Ministry for Primary Industries
Manatū Ahu Matua

Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2012

New Zealand Fisheries Assessment Report 2013/4.

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ISSN 1179-5352 (online)
ISBN 978-0-478-40509-5 (online)

January 2013

New Zealand Government

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EXECUTIVE SUMMARY

O'Driscoll, R.L. (2013). Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2012.

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The FV *Tomi Maru 87* collected acoustic data along 61 transects in ten snapshots on the Bounty Platform between 18 and 26 August 2012. All snapshots surveyed the main southern blue whiting (SBW) aggregation south of the Bounty Islands, which moved to the east during the survey period. Two of the snapshots were aborted due to fish movement or interference from other vessels. The surveyed areas in the other eight snapshots ranged from 10 to 41 km^2, much smaller than those in previous years when snapshot areas were 50–300 km^2. None of the eight completed snapshots appeared to completely cover the main aggregation, with fish detected on the outer transects and at the end of transects. Highest densities of SBW were observed in snapshots 6 and 7 on 21–22 August and snapshot 9 on 24 August, 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 very much smaller. In 2012, transects crossing the high density aggregation were less than 3 n. miles long, compared to 8 n. miles long in 2008. A new target-strength-to-fork-length (TS-FL) relationship for SBW (based on recent *in situ* measurements) was adopted in 2012. This revised TS-FL relationship causes acoustic biomass estimates from all years in the survey series to be approximately halved. The best biomass estimate for 2012, based on the three most extensive snapshots (6, 7, and 9), and using the new TS-FL relationship, was 13 651 t (c.v. 7%). This was similar to the revised estimates from 2010 (14 434 t) and 2009 (14 699 t), but 27% lower than the estimate of 18 718 t from 2011 and less than a fifth of the revised estimates from 2007 (76 240 t) and 2008 (72 704 t). Data on the size distribution of the fish, collected by Ministry for Primary Industries observers, show that this fishery is still dominated by fish from the strong 2002 year-class, but the proportion of younger fish is increasing.

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 38 174 t was reported during the 2011 season, with 30 840 t taken from the Campbell Island Rise, 6590 t from the Bounty Platform, and 677 t from the Pukaki Rise (Ministry for Primary Industries 2012). 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 frequently. 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 for Primary Industries 2012).

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 seven estimates of biomass of spawning SBW on the Bounty Platform in 2004, 2006, 2007, 2008, 2009, 2010, and 2011, 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 and 2011 presented by O'Driscoll (2011b, 2011c, 2012).

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 and 2011 surveys (O'Driscoll 2011b, 2012). 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, 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 for Primary Industries 2012).

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 2012 following the same protocols as in 2004–11 (O'Driscoll 2011a).

This report is the final reporting requirement for Ministry for Primary Industries Research Project SBW2010/02B. 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 ES70 echosounder on *Tomi Maru* took place in the Hauraki Gulf on 20 June 2012 (Appendix 1). Diagnostics indicated a calibration of good quality. The estimated peak gain (G_0) in 2012 was 0.26 higher than that estimated from 2011, but identical to that from the ES70 calibration in 2010 (Appendix 1). The 2012 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 a NIWA staff member (Adam Dunford) in Timaru on 3 August 2012.

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 2012.

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 2012, estimated from scientific observer data (Figure 1).

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

$$TS = 38 \log_{10} FL - 97 \quad (1)$$

where *TS* is in decibels and *FL* is in centimetres. Recent work on the TS of SBW (O'Driscoll et al. 2013) has found that the TS-FL relationship of Dunford & Macaulay (2006) may underestimate SBW TS. The implications for this change in TS is discussed in Section 4.

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

$$w = 0.00439 * FL^{3.133} \quad (2)$$

The mean length of SBW caught at the Bounty Platform in 2012 by *FV Tomi Maru 87* was 39.7 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 462 g. Mean backscattering cross-section was 0.000249 m^2 (equivalent to –36.0 dB), giving a ratio, r, of 1855 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

Acoustic data were recorded continuously from *FV Tomi Maru 87* from departing Timaru on 9 August 2012 to arriving back in port on 31 August 2012. The vessel was on the Bounty Platform fishing grounds from 9 to 29 August. Although data collected while fishing and searching was 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 one acoustic transects were carried out in ten snapshots on the Bounty Platform between 18 and 26 August 2012 (Table 2). However, two of the snapshots (snapshots 5 and 8) were aborted due to fish movement or interference from other vessels. 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 during the survey period (Figure 2). This movement pattern is 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 ten 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 2012 ranged from 10 to 41 km^2 in the eight completed snapshots (Table 2), much smaller than those in previous years when snapshot areas were 50–300 km^2 (O'Driscoll 2011a, 2012). The spacing between adjacent transects was also lower than in previous surveys, with an average spacing of 700–1000 m between transects in 2012 compared to 2–3 km in previous surveys. The eight completed snapshots in 2012 were the same number that was carried out in 2011 (O'Driscoll 2012), and more than in any other survey. The survey duration covered by the eight snapshots (9 days) was less than in 2011 (when survey duration was 13 days), but greater than in most 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 2012 survey was within the main spawning period. Scientific observers on *Tomi Maru 87* recorded fish actively spawning (defined as more than 10% running ripe females) between 18 and 24 August.

3.2 Acoustic data quality

The quality of the acoustic data from Bounty Platform in 2012 was very good due to relatively calm weather and sea conditions during the survey period. There were few incidences of ping drop-outs. ES70 transceiver settings and other relevant parameters during data collection (see Table 1) followed recommended protocols. There was some acoustic interference from another instrument in two of the 61 transect files, but this instrument was turned off before any fish were encountered and so did not impact the analysis.

3.3 Acoustic mark types

Relatively dense adult SBW marks were observed in all snapshots. Marks were usually within 50 m of the bottom in 250–300 m water depth (e.g., Figures 4 and 5). 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 10 snapshots is shown in Figure 6. As noted in Section 3.1, transects in all snapshots were carried out sequentially from east to west.

None of the eight completed snapshots appeared to completely cover the main aggregation, with fish detected on the outer transects and at the end of transects (Figure 6). Highest densities of SBW were observed in snapshots 6 and 7 on 21–22 August and snapshot 9 on 24 August (Figure 6). 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 very much smaller. In 2012, transects crossing the high density aggregation were less than 3 n. miles long, compared to 8 n. miles long in 2008 (Figure 7). Densities were lower and spread over a wider area in the final snapshot on 26 August (Figure 6), which is typical of SBW dispersing post-spawning.

3.5 Biomass estimates

Biomass estimates for all Bounty Platform snapshots in 2004–12 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 (only three in 2012). 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 completed snapshots in 2012, with zero transects removed, ranged between 466 t (c.v. 82%) for snapshot 2 and 28 294 t (c.v. 18%) for snapshot 9.
At its meeting on 27 November 2012, the Deepwater Fishery Assessment Working Group (DFWG) agreed that the "best" estimate of the SBW spawning aggregation in 2012 is the average estimate from snapshots 6, 7, and 9. These three snapshots were all within the peak spawning period (see Figure 3) and appeared to best cover the distribution of fish (see Figure 6). Snapshot 10 was outside the spawning period, and SBW did not appear to be fully aggregated in Snapshots 1–4. The average of snapshots 6, 7, and 9 was 26 150 t (Table 4). 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 7% The second method assumes that 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 4%.

The 'best estimate' from 2012 was similar to the estimates from 2010 (27 782 t) and 2009 (28 242 t), but 27% lower than the estimate of 35 597 t from 2011 and less than a fifth of the abundance estimated in 2007 (159 589 t) and 2008 (144 187 t) (Table 4). However, the DFWG 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 2012 is still dominated by fish from the strong 2002 year-class (modal length 42 cm for females and 39 cm for males), but that the proportion of younger fish is increasing - apparent as a smaller mode at length 37 cm for females and as a shoulder on the main mode for males.

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 dominant 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 more extensive surveys in 2010 and 2011, which supported the low biomass observed in 2009 (O'Driscoll 2011b, 2012). The 2012 survey results again indicate a much lower biomass than was observed in 2007 and 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.

Recent work on the acoustic TS of SBW (O'Driscoll et al. 2013) suggests that acoustic estimates based on the TS-FL relationship of Dunford & Macaulay (2006) may overestimate SBW biomass. Estimates of *in situ* TS at 38 kHz were obtained using an autonomous acoustic optical system (AOS) mounted on a demersal trawl at Campbell Island in 2011. A logarithmic fit through the mean TS values for immature and adult southern blue whiting produced a new optically-verified TS-FL relationship of:

$$TS = 22.06 \log_{10} FL - 68.54 \qquad (3)$$

This new relationship gives TS values within 1 dB of those estimated using the relationship recently adopted by ICES for blue whiting (*Micromesistius poutassou*) (Pedersen et al. 2011), but higher values than those estimated from Dunford & Macaulay (2006). It appears likely that the steep slope in swimbladder model estimates of SBW TS (Dunford & Macaulay 2006) was due to an inappropriate application of the Kirchhoff-approximation model at small swimbladder sizes (O'Driscoll et al. 2013).

If we apply the new TS-FL relationship (Equation (3)) in place of Equation (1) in calculating the ratio of mean weight to mean backscattering cross section, estimates of SBW biomass from industry surveys at the Bounty Platform are approximately halved (Table 5). Because of the 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 8). If the relationship proposed by O'Driscoll et al. (2013) 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 2.1 (Table 5). The estimates for 2012 using the new TS-FL relationship were 52% of the estimates in Tables 3 and 4 (Table 5). On 27 November 2012 the DFWG decided to use acoustic indices based on the new TS-FL relationship (Table 5) as their basis for management advice for SBW6B in 2013.

5. CONCLUSIONS

Acoustic data from the Bounty Platform in 2012 were collected with appropriate acoustic settings and were of sufficient quality to estimate biomass. The eight completed snapshots were all in the region to the

south of the Bounty Islands where the largest aggregations was observed in 2007–11 (see Figure 2) and were in the vicinity of the main commercial fishing effort on the survey dates. Survey design protocols were generally followed, although none of the snapshots appeared to completely cover the main aggregation, with fish detected on the outer transects and at the end of transects.

A new TS-FL relationship for SBW (based on recent *in situ* measurements) was adopted in 2012. This revised relationship causes acoustic biomass estimates from all years in the survey series to be approximately halved. The best biomass estimate for 2012, based on the three most extensive snapshots (6, 7, and 9), and using the new TS-FL relationship, was 13 651 t (c.v. 7%). This was similar to the revised estimates from 2010 (14 434 t) and 2009 (14 699 t), but 27% lower than the estimate of 18 718 t from 2011 and less than a fifth of the revised estimates from 2007 (76 240 t) and 2008 (72 704 t).

Because of uncertainty about the proportion of fish surveyed every year, it is difficult to interpret results from aggregation-based acoustic surveys and incorporate these into assessment models (Dunn & Hanchet 2011).

6. ACKNOWLEDGMENTS

Thanks to Tatsushi Yamamoto (captain), Hitohiko Ogasawara (fishing master), Peter Ballantyne (vessel manager), Simon Beatson and Bobby Anthony (MPI observers), and the crew of *Tomi Maru 87* for their assistance. Ian Tuck reviewed a draft of this report. This work was funded by Ministry for Primary Industries Research Project SBW2010/02B.

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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 2012.

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 (º) alongship/athwartship	7.10/7.10
Angle offset (º) alongship/athwartship	0.00/0.00

Table 2: Summary of acoustic snapshots carried out at the Bounties in 2012 by *FV Tomi Maru 87*. Times are NZST.

Snapshot	Area (km^2)	Start time	End time	No. of transects
1	23.9	18 Aug 02:04	18 Aug 04:07	6
2	10.2	19 Aug 00:27	19 Aug 01:56	6
3	17.8	19 Aug 02:55	19 Aug 04:55	6
4	16.8	20 Aug 00:21	20 Aug 02:25	6
5*	4.6	20 Aug 03:38	20 Aug 04:12	3
6	32.9	21 Aug 00:42	21 Aug 04:14	10
7	20.2	21 Aug 23:23	22 Aug 02:03	8
8*	16.7	24 Aug 19:01	24 Aug 20:13	3
9	28.2	24 Aug 20:27	24 Aug 23:31	8
10	41.2	26 Aug 19:59	26 Aug 22:50	5

* Snapshots 5 and 8 were aborted due to fish movement or interference from other vessels

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 2004–12. 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 5. Estimates for 2004–11 are from O'Driscoll (2012). All estimates calculated using the TS-FL relationship of Dunford and Macaulay (2006).

			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 3 cntd: 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 2004–12. Snapshots in bold were averaged to produce the biomass estimates in Table 4. All estimates calculated using the TS-FL relationship of Dunford and Macaulay (2006).

			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. (%)
2012	1	6	23.9	5 649	51	1	20.3	5 756	47
	2	6	10.2	446	83	1	8.7	466	82
	3	6	17.8	2 811	46	0	17.8	2 811	46
	4	6	16.8	9 782	39	0	16.8	9 782	39
	5*	3	4.6	69	29	0	4.6	69	29
	6	**10**	**32.9**	**26 072**	**17**	**1**	**30.4**	**25 916**	**15**
	7	**8**	**20.2**	**24 242**	**18**	**0**	**20.2**	**24 242**	**18**
	8*	3	16.7	3 231	61	0	16.7	3 231	61
	9	**8**	**28.2**	**28 294**	**18**	**0**	**28.2**	**28 294**	**18**
	10	5	41.2	5 447	15	0	41.2	5 447	15

* Snapshots 5 and 8 were aborted due to fish movement or interference from other vessels

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 2011–12 were obtained by averaging selected snapshots. All estimates calculated using the TS-FL relationship of Dunford and Macaulay (2006).

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%)
2012	–	**26 150 (7%)**

Table 5: Estimates of SBW spawning stock biomass (t) from acoustic estimates from industry vessels using existing TS-FL relationship of Dunford and Macaulay (2006) (from Table 4), and estimates derived using new TS-FL relationship of O'Driscoll et al. (2013). Ratio is the ratio of the two estimates.

Year	Dunford & Macaulay (2006)	O'Driscoll et al. (2013)	Ratio
2004	13 473	7 955	0.59
2006	21 765	12 039	0.55
2007	159 589	76 240	0.48
2008	144 187	72 704	0.50
2009	28 242	14 699	0.52
2010	27 782	14 434	0.52
2011	35 597	18 718	0.53
2012	26 150	13 651	0.52

9. FIGURES

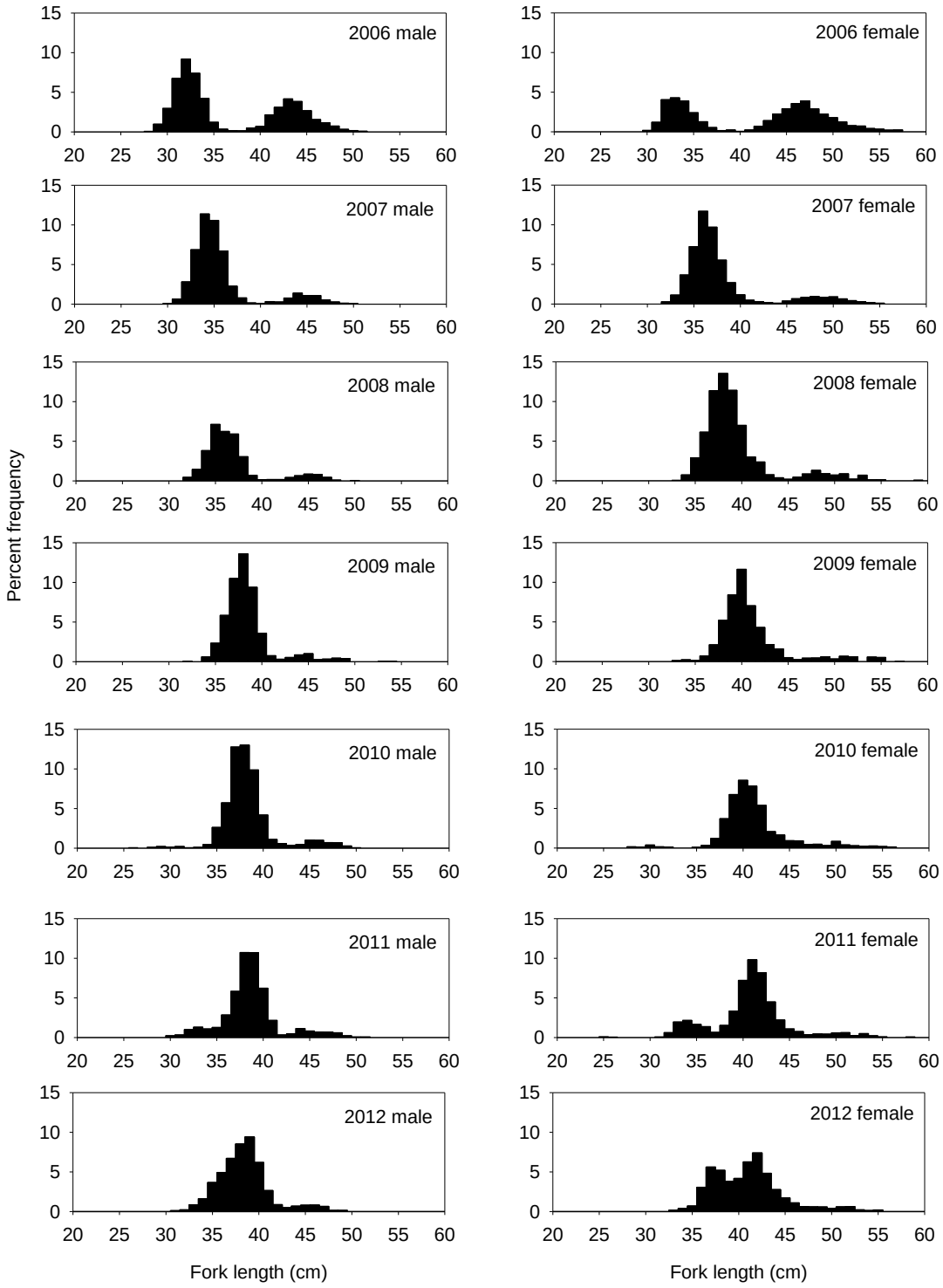


Figure 1: Scaled length frequency of SBW caught on the Bounty Platform by *FV Tomi Maru 87* in 2006–12 based on scientific observer data. Data from 2012 are from observer trip 3549.

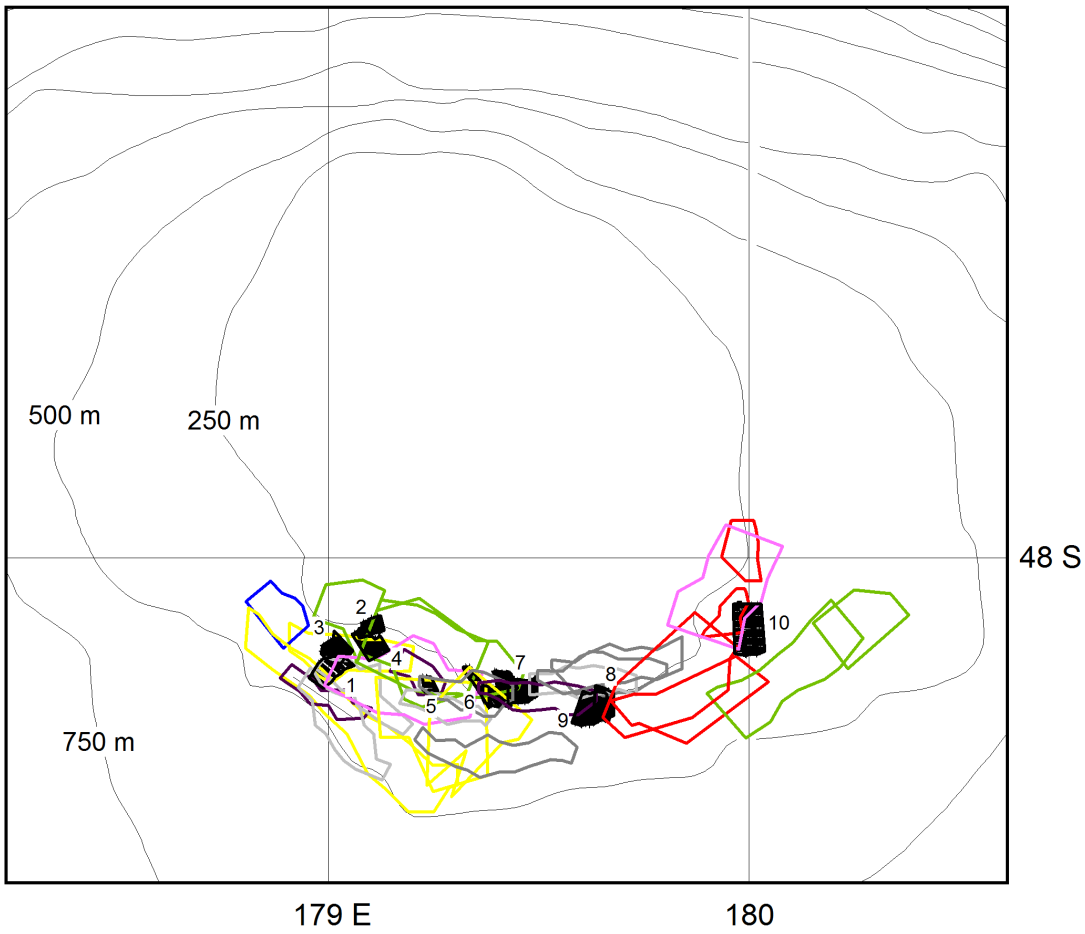


Figure 2: Map showing location of transects carried out in snapshots by *FV Tomi Maru 87* at the Bounty Platform in 2004-2012. Survey area and transects for the ten snapshots in 2012 (black lines and boxes) are compared with the areas surveyed by in 2004 (blue), 2006 (red), 2007 (green), 2008 (pink), 2009 (yellow), 2010 (magenta), and 2011 (grey).

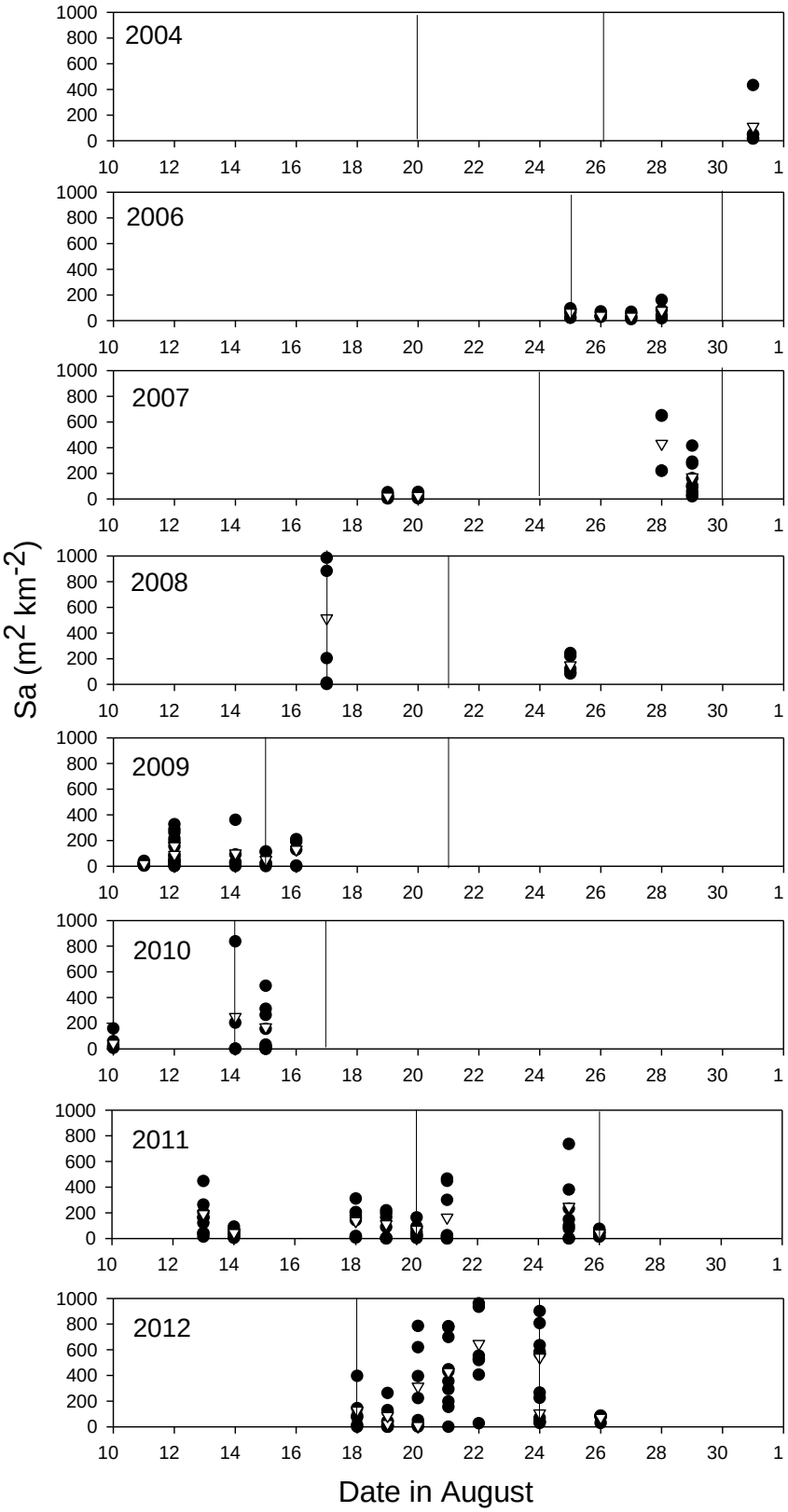


Figure 3: Non-zero transect density estimates (solid circles) plotted as a function of date for all transects carried out by industry vessels on the Bounty Platform 2004–12. Weighted (by transect length) mean densities for each snapshot are shown as the inverted open triangles. Vertical lines indicate estimated period of peak spawning based on gonad staging by observers.

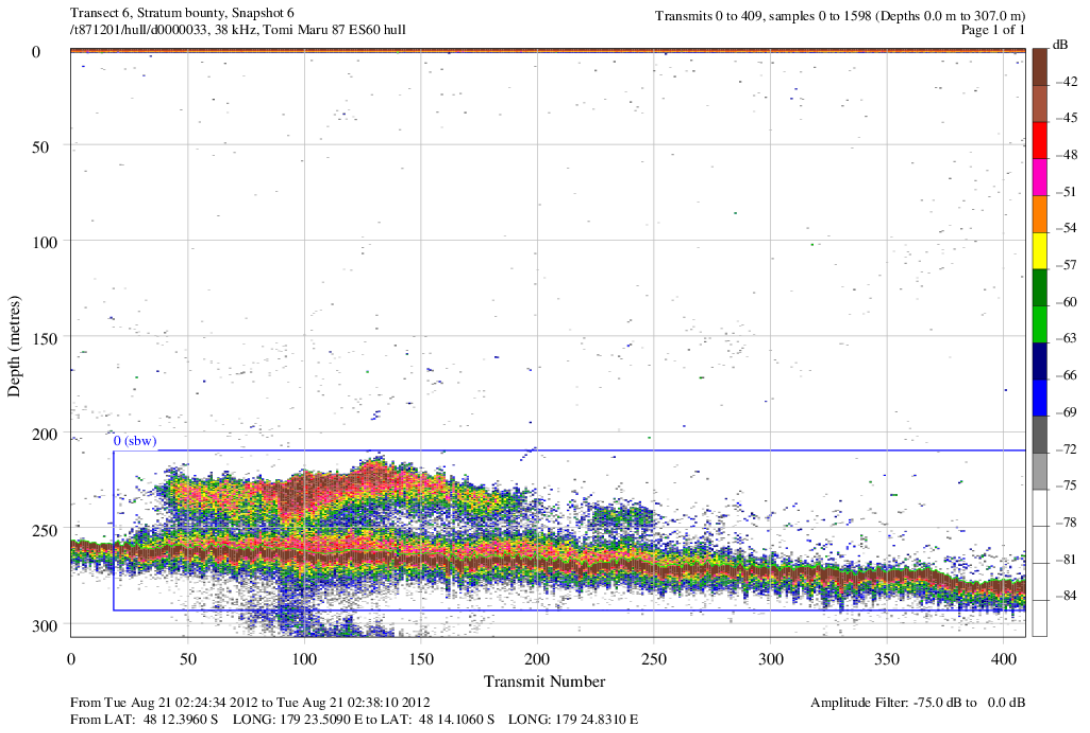


Figure 4: Example of acoustic echogram collected at the Bounty Platform in snapshot 6 on 21 August 2012 showing strong SBW mark.

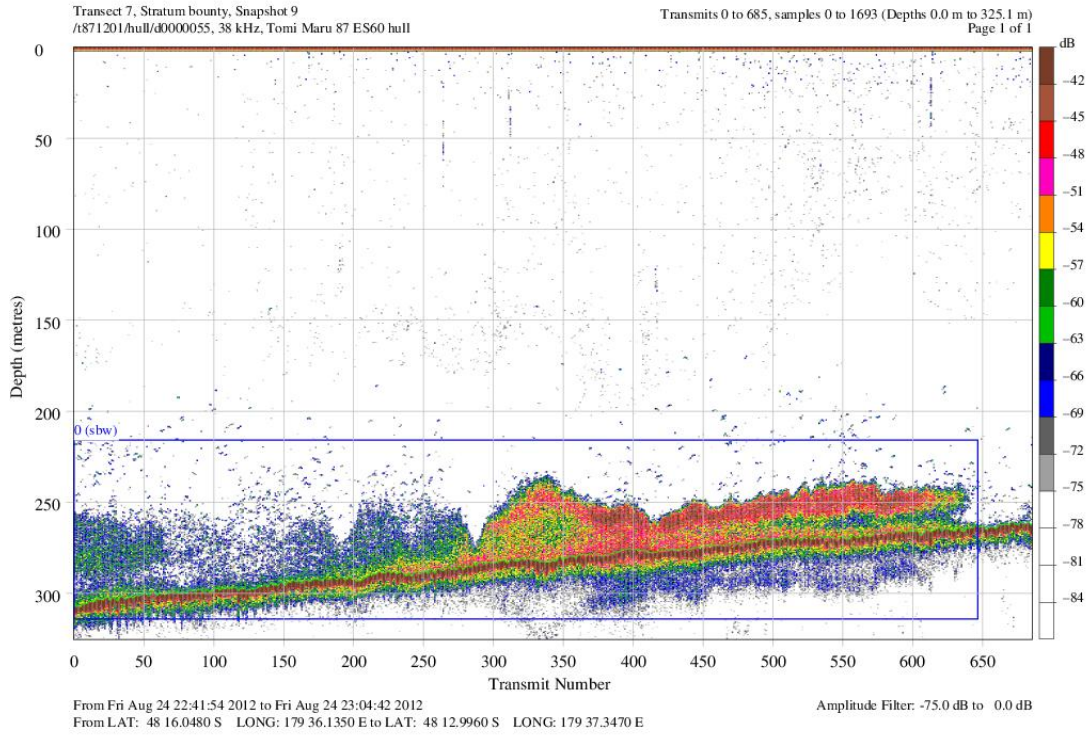


Figure 5: Example of acoustic echogram collected at the Bounty Platform in snapshot 9 on 24 August 2012 showing SBW marks which are not completely covered by the transect (mark is already present at the start of the transect).

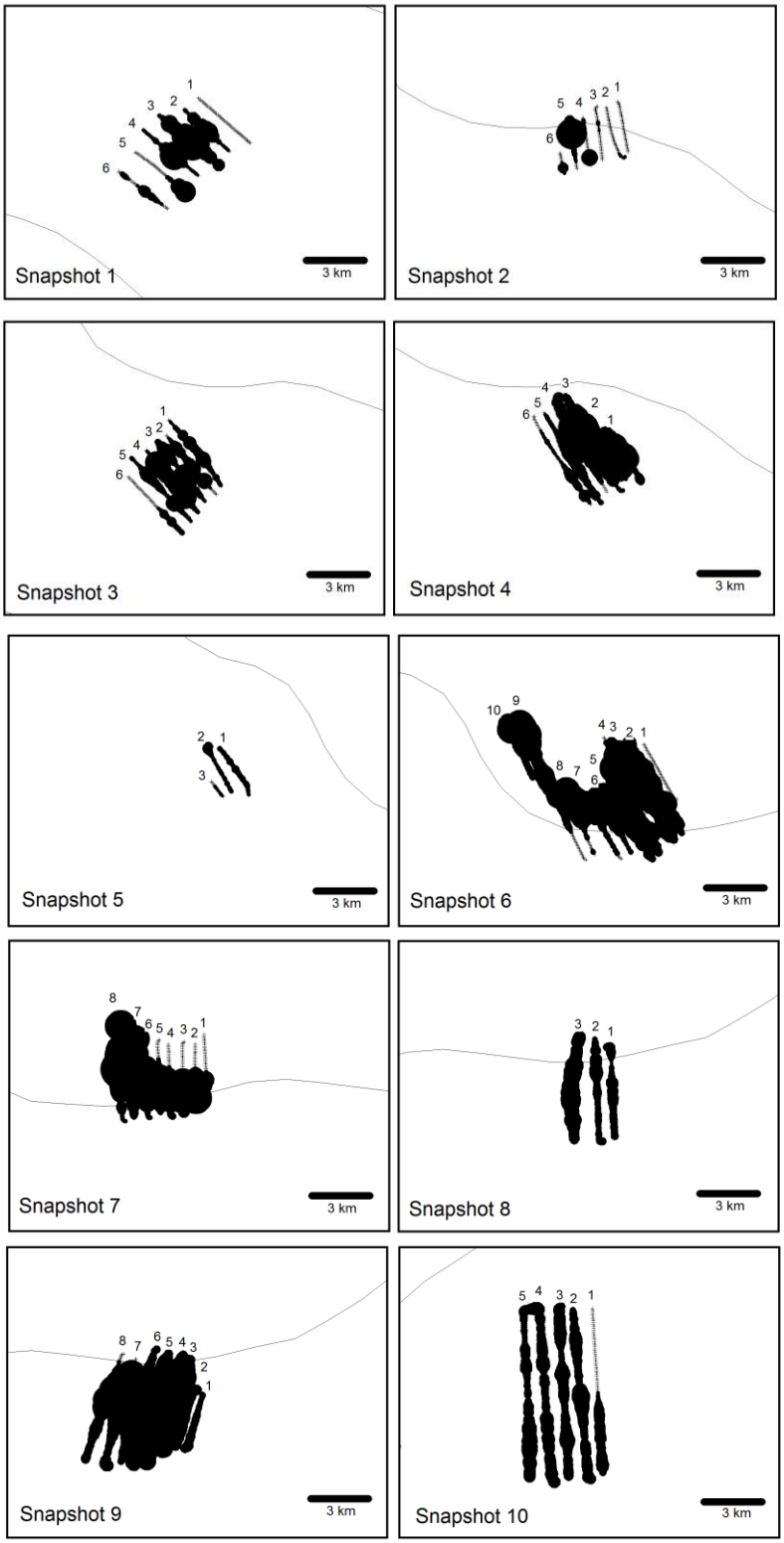
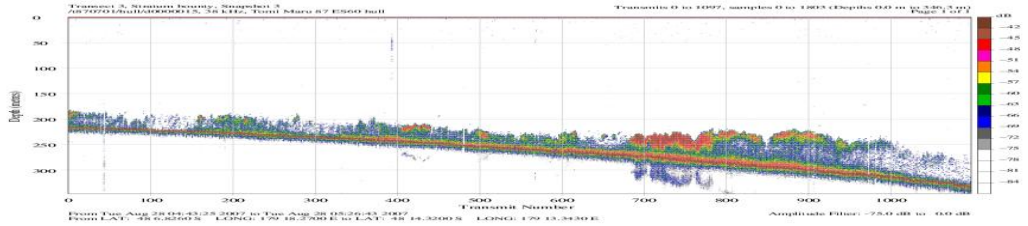
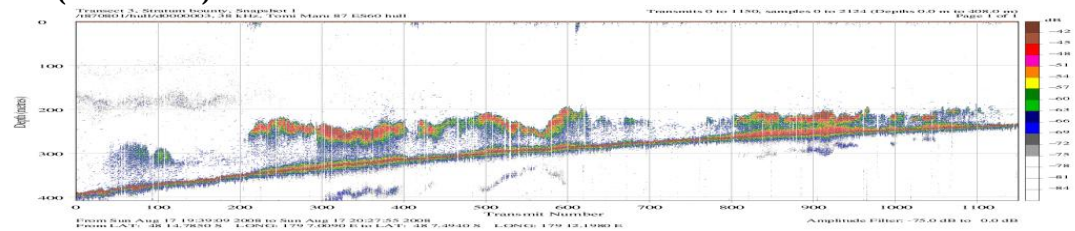


Figure 6: Spatial distribution of SBW backscatter plotted in 10-ping bins for the 10 snapshots at the Bounty Platform in 2012. Transects are numbered in the order in which they were carried out. Circle area is proportional to the log of the acoustic backscatter. Crosses indicate zero backscatter.

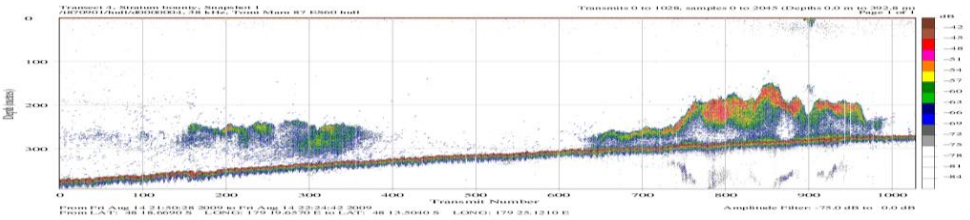
2007 (653 m^2 km^{-2})



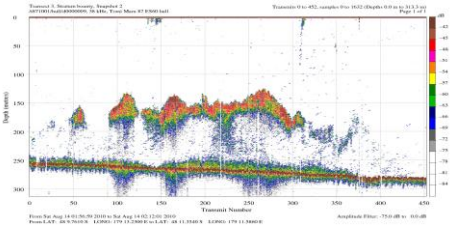
2008 (986 m^2 km^{-2})



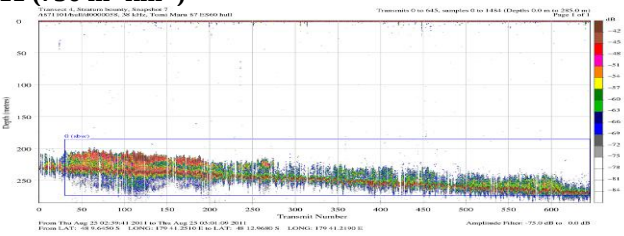
2009 (361 m^2 km^{-2})



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



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



2012 (1007 m^2 km^{-2})

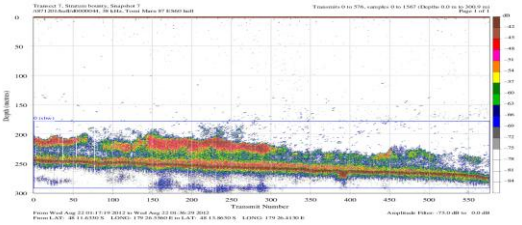


Figure 7: Echograms illustrating the densest SBW marks observed in surveys of the Bounty Platform by FV *Tomi Maru 87* in 2007–12. Values in parentheses are transect sa values. Echogram size has been scaled so distance scales (x-axes) are equivalent.

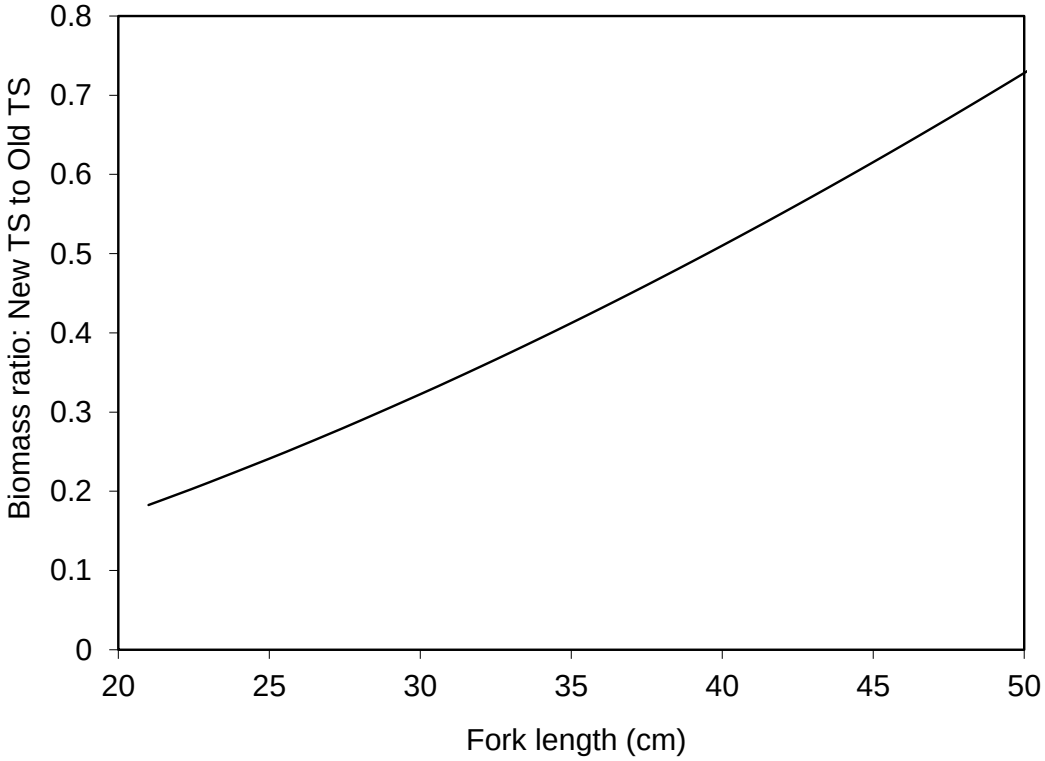


Figure 8: Ratio of biomass estimates for SBW calculated using the recent *in situ* TS-FL regression estimated for SBW by O'Driscoll et al. (2013) (new TS) to estimates calculated using the TS-FL relationship of Dunford & Macaulay (2006) (old TS). The ratio varies with fish length.

APPENDIX 1: Calibration Report: *Tomi Maru 87* 20 June 2012

Calibration of the Simrad ES70 echosounder on *Tomi Maru* took place in the Hauraki Gulf (36° 38.83 S 175° 00.27 E) on 20 June 2012. Water depth was about 31 m (below the transducer). This was the eighth time that the echosounder on this vessel has been calibrated, with annual calibrations since 2005. The ES70 computer and software were installed on *Tomi Maru 87* in April 2010 and connected to the same 38-kHz GPT and transducer as the previous ES60 system. 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 and Nelson 2010). The 2012 calibration was carried out by Richard Nelson (NIWA) following the procedures in MacLennan & Simmonds (1992).

The ES70 was configured to recommended settings (2000 W power and 1.024 ms pulse). 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 knot breeze and no swell. The vessel was allowed to drift, and the drift speed was about 0.4 knots. The sphere was located in the beam almost immediately at 11:06 NZST and the calibration was completed at 12:33 NZST. Calibration data were recorded into a single ES60 raw format file (t871201-D20120619-T230701.raw). Raw data are stored in the NIWA Fisheries Acoustics Database. The ES70 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 15.2º at the surface, increasing slightly to 15.7º at 35 m. The temperature at the depth of the sphere (30 m) was 15.7º. 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 data in the ES70 file 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 ES70 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 ES70 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 0.21 dB (Table A3), indicating that the calibration was of good 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 2012 was 0.26 higher than that estimated from 2011, but identical to that from the ES70 calibration in 2010 (Table A3). O'Driscoll (2012) noted that the scatter around the fitted beam pattern close to on-axis was lower for the 2011 calibration (Figure A3) than for previous calibrations of this system and for ES60 calibrations in general. The 2012 calibration had a more usual level of variability (see Figure A2). The effect of this was that the maximum sphere target strength (TS) close to on-axis (on which G_0 is calculated) was lower in 2011, but mean on-axis TS and on-axis TS from beam-fitting were more similar between years (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 previously we have forwarded our results to this group as a useful and potentially informative example.

The 2012 calibration will be used for analysis of results from the 2012 Bounty southern blue whiting survey.

Table A1: ES70 transceiver settings and other relevant parameters during the calibration.

Parameter	Value
Echosounder	ES70
ES70 software version	1.0.1.0
Transducer model	ES38B
Transducer serial number	1599
ES60 GPT serial number	GPT 38 kHz 009072056ad6 1 ES38B
GPT software version	070413
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)	9.75
Speed of sound (m/s)	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 and temperature measurements.

Parameter	Value
Mean sphere range (m)	22.5
S.D. of sphere range (m)	0.9
Mean sound speed (m/s)	1 508
Mean absorption (dB/km)	8.72
Sphere TS (dB re $1m^2$)	–42.42

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	2012	2011		2010	2009	2008	2007	2006	2005
	ES70	ES60	ES70	ES60	ES60	ES60	ES60	ES60	ES60
Mean TS within 0.21° of centre	-46.5925	-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	0.4155	0.1645	0.1968	0.4178	0.4025	0.0166	0.2343	0.3639	0.4606
Max TS within 0.21° of centre	-45.9441	-46.4650	-45.9478	-45.9913	-46.0580	-46.5222	-45.8414	-45.4503	-45.2827
No. of echoes within 0.21° of centre	340	422	1 274	6 438	279	2	98	17	1 841
On axis TS from beam-fitting	-46.6729	-46.6851	-46.6375	-46.7343	-46.8018	46.3327	-46.2647	-45.9472	-46.0144
Transducer peak gain (dB)	24.74	24.48	24.74	24.71	24.67	24.45	24.79	24.96	25.05
Sa correction (dB)	-0.66	-0.69	-0.67	-0.71	-0.60	-0.49	-0.65	-0.75	-0.69
Beamwidth (º) alongship/athwarthship	7.1/6.8	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	-0.00/-0.00	-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	0.21	0.11	0.13	0.21	0.20	0.20	0.15	0.20	0.22
Number of echoes	23 423	29 780	30 727	23 277	7 362	951	1 416	4 632	19 534

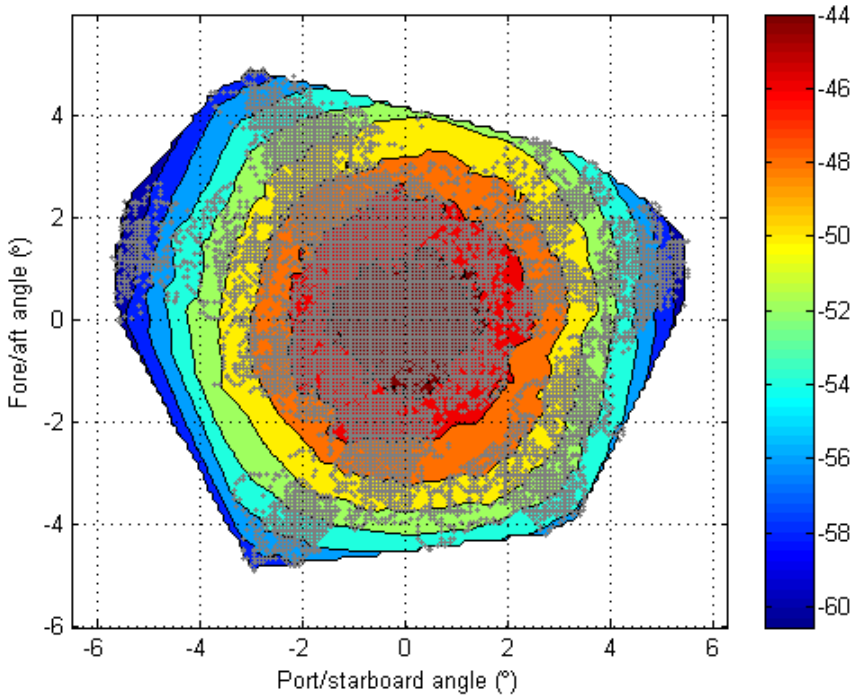


Figure A1. The estimated beam pattern from the sphere echo strength and position for the calibration. The '+' symbols indicate where sphere echoes were received. The colours indicate the received sphere echo strength in dB re 1 m^2.

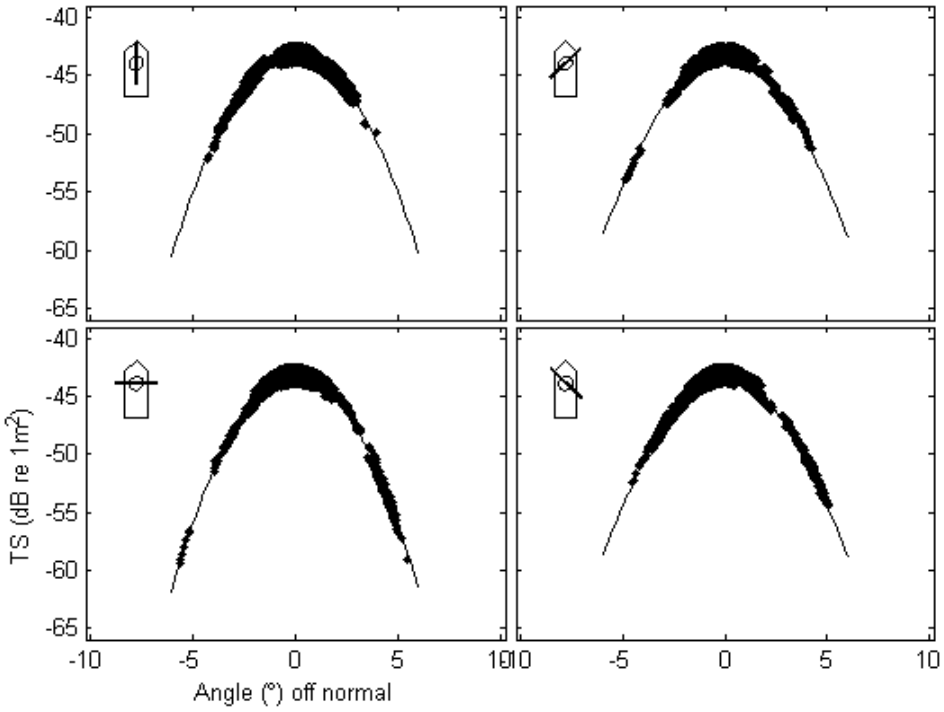


Figure A2. Beam pattern results from the calibration analysis. The solid line is the theoretical beam pattern fit to the sphere echoes for four slices through the beam.

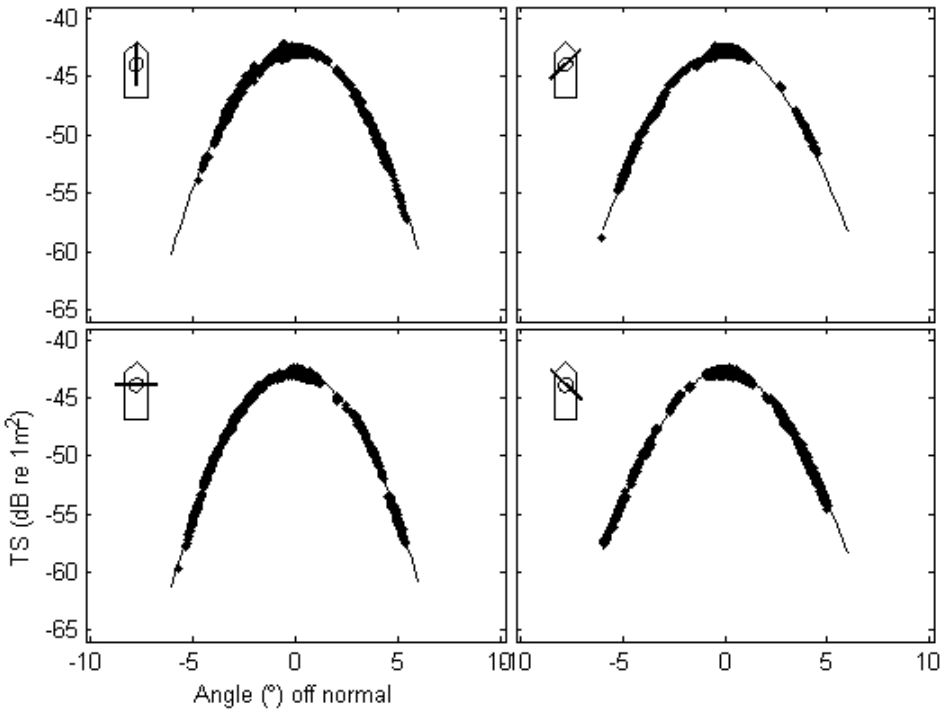


Figure A3. Beam pattern results from the calibration analysis from the ES60 on *Tomi Maru 87* in 2011 (from O'Driscoll 2012). Note the narrower spread of values close to on-axis compared to values in 2012 (see Figure A2).