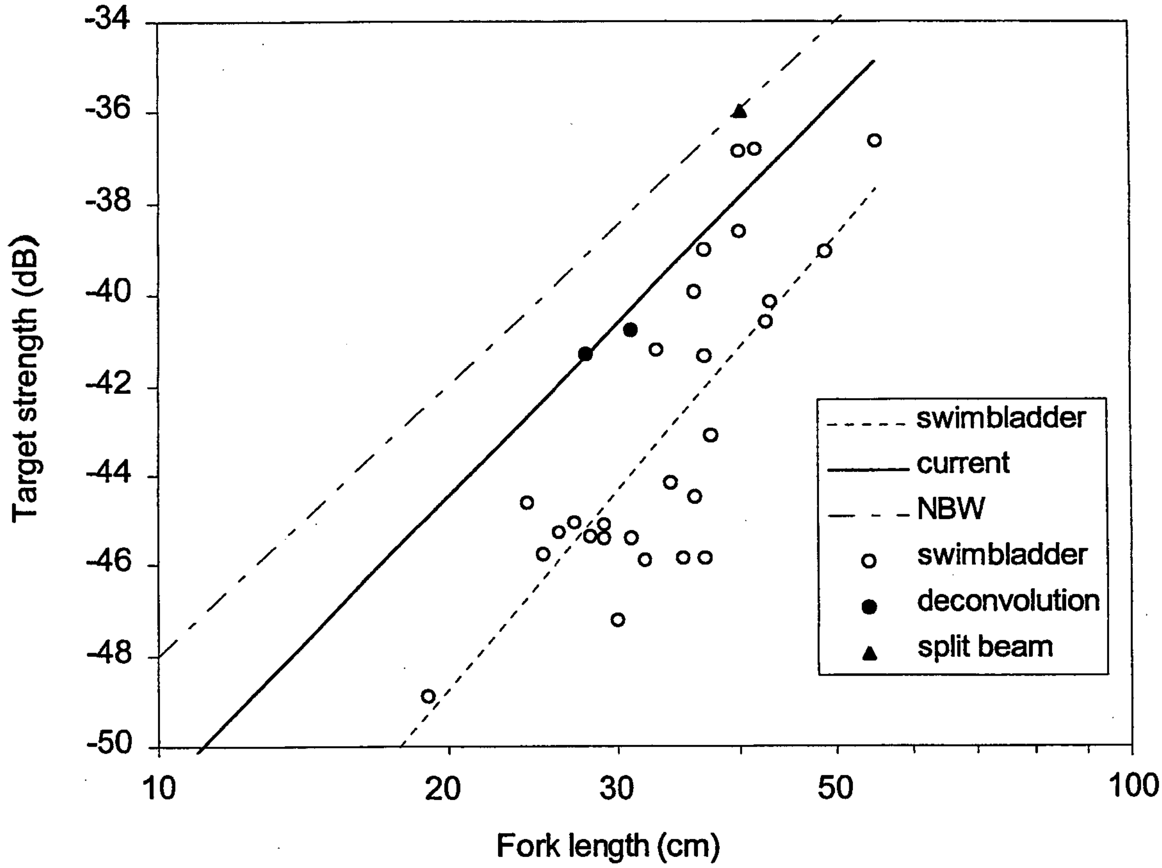
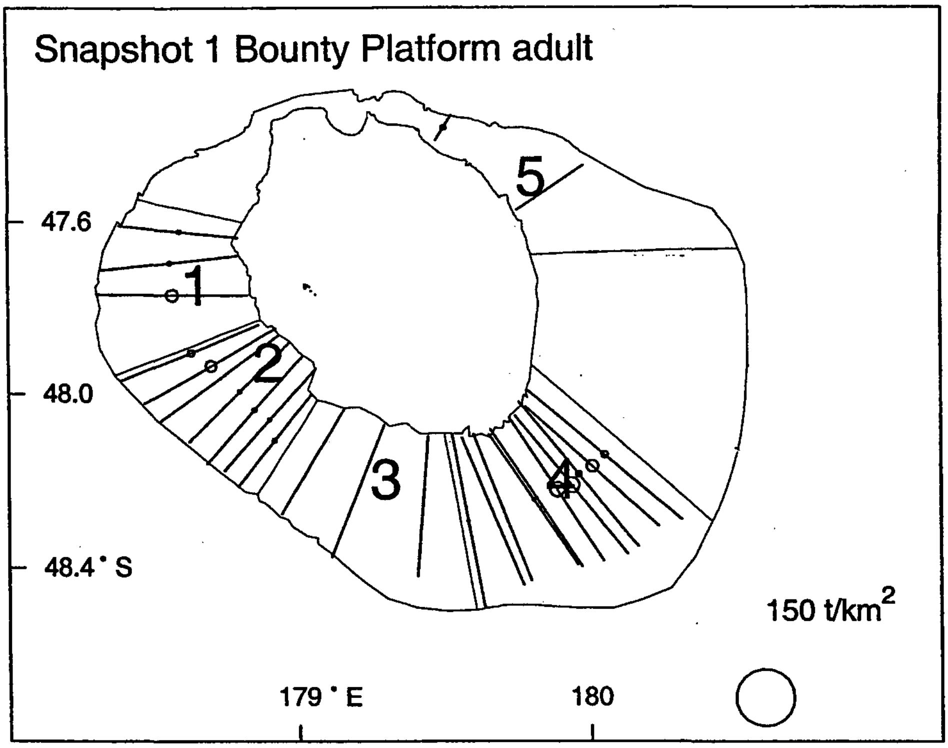


Figure 4: Target strength – fish length relationship for SBW. The solid line is the existing regression used for biomass estimation. The solid symbols are estimates of target strength from *in situ* studies. The open circles are estimates from swimbladder casts, and the dashed line labelled swimbladder is a regression fit to these points from McClatchie *et al.* (1998). The dashed line labelled NBW is the relationship currently assumed for Northern Hemisphere gadoids (Rose 1998).



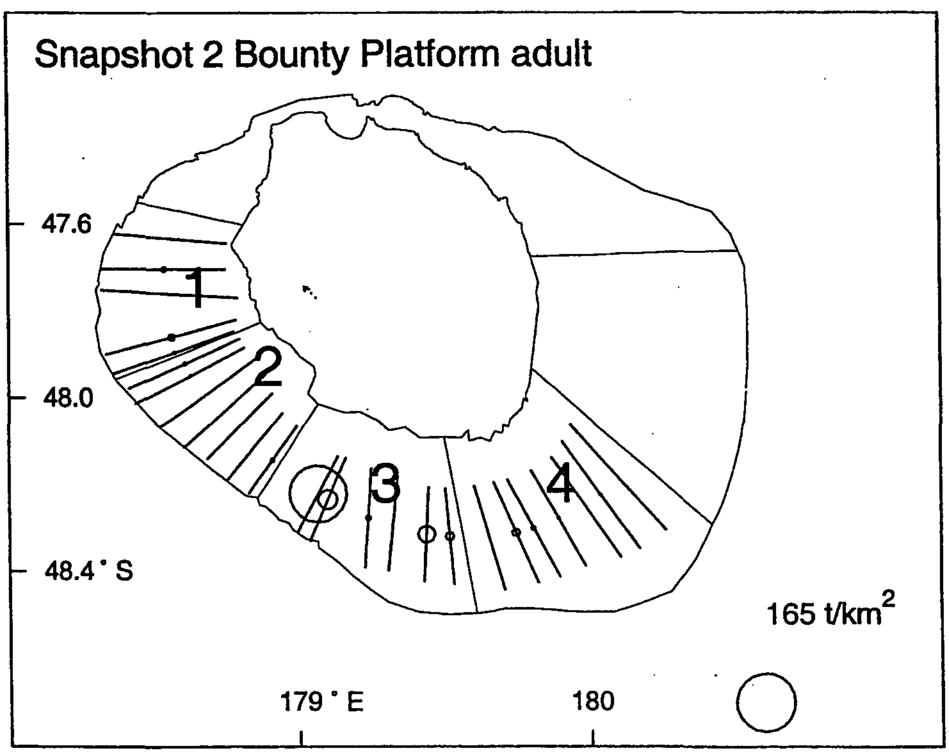
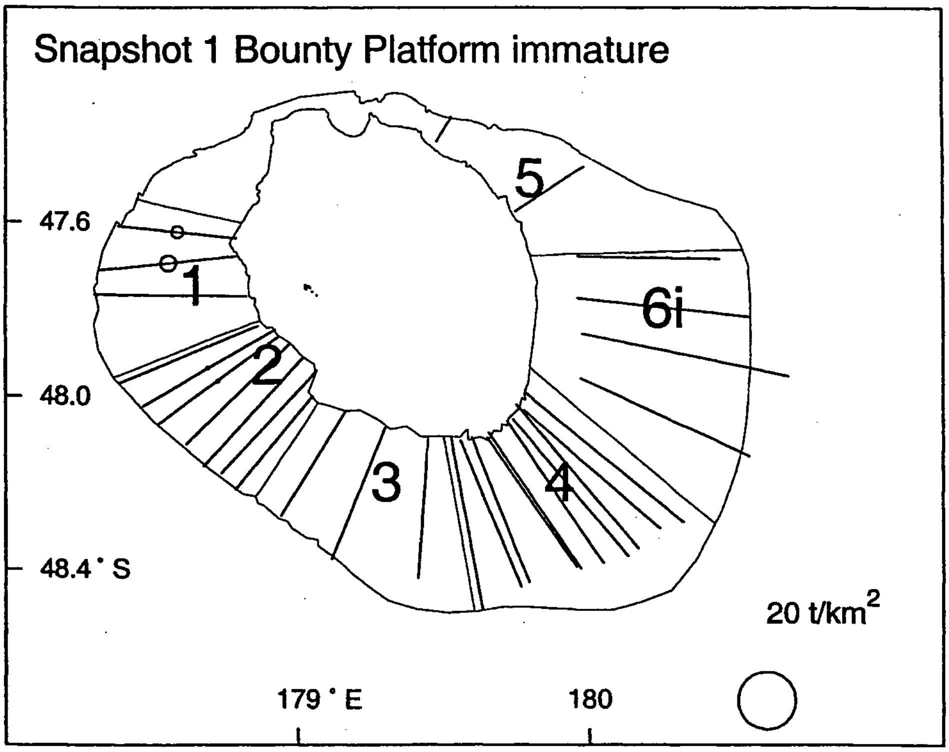


Figure 5: Density estimates of adult southern blue whiting (t. km^{-2}) by transect for snapshots 1 (top) and 2 (bottom) on the Bounty Platform.



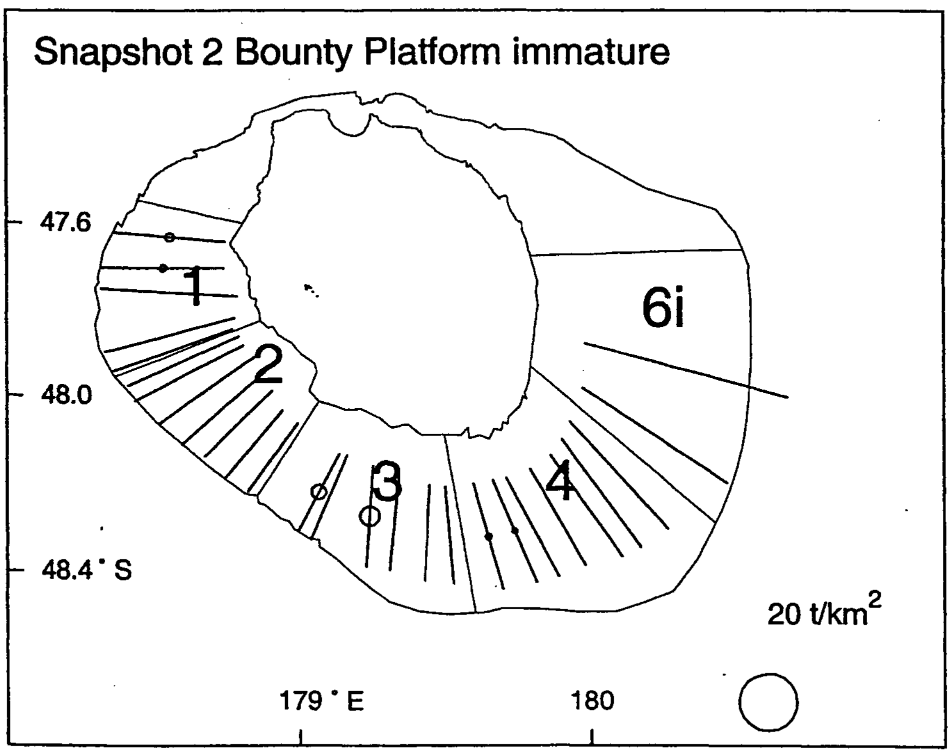
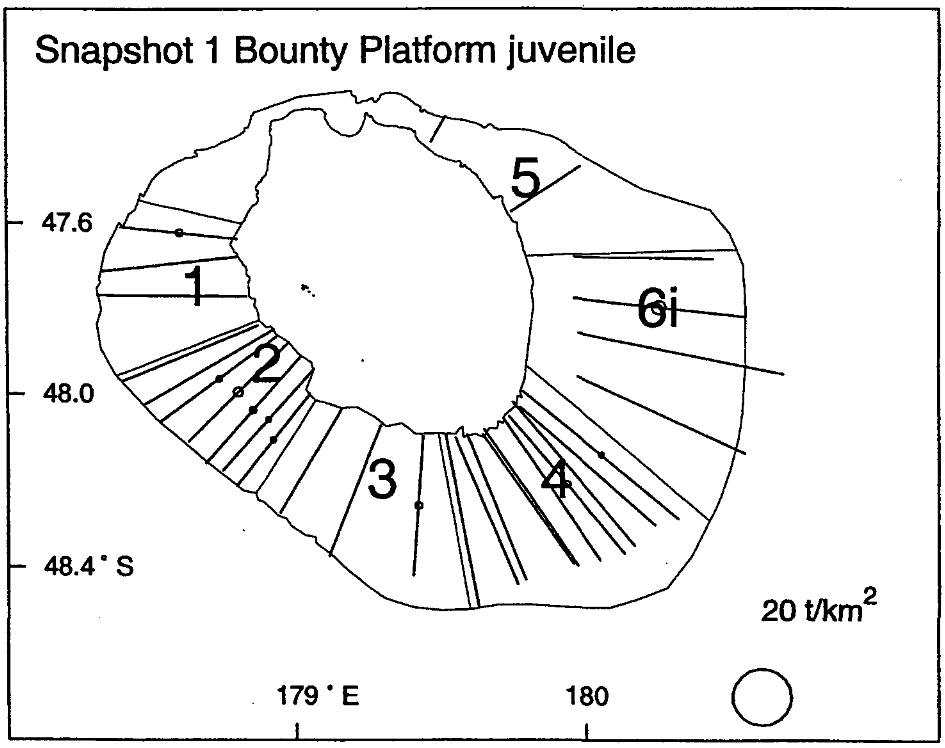


Figure 6: Density estimates of immature (mainly 3 year old) southern blue whiting (t. km^{-2}) by transect for snapshots 1 (top) and 2 (bottom) on the Bounty Platform.



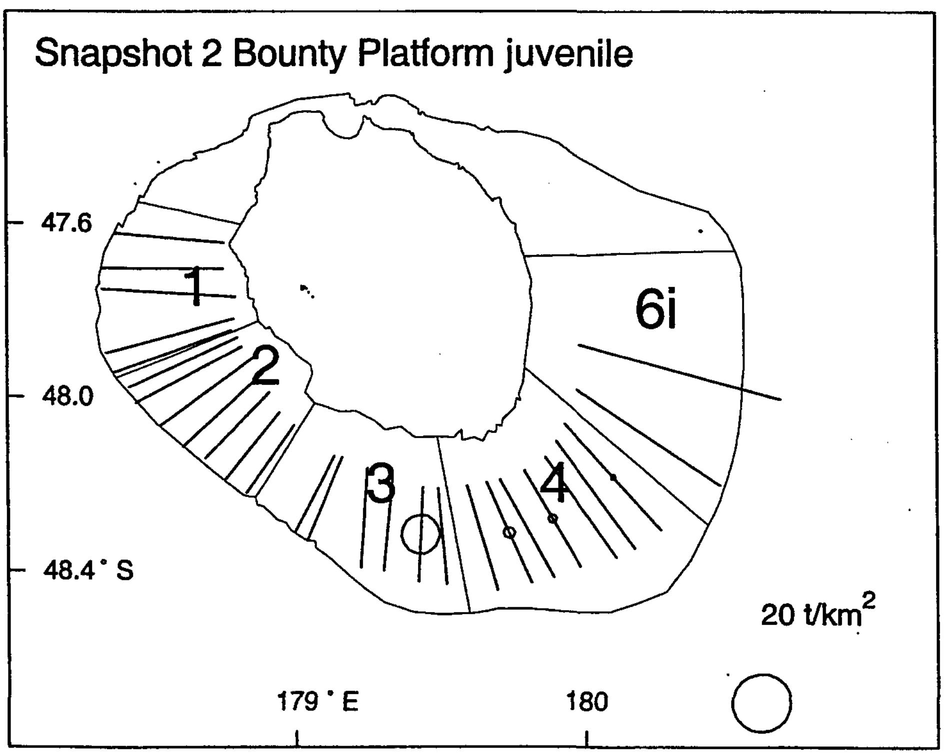


Figure 7: Density estimates of juvenile (mainly 1 and 2 year old) southern blue whiting (t. km^{-2}) by transect for snapshots 1 (top) and 2 (bottom) on the Bounty Platform.

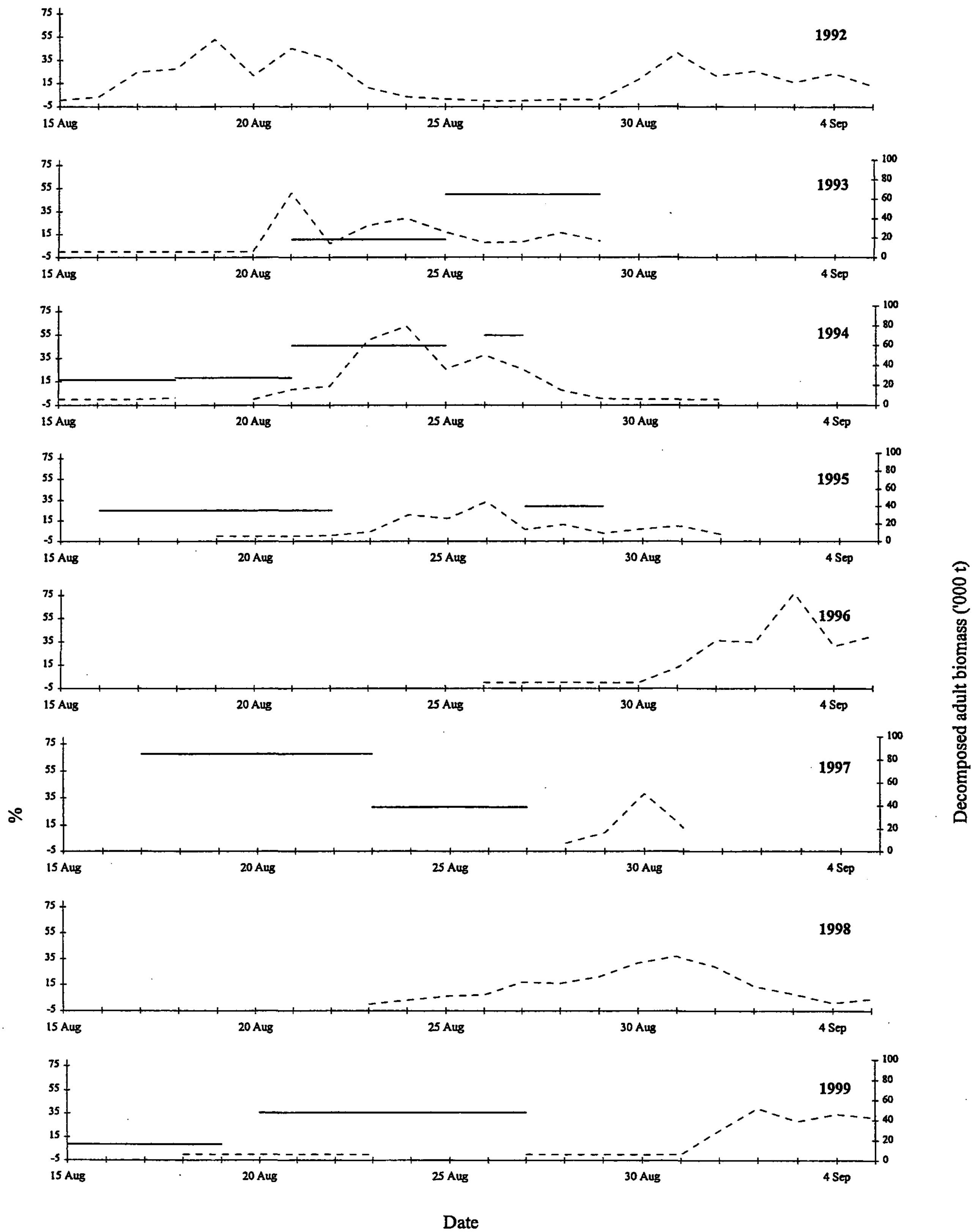


Figure 8: Timing of spawning in relation to the timing and biomass estimates of each of the acoustic snapshots. Percentage running ripe females (dashed) and decomposed adult (>=3+) biomass estimates (solid).

Appendix 1: Details of the two acoustic towbodies and settings used during the survey

System	#1	#2
Nominal frequency (kHz)	38	38
Transducer model	Simrad ES38DD	Simrad ES38DD
Transducer serial no.	28326	28327
Nominal 3dB beamwidth(°)	6.9	7.0
Effective beam angle (sr)	0.0079	0.0079
Operating frequency (kHz)	38.156	38.156
Transmit interval (s)	2.0	2.0
Nominal pulse length (ms)	1.0	1.0
Filter bandwidth (kHz)	1.5	1.5
Initial sample rate (kHz)	100.0	100.0
Decimated sample rate (kHz)	4.0	4.0
TVG	$20 \log R + 2\alpha R$	$20 \log R + 2\alpha R$
Nominal absorption (dB/km)	8.0	8.0
SL+SRT (dB re 1V at 1m)	61.1	61.1
Calibration valid at (m)	100	100
$20\log_{10}G$	60.7	61.3