OCEANS AND ATMOSPHERE
www.csiro.au

# Orange roughy biomass estimation in SIOFA

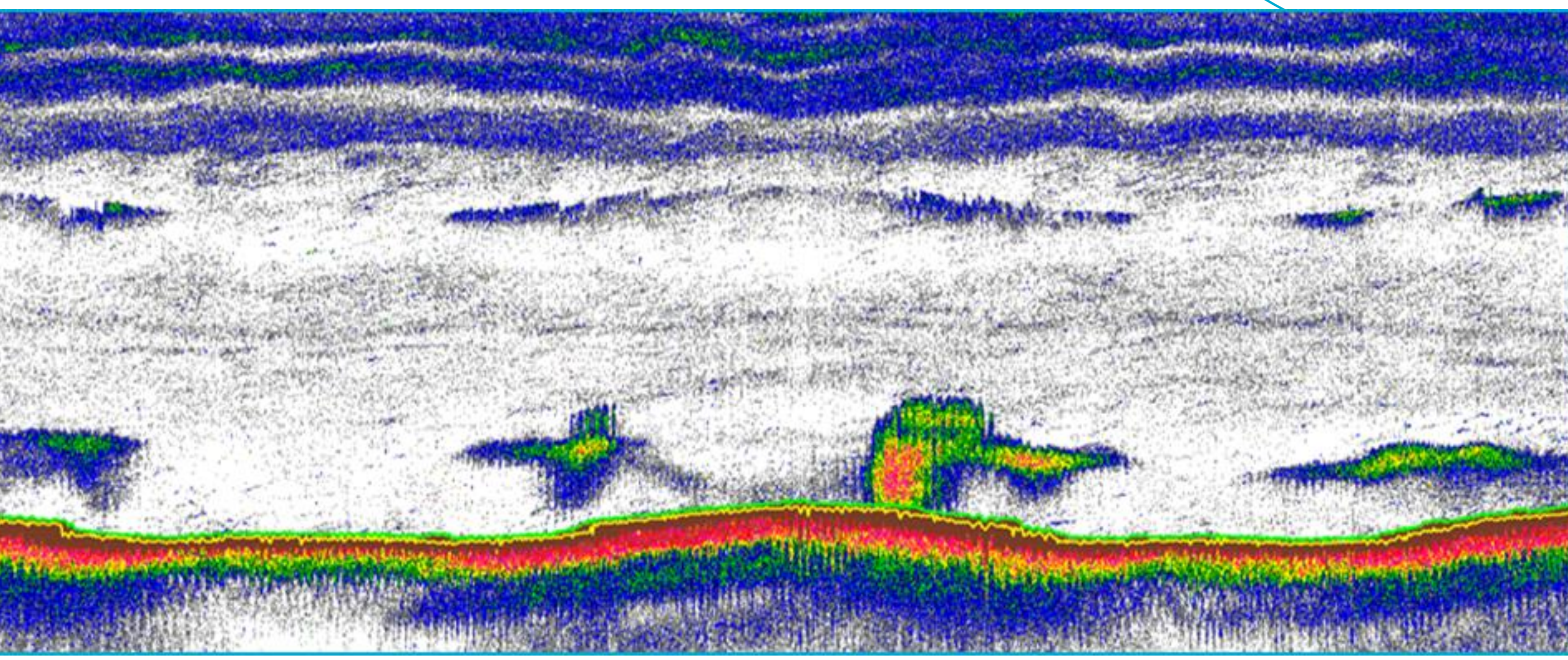
## Review of the use of acoustics from industry vessels

Feb. 2018

Kloser R.J. and Scoulding, B. CSIRO Australia

Niklitschek, E. and Toledo, P. ULL Chile

Patchell, G. Sealord NZ



# Contents

# 1 Introduction

## 1.1 Background

During the South Indian Ocean Fisheries Agreement's (SIOFA) third meeting, the parties agreed to a science budget that included:

"Start the analysis of existing acoustic data (collected by industry vessels). The Scientific Committee (SC) discussed that these data may be important for stock assessments (initially orange roughy). These data need to be reviewed, to consider such things as the uncertainty in species composition and check the calibration of the systems. The data from one or two grounds could be analysed to estimate biomass and the associated uncertainties. This is estimated as ~1 month work for the appropriate expert".

This activity was based on the SC1 discussion around progressing towards assessments for key fisheries resources. The SC1 noted the work tabled by the Cook Islands (analysing data 2004-08 and the suggestion that more recent data will be analysed prior to SC2 (Niklitschek and Patchell, 2015)) and the need for specialist technical expertise to assist the SIOFA SC. The SC operational work plan included analysis of acoustic data prior to SC2, building towards orange roughy assessments. Furthermore, CMM 2016/01 identifies that the status of stocks of principal fishery resources targeted to be undertaken by 2019 SC

This work recognises the SC1 discussion on the role of industry vessels as platforms for collecting data to inform stock assessments. Given the previous work analysing the existing acoustic data and in working towards stock assessments, there is a need for the SC to consider standards that assist in understanding how the data should be interpreted and used within an assessment framework.

## 1.2 Terms of Reference

1. Describe the use and interpretation of acoustic data within a deep-water orange roughy stock assessment framework. This would consider various levels of uncertainty (e.g. species identification, survey design, target strength, absorption, calibration and data quality). This would also propose guidance to evaluate the quality of the data and the corresponding estimations.

2. Recommend methods for acoustic data collection from fishing vessels without on-board dedicated technicians to meet the stock assessment objectives above. Including issues such as data collection, quality control, survey design and ancillary species identification, target strength and biological parameters.

3. Provide an evaluation of the existing industry data, focused on one or two fishing grounds, against the adopted framework and how these data may be used within single stock assessments, as for orange roughy. This will include consideration of uncertainty in species identification, absorption, dead zone, data quality, calibration and survey strategy. This will be dependent on access to the industry data collected to date negotiated with the assistance of the SIOFA Secretariat.

## 1.3 Agreed work plan

A work plan addressing the terms of reference was agreed as below:

1. Building on the FAO/ABNJ Rome workshop describe and quantify the various sources of uncertainty in estimates of orange roughy biomass using acoustic data. The FAO/ABNJ meeting highlighted that error factors of 2 to 4 times actual abundance were possible and these need to be summarised and quantified prior to use of the results in stock assessments (FAO, 2017).

Based on the potential uncertainty in the acoustic data, suggest and demonstrate how the biomass estimates could be used in a stock assessment as ground snapshots (absolute estimates) and as a time series of estimates in a relative sense to reduce uncertainties in target strength and absorption assumptions.

2. Review the protocols for collection of acoustic and ancillary data using the existing data collected and the guidelines provided in the FAO Tech Rep 1020 ( FAO 2006). Build on the work conducted in FAO/ABNJ (2017) to refine and test existing and new survey protocols to facilitate this data collection. In particular address the issue of survey design through analysis of existing data sets as outlined in 3 below.

3. Several surveys were identified at the Rome workshop (e.g. Sleeping Beauty) including vessel mounted and the Sealord net attached Acoustic Optical System (S-AOS) with data provided. These data will be analysed and compared to the original and revised 2009 estimates with appropriate reporting for use in a stock assessment. An important aspect of this work will be to analyse the 2014 net attached acoustic optical system data to inform estimates of the target strength of larger orange roughy as well as to explore the species composition on the SB ground.

Where possible and appropriate, this work would be undertaken in collaboration with the SIOFA industry and other regional experts (e.g. Edwin Niklitschek from Chile).

# 2 Acoustic biomass estimations used in stock assessments

Acoustic biomass surveys for orange roughy were first trialled in the mid-1980s (Do and Coombs, 1989). Acoustic vessel mounted and deep towed surveys have been conducted regularly since 1993 in Australia and the early 2000s in New Zealand, when results were initially used as absolute biomass estimates, later being used as relative biomass estimates with an informed prior on survey catchability from the early 2000s. Deep towed surveys were done to reduce uncertainties in range dependent factors of absorption, near seabed sampling, data quality and species identification. The greatest acoustic problem was species identification/mix, and trying to get an accurate estimate of the target strength of orange roughy (the proportion of energy that an individual fish reflects). Problems with species identification/mix, where a small amount of fish having gas-filled swim-bladders can bias orange roughy biomass estimates when they are misidentified or in mixed species shoals, was minimised by focusing surveys on spawning aggregations using deeply towed multi-frequency acoustics (Kloser et al., 2000; Kloser et al., 2002). Improvements in obtaining remotely sensed species composition during a survey and the ability to obtain visually verified target strength have significantly improved the estimates of biomass. Development of a multi-frequency net-attached acoustic optical system (AOS) enables both visually verified target strengths and species mixtures in acoustic records to be determined (Ryan et al., 2009; Ryan and Kloser, 2016). Using this AOS system attached to a commercial fishing net which could simultaneously 'ping' and visually confirm the species identity of the target yielded similar results in both New Zealand and Australian 35 cm orange roughy (Kloser et al., 2013; Macaulay et al., 2013). A further advance has been to use the net attached AOS to estimate biomass at two frequencies greatly improving the precision and confidence in the estimates (Kloser et al., 2011; Ryan and Kloser, 2016).

Stock assessments for orange roughy have included 38 kHz acoustic estimates of spawning biomass using both vessel mounted and deep-water-towed and net attached platforms since 1990 e.g. (Kloser et al., 1996; Niklitschek and Roa, 2006). The use of these biomass estimates in a stock assessment context was recently summarised for an Australian acoustic biomass index from 1990 to 2013 (Kloser et al., 2015) and Australian and New Zealand snapshot biomass estimates (Ryan and Kloser, 2016). A time series of acoustic data for the Australian spawning grounds 1990 to 2016 highlights the use of acoustic survey data to a stock assessment model and the estimated Coefficient of Variation (CV) of the results improving in later years as changes were made in the technology and methodology. In this example a vessel mounted survey had a CV of ~40% due mainly to poor species identification and this improved to a CV of ~20% in later years due to the use of multi-frequencies on a net attached AOS system. This example highlights several key issues of relevance to the Indian Ocean, firstly, that the uncertainty of vessel mounted biomass estimates are greater than those derived from deep towed system, secondly, that the absolute snapshot estimates are in general agreement with the stock assessment and thirdly that natural variations in fish availability will impact an index (see survey results for the 2012 and 2013 years in Fig. 2.1 where there was no commercial fishing).

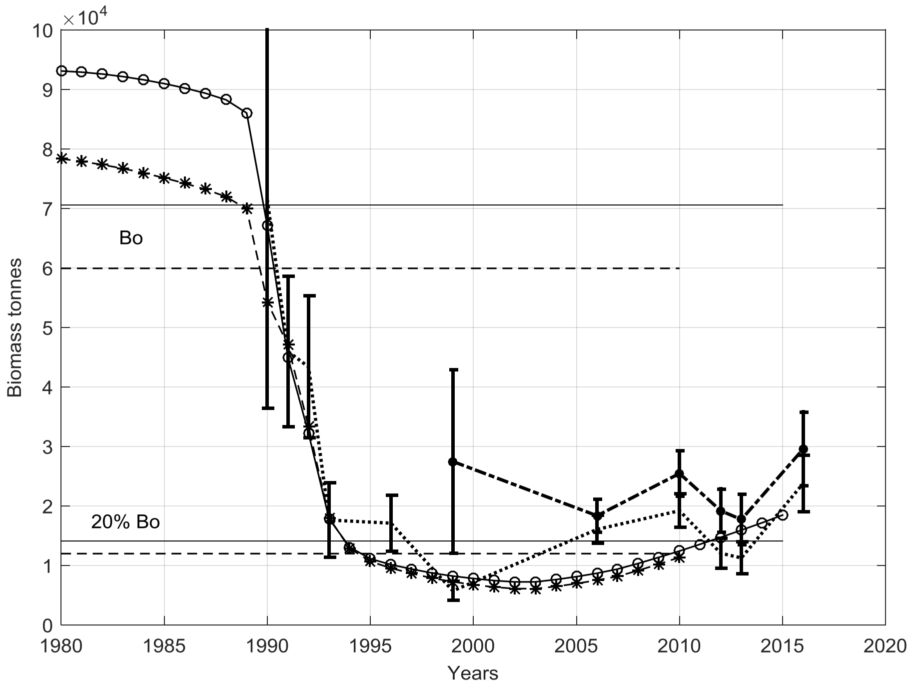



**Figure 2.1 Estimated change in spawning biomass at St Helens Hill (dashed line, s.d. solid line) based on a vessel mounted survey in 1990 and towed body surveys from 1991 to 2016. Combined St Patricks and St Helens spawning orange roughy estimate of acoustic biomass in 1999, 2006 to 2016 (dot dashed line, s.d. solid line). Stock assessment model in 2006 for spawning biomass of orange roughy prior to updated acoustic biomass estimates due to change in target strength (star, dashed line) and the 2014 stock assessment model that includes target strength and acoustic surveys up to 2016 (circle, solid line) Kloser et al. (2015, 2017).**

The normal process for acoustic survey biomass estimates to be accepted for stock assessments in Australia and New Zealand is to be reviewed by a working group during two to three meetings. Typically the data collection outlining the surveys, data quality and any issues that could impact the use of the data is reported and presented at a working group with feedback given. A second meeting with a detailed report of the analysis of the data and estimated biomass and error are presented. Depending on the feedback a third meeting may be required to present the final results and provide a report (Figure 2.2).

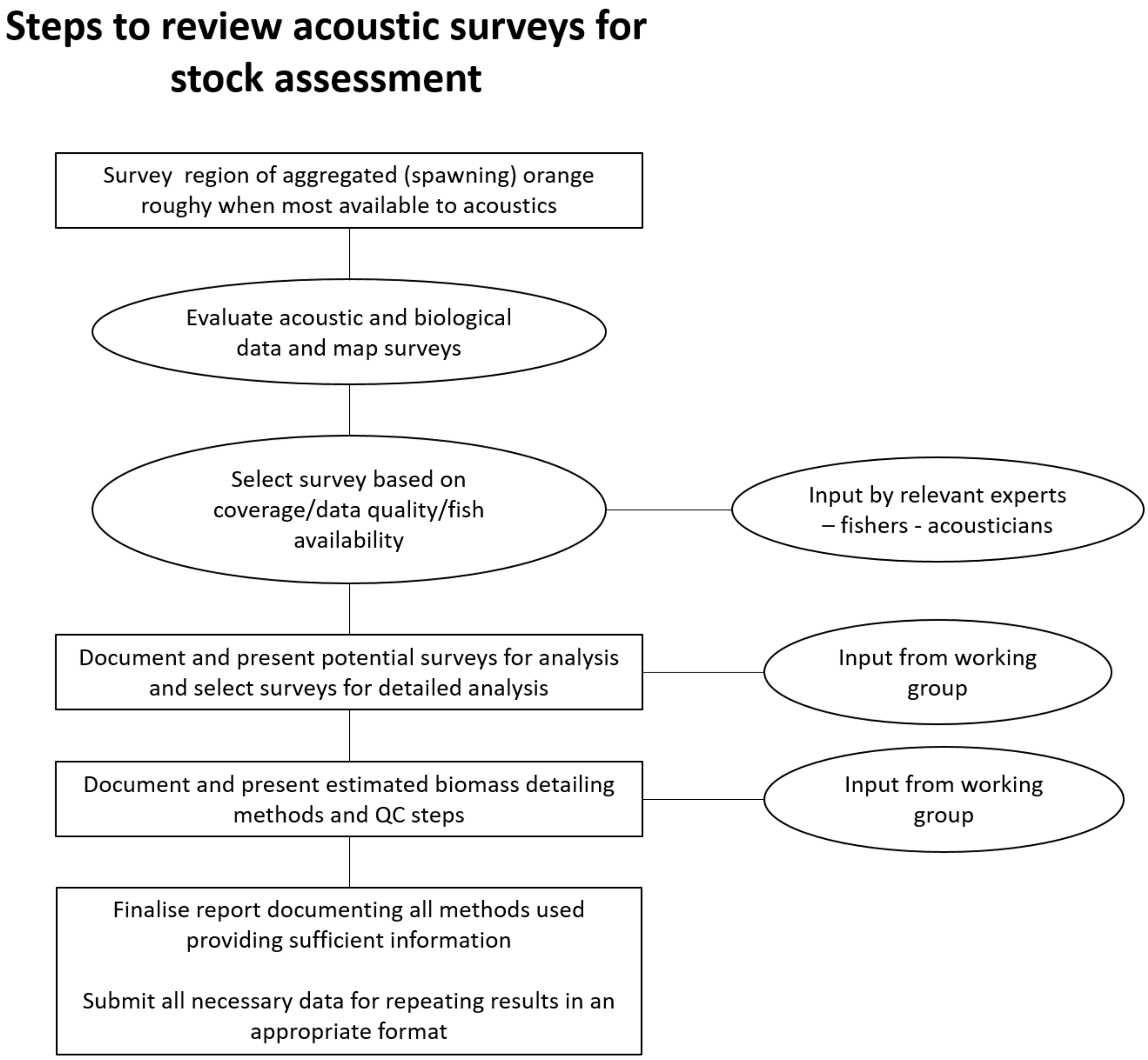



**Figure 2.2 Flow chart of how acoustic estimates of biomass are selected and adopted for use in a stock assessment framework, New Zealand and Australian national example.**

In this report we focus on acoustic survey biomass estimate use in a high seas context from Indian Ocean high seas industry vessels (FAO, 2017). Potential error sources in the data were evaluated and discussed with errors of a factor of 2-4 encountered and documented based on the available knowledge. In summary, high precision acoustic surveys and biomass estimates of orange roughy are possible if the following conditions apply; the acoustic systems (commonly 38 kHz and if deep towed 38 and 120 kHz) are calibrated, the orange roughy are in schools with low to no species contamination and well clear of the seabed echo and the schools are stationary compared to the acoustic survey time. The common sources of error are summarised in Table 2.1. If the acoustic biomass estimates are to be used as a time series (relative index) then constant errors in target strength and absorption will not impact on their use. If the biomass estimates are used as an absolute estimate then knowledge of the species target strength and measured absorption are required (Table 2.1).

The only error factor that will not influence the estimation of a snapshot biomass estimate is the fish availability, although it will require many surveys to capture the maximum fish availability for use in a stock assessment.

**Table 2.1** Errors that will influence the use of acoustic data for a time series index and absolute snapshot biomass estimates used in stock assessments (Kloser et al., 2011).

| | **Biomass estimate used in stock assessment** | | |
|---|---|---|---|
| **Potential Source of Error** | **Index** | **Absolute snapshot** | **Notes** |
| Calibration by sphere | yes | yes | |
| Species ID | yes | yes | |
| Target strength | no | yes | Yes for index if variable size |
| Near seabed estimate | yes | yes | |
| Absorption | no | yes | |
| Data quality | yes | yes | |
| Fish availability | yes | yes | Changing population availability to the survey |
| Fish movement | yes | yes | |
| Survey analysis method | yes | yes | If methods change or survey strategy varies effects both index and absolute snapshot |

Table 2.2 outlines potential error sources that could affect an acoustic biomass estimate that are summarised from previous use of vessel mounted surveys in deep water and analysis of Indian Ocean data (Kloser et al., 2011; Scoulding and Kloser, 2018). Given the range of potential error sources in estimating biomass it is prudent to have a review process to ensure world's best practice and that the methods are appropriate and results reproducible. We recommend a review mechanism is established based on current methods (Figure 2.2) but tailored to the SIOFA situation where surveys are not funded by a National agency (Figure 2.3). To assist the review process we recommend guidelines be followed for analysis, with a reporting method that at least contains the information as outlined in section 4. It is also recommended that member states store all necessary data and documents for repeating results in a common format. This acknowledges data sensitivity for collaborating industry partners. Several major sources of uncertainty were considered in this review being, species identification, target strength, absorption, noise and survey analysis method detailed in Scoulding and Kloser (2018) and results summarised in Section 4.

**Table 2.2** Range of significant potential sources of uncertainty expected for vessel mounted surveys of Indian Ocean orange roughy that need to be considered in the analysis and interpretation of the data (Kloser et al., 2011; Scoulding and Kloser, 2018). The significant potential errors considered in this review are highlighted.

| | **Impact on biomass estimate** | | |
|---|---|---|---|
| **Uncertainty** | **Factor range** | **Risk not bounded by range** | **Notes** |
| Calibration on axis gain | 0.9 to 1.1 | low | If done appropriately (Demer et al., 2015) |
| Calibration of beam | 0.8 to 1.2 | low | Effect if not done (Haris et al., 2017) |
| Species ID | 0.25 to 1 | high | Depends on the species present (Kloser et al., 2002). |
| Target strength | 0.5 to 1 | medium | Moving from current knowledge of 35 cm orange roughy TS and new measurements of 45 cm fish based on the AOS (Scoulding and Kloser, 2018). |
| Near seabed estimate | 0.8 to 1.2 | medium | Error in estimating fish in the deadzone on different slopes of seabed |
| Absorption | 1 to 1.31 | low | Difference in moving from Doonan to Francois and Garrison equations at 1050 m (FAO, 2017) |
| **Data quality** | | | |
| vessel motion | 1.0 to 1.2 | high | Significantly reduced if motion measured |
| bubble layer/attenuation | 0.7 to 1.0 | high | Depends on sea state and wind direction to steaming |
| noise | 0.7 to 1.3 | high | |
| Fish availability | Unknown but <1 | high | Changing population availability to the survey |
| Fish movement | Unknown | high | Could be significant and detected for one Indian ocean survey reviewed in this project (Scoulding and Kloser, 2018). |
| Survey mean estimation | 0.7 to 1.1 | high | Depends on adopted survey design and analytical method |
| Survey sampling error | 0.5 to 1.5 | high | Depends on adopted survey design and analytical method |

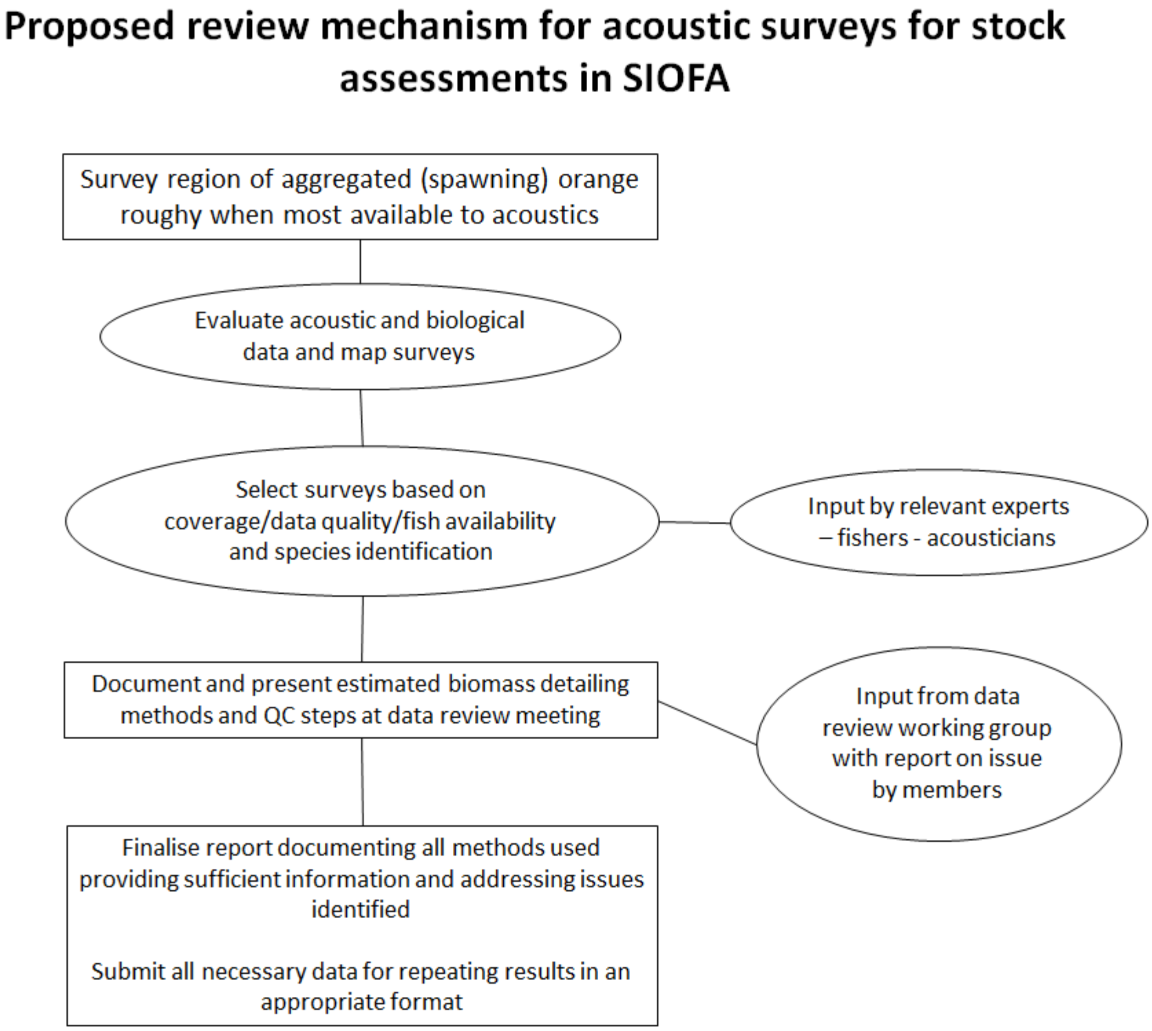



**Figure 2.3 Review mechanism to review acoustic data in SIOFA**

# 3 Data collection on industry vessels

A protocol has been previously defined for undertaking acoustic surveys on commercial vessels in the SIOFA region (FAO 2006). It was further updated during a 2012 FAO workshop on, "fishing vessel execution of acoustic surveys for deep-sea species", and the main issues and way forward documented (FAO, 2012). This 2012 workshop focused on results from acoustic surveys in the Indian Ocean for both orange roughy and alfonsino. Since that FAO2012 review, substantial further developments have occurred, including the development of Sealord's Acoustic Optical System (S-AOS) for use on commercial fishing vessels (Ryan et al. 2009). In 2017 a workshop to discuss data collected from an industry vessel in the Indian Ocean was held and noted these advances and recommended additional work to be undertaken (FAO, 2017). In particular the meeting highlighted the successful deployment of the S-AOS in SIOFA during 2014 showing that data on TS and species ID could be collected by commercial fishers during routine vessel operations.

Instrument considerations

- Calibration is a critical aspect for surveys and is recommended at least annually where a calibration report is done and the raw data stored by the company.
- Over the time series of Will Watch acoustic surveys 2004-2017, the stability of the echosounder was found to be much less than originally expected with the ES60 system. This includes loss in sensitivity over time, from both GPT and transducers.
- To check on vessel calibration stability a standard transect on the grounds may allow comparisons between vessels and years (Appendix A). One suggested area of suitable hard flat bottom to run a transect line is from 34 22.4 S 44 12E to 34 22.6 S 44 09.7 E. There are sidescan sonar backscatter maps for this area.
- Noting that the signal:noise ratio is strongly reduced at long range in deep waters, we recommend increasing the pulse duration to 2.048 ms when operating deeper than 700m. To do so the echosounder must be calibrated for operating at both 1.024 and 2.048 ms.
- For consistency between survey years and grounds and given recent equipment changes across fishing vessels globally (ES60 to EK/ES80 and new ceramic transducers), continuous wave (CW) at 38 kHz should be used in all subsequent assessment surveys.
- To compensate for vessel movement signal attenuation a motion reference unit should be logged with the acoustic data where possible.
- Check on vessel noise at different speeds (4kn, 8kn, full speed).

Recommendations for surveys of regions:

- Define a target survey area (where the stock is expected to be present) for each ground
- Target a minimum of three surveys per ground within a year to reduce overall CV below 20%
- The priority is for repeated and precise estimates in a limited number of areas over an extensive but imprecise coverage of many grounds.

Selection criteria for undertaking a survey

- Surveys should be conducted/included only when fish are aggregated for spawning and preferably when they become fully available (clear of the seabed echo) to the acoustic observation system. One of the best indicators is when the fish begin to form plumes.
    - Some other preliminary criteria for triggering a survey:
        - Female fish GSI be above a certain stage (e.g.10%, as 12% is the mean GSI for stage 4 in SIOFA). This is typically when plumes begin to develop.
- In areas of complex species mixing and or steep slopes the AOS is needed to reduce uncertainty. The AOS also reduces range dependent errors of absorption, motion and noise effects in general.
- To resolve target strength uncertainty the AOS is needed to obtain measurements on selected grounds. Orange roughy targets are needed at ranges from 5 - 10 m to be within acoustic and optical ranges (Scoulding and Kloser, 2018).

# 4 Review of existing data and biomass estimates

A review of the Sleeping Beauty 2005 and 2009 vessel mounted surveys and the 2014 trials of the S-AOS for target strength and species identification are outlined here following ToR 3. These data were chosen as they represented good quality data with well executed grid surveys in a region of assumed low gas-bladder species contamination and where aggregations were well clear of the seabed. Hence many of the issues associated with vessel mounted surveys of deep water orange roughy were minimised.

**Biomass estimate**

Several issues were uncovered during the review highlighting the need to have rigorous checking of the methods and calculations. To summarise the methods used by the two groups (CSIRO-Review 1, ULL -Review 2) it was decided to standardise on some key analysis inputs to compare results to the original estimates using the geostatistical approach (Niklitschek and Roa, 2006). The CSIRO – Review 1 analysis is detailed in Scoulding and Kloser (2018) and used an EDSU approach to calculate the area backscatter mean with geostatistics used to derive the sampling error. The main findings showed that a factor of up to 3.2 was detected between original and revised estimates due mainly to inference area assumptions and fish movement. In these two examples there remained a significant up to factor of 1.6 difference between the EDSU and geostatistic mean estimates (Table 4.1). The following summarises the main issues discussed at the review meeting between the groups.

a. Data quality was high and methods used were consistent with standard practice. The data workshop enabled a thorough and informative checking of each step in the biomass assessment process that could detect and correct errors. We recommend that standardised reporting and acoustic data workshop/reviews are held prior to biomass estimates being used in a stock assessment. This meeting developed guidance for what the standardised reporting should contain;
    i. error table check list Table 2.2 and Table 6.1.

ii. parameter table of all key variables and results (Table 4.1).
iii. maps of inference area and intensity (Figure 4.1).
iv. It is also recommended that key metadata and data storage methods are developed so that results can be replicated.

b. Inference area calculation and fish movement within surveys lead to calculated biomass differences up to 3 times increase or decrease. Previous inference area estimates presented were reviewed and selected biomass estimates recalculated (Table 9.2). Fish movement needs to be mitigated against and appropriate planning and analytical methods used prior to using data and results in a stock assessment.

c. To mitigate effects of fish movement requires investigation at the time of the survey and to either survey when aggregations are stationary or use a survey design that can mitigate effects of fish movement (e.g. interlaced transects) and or analytical strategy to decrease effect (e.g. splitting surveys).

d. There were two lines of evidence that the 2005 data had reduced sensitivity compared to the 2009 data. Firstly, visual inspection of scattering layer strength in 2005 was weaker than the 2009 data (Scoulding and Kloser, 2018). Secondly, the 2005 data had reduced seabed echo strength compared to other years over a common seabed region (Appendix A). If this is substantiated it suggests the biomass estimated in 2005 are biased low.

e. Due to the large depth range to aggregations of orange roughy, greater than 1050 m in SIOFA fisheries, absorption has a large uncertainty as there are no validated measurements in deep-water worldwide. We compared the two most commonly used equations of Francois and Garrison and of Doonan et al. (Francois and Garrison, 1982; Doonan et al., 2003) which changed the biomass estimate by 30% for aggregations at a mean depth of 1050 m. Until this important difference in outcome is resolved we standardised our analysis on the most conservative set of equations (Doonan et al., 2003). We recommend measurements are made to resolve this source of uncertainty for all deep-water (> 300 m range) acoustic estimates in the Indian Ocean and elsewhere. Using a deep towed AOS would reduce this uncertainty significantly by factor of 2-3.

f. We found important differences in the analytical approach of estimating the area backscatter ($S_A$) mean based on the assumption of the distribution of the data and the inference tools being used to compute the mean (e.g. geostatistics or EDSU). The biomass obtained with the geostatistical approach being used was often lower (factor range 0.6 to 0.8) than applying the conventional transect EDSU method. We recommend that survey data simulations are done to determine an appropriate method, depending on the survey type and data, with reporting diagnostics. At the simplest level a map of the collected data and the inferred distribution is needed (Figure 4.1). In this example of the 2009 grid survey data it is not apparent that the geostatistic inferred $S_A$ distribution is honouring the gridded transect data.

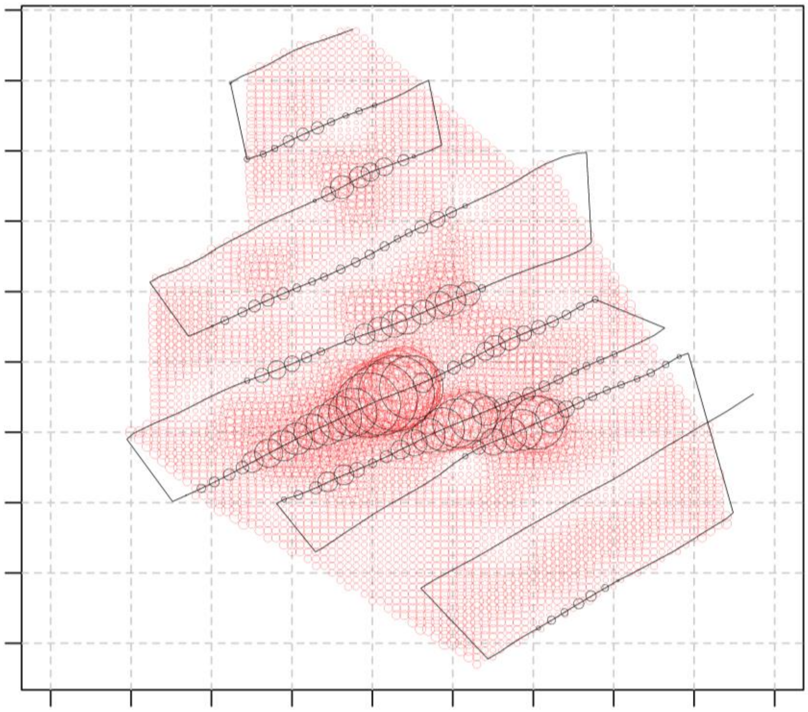


**Figure 4.1 Area backscatter (black circles) recorded for defined orange roughy schools for the 2009 survey grid (black line) at 100 m intervals and the predicted distribution of area backscatter at 50 m grid using the geostatistical method (red circles). Map grid is 500 m.**

g. During the workshop it became apparent that the area backscatter sampling coefficient of variation differed significantly (factor of 2-4) between the area backscatter EDSU mean (e.g. 2009 -11%) and geostatistic mean method (e.g. 2009 - 30%, Table 4.1, Figure 4.2). Guidance on which method is the most appropriate depending on the survey design should be investigated.

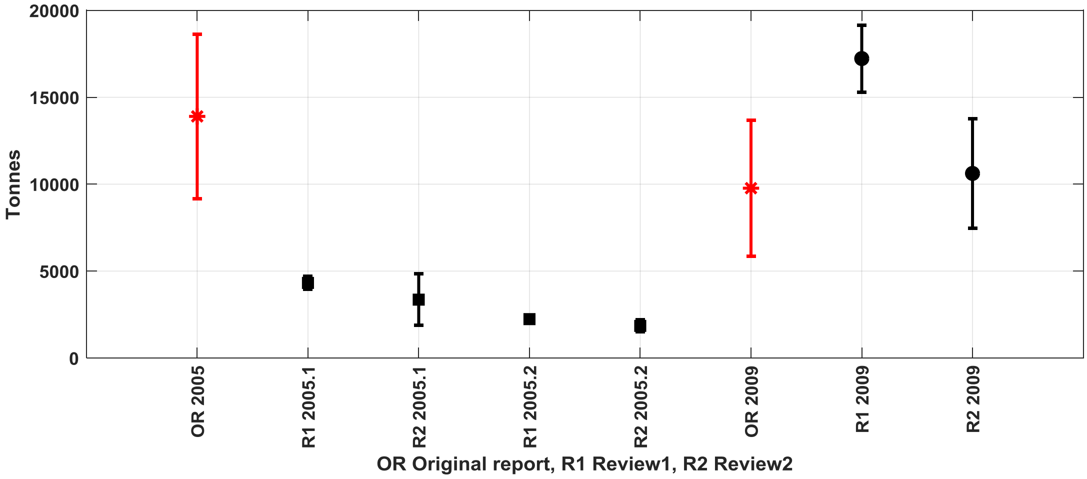



**Figure 4.2 Summary of biomass estimates for the Original Report (Niklitschek and Patchell, 2015), red star, and the Review 1 CSIRO EDSU mean (Scoulding and Kloser, 2018) and ULL Review 2 Geostatistic mean for the 2005 (solid square) and 2009 (solid circle) surveys. Note the 2005 survey had to be split due to overlapping surveys and detection of fish movement (Table 4.1).**

**Table 4.1. Summary of biomass estimate comparisons between original estimate and review 1 (CSIRO), review 2 (ULL) for two original surveys (Scoulding and Kloser 2018)**

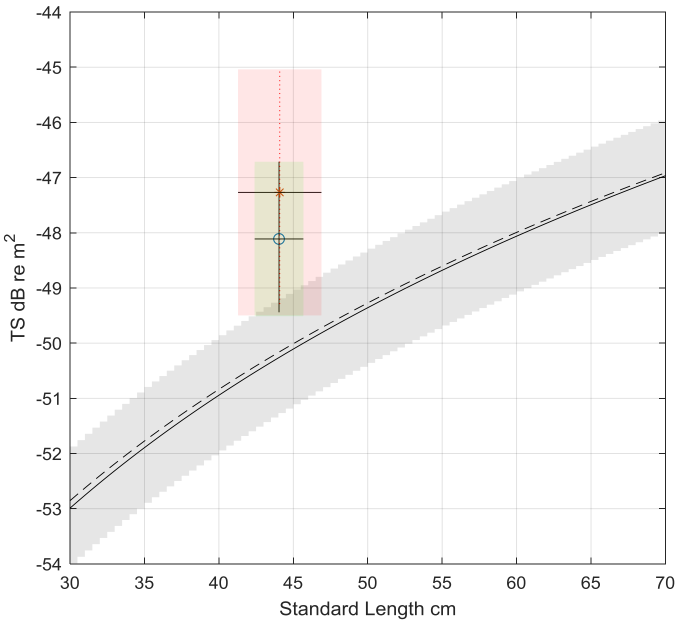
| | 2005 | 2005.1 | | 2005.2 | | 2009 | | |
|---|---|---|---|---|---|---|---|---|
| | Original Industry report | Review 1: EDSU approach | Review 2: Geostatistical approach | Review 1: EDSU approach | Review 2: Geostatistical approach | Original Industry report | Review 1: EDSU approach | Review 2: Geostatistical approach |
| EDSU $s_A$ mean above DZ (m$^2$ n.mile$^{-2}$) | NA | 165.0 | 174.0 | 57.1 | 55.1 | NA | 216.0 | 224.0 |
| Geostat $s_A$ mean above DZ (m$^2$ n.mile$^{-2}$) | 123.0 | NA | 128.7 | NA | 47.0 | 157.0 | NA | 140.0 |
| **$s_A$ Sampling CV (%)** | **34.0** | **8.7** | **44.0** | **5.5** | **18.5** | **40.0** | **11.2** | **29.7** |
| Inference Area (n.mile$^2$) | 3.79 | 1.11 | 1.11 | 1.68 | 1.68 | 2.71 | 3.46 | 3.46 |
| Numeric density (fish m$^{-2}$) | 0.28 | 0.52 | 0.3 | 0.13 | 0.11 | 0.36 | 0.52 | 0.33 |
| Biomass above DZ (tonnes) | 13806 | 4309 | 3358 | 2236 | 1848 | 9562 | 17050 | 10618 |
| DZ estimate (%) | 0.67 | 0.25 | | 0.05 | | 2.17 | 1.03 | |
| **Biomass estimate** | **13899** | **4320** | **3358** | **2237** | **1848** | **9769** | **17226** | **10618** |
| Doonan cum absorption @ 1050 m (dB/km) | 8.32 | 8.41 | 8.41 | 8.41 | 8.41 | | 8.33 | 8.33 |
| Absorption Correction Factor | 0.52 | 0.53 | 0.53 | 0.53 | 0.53 | 0.5 | 0.51 | 0.51 |
| Mean TS (dB re m$^2$) | -50.05 | -49.98 | -49.98 | -49.98 | -49.98 | -50.05 | -50.18 | -50.18 |
| TS intercept | -76.7 | -77.2 | -77.2 | -77.2 | -77.2 | -77.2 | -77.2 | -77.2 |
| TS slope | 16.2 | 16.4 | 16.4 | 16.4 | 16.4 | 16.4 | 16.4 | 16.4 |
| Geometric mean Length (SL cm) | 44.8 | 45.8 | 45.8 | 45.8 | 45.8 | 44.8 | 44.5 | 44.5 |
| Mean Weight (g) | 2858 | 2952 | 2952 | 2952 | 2952 | 2858 | 2743 | 2743 |
| LW intercept | | 2.49 (f) 2.36 (m) | | 2.49 (f) 2.36 (m) | | | 2.49 (f) 2.36 (m) | |
| LW slope | | 0.23 (f) 0.33 (m) | | 0.23 (f) 0.33 (m) | | | 0.23 (f) 0.33 (m) | |
| Calibration Correction Factor | 1.45 | 1.22 | 1.22 | 1.22 | 1.22 | 1.91 | 1.91 | 1.91 |
| Sa Gain (dB re 1) | -0.69 | -0.75 | -0.75 | -0.75 | -0.75 | -0.71 | -0.71 | -0.71 |
| Sv Gain (dB re 1) | 25.62 | 26.45 | 26.45 | 26.45 | 26.45 | 25.45 | 25.45 | 25.45 |
| Other CFs | | 0 | 0 | 0 | 0 | | 0 | 0 |
| EDSU distance (m) | | 100 | | 100 | | | 100 | |
| Mean transect separation (m) | | 248 | | 387 | | | 543 | |
| Number of EDSU | | 157 | | 155 | | | 245 | |
| Number of transects | | 6 | | 5 | | | 10 | |
| Start time (UTC) | | 6:55 | | 7:57 | | | 5:34:00 | |
| End time (UTC) | | 7:55 | | 8:54 | | | 7:14:00 | |
| Date start | | 15/07/2005 | | 15/07/2005 | | | 12/07/2009 | |
| Date end | | 15/07/2005 | | 15/07/2005 | | | 12/07/2009 | |
| Geostatistical grid distance (m) | 200 | 50 | 200 | 60 | 200 | | 140 | 200 |
| Aggregations bounded (yes) | no | no | no | no | no | yes | yes | yes |
| Fish movement suspected (yes) | yes | no | no | no | no | no | no | no |
| Survey design pattern (grid star random walk) | grid | grid | grid | grid | grid | grid | grid | grid |

# 5 Target strength and species identification from the S-AOS in 2014

Analysis of the 2014 net attached Sealords Acoustic Optical System (S-AOS) and associated biological data were done to estimate target strength and species identification of the larger orange roughy in the Indian Ocean (Scoulding and Kloser 2018). We summarise the major findings below;

a. That net attached acoustic optical systems was used successfully on the high seas by fisher's to collect critical target strength and species identification information to reduce biomass estimate uncertainty.

b. Prior to this workshop the target strength of 45 cm orange roughy was very uncertain as all previous measurements were on smaller 35 cm fish. Target strength measurements on 45 cm orange roughy were carried out using industry collected net attached S-AOS that were 2 to 3 dB higher than that predicted from the recommended formula used in the analysis (




c. Figure 5.1). This TS estimate if correct and precise would reduce the biomass by a factor of 0.79 to 0.63. Extra investigations and measurements are recommended to resolve this uncertainty.

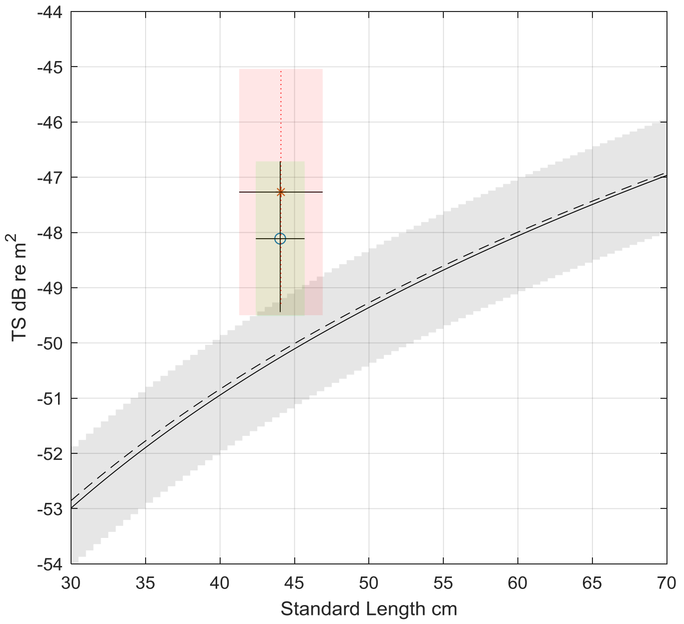



**Figure 5.1** Target strength (dB re 1 $m^2$) versus standard length (cm). Solid line shows values derived from *TS-L* = 16.37*$\log_{10}$(*SL*)-77.17, where 16.37 is taken from McClatchie *et al*., (1999) and 77.17 is taken from Kloser *et al*., (2013). The dashed line shows values derived from *TS-L* = 16.15*$\log_{10}$(*SL*)-76.71 as given by Niklitschek and Patchell (2015). The solid circle represents the mean *TS* based on *in situ* single target detections of orange roughy detected at ranges of 3 m and greater from the transducer with an assumed geometric mean standard length of 44.0 cm. The solid square represents the mean *TS* based on *in situ* tracked orange with mean detection ranges of 3 m and greater in range with an assumed geometric mean standard length of 44.1 cm (Scoulding and Kloser, 2018). Shading represents estimated 95% Confidence Intervals for the data.

d. Species identification is a major source of uncertainty for deep water surveys and requires a multiple lines of evidence approach to support assumptions used for each survey. Lines of evidence include behaviour, net catch, depth range and time, skipper expert judgement and technology from acoustic and optical systems (e.g.net attached AOS (Ryan and Kloser, 2016)).

e. The AOS species identification using 38 kHz and 120 kHz frequencies demonstrated that the frequency difference observed on the larger 45 cm orange roughy was ~4 dB and similar to that observed for the 35 cm fish in Australia and New Zealand.

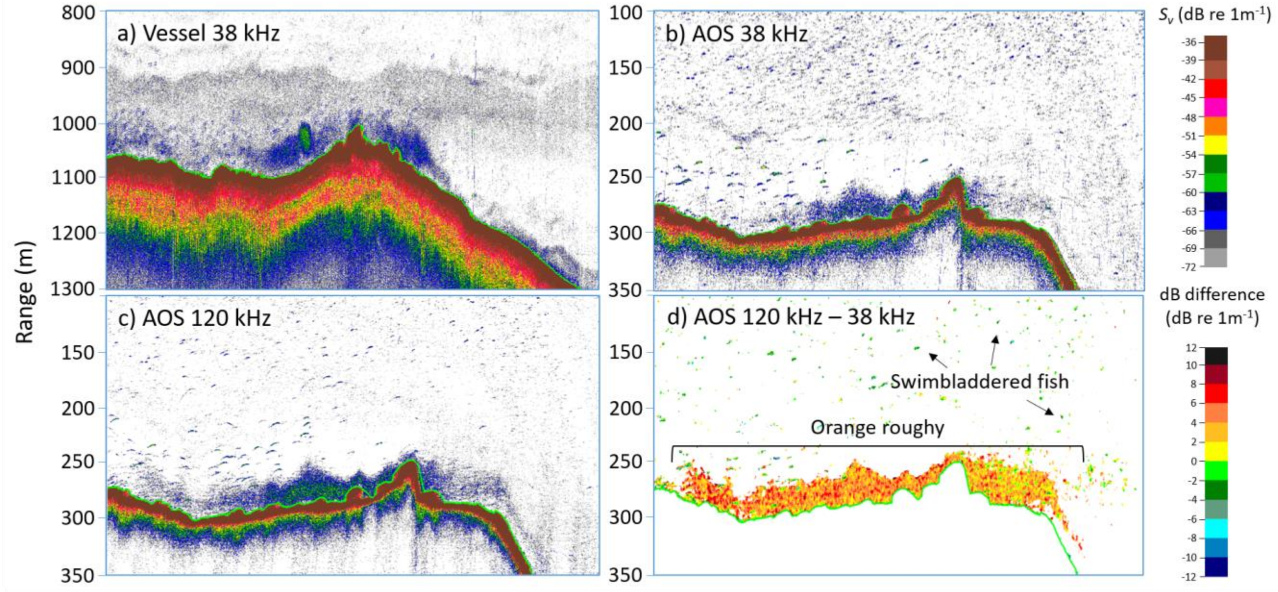



**Figure 5.2 Example of two frequency species identification of orange roughy on the sleeping beauty ground at 1050 m depth comparing the a.), vessel mounted data and the net attached Acoustic Optical System (AOS) at 250 m above the seabed for the b.), AOS 38 kHz, c.), AOS 120 kHz and d.), AOS frequency dB difference. The dB difference between frequencies is ~4 dB for this school. Note the large scattering single fish in the region that could impact a vessel mounted biomass estimate (Scoulding and Kloser, 2018).**

# 6 Qualitative error assessment of the 2009 survey

For the 2009 survey the review panel completed a qualitative check on all the major errors that could impact the use of the survey data in a stock assessment. A quantitative assessment of the errors is beyond the scope of this study but the table highlights several key areas that could improve the certainty of the estimates, being target strength, survey sampling error, survey analytical method and absorption estimate. Both the target strength and absorption errors would affect use of the data for absolute snapshot estimates. The errors associated with the survey sampling C.V. and survey analytical method represent the different results obtained between the traditional transect EDSU method implemented in this review and the geostatistical method used in the original analysis. These errors impact use of the data for an index and absolute snapshot estimate. A full description of the errors is given in Scoulding and Kloser (2018).

- It is recommend that an error table and reporting table be part of standard reporting to enable key uncertainties to be easily identified

**Table 6.1 Error assessment for the 2009 survey based on typical error sources outlined in Table 2.2, four key areas of remaining uncertainty highlighted in yellow.**

| | Expected error bounds | | | |
|---|---|---|---|---|
| **Error** | **Factor** | **Measured or assumed** | **Uncertainty of error not bounded** | **Notes** |
| Calibration on axis gain | 0.9 to 1.1 | assumed | low | Calibration followed standard procedures |
| Calibration of beam | 0.8 to 1.2 | assumed | high | Beam pattern not measured |
| Species ID of echo's | 0.8 to 1.1 | assumed | low | Fishers feedback of low bycatch in region, expert judgement, and AOS in 2014 showed similar structures were orange roughy |
| Target strength | 0.63 to 1 | measured | low | Difference in observed to default equation |
| Near seabed estimate | 0.95 to 1.05 | measured | low | Very low <2 % estimate of fish in deadzone |
| Absorption | 1 to 1.31 | measured | low | Default use of Doonan equation difference to F&G |
| Data quality | | | | |
| vessel motion | 1.0 to 1.2 | assumed | low | Weather was good |
| attenuation (e.g. bubble noise) | 1.0 to 1.1 | assumed | low | Weather was good |
| noise | 0.95 to 1.0 | measured | low | Low noise measured |
| Fish availability | 1 to 1.2 | assumed | med | Feedback from industry and compared to other estimates in same area over years, survey bounded the aggregation |
| Fish movement | 0.8 to 1.2 | assumed | low | Could be significant but checked for this example |
| Survey sampling error | 0.7 to 1.3 | measured | low | Reference use of geostatistics |
| Survey analytical method | 0.8 to 1.7 | measured | low | Reference use of geostatistics |
| Area inference | 0.78 to 1.0 | measured | low | Reference new inference area |

# 7 Recommendations

1. That standardised reporting is adopted and acoustic data workshop/reviews are held prior to biomass estimates being used in a stock assessment.
2. That key metadata and data storage methods are developed and adopted so that results can be replicated.
3. Caution in use of the 2005 data due to reduced sensitivity and hence lower than expected biomass.
4. Support research to reduce absorption uncertainty of the two current formula's (F&G and D) by undertaking measurements in the Indian Ocean and elsewhere for all deep-water (> 300 m range) acoustic estimates.
5. That further investigations are made to resolve the analytical difference in the geostatistical and transect mean and variance estimates that could affect all surveys.
6. Subject to the outcome of recommendation 5 that for closely spaced parallel grid based surveys the EDSU mean and geostatistical variance is adopted as used in current Australian and New Zealand stock assessments.
7. We recommend that the net attached AOS is used in areas of complex species mixing and or steep slopes to reduce biomass estimation bias and uncertainty.
8. To resolve the potential target strength bias of a factor of 2 more visually verified target strength measurements are obtained ideally with the industries net attached AOS on selected grounds.
9. Follow recommendations in section 3 and previous documents for industry data collection (FAO, 2012; FAO, 2017).

# 8 References

Demer, D., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R., et al. 2015. Calibration of acoustic instruments. ICES Cooperative Research Report, 326: 133.

Do, M. A., and Coombs, R. F. 1989. Acoustic measurements of the population of orange roughy (*Hoplostethus atlanticus*) on the north Chatham Rise, New Zealand, in winter 1986. New Zealand Journal of Marine and Freshwater Research, 23: 225-237.

Doonan, I. J., Coombs, R. F., and McClatchie, S. 2003. The absorption of sound in seawater in relation to the estimation of deep-water fish biomass. ICES Journal of Marine Science, 60: 1047-1055.

FAO 2012. Fishing vessel execution of acoustic surveys of deep-sea species: main issues and way forward. FAO Fisheries and Aquaculture Circular. No 1059 Rome 91pp.

FAO 2017. Workshop to review orange roughy acoustic data. ABNJ Deep Sea Project, 30th Jan - 3rd Feb 2017 Rome Italy 13pp.

Francois, R. E., and Garrison, G. R. 1982. Sound absorption based on ocean measurements. Part II: Boric acid contribution and equation for total absorption. The Journal of the Acoustical Society of America, 72: 1879-1890.

Haris, K., Kloser, R. J., Ryan, T. E., and Malan, J. 2017. Deep-water calibration of echosounders used for biomass surveys and species identification. ICES Journal of Marine Science.

Kloser, R., Koslow, J., and Williams, A. 1996. Acoustic assessment of the biomass of a spawning aggregation of orange roughy (Hoplostethus atlanticus, Collett) off south-eastern Australia, 1990-93. Marine and Freshwater Research, 47: 1015-1024.

Kloser, R., Ryan, T., Williams, A., and Soule, M. 2000. Development and implementation of an acoustic survey of orange roughy in the Chatham Rise spawning box from a commercial factory trawler, FV Amaltal Explorer. Technical Report, CSIRO Marine Research.

Kloser, R. J., Knuckey, I. A., Ryan, T. E., Pitman, L. R., and Sutton, C. 2011. 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, ISBN: 9781921826535: 153 pp.

Kloser, R. J., Macaulay, G. J., Ryan, T. E., and Lewis, M. 2013. Identification and target strength of orange roughy (*Hoplostethus atlanticus*) measured in situ. Journal of the Acoustical Society of America, 134: 97-108.

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., Sutton, C., Krusic-Golub, K., and Ryan, T. E. 2015. Indicators of recovery for orange roughy (Hoplostethus atlanticus) in eastern Australian waters fished from 1987. Fisheries Research, 167: 225-235.

Macaulay, G. J., Kloser, R. J., and Ryan, T. E. 2013. In situ target strength estimates of visually verified orange roughy. ICES Journal of Marine Science, 70: 215-222.

Niklitschek, E., and Roa, R. 2006. Likelihood-based geostatistical biomass estimation using acoustic data collected by industry vessels in the South West Indian Ocean. In: Shotton R (ed) Management of demersal fisheries resources of the Southern Indian Ocean. FAO Fisheries, Rome, Italy, p 75–79.

Niklitschek, E. J., and Patchell, G. J. 2015. Acoustic abundance indexes for orange roughy and alfonsino in the indian ocean (SIOFA) from industry acoustics 2004-2008. Southern Indian Ocean fisheries Agreement, Scientific Committee Report.

Ryan, T. E., and Kloser, R. J. 2016. 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., Kloser, R. J., and Macaulay, G. J. 2009. Measurement and visual verification of fish target strength using an acoustic-optical system attached to a trawlnet. ICES Journal of Marine Science, 66: 1238-1244.

Scoulding, B., and Kloser, R. J. 2018. Review of orange roughy surveys in SIOFA. South Indian Ocean Fisheries Agreement.

# 9 Appendix A

**SEABED ANALYSIS**

In order to evaluate echosounder sensitivity across years, we compared the intensity of the seabed echo measured at a single trawling ground visited most years by the industry. After initial scrutiny, 7.6 GB of data were obtained from five years (2005, 2009, 2010, 2012 and 2014) during which standard sphere calibrations were available. Bottom echoes were integrated at 50 m intervals, between an upper limit defined 2 m below the maximum Sv line pick and a lower limit defined 10 m below the maximum Sv line pick. Extreme values above the 95 percentile of the whole dataset were excluded in order to avoid noise picks. Available data was then aggregated in 220x220 m cells, selecting a total of 22 cells which exhibit at least three records at each of the five years being compared. Median Sv values were then computed to represent each cell, within each year. Variability among years was then evaluated through a one-way ANOVA, which indicated significant differences among years ($p<0.001$). Low sensitivity was apparent in 2005, which contrasted with the enhanced sensitivity apparent in years 2010 and 2014 (Table 1).

**Table 9.1** Bottom echo mean Sv measured at a common trawling ground in the SWIO over time.

| Year | Mean Sv | SE |
|---|---|---|
| 2005 | -23.55 | 0.53 |
| 2009 | -21.49 | 0.53 |
| 2010 | -15.99 | 0.5289 |
| 2012 | -22.28 | 0.53 |
| 2014 | -16.42 | 0.53 |

**REANALYSIS OF SURVEYS**:

Summary of the reanalysis of selected surveys presented in Niklitschek and Patchell (2015) are shown in Table 9.2.

Main methodological changes were:

1. Inference area recalculated, after excluding marginal tracks, using a concave hull (R library concaveman) with a concavity factor of 5.
2. Recommended TS equation used instead of previous one
3. Biological backscattering correction not applied as recommended.

**Table 9.2 Reanalysis of selected surveys updating on the inference area that were deemed necessary for the stock assessment for surveys previously reported (Niklitschek and Patchell, 2015).**

| ZONA | YEAR | SURVEY | ESDU_SA m^2/n.mile^2 | GEOSTAT.SA m^2/n.mile^2 | Inference.area n.mile^2 | Numerical density fish/m^2 | Biomass Tonnes | sA.sampling cv | TS dB re m^2 | TS.intercept dB | TS.slope | Geom.mean length SL cm | Mean.weight g | Aggregation Bounded | Aggregation Moving | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **AR** | 2010 | 23.1 | 69.2 | 72.1 | 1.91 | 0.16 | 895 | 25.2 | -50.08 | -77.17 | 16.37 | 45.19 | 2886 | | No | |
| **BD** | 2007 | 1 | 16.7 | 18.4 | 23.56 | 0.05 | 2,902 | 11.0 | -50.67 | -77.17 | 16.37 | 41.59 | 2568 | | Yes? | |
| **BD** | 2015 | 4 | 404.7 | 255.2 | 3.26 | 0.66 | 5,534 | 28.9 | -50.67 | -77.17 | 16.37 | 41.59 | 2568 | | Yes? | |
| **HV** | 2004 | 1 | 74.1 | 48.1 | 1.95 | 0.11 | 604 | 72.1 | -50.14 | -77.17 | 16.37 | 44.77 | 2797 | | No | |
| **HV** | 2005 | 11 | 24.9 | 22.6 | 4.22 | 0.05 | 611 | 31.7 | -50.14 | -77.17 | 16.37 | 44.77 | 2797 | | No | |
| **OK** | 2015 | 2 | 348.8 | 179.3 | 2.68 | 0.41 | 3,164 | 11.7 | -50.14 | -77.17 | 16.37 | 44.77 | 2858 | | No | |
| **PK** | 2015 | 29 | 115.7 | 123.6 | 4.51 | 0.29 | 3,779 | 19.8 | -50.21 | -77.17 | 16.37 | 44.36 | 2847 | | No | |
| **SB** | 2005 | 14.1 | 174.0 | 128.7 | 1.11 | 0.30 | 3,358 | 44.0 | -49.98 | -77.17 | 16.37 | 45.84 | 2952 | No | No | Peer reviewed in Puerto Montt |
| **SB** | 2007 | 5 | 80.0 | 57.4 | 21.10 | 0.13 | 7,923 | 9.9 | -50.14 | -77.17 | 16.37 | 44.77 | 2858 | | No | |
| **SB** | 2009 | 12 | 224.0 | 140.0 | 3.46 | 0.33 | 10,618 | 29.7 | -50.14 | -77.17 | 16.37 | 45.84 | 2952 | Yes | No | Peer reviewed in Puerto Montt |
| **SH** | 2005 | 10 | 20.8 | 19.8 | 7.15 | 0.05 | 862 | 21.2 | -50.49 | -77.17 | 16.37 | 42.66 | 2443 | | Yes? | |
| **SH** | 2009 | 8 | 69.9 | 122.3 | 1.15 | 0.31 | 860 | 19.5 | -50.49 | -77.17 | 16.37 | 42.66 | 2443 | | No? | |
| **SH** | 2009 | 14 | 112.2 | 72.2 | 6.25 | 0.18 | 2,752 | 27.5 | -50.49 | -77.17 | 16.37 | 42.66 | 2443 | | Yes? | |
| **SH** | 2011 | 15 | 416.1 | 324.8 | 0.87 | 0.81 | 1,737 | 42.8 | -50.49 | -77.17 | 16.37 | 42.66 | 2443 | | No | |

CONTACT US

**t** 1300 363 400
+61 3 9545 2176
**e** csiroenquiries@csiro.au
**w** www.csiro.au

AT CSIRO, WE DO THE EXTRAORDINARY EVERY DAY

We innovate for tomorrow and help improve today – for our customers, all Australians and the world.

Our innovations contribute billions of dollars to the Australian economy every year. As the largest patent holder in the nation, our vast wealth of intellectual property has led to more than 150 spin-off companies.

With more than 5,000 experts and a burning desire to get things done, we are Australia's catalyst for innovation.

CSIRO. WE IMAGINE. WE COLLABORATE. WE INNOVATE.

FOR FURTHER INFORMATION

**Oceans and Atmosphere**
Rudy Kloser
**t** +61 3 62325000
**e** **rudy**.kloser@csiro.au
**w** www.csiro.au