# Biomass estimates of orange roughy spawning aggregations in ORH7B using a net-attached acoustic optical system, July 2017

Tim Ryan[1] and Rob Tilney[2]

1st May 2018

**Final Report to Deepwater Group Ltd, New Zealand**

1. CSIRO Oceans and Atmosphere, Hobart, Tasmania
2. Clement and Associates Ltd, New Zealand

# 1 EXECUTIVE SUMMARY

Acoustic surveys of ORH7B zone spawning orange roughy aggregations were conducted between the 3rd and 8th of July 2017 on the FV *Amaltal Explorer*. The primary survey instrument was the Sealord AOS attached to the vessel's demersal trawl net. Simrad ES60 38 kHz and 120 kHz echosounder provided calibrated measurement of acoustic backscatter. The 2017 survey focused on regions with historical effort and where spawning aggregations had been previously observed. Spawning orange roughy aggregations were found in the same location (Eastern end of Cook Canyon) identified from the 2015 and 2016 surveys. In 2017 this aggregation was acoustically surveyed three times using the AOS and sampled by three trawls with regular acoustic observation outside of formal survey periods. The identified orange roughy aggregations were notable for their low numeric densities when compared to our experience with other spawning locations (e.g. Mid-East Coast, ORH7A Challenger and ORH3B Chatham Rise at Rekohu and Spawn Plume). The three acoustic surveys estimated biomass of the main aggregation to be between 627 and 930 tonnes using the AOS 38 kHz data.

Trawl catch information indicated that spawning was well underway with female orange roughy 30% spent for the first two trawls and 70 % spent for the last one. Similarly the 2015 biological sampling indicated that surveying commenced after the spawning peak. However, the 2016 trawl survey found that peak spawning for that year (i.e. when 20% of female gonads were in spent condition), occurred between 8 - 11 July (Doonan et al., 2016). Identifying the optimal survey period for future surveys will be difficult given that there is no opportunity to review year-by-year spawning as this is a closed fishery.

Surveys of the wider region including Moeraki Canyon, The Abut and wide area transects in-between did not locate orange roughy. All indications from 2017 survey and the previous 2015 and 2016 surveys, point to a modest stock concentrated on a small area in Cook Canyon during the winter spawning period.

# 2 INTRODUCTION

This report documents biomass estimates of orange roughy in the ORH7B Management Area based on measurements from a net-attached Acoustic-Optical System (AOS) deployed from an industry vessel. Survey activities were carried out between the 3rd and 8th of July 2017. The main focus was on the Cook Canyon region but Moeraki Canyon and wider areas in the region also received attention. 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 transect surveys. Demersal trawls provided biological samples which were processed to provide species composition and measures of fish length, weight, sex and spawning condition. The AOS-demersal trawls also provided acoustic target strength (TS) information at two frequencies, 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 occasionally used during searches for fish to take advantage of the increased coverage provided by the port and starboard 7 degree angle echosounder beams. This report details the voyage activities, giving a brief overview of observations made at each of the spawning locations, summaries of biological measurements and acoustic-based biomass estimates.

The objectives were as follows:

**Overall objective:**

To estimate the abundance of spawning orange roughy aggregations in Cook Canyon and Moeraki Canyon.

**Specific Objectives:**

1. To locate one or more orange roughy spawning aggregations.
2. To assess abundance in the spawning aggregation(s) using an acoustic survey.
3. To collect catch composition and other biological data (length, sex, & gonad stage) from the spawning aggregation(s), including otoliths.
4. To calibrate acoustic equipment used in the survey.
5. To collect environmental data required for acoustic analysis.

**Continuous improvement objectives**

6. Use of the fibre optic connection to the Acoustic Optical System (AOS) for real-time configuration and operation of optics and acoustics to optimise survey execution.
7. Use the optic-fibre connectivity to additionally facilitate the following:
    a. Opportunistic trials of Simrad EK80 and Simrad WBT broadband echosounders to assess noise performance and to obtain broadband acoustic measures of orange roughy and co-occurring species.
    b. Calibration of the AOS at depth (weather permitting) taking advantage of optic-fibre connectivity to record and observe calibration data in real-time.
    c. Refinement of the stereo digital still cameras for image quality and performance of the strobe systems.

## 2.1 Background of fishery

Fishing for orange roughy on the West Coast South Island (WCSI) in Fishery Management Area ORH7B (Figure 1) was first reported in the winter of 1985. The initial TACC was 1,558 t, which peaked at 1,708 t a few years later, but from the 1st of October 2008 the TACC was reduced to 1 t, essentially closing the fishery. The last accepted stock assessment was in 2004 and used CPUE as the abundance series to produce an estimated stock status of 17% B0 (MPI, 2014).

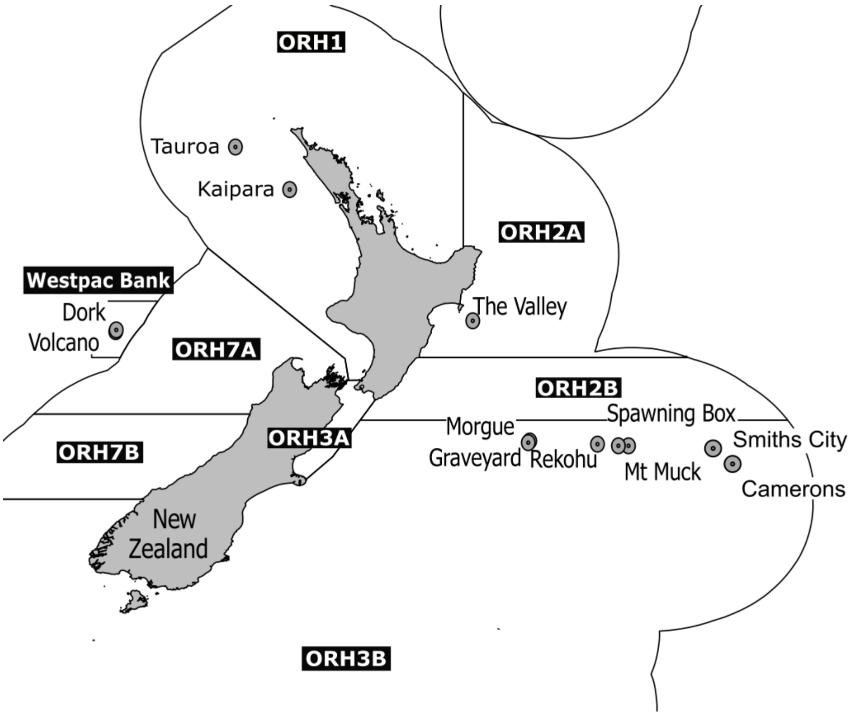



**Figure 1. The New Zealand EEZ showing the location of the ORH7B Fishery Management Area off the West Coast of South Island.**

As this is a closed fishery, no information is available from the fishery and nor are biomass surveys scheduled as a basis for monitoring the rate of stock rebuild. The purpose of this survey was to provide the data for a stock assessment that, in turn, will inform management on whether the fishery can be reopened or not. Locating spawning aggregations and estimating their abundance was a key objective since this is the only way of assessing stock rebuild in a closed fishery.

The current distribution of spawning orange roughy in ORH7B is not well known, but a spawning aggregation was detected on the edge of Cook Canyon in the winter of 2015, during an acoustic survey conducted by DWG using FV Amaltal Explorer (Ryan.T.E and Tilney, 2016) and in 2016 during a trawl survey conducted by Talley's using FV Cook Canyon (Doonan, 2016). In both surveys, a single large catch (~18-19 t), of orange roughy was taken on the edge of Cook Canyon and the fish were in spawning condition. In 2017 a similar approach to the 2015 acoustic survey was followed where an AOS was used to provide multifrequency acoustic data to enable species identification and biomass estimation from transect survey designs. To inform the age distribution of the fish population otoliths were collected as part of the biological sampling program.

**Voyage dates:**
Depart Nelson 2nd July 2017
Arrive Nelson 11th July 2017
Vessel: FV *Amaltal Explorer*

# 3 METHODS

## 3.1 Equipment

### *3.1.1 Acoustic-Optical System (AOS)*

CSIRO has developed and built a multi-frequency acoustic and optical system (AOS) for Sealord Group Ltd, to improve biomass assessments of deepwater resources based on an established design, Figure 2. The AOS has proven to be effective for estimating the biomass of deepwater orange roughy stocks and, in particular, to improve estimates of biomass on undersea topographic features (UTFs) and in mixed species assemblages (Ryan and Kloser, 2016a). The AOS was deployed on the headline of the FV *Amaltal Explorer's* commercial fishing net with the primary objective of quantifying biomass of aggregated spawning orange roughy. Surveys of UTFs using the AOS technology are well established and only briefly outlined here (Kloser et al., 2011b). For this survey, the AOS housed a two–frequency acoustic system (38 and 120 kHz) using Simrad ES60 transceivers. The system was battery powered with all data logged to internal storage media. AOS components are detailed in Table 1.

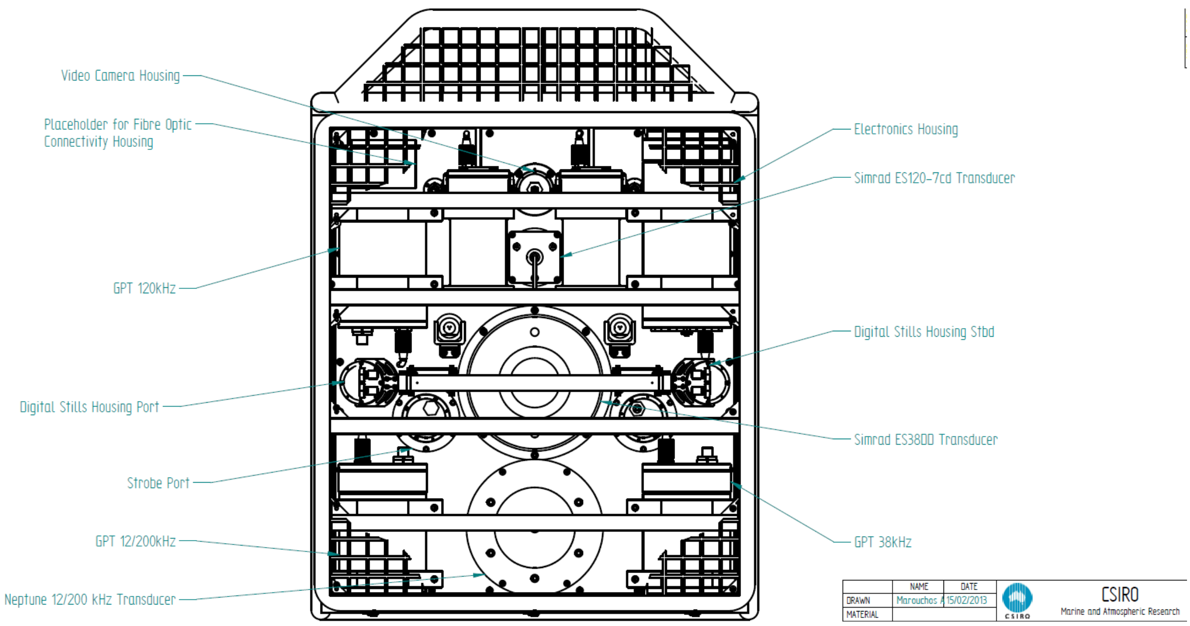



Figure 2: The componentry and lay-out of Sealord's Acoustic Optical System (AOS).

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 EK60 (on loan from CSIRO*), 38 and Simrad ES60 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. |
| 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, 25mm focal length Distagon F mount Lens. Quantum Trio strobe. |
| Reference scale | Two Laserex LDM-4 635 nm 8 mW 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 |

* The Sealord AOS ES60 38 kHz transceiver failed at the end of the previous survey (Ryan et al., 2017). Hence during this survey the AOS used a Simrad EK60 38 kHz on loan from CSIRO.

## AOS calibration

The AOS acoustics needs to be calibrated for the depths that it works in. This requires lowering the system through the water column from surface to ~ 900 m with a calibration sphere suspended at ~ 20 m beneath the transducers. Calm conditions and low wind and currents are pre-requisites that allow the calibration sphere to remain within the acoustic beam. The AOS was calibrated on two occasions in 2017, once on the Mid East Coast survey and a second time on the ORH7B survey. Fibre optic connectivity of the AOS to the surface greatly improved the outcome by enabling real time observation of the sphere backscatter acquisition process. Results for the ORH7B calibration for a platform depth of 600 m are given in Table 2. The variation in Gain and Sa correction with depth was characterised by a polynomial fit to the data. A secondary calibration connection based on the polynomial fit was applied to the acoustic echointegration NASC values measurements to account for the change in Gain and Sa correction as the platform moved above or below the nominal 600 m operating depth. Further details can be found in Appendix 3.

Table 2. Calibration values for nominal platform depth of 600 m.

| Frequency | Gain | Sa correction | Two way beam angle* |
|---|---|---|---|
| 38 (CSIRO GPT on loan) | 23.69 | -0.44 | -20.72 |
| 120 (Sealord GPT) | 28.09 | -0.303 | -20.25 |

* based on manufacturer's factory measurements, adjusted for location environmental conditions.

### *3.1.2 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 Gigabyte Ethernet 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.

### 3.1.3 Vessel acoustics

The FV *Amaltal Explorer*'s 38 kHz Simrad ES60 vessel-mounted echosounder provided continuous echogram data to guide AOS and trawl decisions.

The Vessel's Simrad ES60 38 kHz echosounder was calibrated in 30 m water depth off the East Coast of North Island using the standard reference sphere method (Demer et al., 2015) on the 28$^{th}$ June 2017 as the last operation of the previous Mid East Coast survey (Ryan et al., 2017). Details of the vessel calibration are given in Appendix 2. Calibration Report Amaltal Explorer.

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.

Exceptionally calm conditions prevailed for almost all of the survey hence vessel-acoustic data quality was high.

### 3.1.4 Acoustics: Seawater absorption

**AOS acoustics**

Values for seawater absorption at 38 and 120 kHz and sound speed were calculated from the equations of (Francois and 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 3). 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.

**Table 3. 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 (dB/m) | 0.00928** | 0.03131** |
| Sound speed (m/s) | 1500* | 1500* |

* Nominal Simrad values; ** calculated from CTD data

**Vessel acoustics**

Following the Deep Water Working Group's protocols, absorption estimates for application to the hull-mounted 38 kHz echosounder were made using the equations of Doonan et al. (2003).

## 3.2 Acoustic survey design

The survey design was guided by the principles detailed in the NIWA presentation to the Deepwater Working Group (Doonan, 2017). Cook Canyon and Moeraki Canyon were the regions of highest historic significance and hence were prioritised for initial investigations.

## 3.3 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 4).

**Table 4. 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 commercial and 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 and Kloser, 2016b). These are referred to as Mode 1 surveys. To minimize gear avoidance by orange roughy and deadzone uncertainty, the AOS-net system was towed in the midwater at a distance of 250–350 m above the seafloor. Grid transect surveys were applied for the flatter grounds around the edges of Cook Canyon.

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

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

**Biomass estimation surveys**

Interlaced grid-survey design was the primary design for the purpose of echointegration-based biomass estimates. The option of star-pattern design was available should fish distribution be localised and in a small area. A minimum of two surveys at any one location was intended but preferably up to five surveys if possible. Grid surveys aimed to have a minimum of four transects across the main body of the fish with bounding transects at either end.

**Wide area survey and ad-hoc surveys of found aggregations**

Wide area vessel-based acoustic surveys of the Cook Canyon Region between the ~ 750 m and ~ 950 m contours were conducted routinely with the aim of locating significant aggregations of orange roughy which could then be surveyed with a formalised survey design to estimate biomass.

## 3.4 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 and Mitson, 1996) and, on sloping ground, due to seafloor backscatter from off-axis side-lobe signal coinciding with water column backscatter (Kloser, 1996; Ona and Mitson, 1996). For the steep-sided features the contribution to the deadzone due to the sloping ground was by far 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. We assume 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 water column signal became contaminated with seafloor reflection signal. The acoustic seafloor line was first generated via the maximum $S_v$ seafloor detection algorithm implemented in Echoview v.8 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 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 metres immediately above the acoustic seafloor. Two echo-integration signal summations are made: (i) includes only 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.

## 3.5 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 vessel and 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.

## 3.6 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 differences in acoustic backscatter (decibel, dB difference) across frequencies as a "colour-mixed" echogram as per Kloser *et al.* (2002), (ii) a synthetic echogram that represents the decibel difference between 38 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 to 38 kHz were attributed to homogenous schools of orange roughy. 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 to regions of orange roughy. Biological catch composition and inspection of video and Gig-E 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.

## 3.7 Target strength estimates

Orange roughy TS estimates used were from Kloser et al. (2013) which were based on a mean fish length of 34.5 cm. Values of -52.0 and -48.17 dB were used for 38 and 120 kHz respectively, noting that the 120 kHz estimated 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 (Ls) observed at each spawning ground, assuming a TS – length slope of 16.15*log10(Ls) (McClatchie et al., 1999). This resulted in TS values of -52.2 and -48.3 dB for the lengths measured at Cook Canyon.

## 3.8 Biomass estimation of orange roughy for grid transect acoustic surveys

Biomass estimates were calculated for 120kHz, 38 kHz data acquired from the AOS and vessel acoustic data using standard echo-integration methods (Simmonds and MacLennan, 2005). Orange roughy classified echogram regions were echo-integrated in 100 m intervals to calculate the per-interval nautical area scattering coefficient, $s_A$ (m$^2$ n.mile$^{-2}$, (Maclennan et al., 2002)). These were averaged to give a mean $s_A$for the survey region ($\overline{s_A}$). This parameter along with 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.miles$^2$) were used to estimate orange roughy biomass (Equation1). Population sex ratio was assumed to be 1:1 when estimating $\overline{TS}$ and $\overline{W}$.

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

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.

## 3.9 Trawl and catch sampling

Overarching all activities was a programme of biological sampling. Trawls were required for mark identification and collection of biological data and occurred after completion of an acoustic survey. Catches were undertaken against an MPI Special Permit, which allowed for a total orange roughy catch of 30 t. As it is difficult to control the size of catch taken from dense orange roughy aggregations, extra caution was required to ensure target identification catches did not exceed this amount. 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 to monitor the progression of spawning. All catches were sampled for catch composition and length frequencies of abundant species were determined to provide the biological information required to inform the acoustic data Sub-samples of 20 – 40 orange roughy stomachs were examined for stomach content, digestion state and fullness. All vulnerable species (e.g. deepwater sharks) were measured for length, 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 the Cook Canyon area and 250 from Moeraki Canyon.

# 4 RESULTS

Between the 3rd and 8th of July 2017 a program of acoustic and biological sampling was conducted in the ORH7B Fishery Management Area with focus on the Cook Canyon and Moeraki Canyon regions (Figure 3). A table of survey activities is provided in Appendix 4. Fine weather persisted for the majority of the voyage providing high quality vessel-acoustic data throughout.

## 4.1 Overview of the surveys

### *4.1.1 Cook Canyon*

Three AOS surveys and three AOS-biological trawls were conducted at the Cook Canyon at the same location (43° 07S, 169° 02E) where orange roughy aggregations had been observed in 2015 and 2016 (Ryan and Tilney, 2015; Doonan, 2016), Figure 4. Thematic maps of the orange roughy acoustic backscatter recorded on the AOS surveys are provided in Appendix 1.

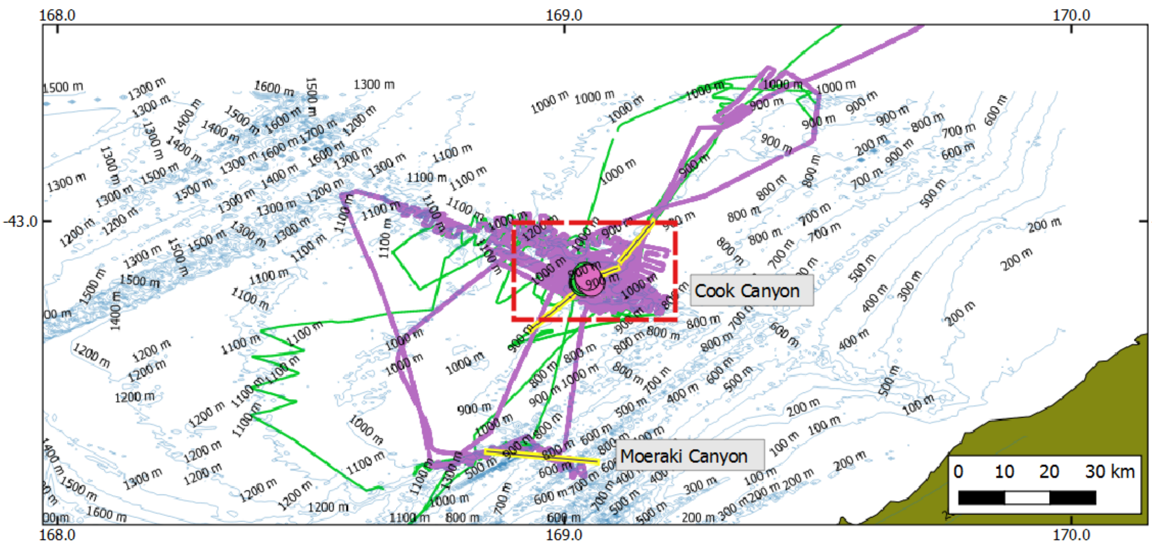



Figure 3. 2017 ORH7B vessel survey track (purple line) with key survey locations shown. Rectangle with red-dash lines indicates main region where orange roughy were found in the three surveys from 2015 to 2017. Yellow lines indicate the location of trawl shots from the 2015 survey. Pink and green circles indicate location of orange roughy observed during 2017 AOS surveys, coinciding with the 2015 trawl line were 18 tonne of spawning orange roughy were caught. Green line indicates vessel survey track from 2015 survey.

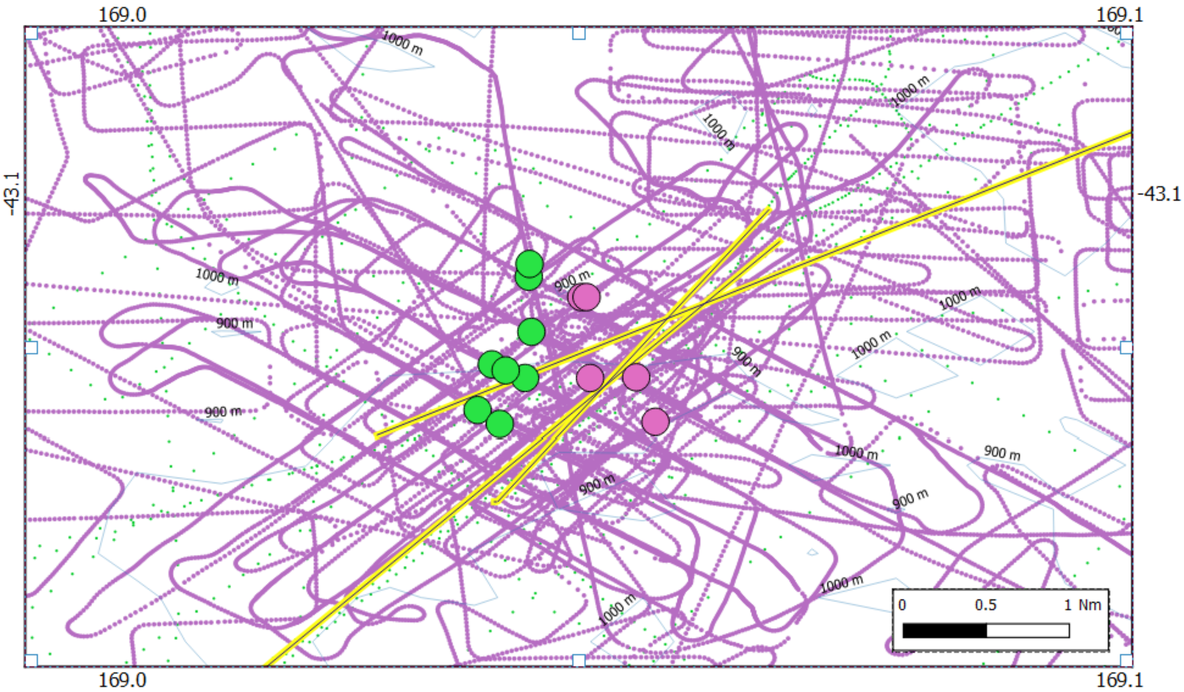



Figure 4. 2017 Cook Canyon vessel survey track at main survey location (purple line). Yellow lines indicate the location of 2015 trawl lines. Green and pink circles indicate location of orange roughy aggregations observed in 2017 during two AOS surveys.

Intensive vessel-acoustic surveys were conducted in and around the location of the main mark to monitor the aggregation throughout the 24 hr day/night cycle. Additionally extensive wide area searching surveys were made along the Cook Canyon feature to deeper water over an east-west extent of ~ 40 nautical miles. Outside of the quite localised main aggregation, no notable orange roughy aggregations were observed.

### *4.1.2 Moeraki Canyon and other wide area surveys*

Moeraki Canyon, situated about 20 nautical miles south of Cook Canyon, was visited on two occasions. Vessel searching surveys failed to locate orange roughy aggregations. The region known as Abut, located ~ 24 nautical miles north of Cook Canyon, was briefly observed during the incoming transit to Cook Canyon and on a return visit. Vessel acoustic searches did not observe any potential orange roughy aggregations. Acoustic data was monitored and recorded during the various transits between sites but no other orange roughy aggregations were found.

## 4.2 Biological analyses

The catch of 11.5 t from three target identification tows on the Cook Canyon aggregation comprised 96% orange roughy by weight. The majority of the bycatch was made up of five species of deepsea sharks, which collectively comprised 2% of the catch (Plunket's shark, seal shark, leaf-scale gulper shark, smooth skin dogfish and Baxter's lantern dogfish), and hake (1%) (Figure 5). Details of all species caught are provided in Appendix 5.

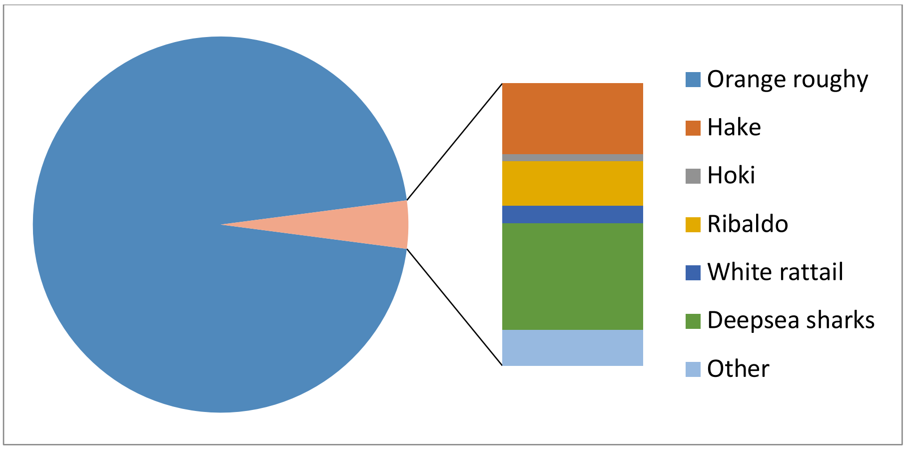



Figure 5. Catch composition from three tows on the Cook Canyon aggregation.

Biological sampling of orange roughy indicated that spawning was at an advanced stage at commencement of surveying, with approximately 43% of female gonads being in spent/partially spent condition on the 5th of July, progressing to 70% spent/partially spent by the 8th of July (Figure 6).

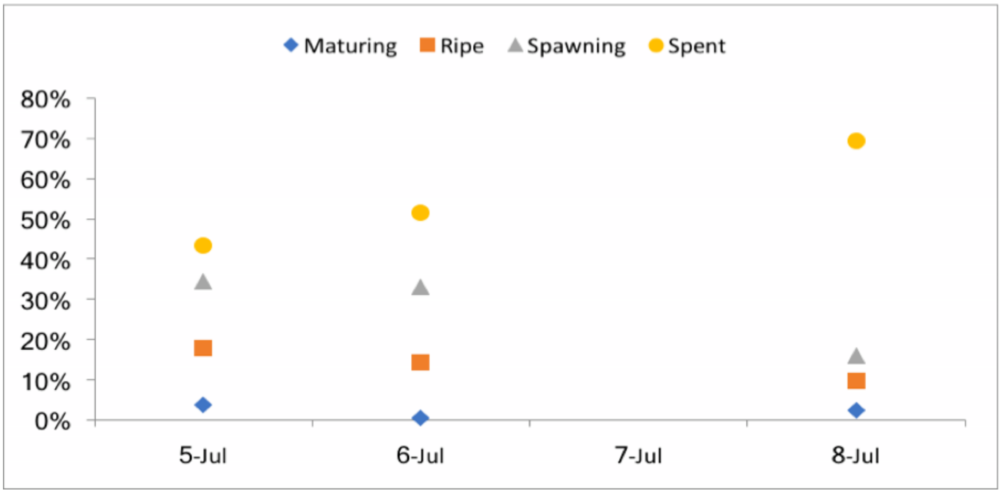



Figure 6. Orange roughy female gonad maturity stages at Cook Canyon during the period 5 – 8 July 2017.

Orange roughy females were more abundant in the catches than males, the ratio being 75% : 25%, and were larger. The mean standard length and weight for females was 34.9 cm and 1.528 kg respectively and for males was 31.9 cm and 1.115 kg respectively (Figure 7). The mean standard length and weight for females and males combined was 34.2 cm and 1.425 kg respectively.

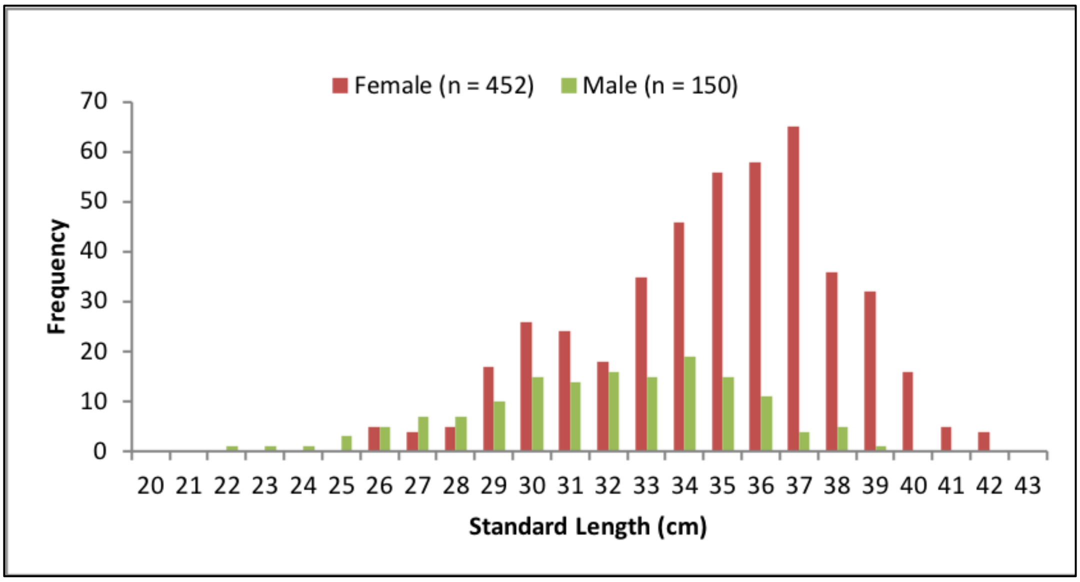



Figure 7. Length frequencies (unstandardized) of orange roughy by sex at Cook Canyon.

A total of 520 orange roughy otolith samples were collected from the Cook Canyon aggregation for use in age frequency determination.

Table 5. Summary of biological parameters with mean weight, length and TS at 38 and 120 kHz all assuming a 50/50 population sex ratio

| Area | Mean SL Females (cm) | Mean SL Males (cm) | Mean Wt Females (kg) | Mean Wt Males (kg) | Proportion Females (%) | Proporption Males (%) | Mean Wt (50/50 pop) | Mean length (50/50 pop) | TS 120 | TS38 |
|---|---|---|---|---|---|---|---|---|---|---|
| Cook Canyon | 34.9 | 31.9 | 1.53 | 1.12 | 80.5% | 19.5% | 1.33 | 33.4 | -48.33 | -52.22 |

## 4.3 Abundance estimates

### *4.3.1 AOS echointegration surveys*

During the 2017 ORH7B surveys modest aggregations were observed at Cook Canyon on the vessel’s echosounders and on the multifrequency AOS during three grid-transect surveys, confirming the species to be orange roughy. The identified orange roughy aggregations were notable for their low numeric densities when compared to our experience with other spawning locations (e.g. Mid-East Coast, ORH7A Challenger and ORH3B Chatham Rise at Rekohu and Spawn Plume). Aggregations were most detectable on the AOS 120 kHz echosounder as orange roughy have a factor of 2 higher backscatter compared to 38 kHz. Orange roughy backscatter signal was often barely above that of the background noise on the AOS 38 kHz and even more marginal on the vessel’s 38 kHz echosounder. Figure 8 shows one of the more substantial orange roughy aggregations recording during the first AOS survey.

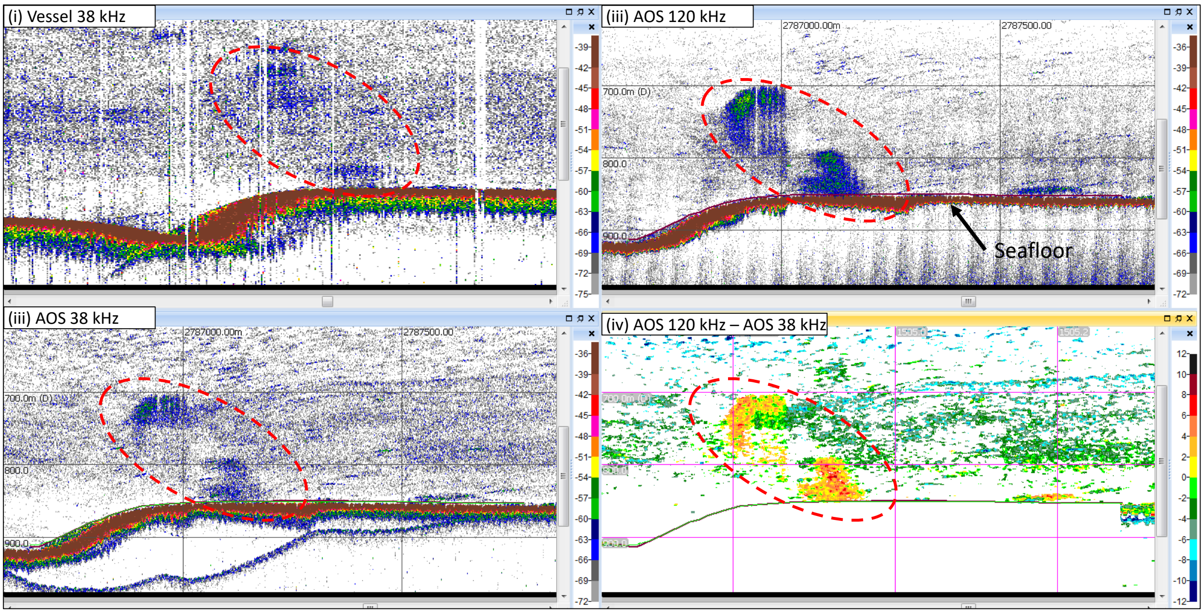



Figure 8. Acoustic echograms from OP3 for (i) Vessel acoustics, (ii) AOS 38 kHz, (iii) AOS 120 kHz and (iv) Decibel difference between AOS 120 kHz minus 38 kHz. Orange pixels indicate higher signal on 120 kHz indicative of orange roughy. Oblong with red dashed lines indicate region identified as orange roughy.

The orange roughy biological parameters and target strength (TS) values used for biomass estimation are provided in Table 5. Biomass estimates for AOS surveys conducted at Cook Canyon for 38 kHz and 120 kHz are given in Table 6 and Figure 9.

Table 6. Biomass estimates for Cook Canyon

| Date | Platform | OP | Frequency | Survey area | Mean NASC | Biomass above acoustic bottom (tonnes) | CV | Deadzone estimate (tonnes, % of total) | Geometric mean Total biomass | Arithmetic mean Total biomass |
|---|---|---|---|---|---|---|---|---|---|---|
| 4-Jul | AOS | 3 | 120 | 1.6 | 25 | 294 | 0.48 | 10 (3.3% ) | 304 | 304 |
| 4-Jul | AOS | 3 | 38 | 1.6 | 22 | 611 | 0.53 | 16 (2.6% ) | 627 | 627 |
| 5-Jul | AOS | 7 | 120 | 2.2 | 28 | 442 | 0.3 | 26 (5.6% ) | 468 | 473 |
| 5-Jul | AOS | 7 | 38 | 2.2 | 23 | 871 | 0.32 | 59 (6.3% ) | 930 | 945 |
| 6-Jul | AOS | 11 | 120 | 3.7 | 16 | 355 | 0.52 | 27 (7.1% ) | 382 | 394 |
| 6-Jul | AOS | 11 | 38 | 3.7 | 15 | 848 | 0.5 | 67 (7.3% ) | 915 | 922 |

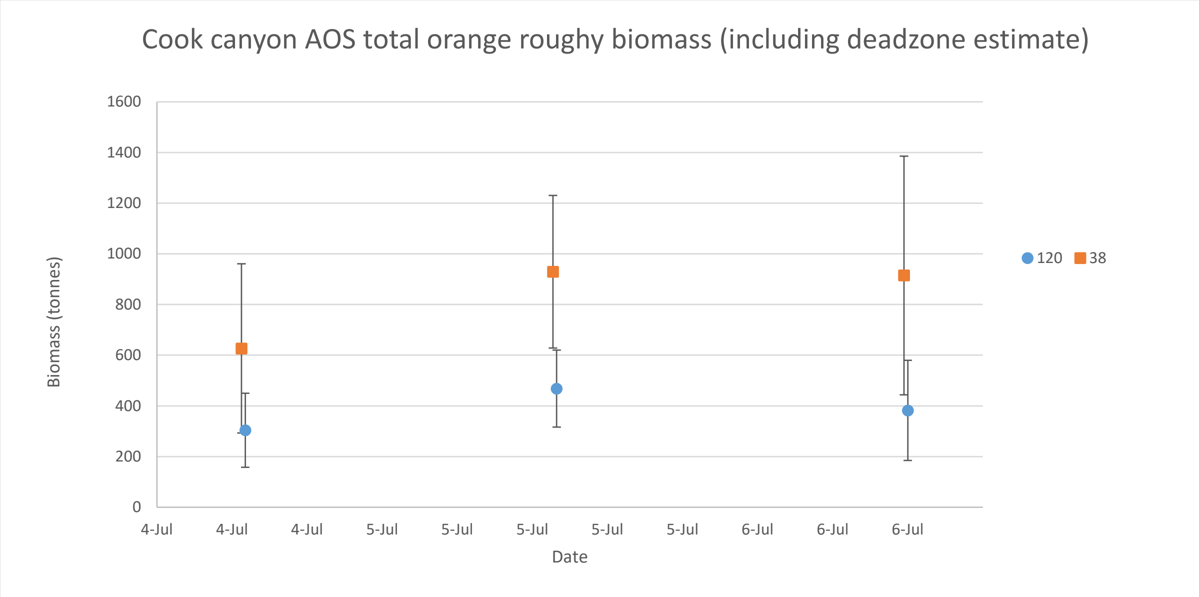



**Figure 9. Biomass estimates of Cook Canyon orange roughy at 38 and 120 kHz for three AOS grid surveys.**

# 5 DISCUSSION

The 2017 survey focused on regions with historical effort and where spawning aggregations had been previously observed. Spawning orange roughy aggregations were located in the same location (Eastern end of Cook Canyon, Figure 3) identified from the 2015 and 2016 surveys. In 2017 this aggregation was acoustically surveyed three times using the AOS and sampled by three trawls with regular acoustic observation outside of formal survey periods.

The three acoustic surveys conducted in 2017 estimated biomass of the main aggregation to be between 627 and 930 tonnes using the AOS 38 kHz data. This modest biomass is not surprising as the identified orange roughy aggregations were notable for their low numeric densities when compared to our experience with other spawning locations (e.g. Mid-East Coast, ORH7A Challenger and ORH3B Chatham Rise at Rekohu and Spawn Plume). Aggregations were readily detectable on the AOS 120 kHz echosounder for which orange roughy have a factor of 2 higher backscatter compared to 38 kHz. Orange roughy backscatter signal was often barely above that of the background noise on the AOS 38 kHz and even more marginal on the vessel's 38 kHz echosounder. This indicates that orange roughy were aggregated at very low densities. Surveys of Moeraki Canyon, the Abut and wide area transects in-between did not locate significant orange roughy aggregations. Some regions of elevated backscatter were occasionally observed in the wider area. These had very weak acoustic signal and were not extensive enough to justify an acoustic survey or to verify the species mix with trawling or AOS investigations. It is quite possible that these low signal regions were backscatter signal from other deepwater species (e.g. rattails) at low densities, but if orange roughy they would represent a small biomass.

There is a large area of potential orange roughy habitat in the 800 m to 1000 m depth range that could not practically be covered. Nevertheless the ORH7B grounds have had quite intensive survey effort between 2015-2017. Notably the 2016 trawl survey served to randomly sample the wider potential habitat and did not locate large amounts of orange roughy away from the main Cook Canyon aggregation. There does not appear to be any historic precedent to suggest that a large biomass of orange roughy might exist in the unsurveyed regions. All indications from 2015-2017 surveys point to a modest stock concentrated on a small area in Cook Canyon during the winter spawning period

Trawl catch information indicated that spawning was well underway at the start of the survey on the 5th of July with 43% of female orange roughy in spent condition and 70 % spent by the last trawl on 8th of July. During the 2015 AOS survey biological sampling indicated that spawning was well advanced at the commencement of surveying on the 29th of June when 25% of female orange roughy were found to be in spent condition (Ryan and Tilney, 2016). However, the 2016 trawl survey found that peak spawning, defined as occurring when 20% of female gonads are in spent condition), occurred around a week later between the 8th and the 11th of 11 July (Doonan et al., 2016). Identifying the optimal survey period for future surveys will be difficult given that there is no opportunity to review year-by-year spawning due to this being a closed fishery.

The AOS 120 kHz based biomass estimates ranged from 304 to 468 tonnes, approximately a factor of two less than the AOS 38 kHz estimates. This is an unexpected outcome. Ryan and Kloser (2016a) conducted 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 could account for some of the variation; the factor of two difference observed in 2017 is outside of the expected error bounds of these parameters. Review of the calibration history of the AOS 38 kHz and 120 kHz systems found that the 38 kHz was relatively stable while the 120 kHz has had large shifts in calibration values (up to 2 dB, 60%) between years. Hence there is some suspicion that the differences between 38 and 120 kHz biomass estimates could be due to an unexplained calibration issue associated with the 120 kHz. However this is not a firm conclusion; the AOS 120 kHz was calibrated twice in 2017 (Mid East Coast survey and ORH7B 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 and Kloser (2016a) is recommended to see if unexpectedly larger differences observed in 2017 are anomalous.

# 6 ACKNOWLEDGEMENTS

George Clement, CEO of Deepwater Group Ltd is thanked for initiating this project as are the New Zealand Deepwater fishing industry for their support. Ministry for Primary Industry are thanked their support of the survey program. Graham Patchell (Sealord NZ) is thanked for his ongoing support of the methods used in this project. We thank Talley's Group and Andy Smith in the provision of their vessel Amaltal Explorer. Skipper John Whitlock, 1st Mate Glen Heale, factory manager Les Bowden and the crew of Amaltal Explorer are thanked for their professional and enthusiastic assistance without which this project would not have succeeded. The MPI observer, Alan Knox is thanked for his assistance with the biological sampling of catches. The CSIRO Oceans and Atmosphere theme supported this project and provided funding co-contributions. The work of the CSIRO Marine Acoustics Group led by Dr Rudy

Kloser is acknowledged for their longstanding contributions to developing the deep water acoustic methods that have been applied in this project. CSIRO's Science Equipment and Technology Group, Hobart led by Mark Underwood along with Matthew Sherlock, Jeff Cordell, Andreas Marouchos and the instrument workshop team are also noted for their development and ongoing support of the technology that underpins these surveys

# APPENDIX 1. THEMATIC BACKSCATTER MAPS OF ACOUSTIC SURVEYS

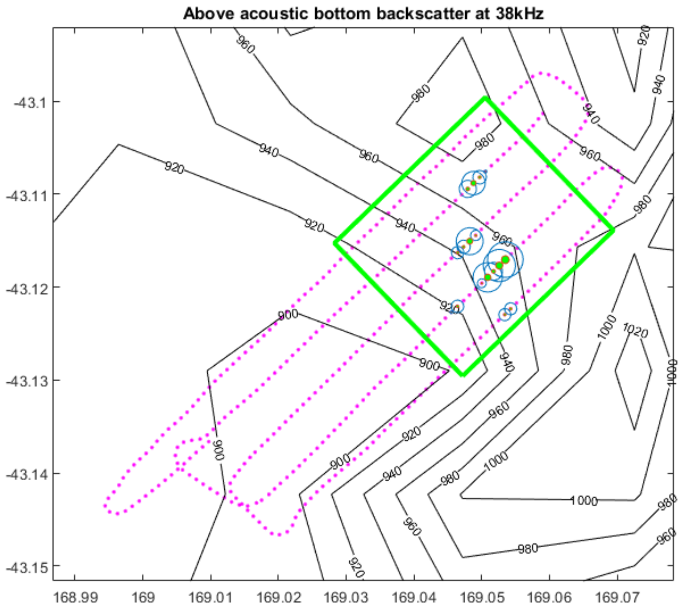



Figure 10. Thematic map of 38 kHz backscatter for identified orange roughy regions, Cook Canyon, OP3.

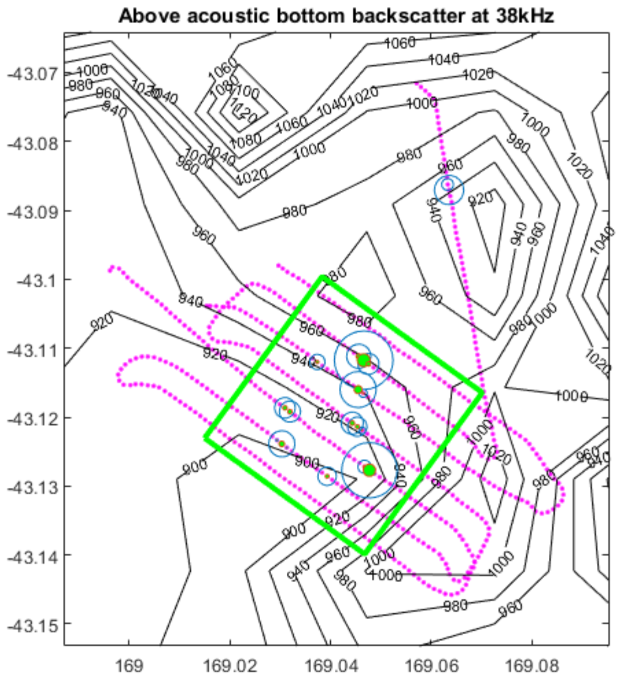



**Figure 11. Thematic map of 38 kHz backscatter for identified orange roughy regions, Cook Canyon, OP11.**

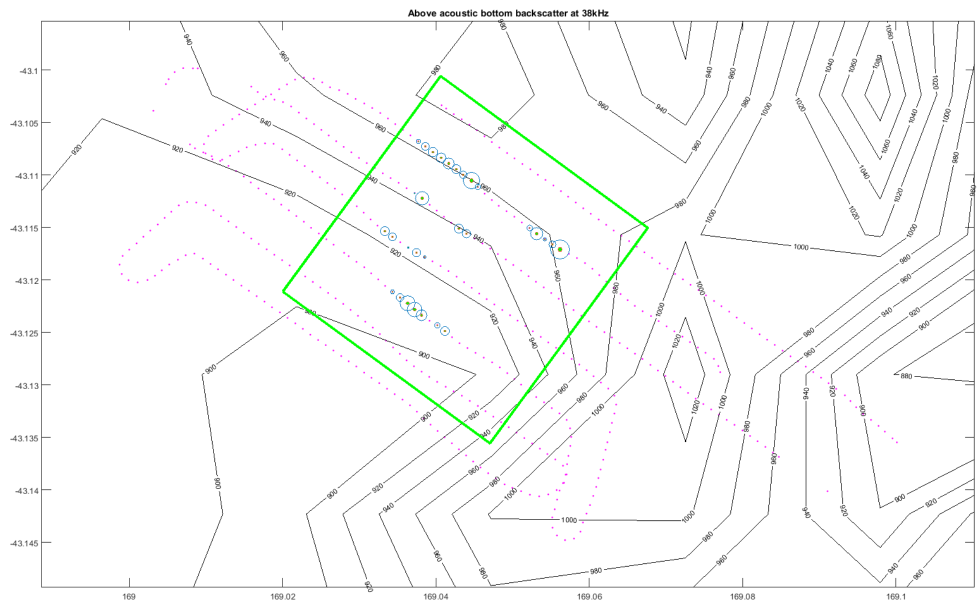



**Figure 12. Thematic map of 38 kHz backscatter for identified orange roughy regions, Cook Canyon, OP7.**

# APPENDIX 2. CALIBRATION REPORT AMALTAL EXPLORER

## *Amaltal Explorer* ES60 calibration

The Amaltal Explorer's Simrad ES60 vessel-mounted acoustic system was calibrated at the start of the survey in Tasman Bay with results given in Tables 7 to 13.

### *Amaltal Explorer calibration*

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 7.

**Table 7. 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 is no information that will tell us which one is in service. EBA values are close at -20.6 and -20.8 respectively while factory tank temperatures were identical at 18 degree, freshwater. We use the mean of the factory EBA values (i.e. -20.7 dB) and adjust for local environmental conditions.

**Table 8. Vessel and site**

| | | | |
|---|---|---|---|
| **Vessel Name** | Amaltal Explorer | **Vessel owner/operator** | Talleys Fisheries |
| **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 | **Longitude** | 178°35.06 |
| **Seafloor depth (m)** | | | |
| **Sea state at start** | calm 2m 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 and | | |
| **Vessel acknowledgements** | Skipper Duncan Bint and crew on board the Amaltel Explorer are tanked for their assistance during the calibration and | | |

Table 9. Environmental

| | | | |
|---|---|---|---|
| **Salinity (psu)** | 34.5 | **Salinty 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 10. Calibration equipment

| | | | |
|---|---|---|---|
| **Calibration sphere** | 60.0 mm copper sphere | | |
| **Counter weight** | no | **Counter weight-sphere distance (m)** | |
| **Mechanical arrangement** | Calibration poll triangulated around the transducer | | |
| **Equipment comments** | Equipment supplied by Rob Tilney | | |

Table 11. Echosounder transceivers*

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

Table 12. 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 beamwidth alongships (°)** | 7.1 | **3-dB beamwidth 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 that will tell us which one is in service. EBA values are close at -20.6 and -20.8 respectively while factory tank temperatures were identical at 18 degree, freshwater. We use the mean of the factory EBA values (i.e. -20.7 dB) and adjust for local environmental conditions.

## *Results*

**Table 13. 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 |

# APPENDIX 3. CALIBRATION REPORT SEALORD AOS

| | |
|---|---|
| Calibration date: | 28 June 2017 & 08 July 2017 |
| Vessel: | Amaltal Explorer |
| Report date: | 21 July 2017 |
| Prepared by: | Haris Kunnath and Tim Ryan |

## Summary

This document summarizes 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 was 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 (AMX201701) was of the Mid East Coast region (MEC, New Zealand North Island, East Coast). AOS surveys were almost completed when the Sealord 38 kHz GPT failed on the 27th June. Weather conditions allowed for an AOS calibration on the 28th of 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 the 8th of July during the second survey (AMX201702) of the Cook Canyon region (West Coast, South Island). The CSIRO EK60 transceiver was also used for this survey and calibration.

AMX201701 survey data was collected with the Sealord ES60 transceiver while 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 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 wharfside 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 was 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 our typical estimate of better than 0.5 dB (12%). The AMX201702 survey (Cook Cayon) 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 transceiver was used for the data acquisition.

The recent Sealord AOS calibration template accessible below was used to create an echoview worksheet.

Z:\echoview_worksheet\templates\AOS calibration templates\Sealord_AOS_2016

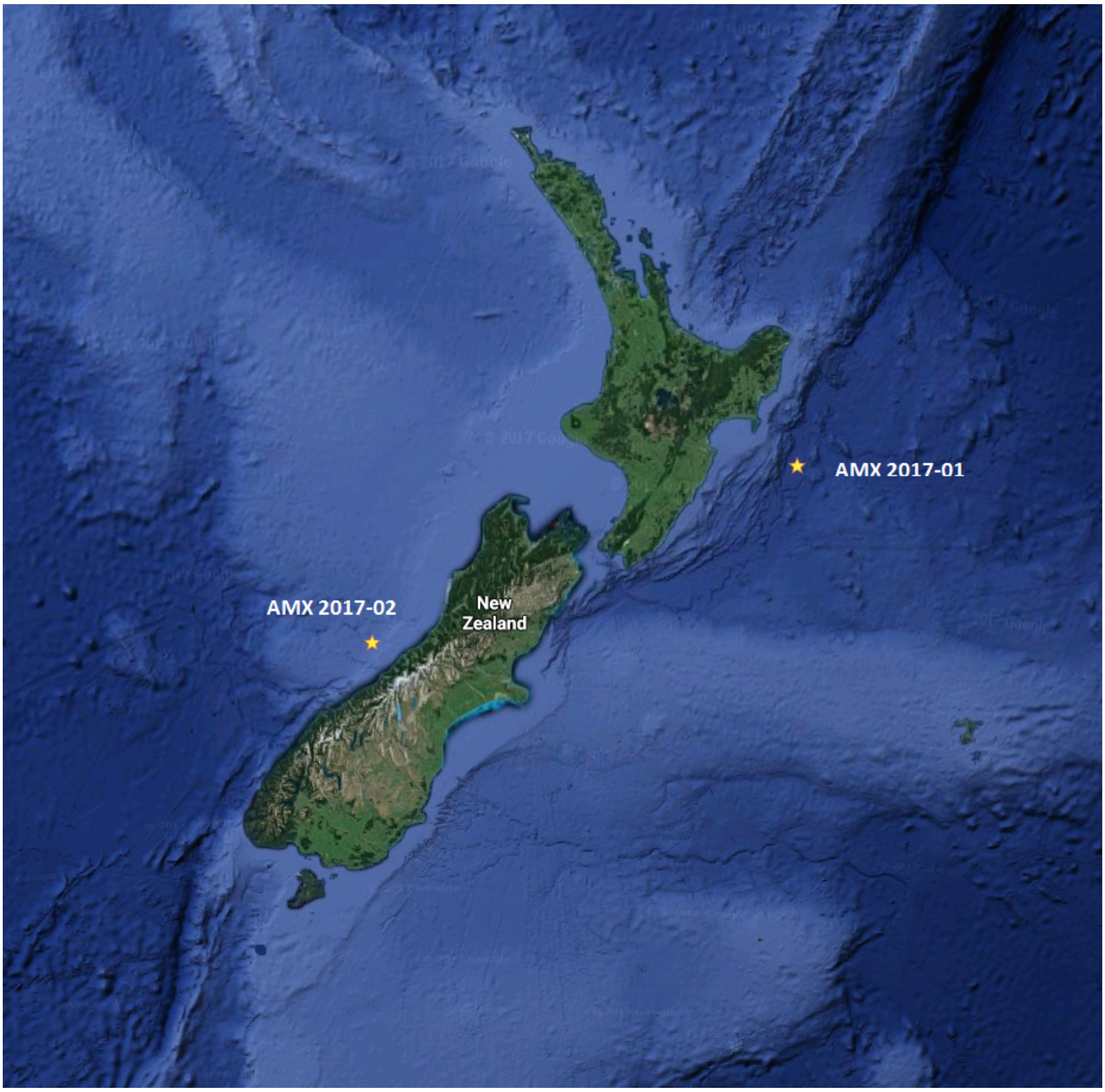
After defining appropriate data regions in echoview worksheet, *AOS_cal_gui* was used to extract parameters required for the calibration.

The resulting parameters were saved to the folders accessible below.

Z:\Equipment\Acoustic_Calibration\Platform\AOS\AMX201701

Z:\Equipment\Acoustic_Calibration\Platform\AOS\AMX201702

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.




**Geographic location of the calibration deployments.**

# Summary of calibration parameters (AMX201701)

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

| | | |
|---|---|---|
| **Year** | **2017** | |
| **Voyage** | **AMX201701** | |
| **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** | | | | |
| | $\times d^3$ | $+ \times d^2$ | $+ \times d$ | $+ c$ |
| 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** | | | | |
| | $\times d^3$ | $+ \times d^2$ | $+ \times d$ | $+ c$ |
| 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 (AMX201702)

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

| **Year** | **2017** | |
|---|---|---|
| **Voyage** | **AMX201702** | |
| **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 |

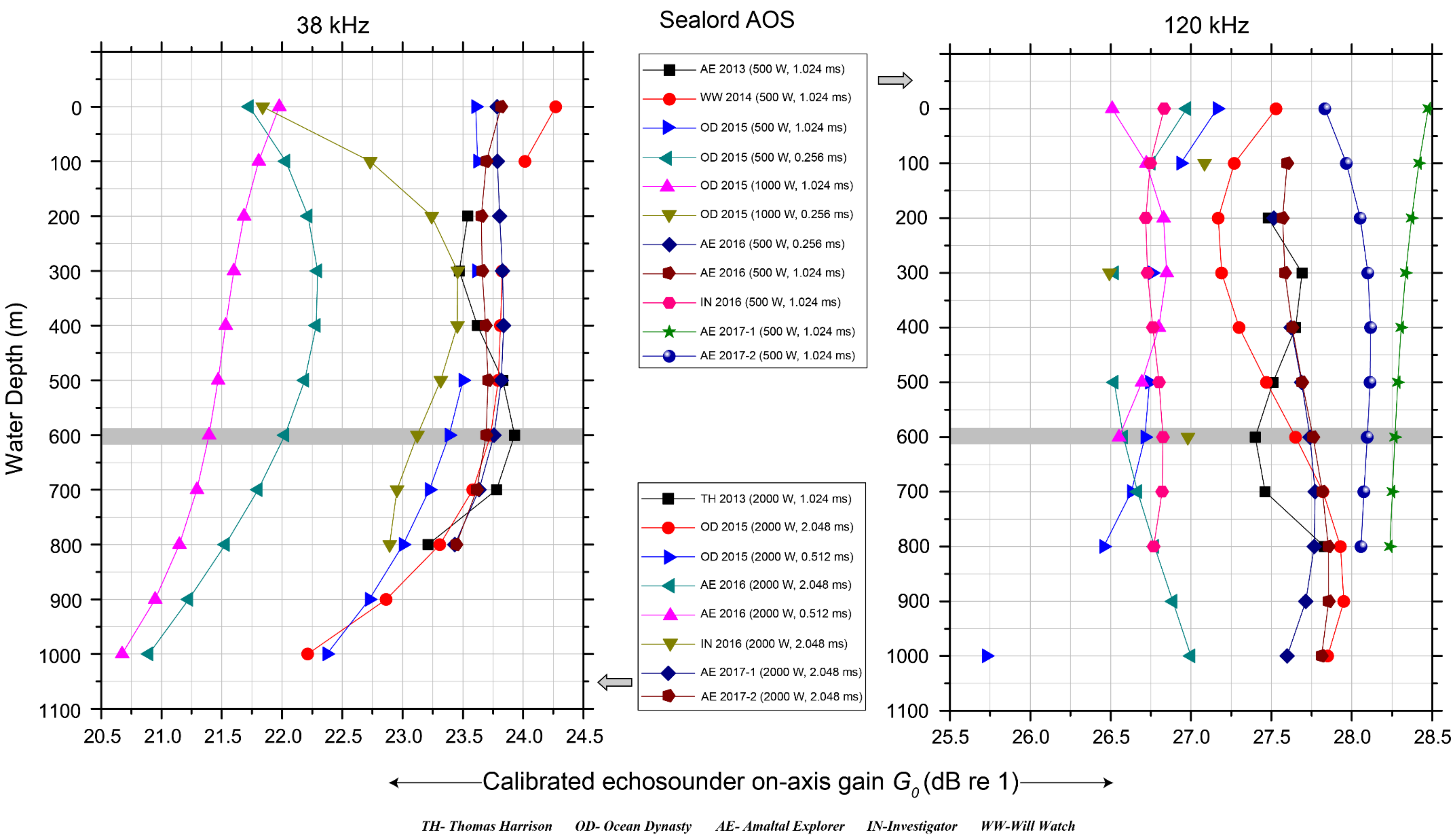
| **ES38-DD (28363), 38 kHz, 2000 W, 2.048 ms** | | | | |
|---|---|---|---|---|
| | x $d^3$ | + x $d^2$ | + x d | + c |
| Gain polynomial parameters | -4.73206e-09 | 5.32442e-06 | -0.00169701 | 23.8168 |
| SA polynomial parameters | 1.33483e-09 | -1.81492e-06 | 0.000458749 | -0.350437 |
| **ES120-7CD (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 | | | | 2016-12-18 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vessel | Thomas Harrison | Amaltal Explorer | Will Watch | Ocean Dynasty | | | | | | Amaltal Explorer | | | | Investigator | |
| Frequency (kHz) | 38 | 120 | 120 | 38 | 38 | 120 | 120 | 120 | 120 | 38 | 38 | 120 | 120 | 38 | 120 |
| Power (W) | 2000 | 500 | 500 | 2000 | 2000 | 500 | 500 | 1000 | 1000 | 2000 | 2000 | 500 | 500 | 2000 | 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 | 2.048 | 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 | 23.1211 | 26.8256 |
| 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 | -0.4340 | -0.3885 |

Continuation

| Year | 2017-06-28 | | 2017-07-08 | |
|---|---|---|---|---|
| Vessel | Amaltal Explorer | | Amaltal Explorer | |
| Frequency (kHz) | 38 | 120 | 38 | 120 |
| Power (W) | 2000 | 500 | 2000 | 500 |
| Pulse length (ms) | 2.048 | 1.024 | 2.048 | 1.024 |
| Gain (dB) | 23.757 | 28.2678 | 23.6933 | 28.0963 |
| Sa correction (dB) | -0.3316 | -0.6278 | -0.4402 | -0.3023 |


Sealord AOS
38 kHz
120 kHz
Water Depth (m)
Calibrated echosounder on-axis gain $G_0$ (dB re 1)
AE 2013 (500 W, 1.024 ms)
WW 2014 (500 W, 1.024 ms)
OD 2015 (500 W, 1.024 ms)
OD 2015 (500 W, 0.256 ms)
OD 2015 (1000 W, 1.024 ms)
OD 2015 (1000 W, 0.256 ms)
AE 2016 (500 W, 0.256 ms)
AE 2016 (500 W, 1.024 ms)
IN 2016 (500 W, 1.024 ms)
AE 2017-1 (500 W, 1.024 ms)
AE 2017-2 (500 W, 1.024 ms)
TH 2013 (2000 W, 1.024 ms)
OD 2015 (2000 W, 2.048 ms)
OD 2015 (2000 W, 0.512 ms)
AE 2016 (2000 W, 2.048 ms)
AE 2016 (2000 W, 0.512 ms)
IN 2016 (2000 W, 2.048 ms)
AE 2017-1 (2000 W, 2.048 ms)
AE 2017-2 (2000 W, 2.048 ms)
TH- Thomas Harrison
OD- Ocean Dynasty
AE- Amaltal Explorer
IN-Investigator
WW-Will Watch

# Results (AMX201701)

## 1. 38 kHz

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

38kHz_GPT  38 kHz 00907205c463 1
ES38D_20170628031501_20170720163739_kun017

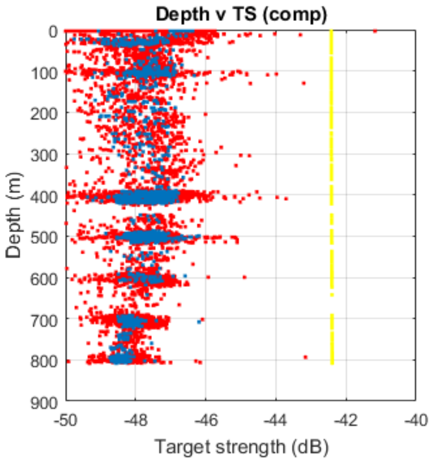
**Data acquisition details**

| | |
|---|---|
| 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 |

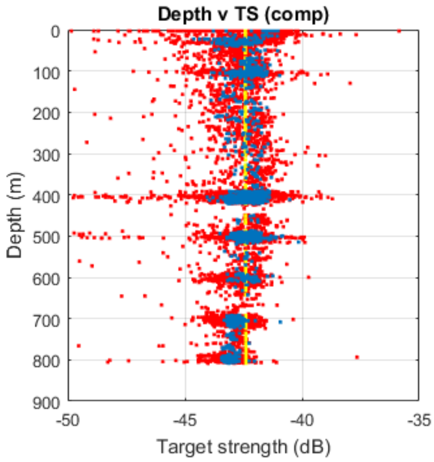
**Calibration parameters**

| | |
|---|---|
| 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 |

**Before**




**After**




# 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

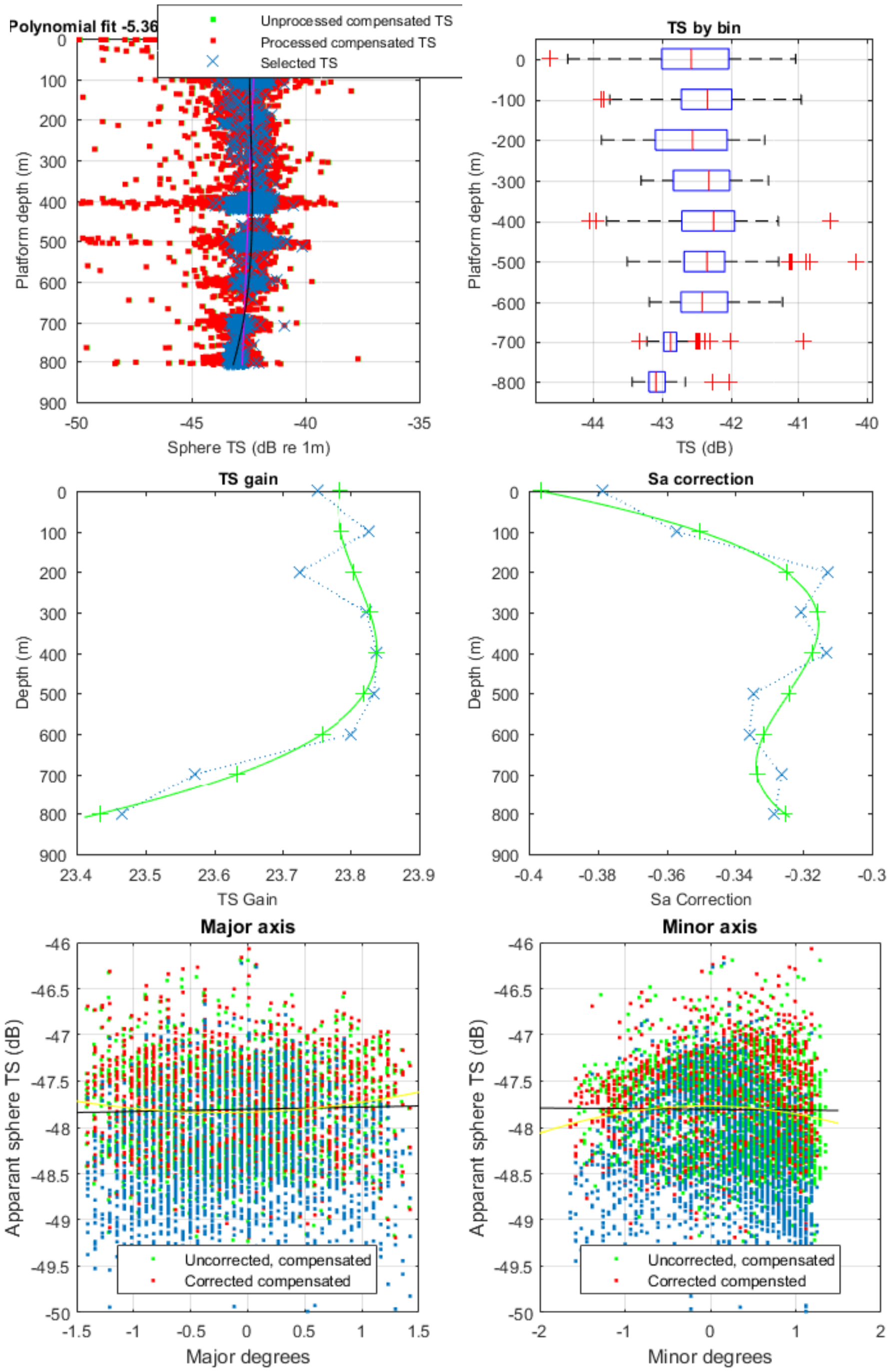
| Transducer serial number: ES38DD 28363 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Transducer tank psi: -20.8 | | | | | | | | | |
| Depth bins: | 0 | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 |
| Targets: | 139 | 170 | 11 | 2 | 214 | 225 | 36 | 21 | 50 |
| TS gain: | 23.7778 | 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

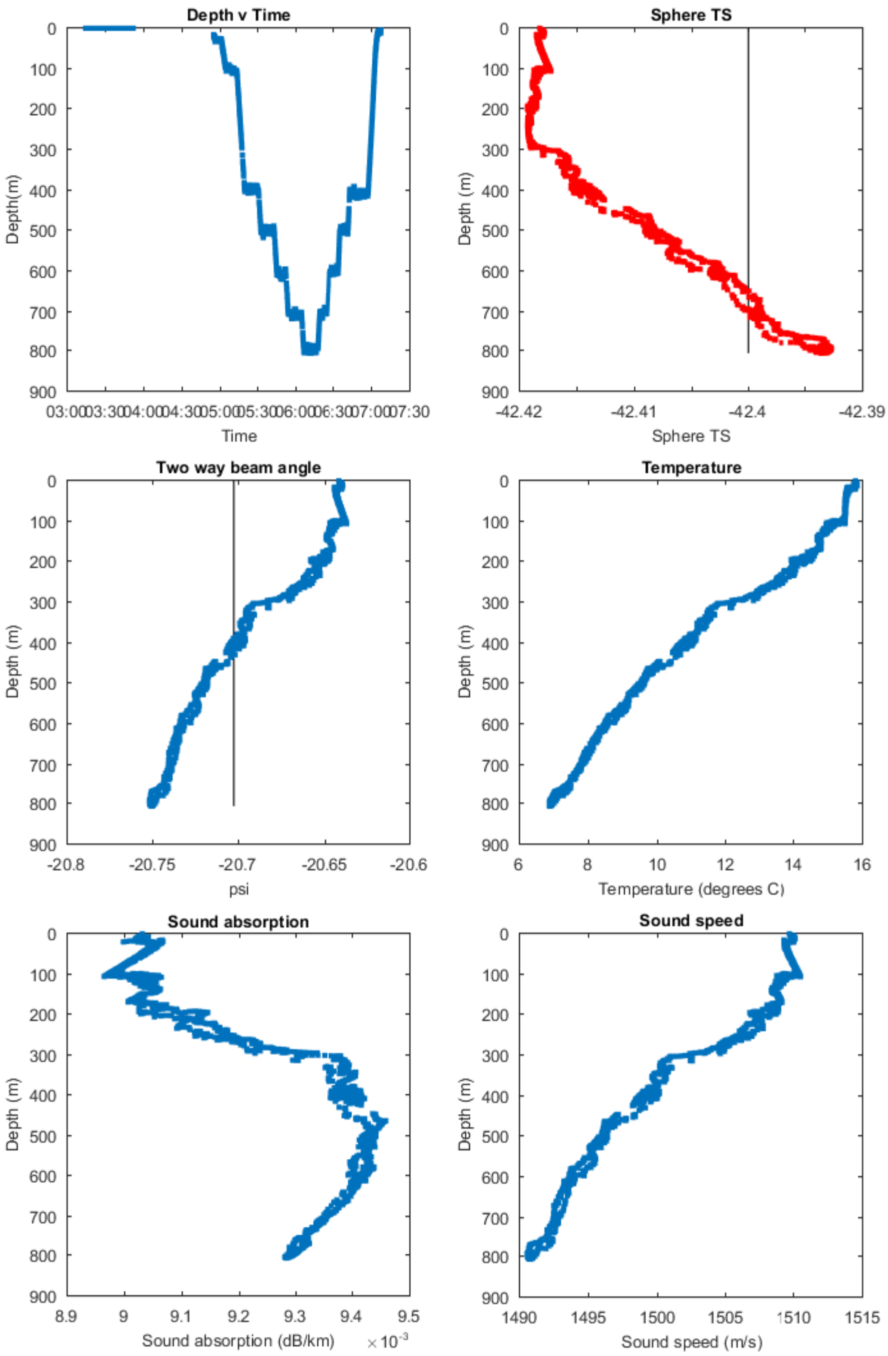
TS polynomial parameters: -1.28493e-09 -1.54372e-06 0.00154697 -42.7315
Gain polynomial parameters: -6.15102e-10 -8.31027e-07 0.00078839 23.6449
SA polynomial parameters: 7.89559e-10 -1.18699e-06 0.000518283 -0.381943

| 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)
0
100
200
300
400
500
600
700
800
900
03:00 03:30 04:00 04:30 05:00 05:30 06:00 06:30 07:00 07:30
Time
Sphere TS
Depth (m)
-42.42
-42.41
-42.4
-42.39
Sphere TS
Two way beam angle
Depth (m)
-20.8
-20.75
-20.7
-20.65
-20.6
psi
Temperature
Depth (m)
6
8
10
12
14
16
Temperature (degrees C)
Sound absorption
Depth (m)
8.9
9
9.1
9.2
9.3
9.4
9.5
Sound absorption (dB/km)
× 10^-3
Sound speed
Depth (m)
1490
1495
1500
1505
1510
1515
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

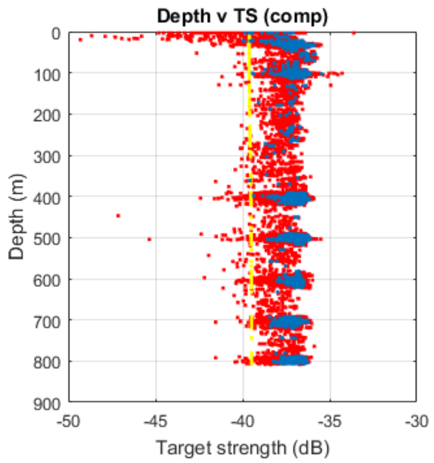
**Data acquisition details**

| | |
|---|---|
| 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 |

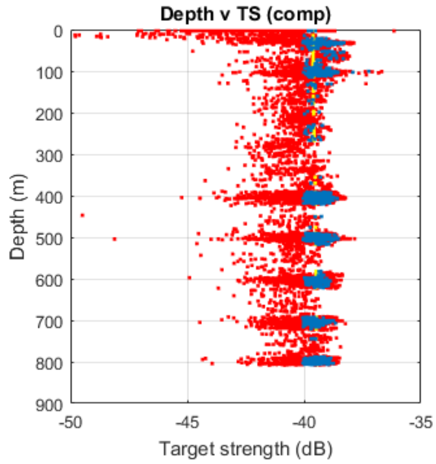
**Calibration parameters**

| | |
|---|---|
| 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

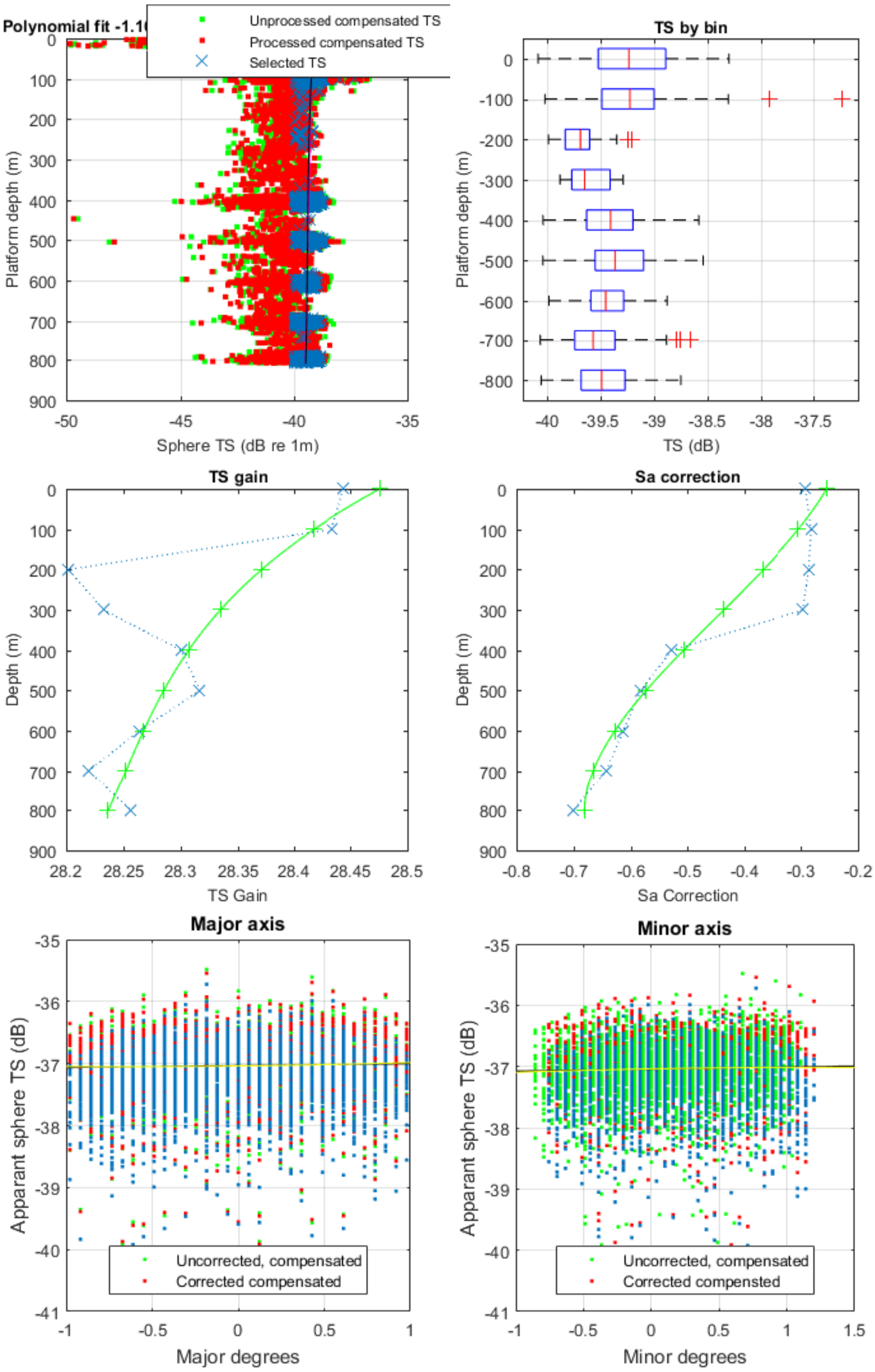
| Transducer serial number: ES120-7CD 115 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Transducer tank psi: -20.3 | | | | | | | | | |
| Depth bins: | 0 | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 |
| Targets: | 182 | 301 | 4 | 0 | 166 | 184 | 127 | 93 | 0 |
| TS gain: | 28.4819 | 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

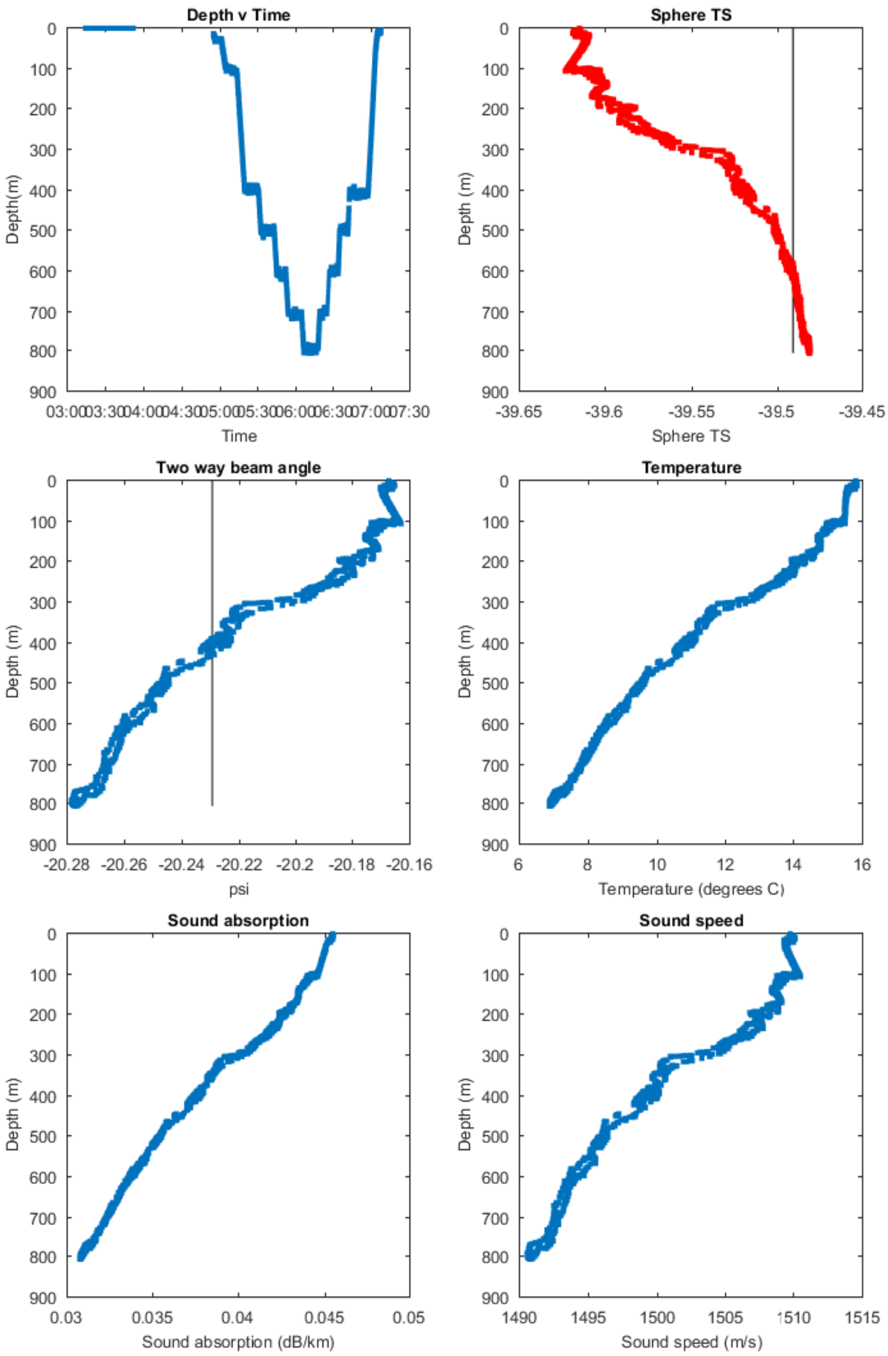
TS polynomial parameters: -1.0265e-09 1.21847e-07 0.000712341 -39.62
Gain polynomial parameters: -4.38887e-10 7.6802e-08 0.000206219 28.2509
SA polynomial parameters: 2.71393e-10 -6.93289e-08 -0.000661681 -0.257402

| Transducer serial number: ES120-7CD 115 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Transducer tank psi: -20.3 | | | | | | | | | |
| Depth bins: | 182 | 301 | 4 | 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
TS (dB)
TS gain
Depth (m)
TS Gain
Sa correction
Sa Correction
Major axis
Apparant sphere TS (dB)
Uncorrected, compensated
Corrected compensated
Major degrees
Minor axis
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 (AMX201702)

## 1. 38 kHz

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

38kHz_GPT 38 kHz 00907205c463 1 ES38B_20170708163227_20170720175925_kun017

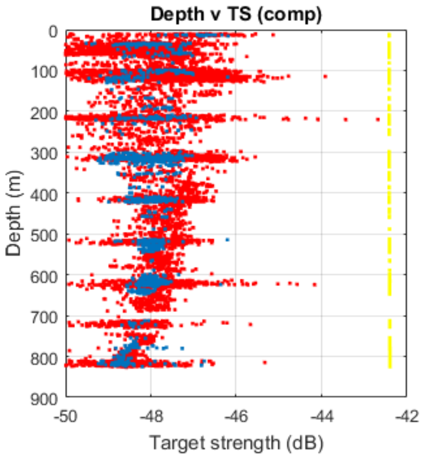
### Data acquisition details

| | |
|---|---|
| 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 |

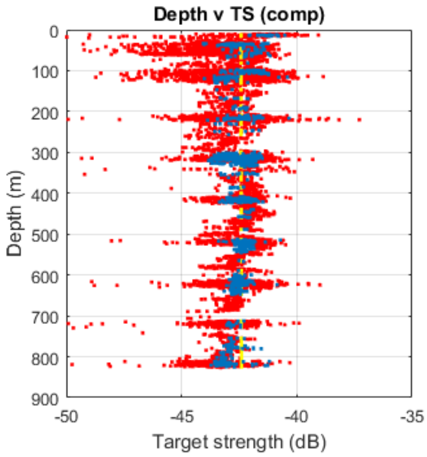
### Calibration parameters

| | |
|---|---|
| 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

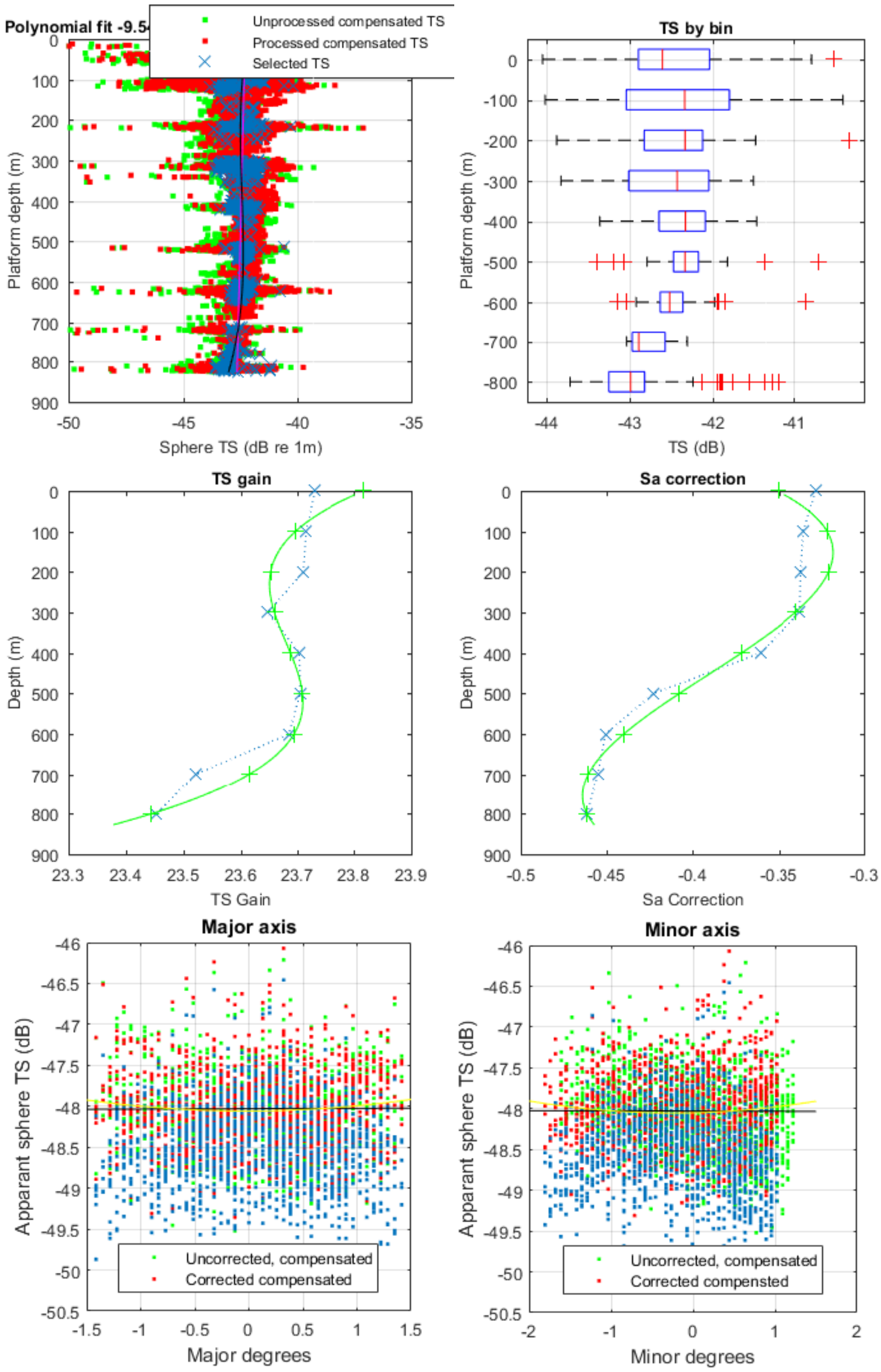
| Transducer serial number: ES38DD 28363 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Transducer tank psi: -20.8 | | | | | | | | | |
| Depth bins: | 0 | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 |
| Targets: | 129 | 79 | 0 | 1 | 0 | 0 | 14 | 0 | 19 |
| TS gain: | 23.6378 | 23.8636 | 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

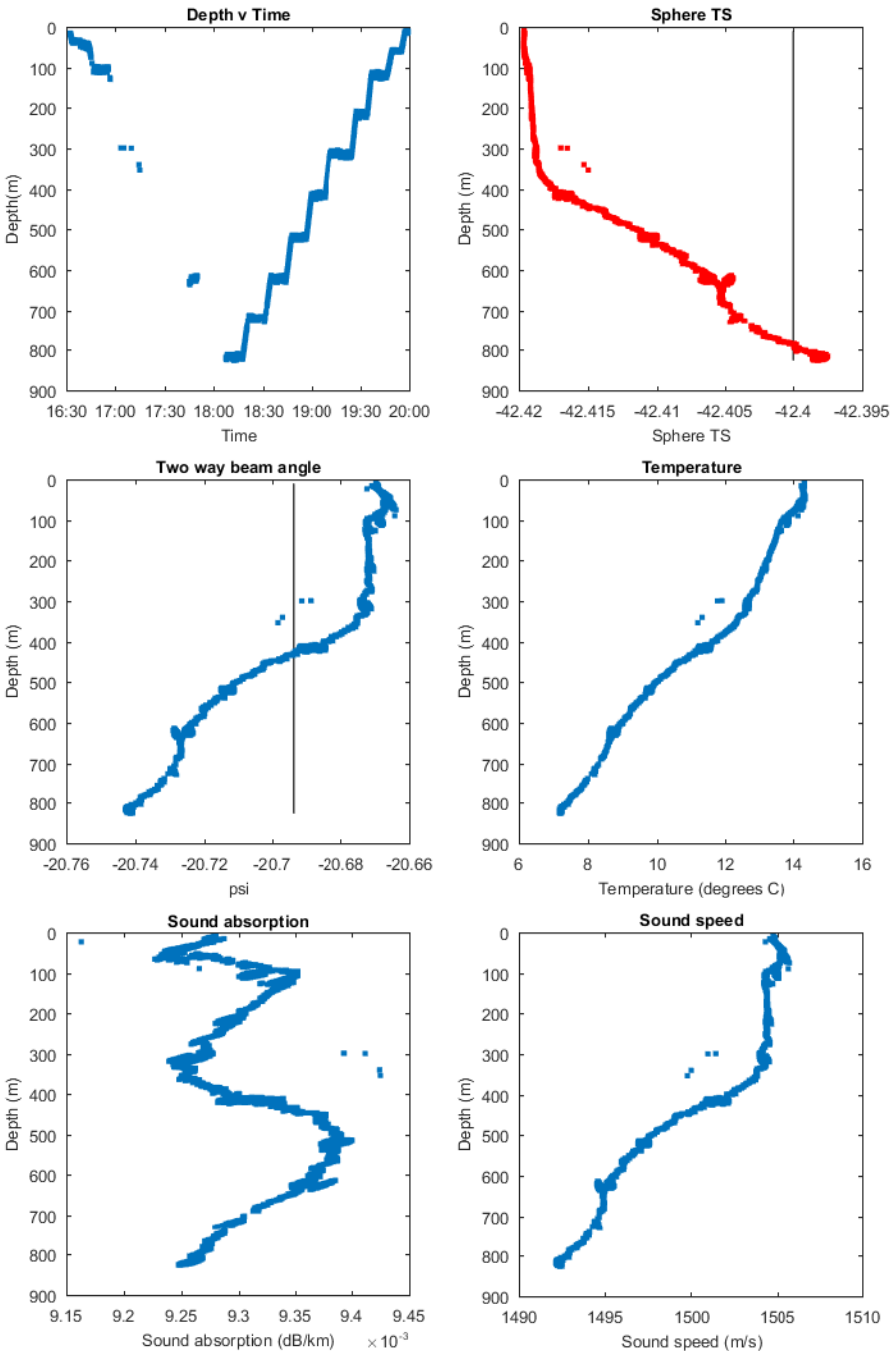
TS polynomial parameters: -1.51534e-08 1.88803e-05 -0.00692401 -41.7471
Gain polynomial parameters: -7.53586e-09 9.36671e-06 -0.00344054 24.0281
SA polynomial parameters: 1.87768e-09 -2.6583e-06 0.000856119 -0.404722

| 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
16:30 17:00 17:30 18:00 18:30 19:00 19:30 20:00
Sphere TS
Depth (m)
Sphere TS
-42.42 -42.415 -42.41 -42.405 -42.4 -42.395
Two way beam angle
Depth (m)
psi
-20.76 -20.74 -20.72 -20.7 -20.68 -20.66
Temperature
Depth (m)
Temperature (degrees C)
6 8 10 12 14 16
Sound absorption
Depth (m)
Sound absorption (dB/km)
9.15 9.2 9.25 9.3 9.35 9.4 9.45
× 10^-3
Sound speed
Depth (m)
Sound speed (m/s)
1490 1495 1500 1505 1510
0 100 200 300 400 500 600 700 800 900

## 2. 120 kHz

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

120kHz_GPT 120 kHz 009072073bbe 1 ES120-7C_20170708163220_20170720184102_kun017

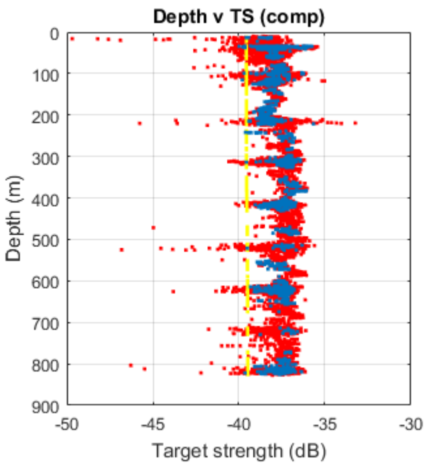
**Data acquisition details**

| | |
|---|---|
| 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 |

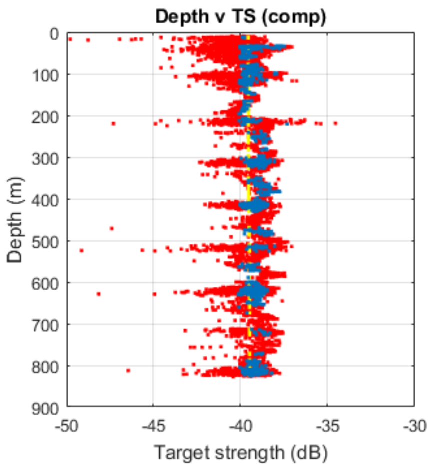
**Calibration parameters**

| | |
|---|---|
| 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

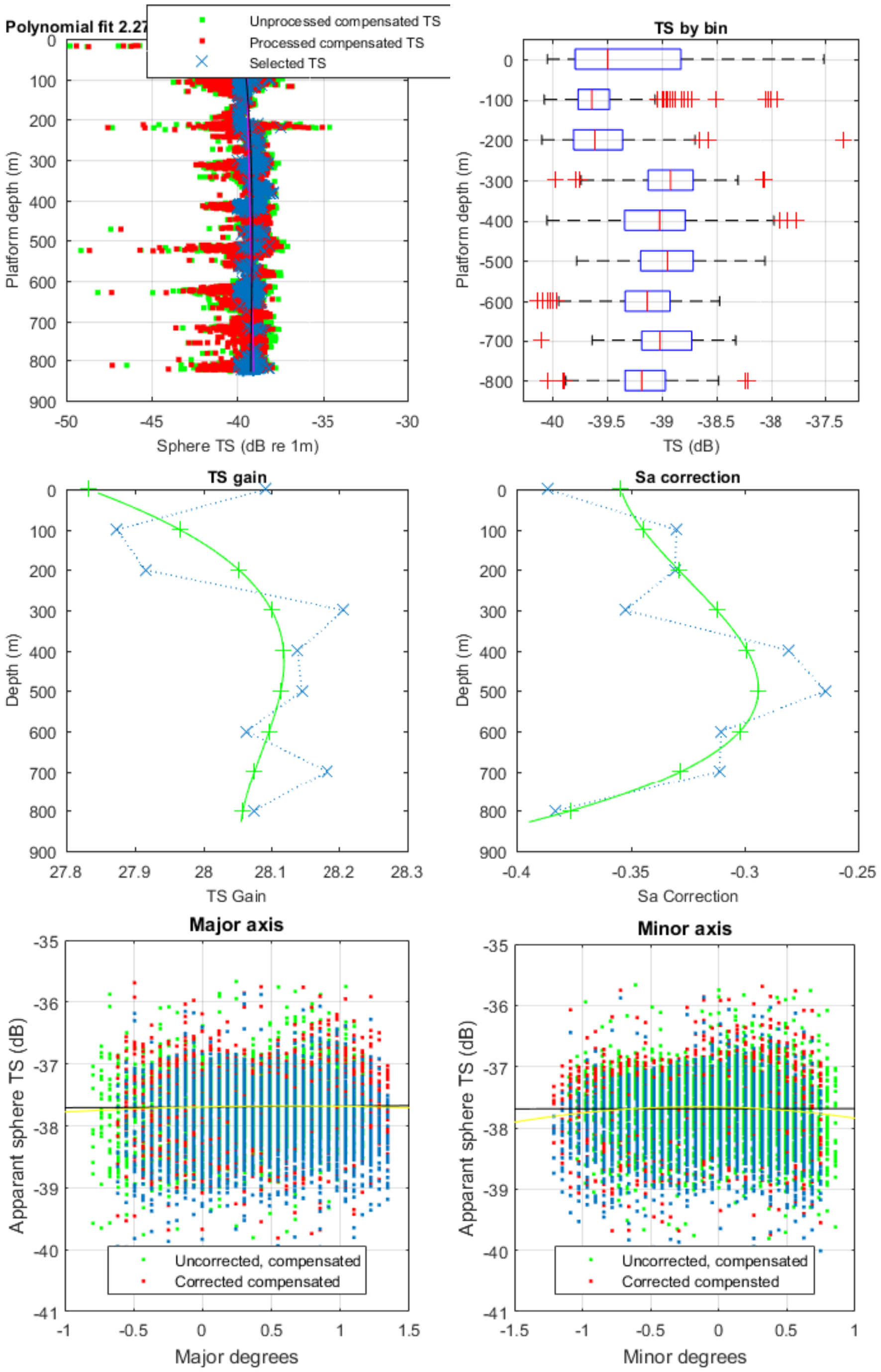
| Transducer serial number: ES120-7CD 115 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Transducer tank psi: -20.3 | | | | | | | | | |
| Depth bins: | 0 | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 |
| Targets: | 108 | 21 | 0 | 0 | 0 | 0 | 25 | 0 | 81 |
| TS gain: | 28.1355 | 28.2129 | 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

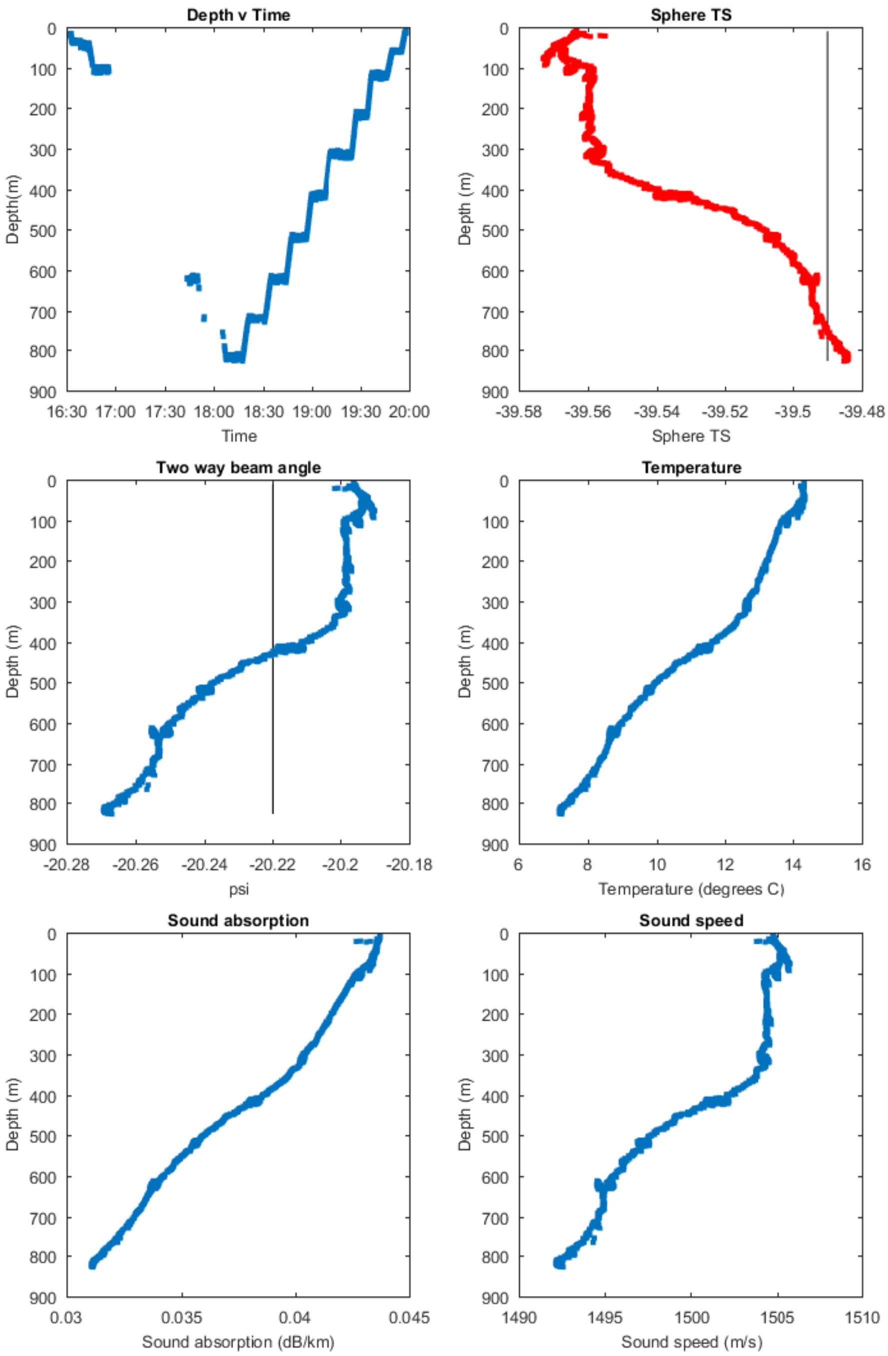
TS polynomial parameters: 7.26301e-09 -1.22958e-05 0.00636753 -40.145
Gain polynomial parameters: 3.95181e-09 -6.59112e-06 0.00329051 27.6277
SA polynomial parameters: -1.23722e-09 1.19163e-06 -0.000236578 -0.319906

| 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)
Sphere TS
-39.58 -39.56 -39.54 -39.52 -39.5 -39.48
Two way beam angle
Depth (m)
psi
-20.28 -20.26 -20.24 -20.22 -20.2 -20.18
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
Sound speed
Depth (m)
Sound speed (m/s)
1490 1495 1500 1505 1510
0 100 200 300 400 500 600 700 800 900

# APPENDIX 4. SURVEY ACTIVITIES

Table 14. Table of activities for voyage AEX1702

| Operation Number | Operation Type | Start Date | Location | Comment |
|---|---|---|---|---|
| **1** | Vessel Search | 03-Jul 10:30 | Cook Canyon | Search of Cook Canyon region with intensive localised search around the location where ORH marks have been observed in 2015 and 2016 plus searching across the wider Cook Canyon feature. |
| **2** | Vessel Survey | 04-Jul 13:00 | Cook Canyon | |
| **3** | AOS Survey | 04-Jul 15:00 | Cook Canyon | 5 transect AOS survey across same area where orange roughy had been seen on the prior vessel grid survey |
| **4** | AOS biological | 04-Jul 21:00 | Cook Canyon | Trawl shot at Cook Canyon on small aggregation in the location where the vessel and AOS surveys were conducted |
| **5** | Vessel Search | 05-Jul 00:36 | Moeraki Canyon | Zig zag search around edit of Moeraki Canyon. No marks of significance. |
| **6** | Vessel Survey | 05-Jul 09:02 | Cook Canyon | Very fine scale survey/search of region where most fish had been seen so far. Mark in the expected location was not there but scratchy marks observed along the edge of W-NW to E-SE ridge and the N-NE to S-SW ridge. Furno FCV 30 was left on during this sur |
| **7** | AOS Survey | 05-Jul 10:36 | Cook Canyon | AOS survey Cook Canyon. Running with fibre optic |
| **8** | AOS biological | 05-Jul 19:00 | Cook Canyon | AOS biological trawl shot with fibre optic cable attached. Quite a long tow on the flat before relocating mark. Reasonable mark off the bottom just past the edge of the dropoff. Most fish taken off the edge of the bank and started to thicken up just prior |
| **9** | Vessel Search | 05-Jul 21:00 | Cook Canyon | wide area searching of Cook Canyon during daylight hours and into the early evening. Furuno on |
| **10** | Vessel Survey | 06-Jul 07:35 | Cook Canyon | Vessel searching survey with Furuno off ahead of AOS |
| **11** | AOS Survey | 06-Jul 09:15 | Cook Canyon | Aos survey in main area of Cook Canyon. Vessel search saw ORH marks but very week.<br><br>Halted survey after second transect as losts connection to fibre optic. AOS still pinging on 38 kHz at least so transect should still be valid. Hauled AOS on at 11:16. Rec |
| **12** | Vessel Survey | 06-Jul 17:50 | Cook Canyon | Wide area search Cook Canyon region. Furuno on during search. Grid along ridge line on the western end of canyon with layers of strong 'fuzz' observed. Unlikely to be roughy. AOS deployment to investigate commenced at the end of this survey. |

| | | | | |
|---|---|---|---|---|
| **13** | AOS survey mode - single pass | 07-Jul 01:20 | Cook Canyon | AOS single pass above fuzz layer along ridge to the west of the canyon system. Primarily a test of the Simard WBT echosounder to investigate range performance at 120 kHz. WBT is being powered from a completely separate battery with its own power lead. Sec |
| **14** | Vessel Search | 07-Jul 07:52 | Moeraki Canyon | Wind at 20 knots but acoustics holding together perfectly with small sea and low swell. FCV30 on. Searching Moeraki Canyon region. Lots of 'fuzz' down deep but nothing of significance. |
| **15** | Vessel Search | 07-Jul 15:00 | Cook Canyon | Search back at Cook Canyon region. No large marks. Small mark on the north west edge. Furuno on |
| **16** | AOS biological | 07-Jul 19:04 | Cook Canyon | Biological shot at small mark. ~ 1 tonne orange roughy. 70% spent. Was planning to run WBT in FM mode but battery was most likely low and sounder would not start up. Ran with conventional EX60 sounders in trawl mode. Video and Gig-E running. Mark had disp |
| **17** | Vessel Search | 07-Jul 21:30 | Wide Area Search | Acoustics still holding together perfectly despite moderate winds. Suggests wind is a poor surrogate for quality for this vessel with complexity of swell and wind directions wrt to vessel heading having a big influence |
| **18** | Vessel Survey | 08-Jul 07:39 | Cook Canyon | Star pattern survey of mark on NW side of Cook Canyon. Very weak mark. First two passes had FCV30 on so commenced formal survey at 07:39. Marks were close to non existant. |
| **19** | AOS survey mode - single pass | 08-Jul 10:18 | Cook Canyon | Single pass AOS with experimental WBT test with EK80 software running WBT in FM mode, 80 to 170 kHz and EK60 38 kHz. ES60 is turned off. |
| **20** | Vessel Search | 08-Jul 12:41 | Cook Canyon | Vessel search with systematic grid. FCV 30 on |
| **21** | AOS deep calibration | 08-Jul 16:20 | Cook Canyon | Successful AOS calibration conducted in highly calm condition starting at 04:00 am. AOS platform was raised and lowered continually through +/- 10 m at each depth station giving much improved chance of sphere swinging through beam. Finished calibration just in time with wind freshening |

# APPENDIX 5. SURVEY CATCH COMPOSITION

| Code | Common Name | Scientific Name | Weight (kg) | No. |
|---|---|---|---|---|
| BEE | Basketwork eel | Diastobranchus capensis | 3.20 | 3 |
| BSH | Seal shark | Dalatias licha | 37.58 | 2 |
| BSL | Black slickhead | Xenodermichthys spp. | 0.46 | 7 |
| BTS | Prickly deepsea skate | Brochiraja spinifera | 0.10 | 1 |
| CBA | Humpback rattail (slender rattail) | Coryphaenoides dossenus | 1.66 | 2 |
| CHX | Pink frogmouth | Chaunax pictus | 0.16 | 3 |
| CIN | Notable rattail | Coelorinchus innotabilis | 0.03 | 1 |
| CMA | Mahia rattail | Coelorinchus matamua | 3.82 | 6 |
| CSE | Serrulate rattail | Coryphaenoides serrulatus | 2.25 | 25 |
| CSQ | Leafscale gulper shark | Centrophorus squamosus | 15.25 | 1 |
| CYO | Smooth skin dogfish | Centroscymnus owstoni | 11.43 | 2 |
| CYP | Longnose velvet dogfish | Centroscymnus crepidater | 0.32 | 1 |
| DEA | Dealfish | Trachipterus trachypterus | 4.53 | 2 |
| DMG | Dipsacaster magnificus | Dipsacaster magnificus | 0.14 | 4 |
| EPR | Robust cardinalfish | Epigonus robustus | 0.07 | 1 |
| EPZ | Epizoanthus spp. | Epizoanthus spp. | 0.03 | 1 |
| ETB | Baxters lantern dogfish | Etmopterus baxteri | 7.40 | 5 |
| ETL | Lucifer dogfish | Etmopterus lucifer | 0.65 | 3 |
| FMA | Fusitriton magellanicus | Fusitriton magellanicus | 0.24 | 5 |
| GBT | Deepsea lightfish | Gonostoma bathyphilum | 0.06 | 2 |
| GDU | Bushy hard coral | Goniocorella dumosa | 1.20 | 0 |
| GLS | Glass sponges | Hexactinellida (Class) | 0.08 | 0 |
| GSP | Pale ghost shark | Hydrolagus bemisi | 0.52 | 2 |
| HAK | Hake | Merluccius australis | 118.72 | 38 |
| HIM | Prickly anglerfish | Himantolophus spp. | 0.06 | 1 |
| HJO | Johnson's cod | Halargyreus johnsonii | 2.81 | 9 |
| HOK | Hoki | Macruronus novaezelandiae | 11.84 | 5 |
| HTH | Sea cucumber | Holothurian unidentified | 0.08 | 1 |
| HTR | Trojan starfish | Hippasteria phrygiana | 0.27 | 5 |
| LCH | Long-nosed chimaera | Harriotta raleighana | 1.72 | 5 |
| MIQ | Warty squid | Onykia ingens | 3.75 | 1 |
| NNA | Nezumia namatahi | Nezumia namatahi | 0.07 | 1 |
| OPI | Umbrella octopus | Opisthoteuthis spp. | 1.20 | 1 |
| ORH | Orange roughy | Hoplostethus atlanticus | 11020.00 | 7945 |
| PED | Scarlet prawn | Aristaeopsis edwardsiana | 0.03 | 1 |
| PHO | Lighthouse fish | Phosichthys argenteus | 0.12 | 2 |
| PLS | Plunket's shark | Proscymnodon plunketi | 106.99 | 6 |
| PYR | Pyrosoma atlanticum | Pyrosoma atlanticum | 8.20 | 0 |
| RAG | Ragfish | Pseudoicichthys australis | 0.13 | 1 |
| RIB | Ribaldo | Mora moro | 74.80 | 54 |
| SBK | Spineback | Notacanthus sexspinis | 0.56 | 3 |
| SCO | Swollenhead conger | Bassanago bulbiceps | 0.22 | 1 |
| SDE | Seadevil | Cryptopsaras couesii | 0.04 | 1 |
| SMC | Small-headed cod | Lepidion microcephalus | 9.48 | 40 |
| SOT | Solaster torulatus | Solaster torulatus | 0.45 | 5 |
| SQX | Squid pieces | | 5.95 | 0 |
| TUB | Tubbia tasmanica | Tubbia tasmanica | 3.24 | 2 |
| VSQ | Violet squid | Histioteuthis spp. | 1.18 | 1 |
| WHX | White rattail | Trachyrincus aphyodes | 29.06 | 30 |
| WOD | Wood | Wood | 1.61 | 0 |

# APPENDIX 6. REFERENCES

Demer, D., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., and Domokos, R. 2015. Calibration of acoustic instruments. ICES Cooperative Research Report, 133.

Doonan, I. J. 2016. Orange roughy, West Coast South Island, ORH 7B winter, 2016. Presentation to Deepwater Working Group, New Zealand, September 2016.

Doonan, I. J. 2017. DWWG2017-17. Orange roughy, West Coast South Island ORH 7B proposed research. . Presentation to DWWG, February, 2017.

Doonan, I. J., Bull, B., and Coombs, R. F. 2003. Star acoustic surveys of localized fish aggregations. ICES Journal of Marine Science, 60: 132-146.

Francois, R. E., and Garrison, G. R. 1982a. Sound absorption based on ocean measurements: Part 1: Pure water and magnesium sulfate contributions. The Journal of the Acoustical Society of America, 72: 896-907.

Francois, R. E., and Garrison, G. R. 1982b. Sound absorption based on ocean measurements: Part I: Pure water and magnesium sulfate contributions. The Journal of the Acoustical Society of America, 72: 896-907.

Kloser, R. J. 1996. Improved precision of acoustic surveys of benthopelagic fish by means of a deep-towed transducer. ICES Journal of Marine Science, 53: 407-413.

Kloser, R. J., Knuckey, I. A., Ryan, T. E., Pitman, L. R., and Sutton, C. 2011a. Orange roughy conservation program: Eastern Zone surveys and trials of a cost-effective acoustic headline system. Final report to the South East Trawl Fishing Industry Association. Copy held at CSIRO Marine Laboratories, Hobart, Tasmania.

Kloser, R. J., Macaulay, G. J., and Ryan, T. E. 2013. Improving acoustic species identification and target strength using frequency difference and visual verification: example for a deep-sea fish orange roughy. In prep.

Kloser, R. J., Ryan, T., Sakov, P., Williams, A., and Koslow, J. A. 2002. Species identification in deep water using multiple acoustic frequencies. Canadian Journal of Fisheries and Aquatic Sciences, 59: 1065-1077.

Kloser, R. J., Ryan, T. E., Macaulay, G. J., and Lewis, M. E. 2011b. In situ measurements of target strength with optical and model verification: a case study for blue grenadier, Macruronus novaezelandiae. ICES Journal of Marine Science, 68: 1986-1995.

Mackenzie, K. V. 1981. 9-Term Equation for Sound Speed in the Oceans. Journal of the Acoustical Society of America, 70: 807-812.

Maclennan, D. N., Fernandes, P. G., and Dalen, J. 2002. A consistent approach to definitions and symbols in fisheries acoustics. ICES Journal of Marine Science: Journal du Conseil, 59: 365.

McClatchie, S., Macaulay, G., Coombs, R. F., Grimes, P., and Hart, A. 1999. Target strength of an oily deep-water fish, orange roughy (Hoplostethus atlanticus) I. Experiments. Journal of the Acoustical Society of America, 106: 131-142.

Ona, E., and Mitson, R. B. 1996. Acoustic sampling and signal processing near the seabed: the deadzone revisited. ICES Journal of Marine Science: Journal du Conseil, 53: 677-690.

Ryan, T. E., and Kloser, R. J. 2016a. Improved estimates of orange roughy biomass using an acoustic-optical system in commercial trawlnets. ICES Journal of Marine Science: Journal du Conseil: fsw009.

Ryan, T. E., and Kloser, R. J. 2016b. Improved estimates of orange roughy biomass using an acoustic-optical system in commercial trawlnets. ICES Journal of Marine Science: Journal du Conseil.

Ryan, T. E., and Tilney, R. 2015. Voyage report : Estimates of biomass of roange roughy in ORH7B and ORH3B Puysegur Bank using a net attached acoustic optical system. Report to Deepwater Group New Zealand: 44.
Ryan, T. E., Tilney, R. L., and Downie, R. A. 2017. Voyage report: Estimation of the Abundance of Orange Roughy in Mid-East Coast Using an Acoustic Survey. Ministry of Fisheries, New Zealand, Fisheries Assessment Report.
Ryan.T.E, and Tilney, R. 2016. Biomass surveys of orange roughy spawning aggregations in ORH3B NWCR and ESCR management sub-areas in June-July 2016 using a net attached acoustic optical system. . Final Report to Deepwater Group Ltd, New Zealand. CSIRO Oceans and Atmosphere, Hobart.
Simmonds, E. J., and MacLennan, D. N. 2005. Fisheries Acoustics Theory and Practice*,* Blackwell Science, Oxford. 437 pp.