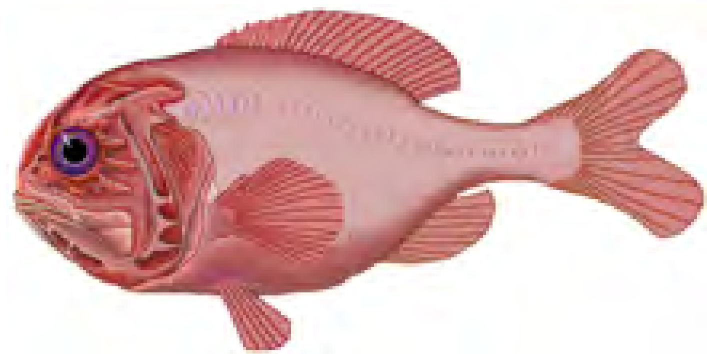

Stock Assessment of the orange roughy (*Hoplostethus atlanticus*) under management by the Southern Indian Ocean Fisheries Agreement (SIOFA): 2000 to 2020

Authors

Rubén H. Roa-Ureta
Rodrigo Wiff
Andrés Flores
Consultants in Statistical Modelling, Marine Ecology and Fisheries

March 7, 2022

Acknowledgements. This work was conducted under contract with SIOFA, project SER 2021-04. We appreciate discussions of data characteristics and approaches to assessment with Pierre Peries, Tom Nishida and Alistair Dunn, as well as comments and corrections to the first version of this report by Alistair Dunn and Thierry Clot. We also acknowledge discussions and request to extend our analysis as a result of SERAWG4 held on March 1-2, 2022. We further express our gratitude to Patrick Cordue for the writing of the original CASAL code that we modified and extended to conduct part of the work reported here.

SIOFA | APSOI

Southern Indian Ocean Fisheries Agreement

Accord relatif aux Pêches dans le Sud de l'Océan Indien

1 Executive Summary

A stock assessment update of the orange roughy (*Hoplostethus atlanticus*) captured in SIOFA's region was conducted using the following data: time series of fishing effort (number of hauls) and catch (kg) from 2000 to 2020 from logbook records, annually aggregated length-frequency data from 2011 to 202, acoustic biomass indices from 2004 to 2018, and age composition data from the catch of 2017.

The assessment updated a previous assessment done with data up to 2017 (SAWG (2018)-01-05 and SAWG (2018)-01-06) using code in the CASAL system for stock assessment for the Walter's Shoal Ridge (WSR) management unit (MU). We updated the age structured model developed for the stock in the WSR, both with migration among features (sub-localities) of the MU as done previously, and by ignoring features inside the WSR as suggested by the acoustic biomass indices data.

For a larger aggregation of MUs connected spatially to the WSR, namely North Walter's, West Walter's, Walter's Shoal Ridge, Seamounts and Meeting (collectively called the Long Walter's Shoal Ridge) we also implemented a new stock assessment model of the generalized depletion family of models in R package CatDyn. Furthermore, we implemented the generalized depletion approach to stock assessment of MUs North Ridge, Middle Ridge and South Ridge (collectively called the Long Eastern Ridge). Finally, using predictions of annual biomass from the generalized depletion models we also fitted surplus production models to the Long Walter's Shoal Ridge and the Long Eastern Ridge writing code in the AD Model Builder software platform.

Spatial analysis of the haul location data in the time series of logbooks and bathymetric data allowed identification of spatial units connecting features of the WSR into a single Sleeping Beauty Complex. The spatial analysis also demonstrated the adequacy of analysing nearly all identified MUs into two larger spatial units, the Long WSR and the Long Eastern Ridge, leaving only the Outside MU (west of the Western Australia) outside the scope of our assessments.

The age structure data and acoustic indices of biomass indicate that the available information is not sufficient to model the stock with migration among features inside the WSR without introducing large degrees of subjectivity in the assessment. We recommend that the age-structured model be continued but with all features aggregated into a single WSR MU, ignoring migration among features. Considering this aggregated analysis of the WSR, the model showed high sensitivity to prior distributions given to the proportionality constant of the acoustic index and its coefficient of variation. Nevertheless, results with a target biological reference point (BRP) of $0.5 \times B_0$ and steepness $h = 0.57$ clearly show that the target BRP is achieved at a constant exploitation rate of 3%. The status of the stock in the WSR shows that the exploitation is currently sustainable, with a low probability ($p = 0.25$) of the stock being overfished. Stock projections between 2021 and 2040 were computed considering nine scenarios of constant catches with percentages (0% and ± 40) of (i) the current catch level (2020), (ii) the average catch of the last 3 years and (iii) the average catch of the last 6 years. Using the current catch levels all projected scenarios have null probability ($p = 0$) that the exploitation rate will be higher than the exploitation rate at BRP at the end of the projected period. This probability increases for scenarios of the average catch in the last 3 and 6 years.

Generalized depletion models combined with surplus production models of the Pella-Tomlinson type applied to the stocks in the Long WSR and the Long Eastern Ridge show that the stock is more productive in the former area. This assessment as pertaining to the Long Walter's Shoal Ridge is consistent with the age structured assessment in showing the stock as being harvested at sustainable rates, with annual catches well below the maximum sustainable yield (MSY), although the age structured model assessed a smaller part of the stock so the comparison is not entirely pertinent. The MSY in the Long WSR was estimated at 3,276 tonnes but with poor statistical precision (215.7 %CV). The MSY estimated for the Long Eastern Ridge was much lower, at 616 tonnes, but with much better precision (88.8 %CV). In the Long Eastern Ridge the stock is being harvested close to the MSY with frequent annual catches much higher than the MSY.

Projections from the surplus production model between 2021 and 2040 were completed for the Long WSR and the Long Eastern Ridge under three scenarios of constant catch: catch equal to the MSY, 75% of the MSY, and 50% of the MSY, all three scenarios with implementation error.

In the Long Eastern Ridge annual catches aiming at the MSY led to a slow decay of biomass and high probability (≈ 0.6) of failing to keep the stock at a biomass equal or higher than the biomass producing the MSY (B_{MSY}) and failing to keep fishing mortality at less than the fishing mortality at the MSY (F_{MSY}). Catches aimed at 75% of the MSY led a slight increase and the stability of biomass with a moderately low probability (≈ 0.3) of biomass lower than B_{MSY} and fishing mortality higher than F_{MSY}. Finally catches aiming at 50% the MSY led to a stronger rise in biomass and subsequent stability with a low probability (≈ 0.1) of biomass lower than B_{MSY} and even lower probability (< 0.1) of fishing mortality higher than F_{MSY}.

In the Long WSR all scenarios for future annual catches led to falls in biomass but the rate of decline was substantially different. Aiming at the MSY led to a 3-times decline in biomass with ≈ 0.8 probability of biomass being below the B_{MSY} and fishing mortality above F_{MSY}. Aiming at annual catches at 75% of the MSY led to biomass dropping by $\approx 30\%$, with a probability of ≈ 0.3 of biomass below B_{MSY} and ≈ 0.4 of fishing mortality higher than F_{MSY}. Finally, aiming at catches around 50% of the MSY led to a slight decrease in biomass, ≈ 0.1 probability of biomass less than B_{MSY} and < 0.1 probability of fishing mortality higher than F_{MSY}.

We recommend that SIOFA considers a simplification of the spatial split from 9 MUs to just two, the Long WSR and the Long Eastern Ridge, since each of those form a continuous ridges and the available data and the very irregular pattern of the catch in time and space makes it inadequate to attempt assessing the stock into fine spatial divisions.

We also recommend the continued use of both the age structured model implemented in CASAL (though without migration among features) for the Walter's Shoal Ridge MU and the generalized depletion model combined with surplus production models for the Long WSR and the Long Eastern Ridge.

Finally, the exploitation in WSR and the larger Long WSR is found to be well within sustainability limits while the exploitation in the Long Eastern Ridge is too close to limit harvest rates (MSY) and should be considered for a biomass rebuilding program.