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Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2011

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EXECUTIVE SUMMARY

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The FV *Tomi Maru 87* collected acoustic data along 69 transects in eight snapshots on the Bounty Platform between 13 and 25 August 2011. All snapshots surveyed the main southern blue whiting (SBW) aggregation south of the Bounty Islands, which moved to the east during the survey period. The surveyed areas in 2011 ranged from 51 to 134 km^2 in the eight snapshots, similar to the areas surveyed in 2010 and smaller than in some previous years when snapshot areas were 200–300 km^2. All of the snapshots appeared to adequately cover the main aggregation, although in most snapshots fish were detected at or near the ends of some transects. Highest densities of SBW were observed in snapshots 6 and 7 on 21 and 25 August respectively, which were within the peak spawning period. Densities on transects in these snapshots were comparable with those seen in previous surveys (including the high biomass years in 2007 and 2008), but the surveyed aggregations were much smaller. As in 2010, transects crossing the high density aggregation were less than 3 n. miles long, compared to 8 n. miles long in 2008. Acoustic biomass estimates for the eight snapshots in 2011 ranged between 10 017 t (c.v. 20%) for snapshot 8 and 48 048 t (c.v. 36%) for snapshot 7. The average estimate from all snapshots was 22 106 t (c.v. 24%). The range of the snapshot estimates in 2011 encompassed the best estimates from 2010 (27 782 t) and 2009 (28 242 t), but even the highest snapshot estimate was less than a third of the best estimates from 2007 (159 589 t) and 2008 (144 187 t). Data on the size distribution of the fish, collected by a Ministry of Fisheries observer, show that this fishery is still dominated by fish from the strong 2002 year-class (modal length 39 cm for males and 41 cm for females in 2011).

1. INTRODUCTION

Southern blue whiting (SBW) occur in Sub-Antarctic waters, with known spawning grounds on the Bounty Platform, Pukaki Rise, Auckland Islands Shelf, and Campbell Island Rise (Hanchet 1999). Fish from the four spawning grounds are treated as separate stocks for stock assessment. A total catch of 39 438 t was reported during the 2010 season, with 20 870 t taken from the Campbell Island Rise, 13 912 t from the Bounty Platform, and 4523 t from the Pukaki Rise (Ministry of Fisheries 2011). Spawning occurs on the Bounty Platform from mid August to early September and 3–4 weeks later in the other areas.

A programme to estimate SBW spawning stock biomass on each fishing ground using acoustic techniques from research vessels began in 1993. The Bounty Platform, Pukaki Rise, and Campbell Island Rise were each surveyed annually between 1993 and 1995. After the first three annual surveys it was decided to survey these areas less regularly. The Bounty Platform grounds were surveyed in 1997, 1999, and most recently in 2001. The Pukaki area was surveyed in 1997 and 2000. The only on-going series of research surveys is on the Campbell Island Rise grounds, which have been surveyed in 1998, 2000, 2002, 2004, 2006, 2009, and 2011. All these surveys were carried out from *R.V. Tangaroa* using towed transducers and have been wide-area surveys intended to survey spawning SBW and pre-recruits. The results of these research surveys of spawning and pre-recruit SBW are the main input into SBW stock assessments (e.g., Ministry of Fisheries 2011).

O'Driscoll & Hanchet (2004) carried out an acoustic survey of the Campbell Island grounds from *FV Aoraki* in 2003 and showed that industry vessels with hull-mounted acoustic systems could also be used to collect acoustic data on SBW in good weather (less than 25 knots of wind). They further demonstrated that snapshots of the main spawning aggregations could be carried out using the processing time between commercial trawls without seriously compromising fishing success. Using this approach, there have been six estimates of biomass of spawning SBW on the Bounty Platform in 2004, 2006, 2007, 2008, 2009, and 2010, and two estimates from the Pukaki Rise in 2009 and 2010, and an estimate from the Campbell Plateau in 2010. Surveys from 2004–09 were summarised by O'Driscoll (2011a), with results from surveys in 2010 presented by O'Driscoll (2011b, 2011c).

Very strong SBW marks were observed during the industry survey of the Bounty Platform in 2007 and 2008 (O'Driscoll 2011a). The 2007 survey results suggested that the spawning stock size at the Bounties had increased substantially since the 2005 assessment (Hanchet 2005), and, when taken in conjunction with data on the size and age distribution of the fish caught in the fishery, was indicative of very good recruitment from the 2002 year-class. As a result of this survey, the TACC for Bounty Platform SBW was increased to 10 000 t in 2008. The 2008 acoustic survey confirmed the large increase in SBW spawning stock size and the TACC was further increased to 15 000 t from 1 April 2009. However, estimated acoustic biomass on the Bounty Platform declined by a factor of four in 2009 (O'Driscoll 2011a), and this decline was supported by results from the 2010 survey (O'Driscoll 2011b). O'Driscoll (2011a, 2011b) explored various reasons for the much lower observed biomass estimates from the surveys in 2009 and 2010 compared with 2007 and 2008, including changes in survey methodology, equipment (including calibration), and changes in timing and extent of survey coverage, but could find no reason for these low estimates. They re-iterated the need to adequately survey the entire aggregation, and ensure that some snapshots were carried out whilst fish were actively spawning, and recommended that wide-area surveys encompassing the likely adult distribution on the spawning grounds be considered. Due to the low biomass estimates in 2009 and 2010 and the uncertainty in how to interpret the recent changes in acoustic indices, the TACC for SBW6B was decreased to 6860 t from 1 April 2011 (Ministry of Fisheries 2011).

Given the recent changes in TACC and ongoing uncertainty about the status of the Bounty Platform stock, it is very important to continue to monitor acoustic estimates of spawning SBW in the Bounties area. A further aggregation-based survey was therefore carried out from *FV Tomi Maru 87* in August 2011 following the same protocols as in 2004–10 (O'Driscoll 2011a).

This report is the final reporting requirement for Ministry of Fisheries Research Project SBW2010/02A. The objective of this project is to continue the time-series of acoustic estimates of abundance of spawning SBW on the Bounty Platform using aggregation-based acoustic estimates from industry vessels.

2. METHODS

2.1 Vessel and equipment

FV *Tomi Maru 87* is a 68 m Japanese surimi trawler chartered by Aurora Fisheries Ltd. The vessel is fitted with Simrad ES60 and ES70 echosounders. The Simrad ES70 is an updated version of the ES60 echosounder, which is widely used for commercial fishing and scientific data collection worldwide. The ES70 was released by Simrad in October 2009. Most of the developments to the echosounder are software-based, and the unit uses the same general purpose transceiver (GPT) and hull-mounted 38 kHz split-beam transducer as the ES60. A new ES70 computer and software were installed on *Tomi Maru 87* in April 2010.

Calibration of the Simrad ES60 echosounder on *Tomi Maru* took place in the Hauraki Gulf on 9 June 2011 (Appendix 1). Our intention was to calibrate the ES70 in 2011, but due to a computer failure on the ES70 PC on 8 June 2011, the ES70 was not available and the calibration was carried out on the ES60. Because the ES60 and ES70 use the same hardware, the calibrations with the two software systems are identical within the measurement uncertainty (O'Driscoll & Nelson 2010). Diagnostics indicated a calibration of excellent quality in 2011 (Appendix 1). The peak transducer gain (G_0) in 2011 was 0.23–0.26 lower than that estimated from the two calibrations (ES60 and ES70) in 2010. This difference was greater than expected, although it continues the trend of declining G_0 that we have observed for this transducer and GPT since 2005 (Appendix 1). Other long-term time series of echosounder calibrations have also observed gradual declines in peak gain, possibly as a function of transducer ageing (Knudsen 2009).The change in calibration coefficients since 2010 is equivalent to a 14% increase in biomass (i.e., the same data would give a 14% higher biomass estimate when analysed using 2011 calibration coefficients than when analysed with the 2010 calibration).

The 2011 calibration values from Table A3 in Appendix 1 were used in this analysis. ES70 transceiver settings and other relevant parameters during data collection are given in Table 1.

2.2 Survey design

The aim was to cover the main SBW aggregation(s) using an adaptive design. Detailed written instructions on survey design (described in O'Driscoll 2011a) were translated into Japanese and provided to vessel officers on FV *Tomi Maru 87*, and they were personally briefed by the author in Timaru on 28 July 2011.

Vessel officers were instructed to collect acoustic data continuously while trawling and searching to allow us to examine the spatial distribution of fish. However, estimating SBW abundance requires a number of straight, parallel lines (transects) across an aggregation. Each of these transects was to be run at a constant speed (usually 6–10 knots), with a separate, documented, acoustic file. Transect spacing and orientation was dependent on the size and shape of the aggregation and the prevailing weather conditions, but the aim was to obtain 5–10 transects at regular intervals (e.g., 1 n. mile) across each aggregation. The importance of ensuring that transects were long enough and numerous enough to fully encompass the main aggregation(s) was emphasised.

Clear instructions were also provided on protocols for acoustic data collection, including use of standard scientific settings on the echosounder, turning other acoustic equipment off to avoid interference, and collecting data in suitable weather conditions.

2.3 Acoustic data analysis

Acoustic data were provided to NIWA as raw ES60 files. Data from acoustic transects were extracted and analysed using NIWA's custom ESP2 software (McNeill 2001). Echograms were visually examined, and the bottom determined by a combination of an in-built bottom tracking algorithm and manual editing. Noise spikes and missing pings were manually defined as 'bad transmits' so these were not included in subsequent analysis. Regions corresponding to spawning SBW were then identified. Marks were classified subjectively based on their appearance on the echogram (shape, structure, depth, strength, etc.) after Hanchet et al. (2002b).

Backscatter from marks (regions) identified as SBW was then integrated to produce an estimate of acoustic density (m^{-2}). During integration acoustic backscatter was corrected for a systematic error in ES60 data (Ryan & Kloser 2004) and calculated sound absorption by seawater. The estimated sound absorption was 9.47 dB km^{-1} which was the same value used for previous Bounty surveys (O'Driscoll 2011a), and was based on data collected on the Campbell Island Rise in 2006 (O'Driscoll et al. 2007). No correction was applied for vessel motion. A Microstrain 3DM-GX1 gyro-enhanced orientation sensor was used to record vessel motion on FV *Tomi Maru 87* in 2006, but O'Driscoll et al. (2006) found that correcting for the effects of vessel motion (Dunford 2005) had very little effect (less than 1%) on biomass estimates in good weather and sea conditions because of the relatively shallow depth. Motion sensors were not fitted to FV *Tomi Maru 87* in 2011

Acoustic density was output in two ways. First, average acoustic density over each transect was calculated. These values were used in biomass estimation. Second, acoustic backscatter was integrated over 10-ping bins (vertical slices) to produce a series of acoustic densities for each transect (typically 20–100 values per transect). These data had a high spatial resolution, with each value (10 pings) corresponding to about 100 m along a transect, and were used to produce plots showing the spatial distribution of acoustic density.

2.4 Biomass estimation

Acoustic density estimates were converted to SBW biomass using a ratio, *r*, of mean weight to mean backscattering cross section (linear equivalent of target strength) for SBW. This ratio for the Bounty Platform was calculated from the scaled length frequency distribution of SBW caught by *FV Tomi Maru 87* in this area in 2011, estimated from scientific observer data (Figure 1).

Acoustic target strength was derived using the target-strength-to-fork-length (TS-FL) relationship for SBW estimated by Dunford & Macaulay (2006):

$$TS = 38 \log_{10} FL - 97 \tag{1}$$

where TS is in decibels and FL is in centimetres.

Mean SBW weight, w (in grams), was determined using the combined length-weight relationship for spawning SBW from Hanchet (1991):

$$w = 0.00439 * FL^{3.133} \tag{2}$$

The mean length of SBW caught at the Bounty Platform in 2011 by *FV Tomi Maru 87* was 39.8 cm. Mean weight and mean backscattering cross-sections were obtained by transforming the scaled length frequency distribution in Figure 1 by equations (1) and (2) and then calculating the means of the transformed distributions. Mean weight was 465 g. Mean backscattering cross-section was 0.000252 m^2 (equivalent to –36.0 dB), giving a ratio, r, of 1849 kg m^{-2}.

Biomass estimates and variances were obtained from transect density estimates using the formulae of Jolly & Hampton (1990). The surveyed areas (Table 2) were calculated from transect start and finish positions using the formula: $a = nLW$ where n is the number of transects, L is the mean length of transects, and W is the mean transect spacing. Biomass estimates and c.v.s were then estimated with and without removing "zero-transects" (i.e., the leading and trailing transects, which define the extent of the aggregation). Cordue (2008) suggested that inclusion of zero transects may overestimate c.v.s using the Jolly & Hampton (1990) methodology. Only whole transects with zero density were removed. No attempt was made to remove parts of transects with zero density, as most non-zero transects had SBW over most of their length.

3. RESULTS

3.1 Acoustic data collection

Although specifically requested in the written instructions, acoustic data were not recorded continuously from *FV Tomi Maru 87* while on the Bounties fishing grounds in 2011. As in some previous years (e.g., in 2007 and 2009), raw acoustic data were only recorded along transects. Although data collected while fishing and searching is badly affected by acoustic noise due to sonar and other instruments and is not suitable for quantitative analysis, these data do provide a useful record of vessel activities and the presence of fish outside surveyed areas (e.g., O'Driscoll 2011b).

Sixty nine acoustic transects were carried out in eight snapshots on the Bounty Platform between 13 and 25 August 2011 (Table 2). As requested all transects were carried out at night. Previous acoustic surveys of the Bounty Platform have shown that SBW are very hard to survey acoustically during the day (Hanchet et al. 2000). All snapshots surveyed the main SBW aggregation south of the Bounty Islands, which moved to the east and shallower during the survey period (Figure 2). These movement patterns are consistent with the migration pattern of spawning SBW on the Bounty Platform in previous years (e.g., Hanchet & Grimes 2000, Hanchet et al. 2002a, Figure 2). Transects in all eight snapshots were run from east to west (i.e., counter to the expected direction of fish movement) to reduce the risk of bias due to double counting.

Surveyed areas in 2011 ranged from 51 to 134 km^2 in the eight snapshots (Table 2), similar to the areas surveyed in 2010 (O'Driscoll 2011b) and smaller than those in some previous years when snapshot areas were 200–300 km^2 (O'Driscoll 2011a). The eight snapshots carried out in 2011 were more than carried out in any previous survey (six snapshots were carried out by three vessels in 2009). The survey duration covered by the eight snapshots (13 days) was also greater than in all previous surveys (Figure 3). Between 2004 and 2010 there was a trend in survey dates occurring earlier over the Bounty Platform time series (Figure 3). Timing of SBW spawning has also varied between years (Figure 3). The extended duration of the 2011 survey encompassed both pre-spawning and spawning aggregations. The scientific observer on *Tomi Maru 87* recorded fish actively spawning (defined as more than 10% running ripe females) between 20 and 26 August.

3.2 Acoustic data quality

The quality of the acoustic data from Bounty Platform in 2011 was poorer than in previous surveys with more ping drop-outs due to the vessel pitching in bad weather (e.g., Figure 4). However, in all cases noise could be identified and removed and should not introduce bias. ES70 transceiver settings and other relevant parameters during data collection (see Table 1) followed recommended protocols.

3.3 Acoustic mark types

Relatively dense adult SBW marks were observed in all snapshots. Marks were usually within 50–150 m of the bottom in 250–450 m water depth, but mark types were variable. In the first snapshot strong marks were observed well away from the bottom in relatively deep water (e.g., Figure 5), but the densest marks in later snapshots were closer to the bottom in shallow water (e.g., Figures 4 and 6). Mark identification of adult SBW is relatively certain at the Bounty Platform (Hanchet et al. 2002b).

3.4 Distribution of SBW backscatter

The spatial distribution of SBW along each transect in the eight snapshots is shown in Figure 7. As noted in Section 3.1, transects in all snapshots were carried out sequentially from east to west.

Most snapshots appeared to adequately cover the surveyed aggregation, although fish were detected at or near the ends of some transects, particularly in snapshots 1 and 7 (Figure 7). Low densities of SBW were also observed on one or both of the outer lines in five of the eight snapshots (snapshots 1, 2, 3, 5, and 8), suggesting that fish also occurred beyond the boundaries of the surveyed area.

Highest densities of SBW were observed in snapshots 6 and 7 on 21 and 25 August respectively (Figure 7), which were within the peak spawning period (see Figure 3). Peak transect densities were comparable with those seen in previous surveys (including the high biomass years in 2007 and 2008), but the surveyed aggregations were much smaller. As in 2010, transects crossing the aggregation were less than 3 n. miles long, compared to 8 n. miles long in 2008 (Figure 8).

3.5 Biomass estimates

Biomass estimates for all Bounty Platform snapshots in 2004–11 are given in Table 3. As expected, the variance was reduced by removing zero transects, but the differences were small, as there were relatively few zero transects. Note that the biomass sometimes changed with exclusion of zero transects as the transect spacing was not always uniform.

Acoustic biomass estimates for the eight snapshots in 2011, with zero transects removed, ranged between 10 017 t (c.v. 20%) for snapshot 8 and 48 048 t (c.v. 36%) for snapshot 7. The average estimate from all snapshots was 22 106 t. The sampling precision of the average estimate was calculated in two ways. The first method was to average the variances from each snapshot, which gave a c.v. of 13% This method potentially underestimates the sampling variance as it accounts only for the observation error in each snapshot. The imprecision introduced by the inherent variability of the abundance in the surveyed aggregation is ignored. The second method assumes the snapshot abundance estimates are independent and identically distributed random variables. The sample variance of the snapshot means divided by the number of snapshots is therefore an unbiased estimator of the variance of the mean of the snapshots. The c.v. estimated by this second method was 24%.

The range of the snapshot estimates in 2011 encompassed the best estimates from 2010 (27 782 t) and 2009 (28 242 t), but even the highest snapshot estimate was less than a third of the best estimates from 2007 (159 589 t) and 2008 (144 187 t) (Table 4).

At its meeting on 15 December 2011, the Middle Depth Fishery Assessment Working Group (MDFAWG) agreed that the “best” estimate of the SBW spawning aggregation in 2011 was from snapshots 6 and 7 which were both within the peak spawning period (see Figure 3) and appeared to cover the distribution of fish (see Figure 7). The average of these two snapshots was 35 597 t (c.v. 28%) (Table 4). However, there was considerable discussion about the lack of consistency with previous industry acoustic surveys, where there were fewer snapshots to choose from. The MDFAWG agreed that industry acoustic surveys (Table 4) do not provide a consistent time-series of SBW abundance.

4. DISCUSSION

Data on the size distribution of the fish (see Figure 1) show that the fishery in 2011 is still dominated by fish from the strong 2002 year-class (modal length 39 cm for males and 41 cm for females in 2011). However, the very large decrease observed in acoustic estimates of SBW at the Bounty Platform between 2008 and 2009 was too great to be explained by fishing and natural mortality on the 2002 year-class. O'Driscoll (2011a) considered three other potential explanations for the large apparent decline in biomass:

1. Changes in acoustic survey methodology and equipment.
2. Changes in timing and extent of survey coverage.
3. Movement of fish from the Bounty Platform to other areas.

Acoustic methodology, analysis, and equipment were consistent between years and based on comparisons of the length frequency distribution of the fish, there was no evidence of movement of fish from the Bounty Platform to other areas. Therefore O'Driscoll (2011a) concluded that the very large changes in estimated SBW abundance were probably related mainly to the timing and extent of survey coverage, and that the 2009 survey probably did not encompass the entire spawning aggregation. This conclusion was re-evaluated in light of the 2010 results, which supported the low biomass observed in 2009, with little evidence that the SBW aggregation extended beyond the surveyed area (O'Driscoll 2011b). The results of the 2011 survey, which had a large number of snapshots over a long survey period provide further evidence that there has been a substantial reduction in biomass since 2008.

The inconsistency in the ability of the aggregation type survey to reliably monitor the same proportion of the population each year has led to a non-robust stock assessment of the Bounty stock with high uncertainty (Dunn & Hanchet 2011). Without a wide-area survey periodically to provide a 'ground truthing' for such aggregation survey results, this will be an on-going problem. While the data collected from aggregation surveys are useful for determining if evidence exists for a change in status, they cannot be used to determine the extent of that change. Put simply, it is impossible to determine whether reductions in observed biomass are due to a poor survey or a real reduction in stock size.

Very recent work on the acoustic target strength (TS) of the closely related blue whiting (*Micromesistius poutassou*) raises a further concern that acoustic estimates based on the TS-length relationship of Dunford & Macaulay (2006) may overestimate SBW biomass. Pedersen et al. (2011) carried out *in situ* measurements and found that blue whiting TS was considerably higher than that observed and modelled for SBW. They provide a TS-to-total length (TL) relationship for blue whiting of:

$$TS = 20 \log_{10} TL - 65.2 \qquad (3)$$

If we apply this equation in place of Equation (1) in calculating the ratio of mean weight to mean backscattering cross section (after converting fork length to total length using the relationship $TL = 1.06\ FL - 0.28$), estimates of SBW biomass at the Bounty Platform in 2011 would be only about half (47%) of the estimates in Tables 3 and 4.

Because of the very different slopes of the alternative TS-length relationships in Equations (1) and (3), the effect on biomass is length-dependent, with a greater difference at smaller fish lengths (Figure 9). If the relationship proposed by Pedersen et al (2011) is correct, we may have overestimated SBW abundance at the Bounty Platform in 2007 when the 2002 year-class first dominated the fishery at mean length 35 cm by a factor of three. Target strength experiments on SBW carried out using the acoustic-optical system (AOS) on the Campbell Island Rise in September 2011 (Ministry of Fisheries Research Project SBW2010/04A) should help to reconcile the very large difference in TS estimates for SBW and the new estimates for blue whiting.

5. CONCLUSIONS

Acoustic data from the Bounty Platform in 2011 were collected with appropriate acoustic settings and were of sufficient quality to estimate biomass. The eight snapshots were all in the region to the south of the Bounty Islands where the largest aggregations was observed in 2007–10 (see Figure 2) and were in the vicinity of the main commercial fishing effort on the survey dates. Survey design protocols were followed, although there was evidence that low densities of SBW extended beyond the surveyed area in five of the eight snapshots.

Acoustic biomass estimates for the eight snapshots ranged between 10 017 t (c.v. 20%) and 48 048 t (c.v. 36%). The range of the snapshot estimates in 2011 encompassed the best estimates from 2010 (27 782 t) and 2009 (28 242 t), but even the highest snapshot estimate was less than a third of the best estimates from 2007 (159 589 t) and 2008 (144 187 t). The best estimate (from snapshots 6 and 7) in 2011 was 35 597 t (c.v. 28%).

The range of biomass estimates obtained from the 2011 survey has again raised questions about how to interpret results from aggregation-based acoustic surveys and incorporate these into assessment models (Dunn & Hanchet 2011).

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7. REFERENCES

Cordue, P.L. (2008). Review of estimates of Chatham Rise orange roughy biomass from plume surveys. Report for New Zealand Ministry of Fisheries, 30 August 2008. 39 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Doonan, I.; Coombs, R.; McClatchie, S. (2003). The absorption of sound in seawater in relation to estimation of deep-water fish biomass. *ICES Journal of Marine Science 60* (*5*): 1047–1055.

Dunford, A. (2005). Correcting echo integration data for transducer motion. *Journal of the Acoustical Society of America 118*: 2121–2123.

Dunford, A.J.; Macaulay, G.J. (2006). Progress in determining southern blue whiting (*Micromesistius australis*) target strength: results of swimbladder modelling. *ICES Journal of Marine Science 63*: 952–955.

Dunn, A.; Hanchet, S.M (2011). Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform for 2009–10. *New Zealand Fisheries Assessment Report 2011/26*. 30 p.

Fofonoff, P.; Millard, R. Jr (1983). Algorithms for computation of fundamental properties of seawater. *UNESCO Technical Papers in Marine Science 44*. 53 p.

Grimes, P.; Fu, D.; Hanchet, S. (2007). Estimates of biomass and c.v.s of decomposed age classes of southern blue whiting from previous acoustic surveys from 1993 to 2004 using a new target strength-fish length relationship. Final Research Report for Ministry of Fisheries Research Project SBW2005/01 Objective 3. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

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

Hanchet, S.M. (1999). Stock structure of southern blue whiting (*Micromesistius australis*) in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research 33*: 599–610.

Hanchet, S.M. (2005) Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform for 2004–05. *New Zealand Fisheries Assessment Report 2005/45*. 36 p.

Hanchet, S.M.; Bull, B.; Bryan, C. (2000). Diel variation in fish density estimates during acoustic surveys of southern blue whiting. *New Zealand Fisheries Assessment Report 2000/16*. 22 p.

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.

Hanchet, S.M.; Grimes, P.J.; Coombs, R.F. (2002a). Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, August–September 2001. *New Zealand Fisheries Assessment Report 2002/58*. 35 p.

Hanchet, S.M., Grimes, P.J.; Dunford, A.; Ricnik, A. (2002b). Classification of fish marks from southern blue whiting acoustic surveys. Final Research Report for Ministry of Fisheries Research Project SBW2000/02 Objective 2. 55 p. (Unpublished report held by the Ministry for Primary Industries, 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.

Knudsen , H.P. (2009). Long-term evaluation of scientific-echosounder performance. *ICES Journal of Marine Science 66*: 1335–1340.

MacLennan, D.N.; Simmonds, E.J. (1992). Fisheries Acoustics. Chapman & Hall, London. *Fish and Fisheries Series 5*. 325 p.

McNeill, E. (2001). ESP2 phase 4 user documentation. NIWA Internal Report 105. 31 p. (Unpublished report held by NIWA library, Wellington.)

Ministry of Fisheries (2011). Report from the Fisheries Assessment Plenary, May 2011: stock assessments and yield estimates. Ministry of Fisheries, Wellington, New Zealand.

O’Driscoll, R.L. (2011a). Industry acoustic surveys of spawning southern blue whiting on the Bounty Platform and Pukaki Rise 2004–09. *New Zealand Fisheries Assessment Report 2011/17*. 53 p.

O’Driscoll, R.L. (2011b). Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2010. NIWA Client Report WLG2011-01 for The Deepwater Group Ltd. 28 p.

O’Driscoll, R.L. (2011c). Acoustic biomass estimates of southern blue whiting on the Pukaki Rise and Campbell Island Rise in 2010. NIWA Client Report WLG2011-03 for The Deepwater Group Ltd. 37 p.

O’Driscoll, R.L.; Hanchet, S.M. (2004). Acoustic survey of spawning southern blue whiting on the Campbell Island Rise from FV *Aoraki* in September 2003. *New Zealand Fisheries Assessment Report 2004/27*. 31 p.

O’Driscoll, R.L.; Hanchet, S.M.; Gauthier, S.; Grimes, P.J. (2007). Acoustic estimates of southern blue whiting from the Campbell Island Rise, August–September 2006. *New Zealand Fisheries Assessment Report 2007/20*. 34 p.

O'Driscoll; R.L.; Macaulay, G.J.; Gauthier, S. (2006). Biomass estimation of spawning southern blue whiting from industry vessels in 2006. NIWA Client Report: WLG2006-89 for the Deepwater Stakeholders Group Ltd. 43 p.

O’Driscoll, R.L.; Nelson, R. (2010) *Tomi Maru 87* ES70 and ES60 calibrations, April 2010. NIWA Client Report WLG2010-24 for The Deepwater Group Ltd. 9 p.

Pedersen, G.; Godø, O.R.; Ona, E.; Macaulay, G.J. (2011). A revised target strength–length estimate for blue whiting (*Micromesistius poutassou*): implications for biomass estimates. *ICES Journal of Marine Science* doi:10.1093/icesjms/fsr142.

Ryan, T.E.; Kloser, R.J. (2004). Quantification and correction of a systematic error in Simrad ES60 echosounders. Technical note presented at the Working Group on Fisheries Acoustic Science and Technology (WGFAST), 20–23 April 2004, Gydnia, Poland. ICES CM 2004/B:06.

8. TABLES

Table 1: Echosounder settings and other relevant parameters during acoustic data collection in 2011.

Parameter	Value
Echosounder	ES70
GPT model/serial	GPT 38 kHz 009072056ad6 1 ES38B
GPT software version	Not recorded
Echosounder software version	ES70 1.0.1.0
Transducer model	ES38B
Transducer serial number	1599
Operating frequency (kHz)	38
Transducer draft setting (m)	0.0
Transmit power (W)	2000
Pulse length (ms)	1.024
Transducer peak gain (dB)	26.5
Sa correction (dB)	0.0
Bandwidth (Hz)	2425
Sample interval (s)	0.192
Two-way beam angle (dB)	–20.60
Absorption coefficient (dB/km)	9.75
Speed of sound (m/s)	1500.0
Angle sensitivity (dB) alongship/athwartship	21.90/21.90
3 dB beamwidth (°) alongship/athwartship	7.10/7.10
Angle offset (°) alongship/athwartship	0.00/0.00

Table 2: Summary of acoustic snapshots carried out at the Bounties in 2011 by *FV Tomi Maru 87*. Times are NZST.

Snapshot	Area (km^2)	Start time	End time	No. of transects
1	118.5	13 Aug 00:40	13 Aug 04:46	9
2	136.7	13 Aug 22:32	14 Aug 03:12	11
3	83.6	18 Aug 20:50	19 Aug 00:30	9
4	53.9	19 Aug 21:23	19 Aug 23:43	7
5	80.4	20 Aug 19:41	20 Aug 23:03	8
6	76.8	21 Aug 19:42	21 Aug 23:03	8
7	104.9	25 Aug 01:15	25 Aug 05:00	8
8	132.2	25 Aug 19:44	25 Aug 23:57	9

Table 3: Stratum areas, abundance estimates, and coefficients of variation (c.v.) for all snapshots of spawning SBW on the Bounty Platform carried out by industry vessels from 2004–11. All snapshots carried out by *Tomi Maru 87* except M1 and M2 by *Meridian* and AB1 and AB2 by *A. Buryachenko* in 2009. Snapshots in bold were averaged to produce the biomass estimates in Table 4. Estimates for 2004–10 are from O'Driscoll (2011b).

			Calculated areas			Zero transects removed			
Year	Snapshot	No. of transects	Area (km^2)	Biomass (t)	c.v. (%)	No. of zero transects	Area (km^2)	Biomass (t)	c.v. (%)
2004	1	5	69.7	13 473	69	0	69.7	**13 473**	**69**
2006	1	7	199.4	22 852	16	0	199.4	**22 852**	**16**
	2	5	286.2	20 677	19	0	286.2	**20 677**	**19**
	3	4	41.3	2 415	34	0	41.3	2 415	34
	4	4	57.9	8 207	45	0	57.9	8 207	45
2007	1	7	234.5	8 197	38	1	199.0	8 159	35
	2	5	122.6	5 937	35	0	122.6	5 937	35
	3	5	250.2	173 019	35	1	218.5	**180 950**	**29**
	4&5	10	435.0	136 596	21	1	417.1	**138 228**	**20**
2008	1	6	260.4	226 302	45	1	230.8	**223 751**	**43**
	2	5	229.5	64 624	22	0	229.5	**64 624**	**22**
2009	M1	11	335.7	11 293	16	0	335.7	11 293	16
	M2	8	125.6	36 783	29	1	107.4	**35 175**	**27**
	1	3	232.3	22 776	43	0	232.3	**22 776**	**43**
	2	5	276.2	25 315	45	1	249.9	**26 776**	**44**
	AB1	7	38.8	6 459	26	0	38.8	6 459	26
	AB2	5	25.1	6 060	30	1	21.9	6 060	24
2010	1	6	52.5	4 140	54	0	52.5	4 140	54
	2	4	38.5	17 816	70	1	29.4	18 509	65
	3	9	85.7	26 786	37	2	77.0	**27 782**	**36**
2011	1	9	118.5	41 984	24	0	118.5	41 984	24
	2	11	136.7	11 107	17	0	136.7	11 107	17
	3	9	83.6	21 019	27	0	83.6	21 019	27
	4	7	53.9	11 133	34	2	43.9	11 133	29
	5	8	80.4	10 389	29	0	80.4	10 389	29
	6	**8**	**76.8**	**23 146**	**45**	**2**	**60.7**	**23 146**	**42**
	7	**8**	**104.9**	**48 048**	**37**	**2**	**91.4**	**48 048**	**36**
	8	9	132.2	10 017	20	0	132.2	10 017	20

Table 4: Estimates of SBW biomass (t) for age 4+ fish from research acoustic surveys of the Bounty Platform in 1993–2001 (from Grimes et al. 2007), and 'best estimates' of spawning stock biomass (SSB) from acoustic estimates from industry vessels (with zero transects removed). Estimates in 2006–09 and 2011 were obtained by averaging selected snapshots. Values in parentheses are survey c.v.s.

Year	*Tangaroa* Age 4+ fish	Industry Vessel SSB
1993	47 087 (64%)	–
1994	20 844 (25%)	–
1995	23 480 (24%)	–
1997	31 929 (32%)	–
1999	34 194 (73%)	–
2001	16 396 (36%)	–
2004	–	13 473 (69%)
2006	–	21 765 (12%)
2007	–	159 589 (19%)
2008	–	144 187 (34%)
2009	–	28 242 (21%)
2010	–	27 782 (36%)
2011		**35 597 (28%)**

9. FIGURES

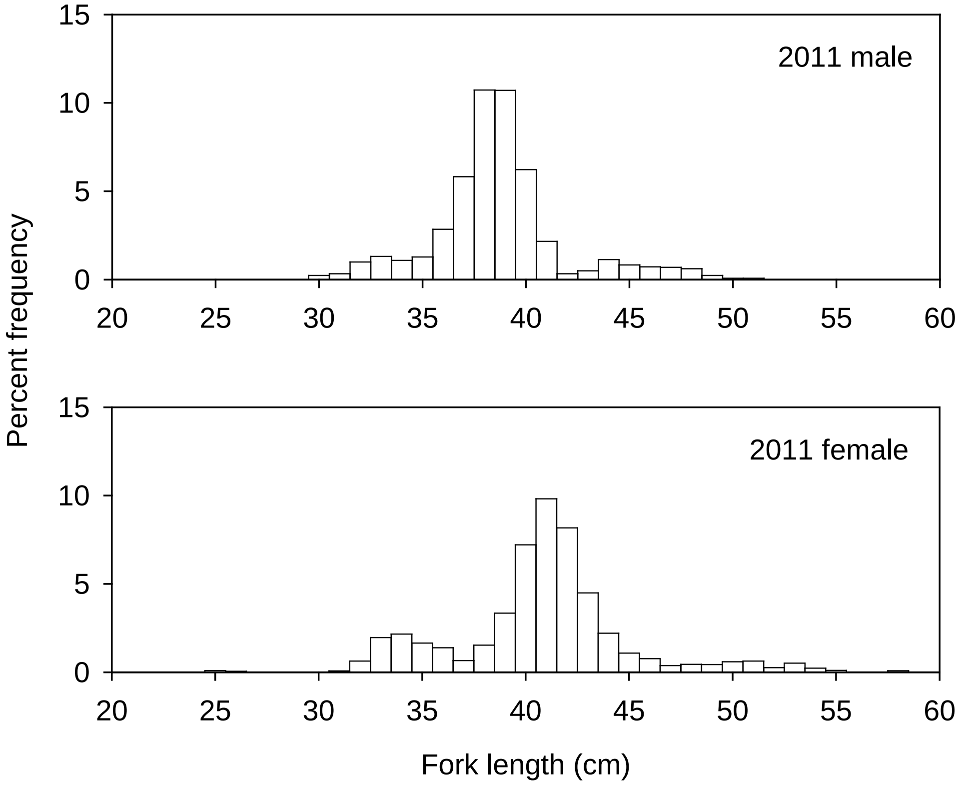


Figure 1: Scaled length frequency of SBW caught on the Bounty Platform by *FV Tomi Maru 87* in 2011 based on scientific observer data (observer trip 3359).

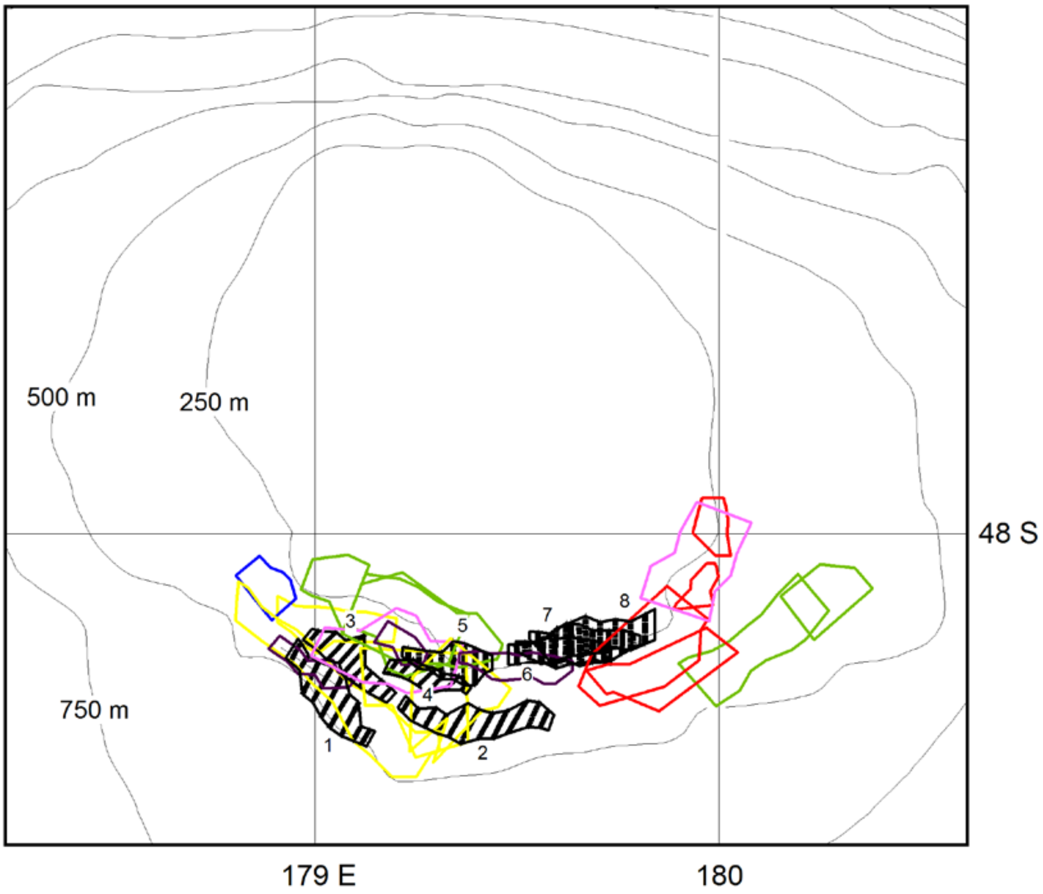


Figure 2: Map showing location of transects carried out in snapshots by *FV Tomi Maru 87* at the Bounty Platform in 2004–2011. Survey area and transects for the eight snapshots in 2011 (black lines and boxes) are compared with the areas surveyed by in 2004 (blue), 2006 (red), 2007 (green), 2008 (pink), 2009 (yellow), and 2010 (magenta).

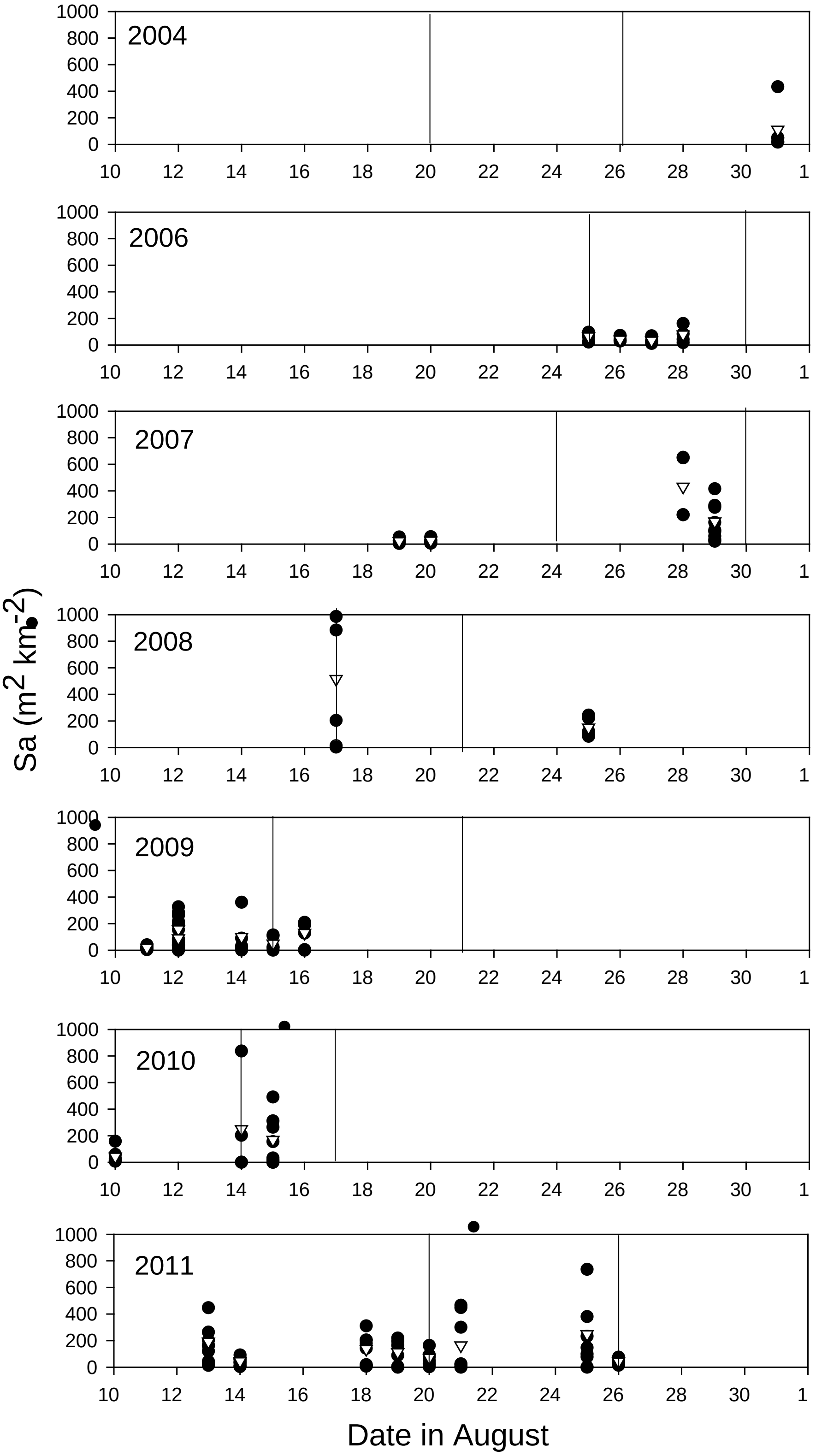


Figure 3: Non-zero transect density estimates (solid circles) plotted as a function of date for all transects carried out by industry vessels on the Bounty Platform 2004–11. Weighted (by transect length) mean densities for each snapshot are shown as the inverted open triangles. Vertical lines indicate estimated period of peak spawning based on gonad staging by observers.

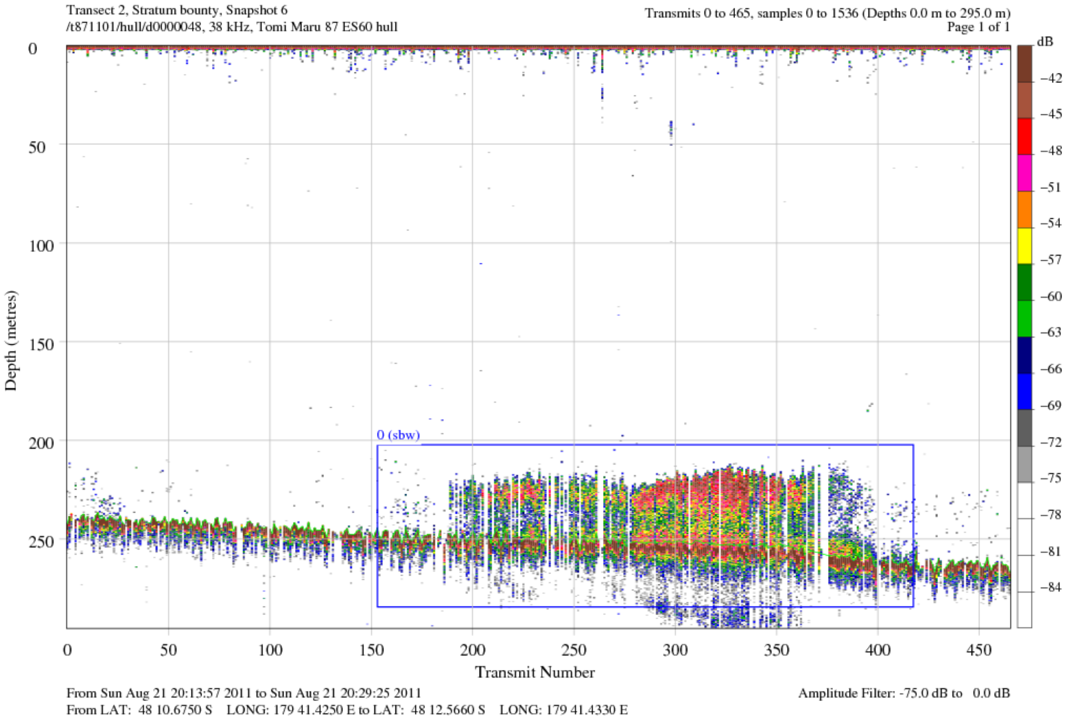


Figure 4: Example of acoustic echogram collected at the Bounty Platform in Snapshot 6 on 21 August 2011 showing ping drop-outs due to pitching in bad weather.

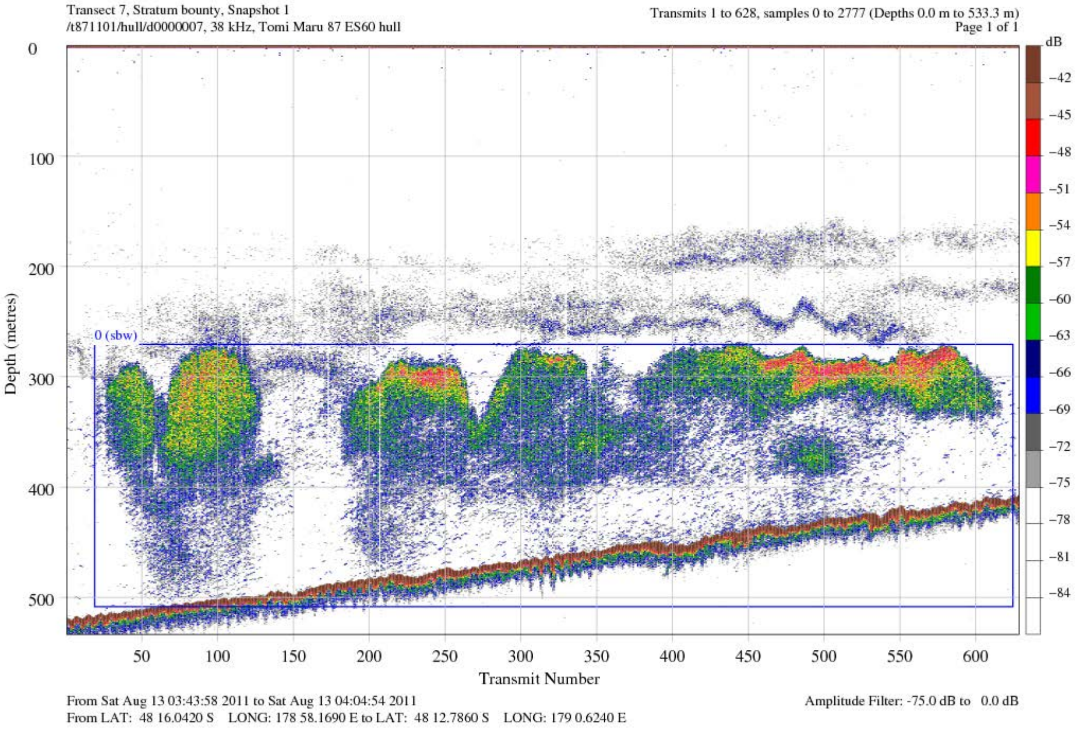


Figure 5: Example of acoustic echogram collected at the Bounty Platform in Snapshot 1 on 13 August 2011 showing SBW marks well off the bottom in relatively deep water.

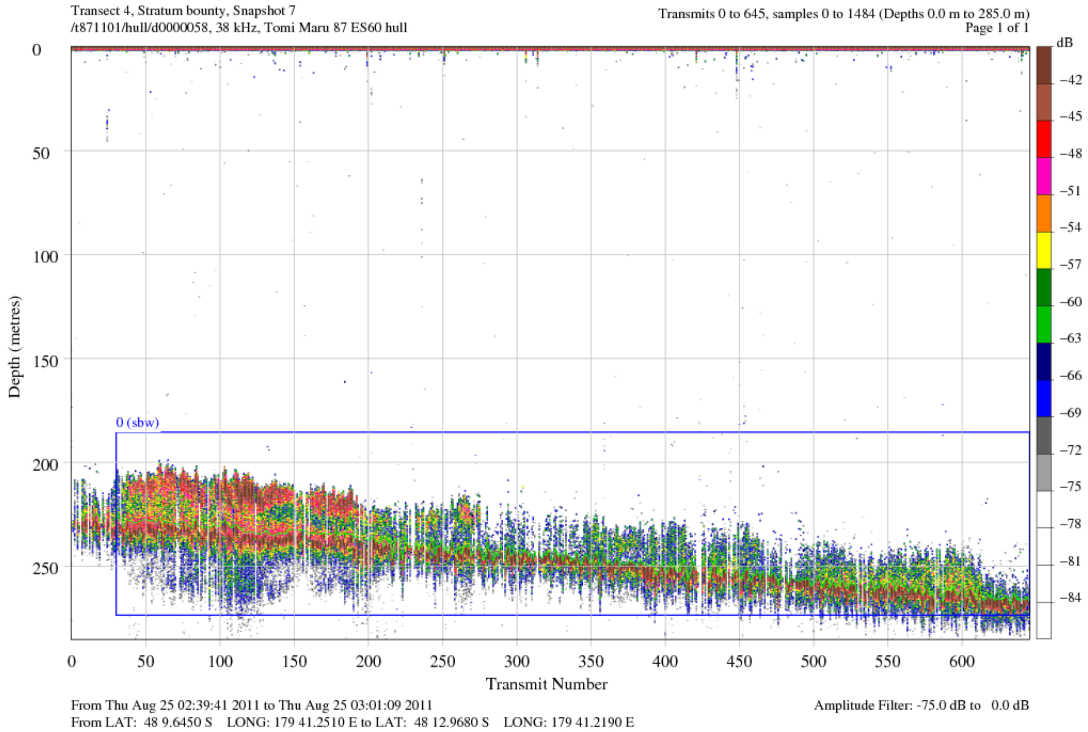


Figure 6: Example of acoustic echogram collected at the Bounty Platform in Snapshot 7 on 25 August 2011 showing extensive SBW marks within 50 m of the bottom in relatively shallow water.

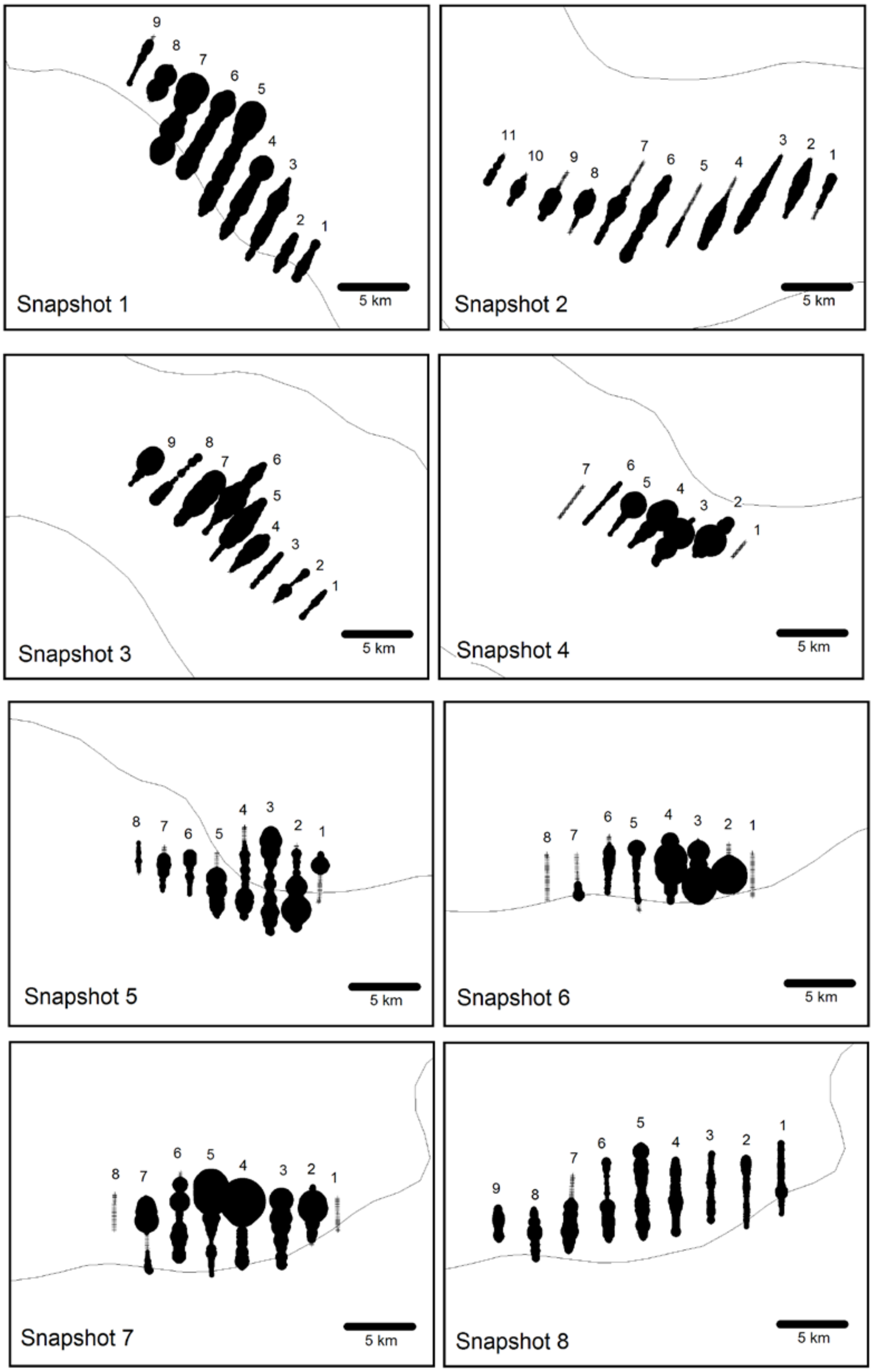
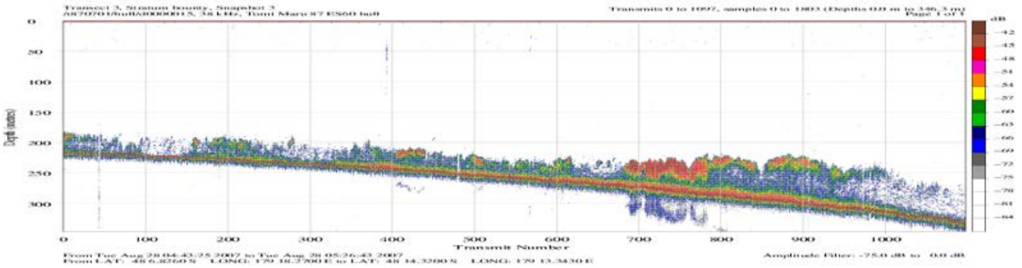
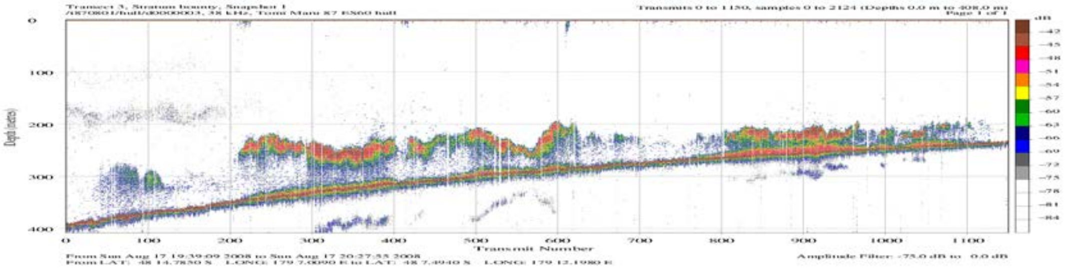


Figure 7: Spatial distribution of SBW backscatter plotted in 10-ping bins for the eight snapshots at the Bounty Platform in 2011. Transects are numbered in the order in which they were carried out. Circle area is proportional to the log of the acoustic backscatter. Crosses indicate zero backscatter.

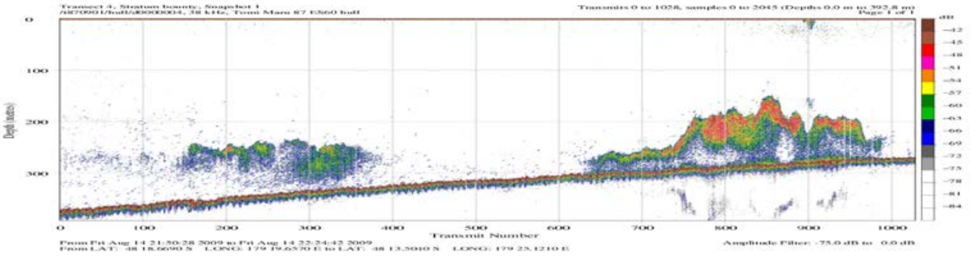
2007 (653 m^2 km^{-2})



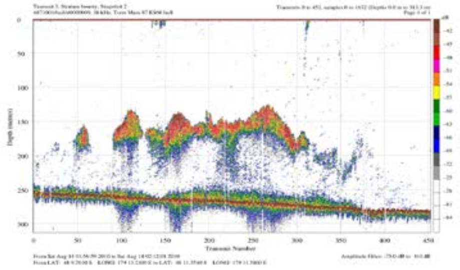
2008 (986 m^2 km^{-2})



2009 (361 m^2 km^{-2})



2010 (837 m^2 km^{-2})



2011 (736 m^2 km^{-2})

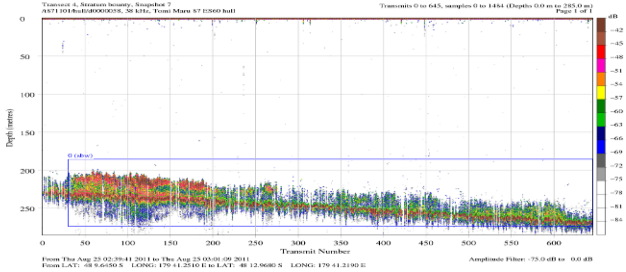


Figure 8: Echograms illustrating the densest SBW marks observed in surveys of the Bounty Platform by FV *Tomi Maru 87* in 2007–11. Values in parentheses are transect sa values. Echogram size has been scaled so distance scales (x-axes) are equivalent.

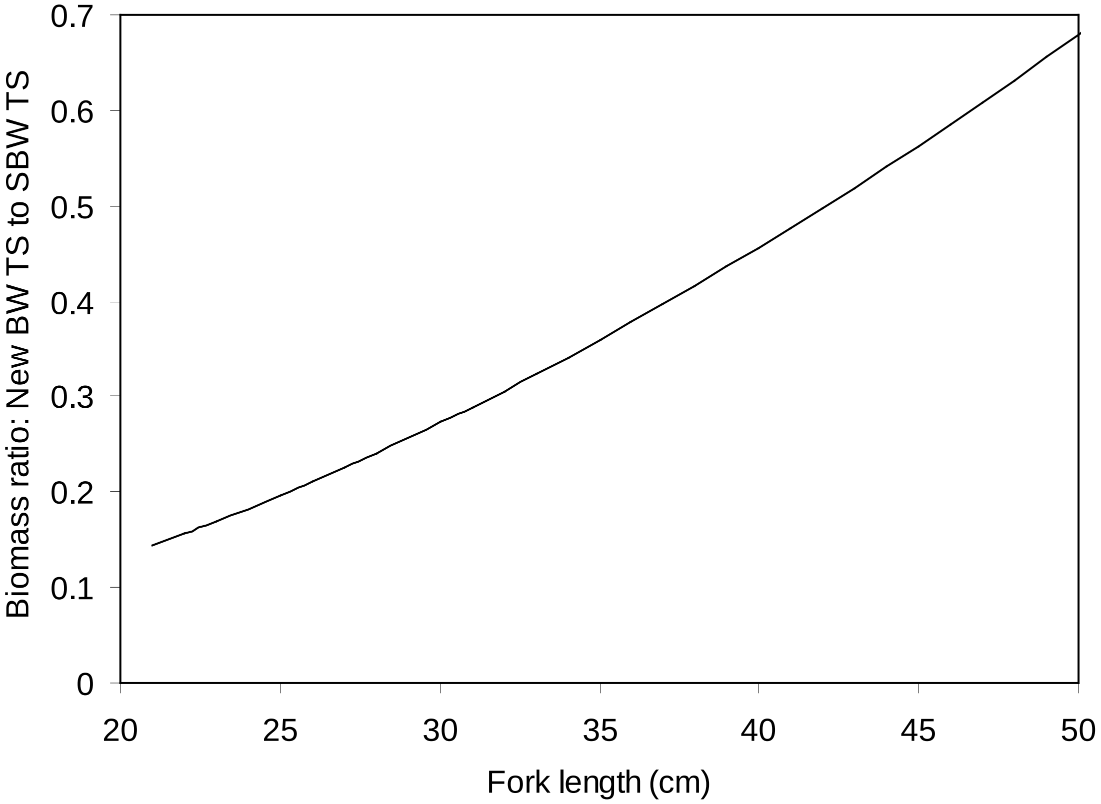


Figure 9: Ratio of biomass estimates for SBW calculated using recently published TS-length regression for blue whiting (new BW TS) to estimates calculated using the TS-length relationship of Dunford & Macaulay (2006) (SBW TS). The ratio varies with fish length.

APPENDIX 1: Calibration Report: Tomi Maru 87 9 June 2011

Calibration of the Simrad ES60 echosounder on *Tomi Maru* took place in the Hauraki Gulf (36° 38.39 S 174° 54.98 E) on 9 June 2011. Water depth was about 30 m (below the transducer). This was the seventh time that the ES60 on this vessel has been calibrated, with annual calibrations since 2005.

A new ES70 computer and software were installed on *Tomi Maru 87* in April 2010 and connected to the same 38-kHz GPT and transducer. Both the ES60 and ES70 were calibrated together on 30 April 2010 (O'Driscoll & Nelson 2010). Because the ES60 and ES70 use the same hardware, the calibrations with the two software systems were identical within the measurement uncertainty (O'Driscoll & Nelson 2010). Our intention was to calibrate the ES70 in 2011, but due to a computer failure on the ES70 PC on 8 June 2011, the ES70 was not available and the calibration was carried out on the ES60. The calibration was conducted broadly as per the procedures in MacLennan & Simmonds (1992).

Richard O'Driscoll and Peter de Joux joined the vessel at Davenport at 07:45 NZST on 9 June and the vessel departed at 08:15 for main engine trials and compass adjustments. The ES60 was configured to recommended settings (2000 W power and 1.024 ms pulse) and the time of the ES60 was adjusted to the GPS. The calibration started at 10:45 NZST. A weighted line was passed under the keel to facilitate setting up the three lines and calibration sphere. Long (3.8 m) fibreglass calibration poles were used to help keep the calibration lines clear of the hull and to allow the rods to point forward. The sphere and associated lines were immersed in a soap solution prior to entering the water. A lead weight was also deployed about 2 m below the sphere to steady the arrangement of lines. The sphere was centered in the beam to obtain data for the on-axis calibration, and was then moved around the beam to obtain data for the beam shape calibration.

The weather was calm with a 5–10 knot northwest breeze, no swell and small whitecaps. The vessel was allowed to drift, and the drift speed was about 0.7 knots. The sphere was located in the beam almost immediately at 10:59 NZST. Calibration data were recorded into a single ES60 raw format file (L0000-D20110608-T225658-ES60.raw). Raw data are stored in the NIWA Fisheries Acoustics Database. The ES60 transceiver settings in effect during the calibration are given in Table A1.

Water temperature measurements were taken using an RBR-2050 temperature depth probe, serial number 11817. The water column was essentially unstratified, with a temperature of 16.7 ºC at the surface, increasing slightly to 17.2 ºC at 29 m. The temperature at the depth of the sphere (18 m) was 16.8 ºC. The salinity was not measured and was assumed to be 35 PSU. An estimate of acoustic absorption was calculated using the formulae in Doonan et al. (2003) and an estimate of sound speed was calculated using the formulae of Fofonoff & Millard (1983).

The calibration was completed at 12:00 NZST. The vessel returned to Davenport and dropped NIWA staff off onto the pilot launch at 13:00.

The data in the ES60 files were extracted using custom-written software. The amplitude of the sphere echoes was obtained by filtering on range, and choosing the sample with the highest amplitude. Instances where the sphere echo was disturbed by fish echoes were discarded. The alongship and athwartship beam widths and offsets were calculated by fitting the sphere echo amplitudes to the Simrad theoretical beam pattern:

$$compensation = 6.0206\left(\left(\frac{2\theta_{fa}}{BW_{fa}}\right)^2 + \left(\frac{2\theta_{ps}}{BW_{ps}}\right)^2 - 0.18\left(\frac{2\theta_{fa}}{BW_{fa}}\right)^2\left(\frac{2\theta_{ps}}{BW_{ps}}\right)^2\right),$$

where θ_{ps} is the port/starboard echo angle, θ_{fa} the fore/aft echo angle, BW_{ps} the port/starboard beamwidth, BW_{fa} the fore/aft beamwidth, and *compensation* the value, in dB, to add to an uncompensated echo to yield the compensated echo value. The fitting was done using an unconstrained nonlinear optimisation (as implemented by the Matlab fminsearch function). The Sa correction was calculated from:

$$S_{a,corr} = 5\log_{10}\left(\frac{\sum P_i}{4P_{\max}}\right),$$

where P_i is the sphere echo power measurement and P_{max} the maximum sphere echo power measurement. A value for $S_{a,corr}$ is calculated for all valid sphere echoes and the mean over all sphere echoes is used to determine the final $S_{a,corr}$.

A correction for the triangle wave error in ES60 data (Ryan & Kloser 2004) was also applied as part of the analysis.

Results

The mean range of the sphere and the sound speed and acoustic absorption between the transducer (about 6 m deep) and the sphere are given in Table A2.

The calibration results are given in Table A3. The estimated beam pattern and sphere coverage are given in Figure A1. The symmetrical nature of the pattern and the zero centre of the beam pattern indicate that the transducer and ES60 transceiver were operating correctly. The fits between the theoretical beam pattern and the sphere echoes is shown in Figure A2 and confirms that the transducer beam pattern is correct. The RMS of the difference between the Simrad beam model and the sphere echoes out to 3.6° off axis was 0.11 dB (Table A3), indicating that the calibration was of excellent quality (less than 0.4 dB is poor, less than 0.3 dB good, and less than 0.2 dB excellent).

The estimated peak gain (G_0) in 2011 was 0.23–0.26 lower than that estimated from the two calibrations (ES60 and ES70) in 2010 (Table A3). This difference was greater than expected, although it continues the trend of declining G_0 that we have observed for this transducer and GPT since 2005 (Table A3). Other long-term time series of echosounder calibrations have also observed gradual declines in peak gain, possibly as a function of transducer ageing (Knudsen 2009).

When the calibration outputs were examined in detail, it was apparent that the scatter around the fitted beam pattern close to on-axis was lower for the 2011 calibration (see Figure A2) than for previous calibrations of this system (e.g., Figure A3) and ES60 calibrations in general. The effect of this was that the maximum sphere target strength (TS) close to on-axis (on which G_0 is calculated) was lower, but mean on-axis TS and on-axis TS from beam-fitting were almost identical (Table A3). There are ongoing discussions between members of the ICES Fisheries Acoustic Science and Technology Subgroup on Calibration about whether to use mean or maximum sphere echoes in calculating G_0 and we have forwarded our results to this group as a useful and potentially informative example.

Table A1: ES60 transceiver settings and other relevant parameters during the calibration.

Parameter	Value
Echosounder	ES60
ES60 software version	1.5.0.74
Transducer model	ES38B
Transducer serial number	1599
ES60 GPT serial number	GPT 38 kHz 009072056ad6 1 ES38B
GPT software version	Not recorded
Sphere type/size	tungsten carbide/38.1 mm diameter
Operating frequency (kHz)	38
Transducer draft setting (m)	0.0
Transmit power (W)	2000
Pulse length (ms)	1.024
Transducer peak gain (dB)	26.5
Sa correction (dB)	0.0
Bandwidth (Hz)	2425
Sample interval (m)	0.3192
Two-way beam angle (dB)	–20.60
Absorption coefficient (dB km^{-1})	9.75
Speed of sound (m s^{-1})	1500
Angle sensitivity (dB) alongship/athwartship	21.90/21.90
3 dB beamwidth (º) alongship/athwartship	7.10/7.10
Angle offset (º) alongship/athwartship	0.0/0.0

Table A2: Auxiliary calibration parameters derived from depth/temperature measurements.

Parameter	Value
Mean sphere range (m)	17.6
S.D. of sphere range (m)	0.4
Mean sound speed (m s^{-1})	1 514
Mean absorption (dB km^{-1})	8.43
Sphere TS (dB re 1m^2)	–42.4

Table A3: Calculated echosounder calibration parameters for *Tomi Maru 87*. All values were calculated using version 6818 of NIWA's Matlab calibration function. Note that the 2008 calibration was rejected and was not used in biomass estimation.

Parameter	2011	2010		2009	2008	2007	2006	2005
		ES70	ES60					
Mean TS within 0.21° of centre	-46.8347	-46.8238	-46.7535	-46.7798	-46.5339	-46.3050	-45.9008	-46.0495
Std dev of TS within 0.21° of centre	0.1645	0.1968	0.4178	0.4025	0.0166	0.2343	0.3639	0.4606
Max TS within 0.21° of centre	-46.4650	-45.9478	-45.9913	-46.0580	-46.5222	-45.8414	-45.4503	-45.2827
No. of echoes within 0.21° of centre	422	1 274	6 438	279	2	98	17	1 841
On axis TS from beam-fitting	-46.6851	-46.6375	-46.7343	-46.8018	46.3327	-46.2647	-45.9472	-46.0144
Transducer peak gain (dB)	24.48	24.74	24.71	24.67	24.45	24.79	24.96	25.05
Sa correction (dB)	-0.69	-0.67	-0.71	-0.60	-0.49	-0.65	-0.75	-0.69
Beamwidth (º) alongship/athwarthship	7.1/6.9	7.0/7.0	6.9/7.0	7.4/7.3	7.1/6.8	7.2/7.2	6.8/7.3	7.0/7.1
Beam offset (º) alongship/athwarthship	-0.06/-0.05	0.00/0.00	-0.00/0.00	-0.00/-0.00	0.00/-0.00	-0.04/-0.12	0.00/0.00	-0.09/0.05
RMS deviation	0.11	0.13	0.21	0.20	0.20	0.15	0.20	0.22
Number of echoes	29 780	30 727	23 277	7 362	951	1 416	4 632	19 534

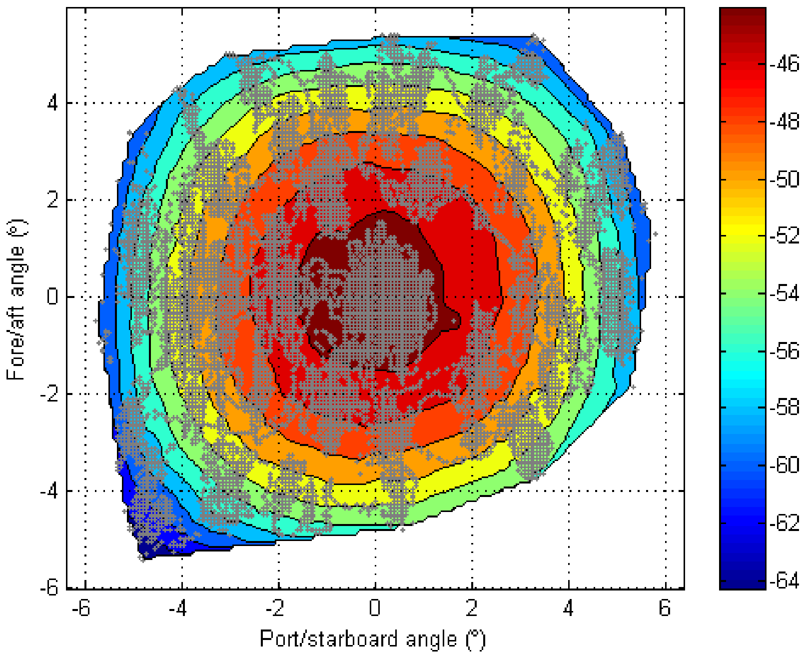


Figure A1: The estimated beam pattern from the sphere echo strength and position for the calibration. The '+' symbols indicate where sphere echoes were received. The colours indicate the received sphere echo strength in dB re 1 m^2.

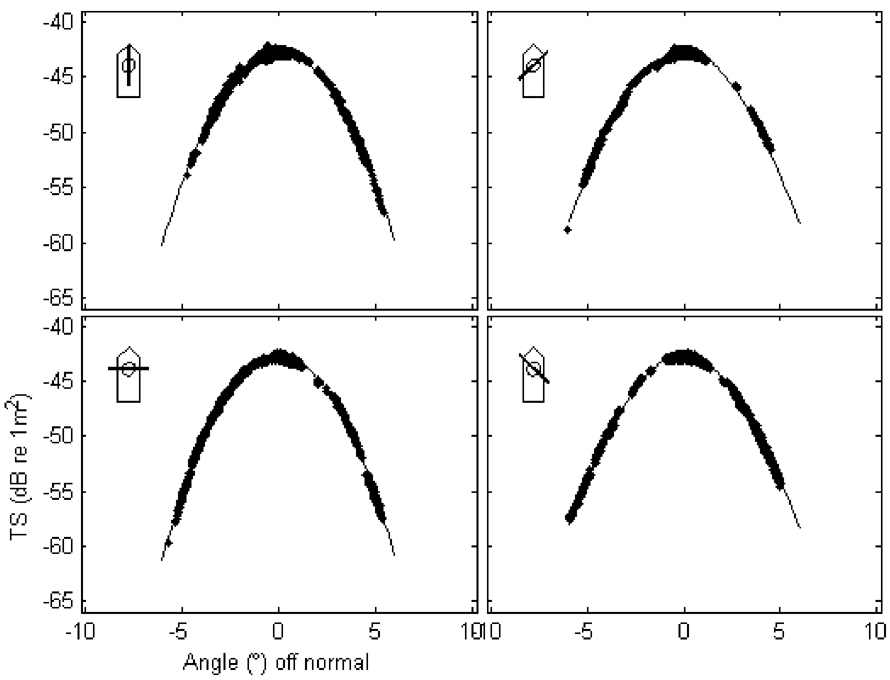


Figure A2: Beam pattern results from the calibration analysis. The solid line is the theoretical beam pattern fit to the sphere echoes for four slices through the beam.

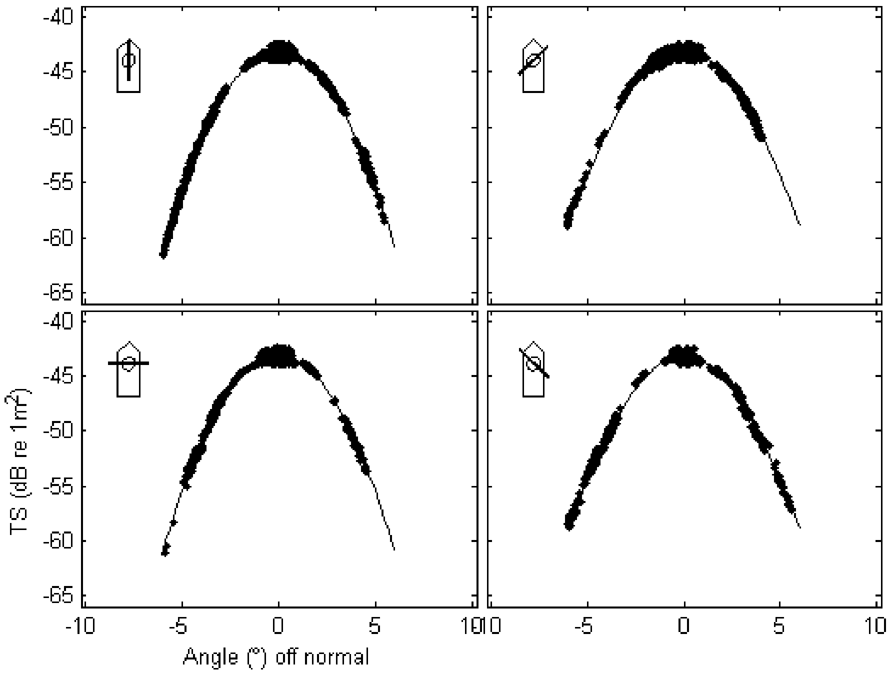


Figure A3: Beam pattern results from the calibration analysis from the ES70 on *Tomi Maru 87* in 2010. Note the wider spread of values close to on-axis compared to values in 2011 (see Figure A2).