Ministry for Primary Industries
Manatū Ahu Matua

Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2016

New Zealand Fisheries Assessment Report 2017/20

R.L. O'Driscoll
Y. Ladroit

ISSN 1179-5352 (online)
ISBN 978-1-77665-544-1 (online)

April 2017

New Zealand Government

Growing and Protecting New Zealand

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-and-resources/publications
http://fs.fish.govt.nz go to Document library/Research reports

TABLE OF CONTENTS

EXECUTIVE SUMMARY 1

1. INTRODUCTION 2
   1.1 Project objectives 2

2. METHODS 3
   2.1 Vessel and equipment 3
   2.2 Survey design 3
   2.3 Acoustic data analysis 4
   2.4 Biomass estimation 4

3. RESULTS 5
   3.1 Acoustic data collection 5
   3.3 Acoustic data quality 5
   3.3 Acoustic mark types 6
   3.4 Distribution of SBW backscatter 6
   3.5 Biological data 6
   3.6 Biomass estimates 6

4. DISCUSSION 6

5. ACKNOWLEDGMENTS 7

6. REFERENCES 7

7. TABLES 9

8. FIGURES 13

APPENDIX 1: Calibration Report: *Tomi Maru 87* 16 July 2015 21

EXECUTIVE SUMMARY

O'Driscoll, R.L.; Ladroit, Y. (2017). Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2016.

***New Zealand Fisheries Assessment Report 2017/20*. 24 p.**

The FV *Tomi Maru 87* collected acoustic data along 17 transects in two snapshots on the Bounty Platform on 4–6 September 2016. Both snapshots appeared to adequately cover the main southern blue whiting (SBW) aggregation southeast of the Bounty Islands. The areas covered by the two snapshots (104 km^2 and 112 km^2 respectively) were similar to the surveyed areas in 2014 and 2015. Spawning was very late in 2016, with running ripe females first recorded on 2 September.

Biomass estimates for 2016 were 4813 t (CV 39%) in snapshot 1 and 7589 t (CV 51%) in snapshot 2. The best estimate of SBW biomass in 2016, obtained from the average of the two snapshots, was 6201 t (CV 35%). This was 8% lower than the best estimate of 6726 t (CV 42%) from 2015, continuing the decline since 2013, and the lowest in the industry acoustic time-series which started in 2004. In 2016, acoustic transects crossing the high density aggregation were an average of 6.3 km long, similar to 2015, but shorter than in 2013 and 2014 (when average crossing transects were 8.3 km long), and much shorter than when SBW abundance was estimated to be highest in 2007 and 2008 (crossing transects up to 15 km long).

Data on the size distribution of the fish, collected by Ministry for Primary Industries observers, show that the strong 2002 and 2007 year-classes are still important, but there is also a mode of younger fish from the 2011 and 2012 year-classes caught at 33–38 cm.

1. INTRODUCTION

Southern blue whiting (*Micromesistius australis*) is one of New Zealand's largest volume fisheries, with annual landings of between 25 000 t and 40 000 t since 2000 (Ministry for Primary Industries 2016). 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. 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, 2011, 2013, and 2016. 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 2016).

An acoustic survey of the Campbell Island grounds was carried out 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) (O'Driscoll & Hanchet 2004). O'Driscoll & Hanchet (2004) 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. Surveys of spawning SBW using this approach have been successfully carried out on the Bounty Platform in 2004 and then annually since 2006 (O'Driscoll et al. 2016).

The TACC for the Bounties southern blue whiting (SBW 6B) was increased from a low level of 3500 t to 14 700 t in 2009–10 after a strong year class (2002 cohort) entered the fishery. A large adult biomass was estimated by industry acoustic surveys in 2007 and 2008 but estimates from later surveys were much lower and the TACC has reduced (O'Driscoll et al. 2016). The age structure is still dominated by the 2002 cohort, but there is uncertainty over the current stock size. The acoustic estimate from the most recent survey in 2015 was the lowest in the industry acoustic time-series which started in 2004 (O'Driscoll & Dunford 2017). The SBW6B TACC was reduced to 2940 t from 1 April 2015.

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 that area. The 10-year research programme for deepwater fisheries identified the need for annual acoustic surveys from industry vessels on the Bounty Platform.

1.1 Project objectives

This report is the final reporting requirement for Ministry for Primary Industries research project DEE2016/05. The objective was to analyse acoustic data collected during the SBW 6B aggregation acoustic survey to estimate current stock biomass.

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 a Simrad ES80 echosounder. The Simrad ES80 was installed on *Tomi Maru 87* in May 2016 and is an updated version of the previous ES60 and ES70 echosounders. A new ES38-7 38 kHz split-beam transducer was also installed in May 2016, replacing the ES38B transducer used in previous surveys. This transducer has a different element configuration, and required a new processing card to be installed in the general processing transceiver (GPT). The echosounder system used in 2016 is therefore different from those used in previous Bounty surveys, and represents the start of a new calibration time series.

A calibration of the Simrad ES70 echosounder on *Tomi Maru* took place in the Hauraki Gulf on 25 May 2016. This calibration was carried out with the new transducer and GPT, but with the old (ES70) software. Data collection during the 2016 SBW season was carried out with the new (ES80 version 1.0.0) software which had different transducer configuration settings (Table 1), and a bug which meant that the echosounder was operating in single-beam mode. This meant that results from the ES70 calibration could not be applied to the data. The ES80 echosounder was calibrated off Timaru on 11 January 2017 using the survey settings (Appendix 1).

In a normal split-beam calibration we estimate the target strength (TS) of our calibration sphere for all echoes where the sphere is very close to (typically within 0.2° of) the centre of the beam and use the mean of these echoes to estimate the calibration coefficients. For a single-beam calibration (as was necessary for these data), we do not know the position of the sphere – the only indication that the sphere is closer to the centre of the beam is that its TS increases – and we use the recorded maximum sphere TS to estimate calibration coefficients. Using calibration coefficients based on the maximum sphere TS we get an estimated peak gain (G_0) of 27.54 dB (see Table A3).

The G_0 based on maximum sphere TS will tend to be higher than that based on mean sphere TS (which averages out stochastic variability in on-axis sphere echoes). For previous *Tomi Maru 87* calibrations (with a different ES38B transducer) the difference in G_0 ranged from 0.19 to 0.46 dB, with an average difference of 0.35 dB (see table A3 of O'Driscoll & Dunford 2017). Following discussion at the Deepwater Working Group on 19 January 2017, it was agreed to subtract 0.35 dB from the estimated G_0 to make the 2016 estimates more consistent with previous surveys in the time series which used calibrations based on mean sphere TS. Therefore survey estimates were calculated using a G_0 of 27.19 dB and sa correction of -0.37 dB.

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 vessel officers on FV *Tomi Maru 87* were also personally briefed by Adam Dunford (NIWA) in Timaru on 11 August 2016.

Vessel officers were instructed to collect acoustic data continuously while trawling and searching to allow examination of 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. Previous acoustic surveys of the Bounty Platform have shown that SBW are very hard to survey acoustically during the day (Hanchet et al. 2000), therefore it was requested that all transects be carried out at night.

Clear instructions were also provided on protocols for acoustic data collection, including the 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 ES80 files. Data from acoustic transects were extracted and analysed using NIWA's custom ESP3 software. Echograms were visually examined, and the data groomed by a combination of algorithmic and manual editing. Echoes from the seabed and below were removed, and noise spikes and missing pings were 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. (2002).

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 using an estimated sound absorption of 9.47 dB km^{-1}, which was the same value used for previous Bounty surveys (O'Driscoll 2011a), and was based originally 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 2016. The systematic triangle-wave error found in ES60 and ES70 data (Ryan & Kloser 2004) was not present in ES80 data.

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 2016, estimated from scientific observer data.

Acoustic target strength was derived using the target-strength-to-fork-length (TS-FL) relationship for SBW of O'Driscoll et al. (2013):

$$TS = 22.06 \log_{10} FL - 68.54 \quad (1)$$

where *TS* is in decibels and *FL* is in centimetres. This TS-FL relationship was based on *in situ* measurements made using a net-mounted acoustic-optical system (AOS) on the Campbell Island Rise in 2011 (O'Driscoll et al. 2013), and was adopted for New Zealand SBW in 2012.

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

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

Mean weight and mean backscattering cross-sections were obtained by transforming the scaled length frequency distribution by equations (1) and (2) and then calculating the means of the transformed distributions.

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 CVs 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 CVs 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* after departing Timaru on 13 August 2015 to arriving back in port on 9 September 2016 (Figure 1). The vessel was on the Bounty Platform fishing grounds from 14 August to 6 September 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 (Figure 1).

Seventeen acoustic transects were carried out in two snapshots on the Bounty Platform on consecutive nights on 4–5 and 5–6 September 2016 (Table 2). Both snapshots surveyed the main SBW aggregation southeast of the Bounty Islands (Figure 2). The vessel moved to the east during the fishing season (see Figure 1). This movement pattern is consistent with the migration pattern of spawning SBW on the Bounty Platform in previous years (e.g., O'Driscoll et al. 2016). Transects in both 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 2016 were 104 km^2 and 112 km^2 in snapshots 1 and 2 respectively (Table 2), similar to the surveyed areas in 2015 when four snapshots covered 75–165 km^2 (O'Driscoll & Dunford 2017), and within the range surveyed in previous years when snapshot areas were 10–300 km^2 (O'Driscoll et al. 2016). The spacing between adjacent transects in 2016 was about 2 km, similar to that in 2013–15.

The 2016 survey from 4–6 September was the latest in the Bounty Platform time-series (Figure 3). Between 2004 and 2010 there was a trend in survey dates occurring earlier, but in 2011–15 surveys were later in August (Figure 3). Timing of SBW spawning has also varied between years (Figure 3). In 2016, spawning on the Bounty Platform was very late, with running ripe females first recorded by scientific observers on 2 September, and the proportion of running ripe females not exceeding 10% until 3 September (Figure 3). Despite being very late, the two snapshots in 2016 were therefore within the main spawning period. The survey duration covered by the two snapshots in 2016 (two nights) was lower than in any survey since 2004 (which only had one snapshot), and much less than in 2011 (when snapshots occurred over 13 days), 2012 (9 days), 2013 (8 days), 2014 (7 days), and 2015 (6 days) (Figure 3).

3.3 Acoustic data quality

The quality of the acoustic data from Bounty Platform in 2016 was adequate during both snapshots, but there were some ping drop-outs due to bubble aeration in snapshots, particularly in snapshot 1 (see Figure 4). ES80 transceiver settings and other relevant parameters during data collection (see Table 1) followed recommended protocols.

3.3 Acoustic mark types

Mark identification of adult SBW is relatively certain at the Bounty Platform (Hanchet et al. 2002). Relatively dense adult SBW marks were observed in water depths from 250–350 m in both snapshots (Figure 4).

3.4 Distribution of SBW backscatter

The spatial distribution of SBW along each transect in the four snapshots is shown in Figure 5. As noted in Section 3.1, transects in all snapshots were carried out sequentially from northeast to southwest. Both snapshots appeared to completely cover the main SBW aggregation. There were no, or very low, densities of SBW on the outer transects and at the end of transects (Figure 5).

Moderately high densities of SBW were observed in all snapshots, with peak densities along transect 4 in snapshot 2 and along transect 3 in snapshot 1 (echograms from these transects are shown in Figure 4). The area of SBW marks moved slightly shallower and to the northeast between snapshots 1 and 2 (see Figure 5). In 2016, acoustic transects crossing the high density aggregation were an average of 6.3 km long, similar to transect lengths in 2015, but shorter than in 2013 and 2014 (when average crossing transects were 8.3 km long), and much shorter than when SBW abundance was estimated to be highest in 2007 and 2008 (crossing transects up to 15 km long).

3.5 Biological data

FV *Tomi Maru 87* was one of two vessels fishing for SBW at the Bounty Platform during the 2016 season, and accounted for most of the catch. The mean length of SBW caught by *Tomi Maru 87* was 40.3 cm (Figure 6). Mean weight was 490 g. Mean backscattering cross-section was 0.000495 m^2 (equivalent to –33.1 dB), giving a ratio, *r*, of 990 kg m^{-2}.

3.6 Biomass estimates

Biomass estimates for all Bounty Platform snapshots in 2004–16 are given in Table 3. The variance of snapshot estimates is generally reduced by removing zero transects, but the differences were small. Note that the biomass sometimes changed with exclusion of zero transects as the transect spacing was not always uniform.

Acoustic biomass estimates for the two snapshots in 2016, with zero transects removed, were 4813 t (CV 39%) in snapshot 1 and 7589 t (CV 51%) in snapshot 2. The 'best estimate' for 2016 was the average of both snapshots of 6201 t (CV 35%). The 2016 estimate was 8% lower than the best estimate of 6726 t (CV 42%) from 2015, continuing the decline since 2013, and was the lowest in the industry acoustic time-series which started in 2004 (Table 4). However, industry acoustic surveys do not provide a consistent time-series of SBW abundance on the Bounty Platform (O'Driscoll et al. 2016).

4. DISCUSSION

Acoustic data from the Bounty Platform in 2016 were collected with appropriate acoustic settings and were of adequate quality to estimate biomass. The two snapshots were both in the region to the south of the Bounty Islands where the largest aggregations were observed in 2007–15 (see Figure 2), and appeared to adequately cover the main SBW aggregation. Although spawning was very late at the Bounty Platform in 2016, both snapshots were within the main spawning period (see Figure 3).

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 average natural mortality on the dominant 2002 year-class (Dunn & Hanchet 2015). 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 2010–12, which supported the low biomass observed in 2009 (O'Driscoll 2011b, 2012, 2013). It is still only possible to speculate on the causes of this decline, but suggested causes include an unusually high natural mortality (Ministry for Primary Industries 2013).

The estimated biomass increased by 75% in 2013, but then declined in 2014 to a level below the estimates from 2009–12, and has declined further in 2015 and 2016 (Table 4). It is uncertain whether these recent changes are a function of changes in survey coverage, changes in the spawning population, or both.

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 (O'Driscoll et al. 2016). 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 changes in observed biomass are due to variability in the survey coverage or to real changes in stock size.

Data on the age distribution of the fish from the commercial fishery (Figure 7) show that the strong 2002 year-class was still present in the 2016 fishery at age 14, and that the 2007 year-class (age 9 in 2016) is also important. Length modes from these cohorts have merged, with a modal length of 40 cm for males and 43 cm for females in 2016 (see Figure 6). In 2016, there was also a mode of younger fish at 33–38 cm from the 2011 year-class at age 5 and 2012 year-class at age 4 (see Figure 7).

5. ACKNOWLEDGMENTS

Thanks to Shohei Takeuchi (captain), Hitohiko Ogasawara (fishing master), and the crew of *Tomi Maru 87*, as well as Paul Hufflett, Peter Ballantyne, and Grant Curtis (Solander Fisheries) for their assistance. Figure 7 was produced by Kath Large. Stuart Hanchet reviewed a draft of this report. The work was funded by Ministry for Primary Industries research project DEE2016/05.

6. 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.)

Demer, D.A.; Berger, L.; Bernasconi, M.; Bethke, E.; Boswell, K.; Chu, D.; Domokos, R.; et al. (2015). Calibration of acoustic instruments. *ICES Cooperative Research Report No. 326*. 133 p.

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.

Dunn, A.; Hanchet, S.M. (2015). Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform up to, and including, the 2011 season. *New Zealand Fisheries Assessment Report 2015/55*. 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.

Fu, D.; Hanchet, S.; O'Driscoll, R.L. (2013). Estimates of biomass and c.v.s of southern blue whiting from previous acoustic surveys from 1993 to 2012 using a new target strength – fish length relationship. Final Research Report for Ministry of Fisheries Research Project DEE201002SBWB. 52 p. (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.; 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.; Dunford, A.; Ricnik, A. (2002). 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.

Ministry for Primary Industries (2013). Report from the Fisheries Assessment Plenary, May 2013: stock assessments and yield estimates. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1357 p.

Ministry for Primary Industries (2016). Fisheries Assessment Plenary, May 2016: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1556 p.

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. (2012). Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2011. *New Zealand Fisheries Assessment Report 2012/16*. 26 p.

O'Driscoll, R.L. (2013). Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2012. *New Zealand Fisheries Assessment Report 2013/4*. 26 p.

O'Driscoll, R.L.; Dunford, A.J. (2017). Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2015. *New Zealand Fisheries Assessment Report 2017/19*.

O'Driscoll, R.L.; Dunford, A.J.: Dunn, A. (2016). Industry acoustic surveys of spawning southern blue whiting on the Bounty Platform, New Zealand. *Fisheries Research 178*: 61–70.

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.; Oeffner, J.; Dunford, A.J. (2013). *In situ* target strength estimates of optically verified southern blue whiting (*Micromesistius australis*). *ICES Journal of Marine Science 70*: 431–439.

O'Driscoll, R.L.; Oeffner, J.; Dunford, A.J. (2015). Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2013. *New Zealand Fisheries Assessment Report 2015/01*. 28 p.

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*.

7. TABLES

Table 1: Echosounder settings and other relevant parameters during acoustic data collection in 2016.

Parameter	Value
Echosounder	ES80
GPT model/serial	GPT T38(2)-F1.0 0090720abft4
GPT software version	150.20
Echosounder software version	ES80 1.0.0
Transducer model	ES38-7
Transducer serial number	130
Operating frequency (kHz)	38
Transducer draft setting (m)	0.0
Transmit power (W)	2000
Pulse length (ms)	1.024
Transducer peak gain (dB)	25.5
Sa correction (dB)	0.0
Bandwidth (Hz)	2425
Sample interval (s)	0.192
Two-way beam angle (dB)	–20.7
Absorption coefficient (dB/km)	10.0
Speed of sound (m/s)	1490
Angle sensitivity (dB) alongship/athwartship	28.00/28.00
3 dB beamwidth (°) alongship/athwartship	7.00/7.00
Angle offset (°) alongship/athwartship	0.00/0.00

Table 2: Summary of acoustic snapshots carried out at the Bounty Platform in 2016 by *FV Tomi Maru 87*. Times are NZST.

Snapshot	Area (km^2)	Start time	End time	No. of transects
1	103.5	4 Sep 20:00	5 Sep 00:04	8
2	112.2	5 Sep 20:43	6 Sep 00:40	9

Table 3: Stratum areas, abundance estimates, and coefficients of variation (CV) for all snapshots of spawning SBW on the Bounty Platform carried out by industry vessels from 2004–16. 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. All estimates calculated using the TS-FL relationship of O'Driscoll et al (2013) and re-calculated in 2013 to correct for a bug in the conversion script and inconsistencies in the estimation of calibration parameters (O'Driscoll et al. 2015).

			Calculated areas			Zero transects removed			
Year	Snapshot	No. of transects	Area (km^2)	Biomass (t)	CV (%)	No. of zero transects	Area (km^2)	Biomass (t)	CV (%)
2004	**1**	**5**	69.7	8 572	69	**0**	**69.7**	**8 572**	**69**
2006	**1**	**7**	199.4	12 600	16	**0**	**199.4**	**12 600**	**16**
	2	**5**	286.2	11 298	19	**0**	**286.2**	**11 298**	**19**
	3	4	41.3	1 327	34	0	41.3	1 327	34
	4	4	57.9	4 504	45	0	57.9	4 504	45
2007	1	7	234.5	4 100	38	1	199.0	4 081	35
	2	5	122.6	2 968	35	0	122.6	2 968	35
	3	**5**	250.2	85 700	35	**1**	**218.5**	**89 629**	**29**
	4&5	**10**	435.0	77 339	20	**1**	**417.1**	**68 942**	**20**
2008	**1**	**6**	260.4	119 017	45	**1**	**230.8**	**117 675**	**43**
	2	**5**	229.5	34 123	22	**0**	**229.5**	**34 123**	**22**
2009	M1	11	335.7	6 233	15	0	335.7	6 233	15
	M2	**8**	125.6	20 519	29	**1**	**107.4**	**19 622**	**27**
	1	**3**	232.3	14 067	42	**0**	**232.3**	**14 067**	**42**
	2	**5**	276.2	15 344	45	**1**	**249.9**	**16 230**	**44**
	AB1	7	38.8	3 858	26	0	38.8	3 858	26
	AB2	5	25.1	3 839	29	1	21.9	3 839	23
2010	1	6	52.5	2 770	51	0	52.5	2 770	51
	2	4	38.5	11 504	69	1	29.4	11 951	64
	3	**9**	85.7	17 426	37	**2**	**77.0**	**18 074**	**35**
2011	1	9	118.5	24 948	23	0	118.5	24 948	23
	2	11	136.7	6 762	17	0	136.7	6 762	17
	3	9	83.6	12 724	28	0	83.6	12 724	28
	4	7	53.9	6 614	34	2	43.9	6 614	30
	5	8	80.4	6 208	28	0	80.4	6 208	28
	6	**8**	76.8	14 090	44	**2**	**60.7**	**14 090**	**42**
	7	**8**	104.9	27 889	36	**2**	**91.4**	**27 889**	**35**
	8	9	132.2	6 304	21	0	132.2	6 304	21

Table 3 cntd: Stratum areas, abundance estimates, and coefficients of variation (CV) for all snapshots of spawning SBW on the Bounty Platform carried out by industry vessels from 2004–16. Snapshots in bold were averaged to produce the biomass estimates in Table 4.

			Calculated areas			Zero transects removed			
Year	Snapshot	No. of transects	Area (km^2)	Biomass (t)	CV (%)	No. of zero transects	Area (km^2)	Biomass (t)	CV (%)
2012	1	6	23.9	3 524	49	1	20.3	3 591	45
	2	6	10.2	322	84	1	8.7	336	82
	3	6	17.8	1 771	45	0	17.8	1 771	45
	4	6	16.8	6 213	39	0	16.8	6 213	39
	5*	3	4.6	46	27	0	4.6	46	27
	6	**10**	32.9	16 386	16	**1**	**30.4**	**16 288**	**14**
	7	**8**	20.2	15 093	17	**0**	**20.2**	**15 093**	**17**
	8*	3	16.7	2 029	57	0	16.7	2 029	57
	9	**8**	28.2	17 618	18	**0**	**28.2**	**17 618**	**18**
	10	5	41.2	3 383	14	0	41.2	3 383	14
2013	1	12	259.2	21 051	31	1	251.1	21 051	31
	2	**14**	175.6	44 517	46	**0**	**175.6**	**44 517**	**46**
	3	**10**	204.5	27 972	37	**2**	**170.9**	**27 491**	**34**
	4	**9**	131.7	14 364	36	**3**	**94.0**	**13 592**	**30**
2014	**1**	**8**	127.8	14 542	72	**2**	**107.2**	**14 336**	**72**
	2	**7**	102.3	18 363	70	**1**	**96.5**	**18 437**	**71**
	3	**8**	105.8	8 301	46	**2**	**84.5**	**8 209**	**43**
	4	**8**	142.3	7 732	56	**2**	**117.1**	**7 721**	**54**
	5	**12**	175.8	10 474	48	**2**	**158.6**	**10 458**	**47**
2015	1	13	165.3	5 634	21	0	165.3	5 634	21
	2	**13**	152.5	5 490	40	**0**	**152.5**	**5 490**	**40**
	3	5	74.6	2 809	78	2	54.1	2 771	80
	4	**7**	110.7	7 927	65	**1**	**98.8**	**7 961**	**65**
2016	**1**	**8**	103.5	4 766	42	**1**	**91.7**	**4 813**	**39**
	2	**9**	112.2	7 592	53	**2**	**92.7**	**7 589**	**51**

* Snapshots 5 and 8 in 2012 were aborted due to fish movement or interference from other vessels

Table 4: Estimates of SBW biomass (t) for adult fish from research acoustic surveys of the Bounty Platform in 1993–2001 (from Fu et al. 2013), and 'best estimates' of spawning stock biomass (SSB) from acoustic estimates from industry vessels (with zero transects removed). Estimates in 2006–09 and 2011–16 were obtained by averaging selected snapshots. All estimates calculated using the TS-FL relationship of O'Driscoll et al. (2013).

Year	*Tangaroa* Adult fish	Industry Vessel SSB
1993	43 338 (58%)	–
1994	17 991 (25%)	–
1995	17 945 (23%)	–
1997	27 594 (37%)	–
1999	21 956 (75%)	–
2001	11 784 (35%)	–
2004	–	8 572 (69%)
2006	–	11 949 (12%)
2007	–	79 285 (19%)
2008	–	75 899 (34%)
2009	–	16 640 (21%)
2010	–	18 074 (35%)
2011	–	20 990 (27%)
2012	–	16 333 (7%)
2013	–	28 533 (27%)
2014	–	11 832 (31%)
2015	–	6 726 (42%)
2016	–	6 201 (35%)

8. FIGURES

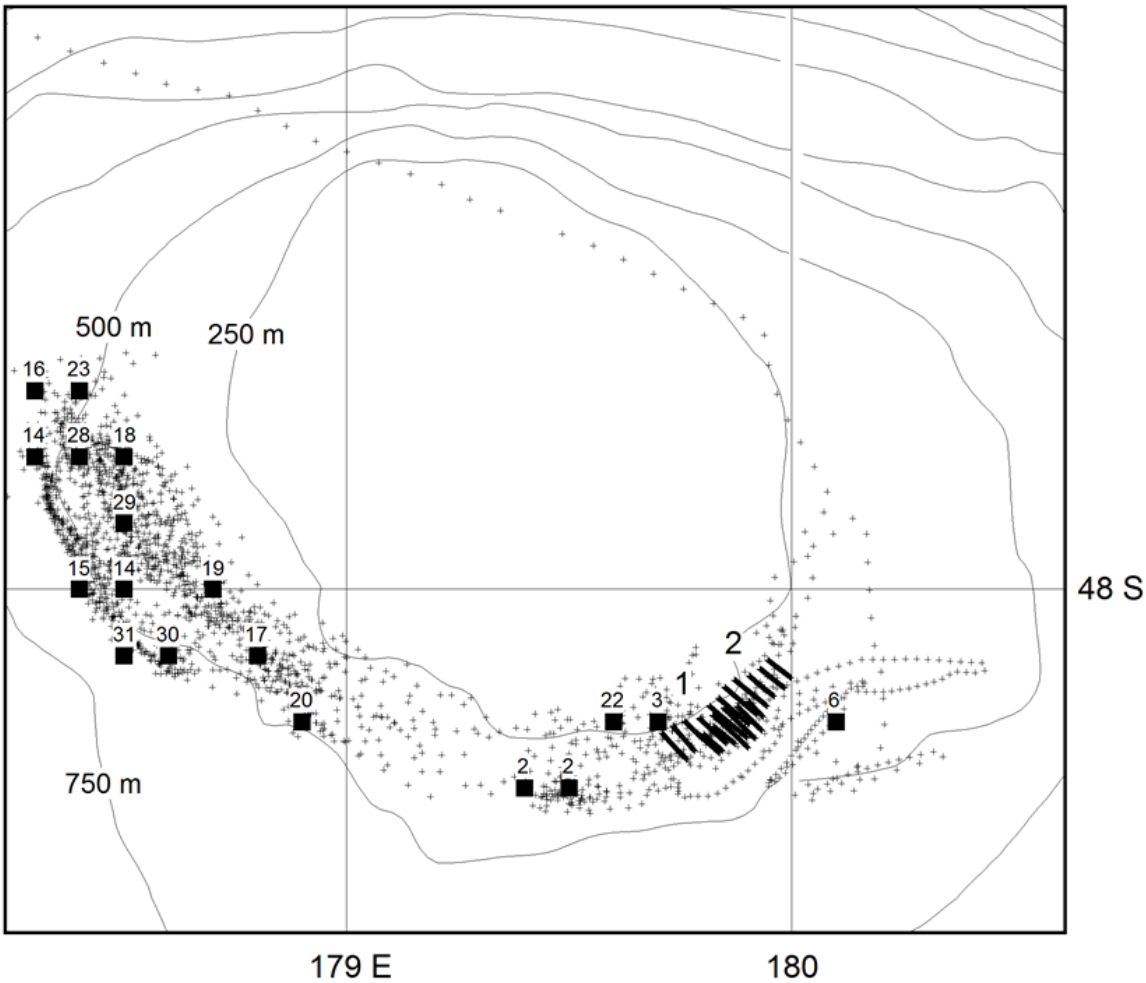

Figure 1: Map showing position of the *FV Tomi Maru 87* at the Bounty Platform in 2016 every 10 minutes from 14 August to 6 September (grey crosses). Solid squares are locations of commercial trawls (plotted to the nearest 0.1 degree), numbered above by date in August or September. Transect locations are shown as black lines, with larger numbers indicating the two snapshots (see Figure 2).

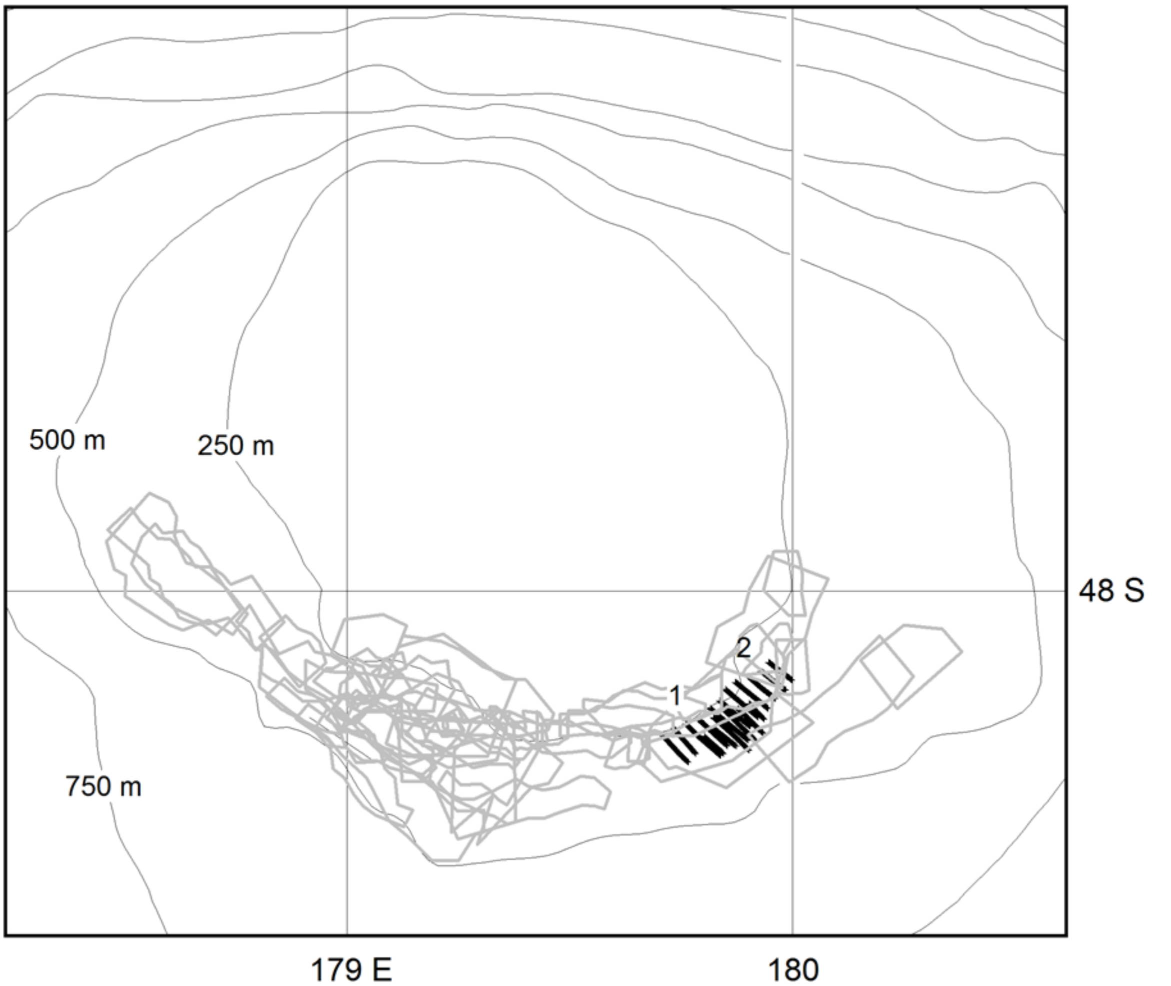

Figure 2: Map showing location of transects carried out in the two snapshots by *FV Tomi Maru 87* at the Bounty Platform in 2016 (black lines). Transect locations are compared with the areas surveyed in 2004–15 (grey polygons).

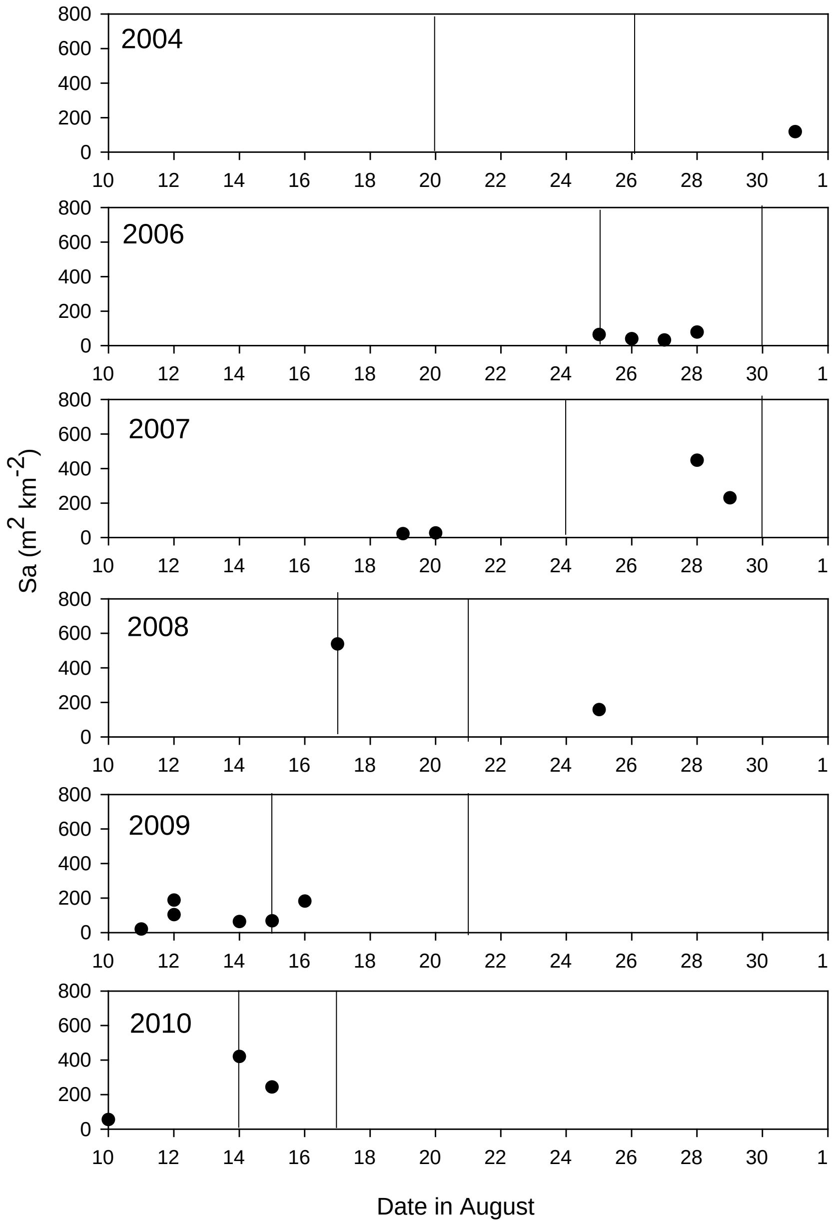

Figure 3: Weighted (by transect length) mean densities for each snapshot (solid circles) plotted as a function of date for all snapshots carried out by industry vessels on the Bounty Platform 2004–10. Vertical lines indicate estimated period of peak spawning based on gonad staging by observers.

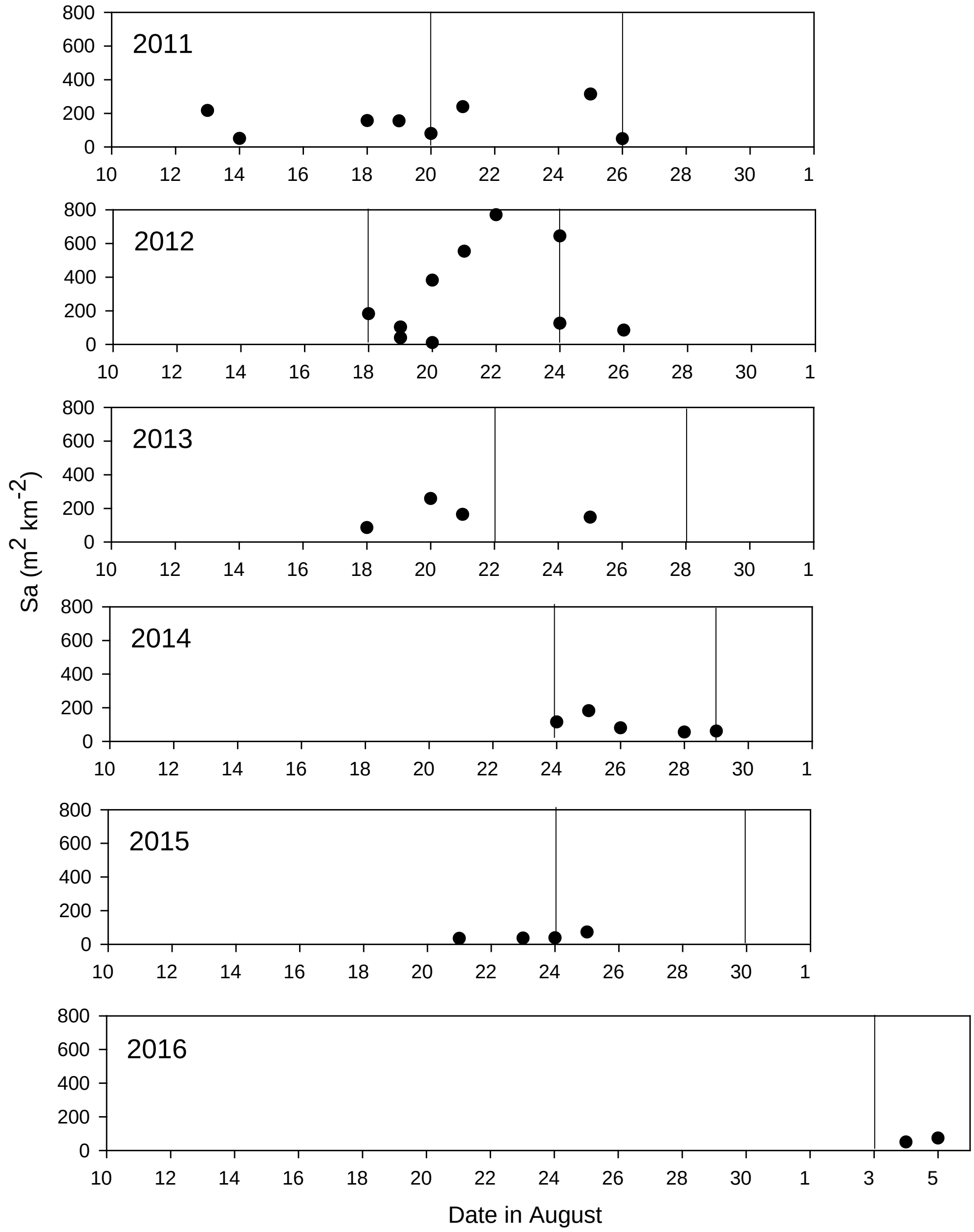

Figure 3 cntd: Weighted (by transect length) mean densities for each snapshot (solid circles) plotted as a function of date for all snapshots carried out by industry vessels on the Bounty Platform 2011–16. Vertical lines indicate estimated period of peak spawning based on gonad staging by observers.

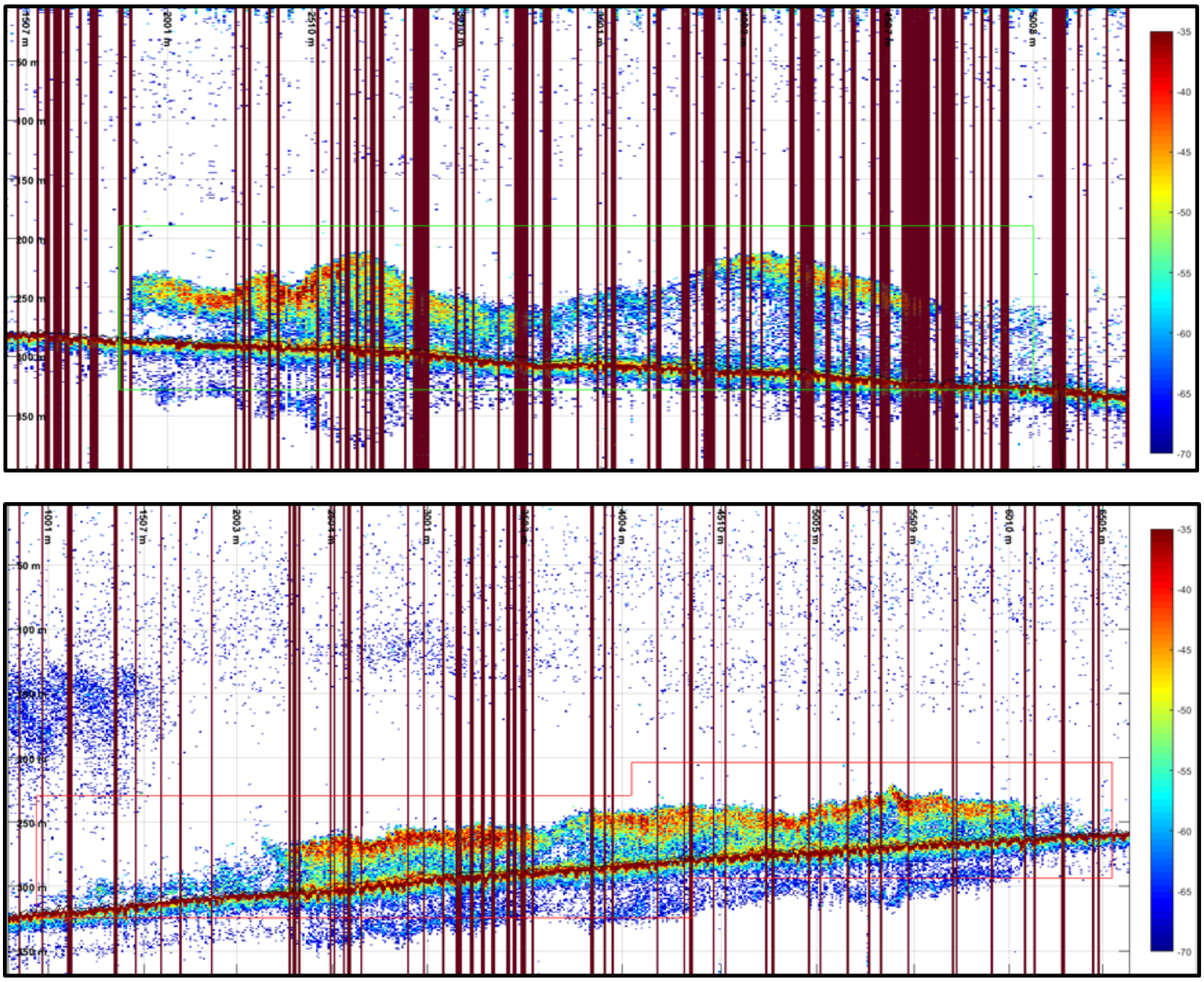

Figure 4: Example of acoustic echogram collected at the Bounty Platform in snapshot 1 on 4 September 2016 (upper panel) and in snapshot 2 on 5 September (lower panel). Red vertical lines are where ping drop-outs due to bubble aeration in poor weather have been removed.

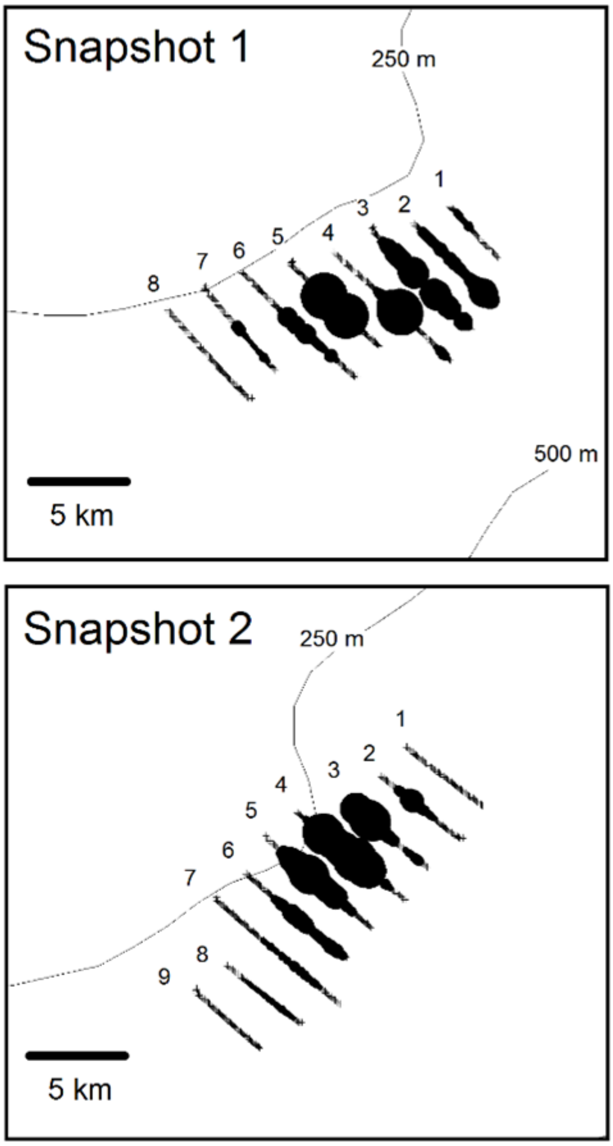

Figure 5: Spatial distribution of SBW backscatter plotted in 10-ping bins for the two snapshots at the Bounty Platform in 2015. Transects are numbered in the order in which they were carried out. Circle area is proportional to the log of the acoustic backscatter. Crosses indicate zero backscatter.

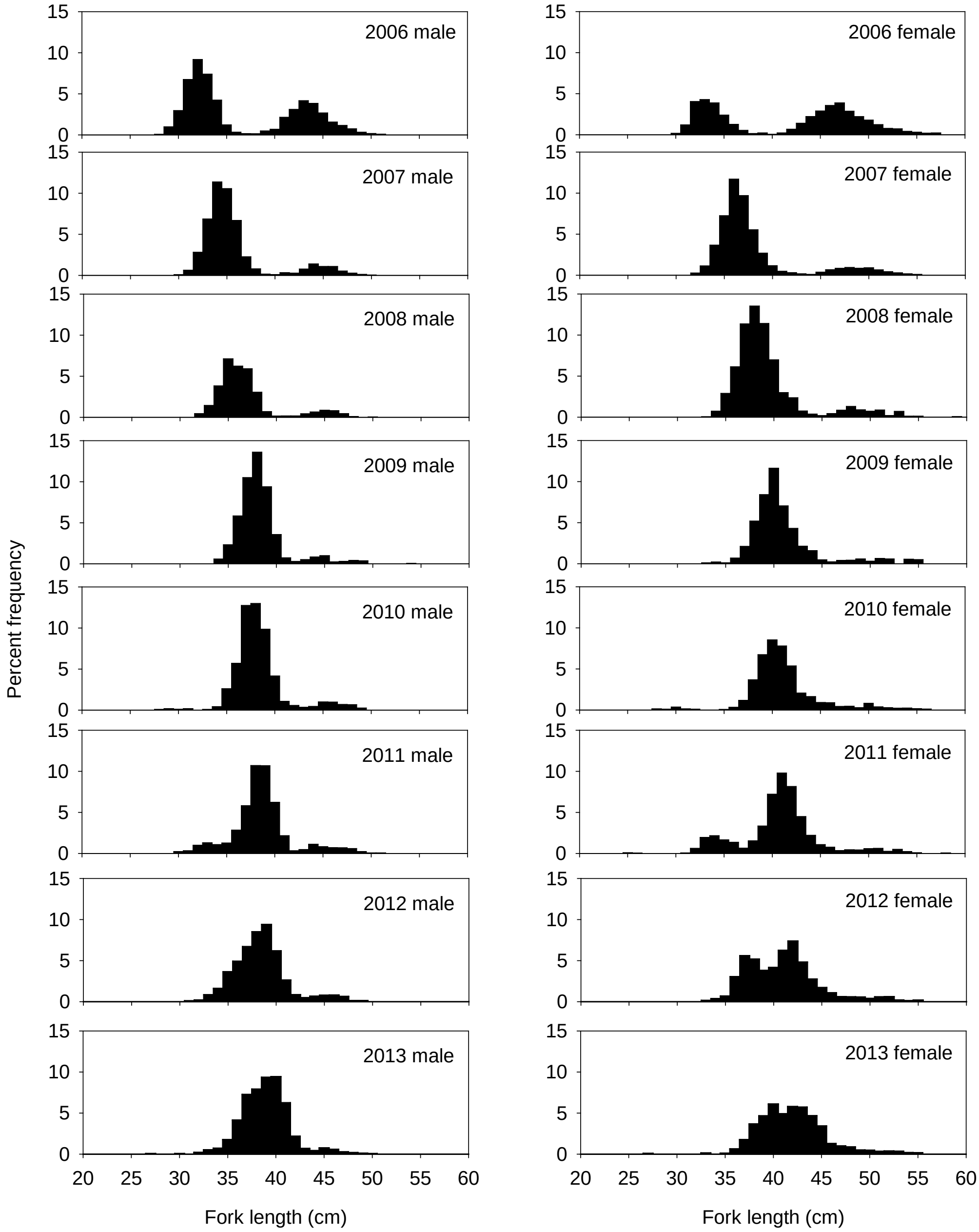

Figure 6: Scaled length frequency distributions of SBW caught on the Bounty Platform by *FV Tomi Maru 87* in 2006–13 based on scientific observer data.

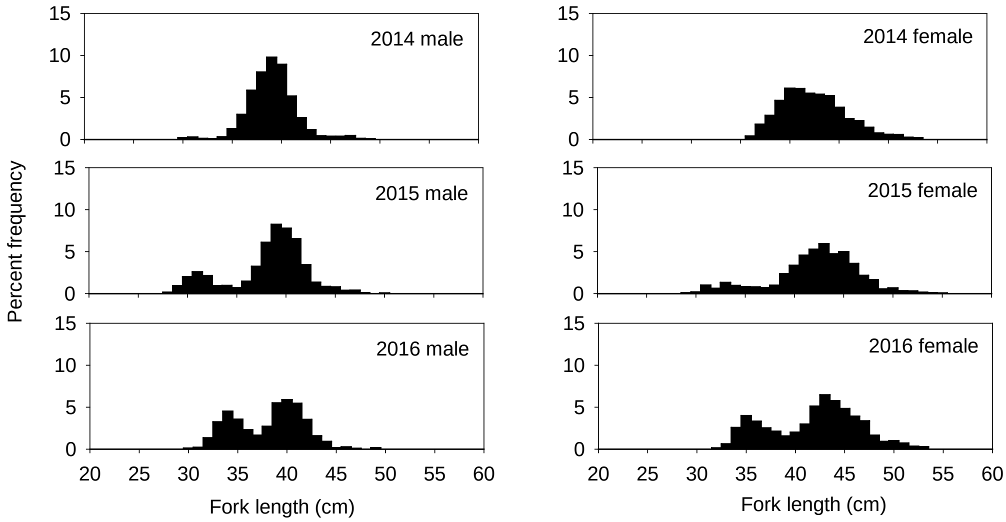

Figure 6 cntd: Scaled length frequency of SBW caught on the Bounty Platform by *FV Tomi Maru 87* in 2014–16 based on scientific observer data. Data from 2016 are from observer trip 4776.

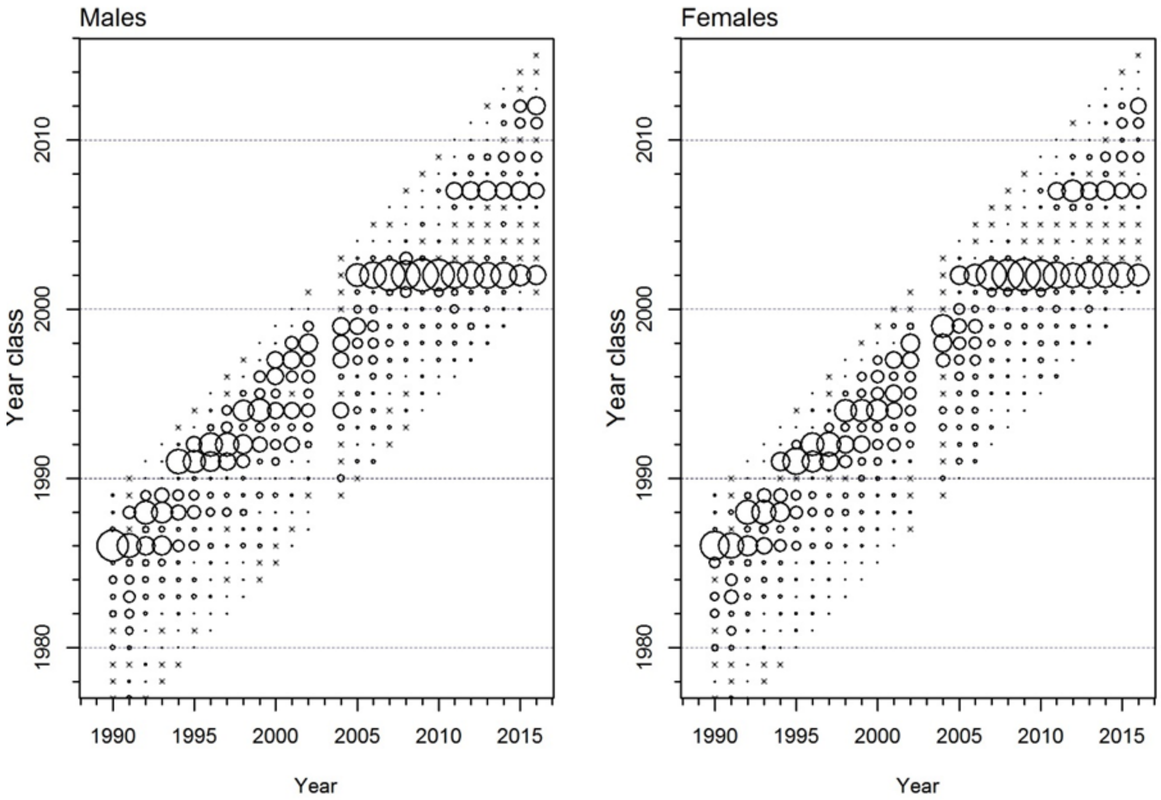

Figure 7: Estimated proportions at age of SBW in the commercial catch from the Bounty fishery 1990–2016.

APPENDIX 1: Calibration Report: *Tomi Maru 87* 11 January 2017

Calibration of the Simrad ES80 echosounder on *Tomi Maru 87* took place off Timaru (44° 24.7’ S 171° 30.4’ E) on 11 January 2017. Water depth was about 31 m (below the transducer). The calibration was carried out by Richard O’Driscoll (NIWA) following the procedures in Demer et al. (2015).

There were 11 calibrations of the previous ES60 and ES70 echosounders on this vessel, with annual calibrations since 2005. In May 2016 the ES38B transducer was replaced with a new Simrad ES38-7 unit which has a different element configuration and required a new processing card to be installed in the GPT. The echosounder system used in 2016 was therefore different from those used in previous Bounty surveys, and represents the start of a new calibration time series. A calibration of the echosounder on *Tomi Maru 87* took place after the installation of the new transducer in the Hauraki Gulf on 25 May 2016. This calibration was carried out with the new transducer and GPT, but with the old (ES70) software. However, data collection during the 2016 SBW season was carried out with newer (ES80 version 1.0.0) software which had different transducer configuration settings (Table A1), and a bug which meant that the echosounder was operating in single-beam mode. This meant that results from the ES70 calibration (see Table A3) could not be applied to the survey data.

Richard O’Driscoll boarded *Tomi Maru 87* from the South Canterbury Coastguard vessel at 07:30 NZDT at the Timaru pilot station, and the vessel steamed to deeper water. The ES80 was configured to survey 38 kHz settings (see Table A1) and the PC time was set to the GPS before the calibration began. The vessel was also fitted with an ES80 70 kHz WBT echosounder and calibration data were also collected for this system, but are not reported here.

The calibration commenced at 08:30 NZDT. 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. The sphere and associated lines were immersed in a soap solution prior to entering the water. A lead weight was also deployed about 4 m below the sphere to steady the arrangement of lines. Because no angle data were available from the 38 kHz echosounder, the sphere was centred in the 70 kHz beam, and was then moved around the beam to obtain data for the beam shape calibration.

The weather was good with light winds and 1 m swell. The vessel was allowed to drift, and the drift speed was about 0.6 knots. The sphere was located in the beam at 09:03 NZDT and calibration data were collected until 09:41 in eight ES80 .raw format files. Raw data are stored in the NIWA *acoustics* database.

Following the collection of calibration data using the 2016 survey settings, a later version of the ES80 software (version 1.1.2) was installed. This was supposed to fix the bug in the earlier software version. However, when the updated software was installed it prohibited the user connecting to the 38 kHz GPT. After consultation with the Simrad agent (Graham Barker) and restarting the GPT and echosounder PC without success, the calibration was finished at 10:51 NZDT and the *Tomi Maru 87* returned to Timaru berthing at about 12:30.

Before leaving the calibration site, water temperature measurements were taken using an RBR 2050 temperature depth probe, serial number 11817. The water column was stratified, with a surface temperature of 16.0º and a temperature at the sphere depth (26 m) of 14.8º. 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 ES80 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.

As noted above, the 2016 survey settings had a bug in the ES80 software that meant that the echosounder was operating in a single-beam mode rather than as a split-beam. This makes analysis of calibration results more challenging. In a normal (split-beam) calibration we estimate the target strength (TS) of our calibration sphere for all echoes where the sphere is very close (typically within 0.2°) of the centre of the beam and use the mean of these echoes to estimate the calibration coefficients. For a single-beam echosounder, we do not know the position of the sphere - the only indication that the sphere is closer to the centre of the beam is that its TS increases - and we use the recorded maximum sphere TS to estimate calibration coefficients.

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 $S_{a,corr}$.

No correction was necessary for the triangle wave error in ES60 and ES70 data (Ryan & Kloser 2004) as this is does not occur in ES80 data.

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 sphere TS in a selected period of the calibration when the sphere was estimated to be close to the centre of the beam (based on the position on the 70 kHz echosounder) is given in Figure A1. The maximum sphere TS was -38.34 dB giving an estimated peak gain (G_0) of 27.54 dB. This estimate should be considered as provisional as we know from experience that there is a difference between calibration parameters calculated with minimum and maximum sphere echoes. The G_0 based on maximum sphere TS will tend to be higher than that based on mean sphere TS (which averages out stochastic variability in on-axis sphere echoes), which means that estimated biomass will be lower. For previous *Tomi Maru 87* calibrations (with a different ES38B transducer) the difference in G_0 ranged from 0.19 to 0.46 dB, with an average difference of 0.35 dB. The G_0 based on maximum sphere TS for the ES80 was within 0.15 dB of the analogous estimate from the calibration of the same transducer and GPT with the ES70 software in May 2016 (Table A3).

The beam pattern could not be determined from the ES80 calibration, but the symmetrical nature of the pattern and the zero centre of the beam pattern in May 2016 (Figure A2) indicate that the transducer and GPT were operating correctly

Table A1: Transceiver settings and other relevant parameters for 38 kHz echosounder during the ES70 calibration in May 2016, and ES80 data collection and this calibration.

Parameter	ES70 25 May 2016	ES80 11 January 2017
Echosounder	ES70	ES80
Software version	Not recorded	1.0.0
Transducer model	ES38-7	ES38-7
Transducer serial number	130	130
ES70 GPT serial number	Not recorded	GPT 0090720abft4
GPT software version	Not recorded	150.20
Sphere type/size	tungsten carbide/38.1 mm diameter	
Operating frequency (kHz)	38	38
Transducer draft setting (m)	0.0	0.0
Transmit power (W)	2000	2000
Pulse length (ms)	1.024	1.024
Transducer peak gain (dB)	25.9	25.5
Sa correction (dB)	0.0	0.0
Bandwidth (Hz)	2425	2425
Sample interval (m)	0.3192	0.256
Two-way beam angle (dB)	–20.1	–20.7
Absorption coefficient (dB/km)	9.75	10.00
Speed of sound (m/s)	1500	1490
Angle sensitivity (dB) alongship/athwartship	27.16/23.52	28.0/28.0
3 dB beamwidth (°) alongship/athwartship	7.20/7.24	7.0/7.0
Angle offset (°) alongship/athwartship	0.0/0.0	0.0/0.0

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

Parameter	Value
Mean sphere range (m)	16.9
S.D. of sphere range (m)	0.04
Mean sound speed (m/s)	1 509
Mean temperature (°C)	15.8
Mean absorption (dB/km)	8.95
Sphere TS (dB re 1m^2)	–42.42

Table A3: Calculated echosounder calibration parameters for *Tomi Maru 87* in 2016–17 based on ES70 calibration on 25 May 2016 and ES80 calibration on 11 January 2017. Values were calculated using EchoAnalysis software. – indicates parameters could not be calculated because ES80 echosounder was operating in single beam mode.

Parameter	11 January 2017	25 May 2016
Echosounder	ES80	ES70
Mean TS within 0.21° of centre	–	-39.80
Std dev of TS within 0.21° of centre	–	0.23
Max TS within 0.21° of centre	-38.34	-39.43
No. of echoes within 0.21° of centre	–	209
On axis TS from beam-fitting	–	-39.76
Transducer peak gain (dB) max TS	27.54	27.39
Transducer peak gain (dB) mean TS	–	27.20
Sa correction (dB)	-0.37	-0.38
Beamwidth (°) along/athwartship	–	6.3/7.5
Beam offset (°) along/athwartship	–	0.00/0.01
RMS deviation	–	0.17
Number of echoes	1 246	1 066

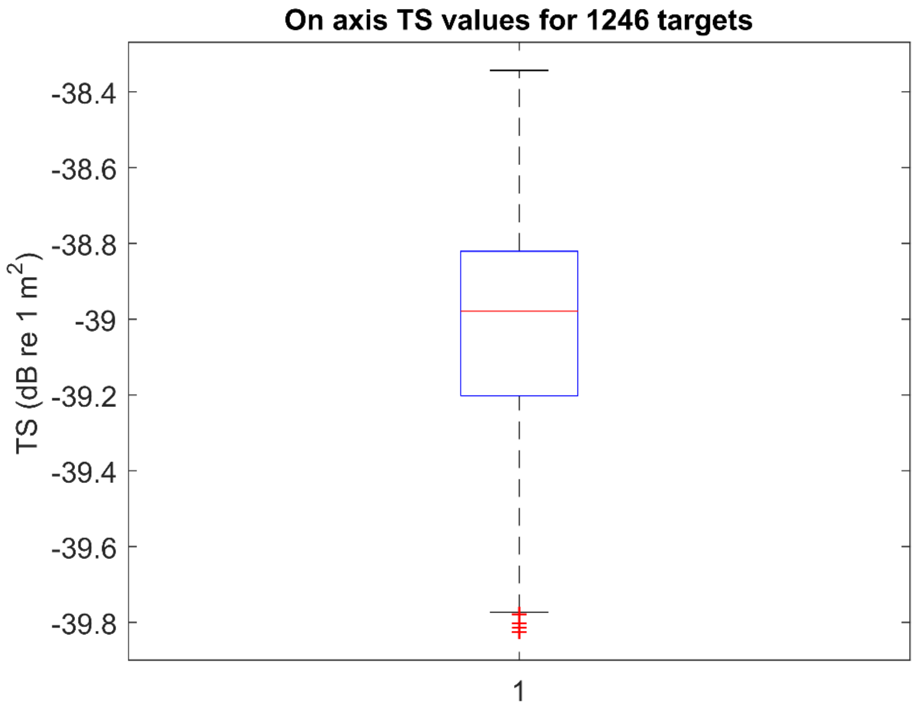

Figure A1. The estimated sphere target strength (TS) from a period of the calibration when the sphere was estimated to be close to on axis at 38 kHz (based on position in the beam of the 70 kHz echosounder).

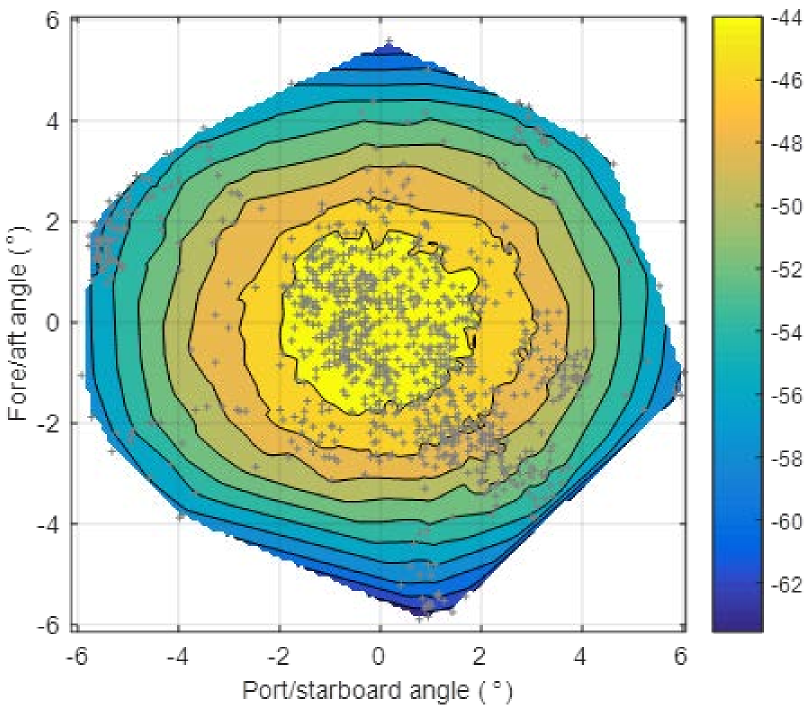

Figure A2. The estimated beam pattern from the sphere echo strength and position for the ES70 calibration on 25 May 2016. The '+' symbols indicate where sphere echoes were received. The colours indicate the received sphere echo strength in dB re 1 m^2.