Preparation for stock assessments and harvest control rules on orange roughy *Hoplostethus atlanticus* stocks in the SIOFA Convention Area

December 13, 2017 (1st draft)
December 18, 2017 (2nd draft)
December 31, 2017 (3rd draft)
January 10, 2018 (4th draft)
January 18, 2018 (5th draft)
January 19, 2018 (final)

SIOFA SAWG (Stock Assessments Working Group)

Contents

1. INTRODUCTION

In the 2nd Session of Scientific Committee (SC02), 2017 (La Réunion), Stock Assessments Working Group (SAWG) was established and Japan was appointed as the Chair Meeting of Party (MoP). Then it was endorsed by MoP04 (2017). Since then, Japan has been working on relevant tasks simulated in SAWG Terms of References (ToR) (SIOFA, 2017). SAWG's major task is to provide advices and recommendations to the MoP on the status of stocks and managements of principle deep-sea resources (orange roughy, alfonsino and Patagonian toothfish) by the end of SC 2019 stipulated in CMM2016/01.

To implement this task, we need to conduct stock assessments for these species. According to the SC plan, we will do orange roughy stock assessments by SC03 (March 2018) and alfonsino + Patagonian toothfish by SC04 (March 2019). Please note that it was agreed in MoP04 (2017) that we will have the SAWG meeting before SC to discuss stock assessment results and make recommendations to SC.

As for 2018, SAWG01 (March 15-18) and SC03 (March 20-24) have been scheduled. Please also note that it was also agreed that stock assessments for Patagonian toothfish will be referred to those conducted in CCAMLR, thus SAWG will not implement its stock assessments. But we need to coordinate with CCAMLR to get information on the stock status of Patagonian toothfish.

We have been working **step by step** mainly by e-mails with SC head delegations and relevant experts. This is because we need time for investigation for some issues and many members are non-native English speakers, thus communications by e-mails are more effective and certain for all to be able to digest discussions/decisions and have mutual understandings in the transparent manner.

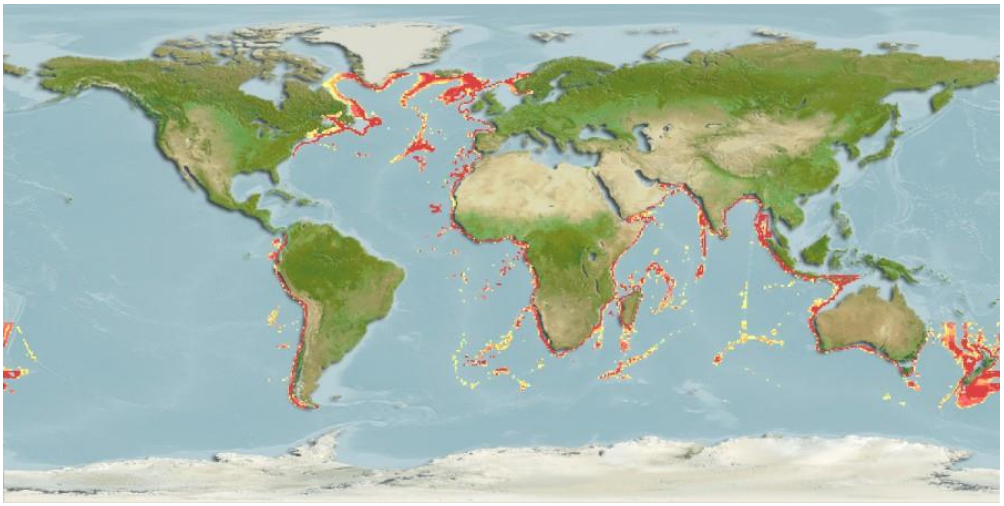
We completed the preparation work based on suggestions made by SC head delegations and relevant experts during Dec 13, 2017-Jan 16, 2018. This document is the final one. As the next step, we will develop ToR and hire Consultants to conduct stock assessments Table 1 shows timelines of various activities.

Please note well that we should be flexible for stock assessments and other relevant works. This means that if agreed contents in this preparatory document cannot be

implemented due to unforeseen problems such as lack of information, violations of assumptions etc. during course of the stock assessment works by consultants, consultants can use alternative methods, but subject to our agreements. In addition, SAWG welcomes any other stock assessment works to be conducted voluntarily by SAWG and other relevant members. Table 1 shows the timeline on relevant activities.

Table 1 Timeline of the orange roughy stock assessments by SAWG

Period	Activities
Dec 13, 2017 – Jan 19, 2018	Development of this document, "Preparation for orange roughy *Hoplostethus atlanticus* stock assessments in the SIOFA Convention Area" by SAWG
By Feb 2, 2018	● Contact a consultant to implement stock assessments by CASAL and biological parameters estimation works to be used in Harvest Control Rule; and ● Preparation of data set for stock assessments and harvest control rule.
Feb 2-28, 2018	(a) Stock assessment using CASAL and biological parameters estimation works undertaken by a consultant and produce two separate working papers. (b) Other voluntary stock assessment works undertaken by SAWG members and produce working papers.
Mar 1-12, 2018	● Circulation of draft working papers by (a) and (b); ● Reviews and requests additional works and/or revisions; and ● Circulate the final drafts
Mar 15-18, 2018	SAWG01 meeting (La Réunion): Presentation documents, discussion, revision and recommendations.
Mar 20-24, 2018	SC03 meeting (La Réunion) Provide the stock status and the management advice



Global distribution of orange roughy

2. BASIC ISSUES

Wwe have been discussing about basic issues on “abundance indices (orange roughy)”, “stock assessment models”, “stock structure and management unit in SIOFA CA” and “Tier approach”. These are fundamental elements that we should mutually understand before we start orange roughy stock assessments.

2.1 Abundance indices (orange roughy) *(fisheries dependent or independent indices?)*

Abundance indices are most basic and key information for stock assessments. There are two types of abundance indices, i.e., fisheries dependent (e.g. CPUE) and independent indices (e.g. acoustic data).

CPUE has been widely used as abundance indices in standard stock assessments. However, CPUE was realized inappropriate as abundance indices for orange roughy stock assessments because CPUE are based on aggregated fish in a small area which produce large biases. Thus, CPUE is not possible for a fishery to index a whole stock if it operates only on a small portion of the stock (e.g., fishing on a single hill or hill complex when the stock is spread over a much larger area) (Cordue, 2014).

Also, although a fishery on spawning aggregations may be sampling most of the stock, CPUE are unlikely to depend on the level of spawning biomass present but more on how the aggregation is fished (e.g., around the edges or targeting the highest concentrations). FAO and Marine Stewardship Council (MSC) made the same conclusions in their reviews.

SC head delegations and relevant experts also suggested that acoustic data are more plausible indices to represent abundance indices than CPUE through discussions.

Thus, it was agreed that acoustic data (fisheries independent abundance indices) will be used instead of CPUE in orange roughy stock assessments. However, it was also suggested to confirm if the current sets of acoustic biomass estimates presented to the SC are plausible as representative abundance indices in an assessment by evaluating many uncertainties raised in the last SC02, March 2017, i.e., species identification, survey design (consistency, cryptic biomass etc.), target strength, absorption, calibration and data quality) (SIOFA, 2017). The report from this review will be completed in late January 2018 and provide critical data for the assessment consultants.

2.2 Stock assessment models

The stock assessment models and data requirements for each model were reviewed, to select suitable stock assessment models considering available data in our hands.

Table 2 shows the summary of stock assessment models including from standard to most recent ones. It was recommended by the SC, and the FAO review on Orange Roughy that stock assessments with abundance indices (acoustic data) should be applied.

Table 2 Summary of major stock assessment models and data requirements

Models		Example	Data required						
			Stock structure	Global catch	Abundance indices (CPUE or fisheries in depend indices such as acoustic/areal survey data)	size/age	LW relation + growth eq	Maturity + fecundity	Space and movement
Data limit approach		SRA (catch only)							
Production model		ASPIC							
		BSP-SS							
Age/size structure model	(without abundance indices)	VPA							
	(with abundance indices)	ADAPT—VPA							
	Integrated model (I)	SCAA and SAM							
	Integrated model (II)	CASAL and SS3							(option)

SRA	*Stock Reduction Analysis*
ASPIC	*A Surplus-Production model Incorporating Covariates*
BSP-SS	*Bayesian State-Space Surplus Production model*
VPA	*Virtual population analysis*
ADAPT-VPA	*ADAPTive framework-Virtual Population Analysis*
SCAA	*Statistical-Catch-At-Size*
SAM	*State-space Assessment Models (e.g. state-space SCAA)*
CASAL	*C++ Algorithmic Stock Assessment Laboratory*
SS	*Stock Synthesis*

2.3 Stock structure and management unit

Scientific knowledge on stock structures are essential to define effective management units. Thus, we review stock structures of orange roughy in the SIOFA CA. SC head delegations and relevant experts suggested that numbers of stocks exist in separate banks, knolls and sea mounts as shown Fig. 1.

But there has been no review of the scientific data available (and provided as SC-01-INFO-16) to establish the stock structures in the SIOFA CA. However interim management areas could be discussed during SC03. We also need to initiate the stock structure research using genetic analyses, noting that decades of genetic studies in New Zealand and Australia have failed to provide useful stock delineations. Programs to collect genetic samples for single-nucleotide polymorphism (SNP) analysis during the 2018 spawning season are under development, and this need to be discussed in SAWG01 as the future work. Australia has been leading this process in SPRFMO.

For stock assessments purpose, SC head delegations and relevant experts suggested one potential management unit, i.e., Walter's Shoal Region, southern part of SIOFA Area 2 (Madagascar Ridges) (Figs. 2-3) including 6 banks and knolls, where fisheries independent abundance indices (acoustic data) are available for 14 years (2004-2017) and their catch is about 50% of the total in the SIOFA CA, and about 30% of the historical catch. They further suggested that stock assessments should be conducted there using acoustic data and assuming the area with 5-6 banks and knolls as a homogenous stock.

There are significant acoustic data sets for other regions in SIOFA (SC-02-08 (01), but a robust analysis for one region was recommended in the FAO-ABNJ acoustic review (FAO 2017) based on the biomass, the similar size of the fish in the different spawning aggregations in this region, the 12 years annual time series and a high number of within year surveys. In addition, there was a net-attached multi-frequency S-AOS survey and target strength tow. Hence, it was suggested that the stock structure research should be done to confirm the homogenous stock assumption in the Walters Shoal Region.

2.4 Tier approaches

During SAWG01 in March 2018, we will discuss and develop the tier approaches to categorise any agreed stock units according to quality and quantities of data to provide effective management advices. The tier approaches are used in some RFMOs (for example SPRFMO) and national levels (for example, NMFS, USA and Australia) (Low, 2014 and Nicol et al., 2017).

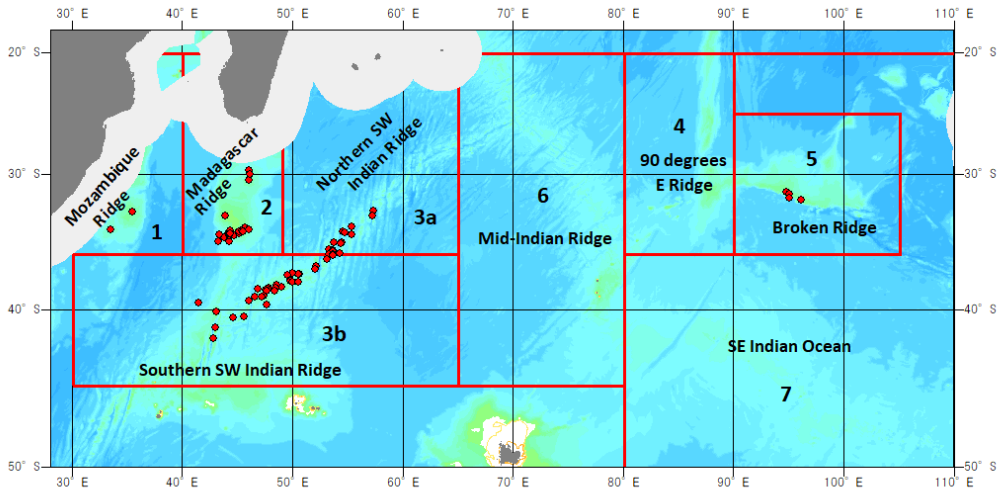


Fig. 1 Major orange roughy spawning areas located in banks, knolls and sea mounts in the SIOFA CA. There is no concrete knowledge on stock structures (management units).

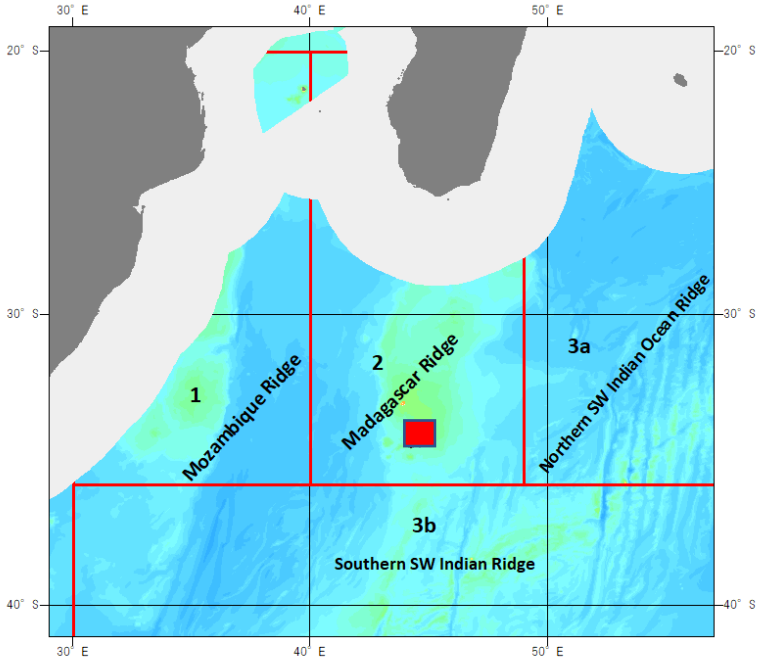


Fig. 2 The Walters Shoal Region area (S 33 50' to S 34 31', E44 to E 46) (red box area) in the southern part of SIOFA area 2 (Madagascar Ridge). It was suggested that this area including 6 spawning aggregations on banks and knolls, could be assumed to be a homogenous stock (management unit) and stock assessment should take place using 14 years (2004-2017) of fisheries independent abundance indices (acoustic data) and catch data.

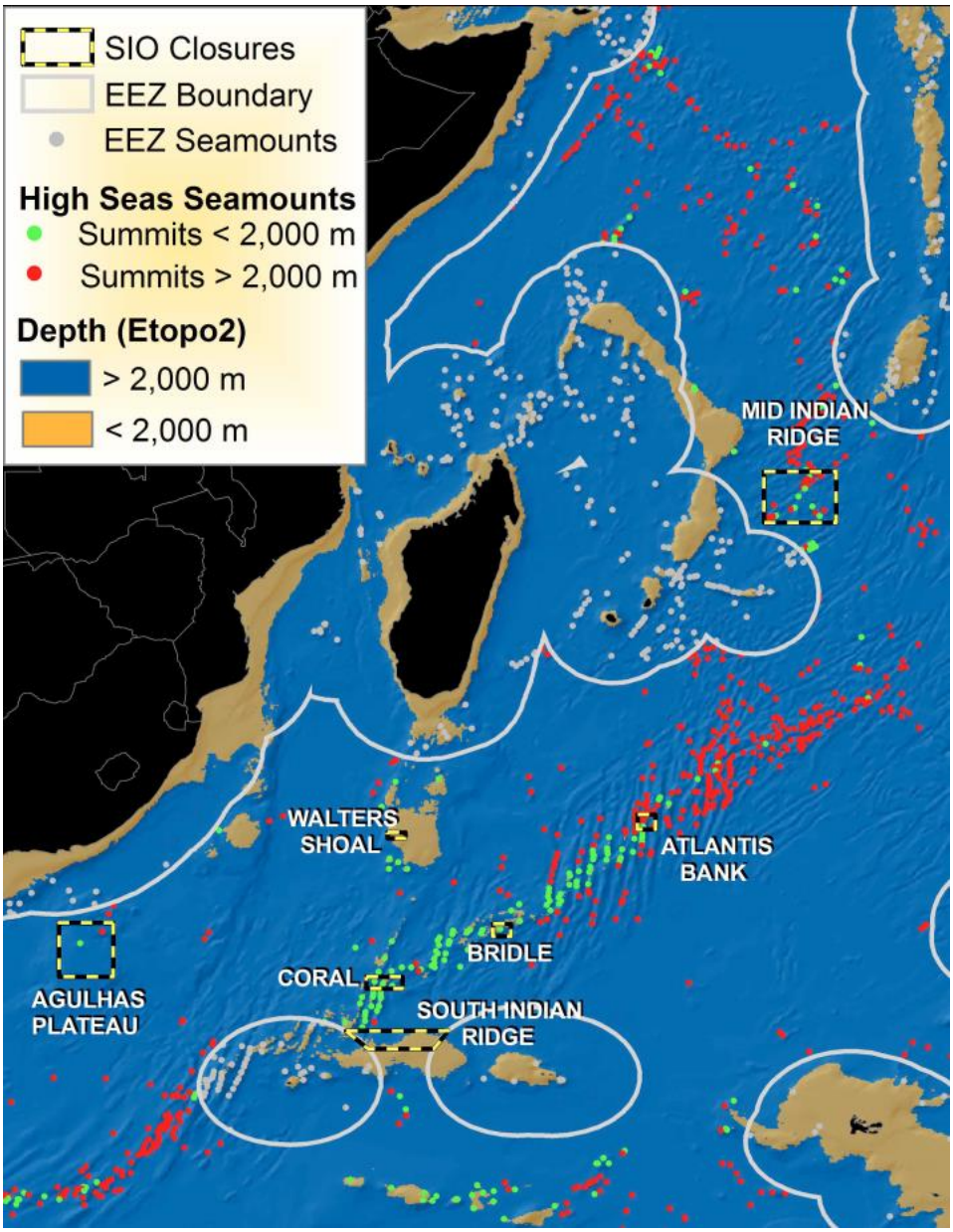


Fig. 3 Location of the Walters Shoal Region and the topography with 2,000 m depth in SIOFA CA.

3. STOCK ASSESSMENTS IN THE WALTERS SHOAL REGION (AREA 2)

As suggested by SC head delegations and relevant experts, we will conduct stock assessments in 6 banks and knolls in the Walters Shoal Region assuming a homogenous stock (one management unit). We now discuss more practical issues, i.e., types of stock assessments models to use, data inventory, biological information and retrospective analyses based on discussions and suggestions made by SC head delegations and relevant experts.

3.1 Selections of stock assessment models

Majority of SC head delegations and relevant experts suggested that at least two different stock assessment models with different structures need to be conducted. This is because with multiple stock assessment models, we can cross check results and if they are similar we will have more confident in the results. Such practices are implemented in major RFMOs and the national levels. However, some members noted that this approach is not commonly implemented for orange roughy in New Zealand, Australia, CCAMLR, or SPRFMO because the models rarely agree.

Majority of SC head delegations and relevant experts suggested two stock assessment models explained below (CASAL and SPM-SS). However, some members expressed their concerns to use surplus production models such a BSP-SS by following reasons. Surplus production models (SPM-SS) have been implemented for orange roughy stock assessments in the SPRFMO area, because of the lack of any biological data or biomass estimates for their stocks. However, at the 2017 Scientific Committee meeting of SPRFMO there was considerable debate over the usefulness of these approaches and it was concluded that surplus production models have proven to be completely unrealistic for orange roughy, as the biological data are critical for producing a robust assessment.

<u>As we could not get the consensus, we will use only CASAL for this time by a consultant.</u>

(1) Age/size structured model (CASAL)

For age structured models, CASAL is recommended, which is the age structured integrated model incorporating many biological parameters including LW relation, M (natural mortality), growth, maturity-at-age and fecundity. The primary reason on suggestions to use CASAL is that major orange roughy fishing nations such as New

Zealand and Australia have been frequently and effectively using CASAL stock assessments in the past. Previous models developed for orange roughy did not take sufficient account of biological parameters, did not deal adequately with uncertainty and failed to provide a realistic assessment of the status of stocks.

(2) Bayesian State-Space Surplus Production model (BSP-SS)

Table 3 shows the evaluation of surplus production models and Bayesian State-Space Surplus Production model (BSP-SS) is the most recent model.

Table 3 Evolution of surplus production models

Evolutions	Specification ➔	No Bayesian framework				Bayesian framework
		Equilibrium conditions		Consideration of Errors		
	Type of SPM (*)	Yes	No (plausible)	Observation errors	Process errors	
Old ↓ New	(1) Original SPM					
	(2) ASPIC (example)					
	(3) Bayesian SPM					
	(4) BSP-SS					

(*) SPM normally considers Schaeffer, Fox or Pell Tomlinson models

3.2 Data inventory

Most catch data for the region are held by Cook Islands (Table 4), as this flag state has taken most of the catch. Australia has some catch data from the relevant area. It is noted that the two spawning socks (SB: Sleeping Beauty and BD: Boulder) contributing most of the biomass for the assessment, were not fished from 1997-2003.

Biological parameters for this region have already been presented to the SC (SC-01-INFO-16). Table 5 is the summary of the updated ones used for the base case.

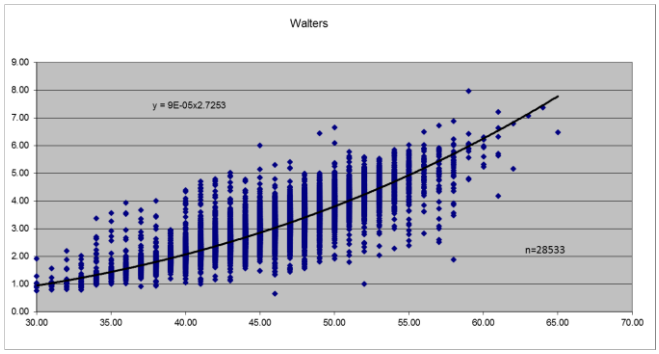
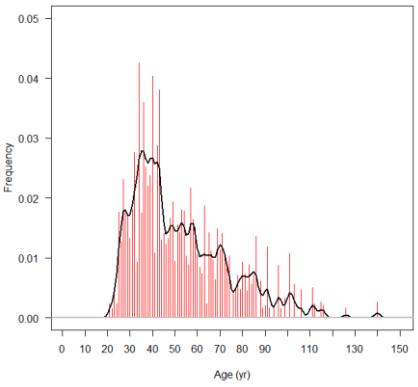
Table 4 Available historical data of orange roughy from trawl fisheries for stock assessments (Cook Islands)
Additional catch data need to collect from other MoP and relevant fishing countries.

	Cook Islands		
	nominal catch	size data	acoustic data
1997			
1998			
1999			
2000			
2001			
2002			
2003			
2004			
2005			
2006			
2007			
2008			
2009			
2010			
2011			
2012			
2013			
2014			
2015			
2016			
2017			

3.3 Biological parameters (base case)

SC head delegations and relevant experts suggested biological parameters for CASAL shown in Table 5.

Table 5 Suggested biological parameters by SC head delegations and relevant experts

Biological parameters	Current scientific knowledge
M (natural morality)	M=0.045 (fixed for all age group) (Cordue, 2014)
Steepness	0.7, 0.8 and 0.9
LW relationship based on samples from the Walter's Shoal Region (SIOFA area 2) (Figs. 1-3)	 $SL=9E\text{-}05W^{2.7253}$ (reference ?) SL: Fork length (cm) W: Whole (green) weight (kg) This will be updated for LW for single sex for the assessment
Age Composition	A spawning age frequency is available for the SB aggregation 
Growth equation	To be estimated by the modeller based on otolith age composition for Sleeping Beauty recently completed by Cook Islands, along with the von Bertalanffy estimates. There are substantial length-weight and age-length data from Sleeping Beauty that will be analysed to produce a length-weight relationship and a von Bertalanffy growth curve that are suitable for use in a single-sex stock assessment model. The equations will be estimated by sex and then an average relationship is calculated.

Maturity-at-age	Maturity will not be estimated externally as it could be from the available data, but should be estimated within the model (given a spawning season age frequency is available). Preliminary analysis indicates the SIOFA orange roughy mature at similar age to New Zealand orange roughy, but are much larger in size and weight.
Fecundity	Gonad weights/maturity stage or others Orange roughy are not saturation spawning fish such as cod or Pollock, but New Zealand orange roughy only produce about 22,000 eggs at first maturity. However, SB orange roughy produce at least 40,000 eggs at first maturity, because the mean weight of fish is twice that of New Zealand fish.

3.4 Sensitivities and Retrospective analyses

Sensitivities (alternative scenarios) to the base case and retrospective analyses should be carried with descriptions of (a) the motivation for the selection of base and alternative cases and (b) how the alternative case assumptions differ from those of the base case. After deciding scientifically best and most plausible parameter estimations from base and sensitivity runs, retrospective analyses using the selected parameters, should be carried to evaluate their robustness.

3.5 Additional tasks for management advices

(1) Reference Points

This needs to be discussed during SAWG01 after we get the stock assessment results, i.e., how do we provide the management advices? It is not advisable to use the MSY approach for orange roughy as Bmsy is not a useful reference point for either New Zealand or Australian orange roughy as it is too close to 20% B_0. This can be estimated in the age structured model, but it may be like NZ (in which case the limit reference point = 20%B0 and target biomass range = 30-50% B_0 is probably a good idea).

(2) Stock status trajectory plot

As routine and standard tasks in the tuna RFMOs, the Kobe plot (stock status trajectory plots) need to be presented especially for mangers and industries to understand changes of the current and historical stock statuses easily. In addition, uncertainties around the final year need to be also evaluated and presented as shown Fig. 4.

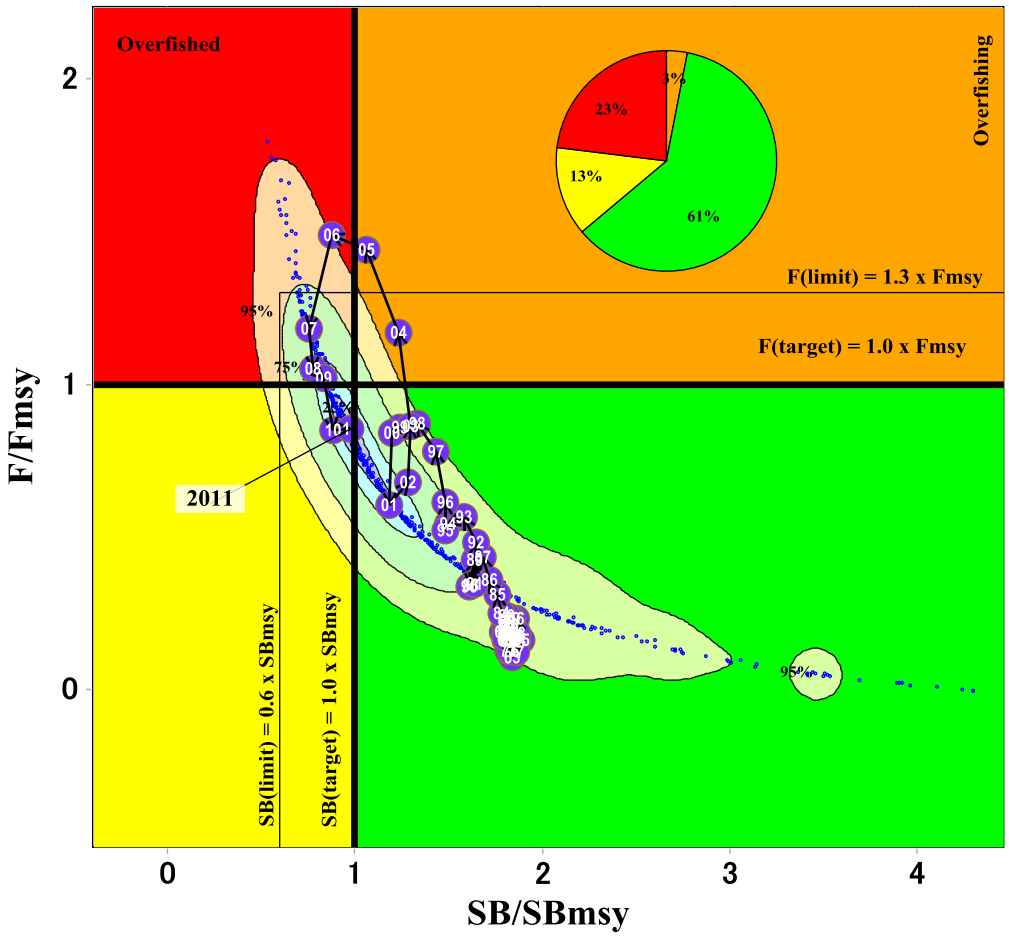


Fig. 4 Example to present the stock assessment results by the Kobe plot (stock status trajectory plot) with uncertainties (confidence surface) around the terminal year and its compositions in four quadrants (pie chart).

*(Note) Target Reference Points for F and SB (spawning stock biomass) are in their MSY levels, while Limit Reference Points (LRP) are defined by RFMO (1.3*Fmsy and 0.6*SBmsy are their LRPs in this example)*

(3) Risk assessments

Risk assessment is routinely conducted in major RFMOs and national levels to provide optimum catch levels to avoid risks not to secure sustainable MSY levels for both F and SB in the future. Table 6 shows an example of risk assessments for F and SB in 3 and 10 years later with 9 different catch scenarios as an example. Risk assessments for both target and limit reference points are demonstrated

Table 6 Example of risk assessments

Probability (percentage) of violating the MSY-based target (top) and limit (bottom) reference points for nine constant catch projections (average catch level from 2014 (427,440 t), ± 10%, ± 20%, ± 30% ± 40%) projected for 3 and 10 years.

Reference point and projection timeframe	Alternative catch projections (relative to the average catch level from 2014) and probability (%) of violating MSY-based target reference points ($SB_{targ} = SB_{MSY}$; $F_{targ} = F_{MSY}$)								
	60% (256,464t)	**70%** (299,208)	**80%** (341,952t)	**90%** (384,696t)	**100%** (427,440t)	**110%** (470,184t)	**120%** (512,928t)	**130%** (555,672t)	**140%** (598,416)
$SB_{2017} < SB_{MSY}$	69	95	91	99	99	100	100	100	100
$F_{2017} > F_{MSY}$	2	54	60	79	100	100	100	100	100
$SB_{2024} < SB_{MSY}$	4	36	50	100	100	100	100	100	100
$F_{2024} > F_{MSY}$	0	22	49	100	100	100	100	100	100
Reference point and projection timeframe	**Alternative catch projections (relative to the average catch level from 2014) and probability (%) of violating MSY-based limit reference points ($SB_{lim} = 0.4\ SB_{MSY}$; $F_{Lim} = 1.4\ F_{MSY}$)**								
	60% (256,464t)	**70%** (299,208)	**80%** (341,952t)	**90%** (384,696t)	**100%** (427,440t)	**110%** (470,184t)	**120%** (512,928t)	**130%** (555,672t)	**140%** (598,416)
$SB_{2017} < SB_{Lim}$	2	15	12	44	33	n.a.	n.a.	n.a.	n.a.
$F_{2017} > F_{Lim}$	0	13	19	70	100	100	100	100	100
$SB_{2024} < SB_{Lim}$	<1	8	15	51	100	100	100	100	100
$F_{2024} > F_{Lim}$	0	2	21	100	100	100	100	100	100

4. HARVEST CONTROL RULES IN OTHER AREAS

Following evaluation of the stock assessment results, prioritization for analysis of data sets for other areas needs to be considered by the SAWG and SC using harvest control rule (HCR). This is because there are sufficient data in other areas. Any harvest control rules for these areas will need to consider the different biological parameters in these areas compared with the Sleeping Beauty complex. We note that harvest control rules can equally be applied to fishing effort.

To apply this method, we need to define areas. As we have four major orange roughy fishing grounds in areas 1, 2, 3a, and 3b (Fig. 5), we tentatively set up these four areas as management units for harvest control rules. Please note that for area 2, we exclude the Walters Shoal Region where stock assessments will take place.

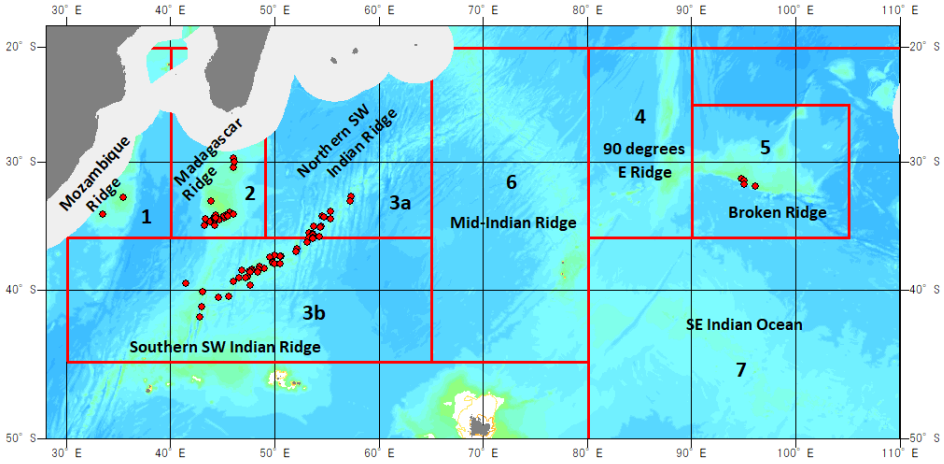


Fig. 5 Four orange roughy management areas (Area 1, 2, 3a and 3b).
For area 2, the Walters Shoal Region is excluded as stock assessments will take place.

A Harvest Control Rule (HCR) for SIOFA orange roughy can be based on the rules developed in New Zealand and Australia, and accepted by the MSC. There are documents available on how this rule can be applied on the MSC website or the New Zealand Deepwater Group website (for an example, Cordue,2014).

This HCR requires three essential information, i.e., (a) acoustic data (processed or unprocessed), (b) estimated B0 and (c) all historical catch data.

We need (a) acoustic data because HCR need any viable biomass estimates from acoustic surveys. Most of the regions have one or more acoustic surveys and these are waiting for the full review of the SB acoustic time series, to establish how the estimates of biomass for these other areas can be used.

We also need (b) B0, because this rule requires understanding of any biological differences between the orange roughy in the region under HCR and those in the control region of Walter's Shoal where the first assessment take place.

We also need (c) catch data because we need to incorporate from low to high level of efforts to implement HCR effectively.

Some of information of (a) and (b) are available by Cook Island (2017). The Secretariat will collect this information and provide to the consultant. If we don't have enough information and cannot apply this HCR, then we may need to use alternative HCR.

5. CONSULTANTS AND BUDGETS

A consultant will be nominated by SC head delegations and/or relevant experts. Then the nominee needs to be agreed by all of SC head delegations. If there are more than two nominees, the finalist will be decided by votes by SC head delegations. The consultant will work on (a) CASAL and (b) biological parameters estimation works to be used in Harvest Control Rule. The consultant shall make two separated documents for (a) and (b) and attend the SAWG01 and present the results and do other works requested.

SAWG has EURO 30,000 (the 2018 budget to be used by the end of SC03, March 24, 2018) which will be allocated for the consultant. The round travel fees between the consultant's home and La Réunion and per diems are included in EURO 30,000. The consultant shall follow Terms of Reference (ToR).

6. DATA HANDLING AND CONFIDENTIALITY

The Secretariat will be the depository of the data to be used for stock assessments and harvest control rule as in RFMOs. Such data will be collected by the Secretariat. The SIOFA confidential rule stipulated CMM 2016_03 is applied for all the data.

The Secretariat will provide the necessary data to consultants and SAWG members planning to do stock assessments voluntarily. The data should be used only by themselves and should not be released to any others. All the data shall be deleted by the end of SC03 (March 24, 2018).

References (available at http://www.siofa.org/meetings)

Cordue, P.L. (2014) The 2014 orange roughy stock assessments, New Zealand Fisheries Assessment Report 2014/50.

Cordue, P.L. (2014) The 2014 orange roughy stock assessments, New Zealand Fisheries Assessment Report 2014/50.

Cordue, P.L. (2014) A Management Strategy Evaluation for orange roughy, ISL Client Report for Deepwater Group Ltd.

Cook Islands (2016) National Report, 1st Meeting of the Southern Indian Ocean Fisheries Agreement (SIOFA) Scientific Committee, Australia, SC-01-05 (04).

Cook Islands (2016) Biological data from orange roughy spawning stocks in the Southwest Indian Ocean. 1st Meeting of the Southern Indian Ocean Fisheries Agreement (SIOFA) Scientific Committee, Australia. SC-01-INFO-16.

Cook Islands (2017) INDIAN OCEAN ORANGE ROUGHY ACOUSTIC SURVEY ABNJ REVIEW 2017. SC-02-08(01).

FAO (2017) Report of the Workshop to review orange roughy acoustic data. ABNJ project. ABNJ project. Roma, Italy.

ICES (2012): ICES Implementation of Advice for Data-limited Stocks in 2012 in its 2012 Advice. DLS GUIDANCE REPORT 2012. ICES ADVISORY COMMITTEE. ICES CM2012/ACOM 68.

Low, L-L. (2014) Presentation on application of stock assessment techniques and fishing control rules according to data quality. Armorhead WS 2012 in Japan. Inf-D9.

Nicol, S., Cryer, M., Bock, T. and Georgeson, L. (2017) A draft stock assessment framework for bottom fisheries within the SPRFMO Convention Area. SPRFMO 5th Scientific Committee, Shanghai, China (SC5-DW04)

SEAFO (2014) Empirical Harvest Rules Their use in the development of advice for the SEAFO fisheries (PowerPoint), 10th Scientific Committee. Namibia

SIOFA (2016) 1st Scientific Committee Report. Australia.

SIOFA (2017) 2nd Scientific Committee Report. La Réunion.

SPRFMO (2017) REPORT OF THE SPRFMO DEEP WATER WORKING GROUP WORKSHOP (SC5-Doc08_rev1)