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Biomass surveys of orange roughy spawning aggregations in Mid-East Coast (ORH 2A South) in June 2017 using a net attached acoustic optical system

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T. Ryan,
R. Downie,
R. Tilney

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EXECUTIVE SUMMARY

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Between 13th and 30th June 2017 a series of acoustic surveys of orange roughy (*Hoplosthethus atlanticus*), complemented by a combined biological trawl sampling programme were conducted in Mid-East Coast (ORH 2A south sub-area) at Sea Valley, Rock Garden, and Tolaga Knoll, with adaptive acoustic surveys of orange roughy habitat undertaken in the wider management area. The primary acoustic instrument was the CSIRO-built, Sealord-owned Acoustic Optical System (AOS) from which biomass estimates were made using both 38 kHz and 120 kHz calibrated frequencies. The multi-frequency AOS was effective in delineating regions of orange roughy from gas bladder species enabling biomass estimation with confident species identification. Vessel-based acoustics were also used to provide sustained observation of fish, and their movement and behaviours, to optimise the utilisation of the AOS for formal transect surveys. Additionally, biomass estimates were made using the 38 kHz vessel acoustics when weather conditions were calm and when orange roughy could be clearly delineated from other sources of backscatter. As far as was possible, surveys were sequenced to coincide with the peak of orange roughy spawning events at each location. A summary of survey outcomes for each key location is given below.

Sea Valley. Significant aggregations of spawning orange roughy were observed over the entire survey period. Biological sampling revealed that spawning condition of aggregated orange roughy varied from running ripe to spawning/spent and then back to running ripe again on the final days of the survey, suggestive of fish turnover during the survey period. Six AOS surveys were carried out at Sea Valley. Biomass estimates of orange roughy ranged from 889 to 7358 tonnes at AOS 38 kHz as the primary measure.

Rock Garden. Spawning aggregations of orange roughy observed by the acoustics at Rock Garden were relatively consistent for the entire survey period but displayed notable diel variation, with detectable schools dispersing during the early morning to daylight period and strong aggregations present between sunset and sunrise. Schools of high-signal, fast moving fish were observed in the vessel echosounder at times while searching. These were thought to be deepsea cardinalfish (*Epigonus telescopus)*, a highly mobile species with a large gas bladder (and therefore high reflectivity) that is found in this region. Multi-frequency AOS was able to clearly delineate orange roughy from other regions of high backscatter. Trawls that focused on likely orange roughy aggregations returned very high proportions of orange roughy.

Five AOS acoustic surveys were carried out at Rock Garden. Biomass estimates ranged from 1697 to 3226 tonnes at AOS 38 kHz as the primary measure.

Tolaga knoll. A small aggregation of orange roughy was observed at this feature where aggregations of gas bladder fish were also common. A single AOS survey was carried out at Tolaga Knoll. The biomass estimate was 419 tonnes for the AOS 38 kHz as the primary measure.

Wide area search. Approximately 65 hours of dedicated vessel-based acoustic surveys of the wider region were conducted between 25th and 27th June. The AOS single pass "survey mode" transects were made on two occasions to identify potential orange roughy marks using multi-frequency acoustics. These marks turned out to be gas bladder species. Apart from this, significant acoustic marks were rare and no orange roughy marks were identified during this search of the greater region. Additional vessel-based searches of the wider region around the key features of Sea Valley, Rock Garden, and Tolaga

Knoll were made opportunistically throughout the survey without locating spawning orange roughy aggregations.

Conclusions, future work, and outstanding issues. The survey programme located and quantified the biomass of spawning orange roughy at three key locations. Wider area searching did not locate orange roughy at other locations. The surveys appeared to be correctly timed with respect to the spawning event, but the variability in spawning progression at Sea Valley in particular underlines the need to allow enough time in the survey for sustained monitoring, to ensure biomass estimates are representative of the spawning population. Larger than expected differences were found between the AOS 38 kHz and 120 kHz biomass estimates for Rock Garden (38 kHz, 45% higher on average, ranging from 30 to 60%). The reasons for this are not clear, but some evidence points to the AOS 120 kHz being low due to calibration issues. This outcome underlines the importance of establishing calibration history for these deeply deployed systems which operate in a rugged environment and through a large range of pressures in their working depths.

1. INTRODUCTION

From 13th to 30th June 2017 a series of acoustic and biological surveys and wide area searches were conducted to quantify the spawning biomass of orange roughy (*Hoplostethus atlanticus*, ORH) in Mid-East Coast (MEC) in the ORH 2A South sub-area. The primary acoustic survey instrument was an Acoustic Optical System (AOS) attached to the headline of the survey vessel's demersal trawl net, which was towed at depth to conduct multi-frequency surveys of aggregating orange roughy. Demersal trawls provided biological samples which were processed to describe species composition and measures of fish length, weight, sex, and spawning condition. During demersal trawls the AOS also provided acoustic target strength (TS) information at 38 kHz and 120 kHz, complemented by video and stereo digital still photographs. During AOS surveys the vessel's calibrated ES60 38 kHz echosounder was running concurrently. A Furuno FCV 30 triple beam echosounder was used during wide area searches for ORH to take advantage of the increased coverage provided by the side-looking echosounder beams. This report details the voyage activities, with a brief overview of observations made at each of the spawning locations, summaries of biological measurements, and acoustic-based biomass estimates.

Overall Objective.

To estimate the abundance of orange roughy in key areas of the ORH 2A South fisheries management area.

Primary Objectives.

1. Quantify the spawning biomass of orange roughy at historically important fishing grounds (Sea Valley and Rock Garden), with a target coefficient of variation (CV) of the estimate of 20–30%.
2. To collect catch composition and other biological data (length, sex, and gonad stage) from the spawning aggregation(s), including otoliths.
3. Conduct a wide area search of the ORH 2A South sub-area and implement adaptive acoustic surveys on any spawning aggregations found.
4. To calibrate the acoustic equipment used in the survey.

Secondary objectives:

1. Calibration of the AOS at depth.
2. Trials of real-time optic fibre capability.
3. Further development of stereo optical methods.

Voyage dates:

Depart:	Nelson, Saturday 13th June 23:30
Arrive:	Nelson, Friday 30th June 06:00
Vessel:	FV *Amaltal Explorer*

The area of survey operations is provided in Figure 1.

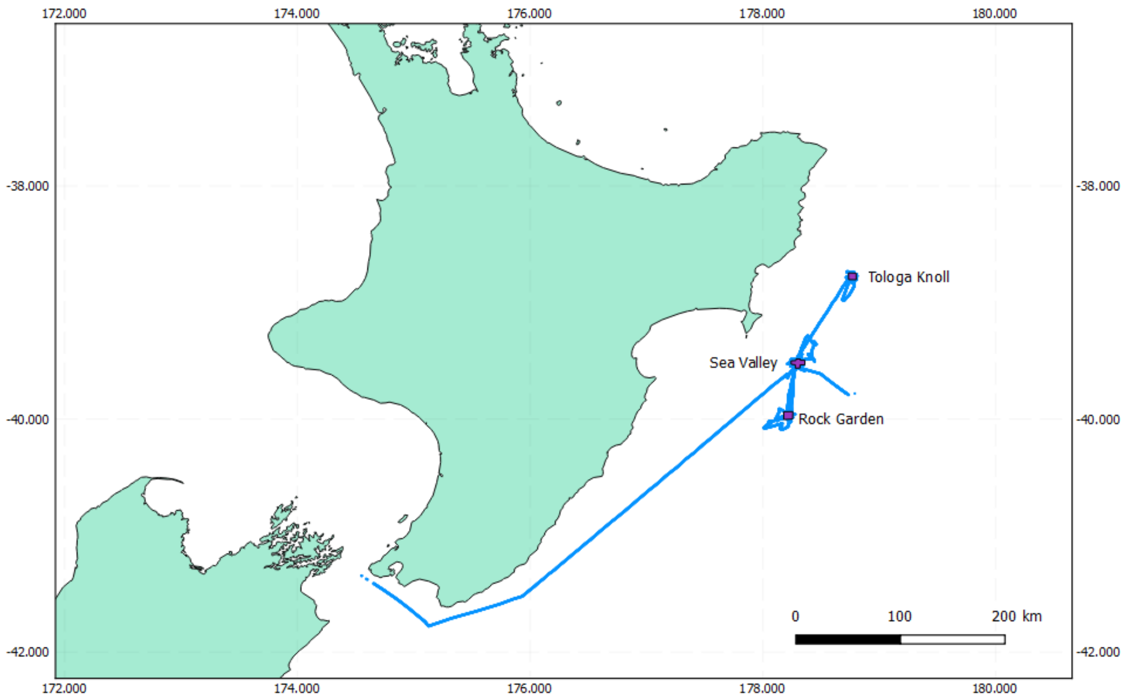

Figure 1: Orange roughy acoustic stock assessment survey track in the ORH 2A South fisheries management area with key survey locations shown.

2. METHODS

2.1 Equipment

2.1.1 Acoustic instrument – AOS

The Sealord Acoustic Optical System (AOS) was the primary survey tool for estimating biomass using echo integration methods. It consisted of a sled-style platform attached to the headline of the vessel's demersal trawl net (Figure 2). This system was built as a collaborative project with Sealord and CSIRO ("Development and application of acoustic-optical technology for sustainable deep-sea fishing"), starting in 2012 and based on previous successful developments and applications in Australia and New Zealand (Kloser et al. 2011a, Kloser et al. 2011b). It is similar in principle to the CSIRO AOS (Ryan et al. 2009), but with technological advances and modifications to improve ease of operation. For this survey, the AOS housed a two-frequency acoustic system (38 kHz and 120 kHz) using Simrad ES60 transceivers. The system was battery powered with all data logged to internal storage media. Specifications of the Sealord AOS system are given in Table 1.

2.1.1.1 AOS calibration

As the final activity of the Mid-East Coast survey, good calibration of the AOS 38 kHz and 120 kHz echosounders was done by lowering the platform to 900 m with a 38.1 mm tungsten carbide reference sphere suspended by thin Kevlar line ~16 m beneath the transducer. The system was deployed in autonomous survey mode, attached to the starboard trawl warp. The system was stopped at 100-m intervals to collect sets of sphere return signals from which the depth-sensitivity relationship of the echosounder system could be characterised to provide correct calibration throughout the range of working depths. A point to note is that the Sealord AOS ES60 38 kHz transceiver failed shortly prior to this calibration exercise which was carried out at the end of the survey program. A spare CSIRO EK60 38 kHz transceiver was installed for the calibration. Thus, the transducer part of the AOS 38 kHz echosounder system was common to both survey and calibration, but the transceiver electronics were different. The expectation is that much of the calibration variation of the AOS 38 kHz is due to changes in transducer characteristics with depth, whereas differences between transceivers should be less significant. To follow up on this question, the Sealord ES60 38 kHz transceiver and CSIRO EK60 38 kHz were tested in Hobart. This involved a wharfside calibration of each of the transceivers that in turn were connected to the same ES38B transducer. Calibration results showed only a slight difference (~0.2 dB, <5%) between the two transceivers. Hence the authors are satisfied that this 'link' between transceivers demonstrates that the calibration results can appropriately be applied to the survey data collected by 38 kHz AOS when the Sealord AOS ES60 38 kHz echosounder was in place. Details of AOS calibration are given in Appendix 1 and summarised in Table 2.

Table 1: Sealord AOS specifications.

Component	Specifications
Physical	Dimensions: 1900 × 1400 × 500 mm, sled-style platform; weight: 750 kg in air; operational depth: 1500 m.
Acoustics	Echosounders: Simrad ES60, 38 kHz and 120 kHz split-beam transceivers. Transducers: 38 kHz - Simrad ES38DD (7° beam width), SN 28363; and 120 kHz - ES120–7CD (7° beam width), SN 115. Simrad ES60 38 kHz and 120 kHz GPTs had new power supplies in 2016.
Video camera	Camera: Hitachi HV-D30P (3° × 1/3" CCD, colour); lenses: Fujion 2.8 mm lens (59° in water); Resolution: 752 × 582 pixels; Format: PAL.
Video capture	AXIS Q7401 Video encoder.
Video Lighting	Two 60 W LED arrays
Digital Stills	Paired Prosillica GX3300 Gigabyte Ethernet cameras with Zeiss F2.8, 25 mm focal length Distagon F mount Lens. Quantum Trio strobe.
Reference scale	Two Laserex LDM-4 635 nm 8 m W red lasers set 400 mm apart.
Environmental	Seabird SBE37si CTD
Computing	Industrial Arc PC (running Simrad ES60 1.5.2 software and providing time-reference for acoustic and video data). Intel NUC i7 computer for Gig-E digital still acquisition.
Motion reference	Microstrain 3DM-GX1
Power	Li-ion. Battery endurance: 18 hours

Table 2: Calibration parameters for AOS 38 kHz and 120 kHz echosounders for Mode 1 echo-integration surveys. Values marked in bold text were applied to the data in Echoview post-processing software.

System	AOS	AOS	Vessel
Frequency (kHz)	38	120	38
Calibration data set	28th June 2017	28th June 2017	28th June 2017
Transducer model	Simrad ES38DD	Simrad ES120-7CD	Simrad ES38B
Serial Number	28363	115	30212 or 30301
Transceiver power (W)	**2000**	**500**	**2000**
Transceiver pulse length	**2.048**	**1.024**	**2.048**
Transducer gain (dB)	**23.757**	**28.27**	**25.165**
Sa correction (dB)	**-0.33**	**-0.63**	**-0.52**

2.1.1.2 AOS Operational modes

The net was deployed and retrieved using the procedures of a routine commercial trawl shot with only minor modifications to accommodate the presence of the AOS. There were two survey modes and a calibration mode (Table 3).

Table 3: Summary of AOS deployment modes

Mode	Objective	Height above seafloor	Comments
1	Echo-integration survey	250–350 m	Parallel or star pattern transect lines
2	Target strength with concurrent optical images, biological samples from research catch	5–30 m	Conventional demersal trawl with net-attached instrumentation
3	Calibration: Transducer sensitivity as a function of depth	0–800 m in 100 m steps	Vertical deployment with AOS detached from net.

Mode 1: Echo-integration surveys

Acoustic echo-integration biomass surveys were done with the AOS attached to the headline of the vessel's demersal trawl net (Kloser et al. 2011a, Ryan & Kloser 2016). These are referred to as Mode 1 surveys. To minimise gear avoidance by orange roughy and deadzone uncertainty, the AOS-net system was towed in midwater at a distance of 250–350 m above the seafloor. Grid transect surveys were applied at Sea Valley because they were appropriate for the distribution of orange roughy aggregations found within a rectangular survey box. At Rock Garden, the recommendations of Doonan et al. (2003a) were followed, where star pattern surveys were appropriate for orange roughy distributed around a central bathymetric feature.

Mode 2: Demersal trawls for target strength, species identification, biological samples

Demersal trawls with the AOS attached were undertaken to provide biological samples. The acoustic systems were set to a short pulse length (0.256 or 0.512 ms) and a fast ping rate (~10 Hz) for close-range fish target strength (TS) measurements. Standard definition video was taken to complement the TS measures. Stereo digital still images from a pair of Prosillica GX3300 Gigabit Ethernet (GigE) cameras, with a frame rate of 1–2 shots per second, were collected throughout these demersal trawls to enable accurate fish length determination.

2.1.2 Real-time fibre-optic connection

During selected operations a fibre-optic "third wire" was attached to the AOS providing real-time Ethernet connectivity. This enabled all acquisition (acoustics, video, and GigE cameras) to be controlled and viewed from a computer installed on the bridge.

2.1.3 Optical instruments – AOS

The Sealord AOS has a wide-angle standard definition, low-light Hitachi video camera with a wide-angle Fujion lens. Two LED lights provide illumination. CSIRO provided a stereo digital still sub-frame system for this voyage. This comprised a pair of Prosillica GX3300 GigE cameras with Zeiss 25 mm focal length F2.8 lenses. Stereo images were illuminated by a Quantum Trio strobe. The stereo cameras operated continuously at 2 frames per second. The AOS components are summarised in Table 1.

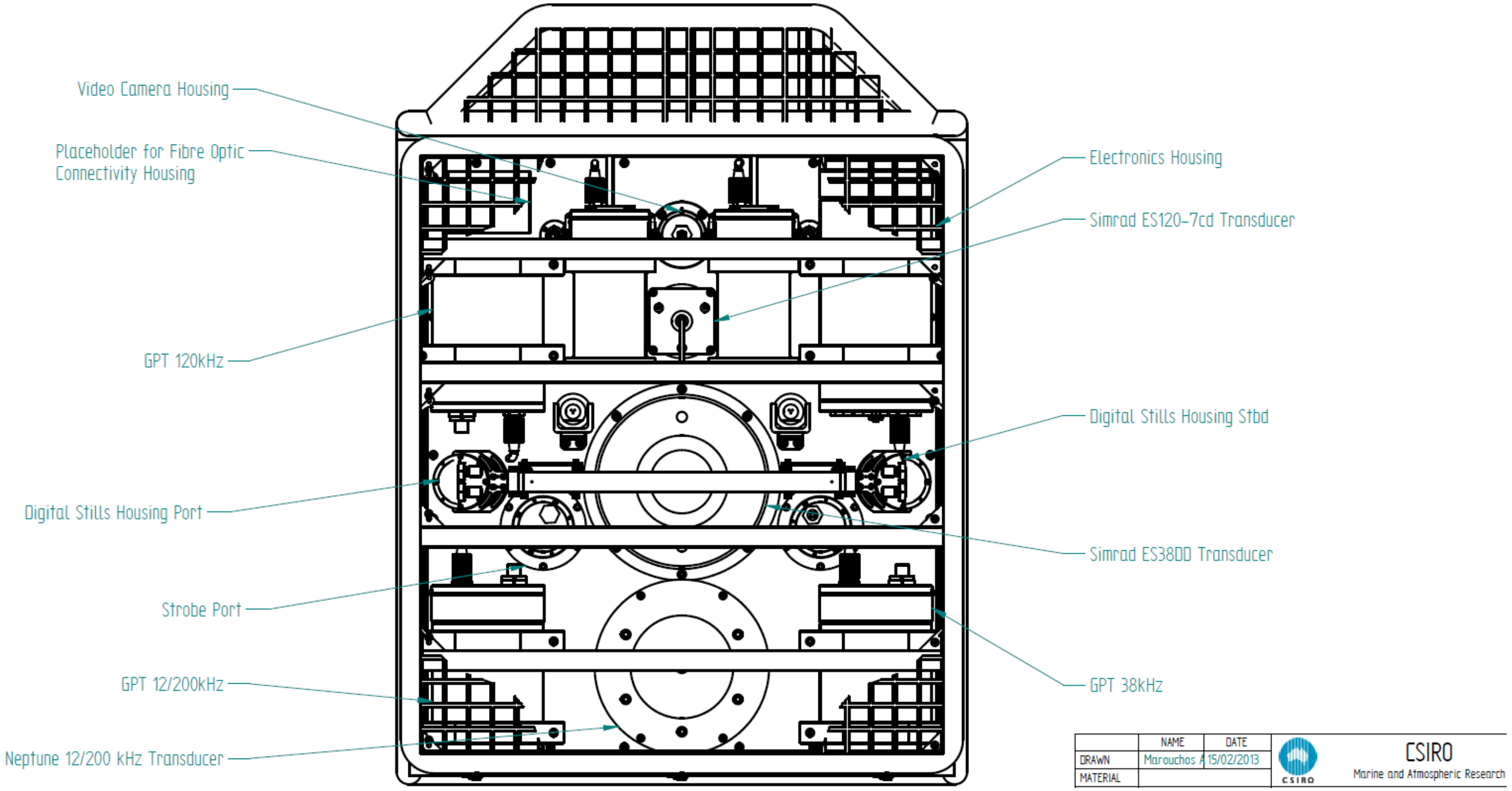

Figure 2: Sealord's Acoustic Optical System.

2.1.4 Acoustic instruments – vessel mounted sounder

The *Amaltal Explorer*'s 38 kHz Simrad ES60 vessel-mounted echosounder provided continuous echogram data to guide AOS and trawl decisions. In calm conditions, Simrad ES60 vessel-acoustic data quality was good, enabling formal echo-integration grid surveys to be carried out for the purpose of biomass estimation. This system was successfully calibrated on 28th June 2017. Details of vessel calibration are given in Appendix 1.

An uncalibrated Furuno FCV 30 triple beam echosounder provided additional observational data. At orange roughy depths (~800 m) this sounder covered a ~250 m "swath" by steering single beams at a 7 degree angle on the port and starboard sides in addition to its downward looking beam. The Furuno sounder was turned off during formal surveys as the additional signal would compromise calibration of the vessel-mounted Simrad ES60 echosounder.

2.1.4.1 Vessel calibration

The vessel's Simrad ES60 38 kHz echosounder was calibrated in open water off the East Coast, North Island, using the standard reference sphere method (Demer et al. 2015) as the penultimate operation of the survey. A 60 mm copper sphere was used as the reference. Details of the vessel calibration are given in Appendix 1 and are summarised in Table 2, and the historical calibration archive is given in Table 4.

Table 4: Historic vessel calibration settings. For each year, the frequency was 38 kHz, the transducer serial number was 30031/30212, the power was 2000 W, and the pulse length was 2.048 ms.

Year	Location	Gain	Sa correction	Overall offset (nominal 26.5 gain) dB
2013	Golden Bay	25.805	-0.482	2.354
2015	Golden Bay	25.695	-0.44	2.49
2016	Golden Bay	25.5	-0.53	3.0
2017	Mid-East Coast	25.165	-0.52	3.7

2.1.5 Acoustics: seawater absorption

AOS acoustics

Values for seawater absorption at 38 kHz and 120 kHz and sound speed were calculated from the equations of Francois & Garrison (1982a) and Mackenzie (1981), respectively, for a nominal platform depth of 600 m and fish school depths of 900 m using measured values of conductivity, temperature, and depth (CTD) data recorded during the AOS deployments (Table 5). The absorption and sound speed values were applied to the data in Echoview post-processing software. A secondary adjustment was made to the echo-integrated data to account for changes in absorption due to the combination of the platform deviating above and below the nominal depth and changes of the range to the fish schools.

Vessel acoustics

Following the protocols of the Fisheries New Zealand Deepwater (Science) Working Group (DWWG), absorption estimates for application to the hull-mounted 38 kHz echosounder were made using the equations of Doonan et al. (2003b).

Table 5: Nominal seawater absorption and sound speed values for a nominal platform depth of 600 m and fish school depths of 900 m.

Parameter		
Frequency (kHz)	38	120
Absorption (dBm^{-1})	0.00928**	0.03131**
Sound speed (ms^{-1})	1500*	1500*

* Nominal Simrad values; ** calculated from CTD data.

2.2 Data processing and interpretation

Processing of the acoustic data was done using Echoview 8 analysis software. Custom Matlab tools were used to extract and process platform depth and motion data embedded in the Simrad EK60 raw files. Platform depth data were applied to the towed body operator in Echoview to create echograms with an absolute depth reference. The AOS platform motion was recorded at 10 kHz by a Microstrain 3DM-GX25 motion reference sensor. These data were applied to the motion correction operator (Dunford 2005) in Echoview to correct for signal loss due to platform motion (Stanton 1982).

2.2.1 Echogram scrutiny and quality control

Calibration offsets given in Table 2 were applied to the 38 kHz and 120 kHz volume backscattering strength (S_v dB re m^{-1}) echograms (Maclennan et al. 2002). The S_v echograms for these two frequencies were visually inspected and regions of noise interference were marked as bad and removed from the analysis.

2.2.2 Acoustic deadzone estimate

The acoustic deadzone is the region close to the seafloor where the acoustic signal cannot be measured due to the physical characteristics of the transmitted pulse (Ona & Mitson 1996) and, on sloping ground, due to seafloor backscatter from the off-axis side-lobe signal coinciding with water column backscatter (Kloser 1996, Ona & Mitson 1996). For the steep-sided features the contribution to the deadzone due to the sloping ground had the greater effect. Orange roughy are a semi-demersal species that can occur at high densities within the deadzone region requiring an estimate to account for this biomass component. Previous acoustic observations of orange roughy schools suggest that scenarios of an increased and decreased density within the deadzone region are both possible. It was assumed that the density of fish immediately above the acoustic bottom was on average representative of the density within the deadzone region.

An estimate of backscatter within the deadzone was made as follows. Firstly an ‘acoustic seafloor’ line was defined, that is the point at which the water column signal became contaminated with the seafloor reflection signal. The acoustic seafloor line was first generated via the maximum S_v seafloor detection algorithm implemented in Echoview v.8.0 software. A back-step of 1.5 m was applied to this line to lift it away from the ‘acoustic seafloor’ signal. This line was visually inspected and manually adjusted if necessary to ensure that contamination by the seafloor signal was avoided. A ‘true seafloor’ line was then defined, based on the maximum S_v value for each ping. The samples between the ‘acoustic seafloor’ and the ‘true seafloor’ are deemed to be the deadzone region. The contaminated sample values in the deadzone region are replaced with an average of the S_v signal in the 5 m immediately above the acoustic seafloor. Two echo-integration signal summations are made: (i) includes only the signal above the acoustic seafloor, i.e., uncontaminated by interference by the seafloor signal and (ii) includes both above acoustic seafloor and the estimated signal from within the deadzone region. From this data biomass estimates for (i) above ‘acoustic seafloor’ and for (ii) above ‘acoustic seafloor’ plus a deadzone component were made.

2.2.3 Platform geolocation

Geolocation was established by applying a time offset between the vessel and the AOS data. The time offset was estimated by inspecting the AOS and vessel echograms, identifying either small terrain features or fish schools, and noting the time difference between the vessel and the AOS as it passes through that same location. Errors in geolocation will occur if either the actual speed/time difference of the AOS differs from the estimated value or if there is an along-track offset between the vessel and the AOS.

2.2.4 Echogram interpretation and allocation of species

Quantitative analysis and subsequent biomass estimation was done for both 38 kHz and 120 kHz. Interpretation of the S_v echograms to partition according to species was a key step in this analysis. Echogram interpretation to distinguish between regions of orange roughy and other species considered multiple lines of evidence. Interpretation was primarily guided by (i) visualising the dB difference across frequencies as a “colour-mixed” echogram (after Kloser et al. 2002), (ii) a synthetic echogram that represents the decibel difference between 38 kHz and 120 kHz according to a colour palette, and (iii) as a graph showing the relative dB values for each frequency. Nominally, regions where mean backscatter was 2–4 dB higher at 120 kHz compared with 38 kHz were attributed to homogenous schools of orange roughy (Ryan & Kloser 2016). Consideration was also given to the depth, location, shape, and texture of echogram regions; echogram regions that are dominated by large high-reflectivity gas bladder fish may be inferred from a more heterogeneous “texture” with higher pixel-to-pixel variability compared with regions of orange roughy. Biological catch composition and inspection of video and GigE still images to identify species obtained during Mode 2 operations were also used to support echogram interpretations. The absolute TS values obtained during Mode 2 operations also provided information regarding the presence of species with certain morphologies, e.g., very high TS values indicating the presence of large fish with a gas bladder.

2.3 Biological sampling

Overarching all activities was a programme of biological sampling. Trawl samples were required for mark identification and collection of biological data and occurred after an acoustic survey of the aggregation had been completed. The catch from each tow was sorted by species to determine catch composition by weight and number of individuals. Orange roughy gonad stages were determined using an 8–stage maturity scale (Pankhurst & Conroy 1987) to monitor the progression of spawning. All catches were sampled for catch composition by weight and number of individuals, and length frequencies of abundant species were determined to provide the biological information required to inform the acoustic data. All vulnerable species (e.g., deepwater sharks) were measured for length and were sexed and staged. From each tow a random sample of up to 100 orange roughy was taken from the catch to record length, gonad development stage, sex, and to collect otoliths. The aim was to collect 500 otoliths from each aggregation. Samples of 20–40 stomachs were examined for stomach content, digestion state, and fullness.

Target identification catches on orange roughy aggregations typically range between 10 and 15 t. However, because the special permit for the survey constrained the allowable catch, extra caution was required to reduce catches to 5–8 t per tow. Catch details are given in Appendix 2.

2.4 Biomass estimation

Biomass estimations were made at both AOS 38 kHz and 120 kHz based on regions that were interpreted to contain only orange roughy, following procedures described in section 2.2.4.

Vessel-based acoustic estimates at 38 kHz were also made where data quality was acceptable. Following protocols of the DWWG, vessel acoustic data were processed without motion correction. Instead, the absorption estimation equation of Doonan et al. (2003b) was used and an empirical correction factor of 1.33 was applied to account for signal loss due to vessel motion and bubble attenuation effects.

Echogram regions of high signal were marked to delineate schooling aggregations from surrounding backscatter and were echo-integrated in 100-m intervals to calculate the nautical area scattering coefficient, s_A (m^2 $n.mile^{-2}$, Maclennan et al. 2002).

Biomass estimations of orange roughy for star pattern acoustic surveys

Star pattern surveys have an uneven sampling intensity, with regions close to the centre of the survey receiving a higher sampling intensity relative to the outer regions (Doonan et al. 2003a). Uneven sampling can result in significant bias depending on the distribution of fish in relation to the centre of the star transect. To minimise the potential for this type of bias, the polar coordinate stratified techniques (Doonan et al. 2003a) were used to estimate the biomass.

Biomass estimation of orange roughy for grid transect acoustic surveys

For larger regions such as Sea Valley where orange roughy locations were not centred around a single feature, parallel transect surveys were the most appropriate choice. To minimise possible bias due to fish movement orthogonal to transect lines, an “interlaced” survey pattern was followed. This involves a set of transects being completed with a certain inter-transect spacing (Survey A). A second set of transects are then completed in the reverse direction that are offset at half the inter-transect spacing of the first set of transects (Survey B). Survey results are combined by calculating the geometric mean of the biomass estimated from the two sets of transects: Combined biomass = √(Survey A biomass * Survey B biomass). Biomass estimates were calculated for 120 kHz and 38 kHz data acquired from the AOS and vessel acoustic data using standard echo-integration methods (Simmonds & MacLennan 2005).

The scattering coefficients were averaged to give a mean s_A for the survey region ($\overline{s_A}$). This parameter and estimates of mean population target strength ($\overline{TS}$, dB re 1 m^2), mean population fish weight ($\overline{W}$, kg), and measurement of the survey area (A, $n.mile^2$) were used to estimate orange roughy biomass (Equation 1). Population sex ratio was assumed to be 1:1 when estimating $\overline{TS}$ and $\overline{W}$.

$$B = \frac{\overline{S_A} \times \frac{\overline{W}}{1000} \times A}{4 \times \pi \times 10^{\frac{\overline{TS}}{10}}} \qquad \text{(tonnes)} \qquad \text{Equation 1}$$

The echogram-defined school regions were assumed to comprise 100% orange roughy. The associated survey sampling CV was calculated using intrinsic geostatistical methods implemented in the *R* software package *RGeostats*.

2.4.1 Target strength estimates

Orange roughy TS estimates used were from Kloser et al. (2013), based on a mean fish length of 34.5 cm. Values of -52.0 dB and -48.17 dB were used for 38 kHz and 120 kHz, respectively, noting that the 120 kHz estimate was adjusted from the Kloser et al. (2013) value of -48.7 dB to match the AOS calibration of this voyage which used a theoretical sphere TS value of ~-39.5 dB. A secondary adjustment was made to the nominal TS to scale values to the fish standard length (SL) observed at each spawning ground, assuming a TS–length slope of 16.15*log10(Ls) (Hampton & Soule 2002).

3. RESULTS & DISCUSSION

3.1 Sea Valley

3.1.1 Summary of survey programme

The Sea Valley region was surveyed for spawning aggregations of ORH between 16th and 28th June 2017. Methods used to quantify spawning aggregations of orange roughy include AOS acoustics and optics, vessel acoustics, and conventional extractive net sampling. The Sea Valley region is a gently sloping basin-shaped feature that is approximately 15 n.mi^2 in area, centred around 178°17.67 E, 39°31.2 S. Six AOS acoustic surveys, five vessel acoustic surveys, and ten biological shots were completed.

The initial acoustic searches conducted in fine weather failed to locate any substantial aggregations of orange roughy and the very first trawl shot to verify small acoustic marks had an unexpectedly high proportion of spawning orange roughy, suggesting the survey may have been late. This initial impression turned out to be a function of the dynamics of orange roughy spawning rather than marking the end of the spawning event. Sustained acoustic and biological monitoring throughout the 13-day survey found substantial aggregations of spawning orange roughy in the region (Figure 3), and multiple interlaced grid surveys were conducted.

During the first of the surveys on 20th June a 5-transect interlaced AOS survey was conducted providing high quality 38 kHz and 120 kHz acoustics data on multiple transects. Given the continued presence of strong orange roughy aggregations, a second AOS survey was conducted in close succession, after biological sampling to verify taxonomic composition of the aggregation and spawning condition. During the second survey on 20th June peak biomass of ORH aggregations were observed. Biological sampling revealed around 50–70% of female gonads were in ripe condition at this time.

During the third and fourth surveys on 23rd June a substantial reduction in biomass was observed and reproductive state had progressed with 60–80% of females spawning and up to 30% in spent condition. Counter to expectations, on 27th June, significant marks were again observed in the Sea Valley region and a 4 transect AOS grid survey observed increased biomass of orange roughy aggregations compared with AOS surveys four days earlier. Further to this the reproductive state of females indicated that 40–50% were spawning and only a very low percentage of spent fish were observed.

In summary, the surveys at Sea Valley collected a series of high quality acoustic survey data complemented by a comprehensive biological sampling programme. Table 6 details the survey activities carried out at Sea Valley.

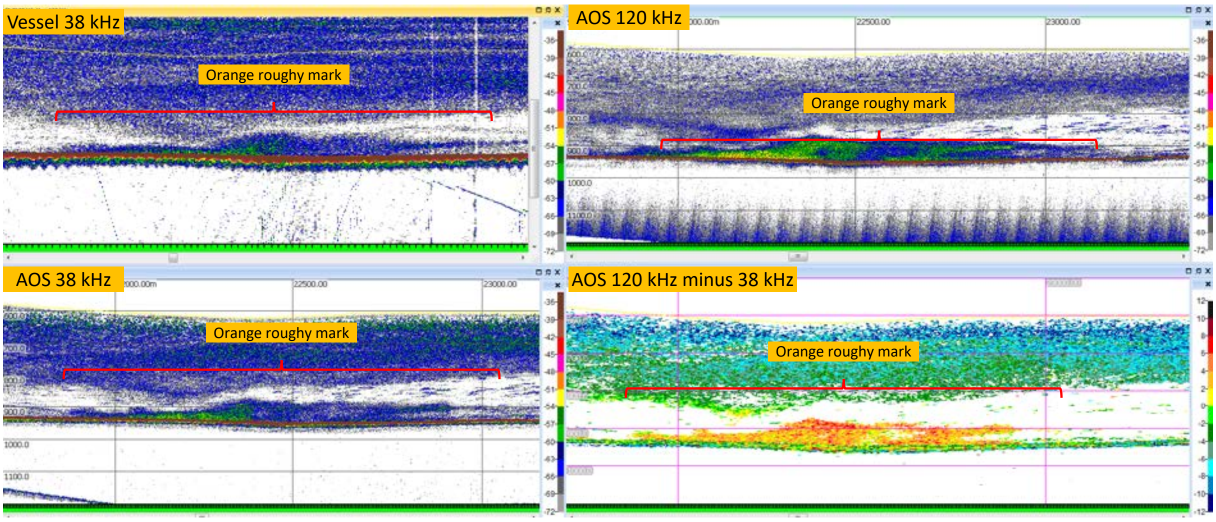

Figure 3: A large aggregation of orange roughy at Sea Valley with an adjacent region of backscatter dominated by gas bladder species. Colour scale on bottom right image indicates Sv_{120-38} where yellow-orange regions show a higher signal on 120 kHz allowing the region to be classified as orange roughy.

Table 6: Vessel and AOS surveys at Sea Valley.

OP number	Operation type	Start date UTC)	Start time (UTC)
2	Vessel Survey	15/06/2017	6:33:00
3	Vessel Survey	15/06/2017	11:27:00
4	AOS Survey	15/06/2017	14:38:00
6	Vessel Survey	16/06/2017	8:00:00
7	AOS Survey	16/06/2017	11:15:00
17	Vessel Survey	18/06/2017	1:22:00
33	Vessel Survey	20/06/2017	1:40:00
34	AOS Survey	20/06/2017	5:40:00
37	AOS Survey	20/06/2017	19:05:00
45	AOS Survey	23/06/2017	0:52:00
47	AOS Survey	23/06/2017	11:27:00
62	AOS Survey	27/06/2017	6:45:00

3.1.2 Biological results

Ten target identification tows at Sea Valley yielded a total of 56 t of fish and confirmed a high percentage of orange roughy (99%). The bycatch by weight comprised mainly sharks (shovelnose spiny dogfish, Plunket's shark, and seal shark), ribaldo, hoki, Johnson's cod, and javelin fish (Figure 4). A list of all species caught at Sea Valley is provided in Table 17 of Appendix 2.

<u>Orange roughy size frequency</u>

The mean standard lengths and weights were 35.7 cm and 1.643 kg for females and 33.8 cm and 1.304 kg for males. Mean standard lengths and weights for sexes combined were 34.9 cm and 1.491 kg (Figure 5).

<u>Spawning progression</u>

The survey at Sea Valley observed three phases of active spawning. At survey commencement, on 16th–17th June, > 50% of female gonads were mature or ripe and 40% were spawning. Following a four-day interval the percentage of fish spawning declined to < 20% on 21st June, then increased to 80% on 23rd June. Five days later, on 28th June, 39% of females were in spawning condition and the incidence of ripe fish had increased to 53%, suggesting there was turnover of fish in the aggregation (Figure 6).

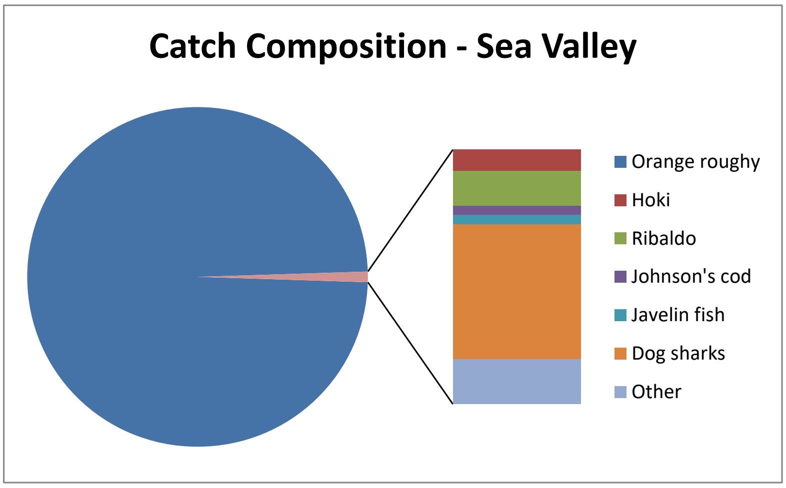

Figure 4: Catch composition at Sea Valley. Orange roughy comprised 99% of total catch.

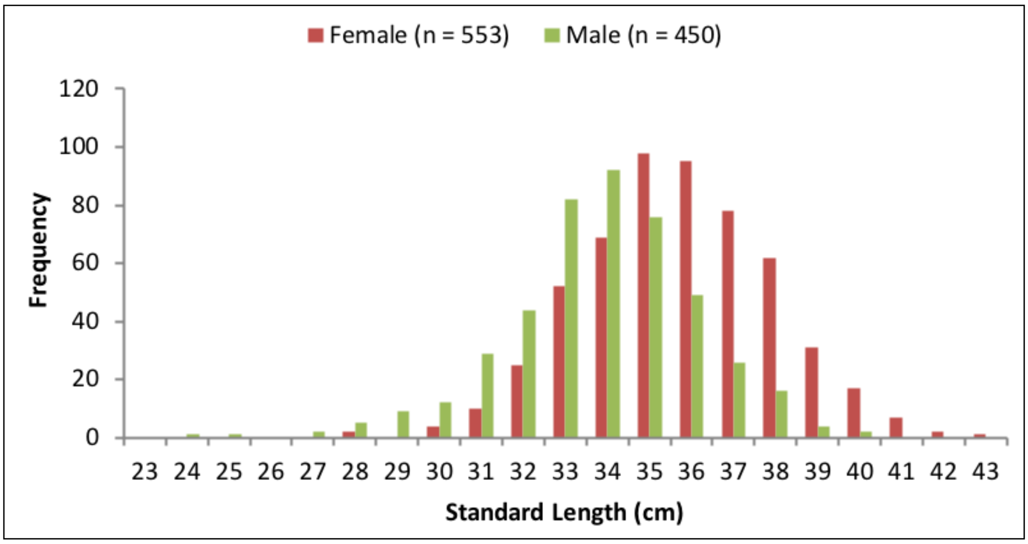

Figure 5: Orange roughy size frequency distribution (unstandardised) - Sea Valley.

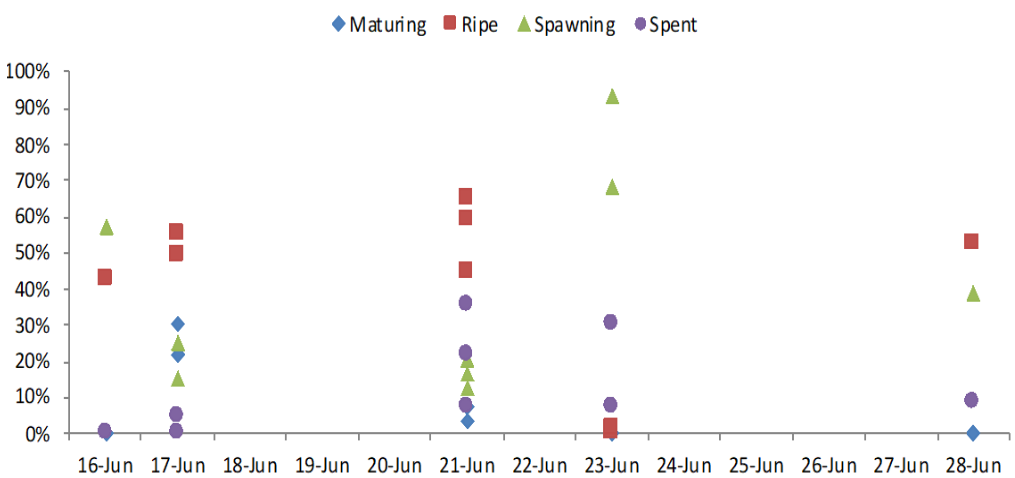

Figure 6: Orange roughy female spawning progression – Sea Valley.

Sex ratio
The sex ratio in catches was highly variable throughout the survey, ranging between 98% females and 93% males. The overall sex ratio for the 10 tows was 55% females:45% males. There was no obvious link between sex ratio in catches and diurnal cycle (Figure 7).

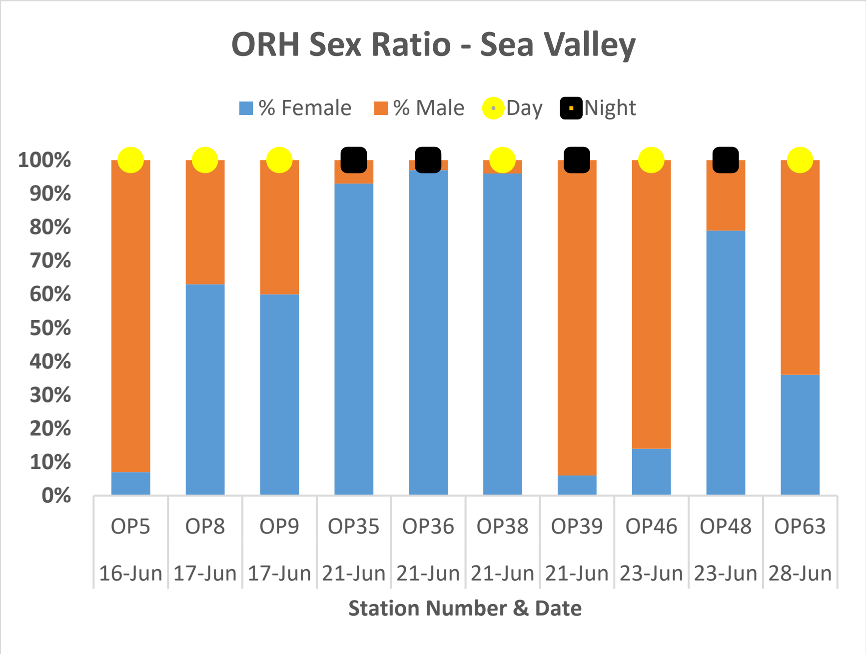

Figure 7: Orange roughy sex ratio in catches at Sea Valley in relation to the diurnal cycle.

Otolith samples
A total of 600 orange roughy otolith samples were collected from the Sea Valley aggregation.

3.1.3 Acoustic biomass estimates

Snapshot acoustic biomass estimates at Sea Valley that are recommended for consideration in the stock assessment process are presented in Table 7, in bold text. These surveys were considered to have suitably low bias and error due to species uncertainty, data quality, and other sources of error. Vessel surveys were selected for analysis only when sea conditions were calm with corresponding high data quality and when orange roughy schools could be clearly delineated from surrounding backscatter.

Biomass estimates are summarised graphically in Figure 8. Figures 21–25 in Appendix 3 display thematic maps of school distributions. Including the deadzone biomass component, total biomass ranged from 889 to 7350 tonnes as the primary measure based on the AOS 38 kHz acoustics. Biomass estimates at 120 kHz ranged from 876 to 5905 tonnes. Vessel-based estimates were made from vessel acoustics collected in calm weather during AOS grid surveys. These ranged from 1087 to 2574 tonnes. These are a factor of 4.5 and 3 less than the associated AOS 38 kHz estimates, for reasons that are unclear.

Table 7: Biomass estimates based on AOS and vessel echo-integration surveys carried out at Sea Valley in June 2017. Estimates recommended for consideration in the stock assessment process are shown in bold. (NASC, Nautical Area Scattering Coefficient.)

Date	Platform	OP	Frequency	Survey area	Mean NASC	Biomass above acoustic bottom (tonnes)	CV	Deadzone estimate (tonnes, % of total)	Total biomass (Geometric Mean, tonnes)	Total biomass (Arithmetic mean, tonnes)
20-Jun	Vessel	34	38	5.1	11	1000	0.2	87 (8%)	1087	1089
20-Jun	AOS 120	34	120	5.1	50	**2847**	**0.40**	**628 (18.1%)**	**3475**	**3598**
20-Jun	AOS 38	34	38	5.1	39	**3589**	**0.46**	**919 (20.4%)**	**4508**	**4714**
20-Jun	Vessel	37	38	4.7	25	1982	0.2	592 (23%)	2574	2584
20-Jun	AOS 120	37	120	6.6	72	**4471**	**0.40**	**1434 (24.3%)**	**5905**	**5910**
20-Jun	AOS 38	37	38	6.6	51	**5251**	**0.46**	**2107 (28.6%)**	**7358**	**7362**
23-Jun	AOS 120	45	120	4.4	14	**783**	**0.54**	**92 (10.5%)**	**876**	**1968**
23-Jun	AOS 38	45	38	4.4	13	**821**	**0.59**	**69 (7.8%)**	**889**	**2469**
23-Jun	AOS 120	47	120	5.1	28	**1179**	**1.21**	**850 (41.9%)**	**2030**	**2202**
23-Jun	AOS 38	47	38	5.1	16	**1403**	**1.69**	**1103 (44%)**	**2506**	**2844**
27-Jun	AOS 120	62	120	6.7	60	**3010**	**0.41**	**128 (4.1%)**	**3138**	
27-Jun	AOS 38	62	38	6.7	21	**2542**	**0.40**	**118 (4.4%)**	**2660**	

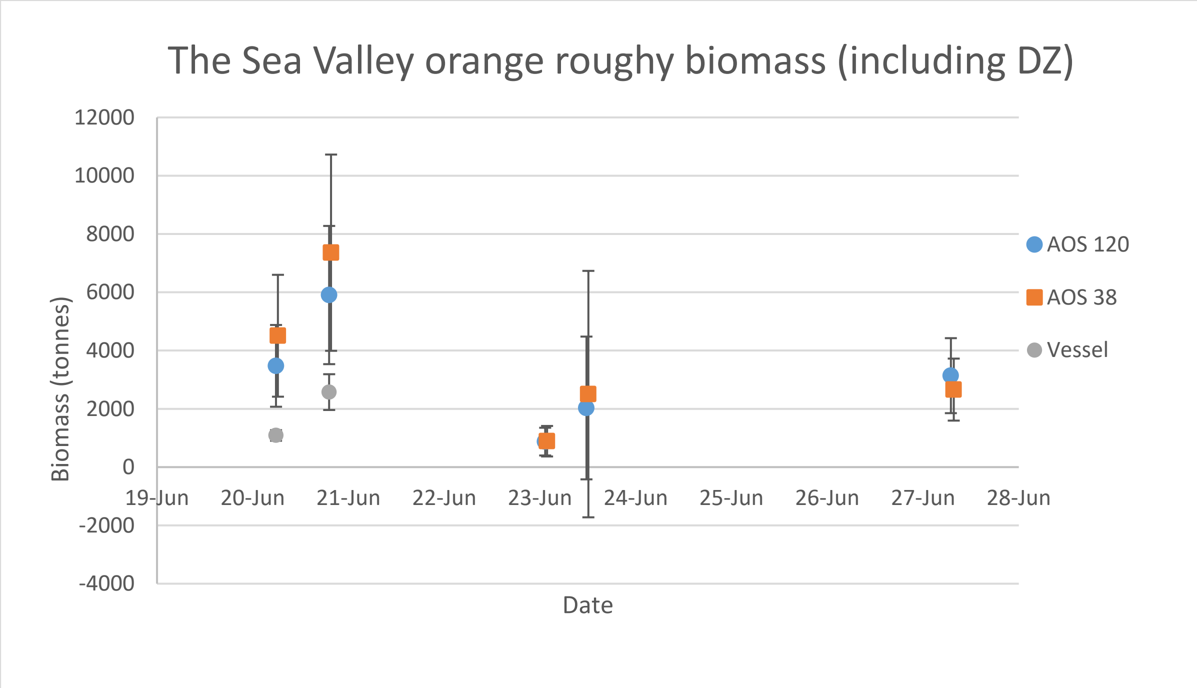

Figure 8: Biomass estimates for AOS 38 kHz and 120 kHz and vessel 38 kHz at Sea Valley. Error bars are +/- 1 sd. Dates for AOS 38 are slightly offset from AOS 120 so that error bars for both frequencies are visible.

3.1.4 Discussion

Orange roughy aggregations were consistently located in the centre and on the eastern side of the Sea Valley basin throughout the survey period. Identified orange roughy aggregations were robustly identified in AOS 38 kHz and 120 kHz acoustics using discrimination techniques described above. Biological sampling observed three phases of active spawning throughout the survey. Whether the changes in spawning condition explains the range of observed biomass estimates is not clear. Multiple observations found the orange roughy aggregations to be quite dynamic. It is therefore not surprising that there was a corresponding variability in biomass estimates. Sustained observation and sufficient time to carry out multiple surveys are important to obtain representative estimates of the spawning population.

3.2 Rock Garden

3.2.1 Summary of survey programme

Rock Garden is a ridge feature located 27 nautical miles south of Sea Valley. Its area is 3 by 3 nautical miles centred around 178° 13.6 E, 39° 58.56 S. During the course of the voyage five AOS surveys, three vessel-acoustic surveys, and seven trawl shots were completed here.

Strong diel variation in orange roughy spawning aggregations was observed during the survey at Rock Garden. In most instances the acoustic surveys were of a single large aggregation of orange roughy where star pattern surveys were employed as an optimal sampling design. On the first survey on 17th June, a stable aggregation was surveyed during the early morning hours in an area that had been barren during the day (Figure 9). A similar diel pattern was observed two days later on 19th June, with a slightly reduced biomass of orange roughy compared with the survey on 17th June, and with a comparable spawning state. Searches of the wider area around Rock Garden did not locate any other likely orange roughy aggregations, but did find aggregations that were most likely to have been deepsea cardinalfish.

The third and fourth high quality AOS surveys that biomass estimates were generated for were conducted on 24th June and produced a variable but significant biomass. Biological sampling revealed continuous, active spawning throughout the survey period at Rock Garden.

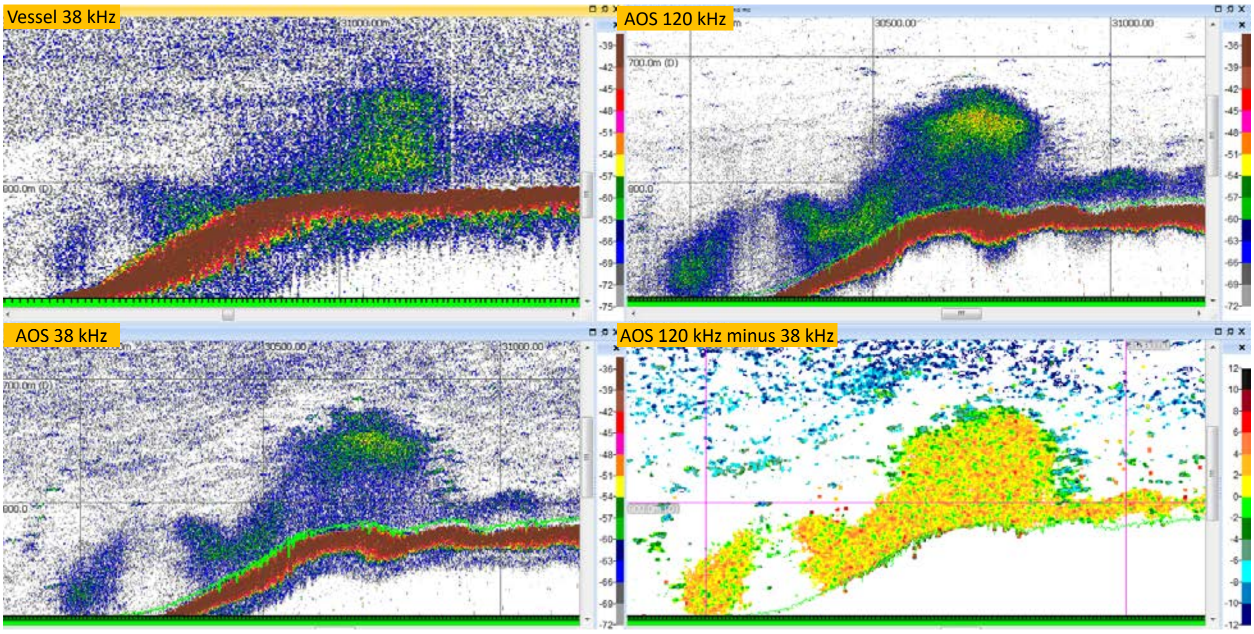

Figure 9: A large aggregation of Rock Garden orange roughy with the adjacent region of backscatter dominated by gas bladder species. Colour scale on bottom right image indicates $Sv_{120\text{-}38}$ where yellow-orange regions show a higher signal on 120 kHz allowing the region to be classified as orange roughy.

3.2.2 Biological results

Seven target identification tows at Rock Garden yielded a total of 26 t of fish of which a high percentage was orange roughy (98%). The bycatch by weight comprised mainly hoki (1%), deepwater sharks (Plunket’s shark, smooth skin dogfish, and longnose velvet dogfish) (0.4%), deepsea cardinalfish (0.2%), and ribaldo (0.1%) (Figure 10). The species composition in catches at Rock Garden, by number and weight, is provided in Table 18 in Appendix 2.

Orange roughy size frequency

The mean standard lengths and weights were 35.8 cm and 1.597 kg for females and 33.6 cm and 1.294 kg for males. Average lengths and weights for sexes combined were 34.5 cm and 1.418 kg (Figure 11).

Spawning progression

Biological sampling from three tows on 18th June showed that between 40–70% of female orange roughy were actively spawning and 9–17% were spent, indicating that the spawning event was near its peak. By the third and last survey on 24th June, 20% of females were in ripe condition and 49% were actively spawning, indicating that the spawning event was still well underway, although the high proportion of spent females (31%) suggested it was beginning to tail off (Figure 12).

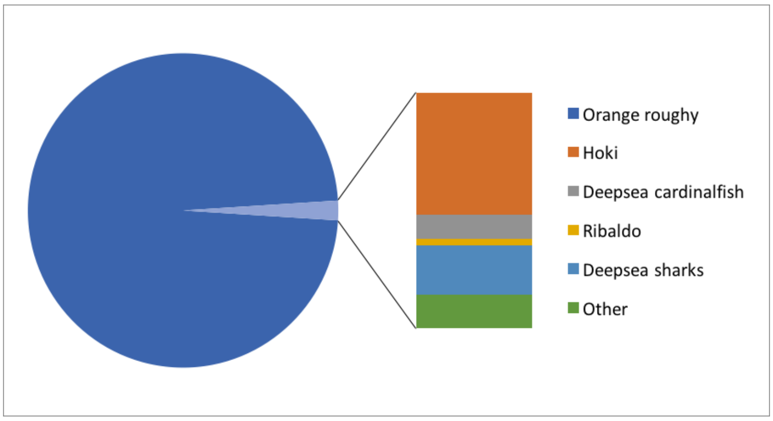

Figure 10: Catch composition at Rock Garden. Orange roughy comprised over 98% of the total catch.

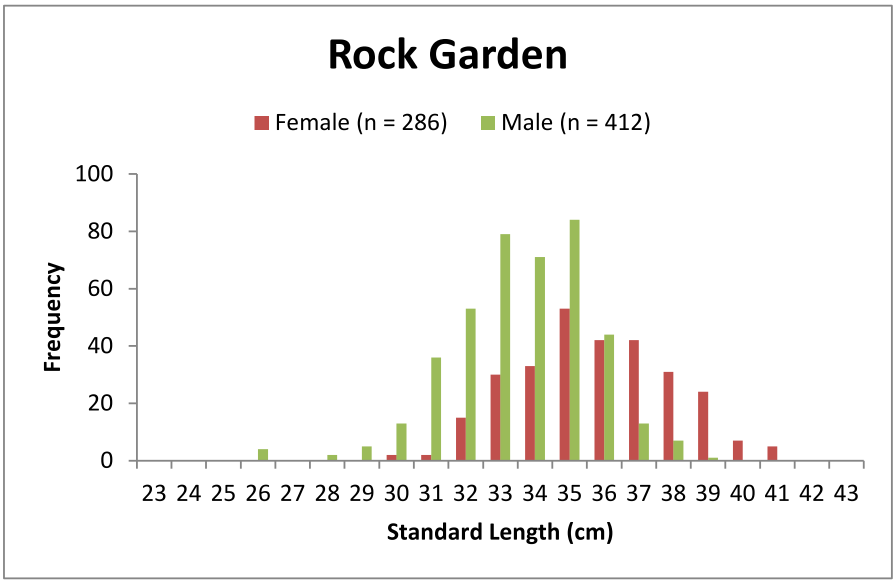

Figure 11: Orange roughy size frequency distribution (unstandardised) – Rock Garden.

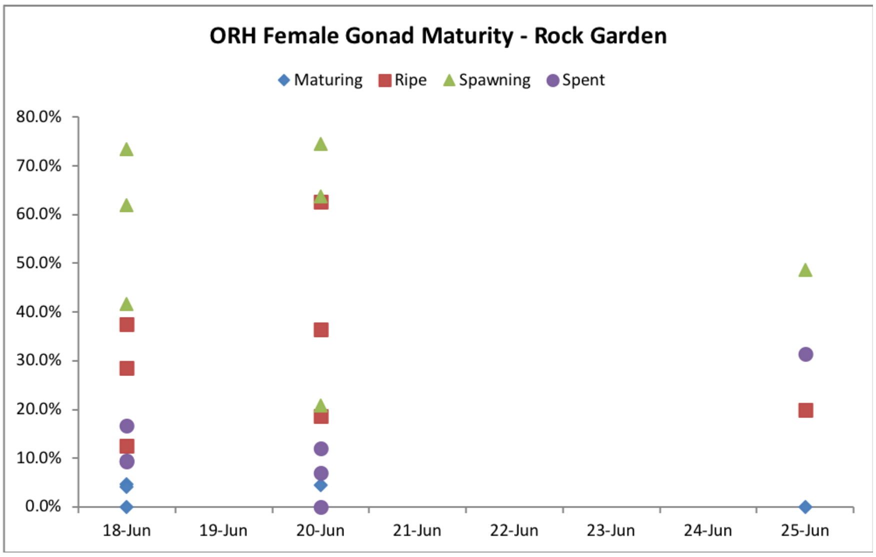

Figure 12: Female orange roughy spawning progression – Rock Garden.

Sex ratio

The sex ratio in catches was variable throughout the survey with an overall average of 41% females and 59% males. There was no obvious link between sex ratio and diurnal cycle (Figure 13).

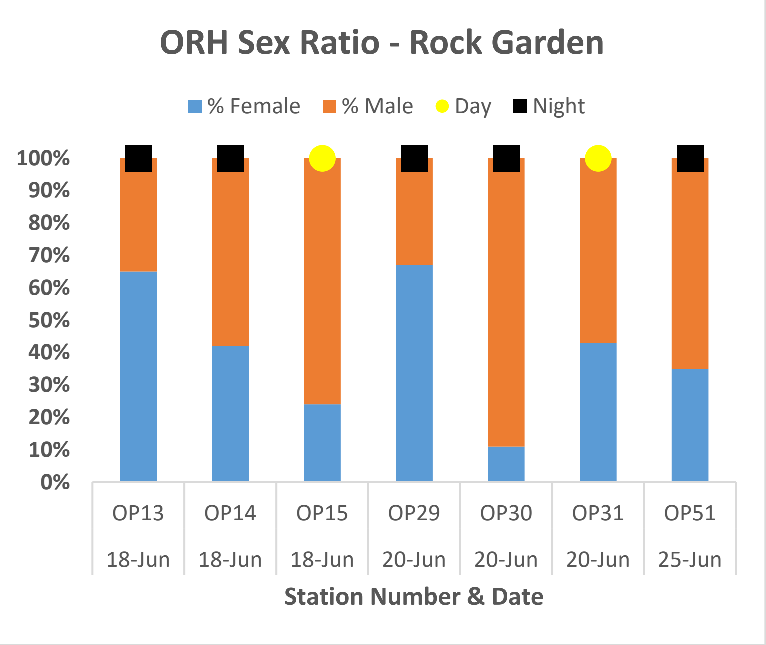

Figure 13: Orange roughy sex ratio in catches at Rock Garden in relation to the diurnal cycle.

Otolith samples

A total of 540 orange roughy otolith samples were collected from the Rock Garden aggregation.

3.2.3 Acoustic biomass estimates

Acoustic biomass estimates at Rock Garden are presented in Table 8 and summarised graphically in Figure 14. Figures 26–30 in Appendix 3 display thematic maps of school distributions. These surveys were considered to have suitably low bias and error due to species uncertainty, data quality, and other sources of error. Including the deadzone biomass component, total biomasses ranged from 1697 to 3226 tonnes for the primary measure based on AOS 38 kHz. 120 kHz estimates ranged from 1055 to 2304 tonnes. Vessel estimates obtained from vessel data collected concurrently in calm weather during an AOS surveys were significantly lower at 567 and 844 tonnes for reasons that are unclear. Note, these surveys were completed using a star pattern design, hence a single biomass value is given. This contrasts to the parallel transect design used for Sea Valley where the biomass from the pair of interlaced surveys is combined using a geometric mean.

Table 8: Biomass estimates based on AOS echo-integration surveys carried out at Rock Garden in June 2017.

Date	Platform	OP	Frequency	Survey area	Mean NASC	Biomass above acoustic bottom (tonnes)	CV	Deadzone estimate (tonnes, % of total)	Total biomass
17-Jun	AOS 120	11	120	0.52	539	2077	0.16	227 (9.9%)	2304
17-Jun	AOS 38		38	0.52	289	2729	0.16	280 (9.3%)	3009
19-Jun	Vessel	27	38	0	191	498	0.99	69 (12.2%)	567
19-Jun	AOS 120	27	120	0.70	321	1667	0.23	243 (12.7 %)	1911
19-Jun	AOS 38		38	0.55	233	2318	0.23	382 (14.1 %)	2700
19-Jun	Vessel	28	38	0	97	605	0.99	239 (28.3%)	844
19-Jun	AOS 120	28	120	0.47	335	1155	0.16	316 (21.5 %)	1471
19-Jun	AOS 38		38	0	187	1574	0.18	496 (24 %)	2070
24-Jun	AOS 120	49	120	2	102	1887	0.49	235 (11.1 %)	2123
24-Jun	AOS 38		38	2	65	2939	0.45	287 (8.9 %)	3226
24-Jun	AOS 120	50	120	0	288	737	0.27	318 (30.1 %)	1055
24-Jun	AOS 38		38	0	177	1110	0.30	588 (34.6 %)	1697

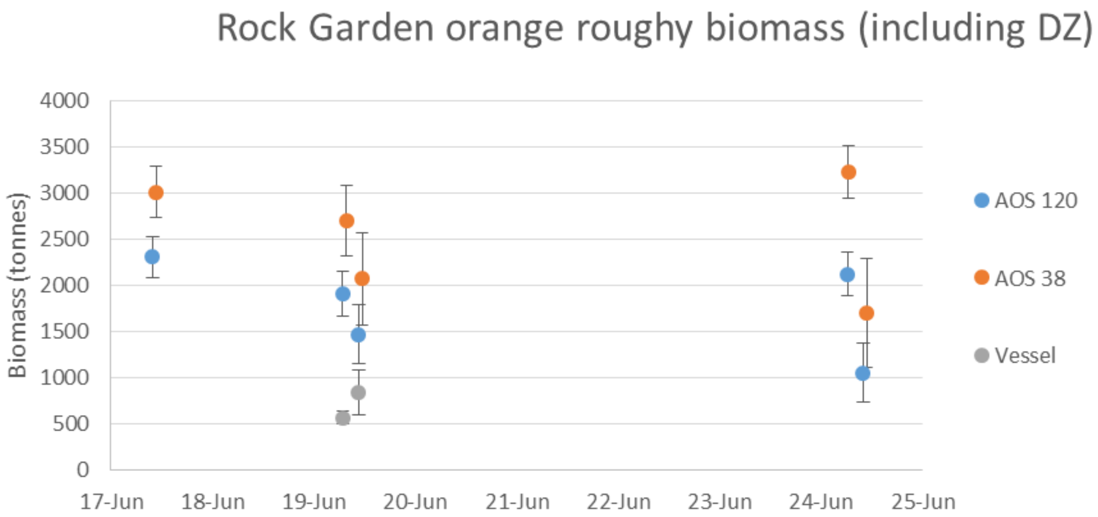

Figure 14: Biomass estimates for AOS 38 kHz and 120 kHz and vessel 38 kHz at Rock Garden. Error bars are +/- 1 sd. Dates for AOS 38 are slightly offset from AOS 120 so that error bars for both frequencies will be visible.

3.2.4 Discussion

Orange roughy schools at the Rock Garden displayed strong day-night variation where highly aggregated regions were observed during the night but had dispersed completely during the day. The night-time schools were identified as orange roughy using multi-frequency techniques, supported by trawling and optical data. They were relatively stable and of high signal indicating high densities of orange roughy. Strong backscatter regions observed in the Rock Garden region were readily identified as originating from gas-bladder species using multi-frequency techniques and were eliminated from the analysis.

3.3 Tolaga Knoll

3.3.1 Summary of survey programme

Tolaga Knoll is located ~50 nautical miles NNE of Sea Valley at 178° 46 E, 38° 46 S, where the seafloor rises to depths of 750 m. The region was visited on 22nd and 26th June. During the first visit acoustic marks visible on the vessel's sounders were investigated with the AOS (Figure 15) and a single biological trawl. During the second visit no aggregation was found and no surveying or trawling was undertaken. The area is characterised by dynamic aggregations with large and very strong acoustic marks often observed and believed to be deepsea cardinalfish. Caution is needed because a 'cardinal mark' abeam of the vessel might have the appearance of orange roughy aggregations if it is ensonified by the side lobes of the vessel sounder. The AOS two-frequency data would be able to clarify such occurrences.

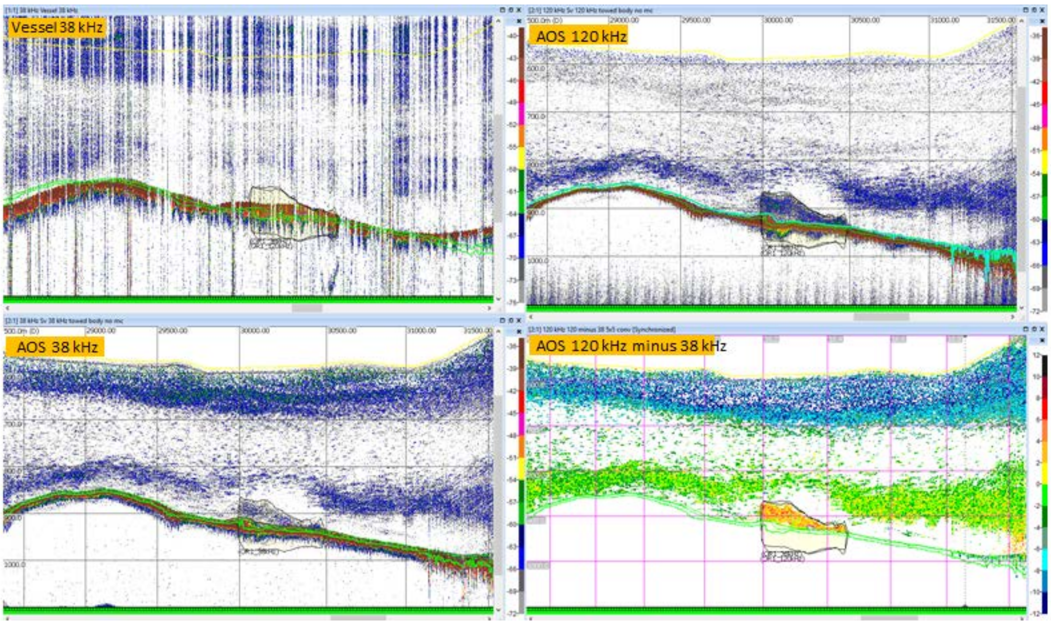

Figure 15: Small aggregation of orange roughy at Tolaga Knoll with the adjacent region of backscatter dominated by gas bladder species. Colour scale on bottom right image indicates $Sv_{120\text{-}38}$ where yellow-orange regions show a higher signal on 120 kHz allowing these to be classified as orange roughy.

3.3.2 Biological results

A single target identification trawl produced a catch comprising 97% orange roughy, with the main bycatch species being deepsea cardinalfish (0.9%) and deepsea dogfish (0.9%) (shovelnose spiny dogfish, Baxter's lantern dogfish) (Figure 16). A detailed breakdown of the catch composition at Tolaga Knoll by number and weight is provided in Table 19 in Appendix 2.

ORH size frequency

The mean length and weight of females was 35.2 cm and 1.520 kg and 33.4 cm and 1.237 kg for males. The average length and weight for females and males combined were 34.6 cm and 1.418 kg. The size frequency distribution of orange roughy at Tolaga Knoll is illustrated in Figure 17.

Spawning state

The catch from a single trawl revealed 30% of females were actively spawning and 47% were spent, suggesting that the spawning event was at an advanced stage (Figure 18). The sex ratio in the single trawl catch on 23rd June was 64% females and 36% males.

Otolith samples

A total of 100 orange roughy otolith samples were collected from the Tolaga Knoll aggregation.

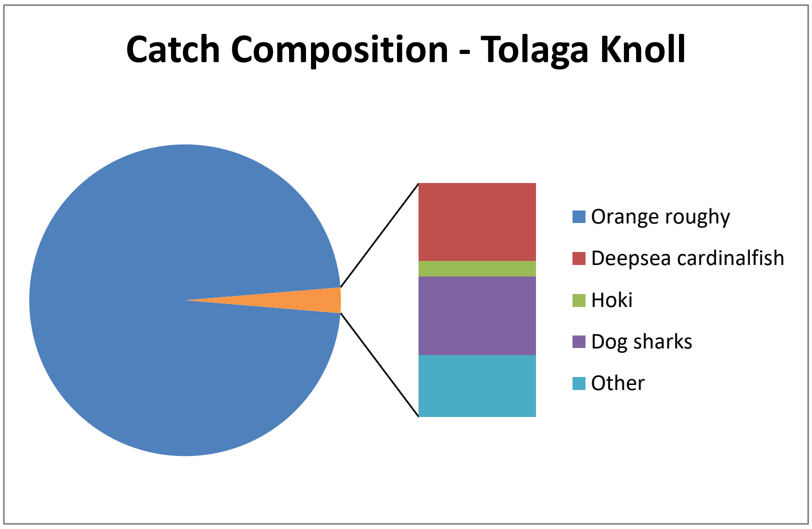

Figure 16: Catch composition at Tolaga Knoll. Orange roughy comprised 97% of the catch.

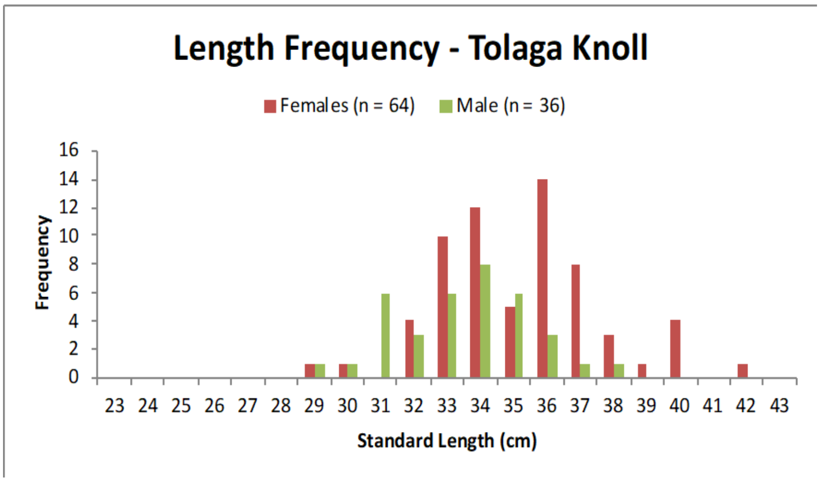

Figure 17: Orange roughy size frequency distribution at Tolaga Knoll.

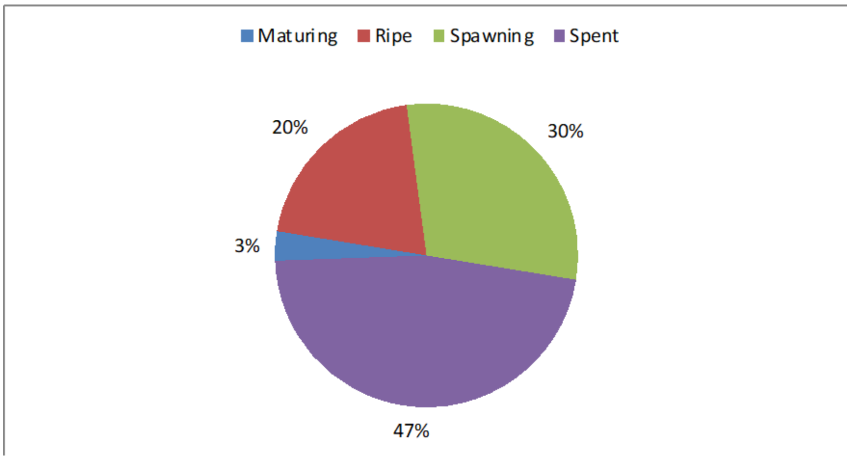

Figure 18: Orange roughy female spawning state at Tolaga Knoll.

3.3.3 Acoustic biomass estimates

Three single-pass AOS tows were conducted to identify species. In addition to confirming the presence of gas bladder species (most likely cardinalfish) small aggregations of orange roughy close to the seafloor were identified by the AOS acoustics. Less equivocal, but potentially significant, was the observation of a possible orange roughy mark 500 m long by 120 m high on the vessel's echosounder. This aggregation had moved by the time the AOS single-pass transect could be carried out. An interlaced grid AOS survey was conducted in very poor weather where small aggregations of orange roughy were identified by the multi-frequency acoustics.

Biomass estimates for the survey are summarised in Table 9. Including the deadzone biomass component, total biomass was 419 tonnes for the primary AOS 38 kHz measurement. Figure 31 in Appendix 3 displays the thematic map of school distributions encountered at Tolaga Knoll.

Table 9: Biomass estimates based on AOS echo-integration surveys carried out at Tolaga Knoll on 22nd June 2017. The survey area was 3.4 km^2.

Platform	OP	Frequency	Mean NASC	Biomass above acoustic bottom (tonnes)	CV	Deadzone estimate (tonnes, % of total)	Total biomass (Geometric Mean, tonnes)	Total biomass (Arithmetic mean, tonnes)
AOS 120	43	120	13	204	0.47	49 (19.2%)	0	252
AOS 38		38	7	280	0.51	139 (33.2%)	0	419

3.3.4 Discussion

On the first survey at Tolaga Knoll a small body of orange roughy was observed. Gas bladder aggregations were also prevalent, but were separated from orange roughy using multi-frequency discrimination techniques. Biological identification tows indicated that spawning was well advanced. Time restrictions and lack of detectable orange roughy schools prevented multiple comprehensive surveys.

3.4 Wide area search

3.4.1 Overview

Approximately 65 hours of dedicated vessel-based acoustic surveys of the wider region were conducted between 25th and 27th June (Figure 19). The AOS single pass survey mode transects were made on two occasions to identify potential orange roughy marks using multi-frequency acoustics. These marks were identified as gas bladder species. Apart from this, significant acoustic marks were rare and no orange roughy marks were identified during this wide area search of the greater region. Additional vessel-based searches of the wider region around the key features of Sea Valley, Rock Garden, and Tolaga Knoll were made opportunistically throughout the survey without locating spawning orange roughy aggregations. The survey had been supplied with desktop-generated survey lines. For practical reasons these could not be followed precisely due to time constraints and vessel manoeuvring. Instead a wider ‘zig-zag’ angle was used where the skippers followed a typical search/prospecting approach to optimise ground covered in the time available. Nevertheless, the wider region received comprehensive survey coverage such that it seems unlikely that large and significant amounts of orange roughy were missed. A second full, wide area survey was planned but not conducted due to time constraints and the lack of orange roughy aggregations on the first wide area search, thus allowing survey activities to be focused elsewhere.

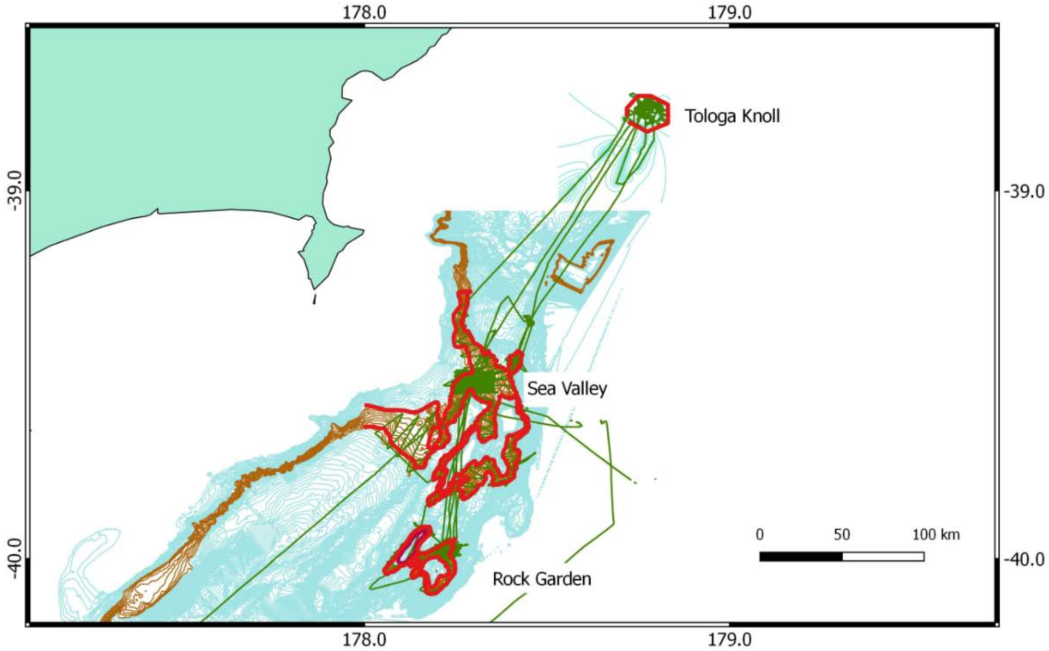

Figure 19: AEX1701 Mid-East Coast survey voyage track. Brown contour lines indicate the 750 to 950 m depths. Red contour lines indicate the bounds of the wide area search that was conducted during the survey. Green lines indicate FV *Amaltal Explorer* vessel track.

3.5 Other activities

Surveys of nearby Sea Valley locations

Vessel-based searches of historic fishing sites within ~ 10 nautical miles of Sea Valley were conducted. These included Richie Hill (aka Strawberry Mountain), North Hill, and Hill 814. On two occasions marks worth further investigation were identified. Single-pass AOS survey mode transects confirmed that the marks were from gas bladder species and were not orange roughy. Apart from this, no potential orange roughy marks were observed.

Optic fibre trials

Further trials of optic fibre connectivity were undertaken with successful connection from the AOS to the vessel. Winch spooling issues prevented routine use of the real-time optic fibre connection.

Trials of new generation broadband echosounders

The newly released Simrad WBT-Tube echosounder was trialed during this voyage. Tests were made for use in conventional continuous wave (CW) mode for comparison with Simrad ES60/EK60 echosounders. Initial findings were that the WBT-Tube noise performance at 120 kHz was limiting working range to ~ 350 m compared with the Sealord AOS 120 kHz which had acceptable signal to noise down to ~ 500 m. Broadband capabilities were also tested with high-signal, gas-bladder species measured from 90–170 kHz fast-ramp chirp signals.

Observations during transit through ORH2B

During the transit back to Nelson the voyage track targeted known locations off the south eastern North Island coast in ORH 2B. Potential orange roughy marks were observed at some locations (e.g., 176° 52 E, 41° 14 S at 2035 h on 28/06/2017), but there was no opportunity to investigate further with either trawl or AOS.

3.6 Discussion of overall outcomes

Acoustic biomass estimates were made using AOS 38 kHz, AOS 120 kHz, and, where suitable, vessel 38 kHz data. For Sea Valley, AOS 38 kHz biomass estimates were on average 12% higher than 120 kHz biomass estimates (n=5), ranging from 30% higher to 16% lower. These results are similar to the findings of Ryan & Kloser (2016), a meta-study of historic orange roughy surveys from 11 key spawning locations in Australia and New Zealand, comparing biomass estimates from 38 kHz and 120 kHz deeply deployed acoustic systems. They found generally good agreement between the two frequencies, where 38 kHz was on average 8% higher than 120 kHz with a standard deviation of 20%. Differences in absorption estimates, contamination by other species, target strength, and calibration accuracy between the frequencies might account for some of the variation. The differences between AOS 38 kHz and AOS 120 kHz were more pronounced at Rock Garden. There, AOS 38 kHz was on average 45% higher than AOS 120 kHz (n=5) ranging from 30% to 60%. At Tolaga Knoll, the AOS 38 kHz was 65% higher than the AOS 120 kHz for the one survey. It is not clear why the difference between AOS 38 kHz and AOS 120 kHz was more pronounced at Rock Garden and Tolaga Knoll.

Review of the calibration history of the AOS 38 kHz and 120 kHz systems found that the 38 kHz has been relatively stable whereas the 120 kHz has had large shifts in calibration values (up to 3 dB, i.e., a factor of 2) between years. Hence there is some suspicion that the differences between 38 kHz and 120 kHz biomass estimates could be due to an unexplained calibration issue associated with the 120 kHz system. However, this is not a firm conclusion. The AOS 120 kHz was calibrated twice in 2017 (Mid-East Coast survey and ORH 7B survey) with reasonably consistent results; so in principle, applying the 2017 calibration parameters to the 120 kHz survey data should give unbiased backscatter measurements. Continued monitoring of the differences between 38 kHz and 120 kHz as described by Ryan & Kloser (2016) is recommended to see if the unexpectedly larger differences observed in 2017 are anomalous.

Comparison could be made between AOS 38 kHz and vessel 38 kHz for two surveys at Sea Valley and two surveys at Rock Garden. At Sea Valley, AOS 38 kHz was higher than vessel 38 kHz by a factor of 4.1 and 2.8 for the two surveys. At Rock Garden, AOS 38 kHz was higher than vessel 38 kHz by a factor of 4.8 and 2.5 for the two surveys. These are large and unexpected differences. Both vessel and AOS systems were calibrated with stable calibration history and running at the same frequency; thus frequency specific considerations such as TS do not apply. Ryan & Kloser (2016) compared AOS 38 kHz and vessel 38 kHz data from a 2013 survey for the same combination of echosounders (i.e., *Amaltal Explorer* and Sealord AOS) and found generally good agreement (e.g., figure 4.5, Ryan & Kloser 2016).

These large differences between vessel 38 kHz and AOS 38 kHz should be monitored in future voyages; dedicated AOS deployments where the platform is towed at controlled depths to compare with vessel acoustic measurements are envisaged as a method to investigate the relationship between the two systems.

4. ACKNOWLEDGEMENTS

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APPENDIX 1: VESSEL AND AOS CALIBRATION

Amaltal Explorer ES60 calibration

The *Amaltal Explorer*'s Simrad ES60 vessel-mounted acoustic system was calibrated towards the end of the survey off the East Coast of North Island (Figure 20).

This report details the calibration experiments and results for FV *Amaltal Explorer* as per the information recorded below. The methods detailed in (Demer et al. 2015), based on the suspended reference sphere method with on-axis analysis, are broadly followed.

Summary of results that would be applied when post-processing are given in Table 10.

Table 10: Summary of calibration results.

Frequency (kHz)	Transducer serial no	Power (W)	Pulse duration (ms)	On-axis gain (dB)	Sa correction (dB)	Adjusted equivalent beam angle (dB)
38		2000	2.048	25.165	-0.52	-20.36

* This vessel has two transducers, Serial numbers 30212 and 30031, but there was no information about which one was in service. EBA values were close, at -20.6 and -20.8 respectively, whereas factory tank temperatures were identical at 18 °C freshwater. The mean of the factory EBA values (i.e., -20.7 dB) was used and adjustments were made for local environmental conditions.

Table 11: Vessel and site.

Vessel Name	*Amaltal Explorer*	Vessel owner/operator	Talley's Group Limited
Site name	Mid-East Coast fisheries management area	Country	New Zealand
Calibration date	2017-06-28	Time zone	[Offset from UTC in hours]
Latitude	39°37.78 S	Longitude	178°35.06 E
Seafloor depth (m)			
Sea state at start	Calm 2 m swell	Sea state at end	Calm 2 m swell
Start calibration time	01:10 (UTC)	End calibration time	03:24 (UTC)

Vessel and site comments	Open water calibration while the AOS was being calibrated. Rob Tilney is thanked for running the calibration.
Vessel acknowledgements	Skipper Duncan Bint and crew on board *Amaltal Explorer* are thanked for their assistance during the calibration.

Table 12: Environmental.

Salinity (psu)	34.5	Salinity source	Estimated
Temperature (°C)	15.5	Temperature source	CTD, seabird electronics
Sound absorption (dB/km)	6.733 (38kHz)	Sound absorption equation	(Francois and Garrison, 1982b)
Sound speed (m/s)	1535.48 at txdr face	Sound speed equations	(Mackenzie, 1981)
Environmental comments	Surface waters were well mixed. Using single value for sound speed and absorption.		

Table 13: Calibration equipment.

Calibration sphere	60.0 mm copper sphere	
Counter weight	No	Counter weight-sphere distance (m)
Mechanical arrangement	Calibration poles triangulated around the transducer. Equipment supplied by Clement & Associates Ltd	
Equipment comments	Equipment supplied by Clement & Associates Ltd	

Table 14: Echosounder transceivers.

Frequency (kHz)	38
Make	Simrad
Model	ES60
Serial number	
Operating software	ES60
Operating software version	

Table 15: Echosounder transducers*.

Frequency (kHz)	38	Make	Simrad
Model	ES38B	Serial number	30212
Beam	single-beam split-aperture	Transducer depth	
Factory equivalent two-way beam angle (dB)	-20.7	Factory tank temperature	18
Factory tank salinity	0		
3-dB beam width alongships (°)	7.1	3-dB beam width athwartships (°)	7.1
Angle offset alongships (°)	Not available	Angle offset athwartships (°)	Not available

* This vessel has two transducers, Serial numbers 30212 and 30031 but there is no information about which one is in service. EBA values are close, at -20.6 and -20.8 respectively, whereas factory tank temperatures were identical at 18 °C freshwater. The mean of the factory EBA values was used (i.e., -20.7 dB)), and adjustments were made for local environmental conditions.

Results

Table 16: Calibration calculations and results.

Frequency (kHz)	38
Calibration analysis method	On-axis
Run number	2
Max beam compensation (dB)	On-axis method
Number of targets	31
Adjusted two-way equivalent beam angle (dB)**	-20.36
Power (W)	2000
Pulse duration (ms)	2.048
Sphere depth (m)	15.92
Sphere TS (dB)	-33.52
On-axis gain (dB)	25.165
S_A correction (dB)	-0.52

AOS calibration results

Calibration date: 28th June 2017 & 8th July 2017
Vessel: *Amaltal Explorer*
Report date: 21st July 2017
Prepared by: Haris Kunnath and Tim Ryan

Summary

This document summarises the calibration of the Sealord AOS 38 and 120 kHz acoustic system carried out on two occasions during the winter 2017 surveys of New Zealand orange roughy.

Calibration was carried out by lowering the AOS system through working depths down to 1000 m with a standard 38.1 mm tungsten carbide sphere suspended ~16 m beneath the transducer. Environmental conductivity, temperature, and depth data were recorded concurrently with the acoustics. The objective of calibrating the acoustics through operating depths was to characterise the related changes in system gain. A polynomial fit to the depth vs gain data allows correction to AOS backscatter measurements as the platform changes depth during survey operations.

Two surveys were conducted in 2017. The first survey (AEX2017-01) was of the Mid-East Coast region (East Coast, North Island). AOS surveys were almost completed when the Sealord 38 kHz GPT failed on 27th June. Weather conditions allowed for an AOS calibration on 28th June where a CSIRO-loaned 38 kHz EK60 transceiver was substituted for the failed Sealord ES60 transceiver. The calibration went well with ample sphere target data collected within the acoustic beam. A second calibration was conducted with similar success on 8th July during the second survey (AEX2017-02) of the Cook Canyon region (West Coast, South Island). The CSIRO EK60 transceiver was also used for this survey and for the calibration.

AEX2017-01 survey data were collected with the Sealord ES60 transceiver whereas calibration was established with the CSIRO EK60 transceiver in place; in both instances the respective transceivers were connected to the same Sealord Simrad ES38 DD transducer. To determine the effect of the

transceiver on calibration the now repaired Sealord ES60 transceiver was sent to Hobart to allow further testing. A simple experiment was carried out where a wharf-side calibration was carried out, first with the CSIRO EK60 transceiver then with the Sealord ES60 38 kHz transceiver, both connected to the same ES38B transducer. A 60 mm copper sphere was used. ES60 data were corrected for triangle wave error. The CSIRO transceiver measured on-axis sphere target strength (TS) as -34.74 dB, the Sealord ES60 TS was -34.97 dB, a difference of 0.23 dB. This is a significant difference but not excessively large. We note also that this comparison was made using the repaired Sealord ES60 transceiver so we cannot be unequivocal as to the differences between the ES60 as used during the survey and the now repaired system. For these reasons the estimate of calibration uncertainty is increased to 0.7 dB (17%) from the typical estimate of better than 0.5 dB (12%). The AEX2017-02 survey (Cook Canyon) used the CSIRO GPT throughout, hence we estimate calibration accuracy of better than 0.5 dB.

Data acquisition

Platform:	AOS
Location:	-39.8058, 178.8763, and -42.8916, 169.6133
Calibration sphere:	38.1 mm tungsten carbide.
Sphere depth:	12 m for first deployment, and 18 m for second deployment

Data processing

The ES60 triangle wave correction was applied to the 120 kHz channel. Triangle wave correction was not applied to 38 kHz data because CSIRO AOS EK60 transceiver was used for the data acquisition.

After defining appropriate data regions in echoview worksheet, *AOS_cal_gui* was used to extract parameters required for the calibration.

The transducer calibration for different settings (as tabulated below) was performed by the Matlab program *transducer_cal_gui.m*. The GUI displays number of parameters that can be adjusted by the user to better perform the calibration. Preliminary calibrations were carried out using the data for each transducer settings and the corresponding **.ecs* files were generated from the calibration results (the **.ecs* files were edited to set the *Sa correction* value as 0). The extraction process using *AOS_cal_gui* was repeated using new *.ecs files to fulfil final calibration.

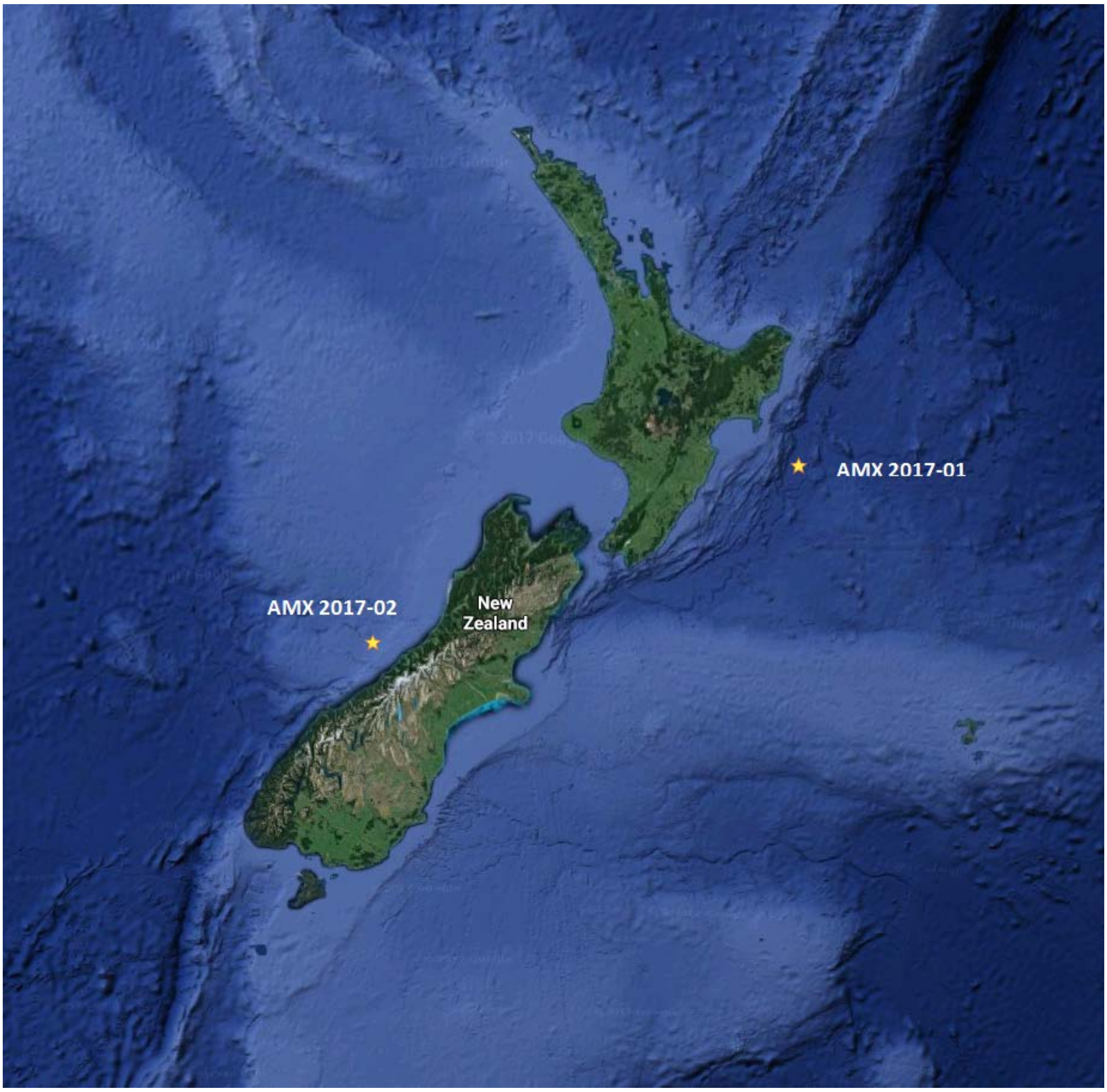


Figure 20: Geographic locations of the calibration deployments.

Summary of calibration parameters (AEX201701)

The calibration parameters for combined up and down casts are tabulated below (@ 600m).

Year	2017	
Voyage	AEX201701	
Transducer settings		
Transducer model	Simrad ES38-DD	Simrad ES120-7CD
Serial number	28363	115
Frequency (kHz)	38	120
Power (W)	2000	500
Pulse length (ms)	2.048	1.024
Calibration parameters		
Gain (dB) @ 600 m	23.7570	28.2678
Sa correction (dB) @ 600 m	-0.3316	-0.6278
Adjusted equivalent beam angle (dB/steradian)	-20.73	-20.26
Absorption @ 600 m (dB/m)	0.0094	0.0336
Sound speed @ 600 m (m/s)	1494	1494

ES38-DD (28363), 38 kHz, 2000 W, 2.048 ms				
	x d^3	+ x d^2	+ x d	+ c
Gain polynomial parameters	-2.65283e-09	1.74998e-06	-0.000140873	23.7845
SA polynomial parameters	8.7535e-10	-1.32352e-06	0.000587346	-0.39665
ES120-7CD (115), 120 kHz, 500 W, 1.024 ms				
	x d^3	+ x d^2	+ x d	+ c
Gain polynomial parameters	-3.35909e-10	7.09391e-07	-0.000651183	28.4757
SA polynomial parameters	9.89037e-10	-9.41633e-07	-0.000411981	-0.255259

Summary of calibration parameters (AEX201702)

The calibration parameters for combined up and down casts are tabulated below (@ 600 m).

Year	2017	
Voyage	AEX201702	
Transducer settings		
Transducer model	Simrad ES38-DD	Simrad ES120-7CD
Serial number	28363	115
Frequency (kHz)	38	120
Power (W)	2000	500
Pulse length (ms)	2.048	1.024
Calibration parameters		
Gain (dB) @ 600 m	23.6933	28.0963
Sa correction (dB) @ 600 m	-0.4402	-0.3023
Adjusted equivalent beam angle (dB/steradian)	-20.72	-20.25
Absorption @ 600 m (dB/m)	0.0093	0.0340
Sound speed @ 600 m (m/s)	1495	1495

ES38-DD (28363), 38 kHz, 2000 W, 2.048 ms				
	x d^3	+ x d^2	+ x d	+ c
Gain polynomial parameters	-4.73206e-09	5.32442e-06	-0.00169701	23.8168
SA polynomial parameters	1.33483e-09	-1.81492e-06	0.000458749	-0.350437

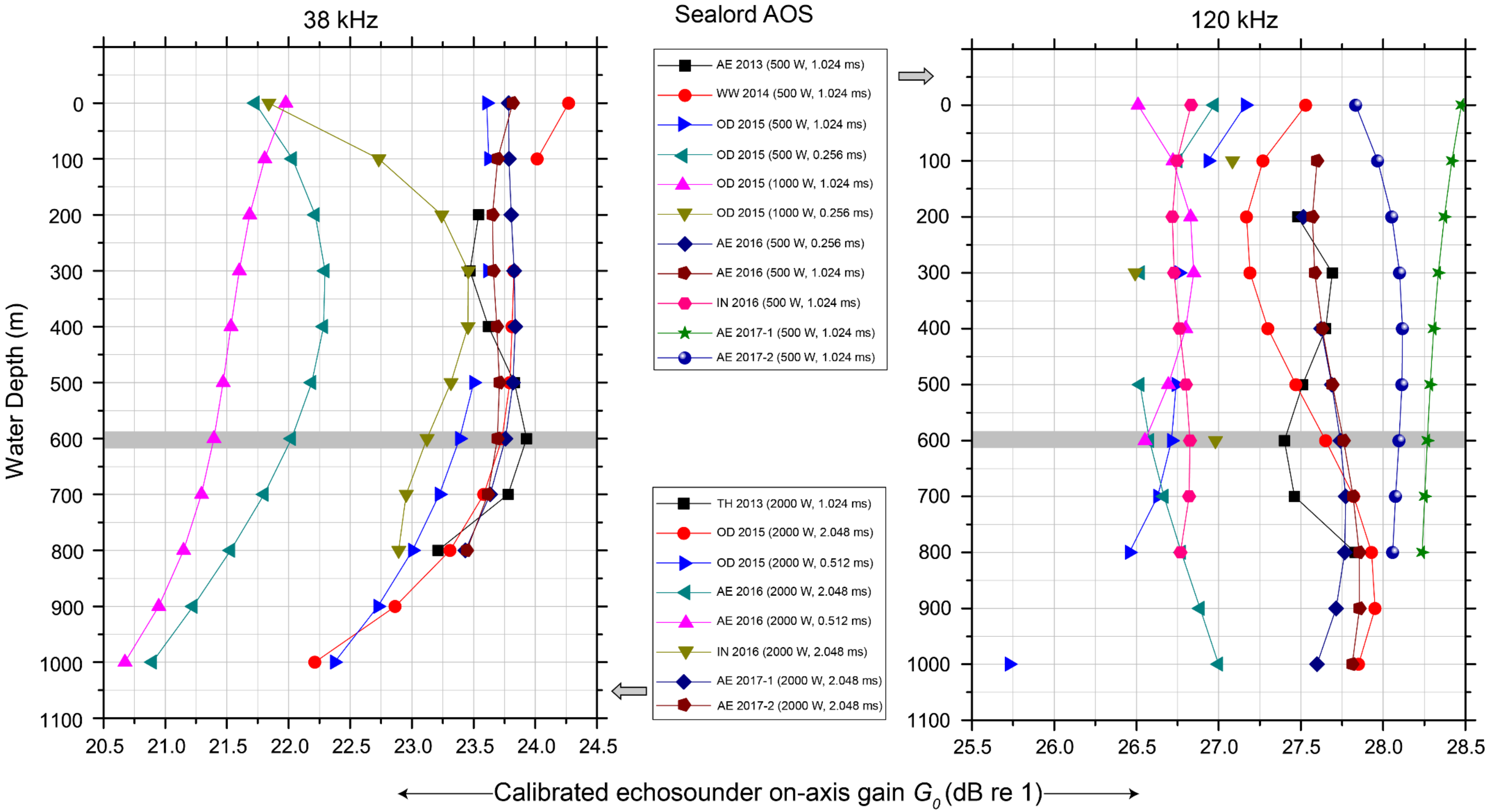
ES120-7CD (115), 120 kHz, 500 W, 1.024 ms				
	x d^3	+ x d^2	+ x d	+ c
Gain polynomial parameters	1.43445e-09	-2.79754e-06	0.00160241	27.8321
SA polynomial parameters	-7.89063e-10	5.32988e-07	5.09443e-05	-0.354276

Summary of previous calibration parameters (Sealord AOS)

Year	2013-06-18	2013-06-30	2014-09-14						2015-09-10				2016-07-12
Vessel	*Thomas Harrison*	*Amaltal Explorer*	*Will Watch*						*Ocean Dynasty*				*Amaltal Explorer*
Frequency (kHz)	38	120	120	38	38	120	120	120	120	38	38	120	120
Power (W)	2000	500	500	2000	2000	500	500	1000	1000	2000	2000	500	500
Pulse length (ms)	1.024	1.024	1.024	2.048	0.512	1.024	0.256	1.024	0.256	2.048	0.512	0.256	1.024
Gain (dB)	23.86	27.4	27.65	23.7992	23.5214	26.6824	26.7377	26.8201	26.7236	22.0196	21.3949	27.6709	27.7371
Sa correction (dB)	-0.45	-0.28	-0.27	-0.3910	-0.6097	-0.3242	-0.6075	-0.3596	-0.6092	-0.3598	-0.4063	-0.5959	-0.3396

Continuation

Year		2016-12-18		2017-06-28		2017-07-08
Vessel		*Investigator*		*Amaltal Explorer*		*Amaltal Explorer*
Frequency (kHz)	38	38	120	38	120	120
Power (W)	2000	2000	500	2000	500	500
Pulse length (ms)	2.048	2.048	1.024	2.048	1.024	1.024
Gain (dB)	23.6933	23.757	28.2678	23.1211	26.8256	28.0963
Sa correction (dB)	-0.4402	-0.3316	-0.6278	-0.4340	-0.3885	-0.3023



TH- Thomas Harrison ***OD- Ocean Dynasty*** ***AE- Amaltal Explorer*** ***IN-Investigator*** ***WW-Will Watch***

Results (AEX201701)

1. 38 kHz

Power (W):	2000
Pulse length (ms):	2.048

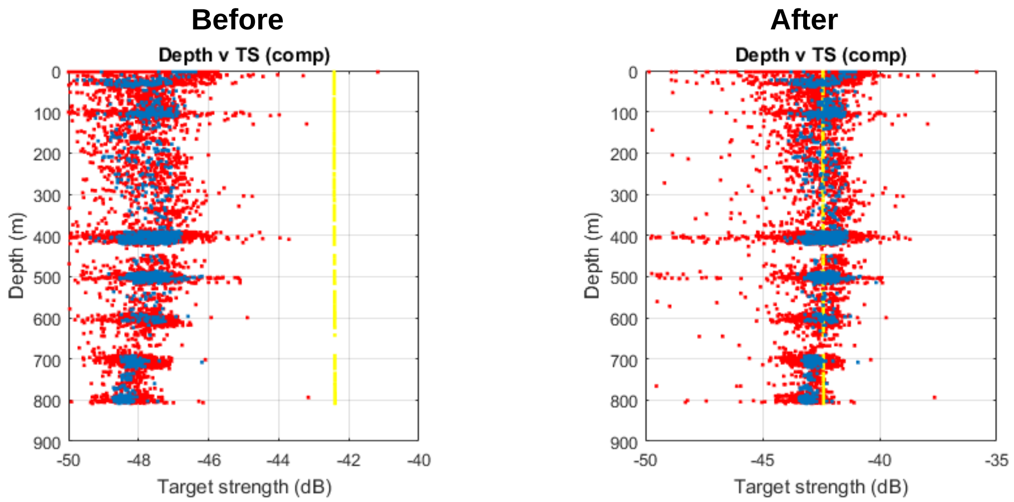
38kHz_GPT 38 kHz 00907205c463 1 ES38D_20170628031501_20170720163739_kun017

Data acquisition details

Transducer	ES38_DD Sn 28363 T1
Channel id	GPT 38 kHz 00907205c463 1 ES38D
Frequency	38000
Pulse length	0.0020480
Transmit power	2000
Gain	26.500
Equivalent beam angle	-20.600
Two Way Beam Angle	-20.600
Ek60 Transducer Gain	26.500
EK60 Sa Correction	0
Transmitted Pulse Length	2.0480
Transmitted Power	2000
Sound Speed	1500
Absorption Coefficient	0.0097472
Ev version	8.0.73.30735

Calibration parameters

Major axis offset	-0.010000
Minor axis offset	0.10000
Polynomial order	3
Onaxis criteria	1
Min TS	-50
Max TS	-46
Min depth	0
Min range	0
After	0
Before	5
Sphere ts	-42.4
View direction	0
Angular constraint	99
Use environment	1
Sound speed	1500
Sound absorption	0.0097472
Pulse length	0.0020480
Transmit power	2000
Gain	26.5
Active	1



Up and down cast

TS polynomial parameters:	5.36388e-09	3.62331e-06	-0.000313675	-42.452
Gain polynomial parameters:	-2.65283e-09	1.74998e-06	-0.000140873	23.7845
SA polynomial parameters:	8.7535e-10	-1.32352e-06	0.000587346	-0.39665

Transducer serial number: ES38DD 28363
Transducer tank psi: -20.8

Depth bins:	0	100	200	300	400	500	600	700	800
Targets:	189	218	71	48	635	365	69	222	250
TS gain:	23.7501	23.8262	23.7243	23.8235	23.8386	23.8344	23.8011	23.5722	23.4655
SA correction:	-0.3786	-0.3572	-0.3126	-0.3206	-0.3133	-0.3346	-0.3360	-0.3265	-0.3287
Overall offset:	0.8613	0.6661	0.7809	0.5985	0.5535	0.6047	0.6740	1.1128	1.3306
TS gain (poly):	23.7845	23.7853	23.8051	23.8281	23.8384	23.8200	23.7570	23.6335	23.4336
SA Correction (poly):	-0.3966	-0.3503	-0.3251	-0.3159	-0.3175	-0.3244	-0.3316	-0.3338	-0.3256
Overall offset (poly):	0.8284	0.7342	0.6442	0.5798	0.5623	0.6131	0.7535	1.0048	1.3883

Down cast

TS polynomial parameters:	-6.0203e-09	4.33359e-06	-0.000290737	-42.3823
Gain polynomial parameters:	-2.97982e-09	2.10332e-06	-0.000128673	23.8193
SA polynomial parameters:	7.5252e-10	-1.20089e-06	0.000551684	-0.399457

Transducer serial number: ES38DD 28363
Transducer tank psi: -20.8

Depth bins:	0	100	200	300	400	500	600	700	800
Targets:	139	170	11	2	214	225	36	21	50
TS gain:	23.7778	23.8548	23.8870	24.0285	23.9303	23.8762	23.9429	23.7442	23.5259
SA correction:	-0.3831	-0.3573	-0.3079	-0.3257	-0.3187	-0.3340	-0.3479	-0.3279	-0.3423
Overall offset:	0.8148	0.6092	0.4460	0.1986	0.3811	0.5200	0.4141	0.7717	1.2372
TS gain (poly):	23.8193	23.8245	23.8539	23.8896	23.9137	23.9084	23.8557	23.7378	23.5369
SA Correction (poly):	-0.3995	-0.3555	-0.3311	-0.3217	-0.3228	-0.3298	-0.3382	-0.3436	-0.3414
Overall offset (poly):	0.7644	0.6662	0.5587	0.4685	0.4223	0.4470	0.5693	0.8158	1.2133

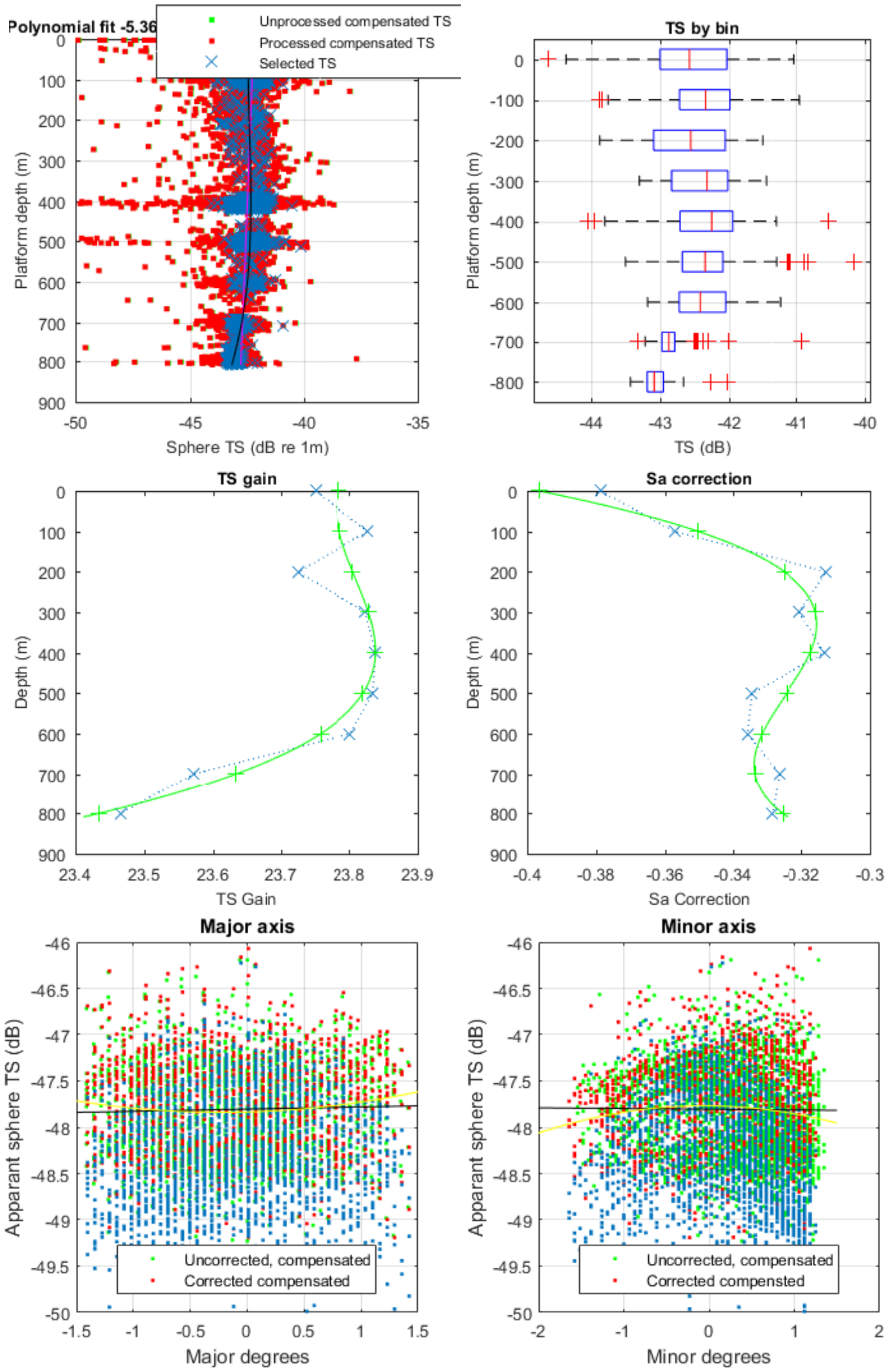
Up cast

TS polynomial parameters:	-1.28493e-09	-1.54372e-06	0.00154697	-42.7315
Gain polynomial parameters:	-6.15102e-10	-8.31027e-07	0.00078839	23.6449
SA polynomial parameters:	7.89559e-10	-1.18699e-06	0.000518283	-0.381943

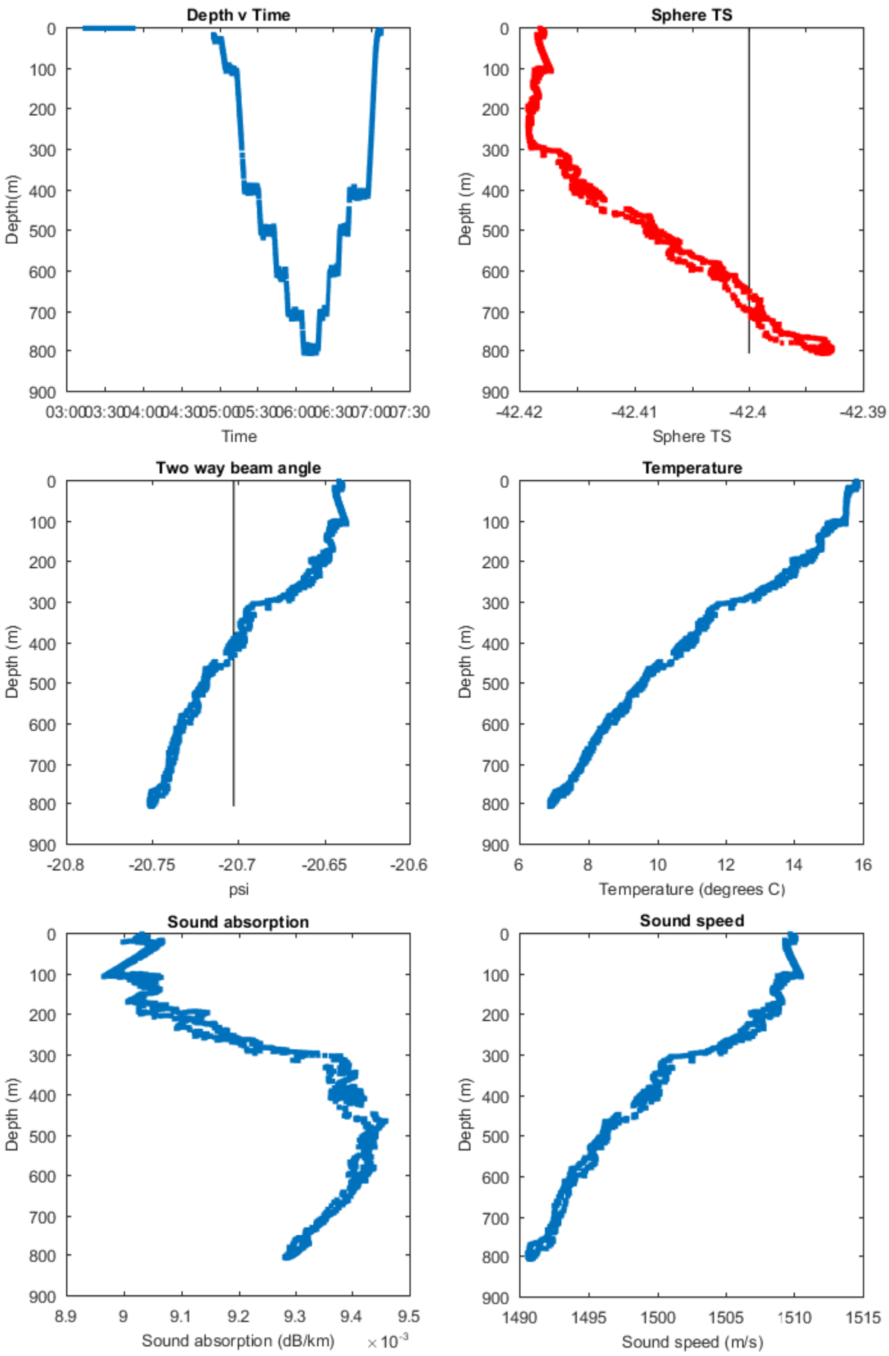
Transducer serial number: ES38DD 28363
Transducer tank psi: -20.8

Depth bins:	0	100	200	300	400	500	600	700	800
Targets:	50	48	60	46	421	140	33	201	200
TS gain:	23.6728	23.7249	23.6945	23.8146	23.7920	23.7673	23.6463	23.5543	23.4504
SA correction:	-0.3656	-0.3567	-0.3136	-0.3204	-0.3103	-0.3356	-0.3212	-0.3264	-0.3251
Overall offset:	0.9897	0.8677	0.8425	0.6159	0.6408	0.7409	0.9539	1.1484	1.3538
TS gain (poly):	23.6449	23.7148	23.7644	23.7900	23.7880	23.7545	23.6859	23.5786	23.4288
SA Correction (poly):	-0.3819	-0.3412	-0.3194	-0.3120	-0.3140	-0.3209	-0.3277	-0.3300	-0.3227
Overall offset (poly):	1.0782	0.8569	0.7142	0.6481	0.6563	0.7370	0.8878	1.1069	1.3920

Figures



Polynomial fit -5.36
Unprocessed compensated TS
Processed compensated TS
Selected TS
Platform depth (m)
Sphere TS (dB re 1m)
TS by bin
Platform depth (m)
TS (dB)
TS gain
Depth (m)
TS Gain
Sa correction
Depth (m)
Sa Correction
Major axis
Apparant sphere TS (dB)
Uncorrected, compensated
Corrected compensated
Major degrees
Minor axis
Apparant sphere TS (dB)
Uncorrected, compensated
Corrected compensted
Minor degrees


Depth v Time
Depth(m)
Time
Sphere TS
Depth (m)
Sphere TS
Two way beam angle
Depth (m)
psi
Temperature
Depth (m)
Temperature (degrees C)
Sound absorption
Depth (m)
Sound absorption (dB/km)
Sound speed
Depth (m)
Sound speed (m/s)

2. 120 kHz

Power (W):	500
Pulse length (ms):	1.024

120kHz_GPT 120 kHz 009072073bbe 1 ES120-7C_20170628031457_20170720172618_kun017

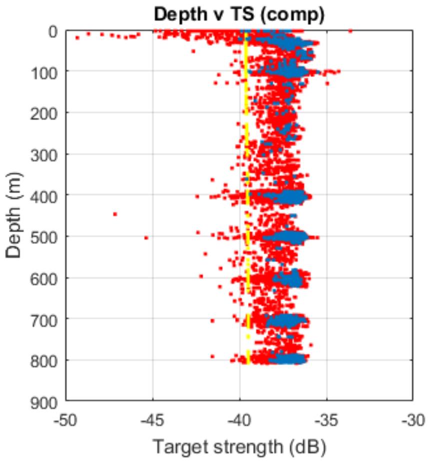
Data acquisition details

Transducer	Simrad ES120-7CD SN115 T2
Channel id	GPT 120 kHz 009072073bbe 1 ES120-7C
Frequency	120000
Pulse length	0.0010240
Transmit power	500
Gain	27
Equivalent beam angle	-21
Two Way Beam Angle	-21
Ek60 Transducer Gain	27
EK60 Sa Correction	0
Transmitted Pulse Length	1.0240
Transmitted Power	500
Sound Speed	1500
Absorption Coefficient	0.037306
Ev version	8.0.73.30735

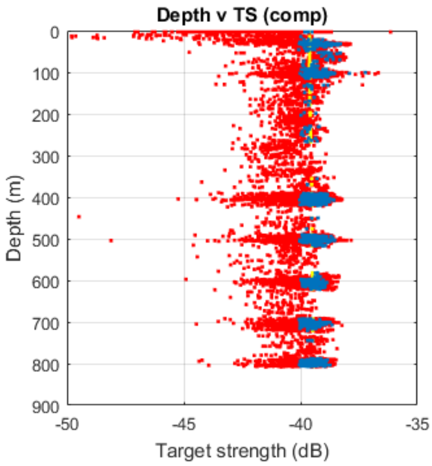
Calibration parameters

Major axis offset	0
Minor axis offset	-0.1
Polynomial order	3
Onaxis criteria	0.5
Min TS	-43
Max TS	-36
Min depth	0
Min range	0
After	0
Before	5
Sphere ts	-39.49
View direction	0
Angular constraint	99
Use environment	1
Sound speed	1500
Sound absorption	0.037306
Pulse length	0.0010240
Transmit power	500
Gain	27
Active	1

Before



After



Up and down cast

TS polynomial parameters:	-1.16268e-09	1.81075e-06	-0.00112567	-39.1716
Gain polynomial parameters:	-3.35909e-10	7.09391e-07	-0.000651183	28.4757
SA polynomial parameters:	9.89037e-10	-9.41633e-07	-0.000411981	-0.255259

Transducer serial number: ES120-7CD 115
Transducer tank psi: -20.3

Depth bins:	0	100	200	300	400	500	600	700	800
Targets:	223	311	21	7	473	305	194	289	240
TS gain:	28.4438	28.4332	28.2019	28.2326	28.3006	28.3171	28.2641	28.2195	28.2565
SA correction:	-0.2923	-0.2822	-0.2864	-0.2969	-0.5282	-0.5825	-0.6130	-0.6431	-0.7006
Overall offset:	0.1933	0.1942	0.6651	0.6248	0.9515	1.0271	1.1939	1.3434	1.3844
TS gain (poly):	28.4757	28.4174	28.3712	28.3351	28.3073	28.2855	28.2678	28.2523	28.2368
SA Correction (poly):	-0.2553	-0.3049	-0.3674	-0.4369	-0.5074	-0.5730	-0.6278	-0.6658	-0.6811
Overall offset (poly):	0.0553	0.2713	0.4887	0.6997	0.8965	1.0713	1.2161	1.3233	1.3848

Down cast

TS polynomial parameters:	-6.3569e-09	7.61628e-06	-0.00307748	-39.0243
Gain polynomial parameters:	-2.50593e-09	3.12823e-06	-0.00148052	28.5425
SA polynomial parameters:	3.46377e-09	-3.6497e-06	0.000377291	-0.292512

Transducer serial number: ES120-7CD 115
Transducer tank psi: -20.3

Depth bins:	0	100	200	300	400	500	600	700	800
Targets:	182	301	4	0	166	184	127	93	0
TS gain:	28.4819	28.4388	28.2531	NaN	28.2794	28.2680	28.2613	28.1577	NaN
SA correction:	-0.2909	-0.2815	-0.2870	NaN	-0.5168	-0.5843	-0.6160	-0.6383	NaN
Overall offset:	0.1142	0.1817	0.5638	NaN	0.9710	1.1287	1.2056	1.4574	NaN
TS gain (poly):	28.5425	28.4232	28.3515	28.3122	28.2904	28.2711	28.2391	28.1795	28.0771
SA Correction (poly):	-0.2925	-0.2878	-0.3353	-0.4143	-0.5039	-0.5833	-0.6319	-0.6287	-0.5530
Overall offset (poly):	-0.0038	0.2254	0.4639	0.7003	0.9230	1.1207	1.2817	1.3947	1.4480

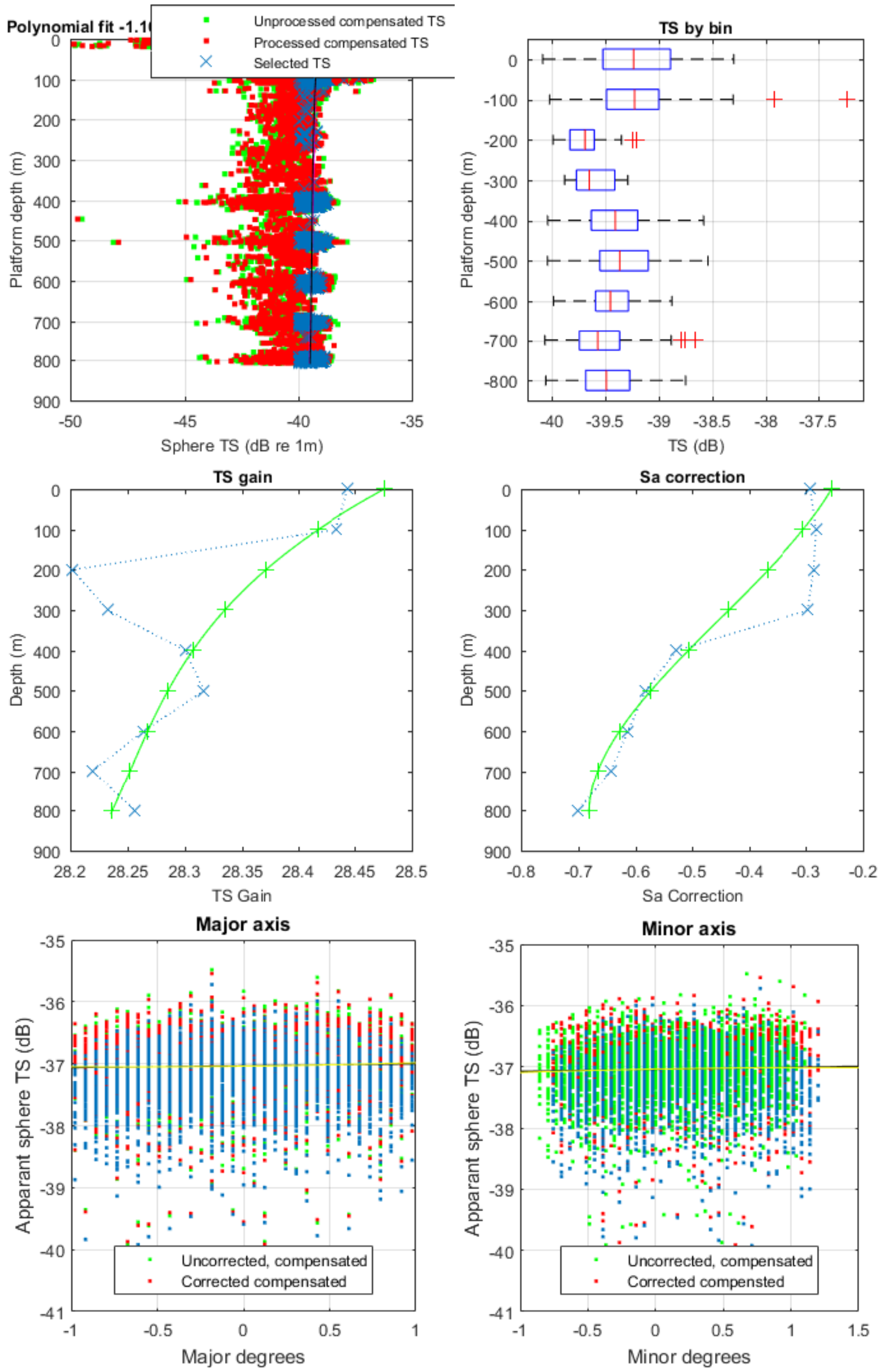
Up cast

TS polynomial parameters:	-1.0265e-09	1.21847e-07	0.000712341	-39.62
Gain polynomial parameters:	-4.38887e-10	7.6802e-08	0.000206219	28.2509
SA polynomial parameters:	2.71393e-10	-6.93289e-08	-0.000661681	-0.257402

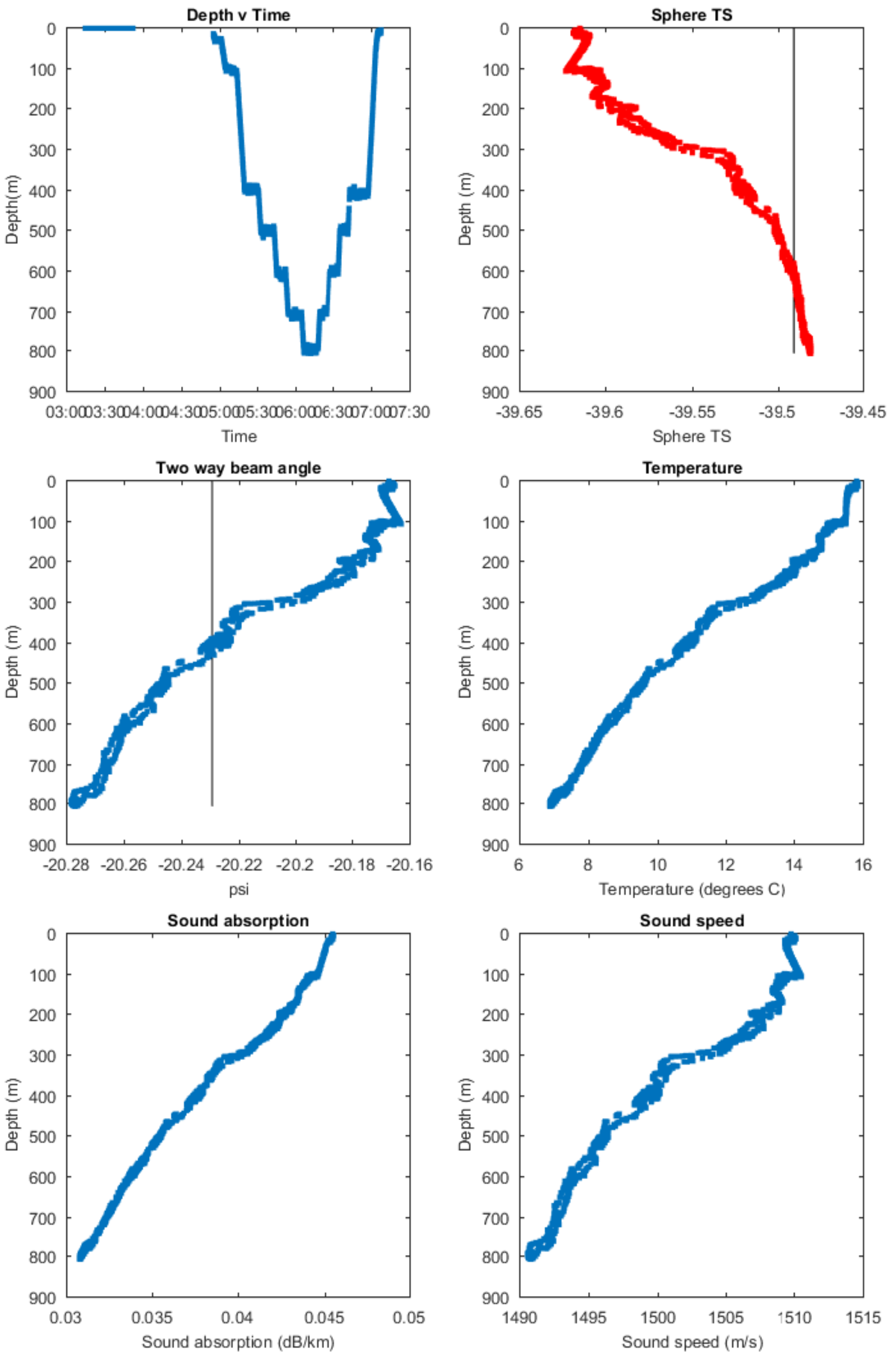
Transducer serial number: ES120-7CD 115
Transducer tank psi: -20.3

Depth bins:	0	100	200	300	400	500	600	700	800
Targets:	41	10	17	7	307	121	67	196	240
TS gain:	28.2746	28.2643	28.1899	28.2326	28.3120	28.3917	28.2696	28.2488	28.2565
SA correction:	-0.2995	-0.3031	-0.2862	-0.2969	-0.5343	-0.5800	-0.6073	-0.6453	-0.7006
Overall offset:	0.5460	0.5739	0.6889	0.6248	0.9409	0.8729	1.1717	1.2892	1.3844
TS gain (poly):	28.2509	28.2719	28.2917	28.3078	28.3176	28.3184	28.3075	28.2824	28.2403
SA Correction (poly):	-0.2574	-0.3240	-0.3903	-0.4548	-0.5158	-0.5717	-0.6207	-0.6615	-0.6922
Overall offset (poly):	0.5092	0.6005	0.6935	0.7902	0.8926	1.0028	1.1227	1.2544	1.3999

Figures



Polynomial fit -1.1
Unprocessed compensated TS
Processed compensated TS
Selected TS
Platform depth (m)
Sphere TS (dB re 1m)
TS by bin
Platform depth (m)
TS (dB)
TS gain
Depth (m)
TS Gain
Sa correction
Depth (m)
Sa Correction
Major axis
Apparant sphere TS (dB)
Uncorrected, compensated
Corrected compensated
Major degrees
Minor axis
Apparant sphere TS (dB)
Uncorrected, compensated
Corrected compensted
Minor degrees


Depth v Time
Depth(m)
Time
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
Sphere TS
Depth (m)
Sphere TS
-39.65
-39.6
-39.55
-39.5
-39.45
Two way beam angle
Depth (m)
psi
-20.28
-20.26
-20.24
-20.22
-20.2
-20.18
-20.16
Temperature
Depth (m)
Temperature (degrees C)
6
8
10
12
14
16
Sound absorption
Depth (m)
Sound absorption (dB/km)
0.03
0.035
0.04
0.045
0.05
Sound speed
Depth (m)
Sound speed (m/s)
1490
1495
1500
1505
1510
1515
0
100
200
300
400
500
600
700
800
900

Results (AEX201702)

1. 38 kHz

Power (W):	2000
Pulse length (ms):	2.048

38kHz_GPT 38 kHz 00907205c463 1 ES38B_20170708163227_20170720175925_kun017

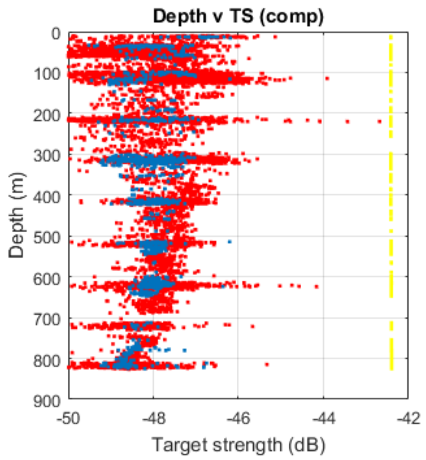
Data acquisition details

Transducer	ES38_DD Sn 28363 T1
Channel id	GPT 38 kHz 00907205c463 1 ES38B
Frequency	38000
Pulse length	0.0020480
Transmit power	2000
Gain	26.500
Equivalent beam angle	-20.600
Two Way Beam Angle	-20.600
Ek60 Transducer Gain	26.500
EK60 Sa Correction	0
Transmitted Pulse Length	2.0480
Transmitted Power	2000
Sound Speed	1500
Absorption Coefficient	0.0097472
Ev version	8.0.73.30735

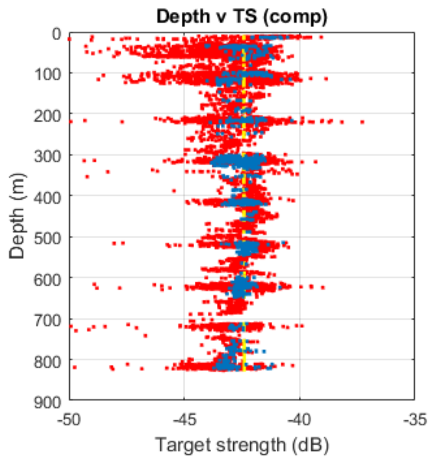
Calibration parameters

Major axis offset	0
Minor axis offset	0.2
Polynomial order	3
Onaxis criteria	1
Min TS	-50
Max TS	-46
Min depth	0
Min range	0
After	0
Before	5
Sphere ts	-42.4
View direction	0
Angular constraint	99
Use environment	1
Sound speed	1500
Sound absorption	0.0097472
Pulse length	0.0020480
Transmit power	2000
Gain	26.5
Active	1

Before



After



Up and down cast

TS polynomial parameters:	-9.53503e-09	1.07797e-05	-0.00342977	-42.1705
Gain polynomial parameters:	-4.73206e-09	5.32442e-06	-0.00169701	23.8168
SA polynomial parameters:	1.33483e-09	-1.81492e-06	0.000458749	-0.350437

Transducer serial number: ES38DD 28363
Transducer tank psi: -20.8

Depth bins:	0	100	200	300	400	500	600	700	800
Targets:	155	138	99	268	158	157	217	15	128
TS gain:	23.7299	23.7145	23.7095	23.6476	23.7026	23.7042	23.6843	23.5220	23.4534
SA correction:	-0.3280	-0.3353	-0.3368	-0.3374	-0.3609	-0.4229	-0.4508	-0.4553	-0.4615
Overall offset:	0.5826	0.6277	0.6409	0.7659	0.7027	0.8237	0.9191	1.2529	1.4025
TS gain (poly):	23.8168	23.6956	23.6526	23.6592	23.6871	23.7079	23.6933	23.6148	23.4440
SA Correction (poly):	-0.3504	-0.3214	-0.3206	-0.3401	-0.3719	-0.4079	-0.4402	-0.4608	-0.4616
Overall offset (poly):	0.4534	0.6377	0.7223	0.7481	0.7558	0.7862	0.8801	1.0782	1.4212

Down cast

TS polynomial parameters:	1.05136e-08	-2.05314e-05	0.00975487	-42.8438
Gain polynomial parameters:	5.28053e-09	-1.03057e-05	0.00488119	23.4809
SA polynomial parameters:	1.89385e-10	2.56068e-07	-0.000528618	-0.293233

Transducer serial number: ES38DD 28363
Transducer tank psi: -20.8

Depth bins:	0	100	200	300	400	500	600	700	800
Targets:	129	79	0	1	0	0	14	0	19
TS gain:	23.6378	23.8636	NaN	24.0491	NaN	NaN	23.8072	NaN	23.4691
SA correction:	-0.3187	-0.3163	NaN	-1.2565	NaN	NaN	-0.4499	NaN	-0.4636
Overall offset:	0.7480	0.2916	NaN	1.8010	NaN	NaN	0.6717	NaN	1.3752
TS gain (poly):	23.4809	23.8713	24.0872	24.1603	24.1224	24.0051	23.8402	23.6592	23.4938
SA Correction (poly):	-0.2932	-0.3433	-0.3872	-0.4237	-0.4516	-0.4699	-0.4773	-0.4728	-0.4553
Overall offset (poly):	1.0109	0.3304	-0.0137	-0.0871	0.0445	0.3156	0.6605	1.0135	1.3091

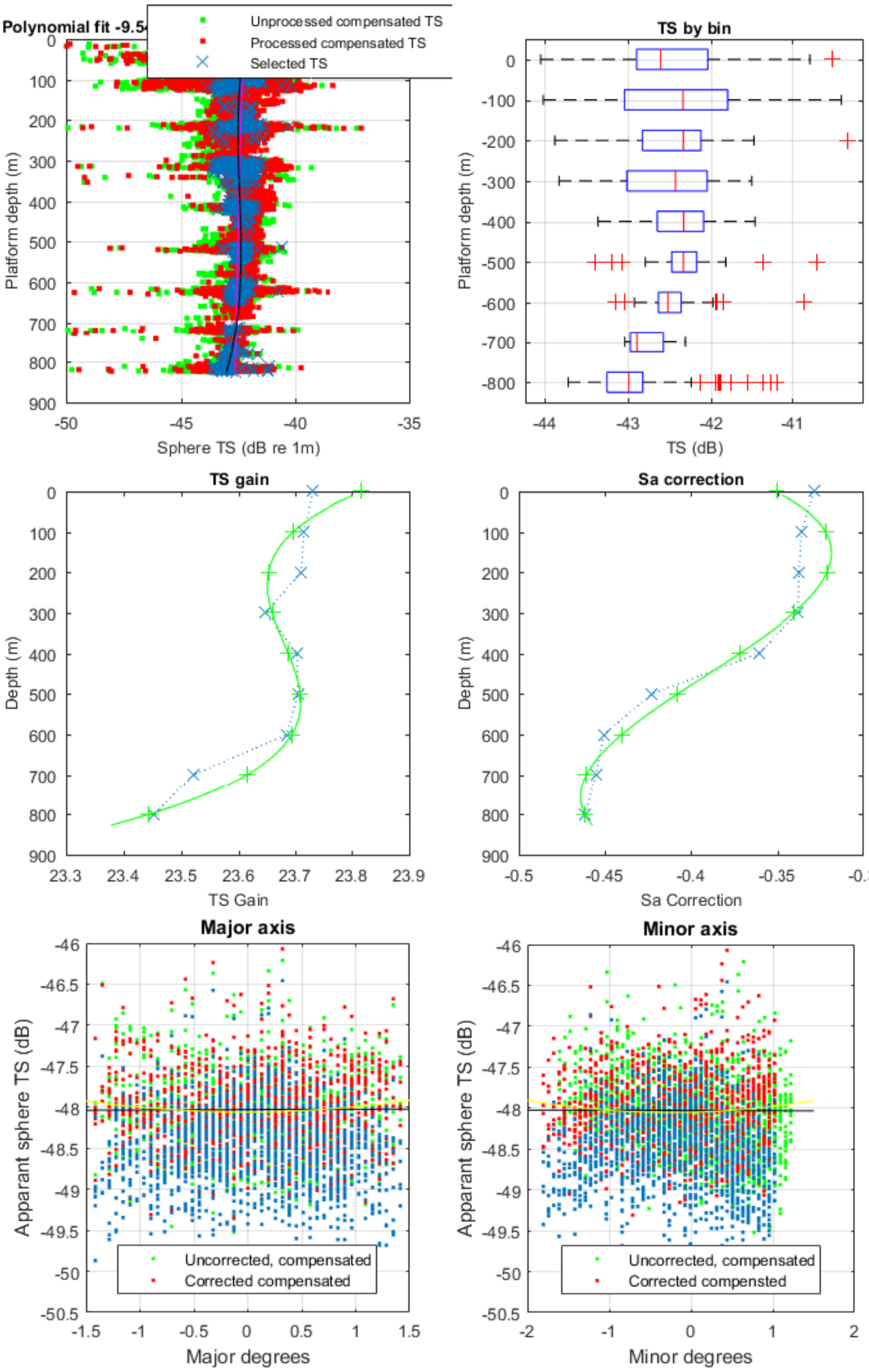
Up cast

TS polynomial parameters:	-1.51534e-08	1.88803e-05	-0.00692401	-41.7471
Gain polynomial parameters:	-7.53586e-09	9.36671e-06	-0.00344054	24.0281
SA polynomial parameters:	1.87768e-09	-2.6583e-06	0.000856119	-0.404722

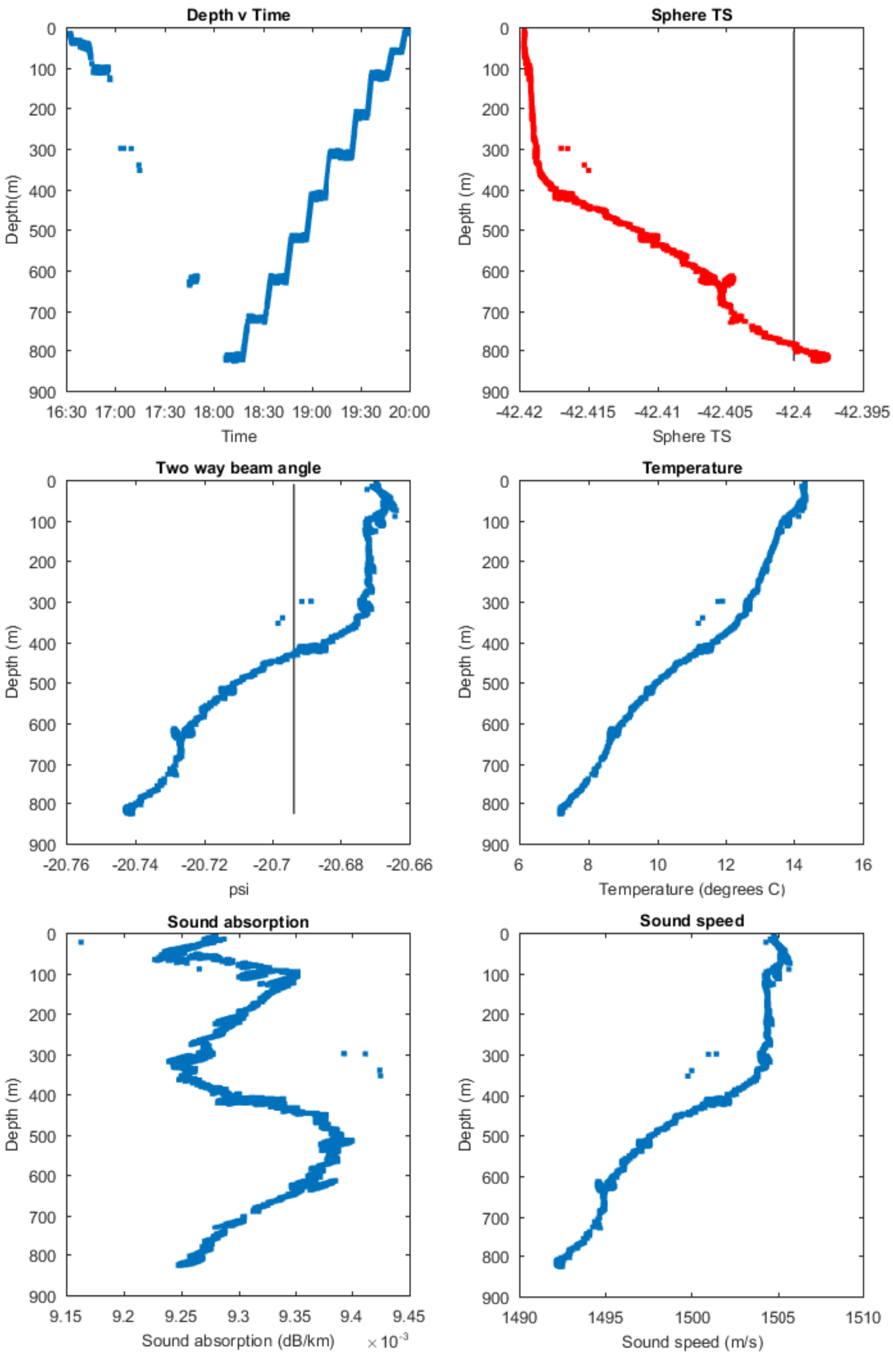
Transducer serial number: ES38DD 28363
Transducer tank psi: -20.8

Depth bins:	0	100	200	300	400	500	600	700	800
Targets:	26	59	99	267	158	157	203	15	109
TS gain:	24.1865	23.5150	23.7095	23.6461	23.7026	23.7042	23.6759	23.5220	23.4506
SA correction:	-0.3643	-0.3654	-0.3368	-0.3341	-0.3609	-0.4229	-0.4509	-0.4553	-0.4611
Overall offset:	-0.2581	1.0871	0.6409	0.7622	0.7027	0.8237	0.9362	1.2529	1.4072
TS gain (poly):	24.0281	23.7701	23.6543	23.6354	23.6682	23.7075	23.7080	23.6246	23.4120
SA Correction (poly):	-0.4047	-0.3438	-0.3248	-0.3364	-0.3674	-0.4065	-0.4425	-0.4640	-0.4598
Overall offset (poly):	0.1395	0.5336	0.7272	0.7882	0.7846	0.7843	0.8551	1.0650	1.4818

Figures



Polynomial fit -9.5
Unprocessed compensated TS
Processed compensated TS
Selected TS
Platform depth (m)
Sphere TS (dB re 1m)
TS by bin
Platform depth (m)
TS (dB)
TS gain
Depth (m)
TS Gain
Sa correction
Depth (m)
Sa Correction
Major axis
Apparant sphere TS (dB)
Uncorrected, compensated
Corrected compensated
Major degrees
Minor axis
Apparant sphere TS (dB)
Uncorrected, compensated
Corrected compensted
Minor degrees


Depth v Time
Depth(m)
Time
Sphere TS
Depth (m)
Sphere TS
Two way beam angle
Depth (m)
psi
Temperature
Depth (m)
Temperature (degrees C)
Sound absorption
Depth (m)
Sound absorption (dB/km)
× 10-3
Sound speed
Depth (m)
Sound speed (m/s)

2. 120 kHz

Power (W):	500
Pulse length (ms):	1.024

120kHz_GPT 120 kHz 009072073bbe 1 ES120-7C_20170708163220_20170720184102_kun017

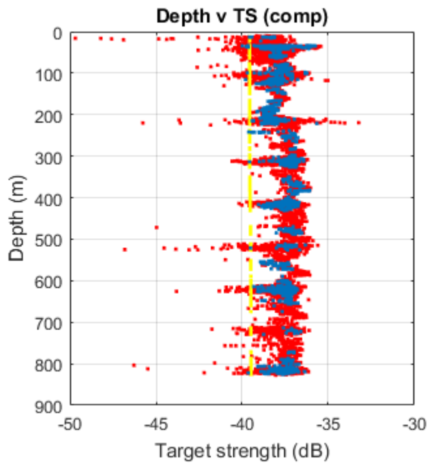
Data acquisition details

Transducer	Simrad ES120-7CD SN115 T2
Channel id	GPT 120 kHz 009072073bbe 1 ES120-7C
Frequency	120000
Pulse length	0.0010240
Transmit power	500
Gain	27
Equivalent beam angle	-21
Two Way Beam Angle	-21
Ek60 Transducer Gain	27
EK60 Sa Correction	0
Transmitted Pulse Length	1.0240
Transmitted Power	500
Sound Speed	1500
Absorption Coefficient	0.037306
Ev version	8.0.73.30735

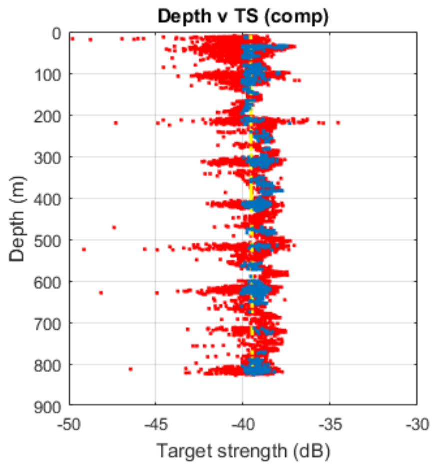
Calibration parameters

Major axis offset	-0.18000
Minor axis offset	0.11000
Polynomial order	3
Onaxis criteria	0.5
Min TS	-40
Max TS	-35
Min depth	0
Min range	0
After	0
Before	5
Sphere ts	-39.49
View direction	0
Angular constraint	99
Use environment	1
Sound speed	1500
Sound absorption	0.037306
Pulse length	0.0010240
Transmit power	500
Gain	27
Active	1

Before



After



Up and down cast

TS polynomial parameters:	2.27082e-09	-4.77235e-06	0.00301961	-39.7403
Gain polynomial parameters:	1.43445e-09	-2.79754e-06	0.00160241	27.8321
SA polynomial parameters:	-7.89063e-10	5.32988e-07	5.09443e-05	-0.354276

Transducer serial number: ES120-7CD 115
Transducer tank psi: -20.3

Depth bins:	0	100	200	300	400	500	600	700	800
Targets:	129	463	67	210	286	65	582	33	207
TS gain:	28.0915	27.8741	27.9157	28.2069	28.1379	28.1440	28.0630	28.1812	28.0743
SA correction:	-0.3865	-0.3300	-0.3307	-0.3523	-0.2801	-0.2643	-0.3104	-0.3113	-0.3828
Overall offset:	0.4386	0.7604	0.6786	0.1395	0.1331	0.0892	0.3433	0.1087	0.4655
TS gain (poly):	27.8321	27.9658	28.0521	28.0998	28.1173	28.1132	28.0963	28.0750	28.0580
SA Correction (poly):	-0.3543	-0.3446	-0.3291	-0.3123	-0.2991	-0.2942	-0.3023	-0.3281	-0.3764
Overall offset (poly):	0.8930	0.6063	0.4025	0.2737	0.2123	0.2105	0.2606	0.3548	0.4853

Down cast

TS polynomial parameters:	4.10989e-09	-6.50544e-06	0.00261456	-39.2226
Gain polynomial parameters:	2.26705e-09	-3.51452e-06	0.0013302	28.0956
SA polynomial parameters:	-1.17805e-09	1.02405e-06	-4.14737e-05	-0.393002

Transducer serial number: ES120-7CD 115
Transducer tank psi: -20.3

Depth bins:	0	100	200	300	400	500	600	700	800
Targets:	108	21	0	0	0	0	25	0	81
TS gain:	28.1355	28.2129	NaN	NaN	NaN	NaN	28.1052	NaN	28.0738
SA correction:	-0.3939	-0.3882	NaN	NaN	NaN	NaN	-0.3052	NaN	-0.3856
Overall offset:	0.3653	0.1993	NaN	NaN	NaN	NaN	0.2485	NaN	0.4722
TS gain (poly):	28.0956	28.1957	28.2392	28.2395	28.2104	28.1654	28.1182	28.0822	28.0712
SA Correction (poly):	-0.3930	-0.3881	-0.3698	-0.3451	-0.3211	-0.3050	-0.3037	-0.3243	-0.3740
Overall offset (poly):	0.4434	0.2333	0.1098	0.0597	0.0700	0.1277	0.2197	0.3328	0.4542

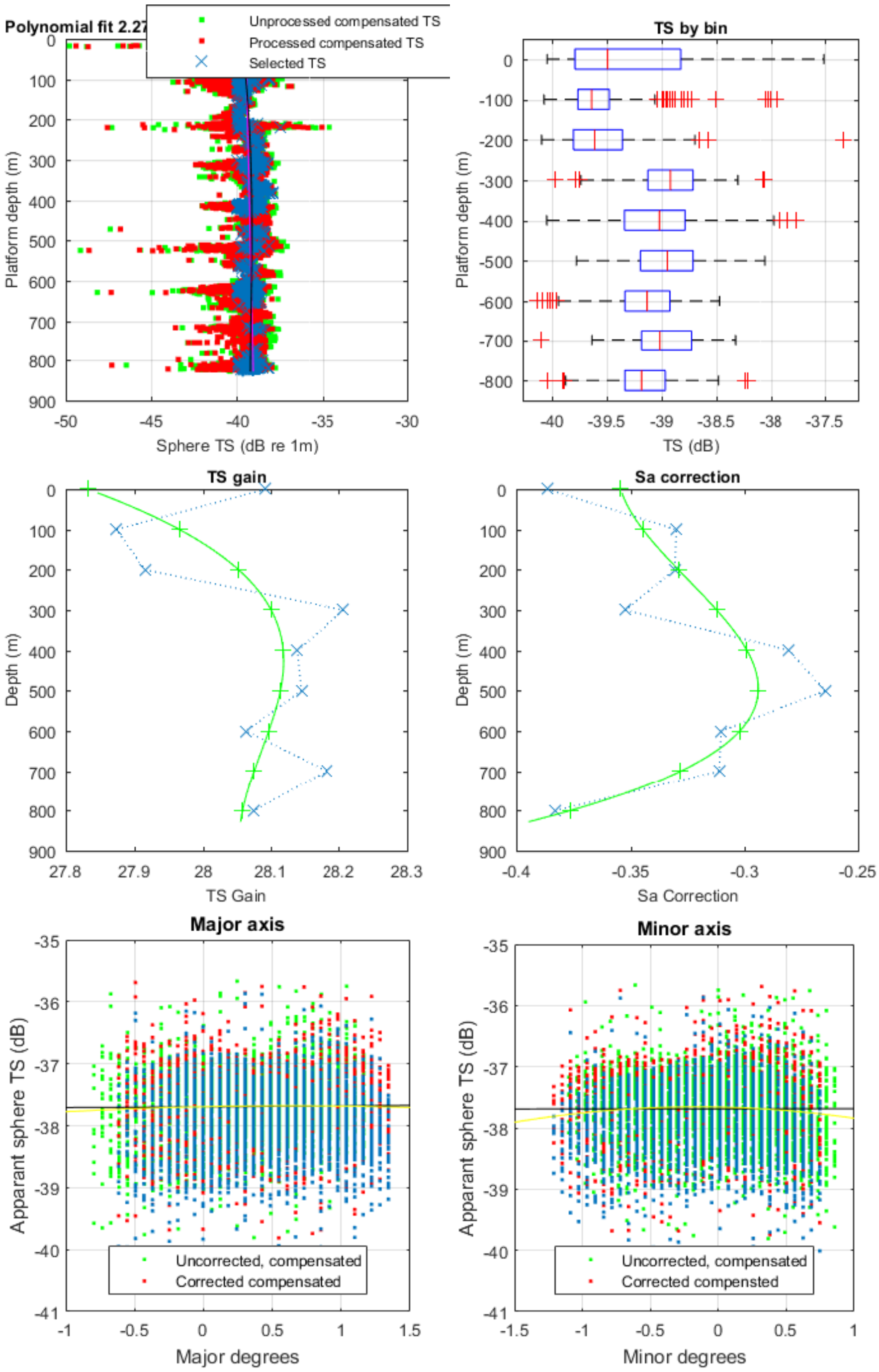
Up cast

TS polynomial parameters:	7.26301e-09	-1.22958e-05	0.00636753	-40.145
Gain polynomial parameters:	3.95181e-09	-6.59112e-06	0.00329051	27.6277
SA polynomial parameters:	-1.23722e-09	1.19163e-06	-0.000236578	-0.319906

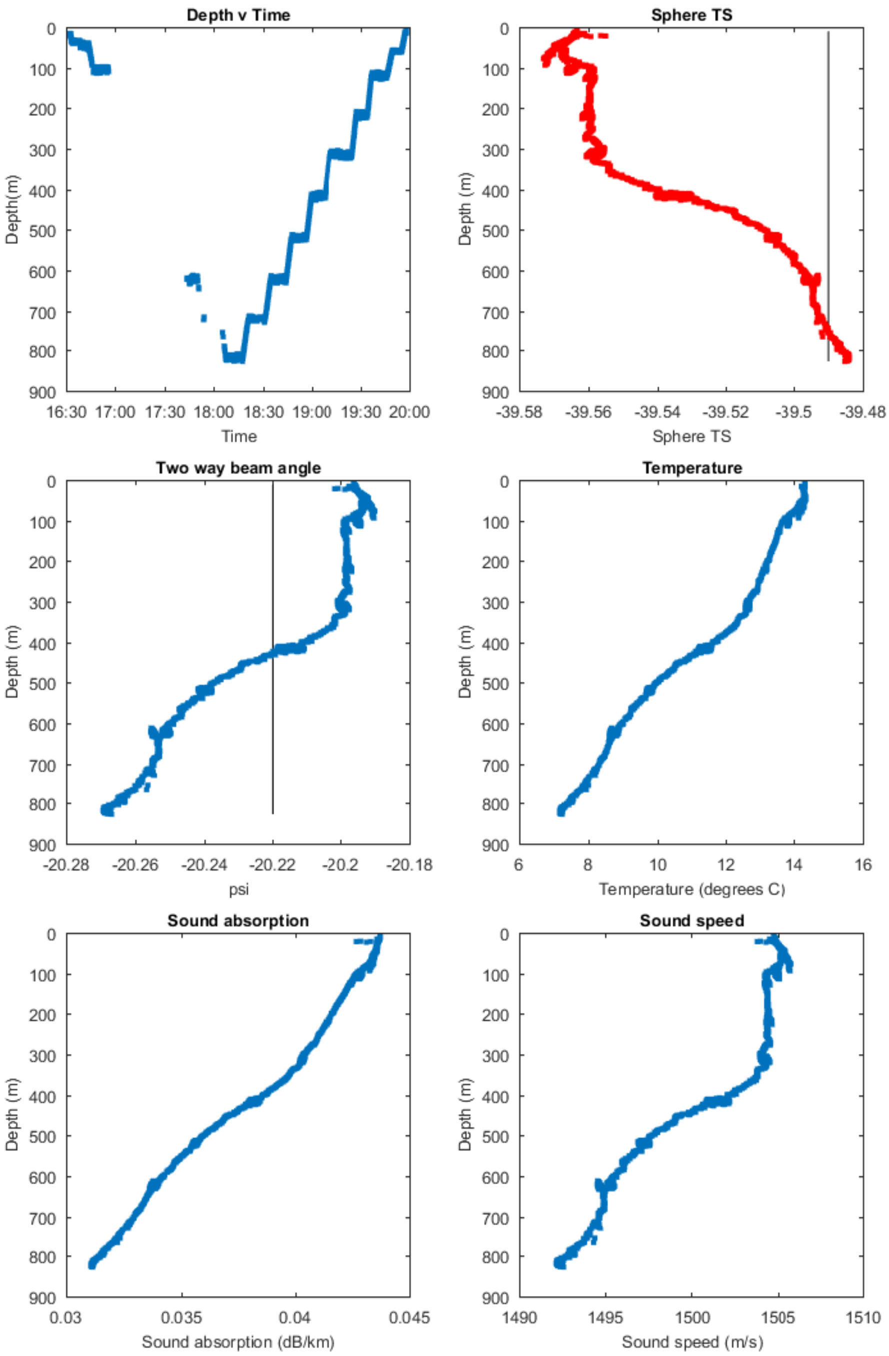
Transducer serial number: ES120-7CD 115
Transducer tank psi: -20.3

Depth bins:	0	100	200	300	400	500	600	700	800
Targets:	21	442	67	210	286	65	557	33	126
TS gain:	27.8650	27.8580	27.9157	28.2069	28.1379	28.1440	28.0611	28.1812	28.0747
SA correction:	-0.3433	-0.3267	-0.3307	-0.3523	-0.2801	-0.2643	-0.3106	-0.3113	-0.3810
Overall offset:	0.8053	0.7861	0.6786	0.1395	0.1331	0.0892	0.3476	0.1087	0.4612
TS gain (poly):	27.6277	27.8948	28.0538	28.1284	28.1423	28.1192	28.0828	28.0569	28.0651
SA Correction (poly):	-0.3199	-0.3329	-0.3295	-0.3170	-0.3031	-0.2949	-0.3001	-0.3260	-0.3800
Overall offset (poly):	1.2330	0.7247	0.3999	0.2259	0.1702	0.2001	0.2832	0.3867	0.4783

Figures



Polynomial fit 2.27
Unprocessed compensated TS
Processed compensated TS
Selected TS
Platform depth (m)
Sphere TS (dB re 1m)
TS by bin
Platform depth (m)
TS (dB)
TS gain
Depth (m)
TS Gain
Sa correction
Depth (m)
Sa Correction
Major axis
Apparant sphere TS (dB)
Uncorrected, compensated
Corrected compensated
Major degrees
Minor axis
Apparant sphere TS (dB)
Uncorrected, compensated
Corrected compensted
Minor degrees


Depth v Time
Depth(m)
Time
16:30 17:00 17:30 18:00 18:30 19:00 19:30 20:00
Sphere TS
Depth (m)
-39.58 -39.56 -39.54 -39.52 -39.5 -39.48
Two way beam angle
psi
-20.28 -20.26 -20.24 -20.22 -20.2 -20.18
Temperature
Temperature (degrees C)
6 8 10 12 14 16
Sound absorption
Sound absorption (dB/km)
0.03 0.035 0.04 0.045
Sound speed
Sound speed (m/s)
1490 1495 1500 1505 1510
0 100 200 300 400 500 600 700 800 900

APPENDIX 2: CATCH COMPOSITION

Table 17: Catch composition – Sea Valley.

Code	Common Name	Scientific Name	Weight (kg)	No.
APR	Catshark	*Apristurus* spp.	0.51	1
BCA	Barracudina	*Magnisudis prionosa*	0.23	1
BEE	Basketwork eel	*Diastobranchus capensis*	4.04	5
BSH	Seal shark	*Dalatias licha*	25.23	3
BYS	Alfonsino	*Beryx splendens*	2.45	2
CBA	Humpback rattail (slender rattail)	*Coryphaenoides dossenus*	1.27	6
CSE	Serrulate rattail	*Coryphaenoides serrulatus*	9.84	44
CSU	Four-rayed rattail	*Coryphaenoides subserrulatus*	0.50	6
CYP	Longnose velvet dogfish	*Centroscymnus crepidater*	1.27	2
DSK	Deepwater spiny skate (arctic skate)	*Amblyraja hyperborea*	0.82	2
EPR	Robust cardinalfish	*Epigonus robustus*	0.28	1
EPT	Deepsea cardinalfish	*Epigonus telescopus*	17.54	7
ETB	Baxters lantern dogfish	*Etmopterus baxteri*	1.10	1
ETL	Lucifer dogfish	*Etmopterus lucifer*	0.33	1
GDU	Bushy hard coral	*Goniocorella dumosa*	1.30	
GRC	Grenadier cod	*Tripterophycis gilchristi*	0.23	1
HAK	Hake	*Merluccius australis*	3.18	1
HJO	Johnson's cod	*Halargyreus johnsonii*	20.76	66
HOK	Hoki	*Macruronus novaezelandiae*	47.68	23
JAV	Javelin fish	*Lepidorhynchus denticulatus*	21.27	65
LAN	Lantern fish	*Myctophidae*	0.06	1
MIQ	Warty squid	*Onykia ingens*	1.07	1
NOG	NZ northern arrow squid	*Nototodarus gouldi*	1.15	1
OFH	Oilfish	*Ruvettus pretiosus*	43.00	1
ORH	Orange roughy	*Hoplostethus atlanticus*	55 702.68	37 959
PER	Persparsia kopua	*Persparsia kopua*	0.06	1
PHO	Lighthouse fish	*Phosichthys argenteus*	0.11	1
PLS	Plunket's shark	*Proscymnodon plunketi*	37.66	5
PYR	Pyrosoma atlanticum	*Pyrosoma atlanticum*	1.79	17
RIB	Ribaldo	*Mora moro*	77.58	43
SAL	Salps		0.78	
SBK	Spineback	*Notacanthus sexspinis*	1.87	8
SFI	Starfish	*Asteroidea & Ophiuroidea*	0.20	
SND	Shovelnose spiny dogfish	*Deania calcea*	234.34	54
SOR	Spiky oreo	*Neocyttus rhomboidalis*	3.87	7
SQX	Squid remains		0.18	2
VSQ	Violet squid	*Histioteuthis* spp.	1.84	4
WHX	White rattail	*Trachyrincus aphyodes*	2.84	1

Table 18: Catch composition – Rock Garden.

Code	Common Name	Scientific Name	Weight (kg)	No.
BEE	Basketwork eel	*Diastobranchus capensis*	0.59	1
BYS	Alfonsino	*Beryx splendens*	6.51	3
CBO	Bollons rattail	*Coelorinchus bollonsi*	0.10	1
CIN	Notable rattail	*Coelorinchus innotabilis*	0.18	2
CMA	Mahia rattail	*Coelorinchus matamua*	0.49	1
CML	Black swallower	*Chiasmodon microcephalus*	0.20	1
CMX	Coryphaenoides mcmillani	*Coryphaenoides mcmillani*	1.00	5
CSU	Four-rayed rattail	*Coryphaenoides subserrulatus*	1.50	9
CYO	Smooth skin dogfish	*Centroscymnus owstoni*	31.00	7
CYP	Longnose velvet dogfish	*Centroscymnus crepidater*	9.46	1
EPT	Deepsea cardinalfish	*Epigonus telescopus*	55.35	19
ETB	Baxters lantern dogfish	*Etmopterus baxteri*	1.10	1
GSP	Pale ghost shark	*Hydrolagus bemisi*	3.14	2
HJO	Johnson's cod	*Halargyreus johnsonii*	9.17	19
HOK	Hoki	*Macruronus novaezelandiae*	272.35	93
JAV	Javelin fish	*Lepidorhynchus denticulatus*	0.71	3
LAN	Lantern fish	*Myctophidae*	0.04	1
OFH	Oilfish	*Ruvettus pretiosus*	44.80	1
ORH	Orange roughy	*Hoplostethus atlanticus*	25 642.50	19 757
PHO	Lighthouse fish	*Phosichthys argenteus*	0.18	1
PLS	Plunket's shark	*Proscymnodon plunketi*	66.38	3
RAG	Ragfish	*Pseudoicichthys australis*	0.32	1
RBM	Rays bream	*Brama brama*	2.74	2
RIB	Ribaldo	*Mora moro*	13.23	12
SOR	Spiky oreo	*Neocyttus rhomboidalis*	4.38	4
TET	Squaretail	*Tetragonurus cuvieri*	0.61	1
VSQ	Violet squid	*Histioteuthis* spp.	1.20	2

Table 19: Catch composition – Tolaga Knoll.

Code	Common Name	Scientific Name	Weight (kg)	No.
BCA	Barracudina	*Magnisudis prionosa*	0.26	1
BEE	Basketwork eel	*Diastobranchus capensis*	1.48	2
CAX	White brotula	*Cataetyx* sp.	1.66	1
CMU	Abyssal rattail	*Coryphaenoides murrayi*	0.26	1
CSE	Serrulate rattail	*Coryphaenoides serrulatus*	1.28	6
CSU	Four-rayed rattail	*Coryphaenoides subserrulatus*	0.56	2
EPT	Deepsea cardinalfish	*Epigonus telescopus*	14	3
ETB	Baxters lantern dogfish	*Etmopterus baxteri*	1.6	1
HJO	Johnson's cod	*Halargyreus johnsonii*	0.72	1
HOK	Hoki	*Macruronus novaezelandiae*	2.74	1
HYP	Pointynose blue ghost shark	*Hydrolagus trolli*	3.68	1
ORH	Orange roughy	*Hoplostethus atlanticus*	1 550	1 093
PHO	Lighthouse fish	*Phosichthys argenteus*	0.54	4
RAG	Ragfish	*Pseudoicichthys australis*	1.54	1
RIB	Ribaldo	*Mora moro*	1.68	1
SND	Shovelnose spiny dogfish	*Deania calcea*	8.82	4
VSQ	Violet squid	*Histioteuthis* spp.	0.68	1

APPENDIX 3: THEMATIC MAPS OF ECHOINTEGRATED OUTPUTS

1.1 Sea Valley

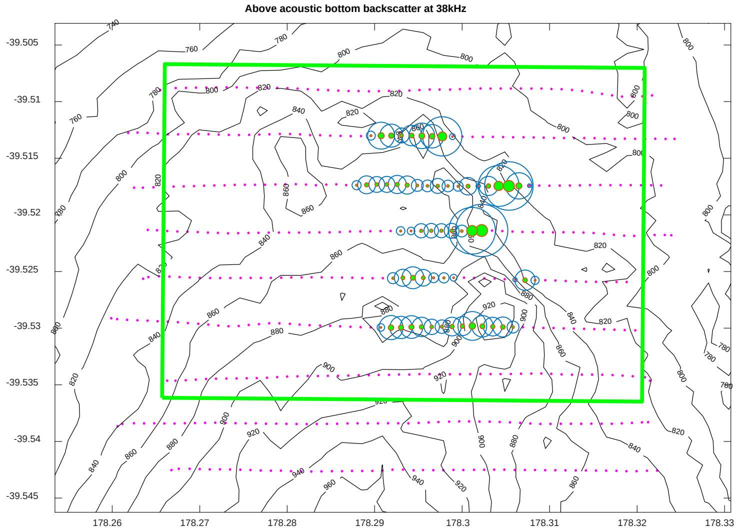


Figure 21: OP 34 thematic map of AOS 38 kHz echo-integration NASC values at the Sea Valley.

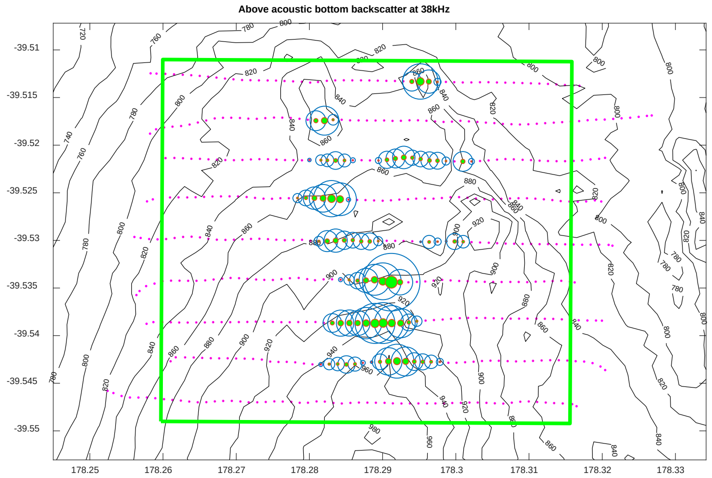


Figure 22: OP 37 thematic map of AOS 38 kHz echo-integration NASC values at the Sea Valley.

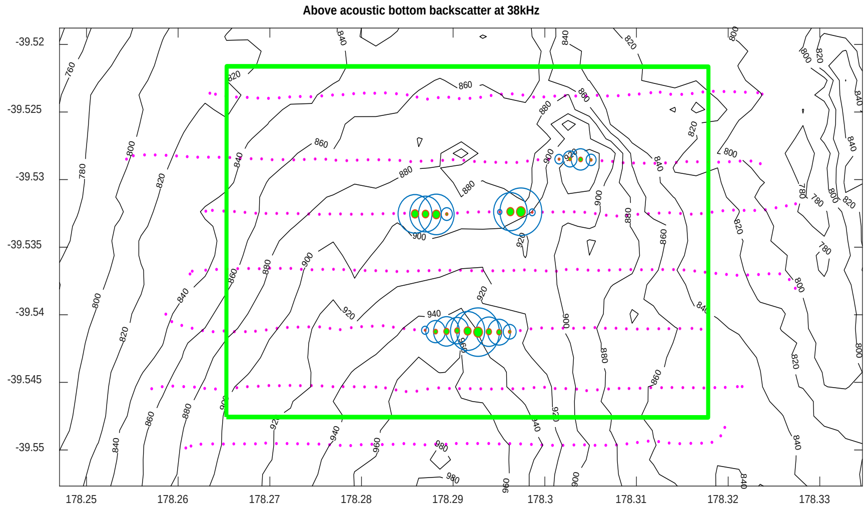


Figure 23: OP 45 thematic map of AOS 38 kHz echo-integration NASC values at the Sea Valley.

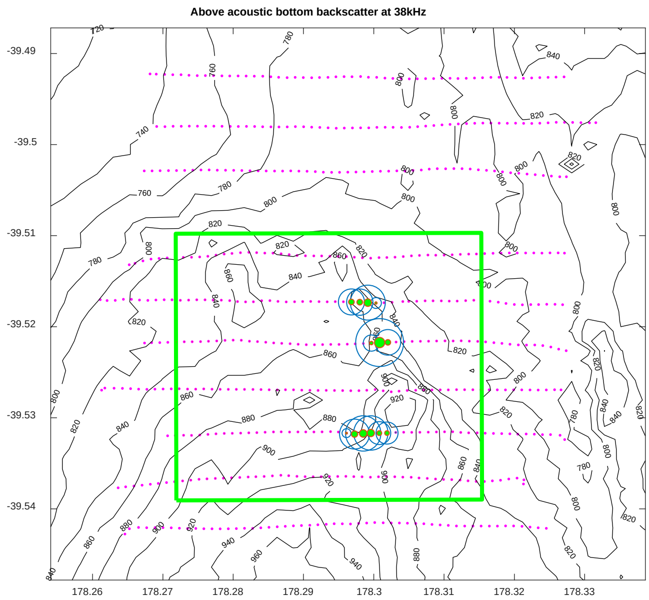


Figure 24: OP 47 thematic map of AOS 38 kHz echo-integration NASC values at the Sea Valley.

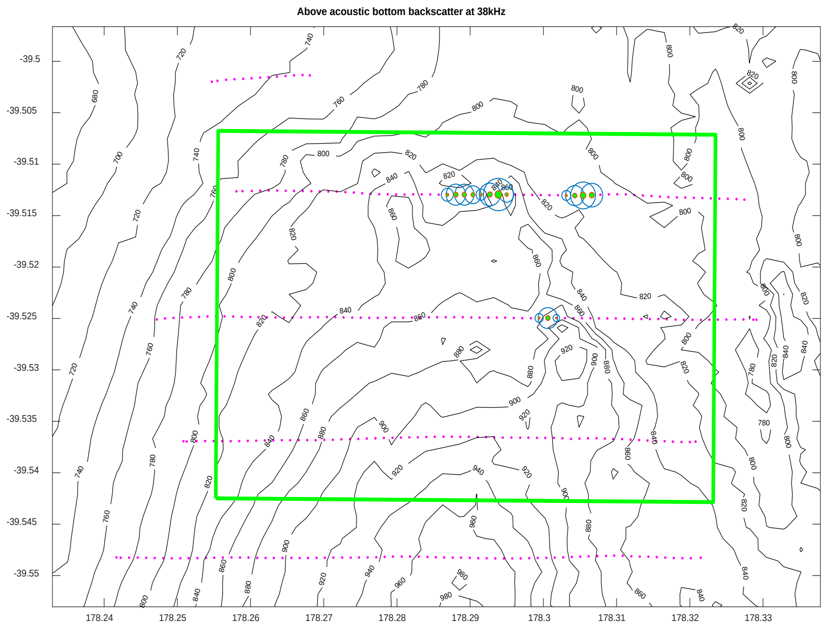


Figure 25: OP 62 thematic map of AOS 38 kHz echo-integration NASC values at the Sea Valley.

1.2 Rock Garden

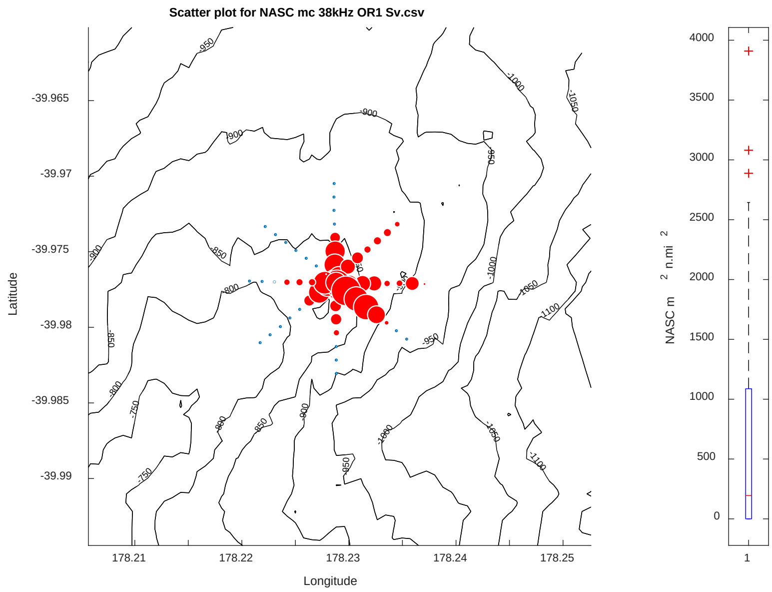


Figure 26: OP 11 thematic map of AOS 38 kHz echo-integration NASC values at the Rock Garden.

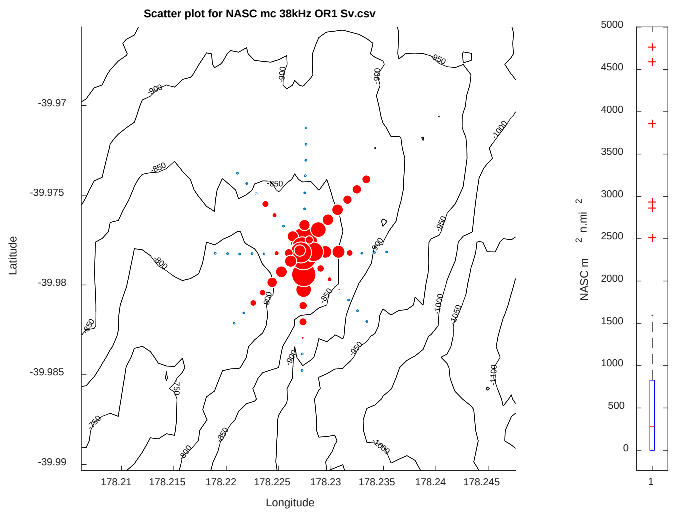


Figure 27: OP 27 thematic map of AOS 38 kHz echo-integration NASC values at the Rock Garden.

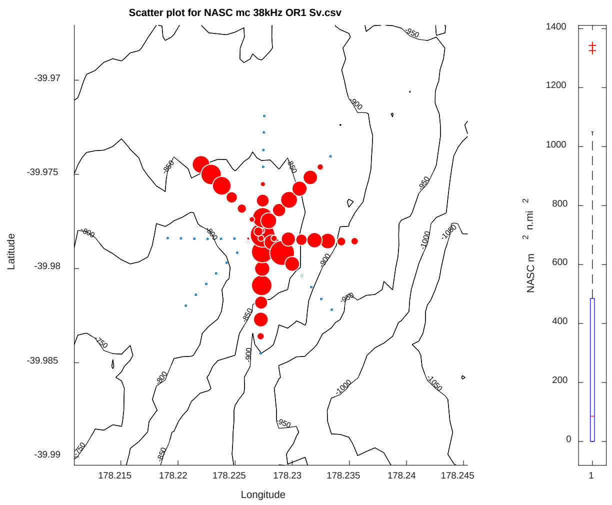


Figure 28: OP 28 thematic map of AOS 38 kHz echo-integration NASC values at the Rock Garden.

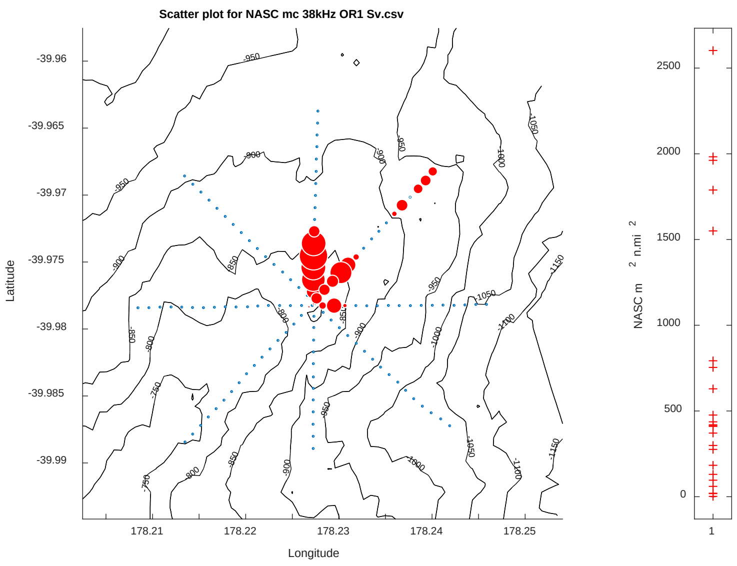


Figure 29: OP 49 thematic map of AOS 38 kHz echo-integration NASC values at the Rock Garden.

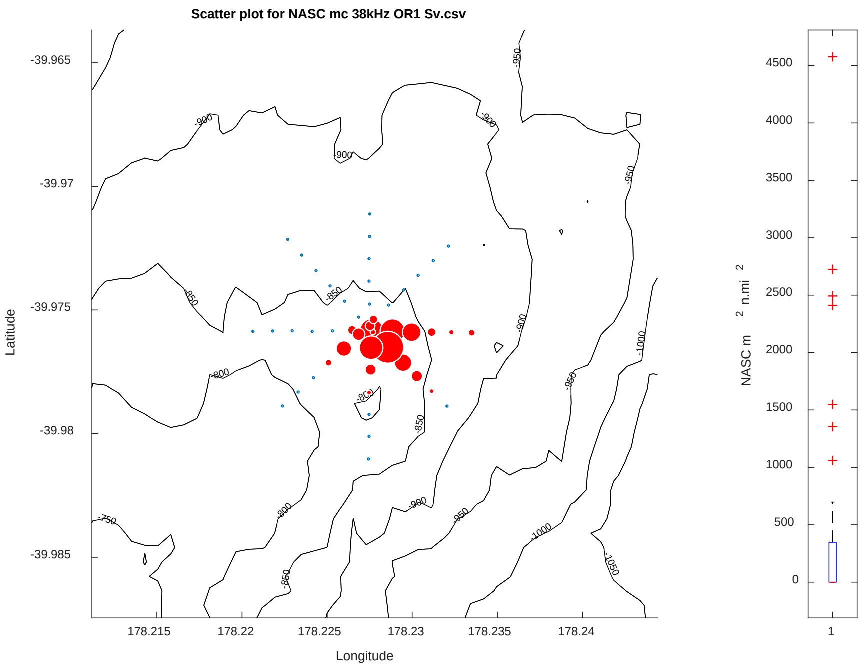


Figure 30: OP 50 thematic map of AOS 38 kHz echo-integration NASC values at the Rock Garden.

1.3 Tolaga Knoll

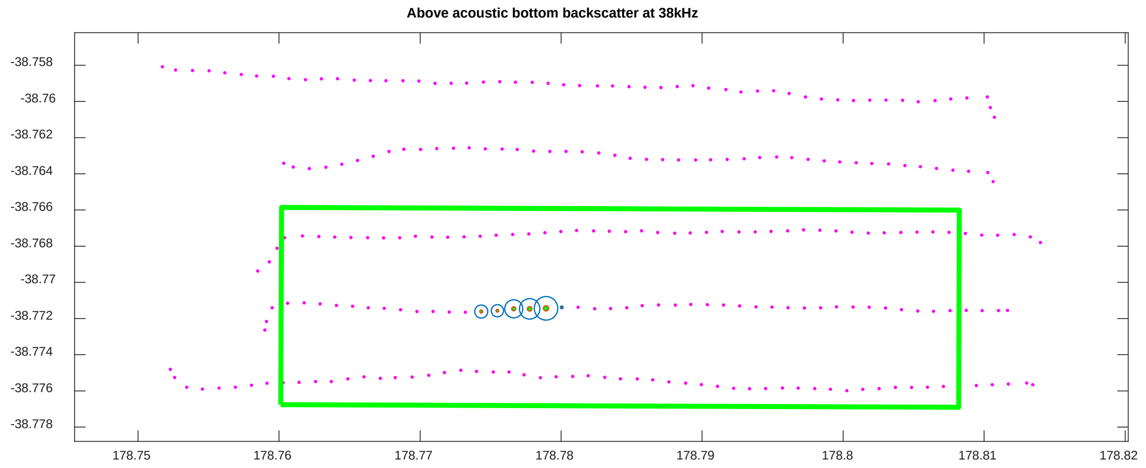


Figure 31: OP 43 thematic map of AOS 38 kHz echo-integration NASC values at Tolaga Knoll.

APPENDIX 4: TABLE OF ACTIVITIES

Table 20: Table of activities.

Operation Number	Operation Type	Start Date & Time (UTC)	Location	Comment
1	Vessel Search	14-Jun 19:29:00	Rock Garden	Quick search over Rock Garden. No sign of fish
2	Vessel Survey	15-Jun 06:33:00	Sea Valley	8 transect interlaced grid. Some moderate marks seen prior to survey commencing but had dispersed by the time these transects went through
3	Vessel Survey	15-Jun 11:27:00	Sea Valley	Some reasonable marks observed over ~ 1000 m area.
4	AOS Survey	15-Jun 14:38:00	Sea Valley	Technical issue with AOS. Survey data not useable
5	AOS biological	15-Jun 23:29:00	Sea Valley	Net bombs changed back to fast ping rates. Need to check data quality and communicate if interference is an issue. About 10 tonne roughy. Found issue with 120 kHz power supply. Exchanged with new unit (SN507333) for old unit (SN555498).
6	Vessel Survey	16-Jun 08:00:00	Sea Valley	
7	AOS Survey	16-Jun 11:15:00	Sea Valley	Pulled AOS after first transect to check that all is good. CTD now giving correct readings. 120 kHz with new power supply (SN 507333) working to 450 m. Changed net bomb batteries at the start of transect 4. Power supply issue on second last transect. 38
8	AOS biological	17-Jun 00:33:00	Sea Valley	New motion logging software running. Small catch ~ 200 kg.
9	AOS biological	17-Jun 02:32:00	Sea Valley	~ 9 tonnes roughy. Mostly stage 4 for males and females
10	Vessel Survey	17-Jun 06:46:00	Rock Garden	
11	AOS Survey	17-Jun 09:55:00	Rock Garden	Excellent marks on all four transects, not disturbed by AOS.
12	Vessel Survey	17-Jun 13:55:00	Rock Garden	Fine scale rectangular vessel survey of Rock Garden.
13	AOS biological	17-Jun 15:43:00	Rock Garden	3t caught. Targeted at large plume but cautious with trawl to avoid big catch.
14	AOS biological	17-Jun 17:24:00	Rock Garden	1t caught. Targeted at large plume but cautious with trawl to avoid big catch.
15	AOS biological	17-Jun 09:00:00	Rock Garden	Third shot to ensure catch was representative. 4t caught. Targeted at large plume but cautious with trawl to avoid big catch.
16	AOS trim warps	17-Jun 21:40:00	Rock Garden	Platform stability experiment Depth ~600m Warp out at level 1146m SOG = 3.2knts 22:03 - 22:10 level 22:11 - 22:16 stb out 5m 22:18 - 22:23 stb out 10m 22:25 - 22:30 stb in 5m 22:31 - 22:36 stb in 10m 22:37 - 22:42 level (note warp markers are o)
17	Vessel Survey	18-Jun 01:22:00	Sea Valley	High quality vessel acoustics in smooth seas. Large strong mark, thought to be orange roughy at first but further observations (e.g. shape, intensity, mobility) suggested a cardinal mark. Post survey searching failed to find any sign of the large aggregation.
18	Vessel Search	18-Jun 07:50:00	Ritchie Hill	Searching circuit of Strawberry Mountain (aka Ritchies)
19	AOS survey mode - single pass	18-Jun 09:39:00	Ritchie Hill	Single pass over Ritchie Hill (aka Strawberry Mountain).

Operation Number	Operation Type	Start Date & Time (UTC)	Location	Comment
20	Vessel Search	18-Jun 11:25:00	North Hill	Searching North Hill then across to Hill 814 via Gentle Annie. Just north of Hill 812 4 km mark observed. Next op will be AOS single pass to key out species
21	AOS survey mode - single pass	18-Jun 14:12:00	Hill 814	Just north of Hill 812, to investigate potential orange roughy aggregation, Acoustics revealed that is undetermined fish bladder species
22	Vessel Search	18-Jun 15:30:00	Hill 814	No sign of orange roughy
23	Vessel Search	18-Jun 16:20:00	Sea Valley	Vessel search in the area that has previously held fish, small cardinal mark at the head of the valley. Very small orange roughy mark on the western side of the valley
24	Vessel Search	18-Jun 17:58:00	Sea Valley	Search other regions of the valley feature to look for orange roughy aggregations. No sign of orange roughy, small cardinal mark on the SW side.
25	Vessel Search	18-Jun 23:45:00	Wider Rock Garden Region	Tim's Bank. Large cardinal mark as we were leaving Tim's bank .
26	Vessel Search	19-Jun 01:10:00	Wider Rock Garden Region	Search of the wider Rock Garden region during the afternoon. Only cardinal marks observed, often impressive and mobile. No sign of orange roughy until returned to Rock Garden on dark.
27	AOS Survey	19-Jun 06:49:00	Rock Garden	Start pattern AOS survey following observation of marks that are highly likely to be orange roughy. Good marks on all transects.
28	AOS Survey	19-Jun 10:40:00	Rock Garden	
29	AOS biological	19-Jun 15:01:00	Rock Garden	300kg of orange roughy caught.
30	AOS biological	19-Jun 17:07:00	Rock Garden	4t of orange roughy caught.
31	AOS biological	19-Jun 18:53:00	Rock Garden	8t orange roughy. Appears that the battery failed at depth for a 8min duration, the system then restarted.
32	Vessel Survey	19-Jun 21:17:00	Rock Garden	
33	Vessel Survey	20-Jun 01:40:00	Sea Valley	Orange roughy observed when first arriving at Sea Valley. Interlaced grid transect survey with 0.25 n.mile transect spacing.
34	AOS Survey	20-Jun 05:40:00	Sea Valley	
35	AOS biological	20-Jun 15:04:00	Sea Valley	~10t orange roughy. Pre-spawning and spawning (5%) males.
36	AOS biological	20-Jun 16:55:00	Sea Valley	~8t orange roughy. Pre-spawning and spawning (2%) males.
37	AOS Survey	20-Jun 19:05:00	Sea Valley	AOS survey with good marks on some of the transects.
38	AOS biological	21-Jun 05:15:00	Sea Valley	Small catch. Trawl did not take many marks.
39	AOS biological	21-Jun 08:30:00	Sea Valley	15 t roughy.
40	AOS survey mode - single pass	21-Jun 18:41:00	Tolaga Knoll	2 "single pass" transects with AOS in survey mode. Review of the data found a mark of orange roughy hard down with suggestion of scare reaction inferred by the void immediately above the mark. Second pass found no roughy.
41	AOS survey mode - single pass	22-Jun 03:50:00	Tolaga Knoll	Orange roughy hard down.
42	AOS survey mode - single pass	22-Jun 07:38:00	Tolaga Knoll	Targeting substantial mark running down slope. Possibly cardinal but if orange roughy a very significant aggregation. Mark dispersed with only gas bladder species observed on the AOS.
43	AOS Survey	22-Jun 09:24:00	Tolaga Knoll	Interlaced grid in very rough weather. Potential orange roughy marks had been very mobile and difficult to track in the extreme weather conditions. Given these factors decided to run interlaced AOS survey at 0.25 n.mile interval to try to encounter orange roughy during the survey.
44	AOS biological	22-Jun 16:09:00	Tolaga Knoll	Identified a small orange roughy aggregation from previous AOS survey and sampled it. Caught ~1t of mostly orange roughy 50:50 M:F. 30% spent, 20% spawning and 40% spent.

Operation Number	Operation Type	Start Date & Time (UTC)	Location	Comment
45	AOS Survey	23-Jun 00:52:00	Sea Valley	Not many marks observed although vessel data quality severely degraded on most runs.
46	AOS biological	23-Jun 09:38:00	Sea Valley	~ 7 t catch orange roughy.
47	AOS Survey	23-Jun 11:27:00	Sea Valley	AOS survey starting 0.6 n.miles north of previous northern-most transect to help ensure we bound the fish. Furuno on for the duration of the survey due to bad weather.
48	AOS biological	23-Jun 23:33:00	Sea Valley	Mods to GigE settings. GigE shutter speed changed from 5000 to 4000us, raw gained from 12 to 10. 3 t orange roughy.
49	AOS Survey	24-Jun 06:15:00	Rock Garden	ES60 somewhat degraded limiting utility for quantitative work. Decided to keep Furuno FCV30 on to get some intel on orange roughy extent either side of the transect line. Good mark on first transect but not so on next three. Repeating survey, moving survey centre north to target main body of the aggregation.
50	AOS Survey	24-Jun 09:56:00	Rock Garden	Weather marginal for quantitative ES60 analysis so Furuno left on to give some intel on fish distribution either side. This star pattern survey was moved slightly North of the previous one (OP49) to relocate to where the centre of the fish was thought to be.
51	AOS biological	24-Jun 14:40:00	Rock Garden	~5t of orange roughy.
52	AOS survey mode - single pass	24-Jun 19:40:00	Wider Rock Garden Region	North-west side of Tim's bank. Gas bladder species. 38 kHz down.
53	Vessel Search	24-Jun 16:15:00	Tim's Bank	Tim's bank wide area search.
54	Vessel Search	24-Jun 22:30:00		Eastern side of the valley, wide area search.
55	Vessel Search	25-Jun 18:44:00	Tolaga Knoll	Systematic searching around Tolaga.
56	Fibre Optic Trial	26-Jun 01:00:00	Tolaga Knoll	Test deployment with fibre optic with WBT tube installed and 120 kHz transducer. Net-AOS system about 50 metres behind vessel and AOS just beneath the surface so quite noisy environment. Collected WBT data in CW and FM. Issues with hydraulics, system haul.
57	Wide Area Search	26-Jun 02:00:00	Mid East Coast 750-950	Wide area search of the region between 750-950 m contours. No significant aggregations observed until end of this period where good marks observed. Potential orange roughy or cardinal.
58	AOS survey mode - single pass	26-Jun 10:06:00	178: 12.6 E, 39:41.6S	Single pass AOS transect over potential roughy mark. Main mark had moved between time of vessel passing over and AOS arriving, suggesting mobile cardinals. Close inspection of the AOS data found 120 kHz suggests a layer of orange roughy but at very low density.
59	Wide Area Search	26-Jun 10:50:00	Mid East Coast 750-950	Continue wide area search, south of Sea Valley, north-west of Rock Garden. No significant aggregations observed.
60	WBT EK80 trial	27-Jun 00:50:00	Sea Valley	Trial of WBT EK80 tube at 120 kHz, CW 1.024 ms, 0-600 m range, 250 W.
61	EK80 trial	27-Jun 04:17:00	Sea Valley	
62	AOS Survey	27-Jun 06:45:00	Sea Valley	Left Furuno on as interested in spatial distribution of schools either side of vessel. Technical issues with survey. AOS 38 kHz transceiver card failed. Second half of survey, i.e. return interlace transects, battery failed at 11:38.
63	AOS biological	27-Jun 18:50:00	Sea Valley	
64	AOS surface calibration	27-Jun 20:53:00		Surface test of Sealord AOS 38kHz with sphere. Quadant still down after re-seating cards.
65	Vessel calibration	28-Jun 01:08:00	Sea Valley	Vessel calibration. At end had FCV on, use data up till 1:25.
66	AOS surface calibration	28-Jun 02:00:00		AOS - with CSIRO EK60 38kHz cards, ethernet and power supply fitted. Surface calibration. 02:40 onwards contains 38/120kHz data.
67	AOS deep calibration	28-Jun 00:00:00		

Operation Number	Operation Type	Start Date & Time (UTC)	Location	Comment
68	FCV 30/ES60 tests	28-Jun 08:31:00	Transit to port heading south	Series of tests with FCV 30 turned on and off to quantify the effect on ES60 return signal. Tests conducted in both passive and active on ES60. Test is relevant only for the particular combination of FCV 30 settings used on this survey
69	Vessel Search	28-Jun 21:00:00	Transit to Nelson, lower MEC	Vessel search in the lower Mid-East Coast during transit to port. Reasonable potential orange roughy marks observed.