ORY-2024-01 Report 3:

The 2025 stock assessment of orange roughy (*Hoplostethus atlanticus*) for the Long Walter's Shoal Ridge and South-West Indian Ocean Ridge covering SIOFA Statistical Areas 1, 2, 3a and 3b

Sophie Mormede and Simon Hoyle (soFish Consulting and Hoyle Consulting)

Abstract

We have developed stock assessment models for orange roughy on Long Walter's Shoal Ridge (LWSR) and for the South-West Indian Ocean Ridge (SWIOR) separately, parts of SIOFA Statistical Areas 1, 2, 3a and 3b, with data to 2023. In a 2025 development, we include all acoustic biomass surveys in the model and assign a normal prior to the sum of the individual acoustic catchability parameters.

Consistent with previous SIOFA conclusions, the SWIOR model possesses no information and is highly uncertain. Only two features have been surveyed for two years and present opposing trends. Length frequency distributions suggest that orange roughy caught on those hills are much larger than elsewhere in the SIOFA Region, and larger than the expected maturity curve. Furthermore, historical catches have been much higher than recent catches, indicating a potentially large initial stock size.

The LWSR stock represents an extended version of the WSR stock, which was assessed elsewhere. Similar results and conclusions apply, specifically that the data contain no information on the potential value of natural mortality and very little information on the potential value of total acoustic catchability, resulting in models driven by the priors assigned to those parameters. Declining acoustic estimates on Sleeping Beauty indicate that lower initial biomass and higher acoustic survey catchability are likely. Projections under certain assumptions indicate that the interim target biomass and fishing pressure could be exceeded.

Consistent with the conclusions of the WSR modelling, better informed models could be achieved through better informed natural mortality and acoustic catchabilities. In the interim, the commonly assumed value of 0.045 could be used as a baseline for the normal prior on natural mortality. The sum of acoustic catchabilities is uncertain for numerous reasons: the time-series of acoustic surveys are still short, only a subset of hills have been surveyed each year, and fish may move hills between years. Acoustic surveys of hills that already have a long time-series should be a priority. Surveying multiple hills per year, although technically difficult, would help to inform this parameter.

For these extended stocks, many hills have only been surveyed once and should be surveyed again. Multiple hills have shown a large decline in acoustic biomass: Da Vinci, Angelo's, Porky's and M.M. In the absence of robust stock assessments, acoustically monitoring these hills should be prioritized to establish for each hill whether there has been local depletion or whether the acoustic estimates have high variability. Meanwhile, catches on those hills could be reduced as a precautionary measure.

Recommendations

- Orange roughy stock sizes and status in the SIOFA Region remain highly uncertain.
- Acoustic surveys provide the main information on those stocks.
- Better informed population models could be achieved with better informed natural mortality (M) and acoustic catchability (q).
- Acoustic surveys of hills with a long time series should remain a priority.
- Acoustic surveys of multiple hills within one season would help inform q.
- Some hills have been surveyed once only and further surveys would allow some degree of monitoring of those hills.
- Multiple hills have shown a large decline in acoustic biomass indices and could benefit from specific management as a precautionary measure (Da Vinci, Angelo's, Porky's and M.M.).

1. Introduction

The orange roughy (*Hoplostethus atlanticus*) fishery in the SIOFA area is mainly carried out using bottom trawls, with most catches associated with underwater features. Although orange roughy have been caught in a wide area of the SIOFA region, the majority of catches have historically been taken from the Walter Shoal Ridge (WSR, Figure 1). The WSR is also the area with most information available, including biomass estimates using acoustics and some length and age information (Hoyle & Mormede 2025).

The SIOFA Scientific Committee (SC) provides scientific advice to the Meeting of Parties (MoP) on the status of stocks and sustainable yields of deep-sea fisheries resources. The stock assessment of orange roughy in the WSR was developed in 2018 (Cordue 2018; Cordue et al. 2018) and updated in 2021 (Roa-Ureta et al. 2022). Two larger stocks were also considered in 2021: the Long Walter's Shoal Ridge and the South-west Indian Ocean Ridge, although these were rejected by SIOFA (SIOFA Secretariat 2023).

As required under SIOFA CMM 15, orange roughy stock assessments are conducted every 3-5 years, and new orange roughy stock assessments were developed in 2025 for consideration by SIOFA. This report investigates potential stock assessments of orange roughy in the LWSR and SWIOR with data up to 2023. The 2025 stock assessment for the Walter Shoal Ridge is detailed elsewhere (Mormede & Hoyle 2025). A glossary of some of the terms used in the document is provided in Table 1.

The Terms of Reference (TORs) for the project are provided in Appendix C. This document addresses part of item 3 of the Project Objectives, which states: 'Review the previous stock assessments, and use all new information (including updated growth, maturity, and local area acoustic abundance data), and other relevant information to undertake a statistical catch-at-age stock assessment to determine the stock status of orange roughy for Walters Shoal and the Southwest Indian Rise.'

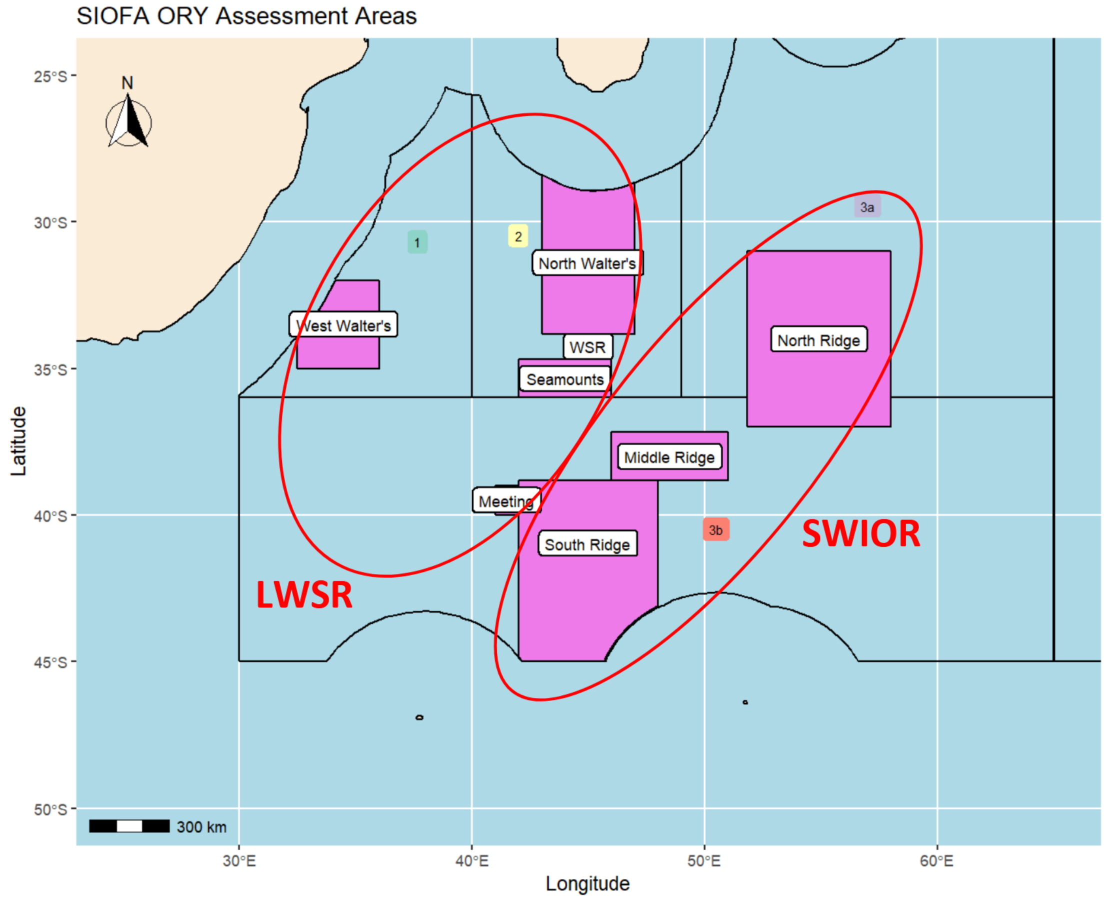


Figure 1: Map of SIOFA areas used for orange roughy assessments (in magenta). Labels indicate the names of single assessment areas with the Walter Shoal Ridge area noted as WSR. The red ovals denote the grouping into two larger areas for stock assessment purposes: the Long Walter's Shoal Ridge (LWSR) and South-West Indian Ocean Ridge (SWIOR). Reproduced from Figure 2 of the SIOFA fisheries summary for orange roughy (SIOFA Secretariat 2023).

2. Methods

2.1 Fisheries data

Catch data were sourced from the 2018 assessments (Cordue 2018b) up to and including 2017, and from the SIOFA fisheries report thereafter (SIOFA Secretariat 2023). These are summarised in Table 2. We note that discrepancies were found between the 2018 stock assessment report (Cordue 2018b), the 2018 stock assessment files, and the data in the fisheries report for the overlapping years (2014-2017).

Additional data used were provided by the SIOFA Secretariat. The data series used in the stock assessment models are summarised in Figure 2.

The 2019 and 2020 unsexed scaled age frequency distributions for the LWSR and SWIOR were calculated based on available data. The growth parameters and length-weight parameters were updated using all the data available. Catch per unit effort were not used for these larger areas as data were sparse (Hoyle & Mormede 2025).

An update of the acoustic biomass estimates was carried out in 2022 (Macaulay 2022). The annual mean biomass per feature was calculated for this study with weight inversely proportional to cv, as per the process carried out in the previous assessment (Roa-Ureta et al. 2022). The resulting estimates are presented in Figure 3.

2.2 Stock assessment models

The structure of the Bayesian age- and sex-based base case model developed for orange roughy in the WSR (Mormede & Hoyle 2025) using the modelling platform Casal2 (Casal2 Development Team 2023) were applied to LWSR and SWIOR. A summary of the parameters used is given in Table 3 and Figure 2. Three time-steps were implemented in the model with recruitment in the first time-step, fishing in the second time-step and ageing in the third time-step.

Ages 1-120 by sex were modelled with the oldest age a plus group, and the model ranged from 1950 to 2023. The models assumed a Beverton-Holt stock-recruit relationship with a steepness value of 0.57 and spawning biomass defined as mature male and females. Maturity was assumed to be equal to selectivity. Growth was assumed to follow a Von Bertalanffy relationship. Both the growth and length-weight relationships were updated using the latest data (Hoyle & Mormede 2025).

Initial biomass, catchabilities and selectivities were estimated (Table 4). As for the WSR base case model, year class strengths were not estimated.

- Initial biomass (B_0) was estimated with a uniform prior on the log scale.
- Natural mortality (M) for both males and females combined was estimated with a normal prior of mean 0.045 and cv 0.1.
- Acoustic catchability q parameters were estimated as free parameters with a uniform prior.
- The sum of the acoustic catchabilities was given a normal prior of various means and cv of 0.1.
- For LWSR, maturity (equal to selectivity) was assumed identical for males and females and estimated with a uniform prior.
- For SWIOR, selectivity was to the right of the expected maturity for orange roughy (see below), so maturity was fixed at the median of the WSR MCMC values (a_{50} = 31.5 years, a_{to95} = 9 years) and selectivity was assumed identical for males and females and estimated with a uniform prior.

Age frequency distributions were provided to the model with their effective sample size, and both acoustic and CPUE series with their externally-calculated cv. Data were weighted with the Francis method (Francis 2011a, 2011b). Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was penalised.

Age frequency distributions can be problematic in orange roughy stocks, particularly for plume aggregations. The mode of the age frequency distributions have been documented to shift by up to 10 years between different years sampled, indicating non homogeneous plumes and difficulty in representative sampling of the population (e.g., Dunn 2024a, 2024a).

Median posterior density (MPD) estimates were used to compare diagnostics and fits between models. For final runs, the full posterior distribution was sampled using Markov chain Monte Carlo (MCMC), based on the Metropolis-Hastings algorithm. Three MCMC chains with a total length of 4×10^6 iterations each were constructed. A burn-in length of 1×10^6 iterations was used, with every 1000th sample taken from the final 3×10^6 iterations (i.e., a final sample of length 3000 was sampled from the posterior for each of the three independent chains).

Once the base model was finalised, sensitivities were carried out to investigate the effect of the main assumptions in the model. Specifically, a range of priors on the sum of the acoustic catchabilities were investigated.

2.3 Projections

For each final model, we calculated the exploitation rate that achieves 50% probability of being above 40% B_0 (F_{40}), the biomass at maximum sustainable yield (B_{MSY}), and the exploitation rate that achieves 50% probability of being above B_{MSY} (F_{MSY}) when possible (that was not always possible due to the high uncertainty in the estimate of B_0). The final models were then projected for 20 years under average future recruitment and with different future catch assumptions (Figure 4):

- Constant catch: 698 t for LWSR or 310 t for SWIOR (mean of the 2015-2020 catches) and ±10, 20, 30, or 40% of that value
- Constant exploitation rate: F_{40} with catch changed every year or every five years
- Constant exploitation rate: F_{MSY} with catch changed every year or every five years

3. Results and discussion

3.1 Model results

Long Walter's Shoal Ridge (LWSR)

As was seen for the Walter Shoal Ridge models (Mormede & Hoyle 2025), the data had virtually no information on initial biomass (B_0), natural mortality (M) and little information on the sum of the acoustic catchabilities *Sum(q)* for the LWSR. Model results were driven by the priors on M and *Sum(q)* (Figure 5).

MCMC runs were carried out for a range of models: the prior on the sum of acoustic catchability *Sum(q)* mean values was assumed to be 0.5, 0.75 or 1.0 with cv of 0.1. One additional model run loosened this prior by applying a cv of 0.4 (R2.0). The normal prior on natural mortality M was maintained with mean of 0.045 and cv of 0.1. Results showed that despite this tight prior, and unlike the WSR model, the estimate of M was variable and correlated with the estimate of *Sum(q)* (Table 5). The data favoured a higher value of the sum of catchabilities q, with a much lower negative log likelihood (NLL) associated with higher estimates of *Sum(q)*. The preferred value for *Sum(q)*, once the prior was relaxed, was 2.07, which is unexpectedly large. A higher value of acoustic catchabilities led to slightly improved fits to the acoustic data despite incurring a higher penalty due to the natural mortality prior (Table 5, Figure 6). Despite this high value of catchability q, the strong decline seen on the Angelo's and Da Vinci features could not be fitted to.

The choice of the prior on the sum of catchabilities had a very strong influence on the estimate of initial biomass and status (Table 5, Figure 7), although only the model with an estimated sum of catchabilities of 2.07 resulted in a status in 2023 below the interim target of 40% B_0. A sum of catchability value of 1.0 is plausible for multiple reasons, including incorrect target strength, under-corrected background scatter, the presence of other species in the marks, and movement between hills during and between surveys. This model construct assumes that there is no movement between the hills between years; the 2018 model estimated movement but data were sparse (Cordue 2018a). Movement between hills during surveys and between years has been inferred on the Challenger Plateau in New Zealand, where the current model now sums the acoustic estimate values between hills (Fisheries New Zealand 2024).

MCMC results of run R1.1 with a *Sum(q)* prior mean of 1.0 and posterior mean of 1.21 are given in Appendix A. The MCMC was well behaved (Figure A.1), *rhat* values were all close to zero and effective sample sizes close to 1 (not shown). The biomass trajectory was uncertain, and status likely above 40% B_0 (Figure A.2). Fits to the acoustic data were mostly adequate although the model could not fit the sharp decline seen in Angelo's and Da Vinci (Figure A.3). Fits to the age frequency distributions were also adequate given the variability of the input data (Figure A.4). Density distributions of the estimated parameters were stable; the distribution of M was lower than its prior and the sum of the acoustic catchabilities was to the right of its prior distribution (Figure A.5). Maturity a_{50} was estimated at age 34.7 (Table 5, Figure A.6), consistent with existing literature, which reported maturity at between 23 and 40 years (Tingley & Dunn 2018; e.g., Dunn 2024b, 2024a).

The Kobe plot shows that, for this run, the biomass has remained above the interim target biomass of 40% B_0, and the exploitation rate has often been below the interim target exploitation rate since 2010 (Figure 8).The long term exploitation rate that achieves a 50% probability of being above 40% B_0 (F_{40}) was estimated at between 0.029 and 0.037 depending on the model; the biomass at sustainable yield (B_{MSY}) was estimated at 30.3 to 30.9% B_0; and the long-term exploitation rate that achieves a 50% probability of being above B_{MSY} (F_{MSY}) at 0.040 to 0.049 (Table 5).

South-West Indian Ocean Ridge (SWIOR)

As for the Walter Shoal Ridge models (Mormede & Hoyle 2025), the data had virtually no information on initial biomass (B_0), and little information on natural mortality (M) or the acoustic catchabilities *Sum(q)* for the LWSR. Model results were driven by the priors on M and *Sum(q)* (Figure 9).

Because the selectivity was so different from the other areas, with the fishery seemingly selecting older animals, selectivity and maturity were split for this region. The maturity was assumed equal to the median MCMC values of the WSR base case model (Mormede & Hoyle 2025) and selectivity was estimated with a logistic selectivity.

MCMC runs were carried out for a range of models: the prior on the sum of acoustic catchability *Sum(q)* mean values was assumed to be 0.5, 0.75 or 1.0 with cv of 0.1. One additional model run freed this prior with cv of 0.4 (R2.1). The normal prior on natural mortality M was maintained with mean of 0.045 and cv of 0.1. Results showed that, unlike the LWSR model, for SWIOR the estimate of M was equal to its prior (Table 6). There was virtually no difference in the fits to the data between models, with all models having an almost identical negative log likelihood (NLL). The preferred value for *Sum(q)*, once the prior was relaxed, was 0.79. The choice of the prior on the sum of catchabilities had a strong influence on the estimate of initial biomass and status (Table 6), although the status in 2023 for all models was above 80% B_0.

MCMC results of run R3.3 with a *Sum(q)* prior mean of 0.75 and posterior mean of 0.78 are given in Appendix B. The MCMC was well behaved although the likelihood was very tight (Figure B.1), *rhat* values were all close to zero and effective sample sizes close to 1 (not shown). The biomass trajectory was highly uncertain, with an initial biomass estimate between 55 000 and 440 000 t and status likely above 40% B_0 (Figure B.2). The model could not simultaneously fit the decline in the acoustic biomass on M.M. and the increase in the acoustic biomass on Zedric (Figure B.3). The age frequency distributions presented very different distributions in 2019 and 2020, leading to a very uncertain estimate of selectivity and biomass (Figure B.4, Figure B.5). Density distributions of the estimated parameters were stable although selectivity a_{to95} was highly uncertain; the distribution of M was identical to its prior distribution and the sum of the acoustic catchabilities was very slightly to the right of its prior distribution (Figure B.6). The Kobe plot shows that, for this run, the biomass has remained above the interim target biomass of 40% B_0, and the exploitation rate has often been below the interim target exploitation rate since 2010 (Figure 8).

The long-term exploitation rate that achieves a 50% probability of being above 40% B_0 (F_{40}) could only be estimated for two of the four models, with mean estimate of about 0.041. The biomass at sustainable yield (B_{MSY}) was estimated at about 31.3% B_0 and the long-term exploitation rate that achieves a 50% probability of being above B_{MSY} (F_{MSY}) at 0.090 (Table 6). The higher constant exploitation rates are due to the (highly uncertain) right-shifted selectivity compare with maturity, with a selectivity a_{50} of about 46 years.

3.2 Projections

Long Walter's Shoal Ridge (LWSR)

Projections were carried out on the sensitivity runs over 20 years for a range of future constant catch scenarios (Table 7, Table 8 and Figure 11).

The model run with a sum of acoustic catchabilities estimated at 2.07 (R2.0) did not satisfy the interim target (50% probability of being above 40% B_0) for any future constant catch scenario as early as 2033 if not prior (Table 7). The model run with a sum of acoustic catchabilities estimated at 1.21 (R1.1) and all but the three lowest constant catch scenarios was the only other model run which did not satisfy the interim target (50% probability of being above 40% B_0) in 2043 (Table 7). Only the two highest constant catch scenarios of runs R2.0 would also not satisfy the interim biomass limit of 90% probability of being above 20% B_0 (not tabled due to the small number of values breaching the interim limit).

The interim target fishing pressure (F_{40}) was exceeded as early as in 2026 for those two same runs with the higher *Sum(q)* estimates (R1.1 and R2.0) in many constant-catch scenarios (Table 8). The model with an estimated *Sum(q)* of 0.89 also exceeded the interim target fishing pressure for the two highest constant catch scenarios.

South-West Indian Ocean Ridge (SWIOR)

Projections were carried out on the sensitivity runs over 20 years for a range of future constant catch scenarios (Table 9 and Figure 12).

All model runs and future constant-catch scenarios satisfied the interim target (50% probability of being above 40% B_0). The interim target fishing pressure (F_{40}) was never exceeded (probability of zero for all future scenarios, not showed).

4. Conclusions

We have developed a range of stock assessment models for orange roughy on Long Walter's Shoal Ridge (LWSR) and for the South-West Indian Ocean Ridge (SWIOR) separately, parts of SIOFA Statistical Areas 1, 2, 3a and 3b, using data up to and including 2023. In a 2025 development, we included all the acoustic biomass surveys in the model and assigned a normal prior on the sum of the individual acoustic catchability parameters.

Consistent with previous conclusions from SIOFA, the SWIOR model is severely lacking in information and results are therefore highly uncertain (SIOFA Secretariat 2023). In particular, only two of the features have been surveyed for two years and present opposing trends, and length frequency distributions seem to indicate that the size of orange roughy caught on those hills is much larger than elsewhere in the SIOFA Region, and larger than the expected maturity curve. Furthermore, historical catches have been much higher than recent catches, indicating a potentially large initial stock size.

The LWSR stock is an extended version of the WSR stock, which is assessed elsewhere (Mormede & Hoyle 2025). Similar results and conclusions apply, specifically that the data contained no information on the potential value of natural mortality (*M*) and very little information on the potential value of total acoustic catchability (*Sum(q)*), resulting in models that were driven by the priors assigned to *M* and to *Sum(q)*. Declining acoustic estimates on Sleeping Beauty indicate that a lower initial biomass and higher acoustic survey catchability are likely. Projections indicate that under certain assumptions the interim targets for biomass and fishing pressure may have been exceeded.

Consistent with the conclusions of the WSR modelling, better informed models could be achieved through better informed *M* and *Sum(q)*. Getting a better handle on natural mortality is likely to be difficult. In the interim, the commonly assumed value of 0.045 could be used as a baseline for the normal prior. The value of the sum of acoustic catchabilities is uncertain for numerous reasons, including because the time-series are still short, only some hills have been acoustically surveyed in any one year, and fish may move between hills and years. Continuation of acoustic surveys of hills that already have a long time-series should be a priority. Additionally, surveying multiple hills in any one year, although technically difficult to achieve, would be helpful for informing this parameter.

For those extended stocks, many hills have only been surveyed once and should be surveyed again at the earliest convenience. Furthermore, several hills have showed a large decline in acoustic biomass: Da Vinci, Angelo's, Porky's and M.M. In the absence of robust stock assessments, acoustically monitoring these hills should be given priority, to establish whether there has been localised depletion or if the acoustic estimates for those hills are highly variable. In the meantime, catches on those hills could be reduced.

5. Acknowledgements

We wish to thank the SIOFA orange roughy project advisory group (Dr Steve Brouwer, Mr Alistair Dunn, Dr Zhou Fang, Dr Marco Milardi and Dr Pavarot Noranartragoon) for guidance and feedback through this process. Thanks to Thierry Clot and Pierre Peries for assistance on the fisheries data. Thanks to the SIOFA Contracting Parties for allowing their data held by the Secretariat be used in this analysis. This project was funded by SIOFA under project code ORY2024-01.

6. References

Casal2 Development Team (2023). Casal2 user manual for age-based models (using source code from https://github.com/alistairdunn1/CASAL2). NIWA Technical Report 139. National Institute of Water & Atmospheric Research Ltd, 270 p.

Cordue, P.L. (2018a). Stock assessment of orange roughy in the Walter's Shoal Region. SAWG(2018)-01-05 Rev1. Southern Indian Ocean Fisheries Agreement (SIOFA), 57 p.

Cordue, P.L. (2018b). Assessments of orange roughy stocks in SIOFA statistical areas 1, 2, 3a, and 3b. SAWG(2018)-01-06 Rev 1. Southern Indian Ocean Fisheries Agreement (SIOFA), 11 p.

Dunn, M.R. (2024a). Assessment of the Challenger Plateau orange roughy stock for 2024. New Zealand Fisheries Assessment Report 2024/58. Ministry for Primary Industries, 42 p.

Dunn, M.R. (2024b). Stock assessment research for Chatham Rise orange roughy in 2023. New Zealand Fisheries Assessment Report 2024/46. 36 p.

Fisheries New Zealand (2024). Fisheries Assessment Plenary, May 2024: stock assessments and stock status. Compiled by the Fisheries Science Team. Ministry for Primary Industries, 1941 p.

Francis, R.I.C.C. (2011a). Corrigendum: Data weighting ins statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68: 2228.

Francis, R.I.C.C. (2011b). Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68: 1124–1138.

Hoyle, S.; Mormede, S. (2025). ORY-2024-01 Report 1: Data characterisation and biological parameters for assessment of SIOFA orange roughy stocks. SC-10-42. Southern Indian Ocean Fisheries Agreement (SIOFA).

Macaulay, G. (2022). Orange roughy acoustic data processing (project SER2021-01)ToR3: estimation of the biomass. SERAWG-04-07. SIOFA, 16 p.

Mormede, S.; Hoyle, S. (2025). ORY-2024-01 Report 2: The 2025 stock assessment of Orange roughy (*Hoplostethus atlanticus*) stock assessment for the Walter Shoal Ridge in SIOFA Statistical Area 2. SC-10-42. Southern Indian Ocean Fisheries Agreement (SIOFA).

Roa-Ureta, R.H.; Wi, R.; Flores, A. (2022). Stock Assessment of the orange roughy (*Hoplostethus atlanticus*) under management by the Southern Indian Ocean Fisheries Agreement (SIOFA): 2000 to 2020. Southern Indian Ocean Fisheries Agreement (SIOFA).

SIOFA Secretariat (2023). SIOFA orange roughy Fisheries Summary 2023. Southern Indian Ocean Fisheries Agreement (SIOFA) 31. https://doi.org/10.13140/RG.2.2.14762.18881

Tingley, G.; Dunn, M. (2018). Global review of orange roughy (*Hoplostethus atlanticus*), their fisheries, biology and management. FAO Fisheries and Aquaculture Technical Paper No 622. 128 p.

7. Tables

Table 1. Glossary of some of the terms used in this document.

Term	Definition
B_0	Initial unexploited spawning stock biomass
B_{lim}	Spawning stock biomass at the limit reference point, the current interim level is 20% B_0
B_{40}	Target spawning stock biomass, the current interim target is 40% B_0
B_{MSY}	Spawning stock biomass at the maximum sustainable yield
MSY	Maximum sustainable yield
F	The instantaneous fishing mortality rate, often expressed as a rate per year. This is a measure of the proportion of the vulnerable biomass that is expected to be caught at a point in time. Reported in this document as the fishing exploitation rate (U), where the annual fishing exploitation rate (U) is calculated using the formula U=1-exp(-F)
F_{MSY}	The long-term instantaneous fishing mortality rate that would result in the spawning stock biomass being at the maximum sustainable yield on average.
F_{40}	The long-term instantaneous fishing mortality rate that would result in the spawning stock biomass being at 40% B_0 on average.

Table 2. Catch (in tonnes) of orange roughy by year and assessment area used in the models and summed for the larger stock assessment areas: LWSR (Long Walter's Shoal Ridge), and SWIOR (South-West Indian Ocean Ridge). The assessment areas are defined in Figure 1.

Year	Meeting	Middle Ridge	North Walters	North Ridge	Seamounts	South Ridge	Western Walters	WSR	LWSR	SWIOR
1999	0	2 540	0	2 991	0	844	0	0	0	6 375
2000	1 655	7 863	0	5 027	880	3 149	250	2 869	5 654	16 039
2001	231	1 186	200	1 979	243	706	120	1 221	2 015	3 871
2002	1	276	0	1 581	350	118	0	11	362	1 975
2003	32	300	6	54	883	275	0	6	927	629
2004	2	908	0	217	780	51	0	397	1 179	1 176
2005	0	662	995	59	1 016	766	0	737	2 748	1 487
2006	0	112	79	120	666	694	243	1 018	2 006	926
2007	0	98	16	32	1 907	97	32	978	2 933	227
2008	0	577	2	745	1 100	294	0	421	1 523	1 616
2009	0	801	200	743	944	155	0	868	2 012	1 699
2010	4	223	119	23	514	88	24	1 004	1 665	334
2011	1	311	9	75	289	39	2	1 186	1 487	425
2012	0	164	54	65	108	61	0	494	656	290
2013	1	1	24	124	69	433	0	770	864	558
2014	0	37	6	62	252	119	0	498	756	218
2015	10	24	22	26	316	4	0	701	1 049	54
2016	0	10	44	89	160	198	28	416	648	297
2017	0	380	8	64	157	439	24	811	1 000	883
2018	0	5	30	33	51	0	14	310	405	39
2019	0	6	85	42	49	450	0	460	594	499
2020	0	111	230	13	27	406	0	174	431	530
2021	0	74	3	53	26	332	0	104	133	459
2022	0	216	7	15	38	0	24	696	765	231
2023	1	17	6	36	3	19	0	462	472	72

Table 3. Setup and model parameters.

Relationship	**Parameter (units)**	**Value**
Ages modelled		1-120
Years modelled		1885-2023
Length bins in the model	(cm)	2 to 68 in 2cm bins
von Bertalanffy growth (males)	t_0 (y)	-4.97
	k (y^{-1})	0.045
	L_∞ (cm)	50.56
	CV	0.10
von Bertalanffy growth (females)	t_0 (y)	-0.67
	k (y^{-1})	0.041
	L_∞ (cm)	55.71
	CV	0.10
Length-weight (males)	a (g.cm^{-1})	$0.86e^{-9}$
	b	2.73
Length-weight (females)	a (g.cm^{-1})	$0.49\ e^{-9}$
	b	2.90
Stock recruitment relationship:		
Spawning stock biomass definition	*SSB*	Mature males and females
Maturity curve (both sexes)		estimated
Stock recruitment steepness	h	0.57
Ageing error	CV	0.1
Age at recruitment	(year)	1
Proportion male at birth		0.5
Maximum exploitation rate	U_{max}	0.6
Natural mortality (both sexes)	M (year^{-1})	estimated

Table 4. Parameters estimated in the models and their priors.

Parameter	**Shape / transformation**	**Starting value**	**Prior**				**Bounds**
			Distribution	**Mean**	**cv**		
B_0	Log transform	50 000	Uniform			8	12.5
Natural mortality (combined)		0.045	Normal	0.045	0.1*	0.01	0.1
Maturity / selectivity (combined)	Logistic		Uniform				
	a50					10	100
	ato95					2.5	20
Acoustic *q*s		0.2	Uniform			$1e^{-4}$	0.8
Sum of acoustic *q*s		0.8	Normal	0.75*	0.1		
CPUE *q*s		0.01	Uniform			$1e^{-4}$	0.8

* A range of values were used.

Table 5. LWSR MCMC results of the model runs. Values provided are medians unless otherwise stated. Results are provided for natural mortality (M), the sum of the acoustic catchabilities Sum(q), the total negative log likelihood (NLL), initial biomass (B_0) and biomass in 2023 (B_{2023}) mean and 95% credible interval (CI), the percentage of MCMC chains where B_{2023} was above 40% B_0, B_{MSY}, F_{40} and F_{MSY}, the 2024 total allowable catch (TAC) corresponding to F_{40} and F_{MSY} and the estimated maturity a_{50}.

Run	M	Sum(q) mu prior	Sum(q) cv prior	Sum(q)	NLL	B_0 (t)	B_0 CI (t)	B_{2023} (%B_0)	B_{2023} CI (%B_0)	B_{2023}>40 %B_0 (%)	F_{40}	B_{MSY} (%B_0)	F_{MSY}	TAC_{F40} (t)	TAC_{FMSY} (t)	Maturity a50 (years)
R1.2	0.047	0.50	0.1	0.58	304	60 980	53 602 – 70 786	69.9	(65.0 - 74.7)	100.0	0.037	0.309	0.049	1 576	2 112	32.8
R1.3	0.044	0.75	0.1	0.89	299	45 588	40 963 – 51 647	58.8	(53.2 - 64.5)	100.0	0.035	0.306	0.047	948	1 274	33.8
R1.1	0.042	1.00	0.1	1.21	293	38 269	34 990 – 42 633	49.7	(43.8 - 55.9)	100.0	0.033	0.303	0.045	640	871	34.7
R2.0	0.037	0.75	0.4	2.07	280	30 143	27 695 – 33 564	33.2	(26.4 - 41.4)	4.8	0.029	0.307	0.040	296	403	36.7

Table 6. SWIOR MCMC results of the model runs. Values provided are medians unless otherwise stated. Results are provided for natural mortality (M), the sum of the acoustic catchabilities sum(q), the total negative log likelihood (NLL), initial biomass (B_0) and biomass in 2023 (B_{2023}) mean and 95% credible interval (CI), the percentage of MCMC chains where B_{2023} was above 40% B_0, B_{MSY}, F_{40} and F_{MSY}, the 2024 total allowable catch (TAC) corresponding to F_{40} and F_{MSY} and the estimated maturity a_{50}. '-' corresponds to values that could not be calculated.

Run	M	Sum(q) mu prior	Sum(q) cv prior	Sum(q)	NLL	B_0 (t)	B_0 CI (t)	B_{2023} (%B_0)	B_{2023} CI (%B_0)	B_{2023}>40 %B_0 (%)	F_{40}	B_{MSY} (%B_0)	F_{MSY}	TAC_{F40} (t)	TAC_{FMSY} (t)	Selectivity a50 (years)
R3.2	0.045	0.50	0.1	0.52	7.5	142 564	74 332 – 652 987	87.7	73.3 - 97.6	100	-	-	-	-	-	44.7
R3.3	0.045	0.75	0.1	0.78	7.4	107 592	54 917 – 442 546	83.6	64.2 - 96.5	100	-	-	-	-	-	46.0
R3.1	0.045	1.00	0.1	1.04	7.3	89 384	45 799 – 359 205	80.3	56.7 - 95.7	100	0.042	0.316	0.090	4 124	8 944	46.5
R2.1	0.045	0.50	0.4	0.79	7.4	109 284	52 545 – 461 068	83.9	62.1 - 96.6	100	0.041	0.311	0.090	5 238	11 472	46.1

Table 7. LWSR projected mean stock status in five-year intervals for the different sensitivity runs and different future catches. Cells highlighted in red represent scenarios which do not satisfy the interim target (50% probability of being above 40% B_0). A future catch of 698 t (rows in bold) represents the 2015-2020 average catch, and the other future catches are ±10, 20, 30 or 40% of that value.

Run		Future catch scenario	R1.2	R1.3	R1.1	R2.0
	Sum(*q*) prior mean	0.50	0.75	1.00	0.75	
	Sum(*q*) prior cv	0.1	0.1	0.1	0.4	
B_{2028} (% B_0)		419 t	71.7	61.1	52.0	35.1
		489 t	71.3	60.5	51.3	34.3
		558 t	70.9	59.9	50.7	33.6
		628 t	70.4	59.3	50.0	32.8
		698 t	**70.0**	**58.8**	**49.3**	**32.0**
		768 t	69.6	58.2	48.7	31.2
		838 t	69.1	57.6	48.0	30.4
		907 t	68.7	57.1	47.3	29.6
		977 t	68.3	56.5	46.7	28.8
B_{2033} (% B_0)		419 t	73.5	63.2	54.3	37.3
		489 t	72.6	62.1	53.0	35.6
		558 t	71.8	60.9	51.6	34.0
		628 t	70.9	59.7	50.2	32.3
		698 t	**70.0**	**58.6**	**48.9**	**30.6**
		768 t	69.1	57.4	47.5	29.0
		838 t	68.3	56.3	46.2	27.4
		907 t	67.4	55.1	44.8	25.8
		977 t	66.5	54.0	43.5	24.2
B_{2038} (% B_0)		419 t	74.7	64.7	56.0	38.9
		489 t	73.4	63.0	54.0	36.4
		558 t	72.2	61.4	52.0	33.9
		628 t	70.9	59.7	50.0	31.5
		698 t	**69.7**	**58.1**	**48.0**	**29.0**
		768 t	68.4	56.4	46.1	26.6
		838 t	67.2	54.7	44.1	24.2
		907 t	66.0	53.1	42.1	21.9
		977 t	64.7	51.4	40.2	19.5
B_{2043} (% B_0)		419 t	75.3	65.5	56.8	39.7
		489 t	73.7	63.4	54.3	36.4
		558 t	72.2	61.3	51.8	33.2
		628 t	70.6	59.2	49.2	30.0
		698 t	**69.0**	**57.0**	**46.7**	**26.8**
		768 t	67.5	54.9	44.1	23.7
		838 t	65.9	52.8	41.6	20.6
		907 t	64.4	50.8	39.2	17.6
		977 t	62.8	48.7	36.7	14.7

Table 8. LWSR projected percentage of simulations where the exploitation rate exceeds the target exploitation rate (F_{40}). Cells highlighted in red represent scenarios which do not satisfy the interim target (50% probability of being below F_{40}). A future catch of 698 t (rows in bold) represents the 2015-2020 average catch, and the other future catches are ±10, 20, 30 or 40% of that value.

Run	**Future catch scenario**	**R1.2**	**R1.3**	**R1.1**	**R2.0**
Sum(*q*) prior mean		0.50	0.75	1.00	0.75
Sum(*q*) prior cv		0.1	0.1	0.1	0.4
F_{2026}	419 t	0	0	0	98.1
>F_{40}	489 t	0	0	0.2	99.8
(%)	558 t	0	0	8.1	100
	628 t	0	0	40.5	100
	698 t	**0**	**0.1**	**78.1**	**100**
	768 t	0	1.6	95	100
	838 t	0	11.5	99.1	100
	907 t	0	34.3	99.9	100
	977 t	0	64.5	100	100
F_{2028}	419 t	0	0	0	97.1
>F_{40}	489 t	0	0	0.1	99.7
(%)	558 t	0	0	7	100
	628 t	0	0	39.5	100
	698 t	**0**	**0.1**	**78.6**	**100**
	768 t	0	1.9	95.5	100
	838 t	0	13.9	99.3	100
	907 t	0	39.5	99.9	100
	977 t	0	70.6	100	100
F_{2033}	419 t	0	0	0	94.0
>F_{40}	489 t	0	0	0	99.5
(%)	558 t	0	0	4.7	99.9
	628 t	0	0	37.6	100
	698 t	**0**	**0.1**	**80.2**	**100**
	768 t	0	3.4	96.6	100
	838 t	0	20.1	99.6	100
	907 t	0	52.9	100	100
	977 t	0	81.4	100	100
F_{2038}	419 t	0	0	0	89.8
>F_{40}	489 t	0	0	0	99.3
(%)	558 t	0	0	4.1	99.9
	628 t	0	0	38.7	100
	698 t	**0**	**0.2**	**82.6**	**100**
	768 t	0	5.6	97.4	100
	838 t	0	28.5	99.8	100
	907 t	0	65.3	100	100
	977 t	0	89.5	100	100
F_{2043}	419 t	0	0	0	87.0
>F_{40}	489 t	0	0	0	99.2
(%)	558 t	0	0	4.8	99.9
	628 t	0	0	44.1	100
	698 t	**0**	**0.5**	**86.5**	**100**
	768 t	0	9.1	98.3	100
	838 t	0	39.8	99.9	100
	907 t	0	76.8	100	100
	977 t	0	94.5	100	100

Table 9. SWIOR projected mean stock status in five-year intervals for the different sensitivity runs and different future catches. Cells highlighted in red represent scenarios which do not satisfy the interim target (50% probability of being above 40% B_0). A future catch of 310 t (rows in bold) represents the 2015-2020 average catch, and the other future catches are ±10, 20, 30 or 40% of that value.

Run	Future catch scenario	R1.2	R1.3	R1.1	R2.0
	Sum(q) prior mean	0.50	0.75	1.00	0.75
	Sum(q) prior cv	0.1	0.1	0.1	0.4
B_{2028}	186 t	87.9	84.1	80.6	84.0
(%B_0)	217 t	87.8	84.0	80.5	83.9
	248 t	87.7	83.9	80.4	83.8
	279 t	87.6	83.8	80.2	83.7
	310 t	**87.6**	**83.7**	**80.1**	**83.6**
	341 t	87.5	83.6	80.0	83.5
	372 t	87.4	83.5	79.8	83.4
	403 t	87.3	83.4	79.7	83.3
	434 t	87.3	83.3	79.6	83.2
B_{2033}	186 t	89.1	85.7	82.5	85.6
(%B_0)	217 t	89.0	85.5	82.3	85.4
	248 t	88.8	85.3	82.1	85.2
	279 t	88.7	85.1	81.8	85.0
	310 t	**88.5**	**84.9**	**81.6**	**84.8**
	341 t	88.3	84.7	81.3	84.6
	372 t	88.2	84.5	81.0	84.4
	403 t	88.0	84.2	80.8	84.2
	434 t	87.9	84.0	80.5	83.9
B_{2038}	186 t	90.0	86.8	83.9	86.8
(%B_0)	217 t	89.8	86.6	83.5	86.5
	248 t	89.6	86.3	83.2	86.2
	279 t	89.3	86.0	82.8	85.9
	310 t	**89.1**	**85.6**	**82.4**	**85.5**
	341 t	88.9	85.3	82.1	85.2
	372 t	88.7	85.0	81.7	84.9
	403 t	88.4	84.7	81.4	84.6
	434 t	88.2	84.4	81.0	84.4
B_{2043}	186 t	90.7	87.7	84.9	87.6
(%B_0)	217 t	90.4	87.3	84.4	87.2
	248 t	90.1	86.9	83.9	86.8
	279 t	89.8	86.5	83.5	86.4
	310 t	**89.5**	**86.2**	**83.0**	**86.1**
	341 t	89.2	85.8	82.6	85.7
	372 t	89.0	85.4	82.1	85.3
	403 t	88.7	85.0	81.7	84.9
	434 t	88.4	84.7	81.2	84.6

8. Figures

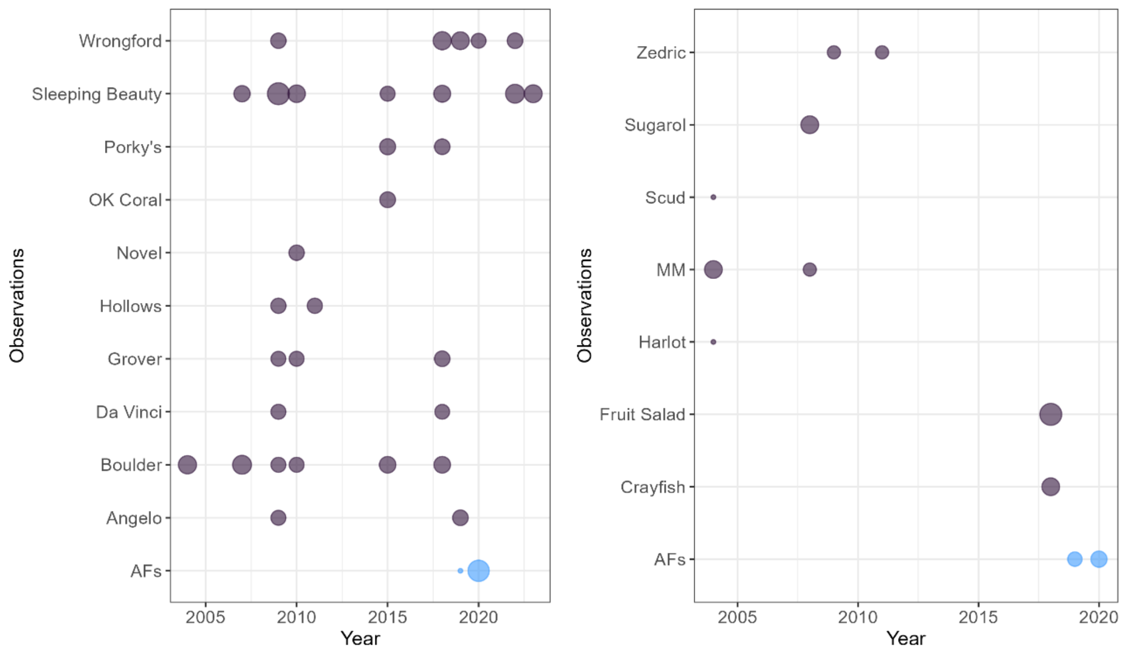


Figure 2. Observations included in the LWSR models (left) and the SWIOR models (right) and their relative adjusted error (CV and additional process error combined). The adjusted errors of abundance and age composition data are not comparable and are plotted as different colours. AF represents age compositions, the other datasets are acoustic series for the feature named.

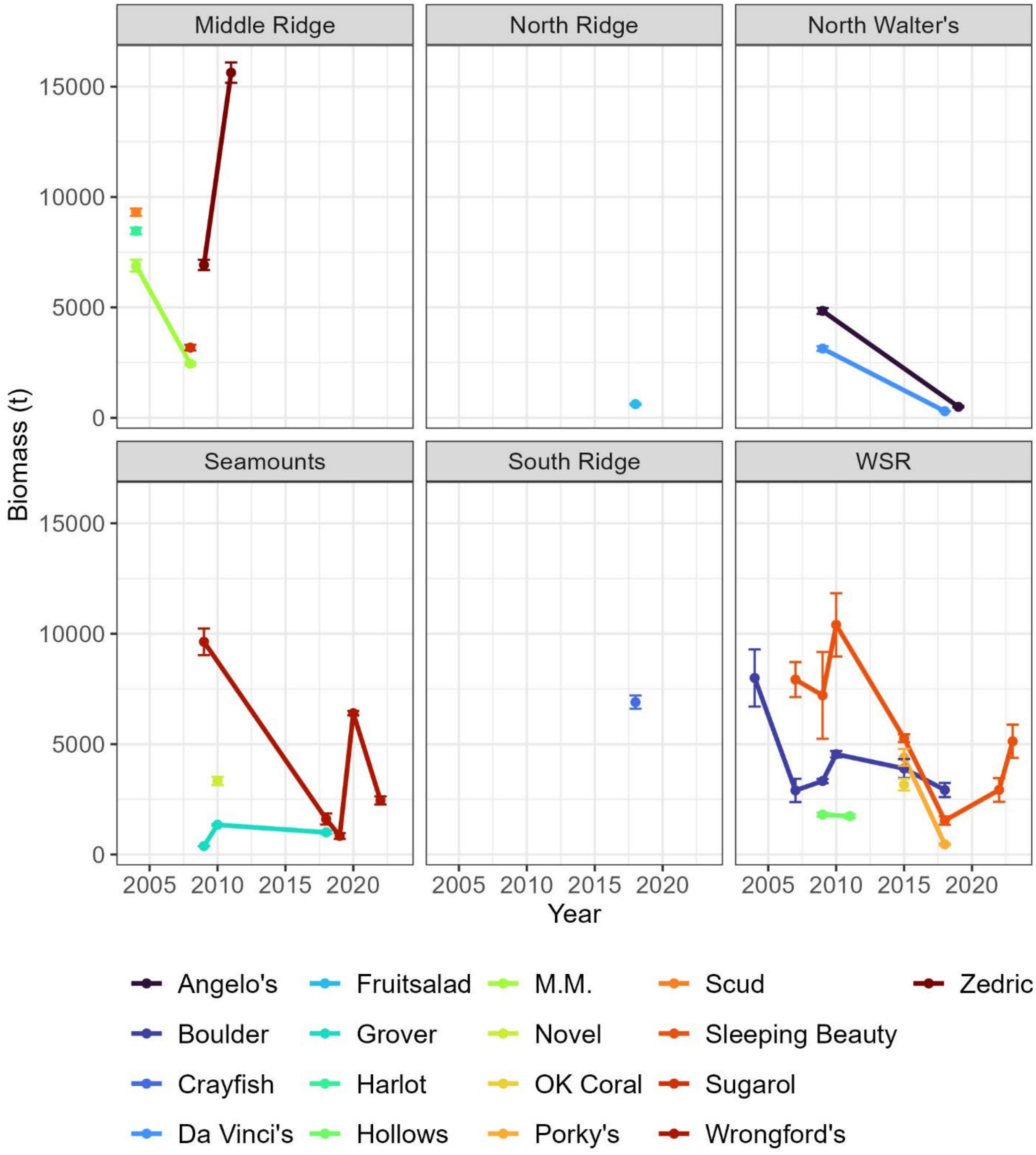


Figure 3. Acoustic biomass estimates of orange roughy in the SIOFA area, by stock name (see Figure 1 for location) and feature.

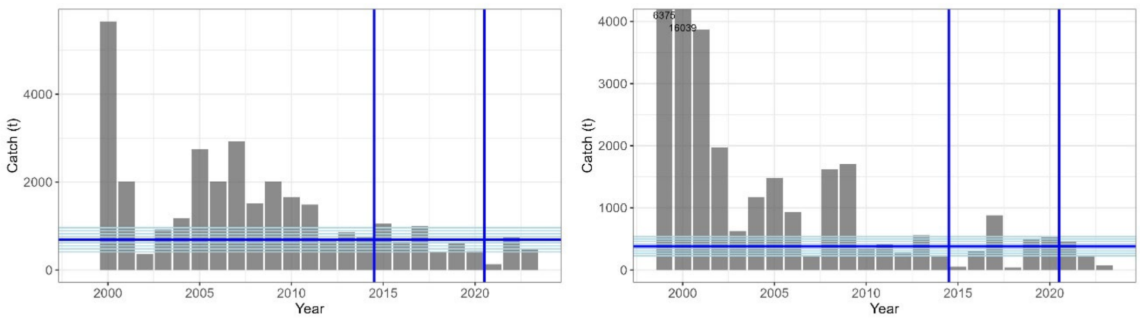


Figure 4. Historic catches used in the stock assessment models for LWSR (left) and SWIOR (right), and level of projected catches: average of 2015-2020 (vertical dark blue lines) catches (horizontal dark blue line) and ±10%, ±20%, ±30%, ±40% of the 2015-2020 level (horizontal light blue lines) of 478 t for LWSR and 310 t for SWIOR. Note that for SWIOR the y-axis is truncated at 4000 t and catches exceeding that value are given.

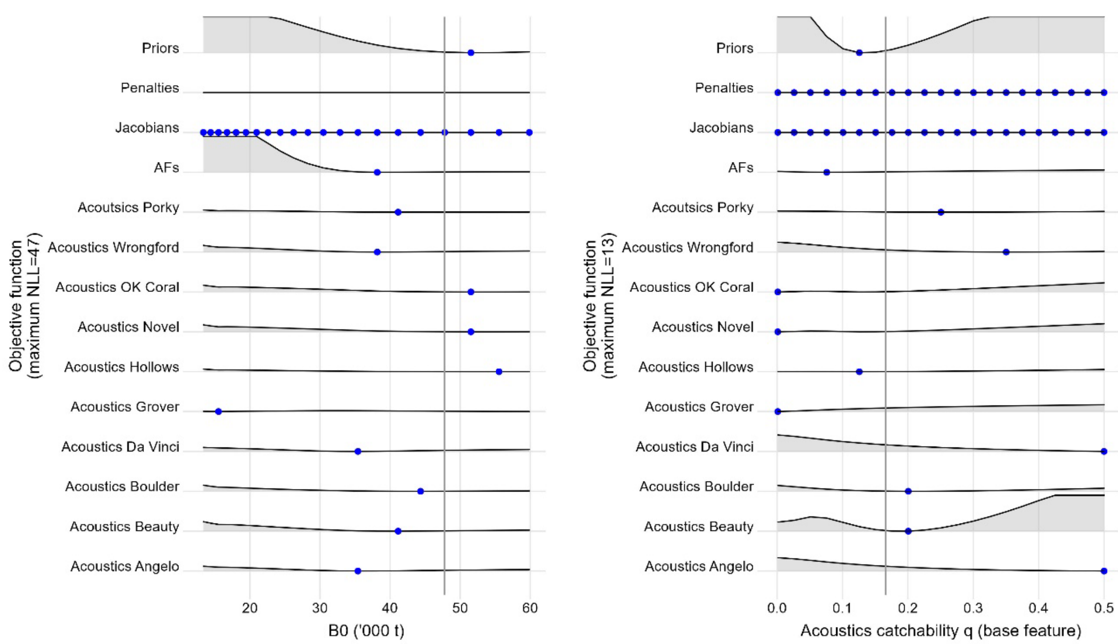


Figure 5. LWSR MPD profile on B_0 (left) and acoustic catchability for Sleeping Beauty (right) for the model with q sum(q) prior mean of 0.75 (R1.3). The blue dot represents the minimum for each series and the vertical line is the MPD estimated value. The maximum negative log likelihood (NLL) difference plotted is given in the y axis.

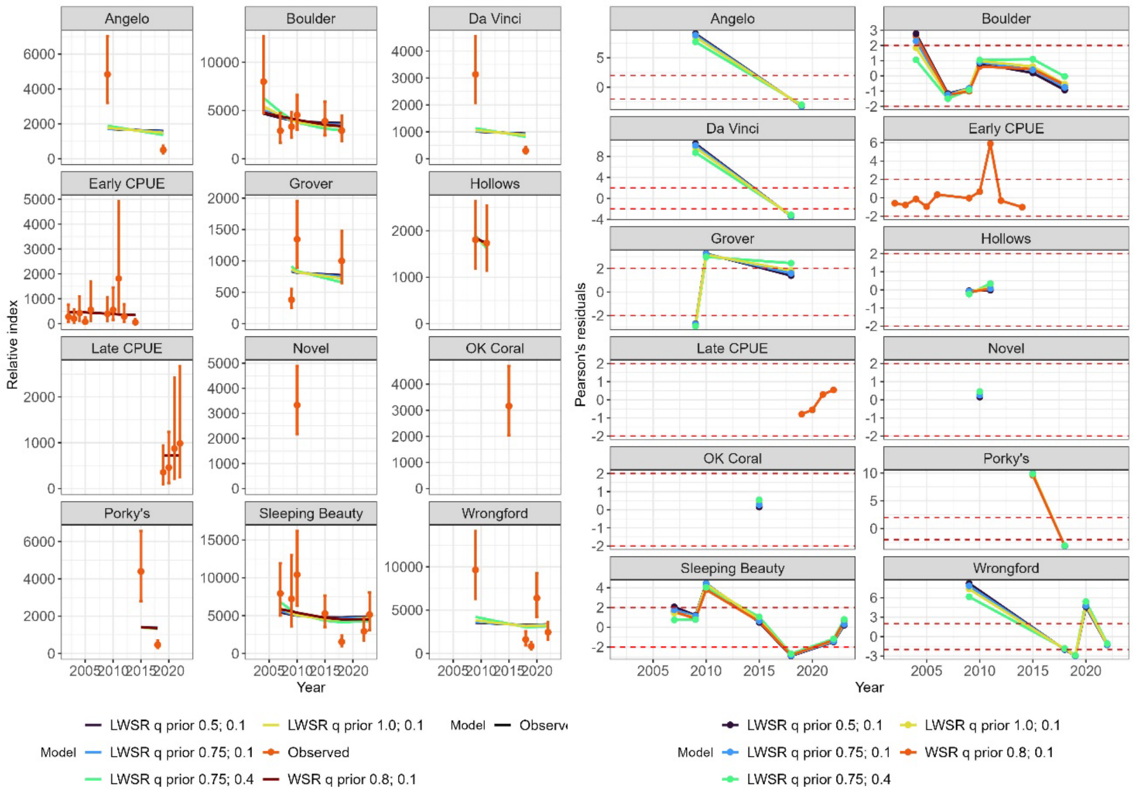


Figure 6. LWSR sensitivity models and WSR base model MPD fits to the biomass index data for the various models (left) and Pearson's residuals (right).

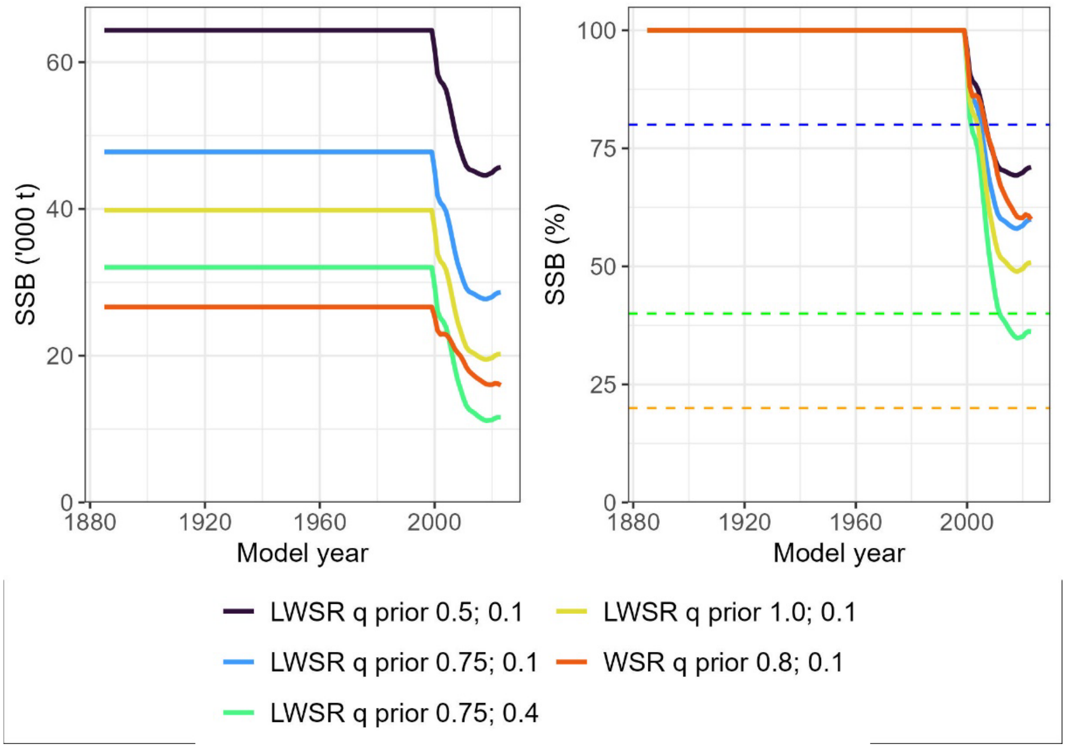


Figure 7. LWSR sensitivity models and WSR base model MPD biomass trajectory, in tonnes (left) and status (right).

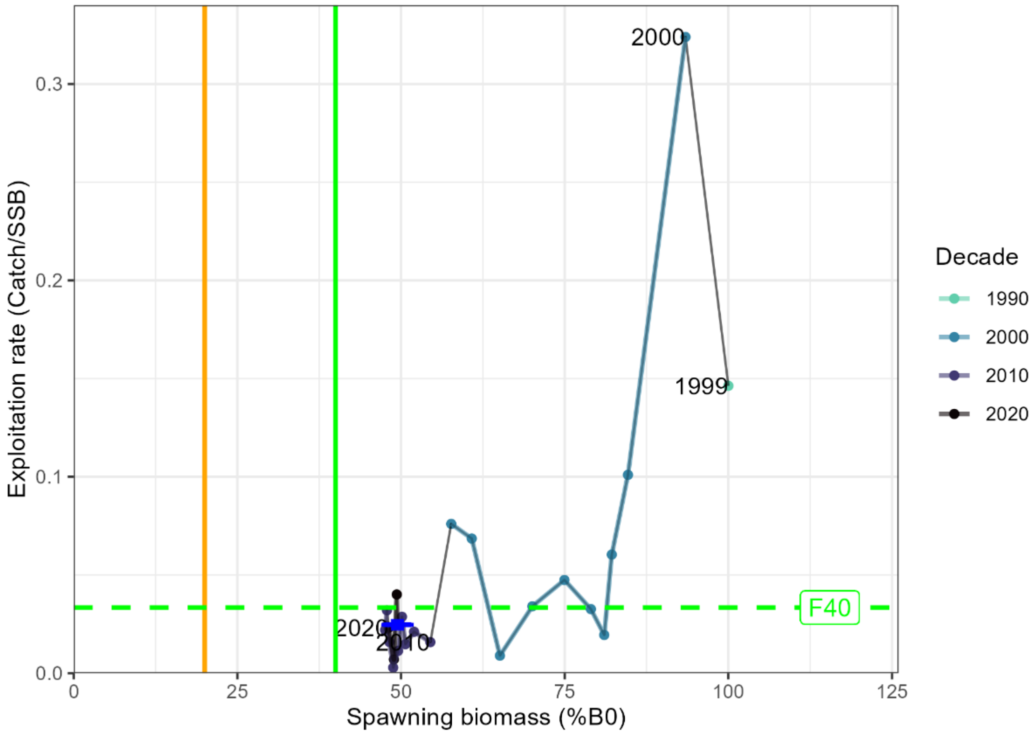


Figure 8. LWSR R1.1 Kobe plot: trajectory over time of exploitation rate (catch/SSB) and spawning biomass (% B_0). The red vertical line at 10% B_0 represents the hard limit, the orange line at 20% B_0 is the soft limit, and green lines are the % B_0 target (40% B_0) and the corresponding exploitation rate (catch divided by SSB F_{40} = 0.033 under average recruitment assumptions). Biomass and exploitation rate estimates are medians from posterior distributions for the base model. The blue cross represents the limits of the 95% credible intervals of the estimated ratio of the SSB to B_0 and exploitation rate in 2023.

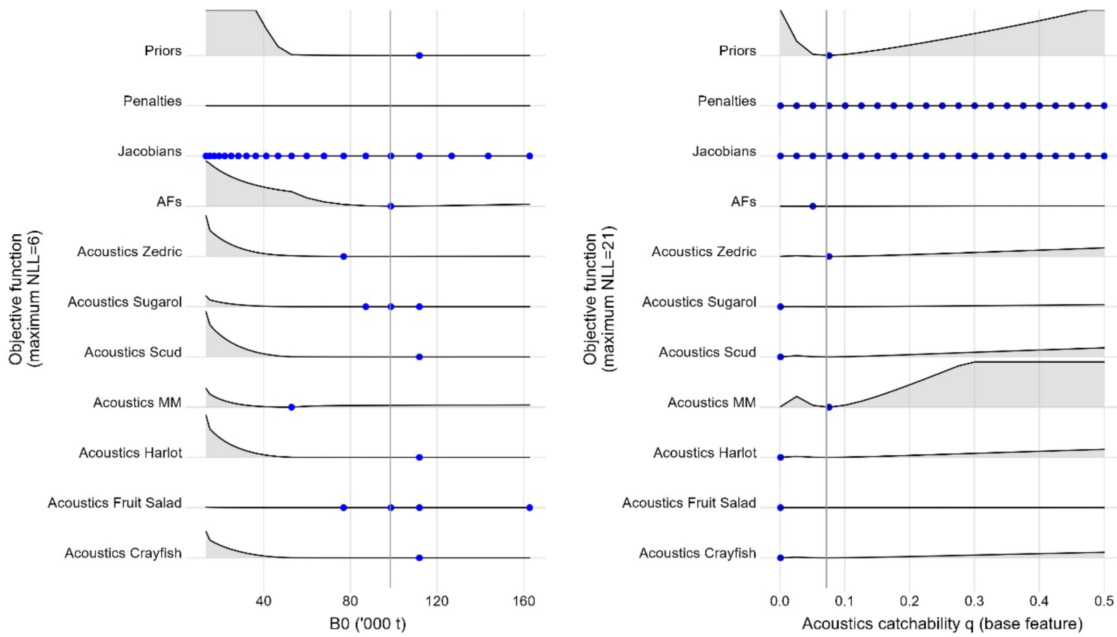


Figure 9. SWIOR MPD profile on B_0 (left) and acoustic catchability for M.M. (right) for the model with Sum(q) prior mean of 0.75 (R3.3). The blue dot represents the minimum for each series and the vertical line is the MPD estimated value. The maximum negative log likelihood (NLL) difference plotted is given in the y axis.

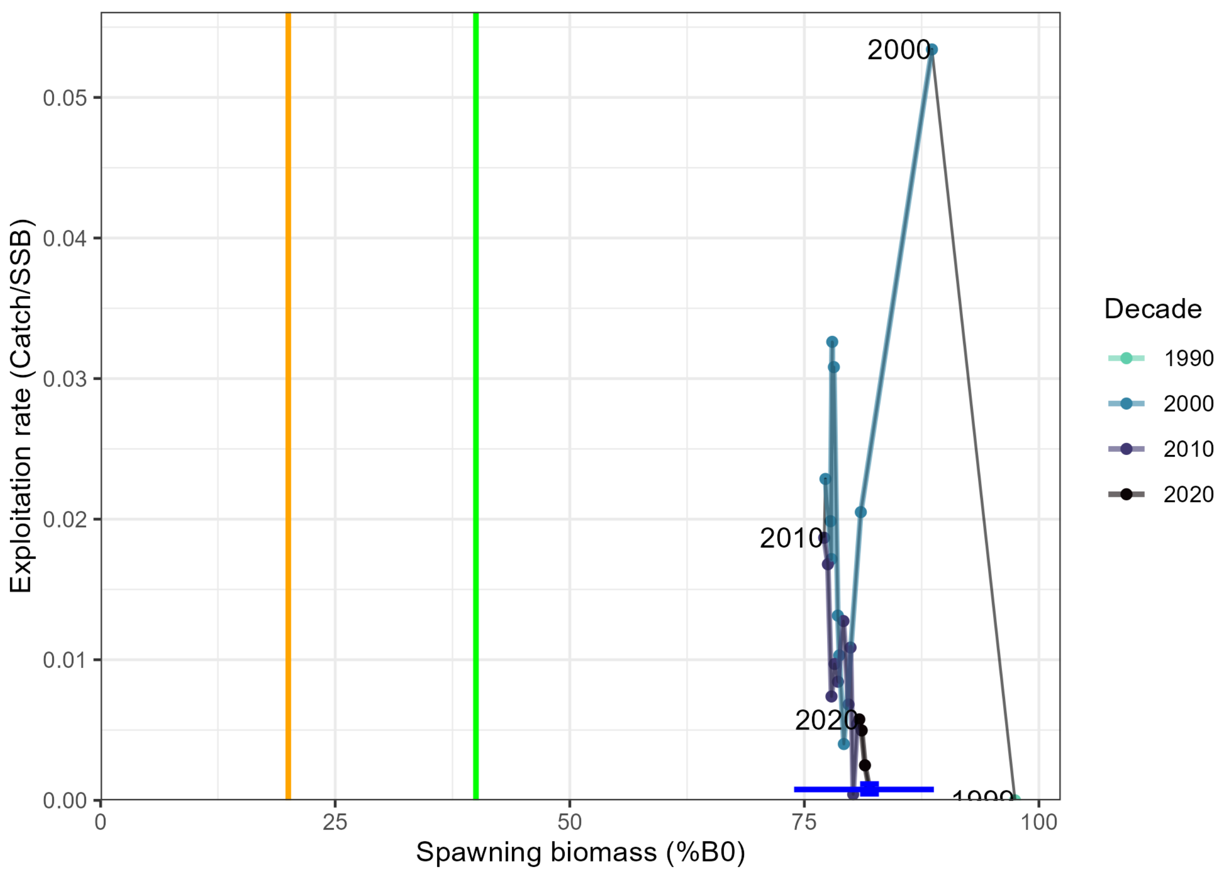


Figure 10. SWIOR R3.3 Kobe plot: trajectory over time of exploitation rate (catch/SSB) and spawning biomass (% B_0). The red vertical line at 10% B_0 represents the hard limit, the orange line at 20% B_0 is the soft limit, and green lines are the % B_0 target (40% B_0). F_{40} could not be calculated due to the high uncertainty in the model and is not plotted. Biomass and exploitation rate estimates are medians from posterior distributions for the base model. The blue cross represents the limits of the 95% credible intervals of the estimated ratio of the SSB to B_0 and exploitation rate in 2023.

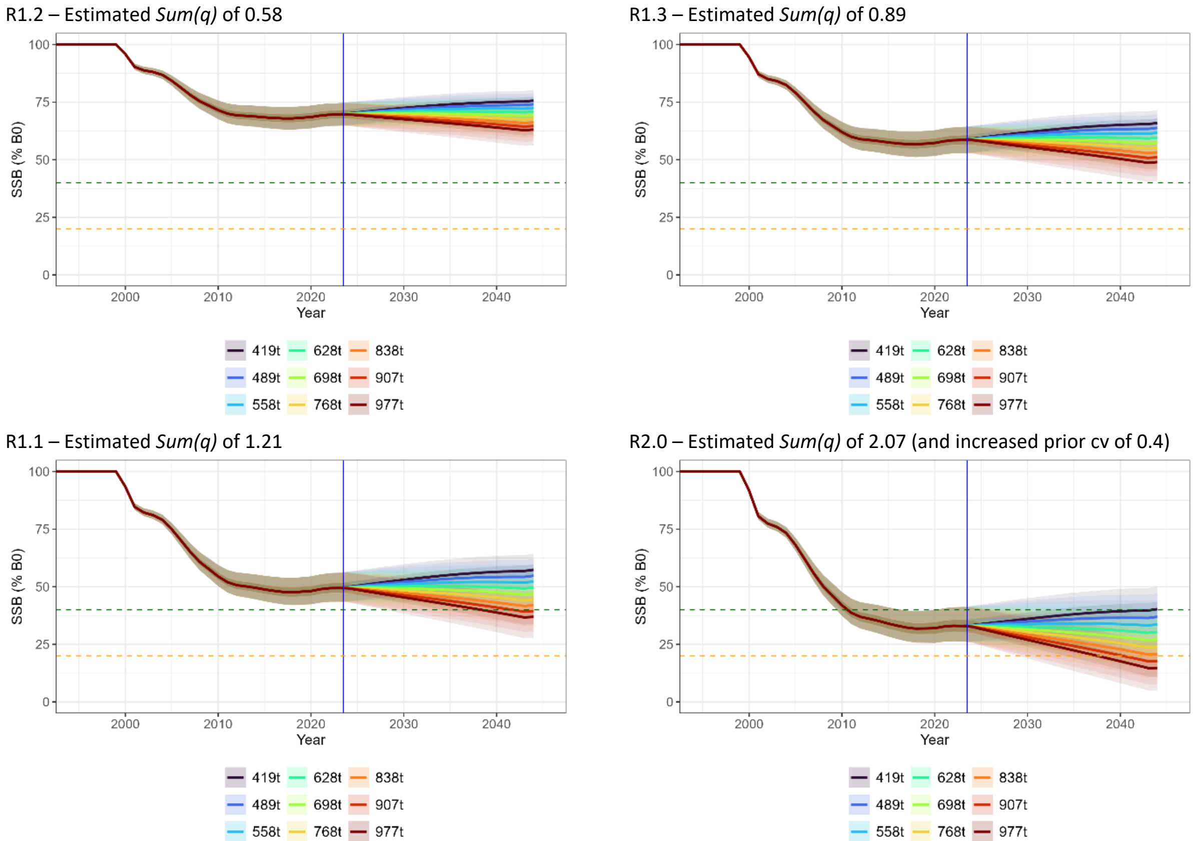
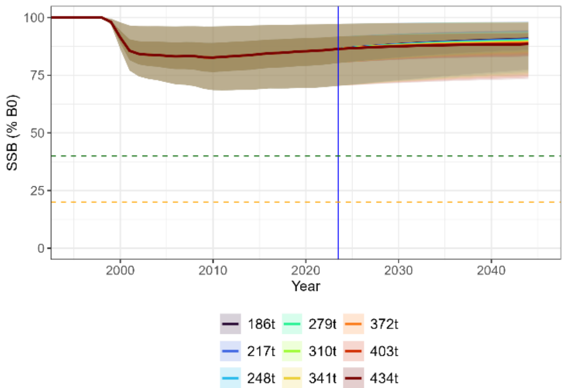
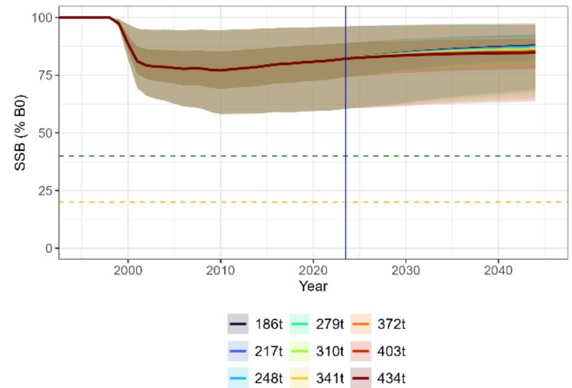


Figure 11. LWSR plots of the projections for the sensitivity runs.

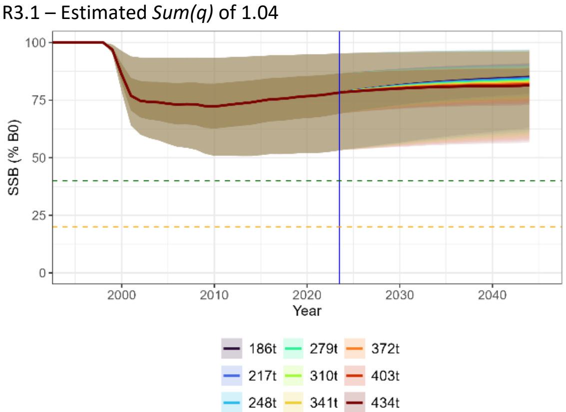
R3.2 – Estimated *Sum(q)* of 0.52



R3.3 – Estimated *Sum(q)* of 0.78



R3.1 – Estimated *Sum(q)* of 1.04



R2.1 – Estimated *Sum(q)* of 0.79 (and increased prior cv of 0.4)

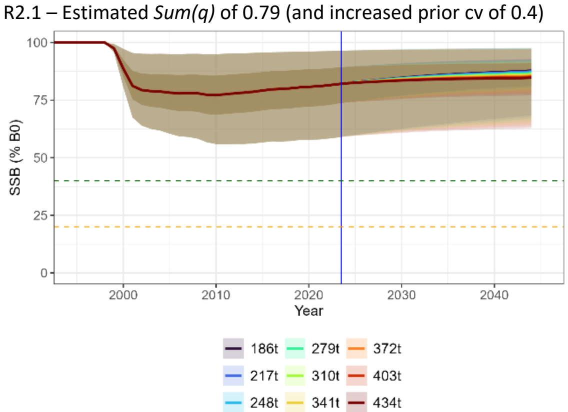


Figure 12. SWIOR plots of the projections for the sensitivity runs.

9. Appendix A – Additional outputs of the LWSR run R1.1 with a sum(q) prior mean of 1.0

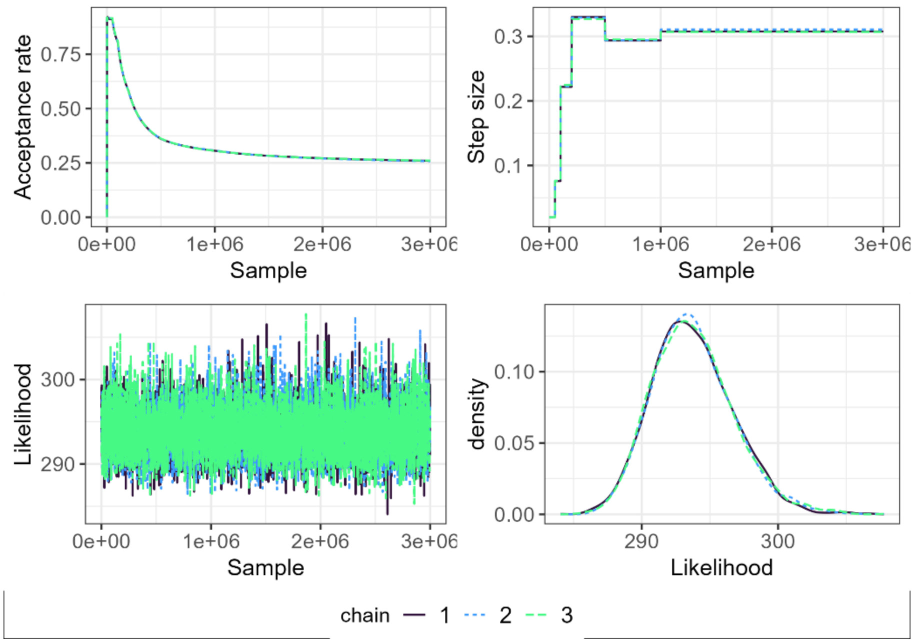


Figure A.1. LWSR MCMC diagnostic plots, showing the acceptance rate for each chain (top left), the adaptive step size for each chain (top right), the likelihood of the objective function as a function of the chain number (bottom left) and as a density distribution (bottom right) for R1.1.

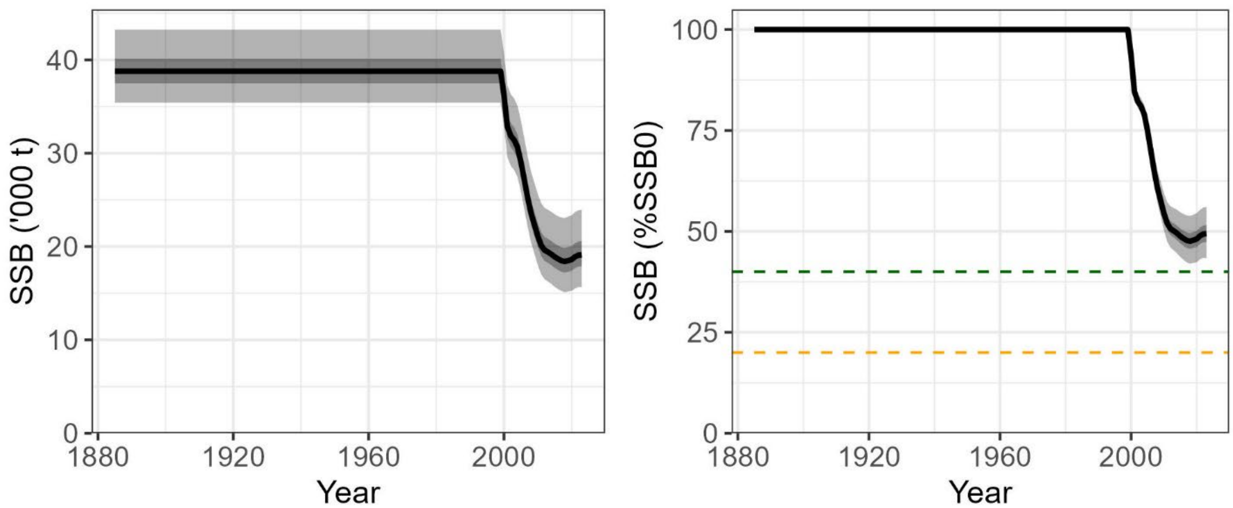


Figure A.2. LWSR MCMC estimates of spawning stock biomass (left) and status (right)for R1.1, with median (lines) and 95% credible interval (shading). Also shown 40% B_0 (green horizontal line) and 20% B_0 (orange horizontal line).

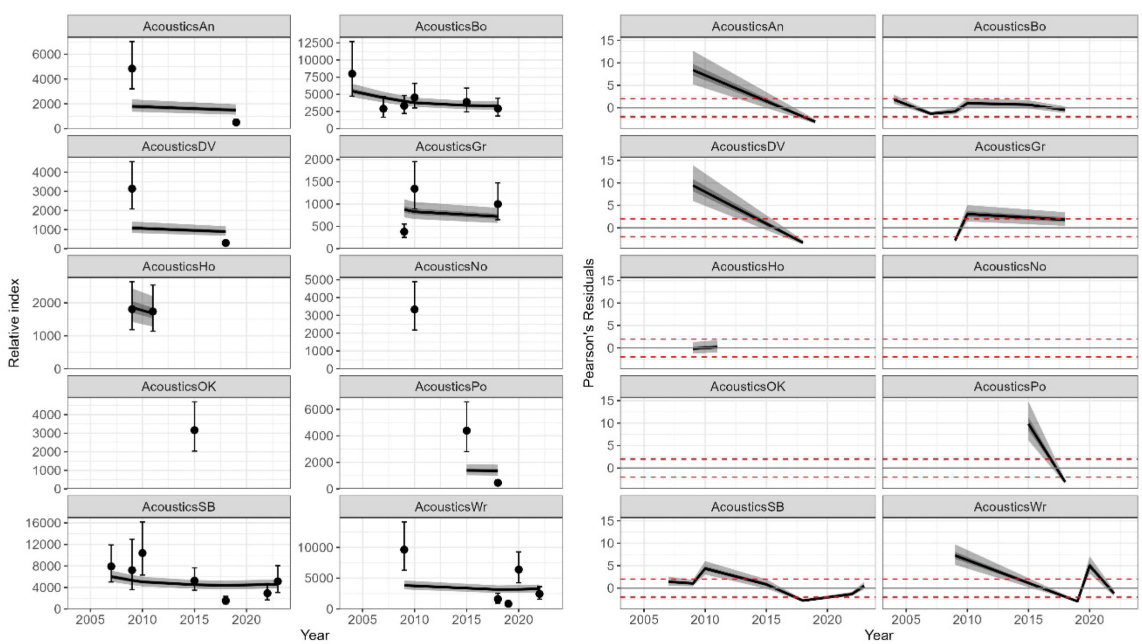


Figure A.3. LWSR MCMC median (black line), 95% credible intervals (dark area) and 50% credible intervals (light area) fits to the acoustic biomass and fishery CPUE series (left) and Pearson's residuals (right) for R1.1. Features are as follows: An – Angelo, B0 – Boulders, DV – Da Vinci, Gr – Grover, Ho – Hollows, No – Novel, OK – OK Coral, Po – Porky's, SB – Sleeping Beauty, Wr – Wrongford's.

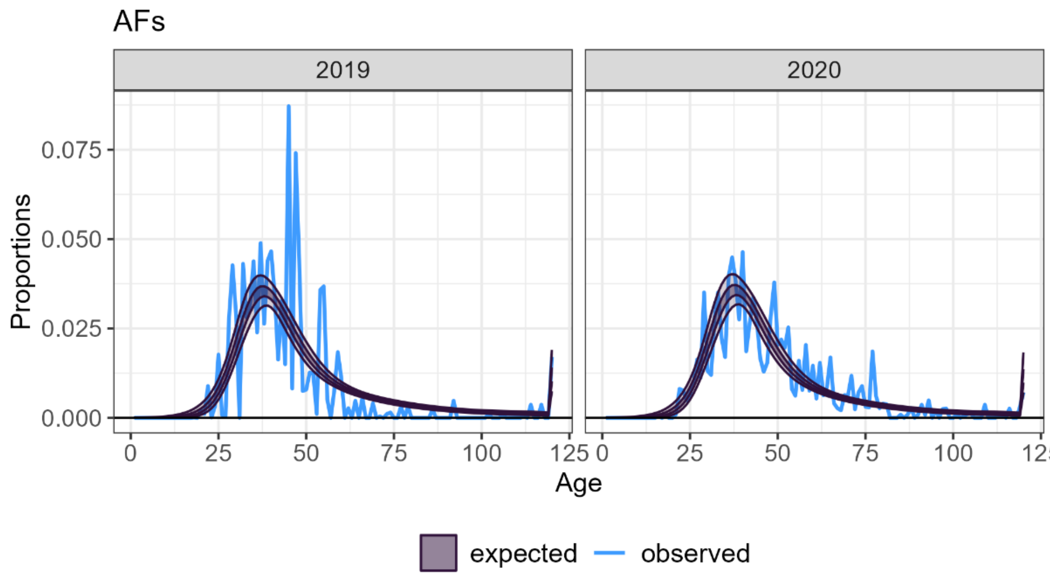


Figure A.4. LWSR MCMC 95% credible intervals (dark area) and 50% credible intervals (light area) fits to *the age frequency distributions (blue line) for R1.1.*

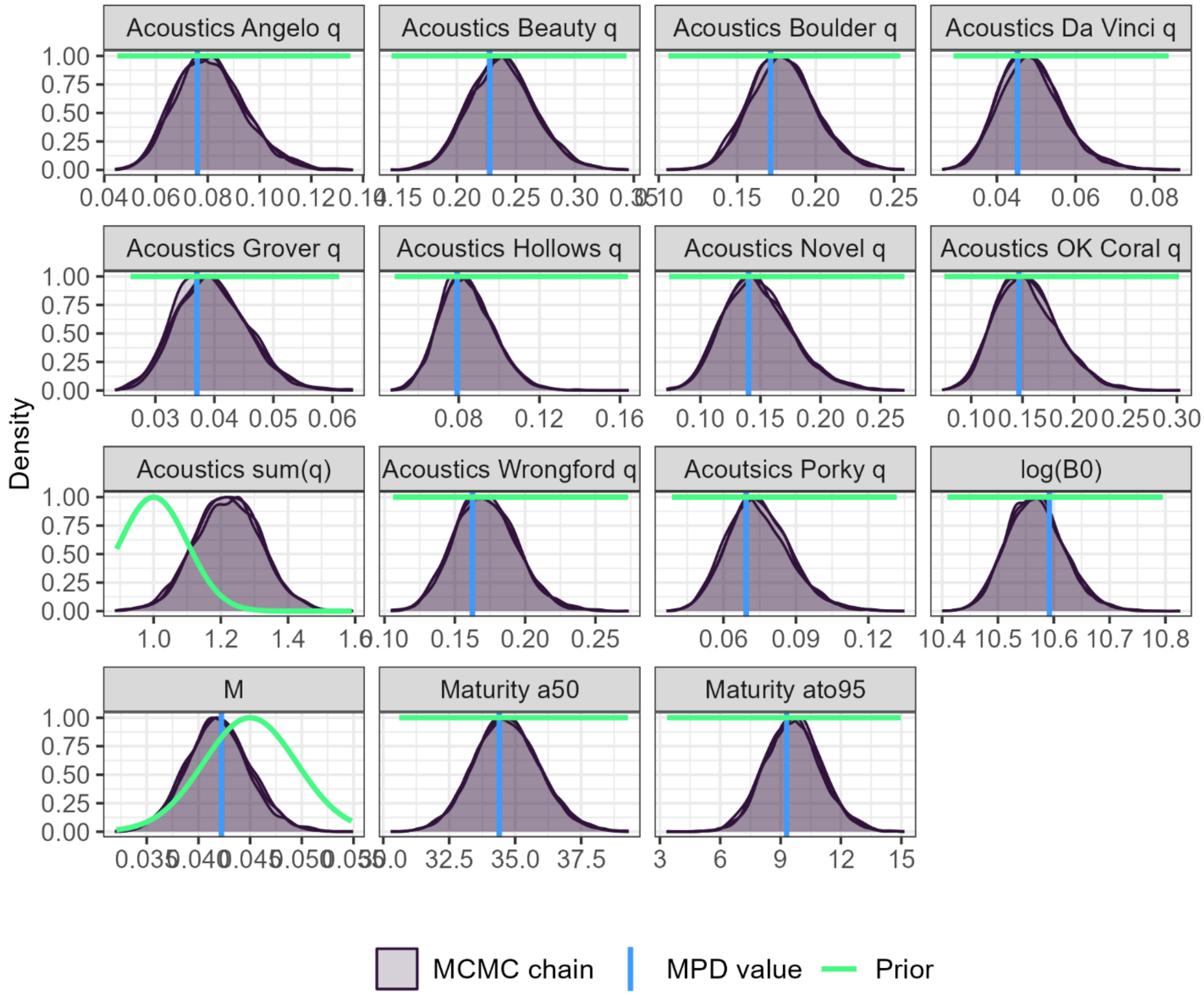


Figure A.5. LWSR MCMC density estimates of the catchability parameters of the three chains for R1.1, with maximum posterior density (MPD) estimated value and prior distribution. The additional prior on the sum of the acoustic catchabilities Sum(q) is also plotted.

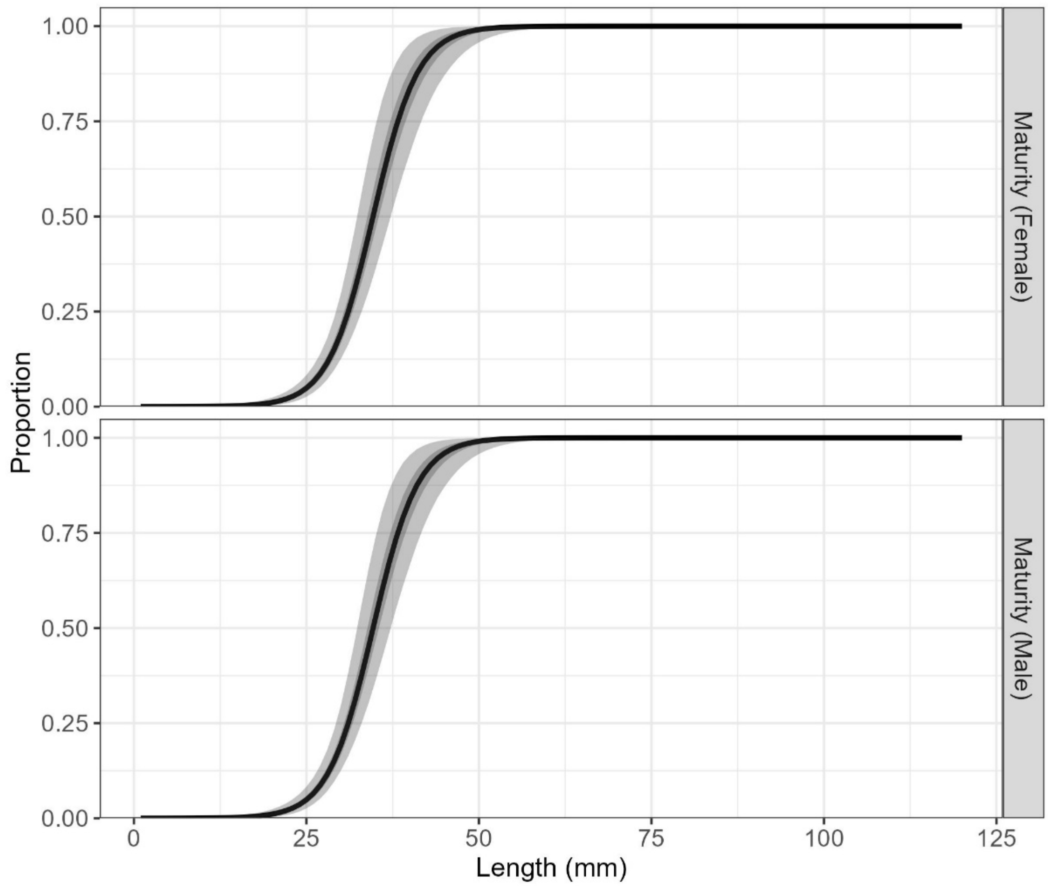


Figure A.6. LWSR MCMC median (black line), 95% credible intervals (dark area) and 50% credible intervals (light area) estimates of maturity (assumed equal to selectivity) for R1.1. Note that both males and females were forced to have the same maturity.

10. Appendix B – Additional outputs of the SWIOR run R13.3 with a sum(q) prior mean of 0.78

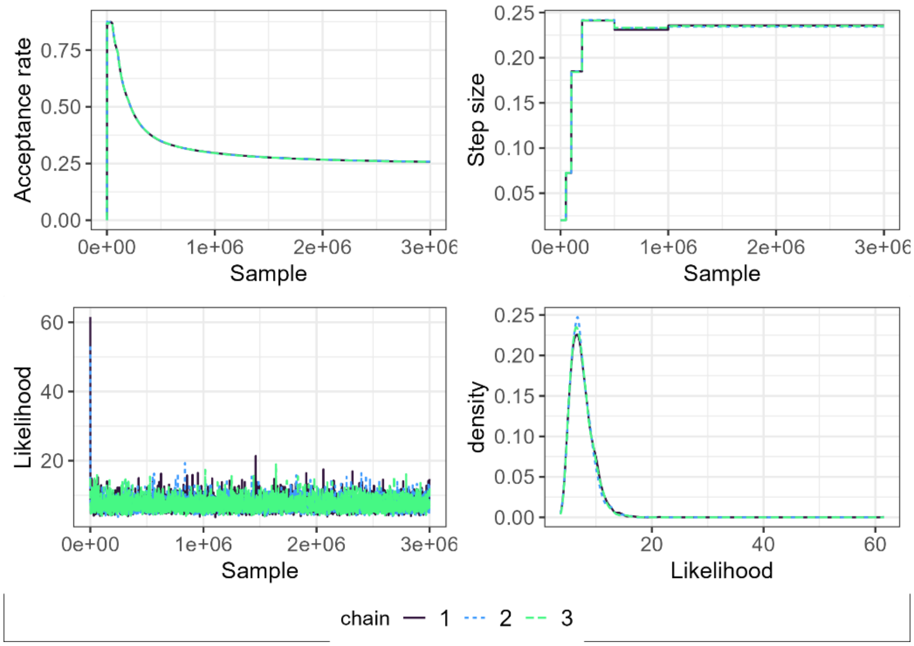


Figure B.1. SWIOR MCMC diagnostic plots, showing the acceptance rate for each chain (top left), the adaptive step size for each chain (top right), the likelihood of the objective function as a function of the chain number (bottom left) and as a density distribution (bottom right) for R3.3.

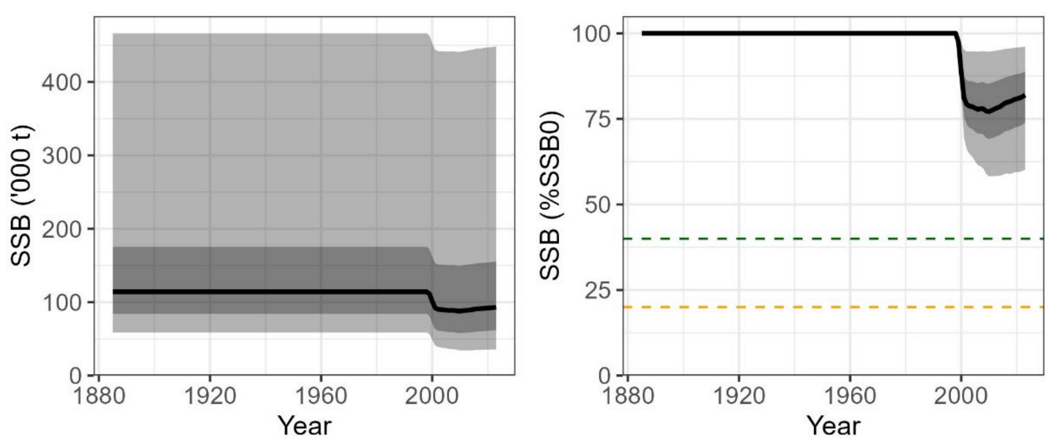


Figure B.2. SWIOR MCMC estimates of spawning stock biomass (left) and status (right)for R3.3, with median (lines) and 95% credible interval (shading). Also shown 40% B_0 (green horizontal line) and 20% B_0 (orange horizontal line).

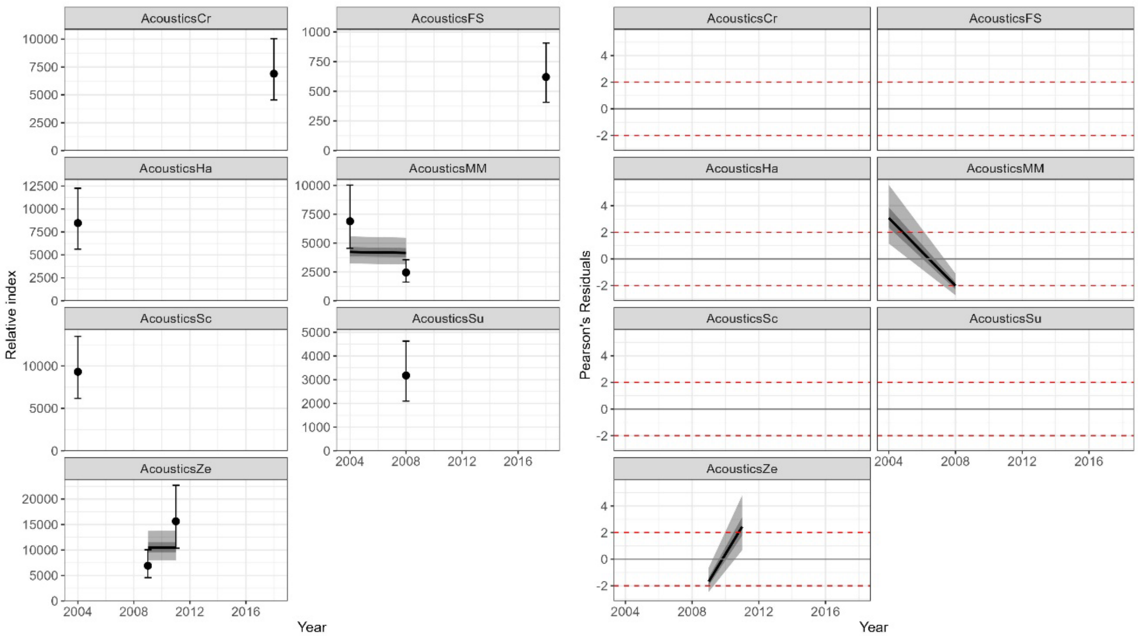


Figure B.3. SWIOR MCMC median (black line), 95% credible intervals (dark area) and 50% credible intervals (light area) fits to the acoustic biomass and fishery CPUE series (left) and Pearson's residuals (right) for R3.3. Features are as follows: Cr – Crayfish, FS – Fruit Salad, Ha– Harlot, MM – M.M., Sc – Scud, Su – Sugarol, Ze - Zedric.

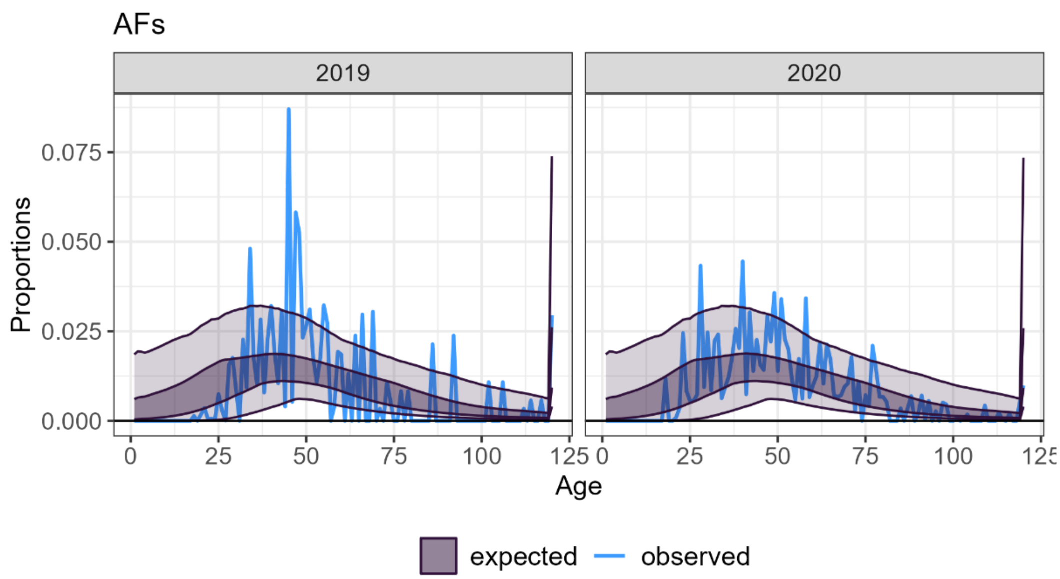


Figure B.4. SWIOR MCMC 95% credible intervals (dark area) and 50% credible intervals (light area) fits to the age frequency distributions (blue line) for R3.3.

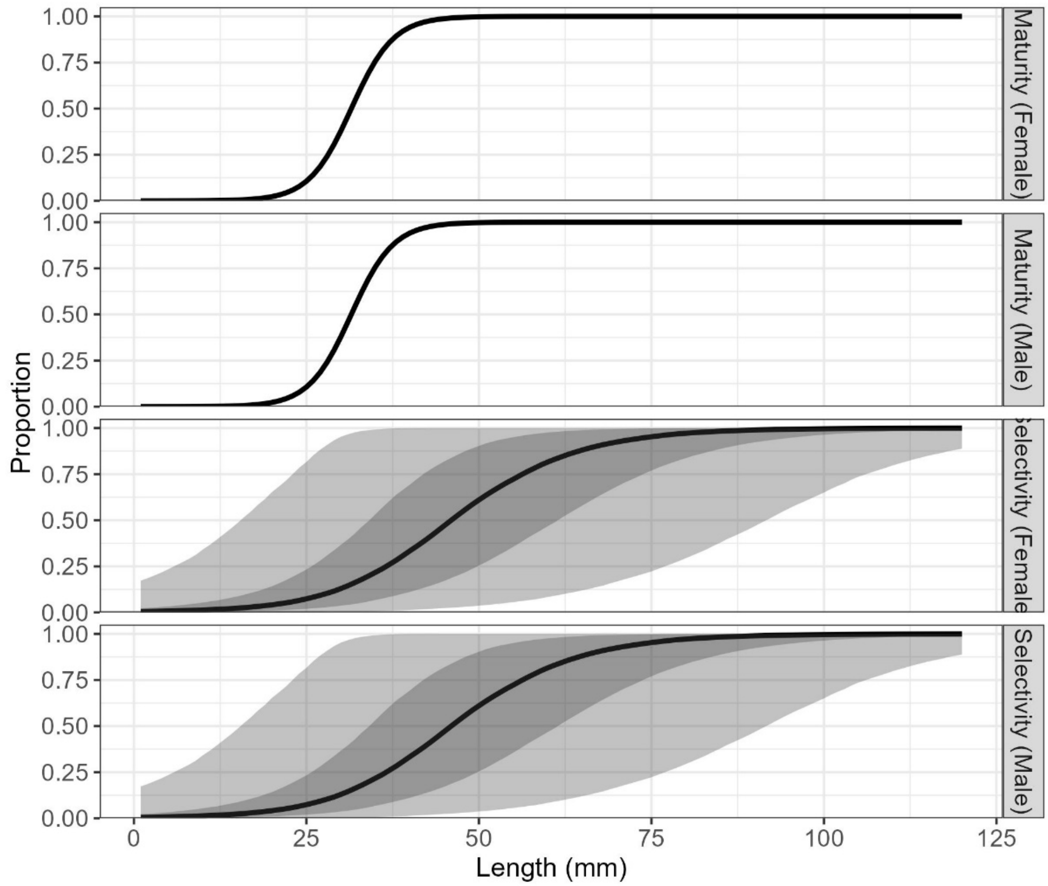


Figure B.5. SWIOR MCMC median (black line), 95% credible intervals (dark area) and 50% credible intervals (light area) estimates of selectivity for R3.3. The maturity assumption is also showed. Note that both males and females were forced to have the same maturity and selectivity.

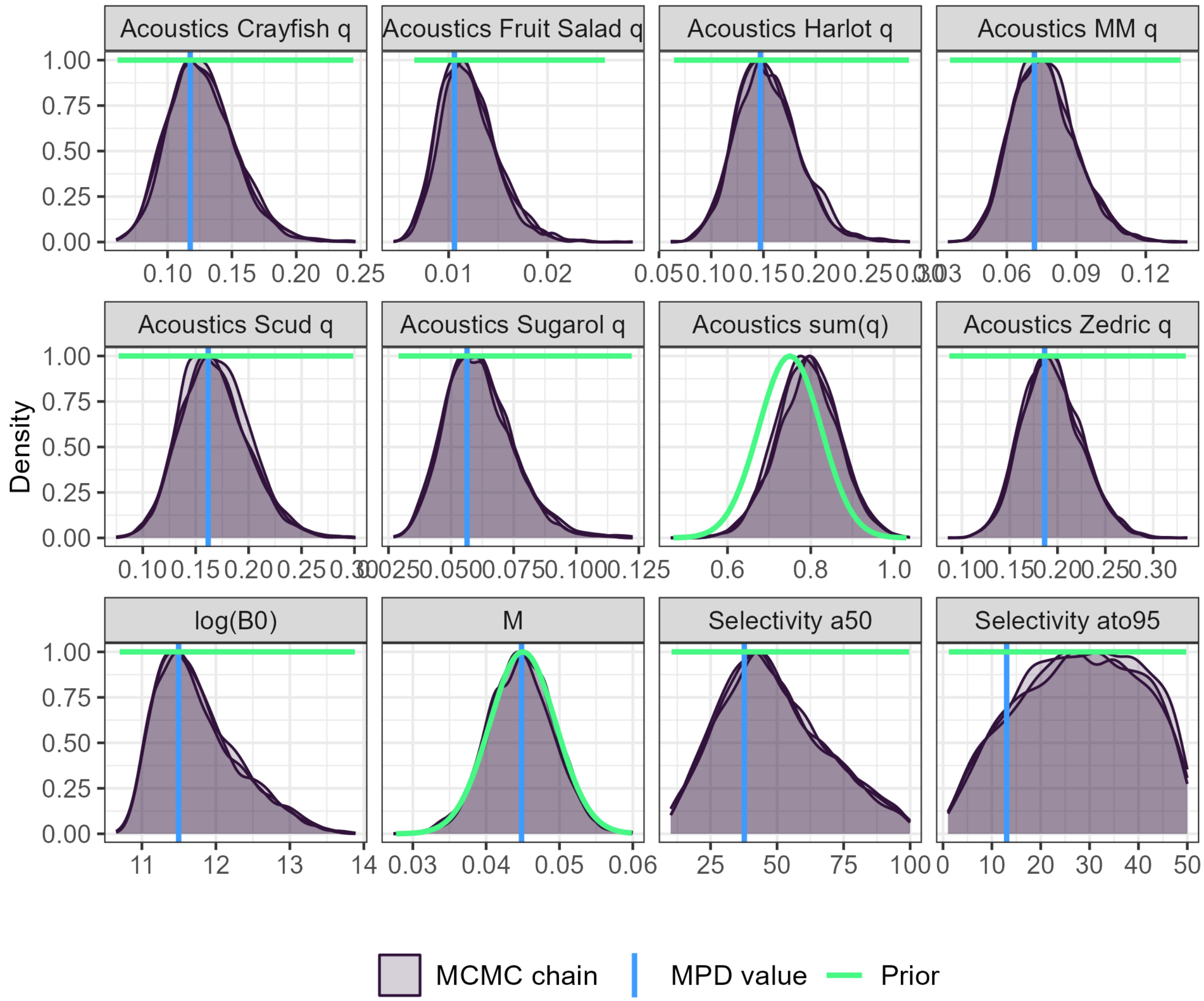


Figure B.6. SWIOR MCMC density estimates of the catchability parameters of the three chains for R3.3, with maximum posterior density (MPD) estimated value and prior distribution. The additional prior on the sum of the acoustic catchabilities Sum(q) is also plotted.

11. Appendix C: Terms of Reference

Project title: Orange roughy stock assessment (2024-2025)

Project Code: ORY-2024-01

Terms of Reference

1. Introduction

The SIOFA Scientific Committee (SC) provides scientific advice to the Meeting of Parties (MoP) on the status of stocks and sustainable yields of deep-sea fisheries resources. In 2018, the SIOFA Scientific Committee (SC3) conducted the first orange roughy stock assessments in the SIOFA region and provided advice to the Meeting of Parties on the stock status and sustainable yields for orange roughy. An updated orange roughy stock assessment was conducted and presented to SC7 in 2022.

As required under SIOFA CMM 15, orange roughy stock assessments are conducted every 3-5 years, and the next Scientific Committee (SC10) (March 2025) will consider the new orange roughy stock assessments to provide its advice to the MoP.

Summaries of the Scientific Committees advice from previous assessments are available in the reports from SC3 and SC7.

2. Methods

Undertake assessments of the orange roughy stocks in the SIOFA area. This should build on and improve the work of the two previous assessments (Cordue 2018a and b, Roa-Ureta et al. 2022). While there could be multiple sub-stocks of orange roughy in the SIOFA area, until work is completed on the stock structure, two stocks should be assumed: one on Long Walter's Shoal Ridge (LWSR, Walter's shoal, Walter's Shoal Ridge, and associated seamounts) and another on the South-west Indian Ocean Ridge (SWIOR, Meeting, South Ridge, Middle Ridge, and North Ridge) (Figure 1).

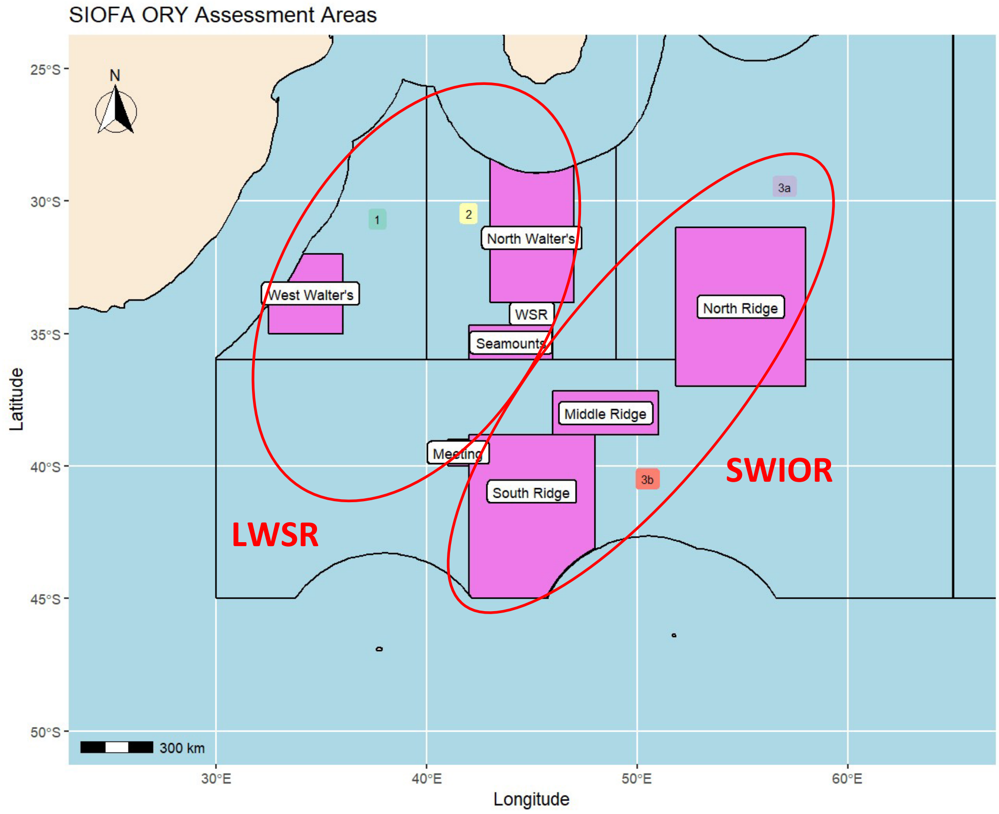


Figure 1 – Map of SIOFA Areas used for assessments (in magenta) for orange roughy as defined by Cordue (2018a, 2018b) and used by Roa-Ureta et al. (2022) (source: SIOFA Spatial layers). Labels indicate names of single assessment areas. Red ovals denote the grouping of single assessment areas into two larger management units for purposes of stock assessment by Roa-Ureta et al (2022). These management units are labelled Long Walter's Shoal Ridge (LWSR) and South-west Indian Ocean Ridge (SWIOR).

New information since the previous assessments include updated age and growth analyses, maturity analyses, acoustic biomass indices, and catch/effort data.

The outcomes of the assessments should be collated in a report and presented to SC10 in 2025. As a part of this project, the consultants will be required to present preliminary methods, draft reports, and results as they are developed to the project Advisory Panel for review.

3. Project objectives

1. During the project, present the work to the SIOFA orange roughy assessment Advisory Panel to discuss data inputs, the assessment approach, and preliminary results.
2. Develop standardised CPUE indices for each stock. Note this should standardise, to the extent possible, using factors such as location (e.g., area and seamount), season, gear parameters, alfonsino bycatch, prevailing weather, etc. As the fishery has been undertaken by 1-3 vessels only, standardisation by vessel may not be possible.
3. Review the previous stock assessments, and use all new information (including updated growth, maturity, and local area acoustic abundance data), and other relevant information to undertake a

statistical catch-at-age stock assessment to determine the stock status of orange roughy for Walters Shoal and the Southwest Indian Rise. The outcomes of the assessment should include the following:

a. Evaluation of the stock against the SIOFA interim reference points (Target = 40%B0 and Limit = 20%B_0). A range of other reference points should also be considered and estimates of stock status, fishing mortality, and biomass should be provided in the terminal year of the assessment and over time including, at least but not limited to status in relationship to B40% and B20%, MSY, SB_{MSY}, SB_0, $SB_{F=0}$, SB/SB_{MSY}, $SB/SB_{F=0}$, SB/SB_0, F, F_{MSY}, F/F_{MSY}, F40%B_0.
b. Appropriate sensitivities to model structural assumptions, choices of biological parameters, acoustic and CPUE abundance indices, and age composition data.
c. Estimates of 20-year projected status (at 5-year intervals) under a range of future catch scenarios and appropriate estimates of future productivity (i.e., year class strengths). Analysis should include projections using constant catch and constant fishing mortality strategies with both annual and 5-year changes in catch limits.
d. Kobe I (stock status trajectories) and appropriate Kobe II (strategy risk matrix) summaries of the stock assessment results. Refer to Table 1 below as an example of the Kobe II risk strategy matrix from Indian Ocean Tuna Commission (IOTC), showing risk probabilities violating target and limit reference levels for F and B (biomass) next 3 and 10 years in 9 different catch levels (0%, ±10%, ±20%, ±30% and ±40% of the current level).

4. Provide relevant text to update Section 6 of the SIOFA Fisheries Summary: orange roughy.

Table 1: Example of a Kobe II Risk Strategy Matrix.

Table 2. Albacore: SS3 aggregated Indian Ocean assessment Kobe II Strategy Matrix based on the model options (i) Model 1 (ii) Model 2 (iii) Model 3 (Model 4 was not used for management advice). Probability (percentage) of violating the MSY-based target (top) and limit (bottom) reference points for constant catch projections (2017 catch level, ± 10%, ± 20%, ± 30% ± 40%) projected for 3 and 10 years.

Reference point and projection timeframe	Alternative catch projections (relative to the catch level for 2017) and probability (%) of violating MSY-based target reference points ($SB_{targ} = SB_{MSY}$; $F_{targ} = F_{MSY}$)								
	60% (22,901)	70% (26,718)	80% (30,534)	90% (34,351)	100% (38,168)	110% (41,985)	120% (45,802)	130% (49,618)	140% (53,435)
$SB_{2020} < SB_{MSY}$	0.614	0.678	0.715	0.769	0.818	0.828	0.87	0.883	0.898
$F_{2020} > F_{MSY}$	0.074	0.224	0.4	0.556	0.654	0.731	0.766	0.788	0.782
$SB_{2027} < SB_{MSY}$	0.176	0.307	0.456	0.572	0.713	0.823	0.898	1	1
$F_{2027} > F_{MSY}$	0.002	0.085	0.287	0.473	0.718	0.878	1	1	1

4. Relevant SIOFA information

1. SIOFA data (provided by the SIOFA Secretariat upon request) 2.
SIOFA spatial data layers. Available at:
https://github.com/SIOFASecretariat/SIOFA_SC_Spatial_layers
3. SIOFA reporting templates. Available at:
https://github.com/SIOFASecretariat/SIOFA_Reporting_templates

4. SIOFA reports:
    a. SIOFA SC, SC Working Group, and National Reports. Scientific Committee Meeting | SIOFA (https://siofa.org/)
    b. SIOFA MoP reports. Meeting of the Parties | SIOFA (https://siofa.org/)
    c. SIOFA technical and scientific reports (public reports and abstracts of restricted reports are available from https://siofa.org/, and full restricted reports will be made available by the SIOFA Secretariat to the project consultant upon request and after the approval of relevant CCPs.

5. Key project indicators

1. Follow the project timeline as detailed in this agreement, including the submission of deliverables, to meet the project objectives.
2. Collect any necessary data as early as possible, e.g., by submitting a data request to the SIOFA Secretariat.
3. Attend the project pre-assessment electronic meeting with the Advisory Panel (composed of members of the SIOFA Scientific Committee and the SIOFA Secretariat) to discuss the project setup and development. Further engage, as requested, with the Advisory Panel during the project to assist the consultant access and interpret reports, data, and obtain the Advisory Panels advice on relevant analyses, methods, and data interpretation for the project.
4. Present preliminary results during the project, as required, to the project Advisory Panel, and respond and revise any project outputs based on their review.
5. Provide regular (i.e. every 2-3 months), proactive updates to the Project Coordinator and the Advisory Panel throughout the project, in particular informing promptly of any unforeseen delay or variations to the project.
6. Submit deliverables on time and appropriately formatted, as required. Each deliverable will go through a SIOFA review to ensure that it meets the quality targets and the project objectives as set out in the Terms of Reference.
7. Appropriately acknowledge the project funding source (SIOFA) within each deliverable.
8. Take into reasonable account the outcomes of the SIOFA review or any comments made by meeting attendees, when revising the deliverables.

6. Deliverables

1. Attend (virtually) the project Advisory Panel meetings.
2. Presentation of methods and results to the SIOFA SC annual meetings (March 2025) 3. A Draft Report that addresses the project objectives and tasks as laid out in this contract. Revise and update the Draft Report based on review by the project Advisory Panel, and the SIOFA Scientific Committee. The report should follow the guidelines and format available at https://github.com/SIOFASecretariat/SIOFA_Reporting_templates. In particular, the report should include a concise (max 300 words) summary, and should detail the methods, the outcomes, conclusions, and concise recommendations. The Draft Report will also be submitted to the SIOFA Scientific Committee.
4. Provide relevant revisions to Section 6 of the SIOFA Fisheries Summary: orange roughy.
5. A Final Report that follows the guidelines and format available at https://github.com/SIOFASecretariat/SIOFA_Reporting_templates and includes any review

comments from the SIOFA Scientific Committee on the Draft Report. The Final Report will also be submitted to the next SIOFA Scientific Committee.

6. Provide all the information collected as a part of this project to the SIOFA Secretariat (including that sourced from the Secretariat) before the final payment of the contract. Such information includes electronic data files, analysis code, biological samples, and other relevant data where applicable.
7. Presentations of reports to the Scientific Committee may be given virtually and travel to the meetings is not obligatory. All project meetings will take place virtually. No additional travel costs will be paid.

7. Acceptance of Draft and Final Reports

1. Draft and Final Reports must be submitted in English to the Project Coordinator at the SIOFA Secretariat.
2. Draft and Final Reports will be reviewed using the procedures outlined in paper MOP-09-12 (Annex B), see also: https://github.com/SIOFASecretariat/SIOFA_Reporting_templates/tree/main/SC%20reports/Review%20template%20for%20consultant%20reports.
3. Payment of contracts milestones will be subject to acceptance of the submitted reports by SIOFA.

8. Intellectual property clause and confidentiality

The Consultant shall submit all the information collected to the SIOFA Secretariat (including that sourced from the Secretariat) before the final payment of the contract is made to the consultant.

Such information includes electronic data files, analysis codes, biological samples, and other relevant data if applicable. Any arrangements for ownership, storage, or disposal of physical samples shall be agreed by SIOFA as a part of the contract. All Intellectual Property generated as a part of this contract shall become the property of SIOFA unless otherwise excluded in the proposal and agreed by SIOFA in the contract.

The Consultant shall not release confidential data provided for conducting this study to any persons nor any organizations, other than SIOFA Secretariat.

The Consultant shall delete all the confidential data upon the completion of the contract.

9. Work timeline and payment schedule

The funds for this project, budgeted under the SIOFA budget, allow for a maximum total budget of 50,000 Euro (including all costs and any travel related expenses).

The consultant shall follow the timeline described in Table 1 below.

Table 1: Timeline for payments, milestones, and report submission

Milestone	Date	Activities
Initiation of contract	September 2024	First instalment payment (30% of the total contract sum)

Delivery of draft report	30 January 2025	Second instalment payment (30% of the total contract sum) upon satisfactorily submission of draft report, in a format suitable for submission to SC, to the Project Coordinator. The draft report will be submitted to SC10 (on 15 February).
Presentation of preliminary results	17-26 March 2025	Presentation of preliminary methods and results to the SC10 meeting (virtual)
Delivery of final report	15 April 2025	Submission of final report in a format suitable for submission to SC and submission of all project information to the project coordinator. Final instalment payment (40% of the total contract sum) on acceptance of the final report by the advisory panel and the final submission of project information

10. Submission of applications

1. A current CV that summarises the applicant(s) relevant educational background and professional experience.
2. A brief proposal (indicatively 3-4 pages) outlining the proposed methods and analyses, including a description of how the objectives of the ToR will be achieved.
3. Any proposed exclusions to the intellectual property clause or variations to the work timeline and payment schedule.
4. The proposed consultancy price (including all consultant expenses and project related costs), noting that the available budget for this work indicated in Section 9.
5. Identification of any project risks and associated mitigation and management required to successfully complete the project.
6. A statement that identifies any perceived, potential, or actual conflicts of interest of the applicant(s), including those described in paragraph 4 of the SIOFA recruitment procedure (see Section 12), and

7. Any additional relevant information the applicant(s) wish to submit.

The applicants must have appropriate experience and knowledge of similar work in their portfolio.

Applications must be submitted to the SIOFA Science Officer Marco Milardi (marco.milardi@siofa.org, CC secretariat@siofa.org). Only those applications received before 12:00 PM (9:00 AM UTC) on Sunday the 1st of September 2024, Reunion Island time, will be considered.

11. Evaluation criteria for the selection of candidates

An evaluation panel, the SIOFA Secretariat, and the Chair and Vice-Chair of the SIOFA Scientific Committee will select one successful applicant for this contract. The selection criteria will include the following:

1. Adequate submission of information to allow the panel to evaluate the candidate
2. Evaluation of the proposal from the candidate, including the proposed contract price
3. Ability to undertake and complete the analyses or work required in this ToR
4. The candidate's agreement with confidentiality provisions required for the project
5. Acceptable conflict of interest statement
6. Agreement with the data submission and intellectual property terms required in this ToR, and
7. Financial and resourcing considerations.

12. Conflicts of interest. Paragraph 4 of SIOFA's Recruitment Procedure

To ensure that situations relating to potential and actual conflict of interests are avoided, persons falling into the following categories may not normally be considered for SIOFA consultancy: (i). any person designated as a designated representative or alternate representative of a CCP to the Meeting of Parties (MOP) as per Rule 3.1 of the Rules of Procedure, and to the SC and any other subsidiary bodies of the MOP, as per Rule 21.3 of the Rules of Procedure; (ii). Any person fulfilling the function of Chair or Vice-Chair of the MOP or Chair or Vice-Chair of a SIOFA subsidiary body or working group; (iii). Any person acting as a member of a delegation involved in the SIOFA decision-making process resulting in recommendations and/or approval for the SIOFA work requiring the engagement of a consultant; and (iv). Individuals who were SIOFA Secretariat staff members at the time when the recommendations and/or approval for the SIOFA works were adopted or who are members of immediate family (e.g., spouse or partner, father, mother, son, daughter, brother, or sister) of any Secretariat staff member or of the persons identified in 4 (i), (ii), and (iii).

13. Contacts

Project Coordinator – SIOFA Science Officer (Marco Milardi, marco.milardi@siofa.org)

Administration – SIOFA Executive Secretary (Thierry Clot, thierry.clot@siofa.org)

14. References

Cordue, P. 2018a. Stock assessment of orange roughy in the Walter's Shoal Region. SAWG(2018)-0105 Rev1, SIOFA. Available at:

https://siofa.org/sites/default/files/documents/meetings/SC-03-07.1.1%2804%29%20Rev1%20Stock%20assessment%20of%20orange%20roughy%20Walter%27s%20Shoal.%20Cordue%2C%202018_0.pdf

Cordue, P. 2018b. Assessments of orange roughy stocks in SIOFA statistical areas 1, 2, 3a, and 3b. SAWG(2018)-01-06 Rev 1, SIOFA. Available at:

https://siofa.org/sites/default/files/documents/meetings/SC-03-07.1.1%2805%29Rev1%20Assessment%20of%20orange%20roughy%20stocks%20SIOFA%20Areas%201%2C%202%2C%203a%20and%203b.%20Cordue%2C%202018_0.pdf

Roa-Ureta R. et al. 2022. Stock Assessment of the orange roughy (*Hoplostethus atlanticus*) under management by the Southern Indian Ocean Fisheries Agreement (SIOFA): 2000 to 2020. SC-07-35, SIOFA. Abstract available at:

https://siofa.org/sites/default/files/documents/meetings/SC-07-35-%5BABSTRACT%5D-ORY-stockassessment-2021-v4-reduced.pdf The full version will be made available on request to the successful consultant.