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Development of harvest strategies for key SIOFA fish stocks (SIOFA PAM-2024-03) Final Report

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Executive summary

The SIOFA-PAM project has aimed to progress the SIOFA precautionary approach to management (PAM). Project PAM-2024-01 developed a management framework, PAM-2024-02 provided proposed biological reference points for the main SIOFA stocks, and PAM-2024-03 carried out testing of potential harvest control rules (HCRs) through management strategy evaluations (MSE, this report). It is important to note that this body of work is a step towards precautionary approach to fisheries management rather than final outcomes. Further iterations of this process, including further management strategy evaluations, should be carried out following feedback from SIOFA.

The species considered as test cases in this body of work were orange roughy and alfonsino. These were test cases for processes and principles rather than aiming at developing final harvest control rules. Although toothfish was initially considered, CCAMLR is undergoing its own MSE process for toothfish, which is likely to be adopted by SIOFA and therefore this species was not investigated further.

Results of PAM-2024-03 indicated that hockey-stick based rules were likely appropriate for stocks with full Bayesian stock assessments, and for those stocks where acoustic estimates of biomass were available. These rules were relatively robust to model misspecification as long as the mis-specified parameters could be adequately modelled. More conservative rules were preferred, particularly if stocks were below target.

Results of PAM-2024-03 further indicated that for stocks with CPUE indices representative of the underlying biomass, CPUE-based rules could be applied, although the setting of the reference catch limit would determine where the stock status would eventually settle.

Finally, for stocks with length data only, a range of length-based methods could be used. Early indications suggested that the stock status of alfonsino using length-based spawner per ratio as an indicator was consistent with the full stock assessment outcomes. A combination of CPUE-based and length-based rules might help to strengthen the management actions.

Performance measures were proposed, for assessed stocks, for management strategy evaluations, and also for stocks that are not currently assessed. These were based on a traffic-light system, with three levels of outcomes. The model-based and MSE-based performance indicators were tested against the species investigated. They seemed to capture most of the relevant information and should be easy to apply. Further performance indicators could be added if required. The fishery-based indicators were not investigated here as they are aimed at low information stocks with no assessment, including bycatch species where applicable. They could be tested by the SIOFA Secretariat on some stocks.

The development of stock assessment models for alfonsino suggested that the status of the east stock may be lower than when assessed in 2020. These models should be updated with full length data investigations, updated ageing and further investigations into selectivity and maturity curves be undertaken.

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1. Introduction

1.1 Project objectives (see Appendix I)

The project objectives, as per the terms of reference of the tender document, are as follows.

1. To consider monitoring strategies and develop harvest control rules and undertake management strategy evaluations designed to help ensure sustainable fisheries within the SIOFA Area, including:
    a. Harvest control rules that are suitable for a range of different levels of available data.
    b. Management strategies that consider the trade-offs between different harvest control rules, levels of risk, and achievement of management objectives.
    c. Breakout rules and default breakout actions.
2. Evaluation of different stock assessment options, based on the level of data available, for key SIOFA fish stocks, and specifically including orange roughy (*Hoplostethus atlanticus*) and toothfish (*Dissostichus eleginoides*).
3. Evaluate how additional objectives such as bycatch, fisheries impacts, benthic impacts, etc., could be included as part of harvest strategies.

1.2 Collaboration and Integration

This project was carried out in close collaboration with projects PAM-2024-01, which identified appropriate policy settings and management approaches, and PAM-2024-02 which developed biological reference points for those key SIOFA species (Mormede 2025; Mormede et al. 2025b; Mormede & Hoyle 2025a; Robertson et al. 2025). It also incorporates feedback from the SIOFA PAM review panel, covered under project PAM-2024-04 and SIOFA workshops WS2025-PAM1 (3rd – 4th February 2025), WS2025-PAM2 (6th August 2025) and WS2025-PAM3 (7th October 2025).

The same modelling frameworks were used to develop and test both the biological reference points (project PAM-2024-02) and the harvest control rules that use those reference points (project PAM-2024-03).

2. Background

2.1 Harvest strategies in SIOFA

Harvest strategies / harvest control rules (HCR) are a pre-agreed set of management decisions such as setting catch limits (e.g., SIOFA Scientific Committee Chair and vice-Chair & SIOFA Meeting of the Parties Chair 2023). These are typically developed and tested using a management strategy evaluation framework (MSE, Figure 1). MSE will typically test various HCRs under multiple model assumptions such as stock productivity and management decisions such as reference points (Punt et al. 2016a). Harvest control rules are typically developed through multiple iterations of MSEs with feedback from stakeholders / managers with regards to what rules and reference levels should be tested. A glossary of commonly used terms is provided in 'Appendix A – glossary'.

At their 10th annual meeting, the SIOFA Parties endorsed the development of harvest strategies for selected SIOFA stocks. Two intersessional workshops followed: SIOFA-WS2023-HSMO and SIOFA-WF2024-HSS, and harvest strategies have been on the SIOFA agenda thereafter. A number of decisions have been made by SIOFA with regards to harvest strategies, including potential management objectives and performance indicators for orange roughy and toothfish (SIOFA-SC9

Annex H and I respectively), potential breakout rules (SIOFA-WS2023-SHMO), and potential performance indicators (SIOFA-WS2024-HSS).

Initial principles for developing harvest control rules in SIOFA were developed by Butterworth et al. (2021), and endorsed by SIOFA. These are, ordered from high information to low information stocks:

- High / medium information stocks: Implementing a harvest strategy based primarily on some multiple of a proxy value of F_{MSY}, where this in turn is based on a proxy value for a B_{MSY} reference point whose value is informed by the most recent assessment of the resource.
- Medium / low information stocks: Implementing an $F_{status\text{-}quo}$ harvesting strategy, which varies catches up or down in proportion to the results from continued collection of some measure or index of abundance.
- Low / zero information stocks: Maintaining catches at present levels (unless there is evidence of a marked downward trend in the resource) until sufficient further data become available for meaningful improvements to the existing assessments.

It was noted that most stocks within SIOFA were in the low / zero information stock category, and therefore management strategy evaluations should initially be tested on orange roughy and toothfish, which were deemed to have the most available information.

The present document reports initial testing of a number of potential harvest control rules and reference levels. These are not final: further testing and tuning of these rules (and others) and reference levels will be required in the future following input from SIOFA prior to the adoption of harvest control rules. Furthermore, these are always subject to further development, particularly should knowledge on the specific stocks change (e.g. change in the natural mortality assumption) or additional information be collected. This continual development process is discussed further in the PAM-2024-01 project report (Robertson & Holmes in prep).

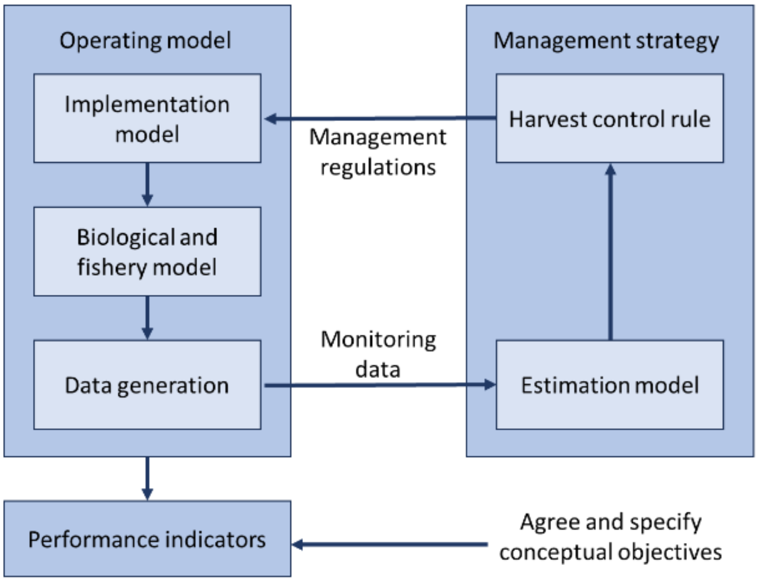

Figure 1: Conceptual overview of the management strategy evaluation modelling process (Figure 1 in Punt et al. 2016b).

3. Methodology

The two main species of interest for this project were orange roughy and toothfish. However, given that toothfish harvest control rules are likely to align with those developed by CCAMLR, the SIOFA-WS2025-PAM2 workshop agreed that alfonsino (*Beryx splendens*) should be investigated instead of toothfish. A summary of the status of the development of harvest control rules for toothfish in CCAMLR is discussed below.

3.1 Proposed classification of stocks

Project PAM-2024-01 recommended the classification of SIOFA stocks for both the information classification (high / medium / low) and the stock status (healthy / under watch / critical). This classification then feeds into a tiered process for management of the stocks (Robertson & Holmes in prep).

3.2 Potential indicators and reference points

Project PAM-2024-02 developed a framework of potential indicators and reference points (Table 1).

3.2.1 Potential indicators

The indicators proposed range from model-based estimates of spawning stock biomass (SSB) for the highest-information stocks, to catch per unit effort (CPUE) or length-based spawner potential ratio (SPR) for low information stocks. Multiple indicators could be used together to increase the robustness of the advice.

Because the orange roughy fishery operates on spawning aggregations, and because search effort is not adequately represented by the standardized CPUE index, CPUE is not deemed a reliable index of abundance and therefore not proposed here as a potential indicator. It can be argued that this is also the case for alfonsino as it is an aggregation fishery and search effort is not adequately included in the CPUE. The use of CPUE is further marred by standardisation issues and data limitations such as the fact that many fisheries involve a single vessel. However, due to the lack of current alternatives, the use of CPUE for alfonsino was also tested in this project, assuming for the sake of illustration that CPUE provides an adequate index of abundance. The time reference for the alfonsino CPUE-based reference points was set at 2010-2013 to match data available within the existing stock assessments (see results below). For other species, the CPUE-based reference was set at the time reference used for setting catch limits (see Appendix B – summary of stock status).

Should an acoustic index become available for alfonsino, then an F-based indicator could be useful.

The WS2024-HSS workshop on harvest strategies recommended that total allowable effort should be considered for orange roughy alongside total allowable catch. However, if CPUE is not deemed a reliable index of abundance for orange roughy, effort limitation is also unlikely to be suitable for this species. Therefore, total allowable effort has not been considered further at this stage but could be included in future work considerations. Changes in effort quantity and spatial distribution has been included in the proposed management performance indicators / breakout rules (see Section 3.8).

3.2.2 Potential reference points

Reference points are management decisions to be made by SIOFA. Some, such as SSB targets (e.g., x% B_0) may be decided directly, while others such as the target fishing mortality (F_{TARGET}) can be calculated based on the assumed SSB targets and stock assessment model assumptions, or based on first principles, here at 0.87 M (where M is natural mortality), see Hoyle & Mormede (in prep) for the rationale.

Model-based F_{TARGET} values were calculated for orange roughy and alfonsino under various options of SSB targets and model assumptions. These are detailed in the results section; the final value(s) will depend on preferred SSB targets and model assumptions. Toothfish targets were based on the CCAMLR management procedure for research blocks (Secretariat 2025), which is also applied within SIOFA.

Table 1: Some potential reference points for the species under consideration, based on PAM-2024-02 proposed classification. Note that multiple reference points can be considered for a single species, as alternative options or to be used in conjunction with each other. The probability in bracket is the required probability of being above the target or limit. B_0 = initial biomass, SSB = spawning stock biomass, $VulnB_{current}$ = current vulnerable biomass, CPUE = catch per unit effort, SPR = spawning potential ratio, C = catch, F = exploitation rate.

Species	Indicator	Target (probability)	Limit (probability)
Orange roughy	SSB (model-based)	40% B_0 (p>50%)	30% B_0 (p>90%)
	Fishing mortality	F =0.033	F = 0.0495
	$VulnB_{current}$ (acoustics)	C = 0.033 $VulnB_{current}$ (p>50%)	C = 0.0495 $VulnB_{current}$ (p>90%)
Toothfish	SSB (model-based – currently unknown)	50% B_0 (p>50%)	20% B_0 (p>90%)
	$VulnB_{current}$ (CPUE by seabed area)	C = 0.04 $VulnB_{current}$ (p>50%)	
Alfonsino	SSB (model-based)	40% B_0 (p>50%)	20% B_0 (p>90%)
	Fishing mortality	Model-based F_{TARGET}* (p>50%)	150% F_{TARGET} (p>90%)
	Standardised CPUE	mean(2010-2013) (p>50%)	50% of target (p>90%)
	SPR from LB-SPR	0.45	0.3
	F from LB-SPR	F_{TARGET} = 0.87M (p>50%)	150% F_{TARGET} (p>90%)
Hapuka / Mora / Oilfish	Fishing mortality	F_{TARGET} = 0.87M (p>50%)	150% F_{TARGET} (p>90%)
	Unstandardised CPUE	mean(set years) (p>50%)	50% of F_{TARGET} (p>90%)
	SPR from LB-SPR	0.5	0.3
	F from LB-SPR	F_{TARGET} = 0.87M (p>50%)	150% F_{TARGET} (p>90%)

* The model-based F_{TARGET} potential value for alfonsino developed in this work is highly uncertain and could range from 0.088 to 0.218 depending on assumptions of ageing and mortality (Table 9). F_{TARGET} should be calculated once ageing and modelling have been updated.

3.3 Potential harvest control rules

As discussed in PAM-2024-01 and PAM-2024-02 project reports and in Section 3.2 of this report, the types of harvest control rule that can be applied will depend upon the level of information available to inform management. A non-exhaustive range of harvest control rule shapes used elsewhere is provided in 'Appendix C – example of existing harvest control rules' for illustration purposes.

- Stocks with accepted assessment models (integrated assessments or surplus production models etc).

    - These models would typically provide estimates of initial biomass and status, as well as current fishing pressure and target fishing pressure (for a given target reference point).
    - Threshold harvest control rules (e.g., hockey stick rules) linking relative exploitation rate (F / F_{TARGET}) as a function of biomass relative to target (B / B_{TARGET}) can be implemented and tested, including estimates of uncertainty (e.g., the probability of being below the limit reference point B_{LIM}).
    - In the context of SIOFA, orange roughy and alfonsino stocks might be candidate species.
- Stocks with an estimate of absolute current biomass but not initial biomass, and assumptions of biological parameters.
    - A constant long term fishing pressure for a determined target reference point for the stock considered and the selectivity of the fishery could be calculated and applied.
    - The CCAMLR ramp rule for research blocks (Figure C.10) is a combination of a constant F_{TARGET} harvest control rule (F_{TARGET} = 0.04) modulated by the trend in the CPUE where a tag-based estimate of local abundance is not available.
    - In the context of SIOFA, this constant F method (combined with a ramp rule) is currently applied to toothfish stocks. It could potentially be applied to some orange roughy hills where acoustic estimates of abundance are available (with assumptions around acoustic catchability), and to other stocks (such as alfonsino) in the future if acoustic estimates are developed.
- Stocks with an index of relative abundance such as CPUE or a survey series.
    - Target and limit-related indicators could be developed based on a reference period of the index.
    - Threshold harvest control rules linking relative harvest (catch / catch at target) as a function of the index relative to target (index / index at target) can be implemented. They could also be tested using simulated models under various conditions.
    - Simpler rules designed to keep the CPUE stable could be applied; these do not rely on establishing a target biomass or index. An example is the CCAMLR ramp rule whereby the catch limit is reduced by 20% if the CPUE trend is decreasing and increased by 20% if the CPUE is increasing (the CCAMLR rule also applies an F_{TARGET}, see below). An illustration of the CCAMLR ramp rule (including the target fishing pressure) is provided in Figure C.10.
    - In the context of SIOFA, species with CPUE series (such as toothfish, alfonsino, oilfish and ribaldo), or orange roughy hills with survey series, could be candidate species, although the usefulness of CPUE to index stock abundance is under question for some of those stocks.
- Stocks with a reliable estimate of length frequency and fishery selectivity.
    - Length-based methodologies based on biological characteristics of the stock could estimate the current fishing pressure relative to a target fishing pressure.
    - A constant F at F_{TARGET} or some lower level could be applied. Hybrid methods using both length-based information and CPUE information could also be applied, such as in Figure C.9 or used in ICES.
    - This methodology is unlikely to be applicable to stocks that aggregate highly based on size such as orange roughy and possibly alfonsino. It might be applicable to SIOFA stocks that have adequate length sampling in space and time, which would need to

be determined through a detailed analysis of such stocks. Species of interest might include oilfish and ribaldo, as well as many other species with length data collected over multiple years (see Table 10 of the PAM-2024-02 report).

- Stocks with no reliable index of relative abundance or fishing pressure.
    - Continue current management at constant catch until a biomass signal is captured in the data. Apply the performance measures to determine whether the level of catch might be compromising the sustainability of the stock.
    - If the catch limit is too low or the data collected too variable, a signal of change in biomass might not be detected. This might lead to undesirable outcomes as wide ranging as under-exploitation or undetected over-exploitation of the stock.

Following discussions with the project Advisory Panel, two hockey-stick rules, one constant exploitation rate rule and one constant catch rule were agreed for testing on orange roughy stocks. Two CPUE-based rules were also developed for alfonsino (Figure 2).

The constant exploitation rate rule (Rule 3) was applied to model-based biomass estimates, as well as to acoustic estimates of orange roughy biomass, akin to the CCAMLR tag-based research block decision rule (Figure C.10). Should acoustic estimates of biomass be developed for alfonsino or other species in the future, such rules could be applied without the need for a reliable stock assessment.

These are only six out of a multitude of potential rules which could be tested. All these rules (and any other developed in the future) will require further refinement following stakeholder involvement.

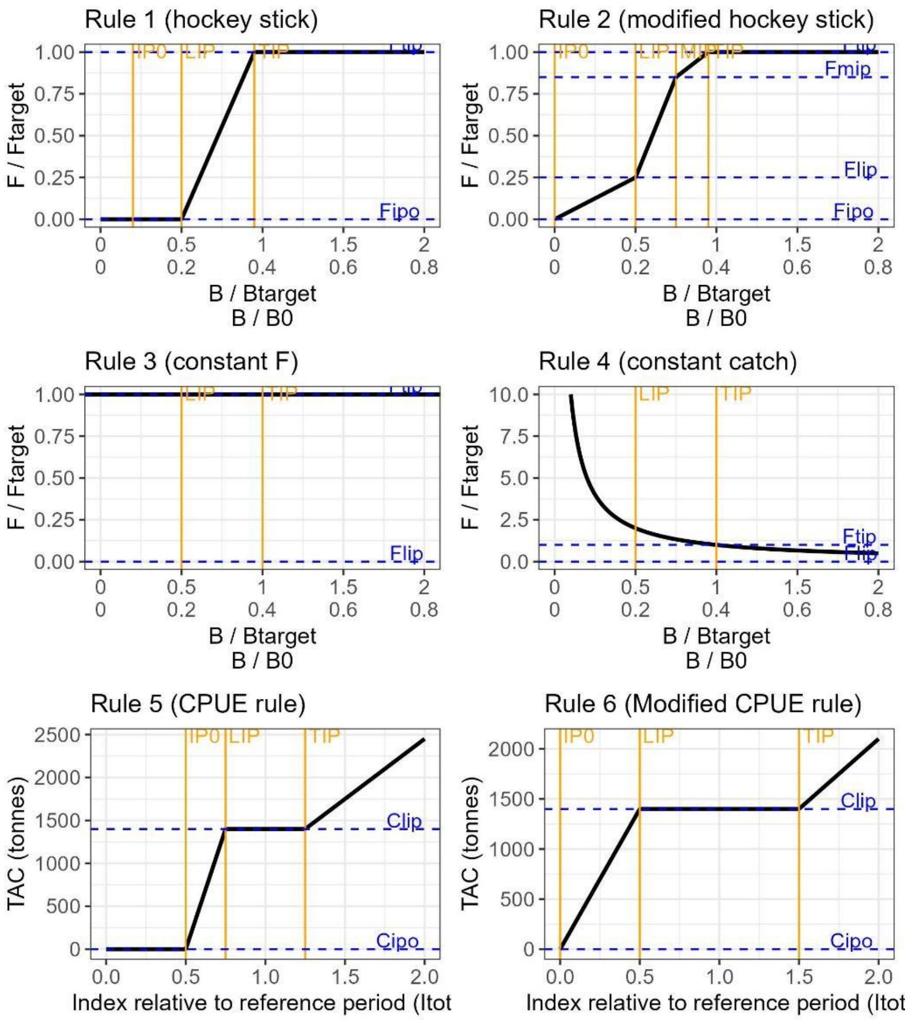

Figure 2: Harvest control rules tested in this project. The constant catch rule is represented with exploitation rate on the y axis to allow comparison with rules 1-4. Rules 5 and 6 are based on a CPUE index and were only applied to alfonsino. IP0, LIP, MIP and TIP correspond to the user-defined initial, low, medium and top inflection points to the functions. F_{IPO}, F_{LIP}, F_{MIP}, F_{TIP} correspond to the user-defined F values for the corresponding inflection points, and C_{LPO} and C_{LIP} correspond to the user-defined catch values for the corresponding inflection points for Rules 5 and 6.

3.4 Climate conditioning

Although harvest control rules can include climate conditioning (e.g., Duplisea et al. 2021; Mormede et al. 2025a), these typically require a high level of knowledge of the relationship between the productivity of the species and climate, for example, the effect of temperature on recruitment. This level of data requirement is beyond current knowledge of SIOFA stocks.

As a result, climate considerations were included in breakout rules only in this instance, as recommended elsewhere (e.g., Carruthers 2024 in ICCAT) and proposed by PAM-2024-02. These were included in two ways: if there is deviation between the models and the data collected (for climate reasons or any other reason), and/or if there is a change in the climate data which might lead to change in the productivity of the stocks managed. Breakout rules are discussed below.

3.5 Length-based spawning potential ratio

Length-based spawning potential ratio (LB-SPR) is a method used to manage low information stocks where only length data and biological characteristics of the species are available (Hordyk et al. 2014, 2015; e.g., Jaugeon et al. 2023). This method relies on a number of simplifying assumptions, including that the length composition is representative of the exploited population at equilibrium, and that the largest animals are selected (logistic selectivity).

This method also relies on the assumption of knowledge of specific biological parameters: namely the ratio of the natural mortality rate to the von Bertalanffy growth coefficient (M/K), and the ratio of the length at 50% maturity to the von Bertalanffy maximum length parameter (L_{50}/L_{INF}). Area-specific values of these parameters are often unknown for low information stocks, and in those instances, analyses can revert to values derived from meta-analyses (e.g., Prince et al. 2023). The values assumed for these two biological parameters are highly influential on the results (e.g., Neubauer et al. 2025a). We investigated different values of these two ratios for alfonsino, as detailed in the results section.

Using this methodology, in any year with a reliable length frequency sample, the spawning potential ratio (SPR) and relative exploitation rate (F/M) can be calculated. These can then be compared with reference values. Targets and thresholds for SPR values are discussed in PAM-2024-02 and summarised in Table 2.

LB-SPR could be developed for many SIOFA low-information stocks, including bycatch species, where reliable representative length data were collected. The usefulness of these methods could be tested using existing stock assessment models where applicable. Once established, LB-SPR could be used as part of monitoring and possibly harvest control rules for some SIOFA species, although this is outside of the scope of the present report.

This method was tested using alfonsino as a case study, and used the R package 'LBSPR' (Hordyk 2021) to carry out the analyses. In preparation for the LB-SPR model, the length data available for alfonsino were investigated spatially using the R package 'INLA' (Blangiardo et al. 2013; Bivand et al. 2015; Bakka et al. 2018).

3.6 Bayesian stock assessment models

Bayesian age- and sex-based models have been developed for orange roughy (Mormede & Hoyle 2025b, 2025c) using the modelling platform Casal2 (Casal2 Development Team 2023). These were used as the basis for the management strategy evaluation testing.

A series of Bayesian age- and sex-based simulation models were developed for alfonsino in the East SIOFA region as part of this project. The initial model followed the assumptions made in the 2020 model of alfonsino (Brandão et al. 2020). Sensitivities were carried out with regards to natural mortality, maturity and selectivity.

These models were used to calculate F_{TARGET} values and to test harvest control rules (see Section 3.7). To calculate F_{TARGET} values, the selected models were projected under constant future average recruitment and with constant exploitation rate for 100 years using 1000 randomly selected Markov Chain Monte Carlo (MCMC) outputs, to determine long-term equilibrium conditions. The various SSB management targets detailed in Table 2 were investigated. We estimated the reference points (F_{TARGET}) for each of those management targets.

3.7 Testing the harvest control rules

Testing harvest strategies is a component of management strategy evaluation (Punt et al. 2016b; SIOFA Scientific Committee Chair and vice-Chair & SIOFA Meeting of the Parties Chair 2023). The models developed were used to test different potential harvest control rules.

For each simulation, the following process was carried out (Figure 1):

1. One of the MCMC chains was selected as the basis of the simulation run.

2. If an assessment year, a new total allowable catch (TAC) was calculated given the HCR tested. The simulations assumed a new TAC was calculated every three years. If not an assessment year, the TAC was rolled over.
3. Both the operating model and the estimation models were updated by one year with the new TAC if applicable or existing TAC otherwise.
4. An additional year of observations was simulated with the operating model (defined with identical or different assumptions from the estimation model).
5. If a "full" MSE, the parameters in the estimation model (representing existing stock assessments) were then re-estimated with the one additional year of catch and simulated observations. Sensitivities were carried out for alfonsino whereby the model was then run rather than re-estimated (see rationale below).
6. Points 2–5 were repeated for the 50/100 years of the projected simulation.
7. Points 1–6 were repeated for 50/100 simulation runs.
8. Performance indicators were calculated over the simulation runs for each specific simulation scenario.

This process was repeated for the different stocks with combinations of different HCR rules and operating and estimation model assumptions. Over 200 simulations were carried out although not all potential combinations were carried out for all stocks.

The outputs of the various simulation scenarios were compared with each other based on a wide range of performance indicators, linked to the proposed performance indicators (see Section 3.8 and Appendix D – proposed performance measures).

The option of running the model after each iteration as opposed to re-estimating parameters was investigated (point 5 above). Runs, also sometimes referred to as "shortcut" MSEs are fast and therefore allow the use of complex models and many investigations of alternative options but often provide less robust results and different outcomes. In this instance, alfonsino models re-estimated through the process tended to be unstable in terms of estimation of spawning stock biomass: the estimated initial biomass increased over time through the simulations as more pseudo-observations were included. To alleviate this issue, runs were also carried out, whereby the initial biomass was not allowed to be re-estimated through the MSE process.

3.8 Management performance indicators / breakout rules

A list of initial proposed management performance indicators was developed based on the proposed indicators for orange roughy (WS2024-HSS Appendix B) and indicators proposed at CCAMLR and elsewhere (Dunn & Mormede 2025; Mormede et al. 2025a). These are provided in 'Appendix D – proposed performance measures'. Further indicators can be added as required.

Not all management performance indicators will be available for all species and stocks. For example, biomass status indicators will not be applicable to stocks with unknown stock status. The range of indicators aims to capture all levels of stock knowledge, from stocks with full Bayesian stock assessment models to fisheries with only catch history available.

As was proposed at CCAMLR, we propose management performance indicators together with reference points that group them into green, amber, and red categories, incorporating both management performance indicators and breakout rules in a single framework. Some management performance indicators are also used as indicators in the HCR. Reference points for these indicators may be determined from the HCR simulation, based on the observed distribution of uncertainty. The three-tier status is structured as a colour-coded flag system, where:

1. Green Flag (Expected Range): All key indicators are within expected ranges and management objectives are being met. No action required beyond routine monitoring.
2. Amber Flag (Warning): One or more indicators show moderate deviation from expected values, or early warning signals are detected. Increased monitoring and scientific review are triggered, but immediate management action is not yet required.
3. Red Flag (Critical): Key indicators breach limit reference points or show persistent, significant anomalies. Immediate management action is required, which could include formal review, and/or a temporary or permanent adjustment of harvest control levels.

The colour-coded system provides graduated responses to emerging management issues, based on scientific evidence from recent assessments, MSE development work, and international best practice (Punt et al. 2016b). This also provides an opportunity to proactively identify issues and ensure that the required scientific work can be conducted before a critical issue requires management intervention. Systematic monitoring and clear trigger points are essential for maintaining precautionary management and adaptive response (Butterworth & Punt 1999; Punt et al. 2016b).

When red flags are triggered, a structured response protocol should be developed that ensures rapid and appropriate action which might include:

(i) Management actions
   a. Immediate catch reductions of [20–50%] (values to be decided upon by SIOFA) if the status is below target until resolution of the issue.
   b. Move to enhanced assessment frequency.
   c. Consider intensified monitoring (e.g. additional acoustic surveys, length data, age estimations).

(ii) Scientific Review Process
   a. Review key parameters assumed.
   b. Reference point review. Re-examine the target and limit reference points to determine if these require revision.
   c. Harvest Control Rule evaluation. Re-test the harvest control rules under updated operating models.

(iii) Recovery and Return Criteria
   a. Objective criteria for returning to normal management, including rebuilding plan, duration of rebuild, monitoring.

If the red status flag is triggered and the stock status is above the target, then the management actions may be to continue the management strategy, but the harvest strategy and underlying stock assessment will need to be re-evaluated within a defined time period.

4. Results

4.1 Proposed classification of some SIOFA stocks

The current knowledge of stock status for several top tier species and stocks is summarised in ‘Appendix B – summary of stock status’. Based on these and project PAM-2024-01, some of the main SIOFA stocks were classified in terms of information classification and stock status (Table 2). The main source used for these classifications is also reported.

The following factors influenced the final classifications:

- South West Indian Ocean Ridge (SWIOR) orange roughy was classified as in the healthy zone due to the high historical catches compared to recent years, indicating low current exploitation rate, and the high length at full selectivity suggesting that part of the spawning population is not vulnerable to fishing. The model-based knowledge on stock status is highly uncertain.

- Toothfish stocks were classified as in the under watch zone, even though no estimate of stock size is available, because the CPUE by seabed area calculation combined with the gamma estimate of catch limit is deemed appropriate to avoid overfishing in the absence of stock status.
- Alfonsino stocks were classified as under watch with a question mark based on the stock models run within this project (see below).
- Mora (*Mora moro*) was classified as in the under watch zone because of decreasing unstandardised CPUE although it is not deemed an index of abundance.
- Oilfish (*Ruvettus pretiosus*) was classified as in the under watch zone because of opposing unstandardised and standardised CPUE trends and because the standardised CPUE trend has been increasing concurrently with a stable annual catch.

Table 2: Proposed classification of the stocks under consideration, based on PAM-2024-01 proposed classification.

Species	Area	Information classification	Stock status	Source / data
Orange roughy	WSR	High / medium	Healthy	Bayesian model
	LWSR	Medium	Healthy	Bayesian model
	SWIOR	Low	Healthy	Historic catches and length data
Toothfish	Del Cano rise	Medium	Under watch	CPUE by seabed area
	South Indian Ridge	Medium	Under watch	CPUE by seabed area
	Western ridge	Low	Unknown	
Alfonsino	East and West	Medium / low	Under watch	Deterministic catch and CPUE model
Hapuka (*Polyprion* spp.)	All	Low	Unknown	Unstandardised CPUE
Mora	All	Low	Under watch	Decreasing unstandardised CPUE
Oilfish	All	Low	Under watch	Standardised CPUE and unstandardised CPUE opposite

4.2 Toothfish

The management of toothfish by SIOFA is aligned with the management of toothfish by CCAMLR, whereby the two SIOFA stocks are managed using the CCAMLR research block trend analysis (Secretariat 2025 and Figure C.10). Although toothfish was initially proposed to be included in this project, the WS2025-PAM2 workshop agreed that there was little point in investigating alternative management options for toothfish independently of CCAMLR, and that project time was better spent investigating another species.

CCAMLR is in the process of developing and testing management strategy evaluations for its assessed toothfish stocks (e.g., Ziegler et al. 2024a, 2024b; Dunn 2025a; Earl et al. 2025). A management strategy evaluation framework is also being developed for toothfish in research blocks, where the full stock extent/size is unknown and/or unmonitored (CCAMLR 2025, para 4.174).

Recent genetic study indicates that that Patagonian toothfish is a single stock for the Indian Ocean (Nieblas & Cowart 2023). The SIOFA toothfish fisheries are adjacent to CCAMLR areas, and tend to capture larger animals rather than the full size composition of the stock (Delegation of the European Union & Delegation French Overseas Territories 2023). This indicates that, as for many research blocks in CCAMLR, the SIOFA areas fished do not represent entire toothfish biological stocks but only parts of those stocks (Milardi et al. 2024). As a result, attempting to derive long term exploitation rates (F_{TARGET}) based on data from these fisheries is likely to lead to higher values than would be precautionary and is not recommended. This was demonstrated for Antarctic toothfish in CCAMLR Subarea 48.4, where the F_{TARGET} values calculated were much higher than the 3.8% used in research blocks (Alewijnse et al. 2025). The Fish Stock Assessment (FSA) working group of CCAMLR '*noted that as the area does not constitute an entire biological stock, using the 3.8% exploitation rate would be precautionary*' (CCAMLR 2025, para 4.34).

4.3 Orange roughy

Bayesian stock assessment models for orange roughy were developed elsewhere (Hoyle & Mormede 2025; Mormede & Hoyle 2025b, 2025c) using the modelling platform Casal2 (Casal2 Development Team 2024). Ages 1-120 by sex were modelled with a plus group at the oldest age, and the model ranging 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 males and females. Maturity was assumed to be equal to selectivity, which was assumed to be logistic (asymptotic) and age-dependent and was estimated within the model. Growth was assumed to follow a Von Bertalanffy relationship. Both the growth and length-weight relationships were updated using the latest data. Initial biomass (B0) 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 0.045 (sensitivities 0.028 and 0.058) and cv of 0.1. Acoustic catchability q parameters were estimated as free parameters with a uniform prior for each acoustic series. The sum of the acoustic catchabilities was given a normal prior with mean of 0.8 for WSR (sensitivities 0.7, 0.9 and 1.0) and cv of 0.1. Maturity (equal to selectivity) was assumed identical for males and females with a uniform prior. Year class strengths (YCS) were initially estimated but ultimately fixed in the final models.

The base model for each of the three main orange roughy stocks (Walter Shoal Ridge – WSR, Long Walter Shoal Ridge – LWSR, and South-West Indian Ocean Ridge – SWIOR) was investigated. These represent different levels of information classification and stock status, hence represent a range of likely model performances. Some of the sensitivity runs investigated as part of the stock assessment process were also considered here.

Four proposed performance measures pertain directly to the stock assessment model performance (see ‘Appendix D – proposed performance measures’). These are assessed for the three orange roughy stocks in Table 3, with suggested scores.

Table 3: Performance of the orange roughy stock assessments against the proposed harvest control rule performance measures pertaining to the stock assessments.

Performance measure	WSR	LWSR	SWIOR
MA01: Assessment model convergence and reliability	Green	Green	Amber
MA02: Fits to the indices of abundance	Green	Amber	Red
MA03: Between assessment catch limit variability (Economic, stability)	Green	Green	Green
ME04: Change in average recent recruitment	Unknown	Unknown	Unknown

4.3.1 Estimating potential values of target fishing mortality for orange roughy

The target fishing mortality (F_{TARGET}) depends on a number of factors, including biological assumptions and management requirements. The effects of the assumed natural mortality and the target spawning stock biomass were investigated separately.

Effect of natural mortality on F_{TARGET}

The fishing pressure target reference point (F_{TARGET}) was calculated for the three stocks under various assumptions of natural mortality (Table 3). The interim target reference point for orange roughy is 40% B_0, which should be achieved with 50% probability. The interim limit reference point is 20% B_0, with the requirement of a 90% probability of being above it.

Under those conditions, F_{TARGET} was about 0.033 for the WSR and LWSR stocks, and 0.041 for the SWIOR base case models. The target fishing pressure for SWIOR is higher than for the other two stocks because the fishing selectivity is right shifted (the fishery catches fewer smaller fish) and therefore part of the spawning stock biomass is not caught by the fishery.

A comparison of those values was made with a default value for F_{TARGET} of 0.87 M (Zhou et al. 2019; Hoyle & Mormede in prep) and F_{MSY}. The F_{TARGET} calculated based on the stock was similar to the baseline assumption of 0.87M. F_{TARGET} was much lower than F_{MSY}, which was more akin to M and consistent with the B_{MSY} calculated at about 30% B_0 for these stocks. This result confirms the recommendation in PAM-2024-02 to use 0.87 M as an F_{TARGET} for those species where a full stock assessment is not available, and an SSB target of 40% B_0.

The concordance between F_{MSY} and M for the simulations for the WSR and LWSR stocks is expected from first principles and reinforces the confidence in the simulations. The apparent discrepancy for the SWIOR stock is explained (as above) by the right-shifted selectivity of this fishery, effectively protecting part of the spawning stock and allowing for a higher exploitation rate regardless of the target biomass.

Table 4: Potential F_{TARGET} for the three assessed orange roughy stocks under various assumptions of natural mortality. WSR = Walter Shoal Ridge, LWSR = Long Walter Shoal Ridge, SWIOR = South-West Indian Ocean Ridge stock. The interim target reference point for orange roughy is 50% probability of being above 40% B_0, and the limit reference point is 90% probability of being above 20% B_0. M = natural mortality. B_{MSY} is provided as a proportion of B_0.

Stock	Run	M	F_{TARGET}	0.87×M	B_{MSY} (pB_0)	F_{MSY}	Model
WSR	1.4	0.044	0.033	0.038	0.31	0.045	Base case
WSR	1.5	0.025	0.025	0.022	0.31	0.025	Sensitivity
WSR	1.6	0.054	0.058	0.047	0.30	0.058	Sensitivity
LWSR	1.2	0.047	0.037	0.041	0.31	0.049	Base case
LWSR	1.3	0.044	0.035	0.038	0.31	0.047	Sensitivity
LWSR	1.1	0.042	0.033	0.037	0.30	0.045	Sensitivity
LWSR	2	0.037	0.029	0.032	0.31	0.040	Sensitivity
SWIOR	2.1	0.045	0.041	0.039	0.32	0.090	Base case

Effect of the choice of the target reference point

MoP11 in July 2024 endorsed recommendations that alternative sensitivity choices should be evaluated for orange roughy and toothfish respectively: "*For orange roughy, analysts should evaluate alternative sensitivity choices of 50-60-70% probability of being at or above a target reference point (TRP) of 30-40-50% B_0, while for toothfish analysts should evaluate the same probability levels but for TRP of 40-50-60% B_0.*"

These sensitivities were carried out with the Walter Shoal Ridge orange roughy base case stock assessment, whilst keeping the limit reference point at 20% B_0 with a 90% probability of achieving it (Table 4).

The choice of B_{TARGET} had a strong effect on F_{TARGET}, with the F_{TARGET} increasing from 0.024 when B_{TARGET} was 50% B_0 to 0.046 when B_{TARGET} was 30% B_0 (which is about B_{MSY} for these stocks). Increasing the probability of reaching the target from 50% to 70% had a comparatively small effect on F_{TARGET}, changing the target fishing mortality by up to 0.003 only.

Hoyle & Mormede (2026) recommended that the limit reference point for orange roughy be set at to 30% B_0 (Hoyle & Mormede, 2026). Furthermore, SC-11 (paragraph 155) suggested that if the limit reference point was raised to 30% B_0, the target reference point might need to be raised to 50% B_0. The F_{TARGET} was calculated for those two scenarios (B_{TARGET} of 40% B_0 or 50% B_0 and F_{TARGET} of 30% B_0). Results indicate that for the Walter Shoal Ridge orange roughy stock assessment, the biomass limit reference point had no effect on the target fishing mortality. It is likely partly due to the limited variability of the stock biomass trajectory as recruitment is not estimated in the model.

Table 5: Potential F_{TARGET} for the base case Walter Shoal Ridge orange roughy stock under various definition of target and limit reference points.

Stock	Run	M	B_{TARGET}	p>B_{TARGET}	B_{LIM}	p> B_{LIM}	F_{TARGET}
WSR	1.4	0.044	40	50	20	90	0.033
WSR	1.4	0.044	40	60	20	90	0.032
WSR	1.4	0.044	40	70	20	90	0.031
WSR	1.4	0.044	30	50	20	90	0.046
WSR	1.4	0.044	30	60	20	90	0.043
WSR	1.4	0.044	30	70	20	90	0.043
WSR	1.4	0.044	50	50	20	90	0.024
WSR	1.4	0.044	50	60	20	90	0.023
WSR	1.4	0.044	50	70	20	90	0.023
WSR	1.4	0.044	40	50	30	90	0.033
WSR	1.4	0.044	50	50	30	90	0.024

4.3.2 Testing potential harvest control rules for orange roughy

A range of management strategy evaluations were carried out on each of the three orange roughy stock base case models, with results detailed by stock below.

Harvest control rules 1 to 4 (Figure 2) were tested, specifically hockey stick, modified hockey stick, constant F and constant catch. The constant F rule was applied to either the outcome of the stock assessment model, or the simulated acoustics data with a three-year average value. The only future constant catch tested used the current constant catch, as projections with multiple catch limits were carried out as part of the stock assessments (Mormede & Hoyle 2025c, 2025b). Target biomass tested were 30, 40 or 50% B_0 although not all combinations were carried out. The catch limit was modified every three years, simulating the assessment cycle, and the total catch limit was assumed caught each year.

Multiple model misspecifications were tested whereby the operating model (representing reality) had different parameters from the estimation model (used for management purposes). Terms tested were natural mortality, acoustic catchability and recruitment variability. In the case of orange roughy, natural mortality, and acoustic catchability are estimated in the estimation model and therefore these misspecifications are only constrained by the estimation model priors on those parameters, given that full MSEs are performed in which the estimation model goes through a new estimation of the parameters every time the TAC is updated (every 3 years in this instance).

Furthermore, for each of the stocks, the base case model was projected forward for ten years with relatively high catches, to artificially deplete the stock to about 10-20% B_0 and test the simulations on a depleted stock.

Walter Shoal Ridge (WSR) orange roughy stock

Details of the WSR simulation models carried out can be found in Table E.1. Harvest control rules 1 to 4 were tested using either model spawning stock biomass or acoustics as the biomass indicator, with model misspecifications for some simulations (noting that the mis-specified parameters were estimated in the estimation model).

The estimation models were robust to the addition of the simulated data over time, with stable estimates of initial biomass (Figure E.1), of selectivity, and estimates of natural mortality consistent with the operating model values (Figure E.2).

Results of the simulations and different harvest control rules are summarised in terms of stock status in Table E.2, Table E.3, Figure E.4 and Figure E.5. The only two simulation base models that did not achieve the target of 40% B_0 were the two simulations with low natural mortality in the operating model (Table E.2). Although the estimation models estimated the correct mortality, the target fishing exploitation rate applied was based on the higher assumed natural mortality, resulting in a higher than appropriate F_{TARGET}. In a similar way, many simulation models did not achieve the 50% probability of being above 50% B_0 as F_{TARGET} was calculated for a B_{TARGET} of 40% B_0 in all but simulations S2 and S3 (Table E.3).

Exploitation rates were higher than F_{TARGET} and the probability of being in the green zone of the Kobe plot lower than the desired target of 50% in most instances (Table E.3) although the Kobe plots over time indicated that many simulation runs trended towards the target (Figure E.4), as a result of reducing the stock status towards the target of 40% B_0 (Figure E.5). The only simulation runs with over 50% of probability of being in the green zone of the Kobe plot were those where natural mortality was assumed at 0.058 (and therefore the fishing mortality applied was lower than what the actual target could be) or where acoustic data were used as a proxy for spawning stock biomass (i.e., assuming acoustic catchability = 1), therefore allowing a buffer margin due to total acoustics catchability being at about 0.8.

The total allowable catch (TAC) was quite variable between simulation runs, ranging from 370 to 660 t in the first 10 years (Table E.4 and Figure E.6), although the between-year variability was mostly lower than 15% (in the green zone of performance measure MC02) without the need for TAC limitation between assessments. The future expected CPUE and acoustic biomass estimates were highly variable, representative of the variability of these indices (Table E.5).

Simulation runs were also carried out on a simulated depleted stock (R1.4L, labelled 'low status' in the tables) to assess the performance of the different rules for rebuilding stocks (Table E.2 to Table E.5 and Figure E.7 to Figure E.9). Any misspecification of the model provided a more extreme effect on a depleted stock.

Although these simulation runs were carried out with an F_{TARGET} relating to a limit reference point of 20% B_0, results were provided with regards to both the probability of being below 20% B_0 and 30% B_0 (e.g. Table E.3). Results indicated that the limit reference point was not a limiting factor for the base simulations but was exceeded in the simulations starting with a low status, which was by design.

In summary, results indicated that the constant fishing pressure rule (Rule 3) and constant catch rule (Rule 4) performed poorly with regards to targets, particularly for depleted stocks. Rule 2 (the modified hockey stick rule – e.g., S7) did not perform as well as Rule 1 (hockey stick – e.g., S4) for a depleted stock given that Rule 2 allows a higher exploitation rate at lower stock status than Rule 1.

Long Walter Shoal Ridge (LWSR) and South-West Indian Ocean Ridge (WSIOR) stocks

Results for LWSR and SWIOR are provided in 'Appendix E – Orange roughy MSE supplement', in the same format as the results for the WSR orange roughy stock. The results were consistent with those of the WSR. Of note, the harvest control rules using the acoustic series as an index of abundance provided even more conservative management than for WSR because the catchability of the total acoustic series for both LWSR and SWIOR is lower than that of WSR.

4.4 Alfonsino

Given that toothfish management follows the CCAMLR management rules, alfonsino was chosen by the PAM02 workshop as the second species for the project to investigate.

The last assessment for alfonsino in the SIOFA region was carried out in 2020 (Brandão et al. 2020), using stock production models. These models were run for the east and west alfonsino stocks separately, fitted to the CPUE series and a single year of commercial catch length distribution. Both stocks were estimated to be at about 60% of their initial biomass. Due to the paucity of data, only deterministic runs were carried out. Since that assessment, bomb-radiocarbon dating of alfonsino has suggested that age might have been overestimated by up to a factor of two (Andrews 2024). Should this be the case, biological parameters used in these assessments will need to be updated, including natural mortality and growth.

The aim of this project was not to develop a full characterisation and stock assessment for alfonsino, but it did require the development of Bayesian simulation models to test various harvest control rules. The 2020 stock assessment models were used to set up the initial simulation model, from which alternative sensitivity models were developed with adjusted biological parameters and selectivity assumptions. These are summarised below. Furthermore, a simple characterisation of the length data available for alfonsino was carried out prior to testing LB-SPR models.

4.4.1 Investigating alfonsino length data

Many fish species aggregate spatially by size and migrate deeper as they get older. Furthermore, gear type and fishing practices can also affect selectivity and therefore the length composition of the catch. For a length-based spawning potential ratio methodology to adequately represent the exploitation level of the stock, the fishing selectivity of the part of the population considered must be logistic, effectively selecting all older fish. Failure to adequately capture all older fish would result in changes in the right-hand limb of the fishing selectivity being interpreted as changes in fishing pressure.

Alfonsino data in SIOFA are potentially problematic in that in most years only one flag has fished for alfonsino, and the methods and flag involved do not overlap much between years, potentially affecting the development of length frequencies (Table F.1). Furthermore, raw alfonsino length data seem to vary by year, location, method and flag. The mean length spatially by method is presented in Figure F.1.

In order to investigate these potential interactions between length and various parameters, alfonsino length data in the east only were analysed spatially using INLA (Rue et al. 2009). The potential parameters provided to the model were location, year, gear and flag; however, only location and year were statistically significant and retained in the final model. This result indicated that the gear and flag effects could be explained by the location of fishing alone, although these might be correlated due to the sparse data available to inform the models (noting that models without space attributed effects to gear and flag).

A cluster analysis was carried out to determine the potential area of interest for the application of the LB-SPR methodology. Results showed that the largest animals were caught in the northern area, north of 30°S (Figure F.2). This area was retained to develop alfonsino scaled length frequencies using the R package 'scala' (Dunn 2025b).

4.4.2 Investigating length-based spawning potential ratio for alfonsino

Deriving alfonsino biological parameters

Additional to scaled representative length frequencies, LB-SPR analyses require two biological parameters: the ratio of the natural mortality to the von Bertalanffy growth coefficient (M/K) and the ratio of length at 50% maturity to the von Bertalanffy maximum length parameter ($L50/L_{INF}$).

These parameters are highly influential, and alfonsino biology is uncertain. An advantage of the LB-SPR method is that it is relatively robust to ageing errors. Specifically for alfonsino in SIOFA, if age was double that currently assumed, M would halve and K double, with M / K effectively remaining constant. On the other hand, the von Bertalanffy growth coefficient value is known to be problematic for this type of analysis as it requires a biologically realistic value of t_0. The K and t_0 parameters of this relationship are confounded and a biologically realistic value of t_0 can only be achieved when young, small fish are available for the estimation of the von Bertalanffy curve, which is not the case for alfonsino in the SIOFA region. In this instance, $t_0 = -5$, which is unrealistic and therefore leads to a potentially biologically unrealistic and negatively biased value of K. Furthermore, the length at maturity in alfonsino in SIOFA is uncertain due to the limited catch of immature animals, and because fish sampled from spawning areas tend to underestimate L50. Therefore alternative runs were carried out using literature-based biological values (Prince et al. 2023), as detailed in Table 5, ranging from using the 2020 model assumptions to literature-only values. The SPR_{TARGET} values corresponding to the assumed biological values and the F_{TARGET} of 0.87 M are also reported.

Potential biological parameters for alfonsino were also investigated using the 'FishLife' R package (Thorson 2023; Thorson et al. 2023). However, the values derived did not appear to be representative of alfonsino stocks in SIOFA, with for example natural mortality at 0.32 and L_{INF} at 53 cm. These values were not used in the analysis.

Alfonsino east stock

The LB-SPR models were fitted to the scaled length frequency from the northeast portion of the population to derive annual length at 50% selectivity (SL50) assuming a logistic selectivity, and the annual SPR and F/M parameters. This region was chosen as representative of where the largest animals have been caught, and therefore the required assumption of logistic selectivity of the fishery.

Despite the spatial selection of the data, the scaled length frequency compositions were highly variable between years (Figure F.3), resulting in highly variable annual estimates of selectivity (Figure F.4), relative stock status SPR (Figure F.5) and relative exploitation rate F/M (Figure F.6).

Results indicated that, apart from the 2020 model assumptions, all other assumptions suggested a status below target; all assumptions resulted in fishing mortality higher than target (Figure 3). In effect, the LB-SPR models indicated that, given the LB-SPR assumptions, the alfonsino east stock was in the red zone of the Kobe plot. Using the literature values for biological parameters resulted in the most pessimistic outcomes, highlighting the need for reliable local estimates of these parameters. We note that annual values were highly variable, and the credible intervals calculated were large (plotted for the second model assumptions in Figure F.7).

The robustness of the methodology to data input was investigated by using all length data from the east alfonsino stock, without partitioning stock areas or scaling the length data to the fishery catch. Results were surprisingly similar in terms of general conclusions although the unstandardised length frequencies suggested a higher recent fishing pressure (Figure F.8), indicating that in some instances raw length data might be sufficient for an analysis of this level, as long as fishing location is relatively consistent and capturing the largest fish in the population.

Table 6: The different scenarios tested for LB-SPR. The standard deviation (sd) of the literature values is reported for ease of comparison with the other parameters; it is not used in the methodology. The SPR_{TARGET} based on F_{TARGET} of 0.87 M is also provided.

M/K	$L50/L_{INF}$	SPR_{TARGET} (with F_{TARGET} = 0.87 M)	Rationale
2.9 = 0.2 / 0.068	0.57 = 35 / 61	0.45	2020 assessment (Brandão et al. 2020)
1.12 (sd 0.42)	0.57 = 35 / 61	0.42	2020 model (Brandão et al. 2020) with literature M/K (Prince et al. 2023)
1.12 (sd 0.42)	0.75 (sd 0.11)	0.48	literature parameters (Prince et al. 2023)

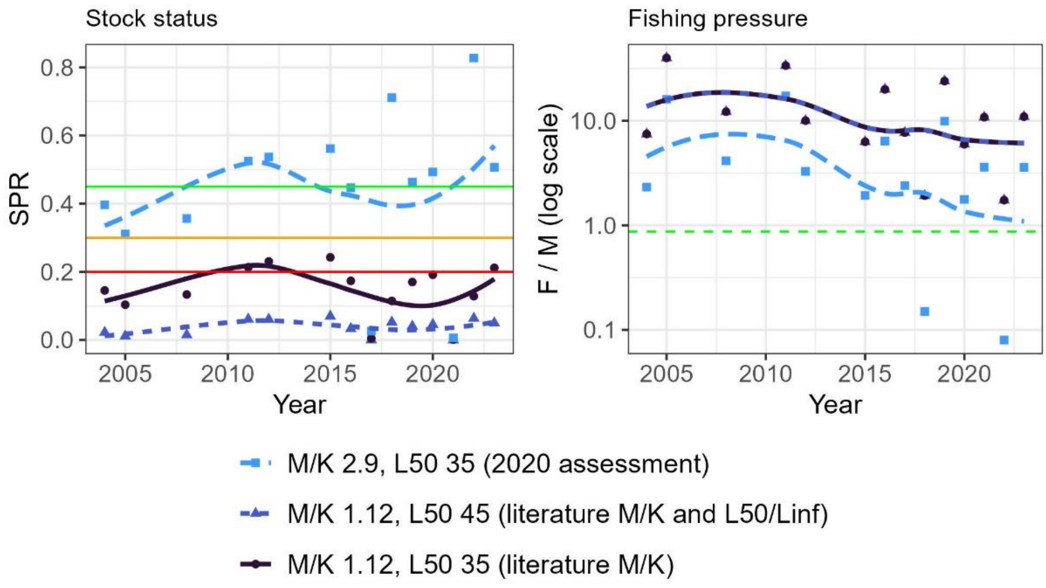

Figure 3: Estimated stock status (left) and fishing pressure (right) of alfonsino in the northeast of the SIOFA region based on various LB-SPR models, and smoother lines. The stock status reference points were plotted at SPR = 0.45 (green), 0.3 (orange) and 0.2 (red) on the left plot, and at F/M = 0.87 (green) on the right plot.

Alfonsino west stock

The method was also naively applied to the west alfonsino stock, despite lengths being highly variable spatially (Figure F.1). Fits to the raw length frequencies indicated that the fishery did not seem to catch the largest animals consistently from year to year (Figure F.9) and therefore the use of this method on the entire west stock length data is unlikely to be appropriate. It also indicated that the use of the east selectivity for the west stock as applied in the 2020 stock assessment (Brandão et al. 2020) was likely inadequate as the selectivity was estimated at about 23 cm (Figure F.10), well to the left of the estimated selectivity in the east (at about 35 cm) and of the assumed maturity. The resulting estimate of SPR was unsurprisingly well below target, most likely representing the overall fishery dome selectivity rather than actual stock status. This highlights some of the potential pitfalls of using this methodology without analysing length data first.

4.4.3 Developing Bayesian simulation models for alfonsino

Bayesian age-based population models for the east and west alfonsino stocks were developed in Casal2 (Casal2 Development Team 2023) as a platform to carry out management strategy evaluations. Therefore, the initial models replicated the existing 2020 stock assessment models and assumptions of growth, maturity and natural mortality (Brandão et al. 2020). In order to simplify the simulation models and because only one year of length frequency sampling was fitted to in the 2020 models, selectivity was fixed at the value estimated in 2020. We note that a single selectivity is unlikely to be adequate for such a complex stock, as shown in the length analyses (e.g., Figure F.1 and Figure F.3).

Our simulation models fitted to the CPUE series; initial biomass (B_0) and CPUE catchability parameters were estimated. In order to capture some of the uncertainty, MCMCs were carried out on these models. The B_0 estimate for the west alfonsino stock was highly uncertain (ranging across two orders of magnitude) and is not considered further in this report as the aim is not to carry out a stock assessment. The initial model for the east alfonsino stock provided results similar to those of the 2020 stock assessment, with B_0 at about 15 700 t, and status in 2018 at about 64% B_0 (Table 6). However, this model assumed 50% maturity at age 9 and estimated 50% selectivity at age 14, resulting in a large proportion of the spawning stock biomass not vulnerable to fishing. If incorrect, this assumption could lead to undetected overexploitation of the stock.

Sensitivity models were carried out. The fixed parameters used in all the model runs are provided in Table G.1, and estimated parameters with corresponding priors in Table G.2. Initially, mid-point selectivity and maturity were assumed equal, at either 14 years of age or 9 years of age (runs R1.1 and R1.2). These assumptions led to the reduction of the initial stock biomass to 7 100 and 9 400 t respectively and of stock status in 2018 to 31 and 34% B_0 respectively.

Further simulations were carried out to investigate the effect of the potential error in ageing. Natural mortality was assumed to be 0.15 or 0.1. Concurrently, the von Bertalanffy growth parameters were adjusted for the alternative ages of fish at length, resulting for example in a halving of K and doubling of t_0 if ages were twice those currently assumed. The maturity and selectivity parameters were also adjusted for the new potential ages. These sensitivities resulted in status in 2018 at about 31% B_0, but also an increase in initial biomass to B_0 of 14 120 t when M was equal to 0.1 (Table 6).

Although the models were not well informed, they were well behaved at MCMC level (see 'Appendix G – Alfonsino stock' for some diagnostic plots). The low estimates of initial biomass were constrained by the total catch over the history of the fishery. Negative log likelihood values suggested that a lower value of M was more consistent with the CPUE data. Models R1.2 (2020 assumptions but with maturity equal to selectivity at age 9) and model R1.5 (equivalent model with ages double those currently assumed) were used in the management strategy evaluation.

The Kobe plots for model runs R1.2 and R1.5 are provided in Figure 4. Results indicate that for both models the status is below target and exploitation rate is higher than it should be. These results are generally consistent with the LB-SPR results, although the LB-SPR results equivalent to model R1.2 were slightly more optimistic, with an SPR status above target.

Table 7: Model runs for the east alfonsino stock, with run name, model assumptions and the MCMC estimates of B_0 (in tonnes) and B2018 (as a percentage of B_0). The negative log likelihood (NLL) of each model is also reported.

Run	M	Selectivity SL50 (cm)	Maturity L50 (cm)	B_0 (t)	B_0 range (t)	B2018 (%B_0)	B2018 range (%B_0)	NLL
	Assumptions							
R1.0	0.2	14	9	15 737	13 349 – 32 698	64.0	57.1 - 83.3	-5.2
R1.1	0.2	14	14	7 134	6 115 – 9 924	30.6	19.6 - 50.1	-0.6
R1.2	0.2	9	9	9 428	8 438 – 11 794	34.1	25.1 - 48.5	-2.6
R1.3	0.15	21	21	8 243	7 403 – 10 704	31.1	25.3 - 45.2	-5.3
R1.4	0.1	28	28	11 448	9 816 – 14 492	31.1	22.1 - 44.2	-8.5
R1.5	0.1	18	18	14 120	12 536 – 17 535	31.9	23.5 - 45.1	-8.9

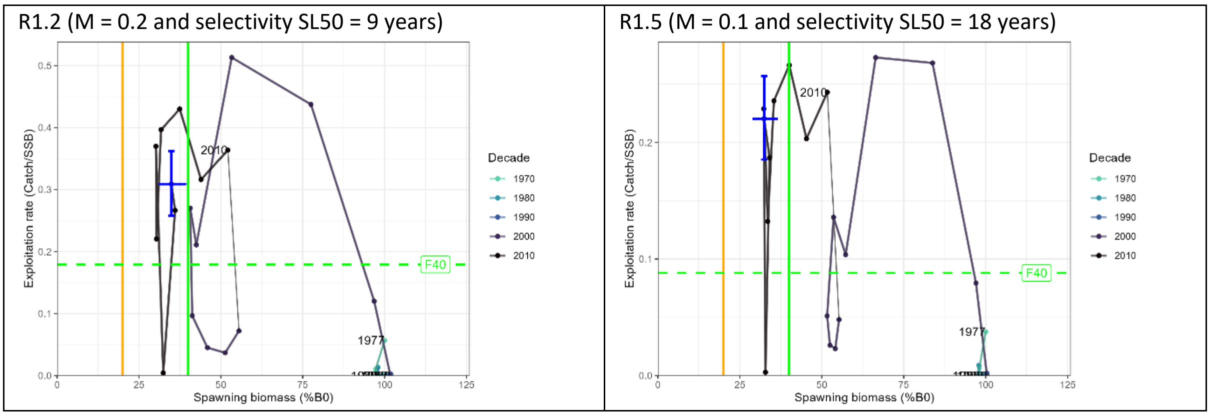

Figure 4: Kobe plots for model R1.2 (M = 0.2 and selectivity SL50 = 9 years, left) and model R1.5 (M = 0.1 and selectivity SL50 = 18 years, right). The target exploitation rate of F50 for each model is also plotted. The blue cross represents the credible interval in both axes for the final year (2018).

Four proposed performance measures pertain directly to the stock assessment model performance (see 'Appendix D – proposed performance measures'). These were assessed for the two alfonsino stocks based on the present analysis in Table 8, with suggested scores. Based on the present analysis, the stock assessment of alfonsino should be updated to include more length data and updated age and maturity information.

Table 8: Performance of the alfonsino stock assessment models developed herein against the proposed harvest control rule performance measures pertaining to the stock assessments.

Performance measure	East	West
MA01: Assessment model convergence and reliability	Amber	Red
MA02: Fits to the indices of abundance	Amber	Red
MA03: Between assessment catch limit variability (Economic, stability)	Red	Red
ME04: Change in average recent recruitment	Unknown	Unknown

4.4.4 Estimating potential values of target fishing mortality for alfonsino

The target fishing mortality (F_{TARGET}) depends on a number of factors, including biological assumptions and management requirements. F_{TARGET} was calculated for the six models of the east alfonsino stock, and the three potential target reference points of the 50% probability of being above 30, 40 or 50% B_0 (Table 3). The limit reference point was kept at the 90% probability of being above 20% B_0.

The results for model R1.0 illustrate the pitfalls of assuming that selectivity was to the right of maturity, effectively assuming that a large part of the spawning population is not vulnerable to fishing: even a fishing mortality of 1 would not reduce the stock to much below 40% B_0 and would never reduce it to B_{MSY} (under average recruitment).

As seen for orange roughy, the choice of B_{TARGET} had a strong effect on F_{TARGET}, with F50 being about half the value of F30 for all models. Furthermore, all F_{TARGET} values increased with an increase in the assumed maturity and selectivity values for equivalent models. The calculated B_{MSY} was lower than the proposed target of 30-50% B_0, at about 20% B_0.

The value calculated for F40 was similar to the default value for F_{TARGET} of 0.87 M (Zhou et al. 2019; Hoyle & Mormede in prep) for models R1.2 and R1.5, as was the case for orange roughy. This result supports the recommendation in PAM-2024-02 to use 0.87 M as an F_{TARGET} and an SSB target of 40% B_0 for those species where a full stock assessment is not available.

The assumed value for natural mortality was highly influential, as seen in orange roughy, highlighting the importance of the value assumed for this parameter.

Table 9: Target fishing mortality for the alternate east alfonsino stock models. The limit reference point is 90% probability of being above 20% B_0 in all instances. M = natural mortality. – indicates the stock cannot be reduced to these targets even at maximum fishing mortality due to the portion of the stock not vulnerable to fishing.

Run	Assumptions								
	M	Selectivity SL50 (cm)	Maturity L50 (cm)	F30	F40	F50	B_{MSY}	F_{MSY}	0.87 M
R1.0	0.2	14	9	-	0.988	0.525	-	-	0.174
R1.1	0.2	14	14	0.323	0.218	0.150	0.221	0.458	0.174
R1.2	0.2	9	9	0.260	0.179	0.125	0.230	0.346	0.174
R1.3	0.15	21	21	0.253	0.169	0.116	0.194	0.412	0.130
R1.4	0.1	28	28	0.159	0.107	0.074	0.205	0.242	0.087
R1.5	0.1	18	18	0.128	0.088	0.062	0.235	0.166	0.087

4.4.5 Testing harvest control rules

A range of management strategy evaluations was carried out on two of the alfonsino stock assessments models (Table H.1): R1.2 with M = 0.2, 50% selectivity and maturity at age 9, and R1.5 with M = 0.1 and 50% selectivity and maturity at age 18. R1.5 is the equivalent of R1.2 if alfonsino age was twice that assumed in the 2020 stock assessment (Brandão et al. 2020), as indicated by bomb radiocarbon work (Andrews 2024).

Harvest control Rule 1 (hockey stick), 4 (constant catch), and 5 and 6 (CPUE-based rules, Figure 2) were tested. CPUE series S1 and S3 were tested as the index of abundance, to test the differing variability in the series (process error was estimated at about 0 for S1 and 0.8 for S3). Different levels of catch at the target CPUE were also tested. The catch limit was modified every three years, simulating the assessment cycle, and the total catch limit was assumed to be caught each year.

Multiple model misspecifications were tested whereby the operating model (representing reality) had different parameters from the estimation model (used for management purposes). Terms tested were natural mortality, maturity and selectivity. Because the starting biomass was already below target, additional models in a more depleted state were not carried out as they were for orange roughy.

Detailed results are provided in 'Appendix H – Alfonsino management strategy evaluation results' and are discussed briefly here.

Full management strategy evaluation runs in which initial biomass was estimated every three years resulted in highly variable initial biomass, orders of magnitude higher than the model-estimated biomass (Figure H.1). The model as it stands is too weakly informed to be stable in a management strategy evaluation. A full MSE should be carried out on better-informed models (which include additional length compositions) with updated parameters. In the meantime, the potential harvest control rules were tested using 'short' MSE, whereby the parameters were not re-estimated.

The results generally indicated that a constant catch harvest control rule did not perform as well as other rules. The hockey stick rule resulted in a biomass exactly at the target biomass (e.g., Figure H.3) although the lack of variability was due to the lack of re-estimation of the parameters.

Harvest control rules based on CPUE resulted in highly variable catch limits due to the high variability of the indices (e.g. Figure H.4) and would benefit from the addition of a maximum TAC change within the HCR, as per simulations S38 to S43. Furthermore, the more variable the CPUE index, the lower the performance of the HCR (e.g. Figure H.6). Rule 5 was more precautionary than Rule 6 (e.g. Figure H.6).

CPUE-based rules rely on the adequate setting of the TAC at the plateau of the rule (the target CPUE), effectively being the equivalent of F_{TARGET}. For the model with M = 0.2, a plateau at a TAC of about 1400 t seemed adequate based on model results (Figure H.5) whilst a plateau at a TAC of about 800 t was required for the model with natural mortality assumption of 0.1 (Figure H.9). These values would be the equivalent of the F_{TARGET} of 0.178 for R1.2 and 0.088 for R1.5 (Table 9).

Because the operating models for these MSEs did not re-estimate parameters, results were highly sensitive to misspecification of parameters (natural mortality, maturity and selectivity). Where those parameters are unknown and not estimable, the harvest control rules should be robust to the likely values of these.

These MSE simulations used alfonsino as a case study but are not intended to represent management advice for alfonsino. In addition to uncertainty about ageing, biological parameters and limited size data, all models assumed that CPUE was proportional to abundance, without scenarios in which CPUE in the alfonsino fishery was hyperstable.

5. Discussion

The PAM-2024 body of work has aimed to progress the SIOFA precautionary approach to management (PAM). Project PAM-2024-01 (Robertson & Holmes in prep) developed a framework, PAM-2024-02 proposed biological reference points for the main SIOFA stocks (Hoyle & Mormede in prep), and PAM-2024-03 carried out initial testing of potential harvest control rules (HCRs) through management strategy evaluations (MSE, this report). It is important to note that this body of work is another step towards the precautionary approach to fisheries management rather than final outcomes. Further iterations of this process, including further management strategy evaluations, should be carried out following feedback from SIOFA.

The species considered as test cases in this body of work were orange roughy and alfonsino. These were test cases for processes and principles rather than aiming to develop final harvest control rules. Although toothfish was initially considered, CCAMLR is undergoing its own MSE process for toothfish, which is likely to be adopted by SIOFA and therefore this species was not investigated further.

High / medium information stocks

Orange roughy was a test case for a species where a relatively robust age-based Bayesian stock assessment is available, although other parameters such as stock structure and natural mortality are uncertain. Results showed that hockey stick HCRs were the most appropriate for such cases, and that the slightly more precautionary Rule 1 provided more robust results for depleted stocks. The rule could be applied to the stock-based estimate of biomass, or to the acoustic-based estimate if available, leading to slightly more conservative management. Constant exploitation rate rules did not perform adequately (and are not deemed acceptable within the MSC framework, Marine Stewardship Council 2022).

The MSE testing suggested that these rules were relatively robust to misspecification of parameters in this instance, as the parameters were adequately estimated by the model. Misspecification of natural mortality, although corrected for by the estimation model, still led to excessive fishing mortality due to the misspecification of F_{TARGET} (calculated based on the incorrect natural mortality), resulting in stock status slightly below target.

Medium / low information stocks

Alfonsino was used as a test case for a species where a robust stock assessment is not available, but a CPUE series represents the underlying biomass. Results indicated that a CPUE-based harvest control rule could be adequate but required the total allowable catch (TAC) at the CPUE reference to be set to the right level. If not, the resulting stock status stabilised at a level that differed from the target biomass. Such rules performed better than constant catch rules. These models were also more susceptible to misspecification of influential biological parameters such as natural mortality or selectivity. Testing suggested that more variable CPUE led to a more variable TAC, requiring the addition of a maximum rate of TAC change to the harvest control rule shape.

We note that CPUE-based management requires catch rates to be proportional to stock biomass. This proportionality assumption may be compromised in fisheries with limited fleet diversity – often conducted by a single flag or vessel – and/or where operations target local aggregations using acoustic marks. Where CPUE is used for management purposes, monitoring for potential serial depletion or changes in fleet selectivity becomes critical. This is addressed by the proposed performance measures FE02 (major spatial redistribution of effort) and FE03 (significant selectivity changes).

Furthermore, CPUE-based management, even with a CPUE representative of the underlying biomass, can be risky (e.g., de Lestang et al. 2024), and it should be combined with other indicators where possible.

Low information stocks

Alfonsino was also used as a test case of a low information stock with length frequency data. Simulations indicated that length-based spawning potential ratio methods (LB-SPR) might be applied to low information stocks. Such methods were insensitive to misspecification of age (as is potentially the case for alfonsino) but were sensitive to assumed biological parameters for the species as well as the assumption of logistic selectivity for the fishery.

Results indicated that the outcomes of the LB-SPR methodology were consistent with the stock assessment outcomes, although the LB-SPR was slightly more optimistic in terms of stock status in some instances.

A next step could be to test harvest control rules based on length-based indicators and compare them with full stock assessment evaluations. Length-based management methods could also be applied in conjunction with CPUE-based management methods. These were not tested due to the uncertainty surrounding the current alfonsino stock assessments.

This method could be applied to low information stocks where no assessment is available, including bycatch species where applicable. They would require initial analyses of spatial temporal length data to identify how to use these data. For example, alfonsino length data had to be subset to an area with logistic selectivity and stable sampling; using all the length data indiscriminately would have resulted in misleading stock status and trends. Furthermore, fishing and therefore data collection has been sporadic in both time and space for many species. These fisheries would benefit from the development of structured fishing programs to ensure that consistent data is collected over space, time and fisheries.

Such methods could subsequently be refined as local estimates of biological parameters were developed. In particular, it would be prudent to recalculate von Bertalanffy growth curves with realistic values of t_0 since t_0 and K are correlated, and to re-estimate maturity.

Performance indicators

The model-based and MSE-based performance indicators were tested against the species investigated. They seemed to capture most of the relevant information and would be easy to apply.

Some performance indicators could be refined: for example, MC02 (the variability of annual catch limits) became irrelevant when the TAC was very small. Further performance indicators could be added if required.

The fishery-based indicators were not investigated here as they are aimed at low information stocks with no assessment. They could be tested and refined by the SIOFA Secretariat for some stocks.

Alfonsino-specific results

The development of stock assessment models for alfonsino suggested that the status of the east stock may be much lower than previously estimated (Brandão et al. 2020), with status in 2020 below 40% B_0. The earlier high estimate of stock status was likely driven by the assumption that the age of full selectivity was five years older than maturity, effectively creating a portion of the spawning stock not susceptible to fishing. This is likely an artefact of the model.

Results from the length analysis and LB-SPR analysis suggested that the current assumption of equal fishing selectivity for the east and west stocks is unlikely to be adequate. These models should be updated with full length data investigations, updated ageing and further investigations into selectivity and maturity curves.

Bayesian population models for the alfonsino east and west stocks. Although these were simplifications of a full population model for MSE purposes, they could be used as a starting point to develop full stock assessment models for alfonsino. An update could consider the inclusion of latest ageing data, estimate of natural mortality and of maturity, fitting to the full annual age or length frequency distributions for each stock separately, and particular attention to the estimated selectivity with regards to the assumed maturity curve.

Orange roughy-specific results

The simulation work was carried out using a biomass target of 40% B_0 with 50% probability, and a biomass limit of 20% B_0 with 10% probability. Hoyle & Mormede (2026) recommended that the limit be set at 30% B_0 for orange roughy. The equivalent F_{TARGET} remained unchanged, indicating that F_{TARGET} was not limited by the biomass limit, even if it was set at 30% B_0. Furthermore, simulations indicated that harvest control rule 1 performed almost as well if the biomass limit was 30% B_0 as when it was 20% B_0.

SC-11 recommended that should the biomass limit be set at 30% B_0 for orange roughy, the target biomass reference point might need to be set at 50% B_0. Results indicate that the biomass limit reference point was not influential in the simulations carried out, even in the scenarios with added variability in annual recruitment strength. However, increasing the biomass target reference point would reduce the target exploitation rate (F_{TARGET}) from 0.033 to 0.024.

6. Recommendations

The recommendations below are specific to this report; recommendations made as part of PAM-2024-01 and PAM-2024-02 are not repeated here.

- Start monitoring the proposed data-based performance indicators for top tier stocks
    - Refine the bracketed values in the data-based performance indicators for top tier stocks.
- Roll out the proposed precautionary approach to management to SIOFA species and stocks, including:
    - For assessment-based management: develop stock assessments where possible and stock assessment-based harvest control rules, and refine the rules tested here based on management feedback (e.g. shape of the HCR, maximum TAC change allowed) , and / or test alternative rules.
    - For CPUE-based management: standardise CPUE indices and develop MSE models to define the appropriate TAC reference level at the CPUE reference level.
    - For length-based management: develop a spatial and temporal data collection plan that allows for the calculation of scaled length compositions, develop area-specific biological parameters, and calculate length-based stock status and fishing pressure.
- Assess harvest control rules using length-based management options.
- Investigate the potential to use length-based and CPUE-based rules concurrently.
- Investigate the potential usefulness of other models not fully considered in this simulation work, e.g. sustainability assessment for fishing effects (SAFE).
- Develop data collection plans to increase knowledge about stocks and management options (including the consideration of new methods such as genetics or independent surveys).
- Alfonsino: update the stock assessment with additional length data, updated ageing, and particular consideration of the relationship between maturity and selectivity.
- Toothfish: follow CCAMLR progress on MSE in research blocks.

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9. Appendix A - glossary

Table A. 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
B_{TARGET}	Target spawning stock biomass, defined as either B_{MSY} or a proxy such as 40% B_0
CPUE	Catch per unit effort
E	The fishing exploitation rate. This is the proportion of the vulnerable biomass that is expected to be caught at a point in time, also referred to as U
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. See also the definition of fishing exploitation rate (E), where the annual fishing exploitation rate (E) is calculated using the formula $E=1-\exp(-F)$
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_{TARGET}	The long-term instantaneous fishing mortality rate that would result in the spawning stock biomass being at B_{TARGET} on average, or some other defined target (e.g. LB-SPR). Examples are F30, F40 or F50.
HCR	Harvest control rule. A rule that describes how the harvest is to be managed based on selected indicators of stock status. Also known as a decision rule or management procedure.
LB-SPR	Length-based spawning potential ratio methodology (suitable for low-information stocks)
L_{INF}	von Bertalanffy maximum length parameter (not the largest animal ever caught)
LRP	Limit reference point
L50	Length where 50% of the population is mature (SL50 is selectivity, see below)
M	Natural mortality
MCMC	Markov Chain Monte Carlo
MSE	Management strategy evaluation
MSY	Maximum sustainable yield
PGK	Probability of being in Green Zone of Kobe Space ($SB>B_{TARGET}$ & $F<F_{TARGET}$)
PNOF	Probability of Not Overfishing ($F< F_{TARGET}$)
SL50	Length at which 50% of the population is selected by the fishing gear
SSB	Spawning stock biomass in this document, also referred to as SB or B
SPR	Spawning potential ratio
TAC	Total allowable catch
TRP	Target reference point
USR	Upper stock reference (for harvest control rule with a top inflation point different from the TRP)
VarC	Mean variation in TAC (%) between management cycles over all years and simulations
VulnB	Vulnerable biomass

10. Appendix B – summary of stock status for some SIOFA stocks

Summary of the current knowledge of stock status for some main species and stocks, based on the SIOFA fishery reports.

10.1.1 Orange roughy (*Hoplostethus atlanticus*)

Orange roughy was last assessed in 2025. Three sets of fully Bayesian age-based stock assessment models were developed: for the Walter Shoal Ridge area (WSR), the Long Walter's Shoal Ridge area (LWSR, including the Walter Shoal Ridge) and the South-West Indian Ocean Ridge area (SWIOR). The data informing those models were catches, acoustic surveys, length compositions and age compositions. Catch per unit effort (CPUE) is not deemed a reliable index of abundance for orange roughy because fisheries usually concentrate on spawning aggregations, and effort is only recorded if fish are located via echo sounders.

The orange roughy stock status for the Walter Shoal Ridge was deemed highly uncertain and likely to be above the interim target biomass status of 40% B_0. The acoustics data were sparse for some hills whilst they showed a large decline in biomass for other hills, warranting caution. Projections resulted in stock status and / or fishing pressure exceeding interim targets.

The Long Walter Shoal Ridge stock represents an extended version of the WSR stock. As for the WSR stock, stock status was deemed highly uncertain and likely to be above the interim target biomass status of 40% B_0. The acoustics data were sparse for some hills whilst they showed a large decline in biomass for other hills, warranting caution. Projections under certain assumptions indicate that the interim target biomass and fishing pressure could be exceeded.

The orange roughy stock status for the South-West Indian Ocean Ridge stock is unknown. Only two seamounts have been surveyed in two years and present opposite biomass trends. Historical catches have been much higher than recent catches, indicating a potentially large initial stock size. Length distributions suggest orange roughy caught in the SWIOR are larger than those caught elsewhere. These suggest that the current stock size might be healthy.

The SIOFA Scientific Committee has provided interim advice, endorsed by the SIOFA MoP, to put in place an interim catch limit for orange roughy corresponding to the average annual catch in 2015–2020. No further management advice has been agreed for orange roughy in the SIOFA area.

10.1.2 Toothfish (*Dissostichus* spp.)

Toothfish are split into two management areas: William's Ridge and Del Cano Rise. Both areas are adjacent to CCAMLR areas.

Preliminary stock assessments were carried out for the Del Cano Rise fishery using stock reduction methods (Sarralde et al. 2020). These models were not able to estimate the current status of the stock but confirmed depletion following a period of high exploitation.

An assessment of the Del Cano Rise stock size was developed based on CPUE by seabed area analogy, following the CCAMLR methodology (SC-09-35). The resulting recommended catch limits were endorsed by MOP11. The number of tags recaptured was insufficient to develop a Chapman estimate of biomass at this stage.

No assessment is available for the Williams Ridge fishery in subarea 7 as data are currently insufficient to inform a full stock assessment. Catches from the Williams Ridge fishery are incorporated into the stock assessment for Heard Island and McDonald Islands that is presented to CCAMLR.

SIOFA has adopted Management Objectives and Performance indicators for defined toothfish management areas (MoP11 Report, Annex O). These include maintaining the stock (or a suitable proxy) fluctuating around (i.e., with a 50% probability) 50% B_0 and ensuring that the stock is above a limit reference point (LRP) of 20% B_0 with a 90% probability. A management strategy evaluation (MSE) should initially evaluate alternative sensitivity choices of 50-60-70% probability of being at or above a TRP of 40-50-60% B_0 for toothfish (MoP11 report, paragraph 148). A harvest strategy to achieve these objectives has not been defined yet.

10.1.3 Alfonsino (*Beryx splendens*)

An age-structured production model for alfonsino was last carried out in 2020, fitted to catch histories, standardised CPUE times series and a length composition (Brandão et al. 2020, 2021). Due to data limitations, only deterministic modeling was carried out, and the selectivity of the different fleets were assumed to be identical. The stock status for both West and East management units was deemed to be at about 60% of B_0, with no current over-fishing.

We note that the ageing protocol for alfonsino in the SIOFA area is being revised and might lead to a reduction in the natural mortality currently assumed. Projections suggested that the biomass could drop below the interim target level within 10 years in the sensitivity analysis which assumed lower natural mortality.

The SIOFA Scientific Committee has provided interim advice, endorsed by the SIOFA MoP, to put in place an interim catch limit for alfonsino corresponding to the average annual catch in 2018–2022. No further management advice has been agreed for alfonsino in the SIOFA area.

10.1.4 Hapuka (*Polyprion* spp.)

There are no stock definitions or assessments for Hapuka in the SIOFA area; the status of this stock is unknown. Catch history and unstandardised catch per unit effort (CPUE) are available. Reliable catch and effort data for this species are only available from 2019. Unstandardised CPUE has been variable over time. Because the hapuka fishery is a mixture of methods and target / non-target fleet, the unstandardised CPUE is not deemed a reliable index of abundance.

The SIOFA Scientific Committee has provided interim advice, endorsed by the SIOFA MoP, to put in place an interim catch limit for hapuka corresponding to the average annual catch in 2018–2022. No further management advice has been agreed for hapuka in the SIOFA area.

10.1.5 Common mora / ribaldo (*Mora moro*)

There are no stock definitions or assessments for mora in the SIOFA area; the status of this stock is unknown. Catch history and unstandardised catch per unit effort (CPUE) are available. Both catch and effort have been variable over time. Unstandardised CPUE has been generally decreasing over the duration of the fishery. Because the mora fishery is a mixture of methods and target / non-target fleet, the unstandardised CPUE is not deemed a reliable index of abundance.

The SIOFA Scientific Committee has provided interim advice, endorsed by the SIOFA MoP, to put in place an interim catch limit for mora corresponding to the average annual catch in 2018–2022. No further management advice has been agreed for mora in the SIOFA area.

10.1.6 Oilfish (*Ruvettus pretiosus*)

There are no stock definitions or assessments for oilfish in the SIOFA area; the status of this stock is unknown. Catch history and unstandardised catch per unit effort (CPUE) are available. Both catch and effort have been variable over time. Unstandardised CPUE has been generally decreasing over the duration of the fishery. There is a standardised CPUE index for oilfish (SC-10-75), showing a general increase over time.

The SC8 recommended that the length distribution and the standardised CPUE should be used as oilfish stock indices in the short term, to monitor the oilfish stock in SIOFA area. The SIOFA Scientific Committee has provided interim advice, endorsed by the SIOFA MoP, to put in place an interim catch limit for oilfish corresponding to the average annual catch in 2018–2022. No further management advice has been agreed for oilfish in the SIOFA area.

11. Appendix C – example of existing harvest control rules

Below is a non-exhaustive list of potential harvest control rules developed elsewhere. They are split in F-based and catch-based harvest control rules.

11.1 Example of F-based rules

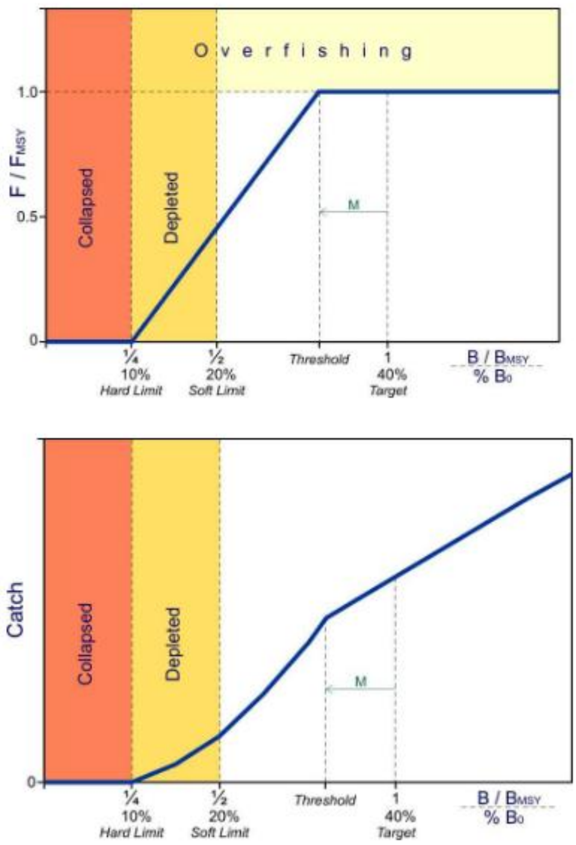

Figure C.1: Example of potential harvest control rule in the 2011 NZ Harvest Strategy Standards (Figure 11 of Ministry of Fisheries 2011).

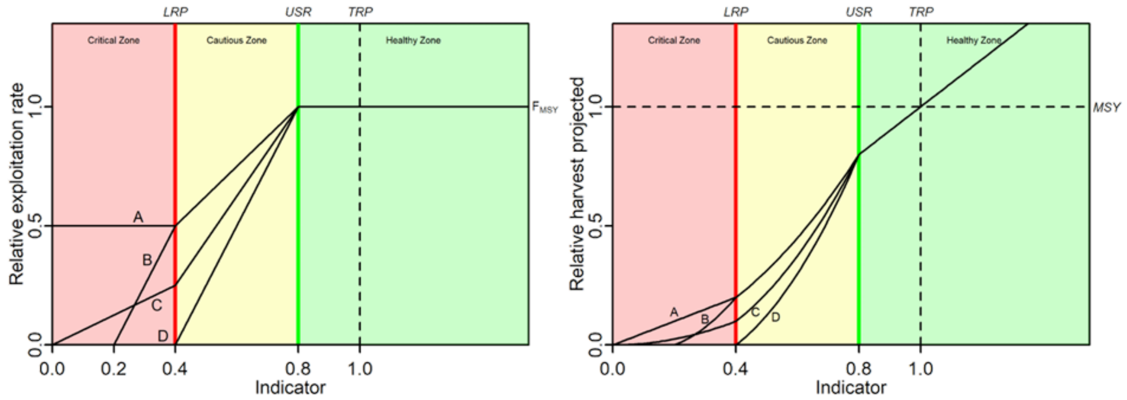

Figure C.2: Example of harvest control rules (HCR) representing relative exploitation rates (e.g., F/F_{TARGET}, left) and relative harvest projected (e.g., catch / catch at target, right) as a function of the stock status indicator (e.g., B/B_{TARGET}). LRP = limit reference point, USR = upper stock reference, TPR = target reference point, MSY = maximum sustainable yield, which could also be the interim target. Figure 10 reproduced from DFO (2023).

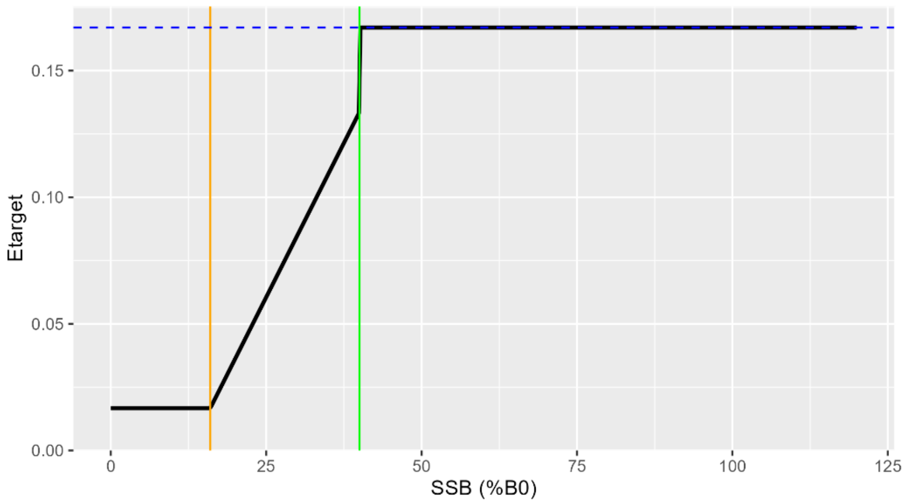

Figure C.3. The SPSS Fox 2 harvest control rule (HCR) applied in simulations for north Atlantic swordfish (Carruthers et al. 2024). The orange vertical line is $B_{LIM} = 0.4 \times B_{THRESH} = 0.16 \times B_0$. The green line represents B_{THRESH} at $0.4 \times B_0$. The blue horizontal line is $E_{PROP} = 0.167$, which is the constant harvest rate that will achieve a 60% and 70% probability of being above B_{THRESH} in order to satisfy the probability of being in the green quadrant of the Kobe plot (KGP) (Figure 2 of Mormede et al. 2025a).

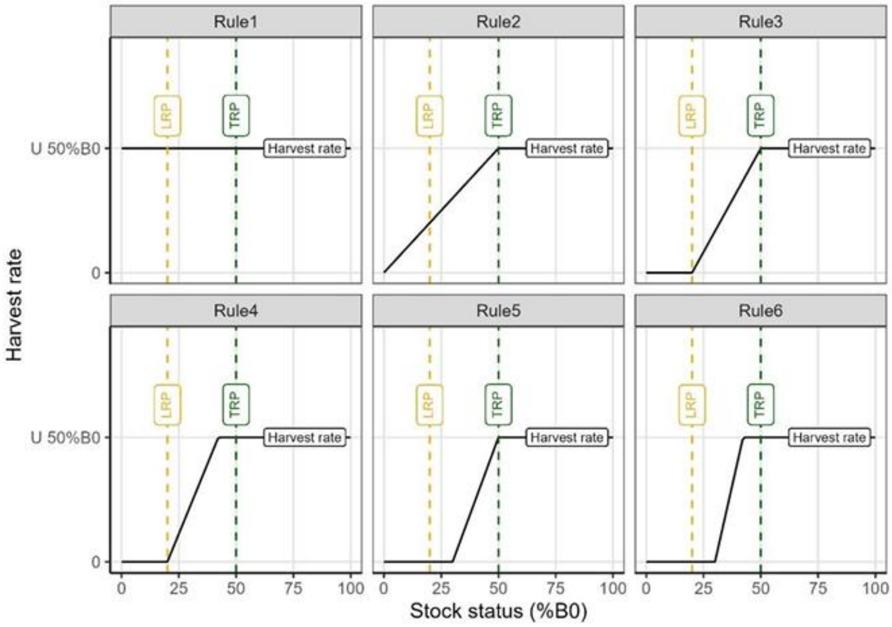

Figure C.4: Some proposed HCRs for CCAMLR (Figure 1 of Ziegler et al. 2024a).

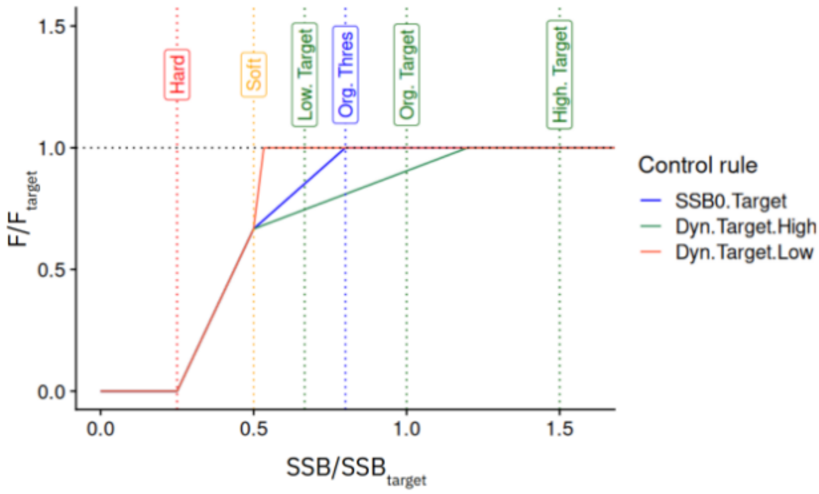

Figure C.5: Example of HCRs tested in New Zealand in a dynamic B_0 framework (Figure 1 of Neubauer et al. 2025b).

11.2 Example of catch-based rules

The translation of F-based rules to catch-based rules can be done mathematically (see Figure C.1 and Figure C.2 for example). One of the characteristics of this translation is a continued increase in the catch limit when the biomass increases above the target biomass. However, some jurisdictions apply alternative rules, (e.g., Figure C.6).

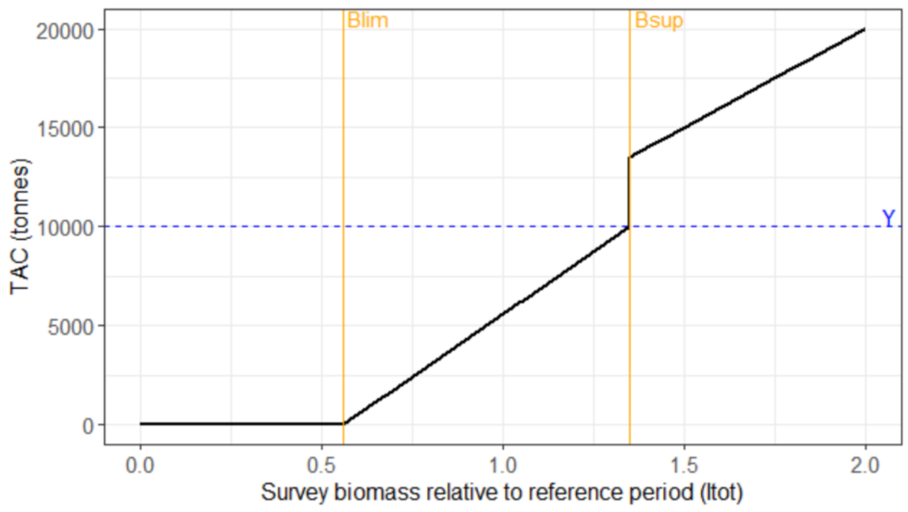

Figure C.6: Plot of the management rule used for setting shrimp TAC in the Gulf of St Lawrence based on survey biomass (Desgagnés & Savard 2012) with survey biomass reference point as the x-axis variable and catch limit (TAC) as the y-axis variable.

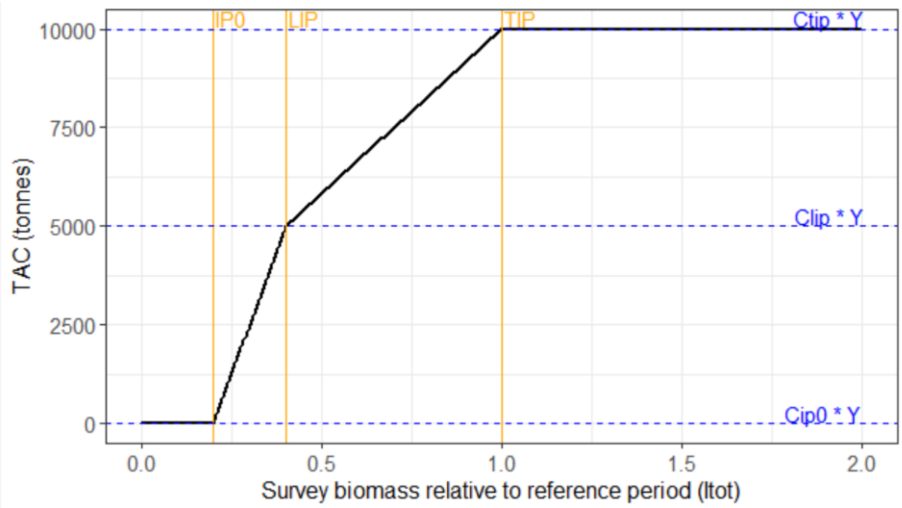

Figure C.7: Plot of the management rule for setting capelin catch limit (TAC) in ICES in 2021 (https://www.fiskeridir.no/Yrkesfiske/Dokumenter/Reguleringsmoetet2/November-2021/_/attachment/download/cc0fbc92-c9be-421d-aa84-8b308e8c70af:7313713b9df4b315dd53629630e22e7f976177ad/Sak-21-vedlegg-cap-27-1-2.pdf) with survey biomass reference point as the x-axis variable and catch as the y-axis variable.

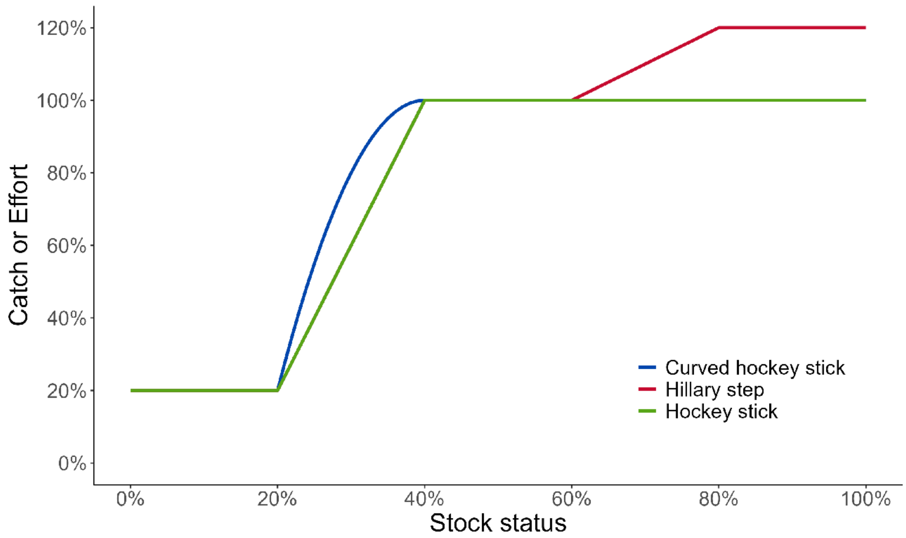

Figure C.8: Example of HCR shapes considered for WCPFC bigeye tuna (Figure 2 of Wickens et al. 2025) with stock status as the x-axis variable and catch as the y-axis variable.

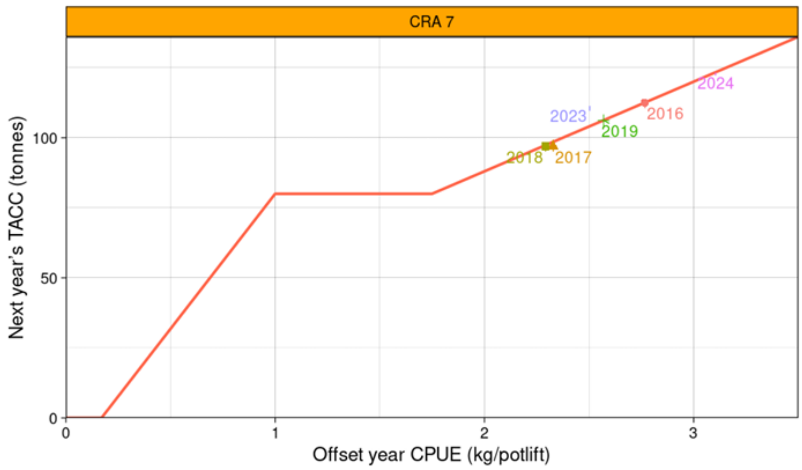

Figure C.9: HCR shape used for rock lobster in CRA7 in New Zealand (figure 4 in Webber et al. 2025).

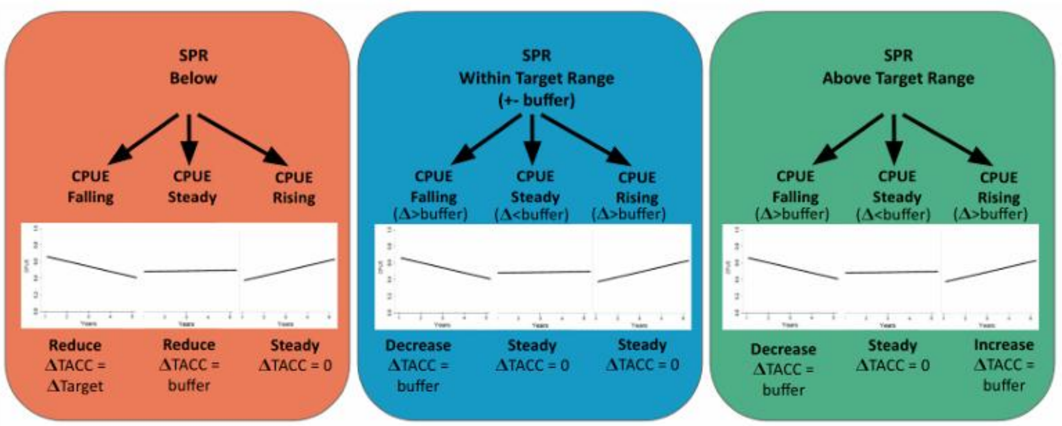

Figure C.10: HCR being considered for paūa in PAU3A in New Zealand (Figure 26 in Neubauer et al. 2025a): length-based spawning potential ratio (LB-SPR-based harvest control rule proposed for PAU 3A: A target spawning potential ratio (SPR) is first set (e.g., 50% of unfished spawning potential). Given a buffer (e.g., 10%) around this target, the SPR is estimated from length data for each management area. If the estimated SPR is within the target zone and catch-per-unit-effort (CPUE) is not declining, no further action is required. If CPUE is declining (e.g., 2 years of CPUE declines in a row), then catch is reduced by 10%. If the SPR is below target by more than the specified buffer, corrective action is taken by reducing the catch by the ratio of SPR to the target (i.e., the reduction is at minimum equal to the buffer). If the SPR is above the target buffer zone, catch is maintained unless CPUE drops rapidly (by >buffer). Similar rules are used in ICES.

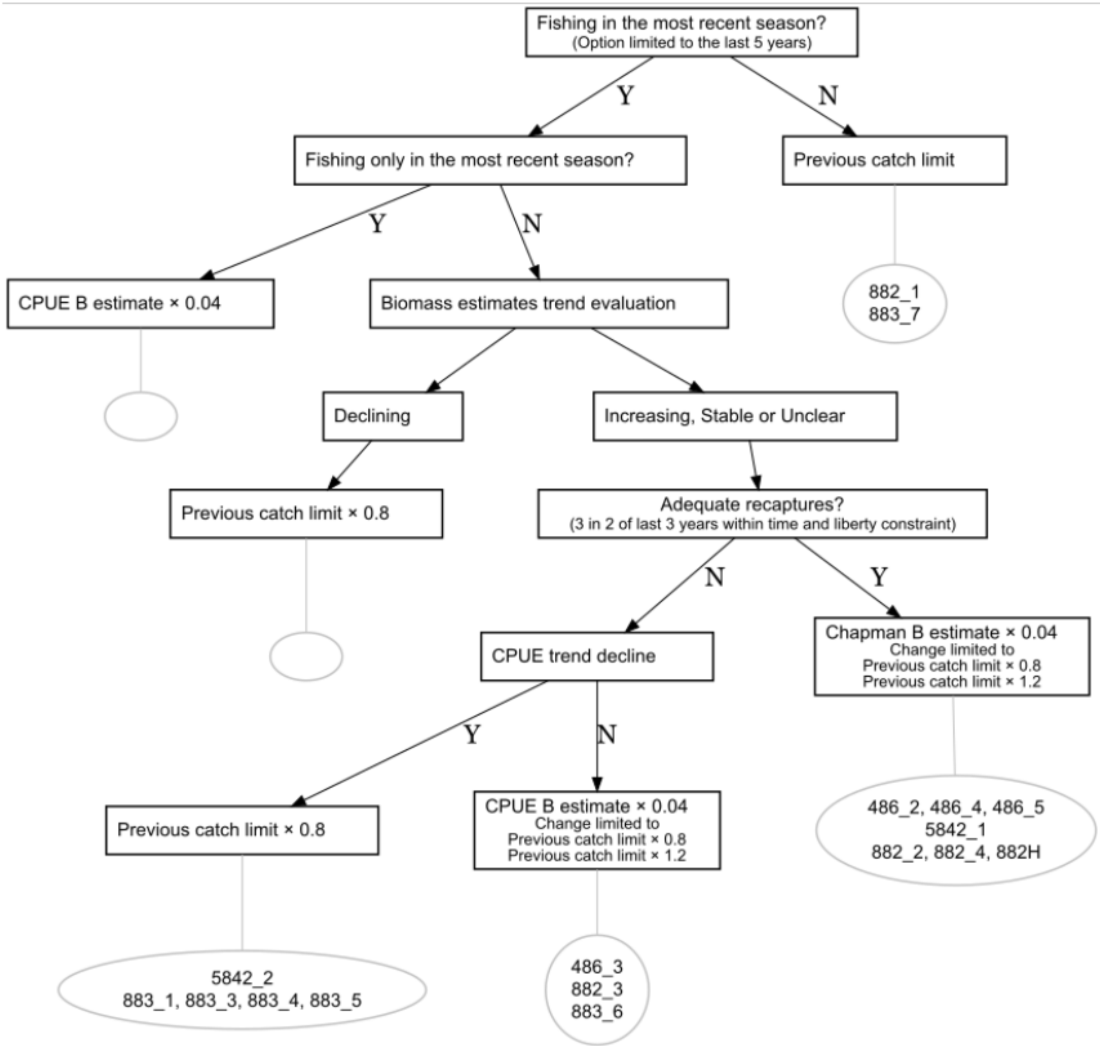

Figure C.11: CCAMLR's approach to data-limited exploratory toothfish fisheries (trend analysis): schematic of the decision rules used to determine catch limits in data-limited fisheries in 2025 (Figure 5 reproduced from https://fishdocs.ccamlr.org/TrendAnalysis_2024.html).

12. Appendix D – proposed performance measures

We note that the specific numerical thresholds presented in this framework are indicative only, as indicated by square brackets, []. These would need to be formally tested and agreed upon for each species and stock, taking into consideration the characteristics of the fishery and the data available.

The performance measures can be relevant to either:

- Model-based performance, applied to models or harvest control rule outputs – these are updated when a model or harvest management strategy evaluation is carried out / updated. They are used to judge the utility of a particular HCR / management system.
- Fishery indicators, calculated for each year of a fishery. These track whether the fishery management system is performing as expected. They could also be used as part of the management system, by explicitly linking the indicators with reference points and breakout rules.

The two categories of performance measures are provided separately below, as the frequency of update is likely to be different. Project PAM-2024-02 suggested the environment-based fishery indicators be its own separate category. Because these can be model-based or data-based, they were kept within the categories proposed herein but could easily be separated out.

The first letter of each performance indicator corresponds to whether it is model-based (M) or fisheries-data based (F), and the second letter corresponds to a broad classification group (P = stock productivity, C = catch and effort, A = assessment, E = ecosystem). The names in bracket, where given, refer to the objectives referred to in WS2024-HSS Appendix B.

Not all performance indicators will be measurable for all species and stocks.

12.1 Harvest control rule performance measures

These measures are typically model-based and / or simulation-based and can only be updated after a new model is carried out or a new management strategy evaluation is carried out.

MP01 Maintain the stock around the target reference point (stock status)

The probability that the stock will go below the target reference point over the defined period. The target reference point will be different between different stocks, for example 40% B_0 for orange roughy and a CPUE target for alfonsino.

Green: A lower than [50%] probability that the stock is or will be below the target reference point over the defined forecasted management period.

Amber: Between a [50-60%] probability that the stock is or will be below the target reference point over the defined forecasted management period.

Red: A higher than [60%] probability that the stock is or will be below the target reference point over the defined forecasted management period.

MP02 Limit reference point (risk / safety)

The probability that the stock will go below the limit reference point over the defined period, for example 20% B_0 for orange roughy.

Green: A lower than [5%] probability that the stock is or will be below the limit reference point over the defined forecasted management period.

Amber: Between a [5-10%] probability that the stock is or will be below the limit reference point over the defined forecasted management period.

Red: A higher than [10%] probability that the stock is or will be below the limit reference point over the defined forecasted management period.

MP03 Probability of being in the green zone of the Kobe plot

The probability that the stock is or will remain in the green zone of the Kobe plot (biomass above target biomass and fishing pressure below target fishing pressure) for those stocks where these values are available. We note that MP03 is the combination of MP01 (biomass above target biomass) and MP04 (probability of overfishing).

Green: A greater than [50%] probability that the stock is or will be in the green zone of the Kobe plot over the defined forecasted management period.

Amber: Between a [40-50%] probability that the stock is or will be in the green zone of the Kobe plot over the defined forecasted management period.

Red: A lower than [40%] probability that the stock is or will be in the green zone of the Kobe plot over the defined forecasted management period.

MP04 Probability of not overfishing

The probability that the fishing pressure is or will remain below target fishing pressure for those stocks where these values are available.

Green: A greater than [50%] probability that the fishing pressure is or will be below the target fishing pressure over the defined forecasted management period.

Amber: Between a [40-50%] probability that the fishing pressure is or will be below the target fishing pressure over the defined forecasted management period.

Red: A lower than [40%] probability that the fishing pressure is or will be below the target fishing pressure over the defined forecasted management period.

MC01 Long term average annual catch limit (economic, yield)

This measure tracks the relative economic viability of the different harvest control rules. There are no flags associated with it. It is calculated as the average catch limit over the defined forecasted management period. This forecast management period might only include later forecast years, i.e., once the population has stabilised to target levels.

MC02 Variability of annual catch limit (economic, stability)

This measure tracks economic stability of the harvest control rule. Is it also a potential sustainability indicator for low information stocks. Note that exceeding the catch limit is also captured by performance indicator C03.

Green: The variability of catch limit over the defined forecasted management period is less than [15%].

Amber: The variability of catch limit over the defined forecasted management period is between [15-25%].

Red: The variability of catch limit over the defined forecasted management period is greater than [25%].

MC03 Long-term predicted annual CPUE (economic, catch rate)

This measure tracks the relative economic viability of the different harvest control rules. There are no flags associated with it. It is calculated as the average projected CPUE over the defined forecasted management period. This forecast management period might only include latter forecast years, i.e., once the population has stabilised to target levels.

MA01 Assessment model convergence and reliability

This indicator captures the adequacy of the stock assessment model to determine status. Applicable to stocks with assessment models.

Green: Diagnostics for all key parameters (biomass indices, and tag-release and recapture observations) are adequate, and no evidence of significant departure from model assumptions.

Amber: The majority of diagnostics for all key parameters (biomass indices, and tag-release and recapture observations) are adequate; sensitivity runs that evaluate alternative choices of parameters where diagnostics are not adequate do not significantly affect estimates of status.

Red: Failure of key parameters to converge at MCMC. Key parameters are poorly estimated; or sensitivity runs that evaluate alternative key choices of parameters with model parameters where diagnostics are not adequate have a significant effect on estimates of status.

MA02 Fits to the indices of abundance

Abundance indices in disagreement with the model trajectory, which might indicate that the model is not adequate or that the abundance indices are not reliable.

Green: The abundance indices are fitted without any significant trend in the residuals.

Amber: The abundance indices that are fitted have a significant trend in the residuals.

Red: Not defined (models should not be used for management purposes if they don’t fit the abundance indices).

MA03 Between assessment catch limit variability (Economic, stability)

The absolute percentage change in catch limits between assessments. This measures changes in advice resulting from the assessment, and hence the assessment stability. It also represents economic stability.

Green: The percentage change in the catch limit from the assessment is less than [0.15] over the defined forecasted management period.

Amber: The percentage change in the catch limit from the assessment is between [0.15 and 0.25] over the defined forecasted management period.

Red: The percentage change in the catch limit from the assessment is greater than [0.25] over the defined forecasted management period.

ME04 Change in average recent recruitment

Evidence of significant reduction in recent recruitment, which may indicate higher or lower productivity than assumed. Only applicable for stocks with an assessment that estimates recruitment.

Green: YCS in the last [10] years lower than [75%] of long-term average YCS.

Amber: YCS in the last [10] years between [50–75%] of long-term average YCS.

Red: YCS in the last [10] years below [60%] of long-term average YCS.

12.2 Management performance indicators

These are typically data-based indicators that can be updated most years when new data are available. These serve as early warning indicators between assessments and for stocks with no assessment available.

FC01 Total annual catch (economic, yield)

This indicator tracks economic viability. Is it also a potential sustainability indicator for low information stocks. Note that exceeding the catch limit is also captured in performance indicator C03. Note that for stocks with small catch limit, a difference in tonnes is likely more robust.

Green: The annual catch is less than a difference of [15% / 5 tonnes] of the current limit.

Amber: The annual catch difference is between [15-25% / 5-10 tonnes] of the current limit.

Red: The annual catch is greater than a difference of [25% / 10 tonnes] of the current limit.

FC02 Total annual effort (economic, yield)

This indicator tracks economic viability. Is it also a potential sustainability indicator for low information stocks.

Green: The mean annual effort is less than a difference of [15%] of the mean annual effort over the defined reference period ([2018-2022]).

Amber: The mean annual effort difference is between [15-25%] of the mean annual effort over the defined reference period ([2018-2022]).

Red: The mean annual effort is greater than a difference of [25%] of the mean annual effort over the defined reference period ([2018-2022]).

FC03 The catch in the most recent seasons is less or equal to the catch limit

The average catch taken in the most recent seasons should be less than or equal to the total catch limit.

Green: The amount of catch taken from the fishery does not exceed the catch limit when averaged over the last [two] seasons.

Amber: Not defined.

Red: The amount of catch taken from the fishery exceeds the catch limit when averaged over the last [two] seasons.

FC04 Mean unstandardised CPUE (economic, catch rate)

This indicator tracks economic viability. Is it also a potential sustainability indicator for low information stocks.

Green: The unstandardised CPUE is less than a difference of [15%] of the mean unstandardised CPUE over the defined reference period ([2018-2022)].

Amber: The unstandardised CPUE is between [15-25%] of the mean unstandardised CPUE over the defined reference period ([2018-2022)].

Red: The unstandardised CPUE is greater than a difference of [25%] of the mean unstandardised CPUE over the defined reference period ([2018-2022)].

FA01 Abundance indices

Applicable to stocks with abundance indicators (e.g. CPUE, acoustics). If abundance indices disagree with each other, it might indicate that one or more of these abundance indices do not provide reliable management advice.

Green: The abundance indices are in general agreement with each other.

Amber: The abundance indices disagree with each other.

Red: Not defined.

FA02 Data availability and quality

Aims to capture when the data collection is no longer adequate for the management of the stock. For example, if management advice is based on length data and insufficient length data are collected, or if based on acoustics data and insufficient surveys have been carried out.

Green: The data used for management advice continues to be of adequate quantity and quality to provide management advice.

Amber: The data used for management advice have not been updated for more than one assessment cycle.

Red: The data used for management advice have not been updated for more than two assessment cycles.

FE01 Major ecosystem regime shift

Evidence of significant ecosystem regime shift affecting stock productivity including major changes in prey abundance, predator populations, oceanographic conditions.

Green: No evidence of a major environmental regime shift

Amber: Indirect evidence of a major environmental regime shift

Red: Direct evidence of a major environmental regime shift that materially effects the assumptions underpinning the harvest control rule and the assessment.

FE02 Major spatial redistribution of effort

Evidence of significant spatial redistribution of effort that may be the result of a management action, changing productivity, serial depletion, or stock collapse.

Green: No evidence of significant spatial redistribution of effort.

Amber: Some spatial redistribution of effort that is unlikely to significantly affect the harvest control rule or the assessment assumptions.

Red: Spatial redistribution of effort that is likely to significantly affect the harvest control rule or the assessment assumptions.

FE03 Significant selectivity changes

Evidence of significant selectivity change that may be the result of a management action or fleet dynamics.

Green: No evidence of significant selectivity change.

Amber: Some selectivity change that is unlikely to significantly affect the harvest control rule or the assessment assumptions.

Red: Significant selectivity change that is likely to significantly affect the harvest control rule or the assessment assumptions.

FE04 Change in biological parameters

Evidence of significant change in biological parameters from the parameters assumed in the management advice. Biological parameters will include length-weight and growth relationship where available.

Green: Biological parameters in the last [5] years within [80–120%] of assumed parameters in the stock assessment model or stock characterisation.

Amber: Biological parameters in the last [5] years within [70–80 or 120–130%] of assumed parameters in the stock assessment model or stock characterisation.

Red: Biological parameters in the last [5] years within [<70% or >130%] of assumed parameters in the stock assessment model or stock characterisation.

FE05 Catch of Vulnerable Marine Ecosystems indicator taxa (Ecosystem goals)

Tracks potential increased benthic effect of fishing.

Green: The annual VME catch is less than a difference of [15%] of the mean annual VME catch over the defined reference period ([2018-2022]).

Amber: The annual VME catch difference is between [15-25%] of the mean annual VME catch over the defined reference period ([2018-2022]).

Red: The annual VME catch is greater than a difference of [25%] of the mean annual VME catch over the defined reference period ([2018-2022]).

FE06 Catch of bycatch species (Ecosystem goals)

Tracks potential increased effect of fishing on associated species.

Green: The annual bycatch catch is less than a difference of [15%] of the mean annual bycatch catch over the defined reference period ([2018-2022]).

Amber: The annual bycatch catch difference is between [15-25%] of the mean annual bycatch catch over the defined reference period ([2018-2022]).

Red: The annual bycatch catch is greater than a difference of [25%] of the mean annual bycatch catch over the defined reference period ([2018-2022]).

FE07 Catch of shark species in Annex I of CMM 12 (2023) (Ecosystem goals)

Tracks potential increased effect of fishing on “high-risk” and of “concern” shark species (Annex 1 of CMM 12 (2023)).

Green: The annual catch of Annex 1 (CMM 12 2023) shark species is less than a difference of [15%] of the mean annual catch of Annex 1 (CMM 12 2023) shark species over the defined reference period ([2018-2022]).

Amber: The annual catch difference is between [15-25%] of the mean annual catch of Annex 1 (CMM 12 2023) shark species over the defined reference period ([2018-2022]).

Red: The annual catch of selected shark species is greater than a difference of [25%] of the mean annual catch of Annex 1 (CMM 12 2023) shark species over the defined reference period ([2018-2022]).

FE08 Catch of seabirds (CMM 13 (2022)) (Ecosystem goals)

Tracks potential increased effect of fishing on seabirds.

Green: The annual seabird catch is less than a difference of [15%] of the mean annual seabird catch over the defined reference period ([2018-2022]).

Amber: The annual seabird catch difference is between [15-25%] of the mean annual seabird catch over the defined reference period ([2018-2022]).

Red: The annual seabird catch is greater than a difference of [25%] of the mean annual seabird catch over the defined reference period ([2018-2022]).

13. Appendix E – Orange roughy MSE supplement

Table E.1: Details of the Walter Shoal Ridge orange roughy simulations.

	Estimation Model (prior to MSE estimation)			Operating Model					HCR	
Simulation	M	q(SB)	YCS	M	q(SB)	YCS	Type	Indicator	F_{TARGET}	B_{TARGET}
S1	0.045	0.28	1	0.045	0.28	1	Rule 1	SSB	0.033	0.4
S2	0.045	0.28	1	0.045	0.28	1	Rule 1	SSB	0.046	0.3
S3	0.045	0.28	1	0.045	0.28	1	Rule 1	SSB	0.024	0.5
S4	0.045	0.28	1	0.045	0.28	mu 1 sd 0.7	Rule 1	SSB	0.033	0.4
S5	0.045	0.28	1	0.045	0.40	mu 1 sd 0.7	Rule 1	SSB	0.033	0.4
S6	0.045	0.28	1	0.024	0.28	mu 1 sd 0.7	Rule 1	SSB	0.033	0.4
S7	0.045	0.28	1	0.045	0.28	mu 1 sd 0.7	Rule 2	SSB	0.033	0.4
S8	0.045	0.28	1	0.045	0.28	mu 1 sd 0.7	Rule 3	SSB	0.033	0.4
S9	0.045	0.28	1	0.045	0.28	mu 1 sd 0.7	Rule 4	-	-	-
S10	0.045	0.28	1	0.045	0.28	mu 1 sd 0.7	Rule 3	Acoustics	0.033	0.4
S11	0.045	0.28	1	0.045	0.40	mu 1 sd 0.7	Rule 3	Acoustics	0.033	0.4
S12	0.045	0.28	1	0.045	0.20	mu 1 sd 0.7	Rule 3	Acoustics	0.033	0.4
S13	0.045	0.28	1	0.058	0.28	mu 1 sd 0.7	Rule 1	SSB	0.033	0.4
S14	0.045	0.28	1	0.024	0.28	mu 1 sd 0.7	Rule 2	SSB	0.033	0.4
S15	0.045	0.28	1	0.058	0.28	mu 1 sd 0.7	Rule 2	SSB	0.033	0.4

Table E.2: Results of the simulation runs for the Walter Shoal Ridge orange roughy stock base case – biomass indicators over the short (0-10 years after the end of the model), medium (10-20) and longer term (20-30) years. The colour coding follows the proposed model-based performance measures detailed in 'Appendix D – proposed performance measures': the probability of being above 40% B_0 is MP01, the probability of being below 20% B_0 is MP02, the probability of being in the green portion of the Kobe plot (PGK) is MP03, and the probability of not overfishing ($F < F_{TARGET}$) is MP04.

Model	**Simulation**	**p(SSB > 40% B0) (%)**			**p(B < 20% B0) (%)**			**PGK (%)**			**p(F < FTARGET) (%)**		
		1-10 years	**11-20 years**	**21-30 years**	**1-10 years**	**11-20 years**	**21-30 years**	**1-10 years**	**11-20 years**	**21-30 years**	**1-10 years**	**11-20 years**	**21-30 years**
Base	S1	100.0	100.0	99.8	0.0	0.0	0.0	21.8	17.6	25.0	21.8	17.6	25.0
Base	S2	100.0	89.2	55.2	0.0	0.0	0.0	19.6	21.6	31.2	19.6	21.6	31.2
Base	S3	100.0	100.0	100.0	0.0	0.0	0.0	34.2	29.6	27.6	34.2	30.0	29.6
Base	S4	100.0	97.6	89.4	0.0	0.0	0.0	39.6	33.7	34.5	39.6	33.7	35.1
Base	S5	100.0	98.8	90.8	0.0	0.0	0.0	50.8	32.4	35.2	50.8	32.4	35.2
Base	S6	77.4	47.4	32.6	0.0	0.0	0.0	19.2	30.2	29.0	23.4	45.6	70.8
Base	S7	100.0	97.4	88.2	0.0	0.0	0.0	43.6	36.0	35.6	43.6	36.0	35.6
Base	S8	100.0	98.4	90.6	0.0	0.0	0.0	50.2	51.4	48.0	50.2	51.4	48.0
Base	S9	100.0	95.0	79.4	0.0	0.0	0.0	43.0	27.8	16.4	43.0	27.8	16.4
Base	S10	100.0	100.0	96.4	0.0	0.0	0.0	84.0	73.8	73.8	84.0	73.8	73.8
Base	S11	100.0	99.2	95.8	0.0	0.0	0.0	76.4	67.4	66.6	76.4	67.4	66.6
Base	S12	98.0	97.0	94.4	0.0	0.0	0.0	82.0	70.6	70.0	83.4	72.0	71.2
Base	S13	100.0	100.0	94.2	0.0	0.0	0.0	62.2	50.6	47.2	62.2	50.6	47.2
Base	S14	75.8	47.0	29.2	0.0	0.0	0.0	16.6	32.4	27.4	21.0	47.6	68.0
Base	S15	100.0	100.0	98.2	0.0	0.0	0.0	71.0	58.8	55.2	71.0	58.8	55.2
Low status	S2	0.0	0.6	5.2	64.0	1.6	0.0	2.8	37.4	28.8	99.0	78.4	33.2
Low status	S4	1.4	10.4	27.8	54.8	3.6	0.0	1.2	8.4	22.4	96.0	73.4	54.6
Low status	S6	0.0	0.0	0.0	100.0	62.2	6.6	0.0	0.0	0.0	98.2	99.6	96.4
Low status	S7	0.2	6.8	17.2	55.4	2.8	0.0	0.0	5.8	15.2	91.8	68.4	46.0
Low status	S8	0.0	6.0	15.8	62.4	9.4	0.8	0.0	4.8	11.6	71.0	55.2	35.4
Low status	S9	0.6	3.6	5.2	55.8	11.2	0.6	0.0	1.6	4.0	1.4	2.0	4.0
Low status	S10	2.0	12.4	32.4	63.2	9.6	0.0	2.0	12.0	29.4	72.0	91.6	82.6
Low status	S13	5.4	39.2	53.6	20.0	0.0	0.0	3.6	27.8	30.8	83.2	52.0	36.4
Low status	S14	0.0	0.0	0.0	100.0	74.2	19.6	0.0	0.0	0.0	95.2	99.2	85.4

Table E.3: Results of the simulation runs for the Walter Shoal Ridge orange roughy stock base case – alternative biomass indicators over the short (0-10 years after the end of the model), medium (10-20) and longer term (20-30) years. The colour coding follows the proposed model-based performance measures detailed in 'Appendix D – proposed performance measures': the probability of being above B_{TARGET} is MP01, the probability of being below B_{TARGET} is MP02.

Model	Simulation	p(SSB < 20% B_0) (%)			p(SSB < 30% B_0) (%)			p(SSB > 40% B_0) (%)			p(B > 50% B_0) (%)		
		1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years
Base	S1	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	99.8	96.2	70.0	31.8
Base	S2	0.0	0.0	0.0	0.0	0.0	0.0	100.0	89.2	55.2	69.6	12.0	0.6
Base	S3	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	100.0	100.0	96.8	94.6
Base	S4	0.0	0.0	0.0	0.0	0.0	0.4	100.0	97.6	89.4	89.8	59.4	38.2
Base	S5	0.0	0.0	0.0	0.0	0.0	0.6	100.0	98.8	90.8	93.2	66.2	45.4
Base	S6	0.0	0.0	0.0	0.0	1.4	9.2	77.4	47.4	32.6	12.4	0.0	0.6
Base	S7	0.0	0.0	0.0	0.0	0.0	0.0	100.0	97.4	88.2	90.4	60.2	38.0
Base	S8	0.0	0.0	0.0	0.0	0.0	0.2	100.0	98.4	90.6	91.4	64.2	48.0
Base	S9	0.0	0.0	0.0	0.0	0.0	0.0	100.0	95.0	79.4	81.6	59.4	30.0
Base	S10	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	96.4	96.0	79.8	61.6
Base	S11	0.0	0.0	0.0	0.0	0.0	0.0	100.0	99.2	95.8	95.2	78.6	57.6
Base	S12	0.0	0.0	0.0	0.0	0.0	0.0	98.0	97.0	94.4	80.4	61.6	45.0
Base	S13	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	94.2	99.8	89.0	68.8
Base	S14	0.0	0.0	0.0	0.0	0.4	6.8	75.8	47.0	29.2	12.6	0.0	0.0
Base	S15	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	98.2	99.0	92.6	79.8
Low status	S2	64.0	1.6	0.0	96.6	53.2	37.4	0.0	0.6	5.2	0.0	0.0	0.0
Low status	S4	54.8	3.6	0.0	87.6	39.0	16.8	1.4	10.4	27.8	0.0	0.4	2.4
Low status	S6	100.0	62.2	6.6	100.0	100.0	84.2	0.0	0.0	0.0	0.0	0.0	0.0
Low status	S7	55.4	2.8	0.0	89.4	42.0	16.2	0.2	6.8	17.2	0.0	0.0	0.0
Low status	S8	62.4	9.4	0.8	93.8	65.0	40.8	0.0	6.0	15.8	0.0	0.0	0.0
Low status	S9	55.8	11.2	0.6	93.0	87.2	80.8	0.6	3.6	5.2	0.0	0.2	2.0
Low status	S10	63.2	9.6	0.0	90.0	56.8	32.6	2.0	12.4	32.4	2.0	2.0	2.6
Low status	S13	20.0	0.0	0.0	60.6	3.4	1.0	5.4	39.2	53.6	0.0	3.8	8.0
Low status	S14	100.0	74.2	19.6	100.0	100.0	96.0	0.0	0.0	0.0	0.0	0.0	0.0

Table E.4: Results of the simulation runs for the Walter Shoal Ridge orange roughy stock base case – future total allowable catch (TAC) mean in tonnes and interannual variability (var) in percentage over the short (1-10 years after the end of the model), medium (11-20) and longer term (21-30) years. These correspond to the proposed model-based performance measures MC01 (mean TAC) and MC02 (variability of TAC) detailed in 'Appendix D – proposed performance measures'. #### denotes variability above 999%, usually linked to a very low TAC value.

Model	Simulation	TAC mean (t) First year	TAC mean (t) 1-10 years	TAC var (%) 1-10 years	TAC mean (t) 11-20 years	TAC var (%) 11-20 years	TAC mean (t) 21-30 years	TAC var (%) 21-30 years
Base	S1	489	494	5	461	3	429	3
Base	S2	684	663	7	559	4	496	3
Base	S3	359	370	4	365	2	354	2
Base	S4	500	509	6	476	3	447	4
Base	S5	523	533	7	520	3	482	4
Base	S6	503	421	11	329	6	278	7
Base	S7	499	508	7	478	3	448	4
Base	S8	523	512	7	476	4	439	3
Base	S9	478	478	-	478	-	478	-
Base	S10	344	418	16	429	7	405	8
Base	S11	358	465	20	469	8	434	9
Base	S12	317	363	15	378	8	362	8
Base	S13	497	527	8	522	3	494	3
Base	S14	503	421	11	329	5	290	5
Base	S15	504	528	7	520	3	504	3
Low status	S2	29	64	####	310	16	398	5
Low status	S4	10	56	####	211	#####	321	####
Low status	S6	12	4	####	25	#####	129	####
Low status	S7	35	89	118	249	24	340	3
Low status	S8	101	155	42	267	9	324	3
Low status	S9	478	478	-	478	-	478	-
Low status	S10	316	190	37	219	15	284	8
Low status	S13	3	133	####	345	16	414	3
Low status	S14	35	19	75	56	57	159	18

Table E.5: Results of the simulation runs for the Walter Shoal Ridge orange roughy stock base case – future sum of standardised CPUE (no units) mean and standard deviation (sd) and sum of acoustic biomass mean and standard deviation (sd) in tonnes in 2035, 2045 and 2055. These correspond to the proposed model-based performance measure MC03 detailed in 'Appendix D – proposed performance measures'.

Model	**Simulation**	**Sum of standardised CPUE (no unit)**						**Sum of acoustic biomass (t)**					
		mean 2035	**sd 2035**	**mean 2045**	**sd 2045**	**mean 2055**	**sd 2055**	**mean 2035**	**sd 2035**	**mean 2045**	**sd 2045**	**mean 2055**	**sd 2055**
Base	S1	1 068	803	951	569	973	634	12 071	3 181	10 996	2 836	10 700	2 845
Base	S2	1 016	1 092	800	585	753	548	10 496	2 810	9 230	2 567	8 633	2 370
Base	S3	1 268	1 009	1 042	633	1 004	692	13 219	3 779	12 723	3 275	11 988	2 977
Base	S4	1 023	690	1 092	840	909	629	11 947	3 636	11 696	3 361	10 965	3 076
Base	S5	1 045	821	865	715	858	693	13 120	4 440	11 974	3 629	11 106	3 120
Base	S6	716	535	814	583	681	479	9 102	2 777	8 246	2 208	7 716	1 952
Base	S7	904	561	998	731	933	741	12 395	3 569	11 337	3 352	10 587	2 984
Base	S8	1 168	689	1 007	735	913	688	12 232	4 203	11 024	3 353	10 794	3 073
Base	S9	1 162	1 014	1 010	699	859	699	12 081	4 577	10 655	3 752	9 727	3 767
Base	S10	1 024	762	1 094	1071	973	671	12 806	3 503	12 544	3 567	11 416	3 575
Base	S11	981	658	886	582	991	748	14 191	4 436	13 248	4 362	12 414	3 800
Base	S12	931	607	1 056	769	1 043	1048	11 378	3 738	11 004	3 503	10 468	2 929
Base	S13	1 195	884	1 156	962	953	723	13 788	4 324	12 829	3 816	12 407	3 643
Base	S14	795	799	665	433	687	528	8 968	2 609	8 163	2 444	7 926	2 272
Base	S15	1 102	881	1 162	1060	1 021	817	13 365	4 139	13 001	4 034	12 675	3 514
Low status	S2	259	290	529	379	661	478	2 710	1 475	6 056	2 015	7 078	2 029
Low status	S4	351	390	571	413	733	520	3 434	2 360	6 753	2 984	8 681	2 774
Low status	S6	102	104	280	297	519	514	1 174	765	3 296	1 434	5 571	1 667
Low status	S7	294	312	608	545	723	650	3 610	2 823	6 740	2 278	8 170	2 547
Low status	S8	272	246	500	429	654	585	3 423	2 243	6 335	2 476	7 928	2 777
Low status	S9	202	197	316	364	318	284	2 877	2 405	4 015	3 128	4 150	3 174
Low status	S10	278	245	542	630	745	720	3 563	2 870	6 440	2 962	8 670	3 468
Low status	S13	558	661	737	580	896	653	5 485	3 036	8 923	2 905	10 103	3 300
Low status	S14	128	195	232	183	395	320	1 112	720	3 188	1 277	5 047	1 625

Table E.6: Results of the simulation runs for the Long Walter Shoal Ridge orange roughy stock base case – biomass indicators over the short (0-10 years after the end of the model), medium (10-20) and longer term (20-30) years. The colour coding follows the proposed model-based performance measures detailed in 'Appendix D – proposed performance measures': the probability of being above 40% B_0 is MP01, the probability of being below 20% B_0 is MP02, the probability of being in the green portion of the Kobe plot (PGK) is MP03, and the probability of not overfishing ($F < F_{TARGET}$) is MP04.

Model	Simulation	p(SSB > 40% B_0) (%)			p(B < 20% B_0) (%)			PGK (%)			p(F < F_{TARGET}) (%)		
		1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years
Base	S1	100.0	100.0	100.0	0.0	0.0	0.0	25.8	21.2	23.4	25.8	21.2	23.4
Base	S4	100.0	94.4	78.2	0.0	0.0	0.0	51.0	47.8	43.4	51.0	47.8	43.4
Base	S5	100.0	97.2	89.6	0.0	0.0	0.0	42.4	43.6	46.2	42.4	43.6	46.2
Base	S6	67.0	33.2	27.0	0.0	0.0	0.0	21.4	26.2	26.2	28.6	53.8	73.0
Base	S7	100.0	99.6	85.0	0.0	0.0	0.0	39.6	38.4	35.4	39.6	38.4	35.4
Base	S8	100.0	95.6	83.8	0.0	0.0	0.0	40.8	32.4	35.6	40.8	32.4	35.6
Base	S9	100.0	99.0	97.2	0.0	0.0	0.0	92.0	88.6	84.2	92.0	88.6	84.2
Base	S10	100.0	99.8	95.0	0.0	0.0	0.0	77.4	62.2	60.2	77.4	62.2	60.2
Base	S11	100.0	100.0	91.0	0.0	0.0	0.0	63.2	53.0	52.4	63.2	53.0	52.4
Base	S12	99.8	98.0	95.8	0.0	0.0	0.0	82.0	75.6	71.8	82.0	75.6	71.8
Base	S13	100.0	99.6	94.2	0.0	0.0	0.0	54.4	43.2	40.0	54.4	43.2	40.0
Base	S14	0.0	0.0	0.0	83.3	73.3	66.7	0.0	0.0	0.0	65.0	100.0	100.0
Base	S15	100.0	99.0	98.0	0.0	0.0	0.0	56.8	45.6	45.8	56.8	45.6	45.8
Low status	S4	0.0	12.6	34.0	63.0	5.4	2.0	0.0	12.6	28.2	95.4	68.4	33.2
Low status	S6	0.0	0.0	0.0	100.0	80.8	28.2	0.0	0.0	0.0	99.8	98.8	57.4
Low status	S7	0.4	6.2	19.4	63.4	0.8	0.0	0.4	6.2	17.8	95.6	74.4	40.2
Low status	S8	2.4	6.8	13.8	75.8	6.0	2.0	2.2	5.0	11.8	62.2	52.4	32.0
Low status	S9	0.0	2.0	8.4	79.0	51.4	24.6	0.0	1.6	6.0	0.0	1.6	8.0
Low status	S10	9.4	18.0	40.2	65.2	5.6	0.0	9.4	18.0	39.6	72.0	91.0	80.0
Low status	S14	0.8	5.2	8.0	95.0	83.0	60.0	0.8	5.2	8.0	99.0	91.0	29.2
Low status	S15	7.8	41.4	62.4	22.0	0.0	0.0	6.0	32.2	44.0	76.4	54.8	45.2

Table E.7: Results of the simulation runs for the Long Walter Shoal Ridge orange roughy stock base case – future total allowable catch (TAC) mean in tonnes and interannual variability (var) in percentage over the short (1-10 years after the end of the model), medium (11-20) and longer term (21-30) years. These correspond to the proposed model-based performance measures MC01 (mean TAC) and MC02 (variability of TAC) detailed in 'Appendix D – proposed performance measures'. #### denotes variability above 999%, usually linked to a very low TAC value.

Model	Simulation	TAC mean (t) First year	TAC mean (t) 1-10 years	TAC var (%) 1-10 years	TAC mean (t) 11-20 years	TAC var (%) 11-20 years	TAC mean (t) 21-30 years	TAC var (%) 21-30 years
Base	S1	944	961	5	897	3	823	3
Base	S4	958	970	6	905	4	831	4
Base	S5	940	942	6	870	4	796	4
Base	S6	932	771	12	596	7	502	6
Base	S7	943	956	7	898	3	826	4
Base	S8	940	970	6	920	4	832	4
Base	S9	698	698	-	698	-	698	-
Base	S10	649	799	14	828	6	789	7
Base	S11	657	849	18	873	6	814	7
Base	S12	631	743	12	762	6	729	6
Base	S13	961	1 000	6	974	3	932	3
Base	S14	932	249	####	88	28	109	7
Base	S15	952	1 024	7	1 021	3	973	4
Low status	S4	-	69	####	438	31	677	3
Low status	S6	2	1	####	83	#####	389	13
Low status	S7	34	113	151	455	19	642	3
Low status	S8	197	289	37	496	10	615	3
Low status	S9	698	698	-	698	-	698	-
Low status	S10	606	336	40	380	16	528	7
Low status	S14	32	26	85	159	68	430	8
Low status	S15	32	300	443	671	8	785	2

Table E.8: Results of the simulation runs for the Long Walter Shoal Ridge orange roughy stock base case – future sum of acoustic biomass mean and standard deviation (sd) in tonnes in 2035, 2045 and 2055. These correspond to the proposed model-based performance measure MC03 detailed in 'Appendix D – proposed performance measures'.

Model	Simulation	Sum of acoustic biomass (t)					
		mean 2035	sd 2035	mean 2045	sd 2045	mean 2055	sd 2055
Base	S1	22 118	5 700	20 074	4 919	18 944	4 904
Base	S4	21 869	6 888	20 400	6 170	18 580	5 378
Base	S5	22 124	6 082	20 350	5 841	20 511	6 156
Base	S6	16 518	5 089	15 010	4 480	14 957	4 481
Base	S7	22 059	6 958	20 458	6 106	19 645	6 119
Base	S8	22 180	6 592	19 932	5 910	19 028	5 689
Base	S9	23 691	7 288	23 620	8 209	22 244	7 694
Base	S10	23 541	7 142	22 646	6 907	21 462	6 538
Base	S11	25 167	7 236	23 643	6 782	21 520	6 470
Base	S12	21 895	6 778	21 045	6 265	19 877	6 520
Base	S13	25 198	7 143	24 002	6 714	21 856	6 478
Base	S14	16 686	4 544	15 106	4 004	13 829	3 507
Base	S15	25 950	7 826	23 997	6 887	22 317	6 676
Low status	S4	5 794	3 237	13 071	4 193	16 489	4 687
Low status	S6	1 499	505	5 589	1 692	9 316	2 723
Low status	S7	5 516	3 382	12 007	3 858	16 007	4 844
Low status	S8	5 624	4 286	10 663	4 402	13 733	4 914
Low status	S9	4 890	3 265	7 424	4 242	9 881	5 018
Low status	S10	5 328	4 170	10 556	4 874	15 475	5 747
Low status	S14	1 522	584	5 555	2 193	8 336	2 741
Low status	S15	9 983	5 010	16 883	5 200	19 469	6 219

Table E.9: Results of the simulation runs for the South West Indian Ocean Ridge orange roughy stock base case – biomass indicators over the short (0-10 years after the end of the model), medium (10-20) and longer term (20-30) years. The colour coding follows the proposed model-based performance measures detailed in 'Appendix D – proposed performance measures': the probability of being above 40% B_0 is MP01, the probability of being below 20% B_0 is MP02, the probability of being in the green portion of the Kobe plot (PGK) is MP03, and the probability of not overfishing ($F < F_{TARGET}$) is MP04.

Model	Simulation	p(SSB > 40% B_0) (%)			p(B < 20% B_0) (%)			PGK (%)			p(F < F_{TARGET}) (%)		
		1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years
Base	S1	99.4	92.8	79.8	0.0	0.0	0.0	37.6	52.6	58.0	37.6	55.2	65.0
Base	S4	97.2	91.2	84.0	0.0	0.0	0.0	50.6	69.2	68.0	50.8	74.4	76.6
Base	S5	99.2	87.4	72.6	0.0	0.0	0.0	59.4	61.0	62.0	60.2	63.6	70.0
Base	S6	82.8	49.8	41.6	5.0	13.6	6.2	31.4	40.0	39.4	36.2	76.8	89.4
Base	S7	98.8	88.8	77.2	0.0	0.0	0.0	57.2	69.2	60.4	57.4	70.6	69.4
Base	S8	98.0	86.0	65.0	0.0	0.0	0.0	43.8	47.0	45.4	43.8	50.6	54.6
Base	S9	98.2	100.0	100.0	0.0	0.0	0.0	98.2	100.0	100.0	100.0	100.0	100.0
Base	S10	100.0	96.8	90.8	0.0	0.0	0.0	90.6	88.6	88.8	90.6	88.6	88.8
Base	S11	100.0	99.0	96.6	0.0	0.0	0.0	93.8	92.2	91.6	93.8	92.2	91.6
Base	S12	100.0	99.6	98.0	0.0	0.0	0.0	94.4	93.4	93.6	94.4	93.4	93.6
Base	S13	100.0	98.0	94.6	0.0	0.0	0.0	76.0	84.6	80.0	76.0	84.8	81.8
Base	S14	79.0	41.2	27.6	2.8	6.6	5.2	35.8	32.2	26.6	43.4	71.4	86.2
Base	S15	100.0	98.0	96.0	0.0	0.0	0.0	77.0	81.0	77.8	77.0	81.0	79.0
Low status	S4	20.6	27.6	28.8	50.8	35.0	24.8	17.4	24.6	28.0	87.0	75.0	67.8
Low status	S6	21.4	21.2	26.6	57.0	44.6	30.0	17.4	20.2	25.2	83.2	90.0	80.4
Low status	S7	26.4	28.4	31.6	49.4	33.0	28.4	22.8	23.4	25.6	80.8	69.6	67.8
Low status	S8	16.8	14.0	17.0	64.0	54.4	40.8	10.4	10.6	15.6	49.8	44.0	40.8
Low status	S9	10.6	23.0	48.4	61.8	40.2	25.2	10.6	23.0	48.4	71.4	81.0	85.0
Low status	S10	23.6	35.8	49.6	53.4	35.4	23.2	23.6	35.8	49.6	79.4	89.8	97.0
Low status	S14	11.2	8.0	8.0	67.0	54.6	46.6	8.0	8.0	8.0	69.4	72.2	71.4
Low status	S15	22.0	29.4	36.0	40.8	20.6	17.4	19.4	27.8	32.0	82.2	70.8	62.2

Table E.10: Results of the simulation runs for the South West Indian Ocean Ridge orange roughy stock base case – future total allowable catch (TAC) mean in tonnes and interannual variability (var) in percentage over the short (1-10 years after the end of the model), medium (11-20) and longer term (21-30) years. These correspond to the proposed model-based performance measures MC01 (mean TAC) and MC02 (variability of TAC) detailed in 'Appendix D – proposed performance measures'. #### denotes variability above 999%, usually linked to a very low TAC value.

Model	Simulation	TAC mean (t) First year	TAC mean (t) 1-10 years	TAC var (%) 1-10 years	TAC mean (t) 11-20 years	TAC var (%) 11-20 years	TAC mean (t) 21-30 years	TAC var (%) 21-30 years
Base	S1	4 793	4 183	37	3 053	13	2 762	8
Base	S4	5 747	5 625	47	3 517	####	3 550	####
Base	S5	7 714	6 700	42	6 357	16	8 142	31
Base	S6	6 326	108 956	####	35 817	####	76 167	####
Base	S7	5 153	5 300	40	5 673	17	7 848	14
Base	S8	5 649	5 355	40	4 142	13	5 596	8
Base	S9	310	310	-	310	-	310	-
Base	S10	1 220	1 635	20	1 671	7	1 541	6
Base	S11	1 305	1 792	21	1 822	7	1 650	6
Base	S12	1 238	1 574	19	1 563	6	1 449	6
Base	S13	5 876	4 594	54	3 663	17	4 219	50
Base	S14	5 153	44 333	221	11 850	57	17 605	37
Base	S15	5 876	4 390	40	3 349	15	3 961	11
Low status	S4	1 414	1 266	####	1 747	####	2 040	####
Low status	S6	2 449	4 296	####	2 641	####	3 360	####
Low status	S7	3 293	2 467	####	3 019	150	4 491	38
Low status	S8	2 486	2 629	96	3 317	26	5 378	47
Low status	S9	310	310	-	310	-	303	-
Low status	S10	1 033	528	35	500	13	682	9
Low status	S14	2 667	3 661	####	3 009	243	4 644	90
Low status	S15	1 515	1 607	####	2 324	123	3 163	54

Table E.11: Results of the simulation runs for the South West Indian Ocean Ridge orange roughy stock base case – future sum of acoustic biomass mean and standard deviation (sd) in tonnes in 2035, 2045 and 2055. These correspond to the proposed model-based performance measure MC03 detailed in 'Appendix D – proposed performance measures'.

Model	**Simulation**						**Sum of acoustic biomass (t)**
		mean 2035	**sd 2035**	**mean 2045**	**sd 2045**	**mean 2055**	**sd 2055**
Base	S1	28 767	8 602	25 004	9 680	22 093	8 221
Base	S4	27 615	10 578	24 188	9 920	21 966	8 809
Base	S5	26 021	9 773	21 241	8 687	19 929	9 748
Base	S6	20 281	10 288	18 093	7 439	18 645	6 829
Base	S7	28 164	10 225	24 650	9 974	22 165	9 931
Base	S8	27 505	10 639	23 418	10 215	22 027	10 135
Base	S9	48 183	15 357	48 881	15 361	49 046	14 563
Base	S10	41 525	12 660	37 641	11 220	36 114	12 281
Base	S11	44 726	14 452	40 471	12 582	37 389	12 040
Base	S12	38 072	12 568	35 185	11 724	33 633	10 776
Base	S13	31 400	12 128	26 059	9 765	24 388	9 381
Base	S14	20 436	8 966	18 840	7 815	18 291	6 859
Base	S15	31 014	11 469	26 404	8 879	24 312	9 361
Low status	S4	7 939	5 821	11 895	6 151	13 395	6 516
Low status	S6	7 491	10 244	6 071	3 948	8 089	4 846
Low status	S7	7 775	5 550	11 454	5 133	12 766	5 468
Low status	S8	7 078	5 805	9 431	4 629	10 803	5 375
Low status	S9	6 090	4 307	10 875	6 323	15 552	9 141
Low status	S10	6 564	4 426	11 888	6 535	16 758	8 642
Low status	S14	7 699	10 352	7 503	3 952	8 742	4 144
Low status	S15	9 399	4 608	14 223	5 679	15 979	6 701

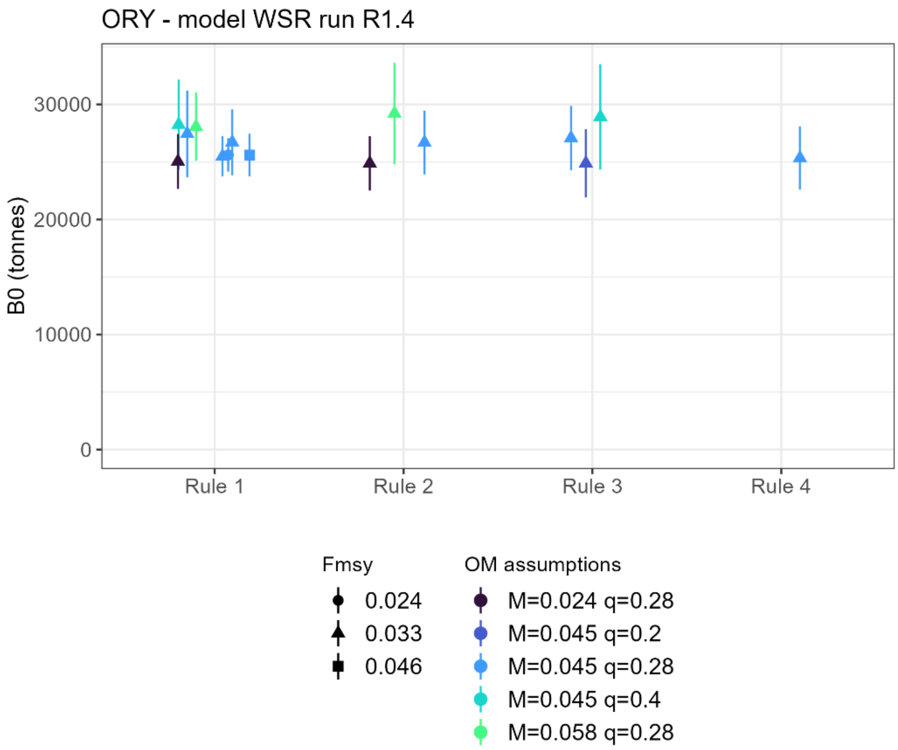

Figure E.1: Value of the initial biomass parameter estimated in the final year of the management strategy evaluation and 95% credible interval for the Walter Shoal Ridge orange roughy stock base case.

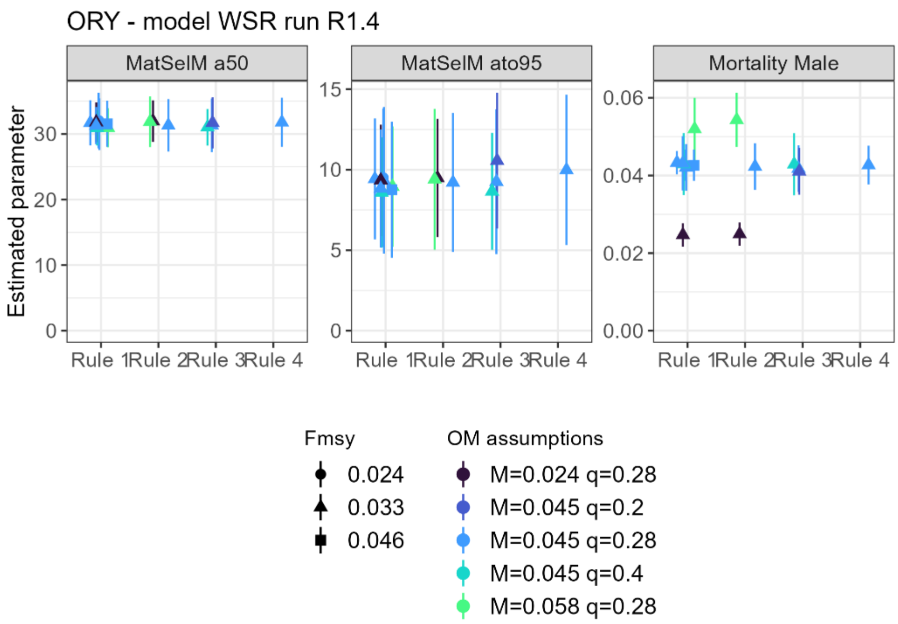

Figure E.2: Value of the selectivity and mortality parameters estimated in the final year of the management strategy evaluation and 95% credible interval for the Walter Shoal Ridge orange roughy stock base case.

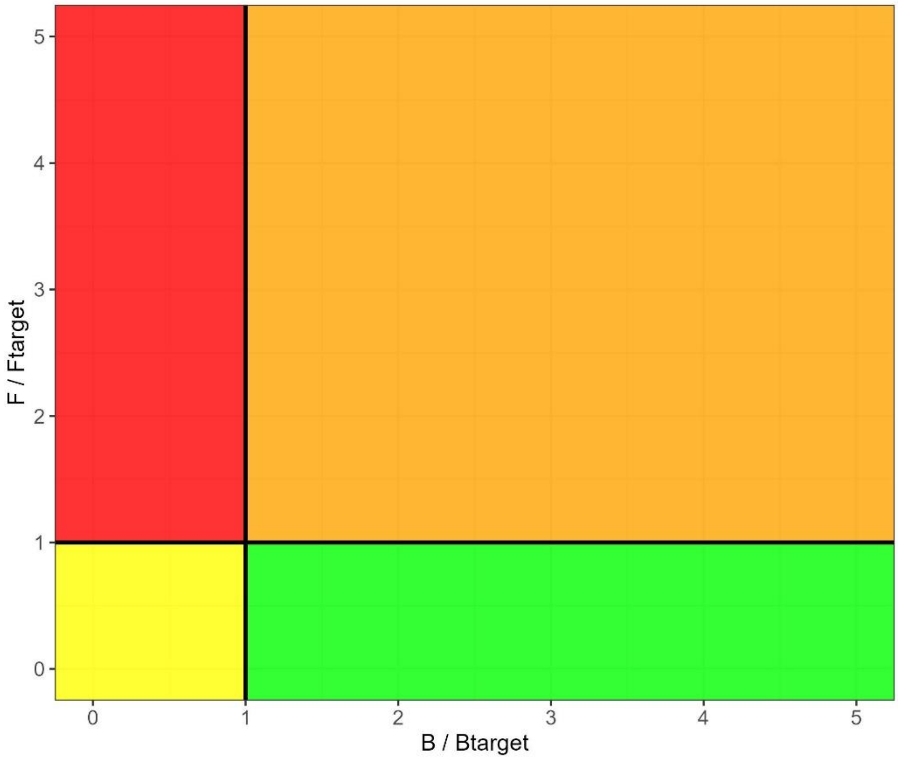

Figure E.3: Representation of the four quadrants of the Kobe plot and their respective colours.

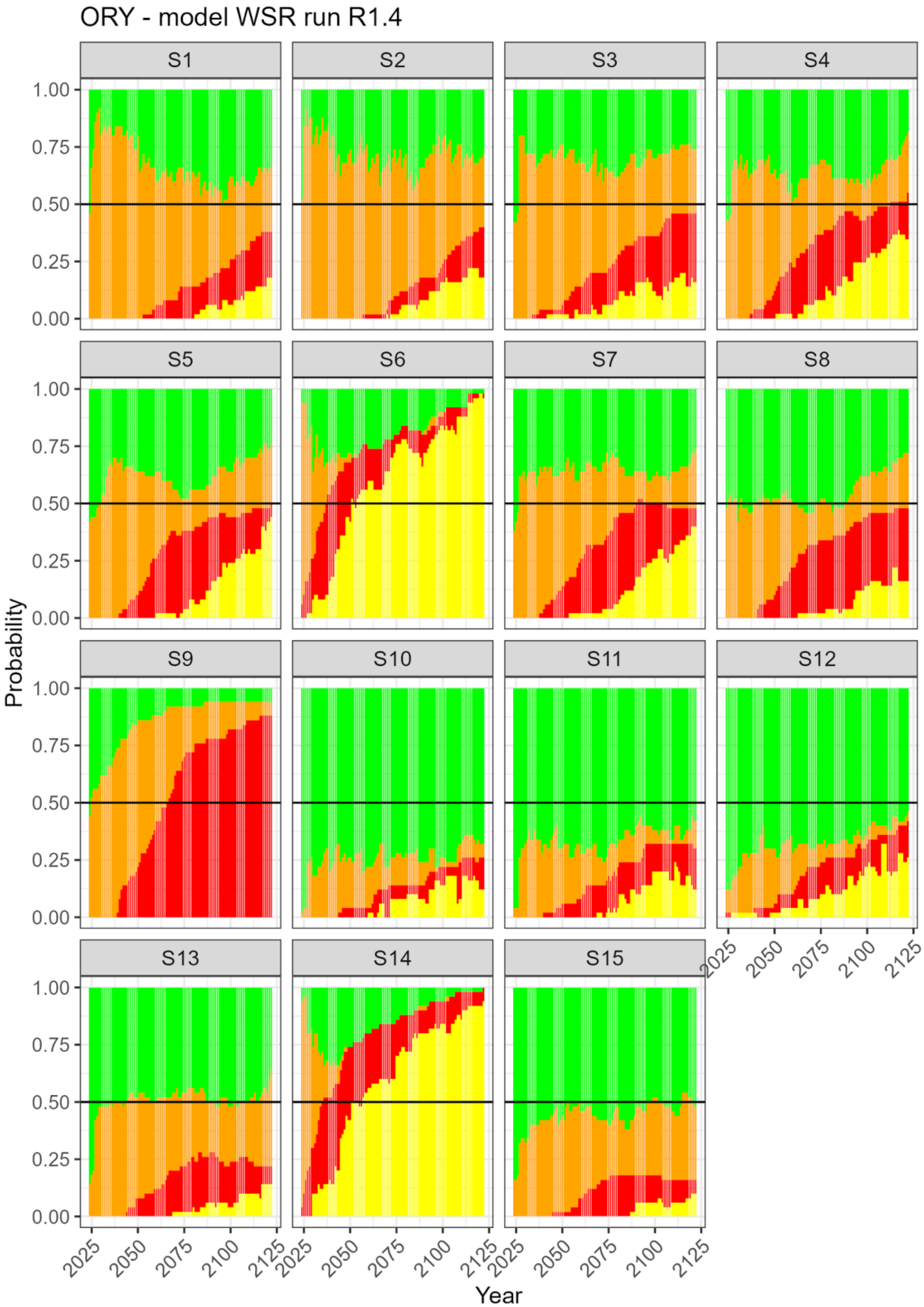

Figure E.4: Kobe time plot for the simulation scenarios for the Walter Shoal Ridge orange roughy stock base case, showing the proportion of the simulations in each quadrant of the Kobe matrix (see Figure E.3 for the definition of the colours) in each year of the projection period. The horizontal line represents the 50% probability.

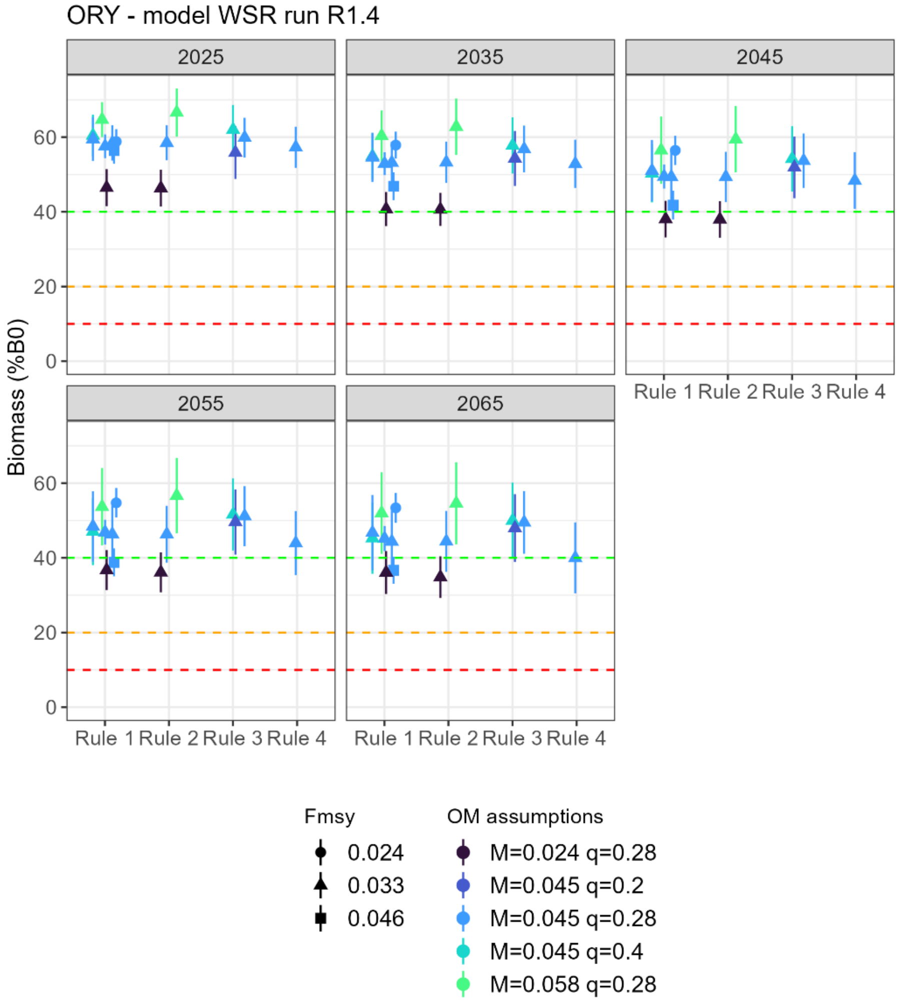

Figure E.5: Spawning stock biomass status as a percentage of initial biomass and 95% credible interval every 10 years for the different simulations for the Walter Shoal Ridge orange roughy stock base case. 40% B_0 is plotted in green, 20% B_0 in orange, and 10% B_0 in red.

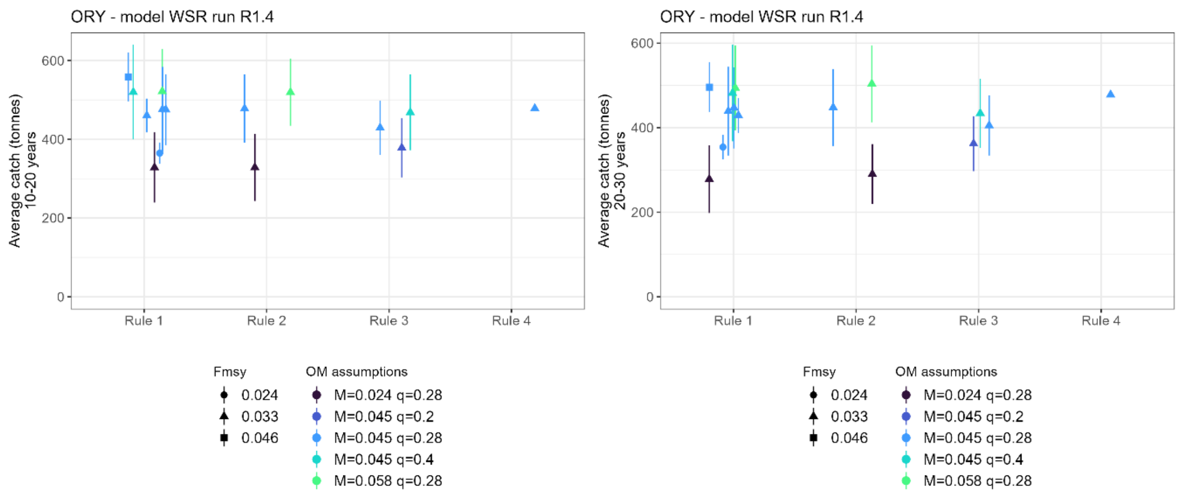

Figure E.6: Predicted total allowable catch (TAC) in tonnes in the medium (10-20 years) and long term (20-30 years) for the Walter Shoal Ridge orange roughy stock base case.

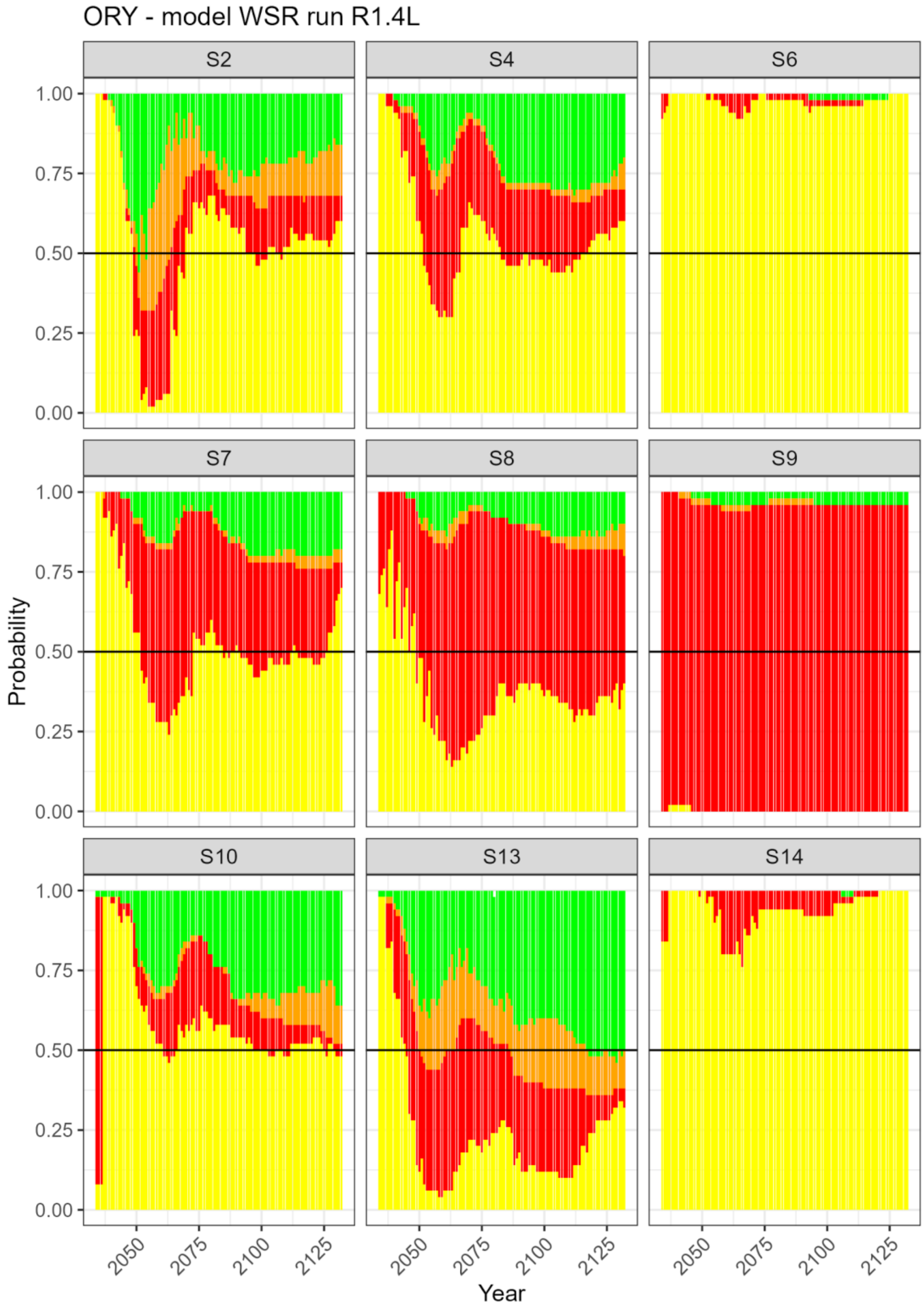

Figure E.7: Kobe time plot for the simulation scenarios for the Walter Shoal Ridge orange roughy model starting in a depleted state, showing the proportion of the simulations in each quadrant of the Kobe matrix (see Figure E.3 for the definition of the colours) in each year of the projection period. The horizontal line represents the 50% probability.

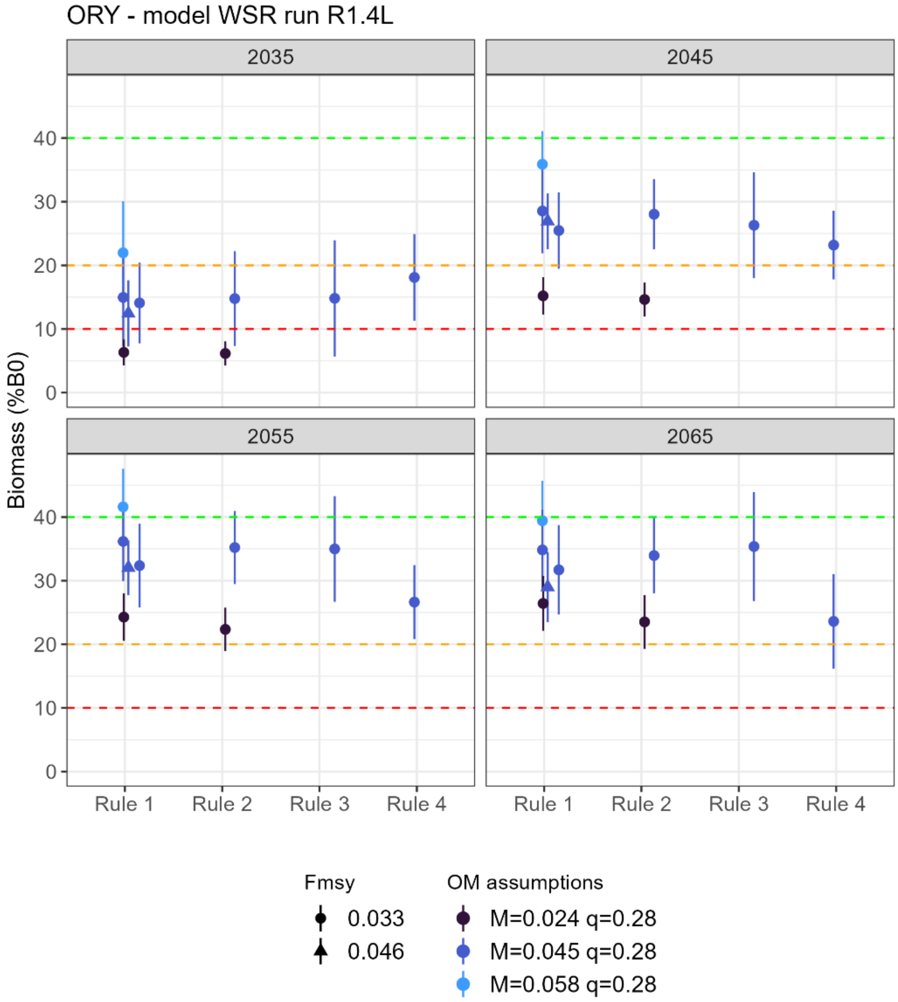

Figure E.8: Spawning stock biomass status as a percentage of initial biomass and 95% credible interval every 10 years for the different simulations for the Walter Shoal Ridge orange roughy stock model starting in a depleted state. 40% B_0 is plotted in green, 20% B_0 in orange, and 10% B_0 in red.

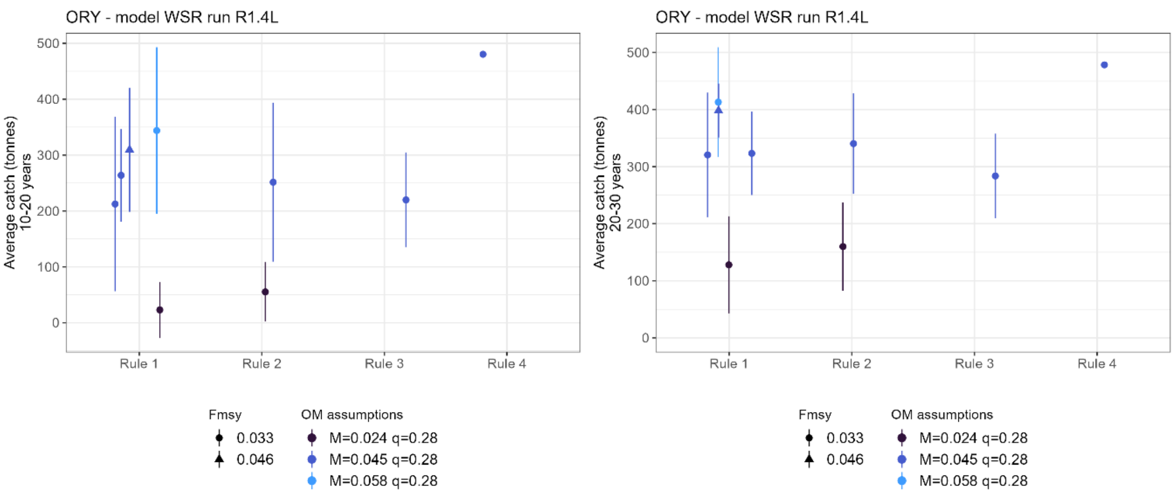

Figure E.9: Predicted total allowable catch (TAC) in tonnes in the medium (10-20 years) and long term (20-30 years) for the Walter Shoal Ridge orange roughy stock model starting in a depleted state.

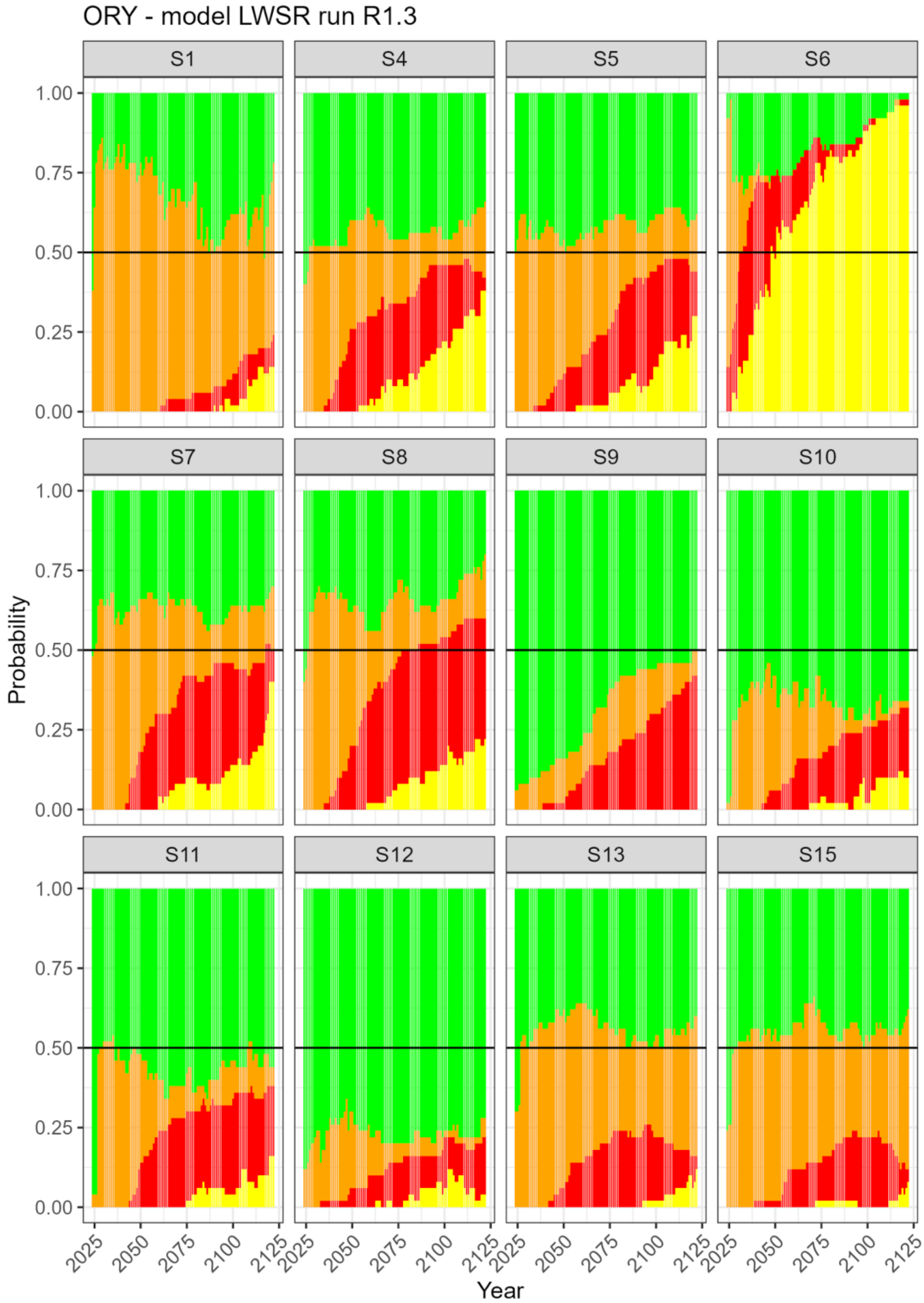

Figure E.10: Kobe time plot for the simulation scenarios for the Long Walter Shoal Ridge orange roughy base case model, showing the proportion of the simulations in each quadrant of the Kobe matrix (see Figure E.3 for the definition of the colours) in each year of the projection period. The horizontal line represents the 50% probability.

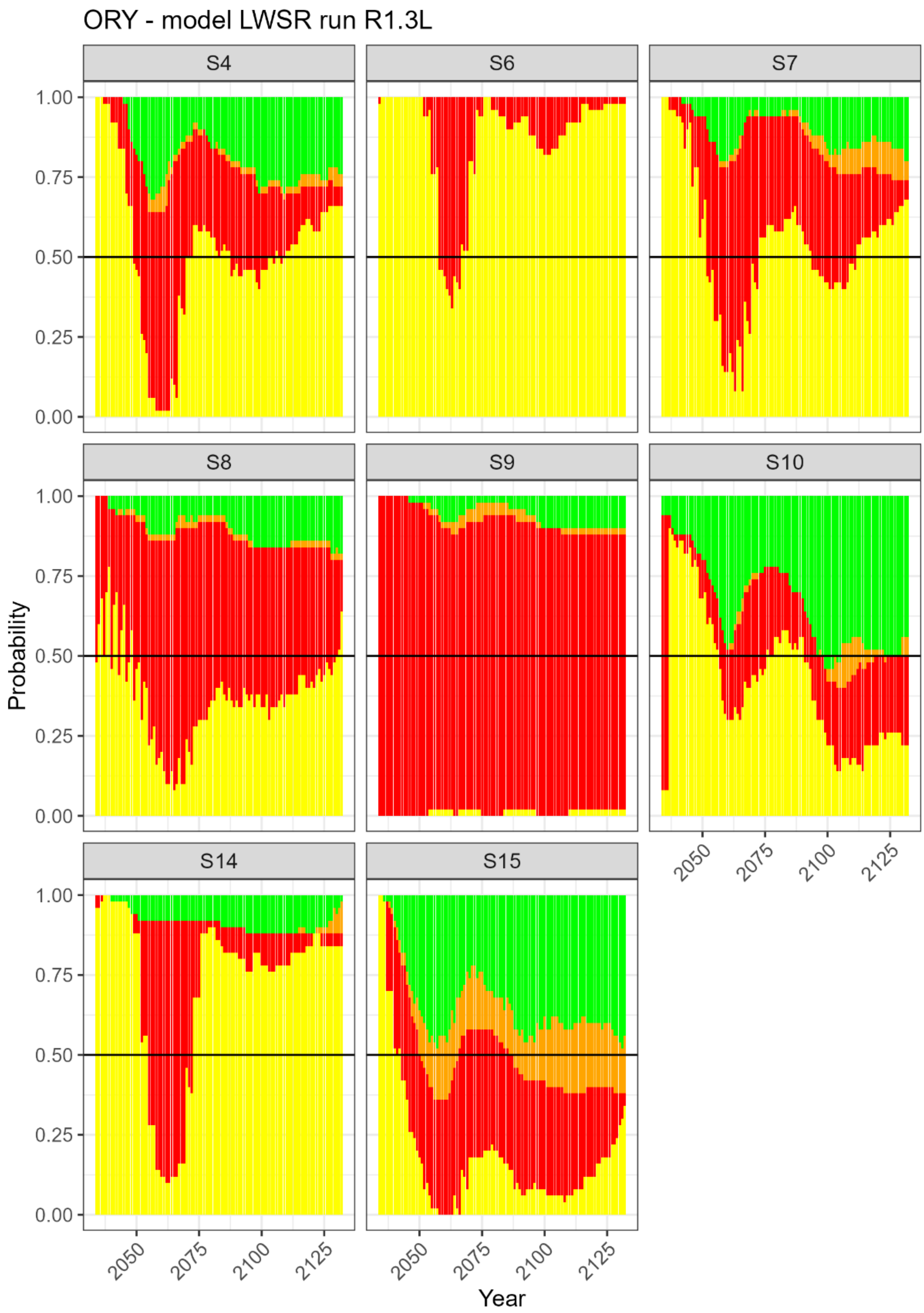

Figure E.11: Kobe time plot for the simulation scenarios for the Long Walter Shoal Ridge orange roughy model starting in a depleted state, showing the proportion of the simulations in each quadrant of the Kobe matrix (see Figure E.3 for the definition of the colours) in each year of the projection period. The horizontal line represents the 50% probability.

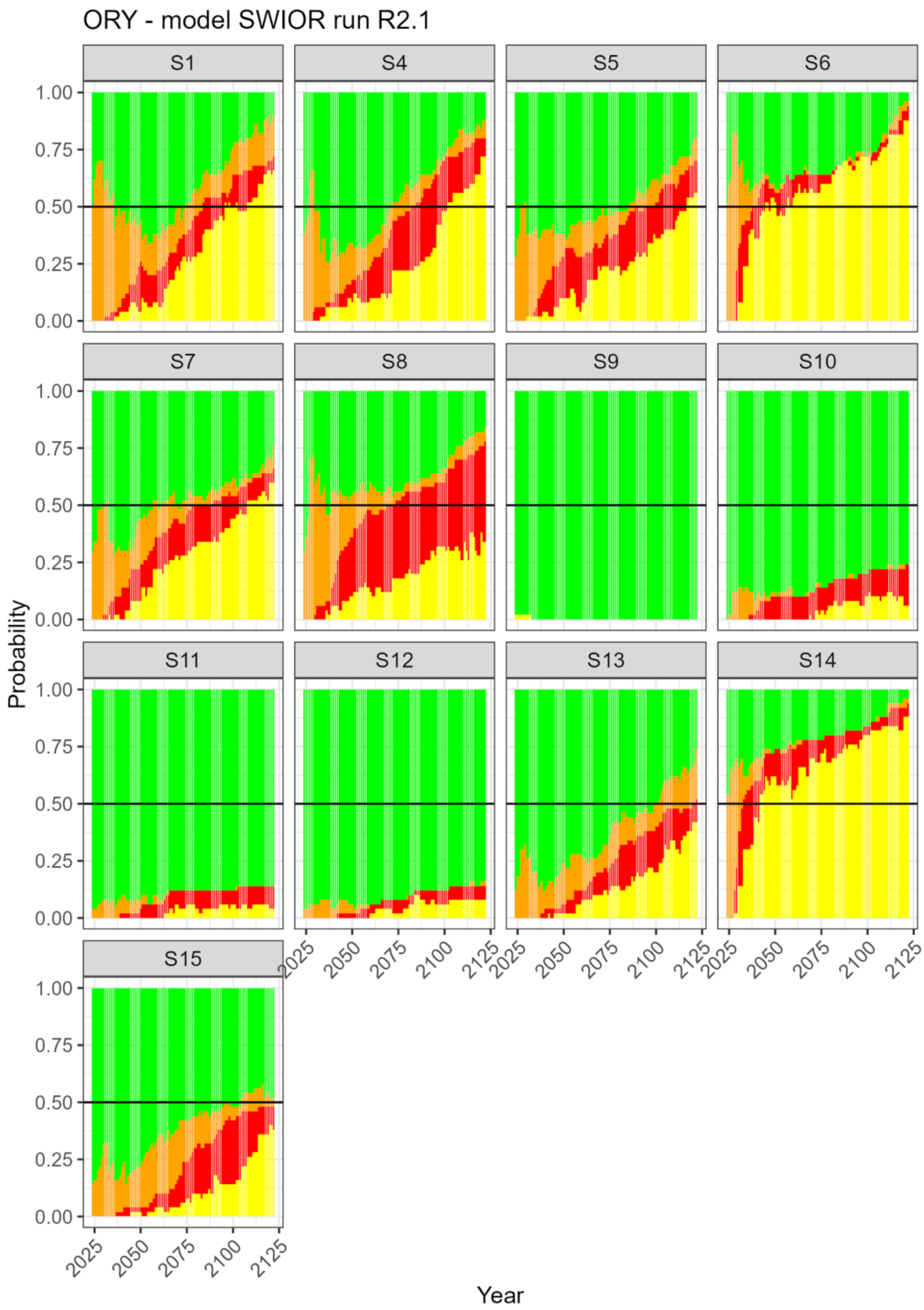

Figure E.12: Kobe time plot for the simulation scenarios for the South West Indian Ocean Ridge orange roughy base case model, showing the proportion of the simulations in each quadrant of the Kobe matrix (see Figure E.3 for the definition of the colours) in each year of the projection period. The horizontal line represents the 50% probability.

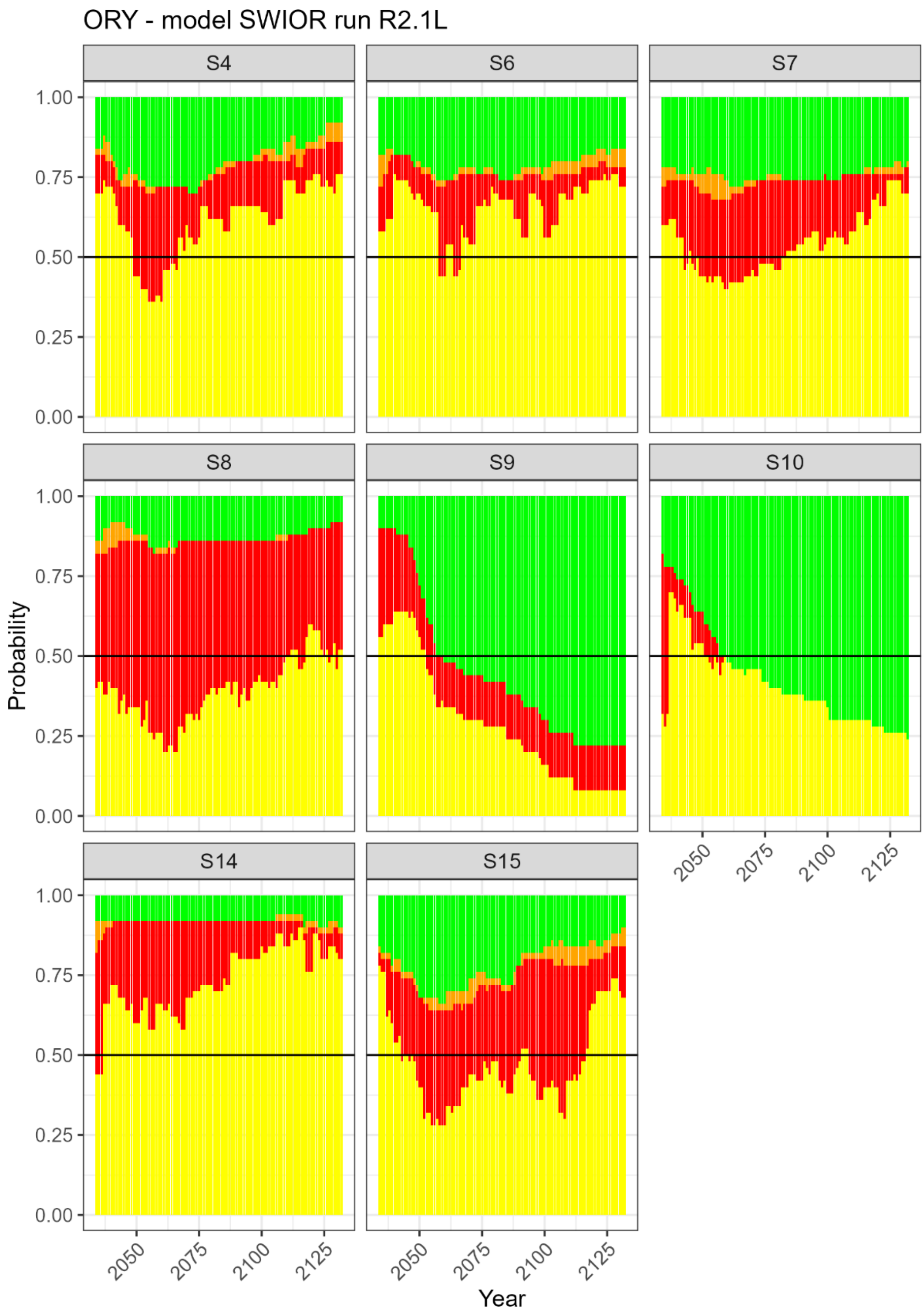

Figure E.13: Kobe time plot for the simulation scenarios for the South West Indian Ocean Ridge orange roughy model starting in a depleted state, showing the proportion of the simulations in each quadrant of the Kobe matrix (see Figure E.3 for the definition of the colours) in each year of the projection period. The horizontal line represents the 50% probability.

14. Appendix F – Alfonsino length-based analyses supplement

Table F.1: Some characteristics of the alfonsino length data available to project PAM-2024-03.

Year	Number of length measurements	Number of sets	Number of methods	Number of nations
2004	2999	52	2	1
2005	525	15	1	1
2008	1076	20	1	1
2011	2531	74	2	1
2012	1017	26	1	1
2013	88	5	1	1
2015	500	18	2	1
2016	475	19	2	1
2017	1328	14	1	1
2018	6500	65	1	2
2019	3697	37	1	2
2020	2600	24	1	1
2021	2034	20	1	1
2022	3930	40	2	2
2023	1300	13	1	1

[this figure is not included in the public version of the report, due to confidentiality limitations set out in CMM 03(2016)]

Figure F.1: Spatial distribution of alfonsino mean length over all years combined by fishing method.

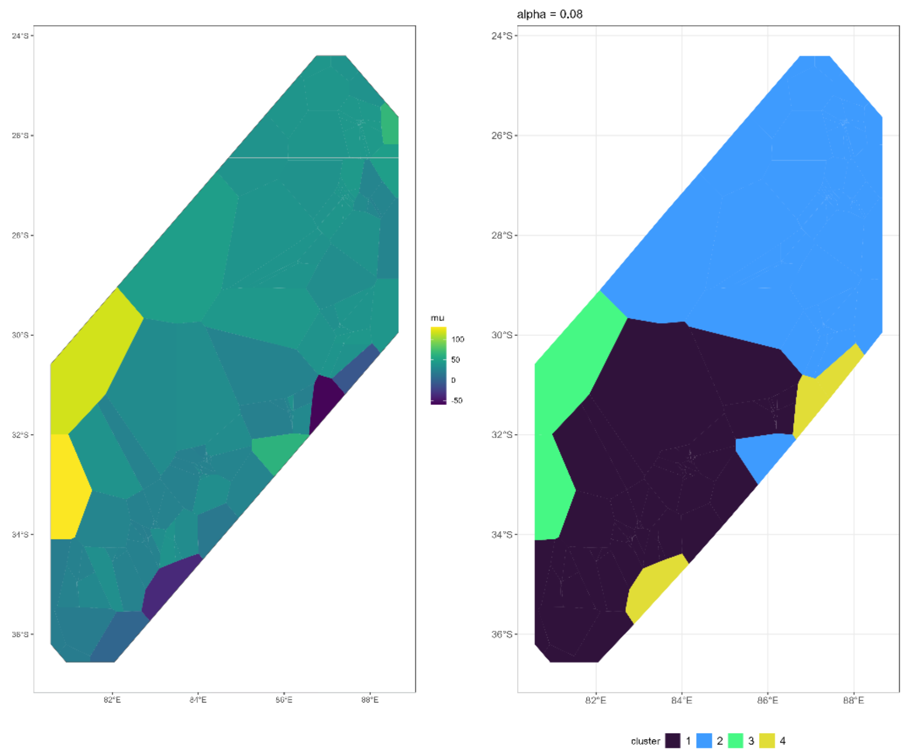

Figure F.2: Results of the INLA analysis of alfonsino length data east of 70°E, with the final model including space and year only. The left plot represents the deviation from the mean length and the right plot the final clusters.

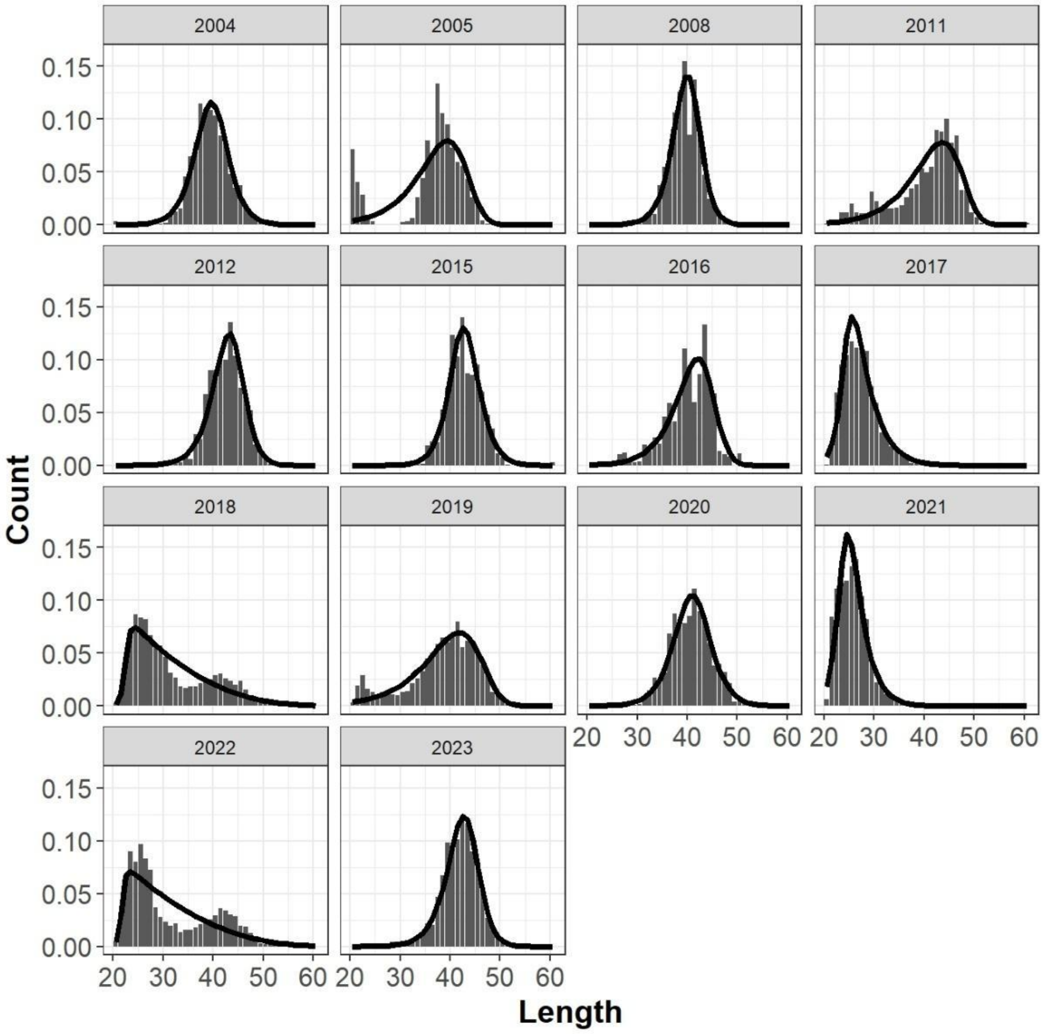

Figure F.3: LB-SPR model fits to the alfonsino scaled length frequency distributions for the north east population. Only the first scenario is depicted as the fits to all models was almost identical.

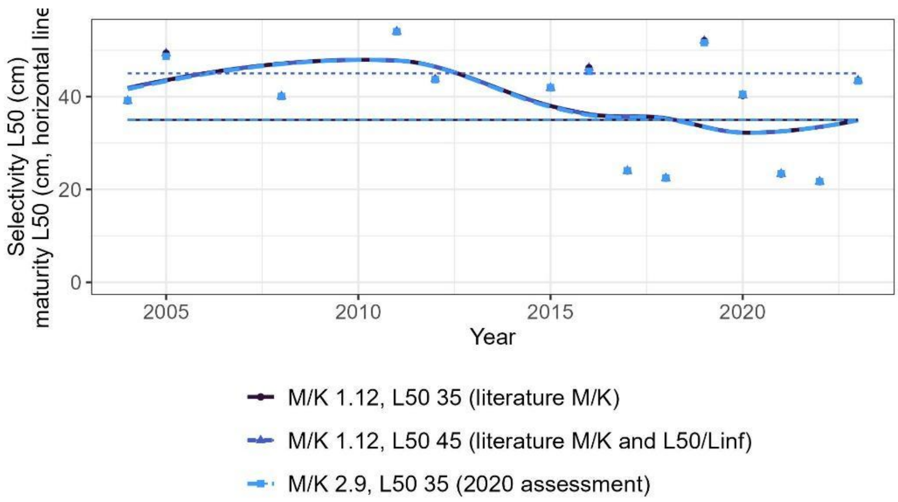

Figure F.4: LB-SPR estimates of length at 50% selectivity for the scenarios tested and smoother line. The assumed maturity is also represented as a horizontal line.

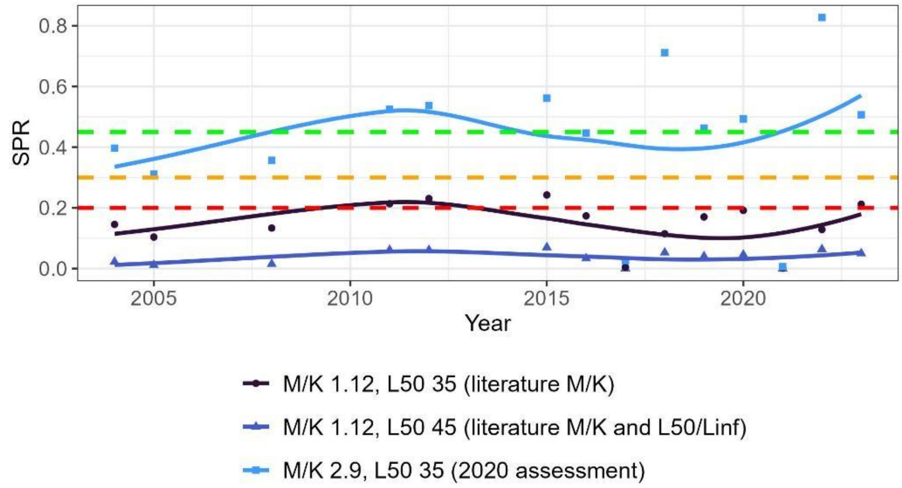

Figure F.5: LB-SPR estimates of SPR (stock status) for the scenarios tested. The reference levels are plotted at SPR = 0.45 (green), 0.3 (orange) and 0.2 (red).

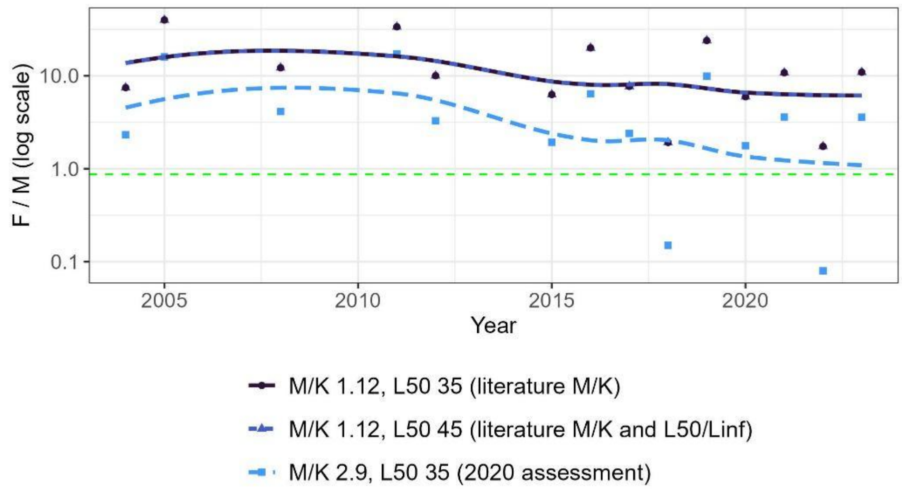

Figure F.6: LB-SPR estimates of F/M for the scenarios tested. The reference level of F / M = 0.87 is plotted in green.

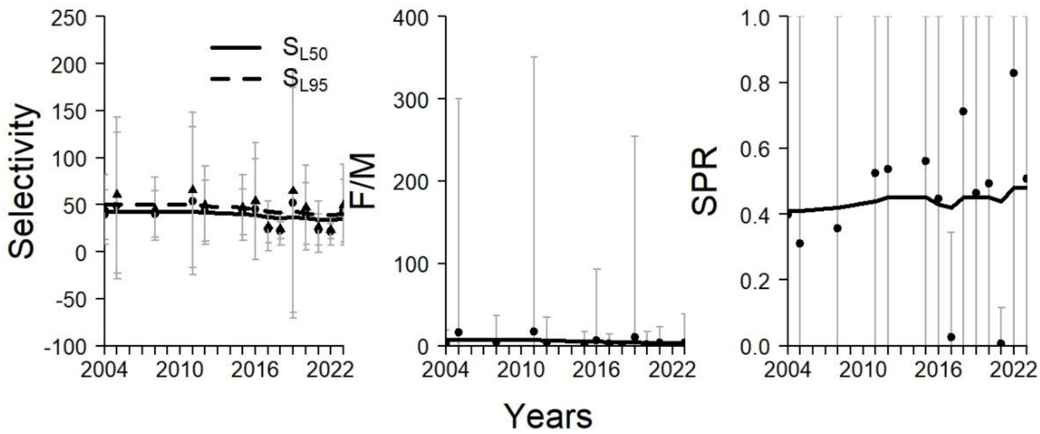

Figure F.7: LB-SPR parameter estimates, smoothers and credible intervals for the first model assumptions (2020 stock assessment assumptions) for the east alfonsino stock based on scaled length frequencies from the north east area (M/K = 0.29 and L50 = 35).

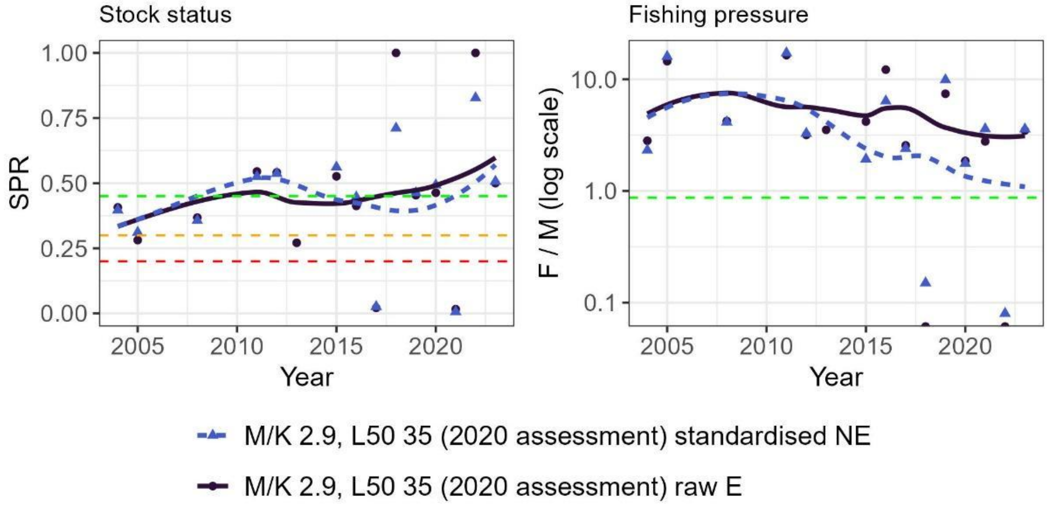

Figure F.8: Estimated stock status (left) and fishing pressure (right) of alfonsino in the east of the SIOFA region using either scaled length frequency data from a restricted area where larger fish are found or based on raw length data from the entire region. The stock status reference points were plotted at SPR = 0.45 (green), 0.3 (orange) and 0.2 (red) on the left plot, and at F/M = 0.87 (green) on the right plot.

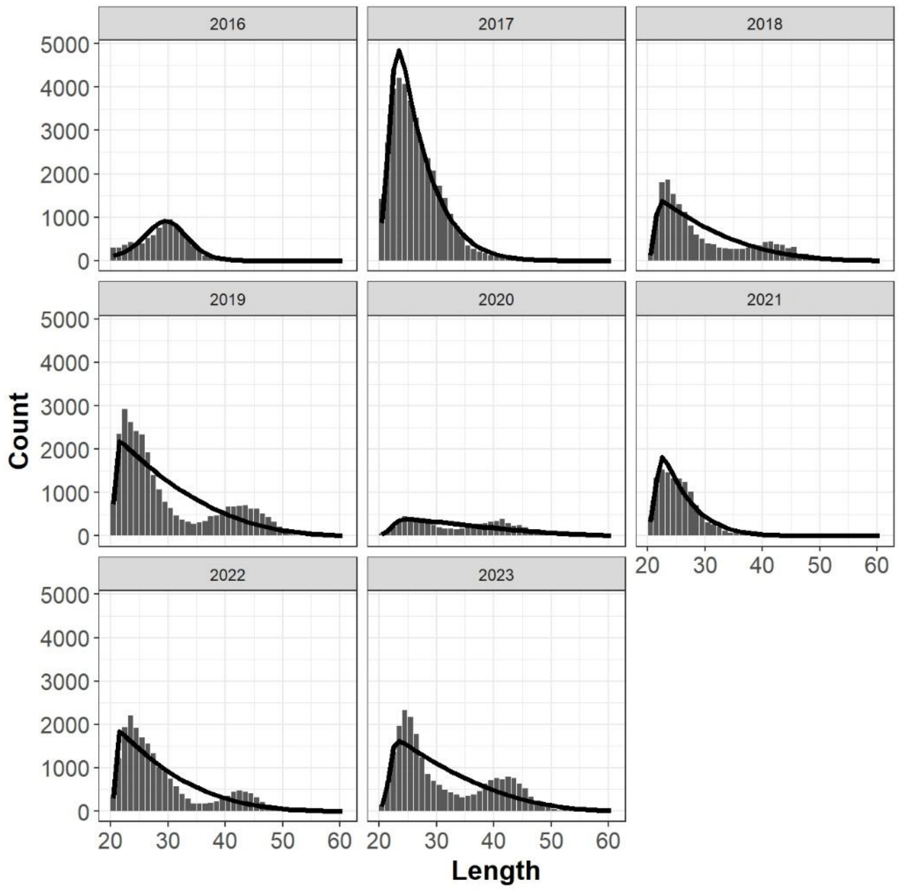

Figure F.9: Fits to the west alfonsino stock unscaled length frequencies for the second model assumptions (M/K = 1 and L50 = 35).

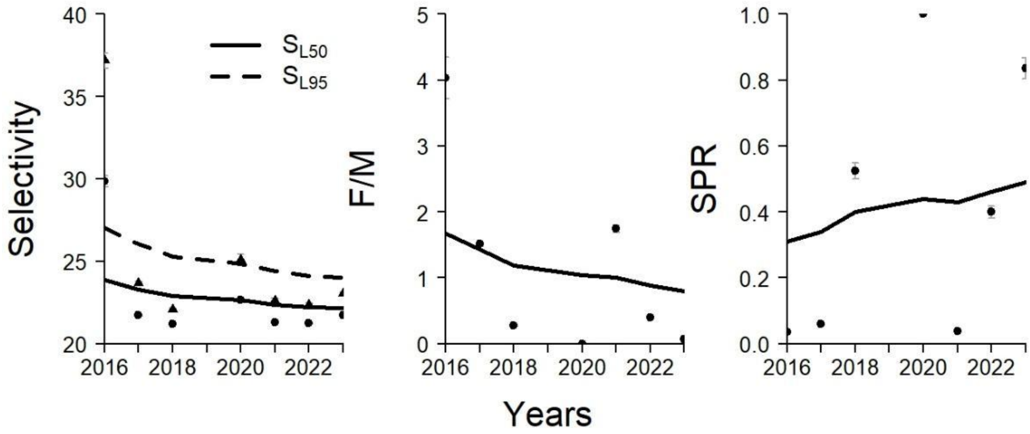

Figure F.10: LB-SPR parameter estimates, smoothers and credible intervals for the first model assumptions for the west alfonsino stock based on unscaled length frequencies from the entire west area (M/K = 2.9 and L50 = 35).

15. Appendix G – Alfonsino stock models supplement

Table G.1: Input parameters used in the alfonsino east stock assessment models.

Relationship	Parameter (units)	R1.0	R1.1	R1.2	R1.3	R1.5	R1.5
Ages modelled	years	1-100	1-100	1-100	1-100	1-100	1-100
Years modelled		1977-2018	1977-2018	1977-2018	1977-2018	1977-2018	1977-2018
Natural mortality (*M*)	year^{-1}	0.2	0.2	0.2	0.15	0.1	0.1
Selectivity	a50 (cm)	14	14	9	21	28	18
	ato95 (cm)	4	4	2	6	8	4
Maturity	a50 (cm)	9	14	9	21	28	18
	ato95 (cm)	2	4	2	6	8	4
von Bertalanffy growth	k (y^{-1})	0.068	0.068	0.068	0.045	0.034	0.034
	t_0 (y)	-5.114	-5.114	-5.114	-7.671	-10.228	-10.228
	L_∞ (cm)	61.3	61.3	61.3	61.3	61.3	61.3
Length-weight	a (g.cm^{-1})	0.29e^{-9}	0.29e^{-9}	0.29e^{-9}	0.29e^{-9}	0.29e^{-9}	0.29e^{-9}
	b	2.98	2.98	2.98	2.98	2.98	2.98
Stock recruitment steepness	h	0.75	0.75	0.75	0.75	0.75	0.75
Maximum exploitation rate	U_{max}	0.9	0.9	0.9	0.9	0.9	0.9

Table G.2: Parameters estimated in the models.

Parameter	Shape/ transformation	Starting values	Prior distribution
B_0	Log transform	50 000 185	Uniform
CPUE catchability q		0.01	Uniform
CPUE catchability process error		0.1*	Uniform-log

* fixed at MPD values

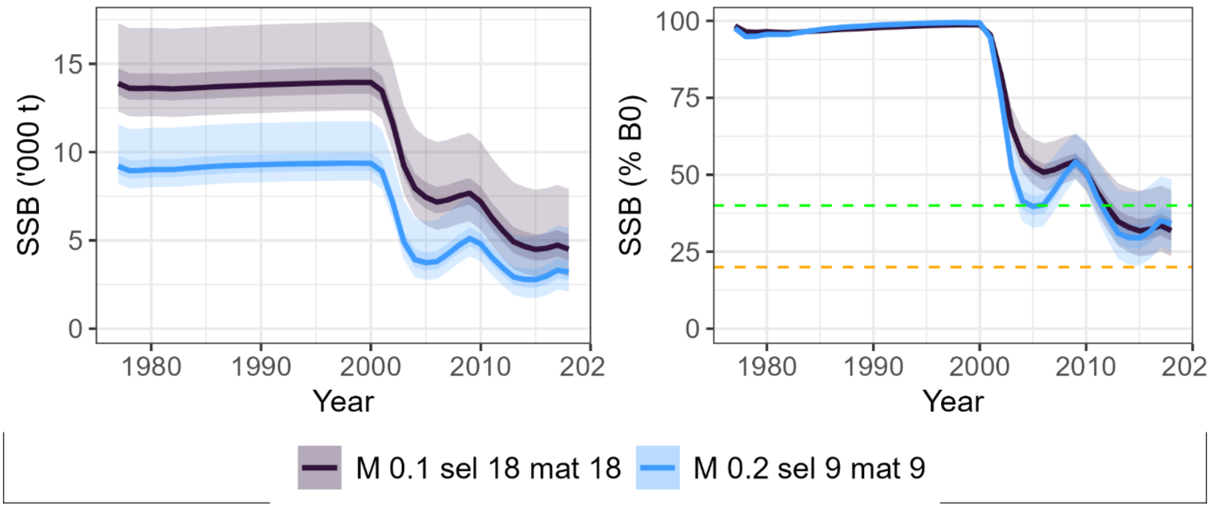

Figure G.1: Alfonsino east stock estimated biomass trajectory for model run R1.2 (M = 0.2 and selectivity SL50 = 9 years) and model R1.5 (M = 0.1 and selectivity SL50 = 18 years) in tonnes (left) or percentage of initial biomass (right) and 95% credible intervals. The target reference of 40% B_0 is plotted in green, and the limit reference of 20% B_0 in orange.

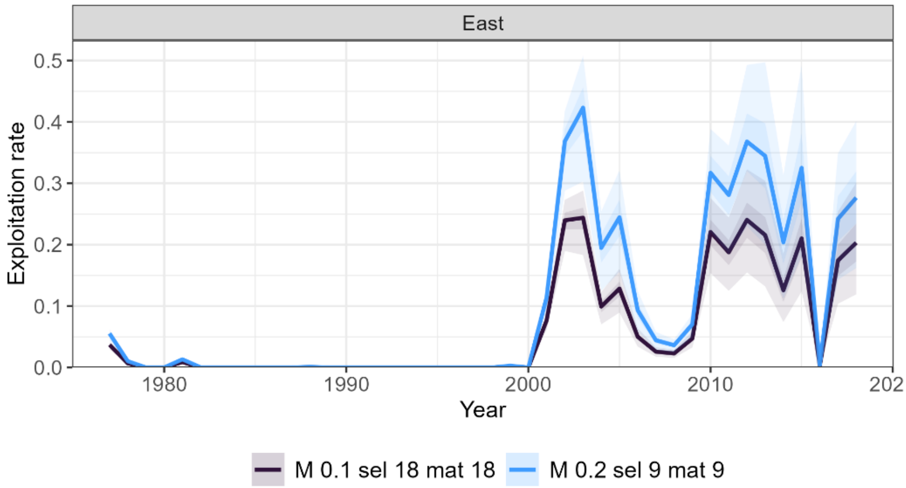

Figure G.2: Alfonsino east stock estimated exploitation rate for model run R1.2 (M = 0.2 and selectivity SL50 = 9 years) and model R1.5 (M = 0.1 and selectivity SL50 = 18 years) and 95% credible intervals.

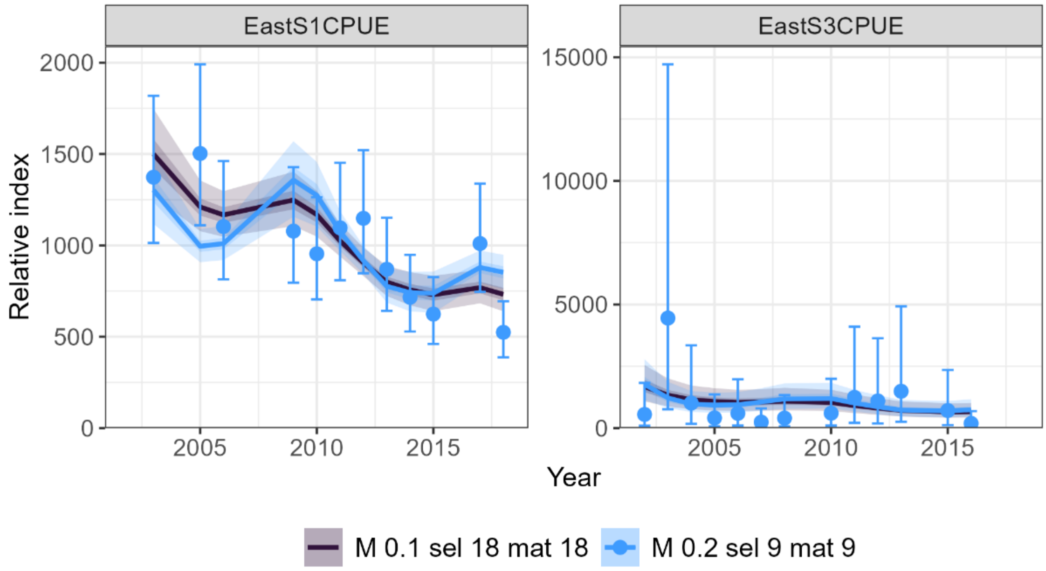

Figure G.3: Alfonsino east stock fits to the CPUE series for model run R1.2 (M = 0.2 and selectivity SL50 = 9 years) and model R1.5 (M = 0.1 and selectivity SL50 = 18 years) and 95% credible intervals. The points and error bars represent the observed CPUE series.

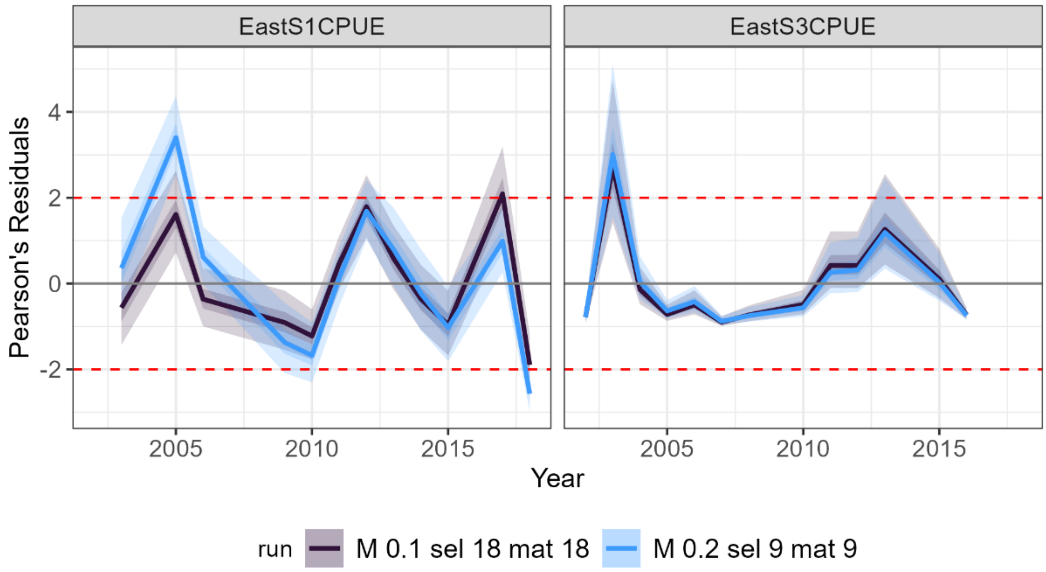

Figure G.4: Alfonsino east stock Pearson residuals to the CPUE series for model run R1.2 (M = 0.2 and selectivity SL50 = 9 years) and model R1.5 (M = 0.1 and selectivity SL50 = 18 years) and 95% credible intervals.

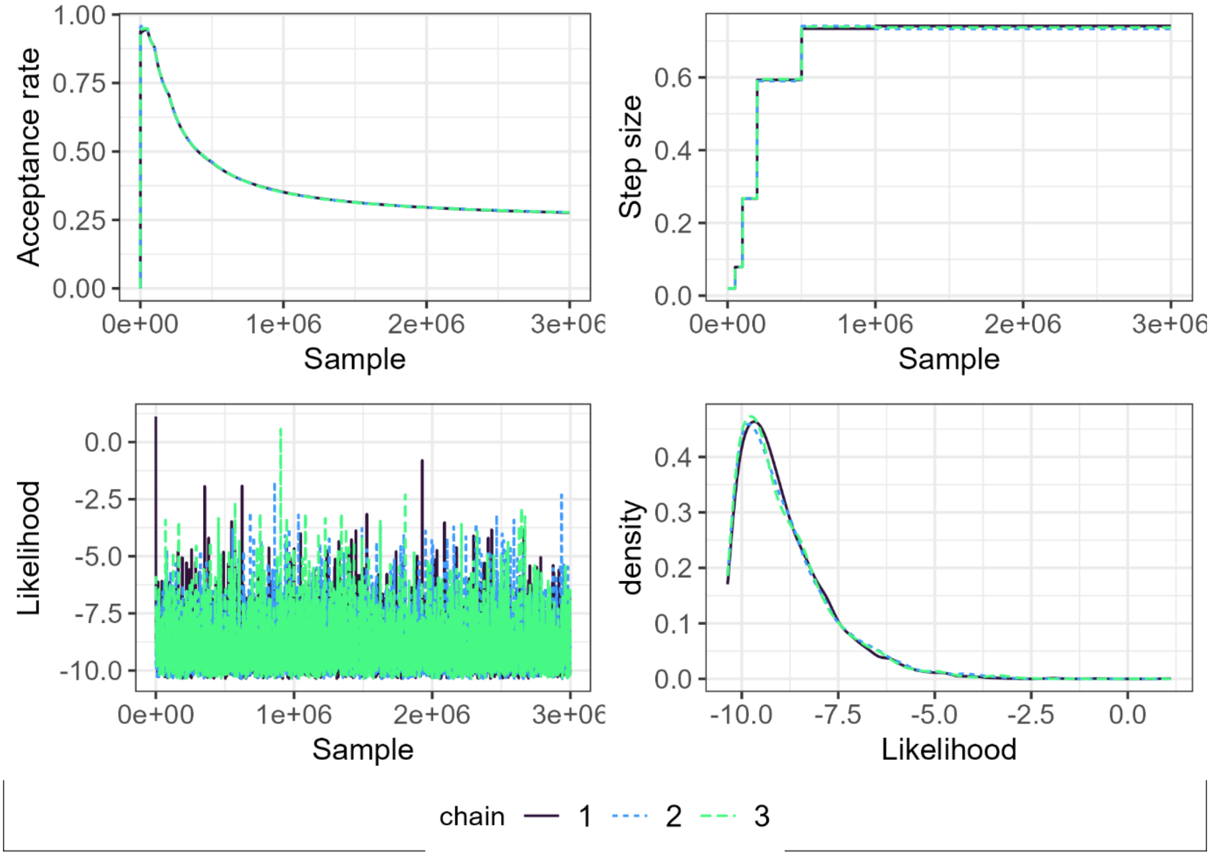

Figure G.5: Alfonsino east stock MCMC diagnostics for model R1.5 (M = 0.1 and selectivity SL50 = 18 years).

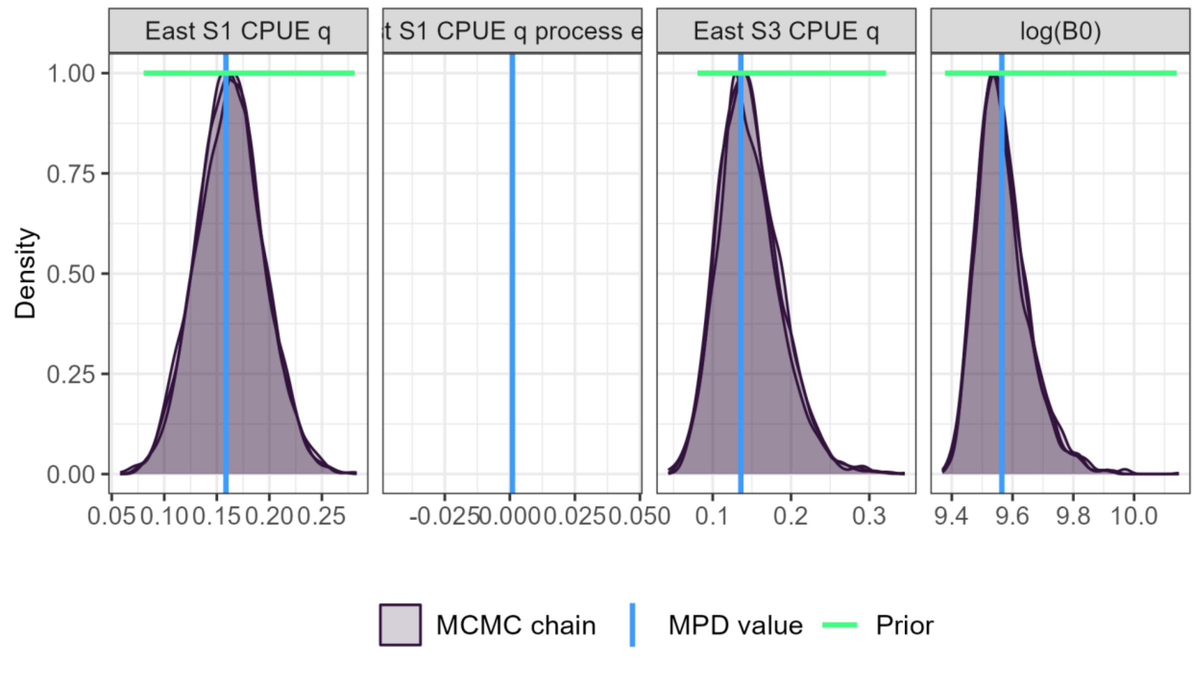

Figure G.6: Alfonsino MCMC density distribution of the estimated parameters for model R1.5 (M = 0.1 and selectivity SL50 = 18 years). The three chains are represented, as well as the MPD value and prior assumptions. The CPUE process error was only estimated at MPD level hence it has no MCMC density distribution.

16. Appendix H – Alfonsino management strategy evaluation results

Table H.1: Details of the alfonsino east stock simulations, carried out on both R1.2 (M = 0.2 and selectivity = 9 years) and R1.5 (M = 0.1 and selectivity = 18 years).

	Estimation model				Operating model				Harvest control rule settings					
Simulation	M	Selectivity	Maturity	YCS	M	Selectivity	Maturity	YCS	Type	Indicator	F_{TARGET}	B_{TARGET}	plateau TAC	TAC max change
R1	0.2	9	9	1	0.2	9	9	mu 1 sigma 0.7	Rule 4	-	-	-	-	-
R2	0.2	9	9	1	0.2	14	9	mu 1 sigma 0.7	Rule 4	-	-	-	-	-
R3	0.2	9	9	1	0.2	14	14	mu 1 sigma 0.7	Rule 4	-	-	-	-	-
R4	0.2	9	9	1	0.2	9	14	mu 1 sigma 0.7	Rule 4	-	-	-	-	-
R5	0.2	9	9	1	0.2	9	18	mu 1 sigma 0.7	Rule 4	-	-	-	-	-
R6	0.2	9	9	1	0.15	13	13	mu 1 sigma 0.7	Rule 4	-	-	-	-	-
R7	0.2	9	9	1	0.1	18	18	mu 1 sigma 0.7	Rule 4	-	-	-	-	-
R8	0.2	9	9	1	0.1	18	21	mu 1 sigma 0.7	Rule 4	-	-	-	-	-
R9	0.2	9	9	1	0.1	18	28	mu 1 sigma 0.7	Rule 4	-	-	-	-	-
R10	0.2	9	9	1	0.2	9	9	mu 1 sigma 0.7	Rule 1	SSB	0.179	40	-	-
R11	0.2	9	9	1	0.2	14	9	mu 1 sigma 0.7	Rule 1	SSB	0.179	40	-	-
R12	0.2	9	9	1	0.2	14	14	mu 1 sigma 0.7	Rule 1	SSB	0.179	40	-	-
R13	0.2	9	9	1	0.2	9	14	mu 1 sigma 0.7	Rule 1	SSB	0.179	40	-	-
R14	0.2	9	9	1	0.2	9	18	mu 1 sigma 0.7	Rule 1	SSB	0.179	40	-	-
R15	0.2	9	9	1	0.15	13	13	mu 1 sigma 0.7	Rule 1	SSB	0.179	40	-	-
R16	0.2	9	9	1	0.1	18	18	mu 1 sigma 0.7	Rule 1	SSB	0.179	40	-	-
R17	0.2	9	9	1	0.1	18	21	mu 1 sigma 0.7	Rule 1	SSB	0.179	40	-	-
R18	0.2	9	9	1	0.1	18	28	mu 1 sigma 0.7	Rule 1	SSB	0.179	40	-	-
R19	0.2	9	9	1	0.2	9	9	mu 1 sigma 0.7	Rule 5	CPUE S1	-	-	1400	-
R20	0.2	9	9	1	0.2	9	9	mu 1 sigma 0.7	Rule 6	CPUE S1	-	-	1400	-
R21	0.2	9	9	1	0.2	9	9	mu 1 sigma 0.7	Rule 5	CPUE S3	-	-	1400	-

	Estimation model				Operating model				Harvest control rule settings					
Simulation	M	Selectivity	Maturity	YCS	M	Selectivity	Maturity	YCS	Type	Indicator	F_{TARGET}	B_{TARGET}	plateau TAC	TAC max change
R22	0.2	9	9	1	0.2	9	9	mu 1 sigma 0.7	Rule 6	CPUE S3	-	-	1400	-
R23	0.2	9	9	1	0.2	9	14	mu 1 sigma 0.7	Rule 5	CPUE S1	-	-	1400	-
R24	0.2	9	9	1	0.2	9	14	mu 1 sigma 0.7	Rule 6	CPUE S1	-	-	1400	-
R25	0.2	9	9	1	0.2	9	14	mu 1 sigma 0.7	Rule 5	CPUE S3	-	-	1400	-
R26	0.2	9	9	1	0.2	9	14	mu 1 sigma 0.7	Rule 6	CPUE S3	-	-	1400	-
R27	0.2	9	9	1	0.15	13	13	mu 1 sigma 0.7	Rule 5	CPUE S1	-	-	1400	-
R28	0.2	9	9	1	0.15	13	13	mu 1 sigma 0.7	Rule 6	CPUE S1	-	-	1400	-
R29	0.2	9	9	1	0.15	13	13	mu 1 sigma 0.7	Rule 5	CPUE S3	-	-	1400	-
R30	0.2	9	9	1	0.15	13	13	mu 1 sigma 0.7	Rule 6	CPUE S3	-	-	1400	-
R31	0.2	9	9	1	0.1	18	18	mu 1 sigma 0.7	Rule 5	CPUE S1	-	-	1400	-
R32	0.2	9	9	1	0.1	18	18	mu 1 sigma 0.7	Rule 6	CPUE S1	-	-	1400	-
R33	0.2	9	9	1	0.1	18	18	mu 1 sigma 0.7	Rule 5	CPUE S3	-	-	1400	-
R34	0.2	9	9	1	0.1	18	18	mu 1 sigma 0.7	Rule 6	CPUE S3	-	-	1400	-
R35	0.2	9	9	1	0.1	18	28	mu 1 sigma 0.7	Rule 5	CPUE S1	-	-	1400	-
R36	0.2	9	9	1	0.1	18	28	mu 1 sigma 0.7	Rule 6	CPUE S1	-	-	1400	-
R37	0.2	9	9	1	0.1	18	28	mu 1 sigma 0.7	Rule 5	CPUE S3	-	-	1400	-
R38	0.2	9	9	1	0.1	18	28	mu 1 sigma 0.7	Rule 6	CPUE S3	-	-	1400	-
R39	0.2	9	9	1	0.2	9	9	mu 1 sigma 0.7	Rule 5	CPUE S1	-	-	400	25%
R40	0.2	9	9	1	0.2	9	9	mu 1 sigma 0.7	Rule 5	CPUE S1	-	-	500	25%
R41	0.2	9	9	1	0.2	9	9	mu 1 sigma 0.7	Rule 5	CPUE S1	-	-	600	25%
R42	0.2	9	9	1	0.2	9	9	mu 1 sigma 0.7	Rule 5	CPUE S1	-	-	800	25%
R43	0.2	9	9	1	0.2	9	9	mu 1 sigma 0.7	Rule 5	CPUE S1	-	-	1000	25%

Table H.2: Results of the simulation runs for the alfonsino east stock R1.2 (M = 0.2) – biomass indicators over the short (0-10 years after the end of the model), medium (10-20) and longer term (20-30) years. The colour coding follows the proposed model-based performance measures detailed in 'Appendix D – proposed performance measures': the probability of being above 40% B_0 is MP01, the probability of being below 20% $B_0$is MP02, the probability of being in the green portion of the Kobe plot (PGK) is MP03, and the probability of not overfishing ($F < F_{TARGET}$) is MP04. These were 'short-MSE' whereby the estimating model was not re-estimated through the procedure.

Model	Simulation	p(SSB > 40% B_0) (%)			p(B < 20% B_0) (%)			PGK (%)			p(F < F_{TARGET}) (%)		
		1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years
R1.2	R1	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.2	R2	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.2	R3	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.2	R4	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.2	R5	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.2	R6	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.2	R7	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.2	R8	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.2	R9	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.2	R10	10.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	60.0	80.0	80.0
R1.2	R11	10.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	60.0	80.0	80.0
R1.2	R12	10.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	60.0	80.0	80.0
R1.2	R13	10.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	60.0	80.0	80.0
R1.2	R14	10.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	60.0	80.0	80.0
R1.2	R15	10.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	60.0	80.0	80.0
R1.2	R16	10.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	60.0	80.0	80.0
R1.2	R17	10.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	60.0	80.0	80.0
R1.2	R18	10.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	60.0	80.0	80.0
R1.2	R19	23.1	51.7	50.2	20.2	23.2	22.0	21.0	40.7	36.7	44.6	57.8	55.4
R1.2	R20	2.5	19.0	24.7	46.8	54.5	46.9	2.4	17.2	22.1	14.4	30.3	38.7
R1.2	R21	24.1	53.7	55.1	14.0	20.0	15.6	21.8	41.1	41.9	50.0	60.8	61.9
R1.2	R22	5.1	25.3	28.2	34.2	38.8	35.7	4.4	22.6	24.0	26.0	41.3	44.8
R1.2	R23	0.2	1.0	11.6	67.7	84.3	44.9	0.2	0.8	11.0	3.6	23.7	64.9
R1.2	R24	0.0	0.0	1.3	70.0	99.7	83.2	0.0	0.0	1.3	0.0	1.6	34.3

Model	Simulation	p(SSB > 40% B_0) (%)			p(B < 20% B_0) (%)			PGK (%)			p(F < F_{TARGET}) (%)		
		1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years
R1.2	R25	1.3	4.0	15.0	62.9	72.3	52.2	1.2	3.4	13.9	8.6	35.0	56.4
R1.2	R26	0.0	0.5	3.8	69.0	96.4	81.2	0.0	0.5	3.8	0.1	4.8	30.1
R1.2	R27	27.1	57.9	66.8	13.1	14.9	11.0	23.7	46.5	52.1	50.5	63.4	66.9
R1.2	R28	2.9	26.2	38.9	34.5	41.9	29.1	2.8	24.0	35.8	22.0	40.5	56.5
R1.2	R29	27.2	64.6	72.0	9.7	12.1	7.2	24.9	51.3	56.8	55.2	67.6	70.1
R1.2	R30	5.5	32.2	43.0	31.0	31.2	28.1	5.2	28.9	38.7	26.9	51.8	59.9
R1.2	R31	28.7	71.6	85.9	7.5	8.7	3.7	25.8	60.1	73.3	54.3	72.6	80.5
R1.2	R32	6.1	49.2	70.9	22.1	14.1	9.8	5.9	46.0	69.5	35.5	67.5	83.0
R1.2	R33	33.9	82.8	88.4	4.8	3.4	3.1	33.0	67.6	77.5	63.5	75.8	83.5
R1.2	R34	12.8	54.5	77.9	15.6	6.5	3.3	11.3	48.9	70.8	43.2	71.3	82.6
R1.2	R35	0.1	1.9	7.4	66.2	69.6	67.1	0.1	1.8	7.2	7.1	32.2	43.2
R1.2	R36	0.0	0.0	0.0	70.0	99.7	97.8	0.0	0.0	0.0	0.0	0.6	9.4
R1.2	R37	0.8	7.4	7.2	64.2	61.9	60.1	0.6	6.7	6.4	9.1	43.1	46.1
R1.2	R38	0.0	0.0	0.8	68.5	96.6	93.8	0.0	0.0	0.8	0.7	4.6	13.9
R1.2	R39	24.6	89.3	93.1	0.2	2.0	2.0	24.6	89.0	92.4	61.0	92.4	94.0
R1.2	R40	21.6	85.0	87.5	0.2	1.2	0.0	21.6	83.3	84.5	58.4	88.5	89.0
R1.2	R41	14.6	73.0	80.6	0.3	4.6	6.5	14.6	72.1	79.7	50.8	79.1	84.8
R1.2	R42	16.6	60.4	65.4	1.0	10.2	10.8	16.6	58.9	61.0	42.3	63.5	66.9
R1.2	R43	5.1	53.8	63.6	3.2	19.6	18.8	5.1	53.2	61.6	20.7	60.0	68.3

Table H.3: Results of the simulation runs for the alfonsino east stock R1.2 (M = 0.2) – future total allowable catch (TAC) mean in tonnes and interannual variability (%) in percentage over the short (1-10 years after the end of the model), medium (11-20) and longer term (21-30) years. These correspond to the proposed model-based performance measures MC01 (mean TAC) and MC02 (variability of TAC) detailed in 'Appendix D – proposed performance measures'. #### denotes variability above 999%, usually linked to a very low TAC value.

Model	Simulation	TAC mean (t) First year	TAC mean (t) 1-10 years	TAC var (%) 1-10 years	TAC mean (t) 11-20 years	TAC var (%) 11-20 years	TAC mean (t) 21-30 years	TAC var (%) 21-30 years
R1.2	R1	1 400	1 213	-	732	-	522	-
R1.2	R2	1 400	1 213	-	732	-	522	-
R1.2	R3	1 400	1 213	-	732	-	522	-
R1.2	R4	1 400	1 213	-	732	-	522	-
R1.2	R5	1 400	1 213	-	732	-	522	-
R1.2	R6	1 400	1 213	-	732	-	522	-
R1.2	R7	1 400	1 213	-	732	-	522	-
R1.2	R8	1 400	1 213	-	732	-	522	-
R1.2	R9	1 400	1 213	-	732	-	522	-
R1.2	R10	471	609	11	667	1	674	0
R1.2	R11	471	609	11	667	1	674	0
R1.2	R12	471	609	11	667	1	674	0
R1.2	R13	471	609	11	667	1	674	0
R1.2	R14	471	609	11	667	1	674	0
R1.2	R15	471	609	11	667	1	674	0
R1.2	R16	471	609	11	667	1	674	0
R1.2	R17	471	609	11	667	1	674	0
R1.2	R18	471	609	11	667	1	674	0
R1.2	R19	1 162	664	####	569	#####	612	####
R1.2	R20	1 400	997	45	619	71	552	93
R1.2	R21	1 227	634	####	599	####	585	####
R1.2	R22	1 400	903	108	629	115	606	116
R1.2	R23	1 162	1 161	####	661	####	333	####
R1.2	R24	1 400	1 213	68	704	42	366	134
R1.2	R25	1 227	1 113	####	652	####	419	####
R1.2	R26	1 400	1 202	66	690	70	400	170
R1.2	R27	1 162	609	####	509	####	507	####
R1.2	R28	1 400	924	55	608	70	510	83
R1.2	R29	1 227	583	####	492	####	494	####
R1.2	R30	1 400	879	105	582	118	522	151
R1.2	R31	1 162	546	####	444	####	329	####
R1.2	R32	1 400	804	67	479	78	360	86
R1.2	R33	1 227	462	####	423	####	302	####
R1.2	R34	1 400	741	134	478	153	411	177
R1.2	R35	1 162	1 127	####	663	####	478	####
R1.2	R36	1 400	1 210	67	701	52	504	64
R1.2	R37	1 227	1 112	####	614	####	558	####
R1.2	R38	1 400	1 187	70	709	94	509	80
R1.2	R39	744	584	21	378	18	372	17
R1.2	R40	744	600	21	400	20	395	20
R1.2	R41	744	630	20	472	20	433	20

Model	Simulation	TAC mean (t) First year	TAC mean (t) 1-10 years	TAC var (%) 1-10 years	TAC mean (t) 11-20 years	TAC var (%) 11-20 years	TAC mean (t) 21-30 years	TAC var (%) 21-30 years
R1.2	R42	744	665	21	514	22	471	21
R1.2	R43	830	750	22	527	23	427	24

Table H.4: Results of the simulation runs for the alfonsino east stock R1.2 (M = 0.2) – future sum of standardised CPUE series (no unit) mean and standard deviation (sd) in 2035, 2045 and 2055. These correspond to the proposed model-based performance measure MC03 detailed in 'Appendix D – proposed performance measures'. These were 'short-MSE' whereby the estimating model was not re-estimated through the procedure.

Model	Simulation	Sum of standardised CPUE (no unit)					
		mean 2035	sd 2035	mean 2045	sd 2045	mean 2055	sd 2055
R1.2 (M=0.2)	R1	458	1 149	242	616	155	192
R1.2 (M=0.2)	R2	292	304	331	587	308	375
R1.2 (M=0.2)	R3	768	1 101	543	810	477	946
R1.2 (M=0.2)	R4	3 927	5 291	2 319	2 881	1 324	2 586
R1.2 (M=0.2)	R5	12 715	10 129	11 737	10 948	10 265	8 462
R1.2 (M=0.2)	R6	224	258	187	284	127	180
R1.2 (M=0.2)	R7	159	171	116	127	77	88
R1.2 (M=0.2)	R8	240	343	88	434	11	27
R1.2 (M=0.2)	R9	2 547	3 125	1 386	2 372	432	827
R1.2 (M=0.2)	R10	1 325	1 366	1 307	1 624	1 168	1 362
R1.2 (M=0.2)	R11	515	713	458	577	468	528
R1.2 (M=0.2)	R12	2 367	2 515	2 078	1 822	2 169	2 233
R1.2 (M=0.2)	R13	5 905	4 982	5 799	4 710	5 985	5 206
R1.2 (M=0.2)	R14	16 373	12 428	14 852	9 798	15 562	15 414
R1.2 (M=0.2)	R15	894	1 167	801	1 308	559	848
R1.2 (M=0.2)	R16	288	445	243	378	159	354
R1.2 (M=0.2)	R17	748	1 150	558	721	337	786
R1.2 (M=0.2)	R18	5 759	3 996	5 828	4 669	4 963	4 237
R1.2 (M=0.2)	R19	1 108	1 058	1 156	1 004	1 515	1 835
R1.2 (M=0.2)	R20	532	880	494	661	414	442
R1.2 (M=0.2)	R21	1 570	1 519	1 717	1 575	1 785	1 955
R1.2 (M=0.2)	R22	640	606	717	942	914	1 282
R1.2 (M=0.2)	R23	1 422	1 630	1 565	1 866	895	848
R1.2 (M=0.2)	R24	1 192	1 583	604	1 227	94	261
R1.2 (M=0.2)	R25	2 238	2 265	1 776	1 717	1 298	1 675
R1.2 (M=0.2)	R26	1 697	1 873	870	1 420	312	694
R1.2 (M=0.2)	R27	1 157	1 272	1 182	1 945	1 315	1 540
R1.2 (M=0.2)	R28	426	534	444	562	362	381
R1.2 (M=0.2)	R29	1 261	1 127	1 583	1 541	1 373	1 421
R1.2 (M=0.2)	R30	601	654	504	560	619	702
R1.2 (M=0.2)	R31	753	608	1 002	780	885	791
R1.2 (M=0.2)	R32	271	278	240	328	245	375
R1.2 (M=0.2)	R33	1 162	1 119	1 210	972	1 231	1 965
R1.2 (M=0.2)	R34	457	838	464	679	379	559
R1.2 (M=0.2)	R35	1 553	1 321	601	701	240	341
R1.2 (M=0.2)	R36	1 207	1 302	252	495	10	29
R1.2 (M=0.2)	R37	2 395	2 096	1 132	1 291	527	711
R1.2 (M=0.2)	R38	1 678	1 718	658	995	87	217

R1.2 (M=0.2)	R39	1 887	1 765	2 420	2 140	2 852	2 698
R1.2 (M=0.2)	R40	1 761	1 545	2 255	1 873	2 843	2 274
R1.2 (M=0.2)	R41	1 791	2 001	1 795	1 303	2 229	1 708
R1.2 (M=0.2)	R42	1 410	1 162	1 693	1 469	2 255	2 017
R1.2 (M=0.2)	R43	1 050	1 038	1 408	1 382	1 877	1 535

Table H.5: Results of the simulation runs for the alfonsino east R1.5 (M = 0.1) – biomass indicators over the short (0-10 years after the end of the model), medium (10-20) and longer term (20-30) years. The colour coding follows the proposed model-based performance measures detailed in 'Appendix D – proposed performance measures': the probability of being above 40% B_0 is MP01, the probability of being below 20% B_0 is MP02, the probability of being in the green portion of the Kobe plot (PGK) is MP03, and the probability of not overfishing ($F < F_{TARGET}$) is MP04. These were 'short-MSE' whereby the estimating model was not re-estimated through the procedure.

Model	Simulation	p(SSB > 40% B_0) (%)			p(B < 20% B_0) (%)			PGK (%)			p(F < F_{TARGET}) (%)		
		1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years
R1.5	R1	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.5	R2	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.5	R3	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.5	R4	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.5	R5	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.5	R6	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.5	R7	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.5	R8	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.5	R9	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.5	R10	50.0	60.0	0.0	0.0	0.0	0.0	50.0	10.0	0.0	100.0	10.0	70.0
R1.5	R11	50.0	60.0	0.0	0.0	0.0	0.0	50.0	10.0	0.0	100.0	10.0	70.0
R1.5	R12	50.0	60.0	0.0	0.0	0.0	0.0	50.0	10.0	0.0	100.0	10.0	70.0
R1.5	R13	50.0	60.0	0.0	0.0	0.0	0.0	50.0	10.0	0.0	100.0	10.0	70.0
R1.5	R14	50.0	60.0	0.0	0.0	0.0	0.0	50.0	10.0	0.0	100.0	10.0	70.0
R1.5	R15	50.0	60.0	0.0	0.0	0.0	0.0	50.0	10.0	0.0	100.0	10.0	70.0
R1.5	R16	50.0	60.0	0.0	0.0	0.0	0.0	50.0	10.0	0.0	100.0	10.0	70.0
R1.5	R17	50.0	60.0	0.0	0.0	0.0	0.0	50.0	10.0	0.0	100.0	10.0	70.0
R1.5	R18	50.0	60.0	0.0	0.0	0.0	0.0	50.0	10.0	0.0	100.0	10.0	70.0
R1.5	R19	10.1	37.5	45.4	15.7	25.3	26.8	9.1	25.8	37.3	46.2	51.6	63.4
R1.5	R20	0.0	0.5	6.4	58.1	71.5	66.3	0.0	0.5	5.8	3.8	10.7	20.7
R1.5	R21	11.5	46.0	41.9	12.6	18.4	23.4	9.9	36.3	32.0	51.0	64.8	69.4
R1.5	R22	0.0	4.4	7.2	42.2	53.4	55.4	0.0	3.7	6.2	16.2	23.5	30.4
R1.5	R23	0.0	0.0	0.0	69.7	99.8	100.0	0.0	0.0	0.0	0.0	1.7	7.1
R1.5	R24	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0

Model	Simulation	p(SSB > 40% B_0) (%)			p(B < 20% B_0) (%)			PGK (%)			p(F < F_{TARGET}) (%)		
		1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years	1-10 years	11-20 years	21-30 years
R1.5	R25	0.1	0.3	0.0	64.9	96.5	97.7	0.1	0.2	0.0	4.8	15.5	23.2
R1.5	R26	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.8
R1.5	R27	3.1	10.7	7.8	41.1	58.2	67.3	2.5	7.1	6.1	19.5	34.4	36.5
R1.5	R28	0.0	0.0	0.7	67.9	92.9	95.1	0.0	0.0	0.6	0.6	2.0	1.3
R1.5	R29	6.4	26.9	14.0	24.6	38.1	47.3	6.0	20.6	9.7	39.2	56.3	50.0
R1.5	R30	0.0	0.6	1.0	59.7	83.8	87.6	0.0	0.4	1.0	3.6	7.2	5.5
R1.5	R31	6.7	21.7	25.0	28.9	37.1	39.2	5.4	16.2	20.5	32.5	46.9	55.0
R1.5	R32	0.0	1.9	7.3	56.0	64.8	63.3	0.0	1.9	7.0	5.7	10.5	26.6
R1.5	R33	11.1	44.6	40.8	14.4	21.0	21.0	10.1	33.6	33.0	50.1	64.7	66.6
R1.5	R34	0.1	7.6	8.2	41.8	47.2	56.8	0.1	5.5	6.3	18.0	25.5	28.1
R1.5	R35	0.0	0.0	0.0	68.9	97.3	97.1	0.0	0.0	0.0	0.0	12.2	11.2
R1.5	R36	0.0	0.0	0.0	70.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R1.5	R37	0.0	0.2	0.0	64.4	90.4	92.7	0.0	0.1	0.0	4.4	26.6	29.9
R1.5	R38	0.0	0.0	0.0	69.6	100.0	99.7	0.0	0.0	0.0	0.0	0.3	0.2
R1.5	R39	0.0	47.8	86.6	0.0	0.0	0.0	0.0	47.7	85.0	17.7	89.3	91.9
R1.5	R40	0.0	39.1	59.2	0.0	1.0	1.1	0.0	39.0	57.5	12.1	61.9	62.9
R1.5	R41	0.0	29.2	46.5	0.0	0.7	5.2	0.0	28.8	44.0	9.2	48.3	57.0
R1.5	R42	0.0	31.0	51.1	0.9	14.1	19.8	0.0	30.7	47.6	9.8	54.6	56.3
R1.5	R43	0.0	19.7	46.7	7.3	28.2	27.1	0.0	19.7	46.5	4.6	50.6	57.1

Table H.6: Results of the simulation runs for the alfonsino east R1.5 (M = 0.1) – future total allowable catch (TAC) mean and interannual variation (var) in tonnes over the short (1-10 years after the end of the model), medium (11-20) and longer term (21-30) years. These correspond to the proposed model-based performance measures MC01 (mean TAC) and MC02 (variability of TAC) detailed in 'Appendix D – proposed performance measures'. #### denotes variability above 999%, usually linked to a very low TAC value.

Model	Simulation	TAC mean (t) First year	TAC mean (t) 1-10 years	TAC var (%) 1-10 years	TAC mean (t) 11-20 years	TAC var (%) 11-20 years	TAC mean (t) 21-30 years	TAC var (%) 21-30 years
R1.5	R1	1 400	1 253	-	775	-	469	-
R1.5	R2	1 400	1 253	-	775	-	469	-
R1.5	R3	1 400	1 253	-	775	-	469	-
R1.5	R4	1 400	1 253	-	775	-	469	-
R1.5	R5	1 400	1 253	-	775	-	469	-
R1.5	R6	1 400	1 253	-	775	-	469	-
R1.5	R7	1 400	1 253	-	775	-	469	-
R1.5	R8	1 400	1 253	-	775	-	469	-
R1.5	R9	1 400	1 253	-	775	-	469	-
R1.5	R10	284	413	18	509	1	496	0
R1.5	R11	284	413	18	509	1	496	0
R1.5	R12	284	413	18	509	1	496	0
R1.5	R13	284	413	18	509	1	496	0
R1.5	R14	284	413	18	509	1	496	0
R1.5	R15	284	413	18	509	1	496	0
R1.5	R16	284	413	18	509	1	496	0
R1.5	R17	284	413	18	509	1	496	0
R1.5	R18	284	413	18	509	1	496	0
R1.5	R19	1 162	623	####	573	#####	392	#####
R1.5	R20	1 400	1 062	31	621	40	451	45
R1.5	R21	1 227	605	####	500	####	424	#####
R1.5	R22	1 400	931	83	639	98	475	109
R1.5	R23	1 162	1 259	84	763	#####	429	#####
R1.5	R24	1 400	1 268	65	768	19	435	16
R1.5	R25	1 227	1 207	####	728	#####	473	#####
R1.5	R26	1 400	1 261	84	762	49	448	52
R1.5	R27	1 162	948	####	629	#####	540	#####
R1.5	R28	1 400	1 191	21	726	31	508	38
R1.5	R29	1 227	765	####	577	#####	593	#####
R1.5	R30	1 400	1 104	52	715	80	545	90
R1.5	R31	1 162	777	####	571	#####	454	#####
R1.5	R32	1 400	1 039	34	621	45	440	50
R1.5	R33	1 227	608	####	505	#####	440	#####
R1.5	R34	1 400	917	75	609	88	522	120
R1.5	R35	1 162	1 258	72	681	#####	476	#####
R1.5	R36	1 400	1 268	49	760	17	443	18
R1.5	R37	1 227	1 197	####	651	#####	502	#####
R1.5	R38	1 400	1 254	57	748	56	473	62
R1.5	R39	744	556	20	346	13	338	14
R1.5	R40	744	575	20	373	17	372	16
R1.5	R41	744	603	18	449	17	408	18

Model	Simulation	TAC mean (t) First year	TAC mean (t) 1-10 years	TAC var (%) 1-10 years	TAC mean (t) 11-20 years	TAC var (%) 11-20 years	TAC mean (t) 21-30 years	TAC var (%) 21-30 years
R1.5	R42	744	650	19	457	20	426	22
R1.5	R43	830	739	21	486	23	383	24

Table H.7: Results of the simulation runs for the alfonsino east R1.5 (M = 0.1) – future sum of standardised CPUE series (no unit) mean and standard deviation (sd) in 2035, 2045 and 2055. These correspond to the proposed model-based performance measure MC03 detailed in 'Appendix D – proposed performance measures'. These were 'short-MSE' whereby the estimating model was not re-estimated through the procedure.

Model	Simulation	Sum of standardised CPUE (no unit)					
		mean 2035	sd 2035	mean 2045	sd 2045	mean 2055	sd 2055
R1.5	R1	252	391	126	169	85	92
R1.5	R2	328	294	342	328	332	270
R1.5	R3	1 463	1 406	1 282	1 907	1 325	1 949
R1.5	R4	5 046	3 772	4 469	3 632	4 386	4 140
R1.5	R5	11 697	7 366	11 384	9 203	9 731	6 906
R1.5	R6	645	757	486	886	300	630
R1.5	R7	258	434	123	105	86	85
R1.5	R8	469	566	230	487	71	141
R1.5	R9	3 152	2 426	2 318	2 673	1 371	1 631
R1.5	R10	1 385	1 130	1 595	1 889	1 571	1 437
R1.5	R11	1 109	1 084	1 084	786	1 098	837
R1.5	R12	3 196	1 974	3 334	2 211	3 211	2 559
R1.5	R13	6 166	4 244	6 276	3 400	6 817	5 330
R1.5	R14	13 254	8 186	12 935	8 156	12 554	6 766
R1.5	R15	2 314	1 826	2 470	1 797	2 599	2 019
R1.5	R16	1 457	1 410	1 530	1 377	1 654	1 638
R1.5	R17	2 229	1 387	2 447	1 945	2 273	1 523
R1.5	R18	6 128	4 342	5 905	3 403	5 258	3 130
R1.5	R19	936	633	1 159	909	983	690
R1.5	R20	435	326	331	318	311	291
R1.5	R21	1 470	1 123	1 117	738	1 459	1 322
R1.5	R22	663	802	483	397	469	474
R1.5	R23	2 863	2 219	2 195	1 903	1 920	1 336
R1.5	R24	3 053	2 049	2 192	1 838	1 730	1 585
R1.5	R25	3 804	4 045	3 036	2 231	2 691	1 717
R1.5	R26	3 335	3 245	2 266	1 827	2 279	2 132
R1.5	R27	1 392	1 095	1 134	1 098	1 305	1 008
R1.5	R28	735	707	672	795	511	452
R1.5	R29	1 803	1 250	1 547	1 303	1 800	1 256
R1.5	R30	969	810	952	873	911	793
R1.5	R31	1 207	885	1 013	542	1 087	871
R1.5	R32	466	371	327	525	315	349
R1.5	R33	1 433	1 344	1 366	1 082	1 414	1 002
R1.5	R34	671	633	528	475	471	385
R1.5	R35	1 698	1 159	1 662	1 347	889	793
R1.5	R36	1 758	1 983	1 198	1 138	278	456
R1.5	R37	2 386	1 701	2 010	1 677	1 469	1 556
R1.5	R38	2 081	1 660	1 699	2 097	698	981

R1.5	R39	1 647	1 096	1 749	1 113	1 861	1 059
R1.5	R40	1 607	1 286	1 643	1 067	1 900	1 271
R1.5	R41	1 500	1 034	1 464	1 096	1 492	892
R1.5	R42	1 333	924	1 490	1 063	1 561	1 066
R1.5	R43	1 034	888	1 144	820	1 327	856

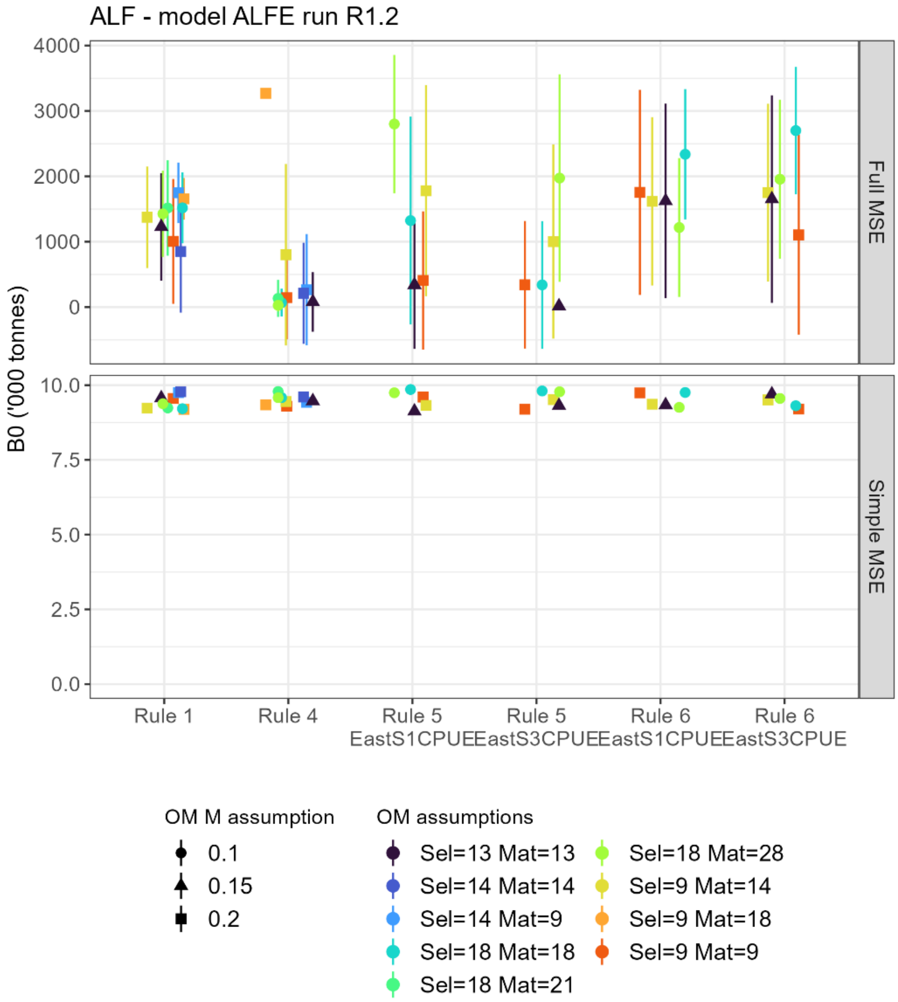

Figure H.1: Value of the initial biomass parameter estimated in the final year of the management strategy evaluation and 95% credible interval for the east alfonsino stock model R1.2 (M = 0.2). The full MSE (top) re-estimates parameters every year the total allowable catch is recalculated whilst the simple MSE (bottom) does not re-estimate parameters and the variability is due to the MCMC sample selection for the MSE.

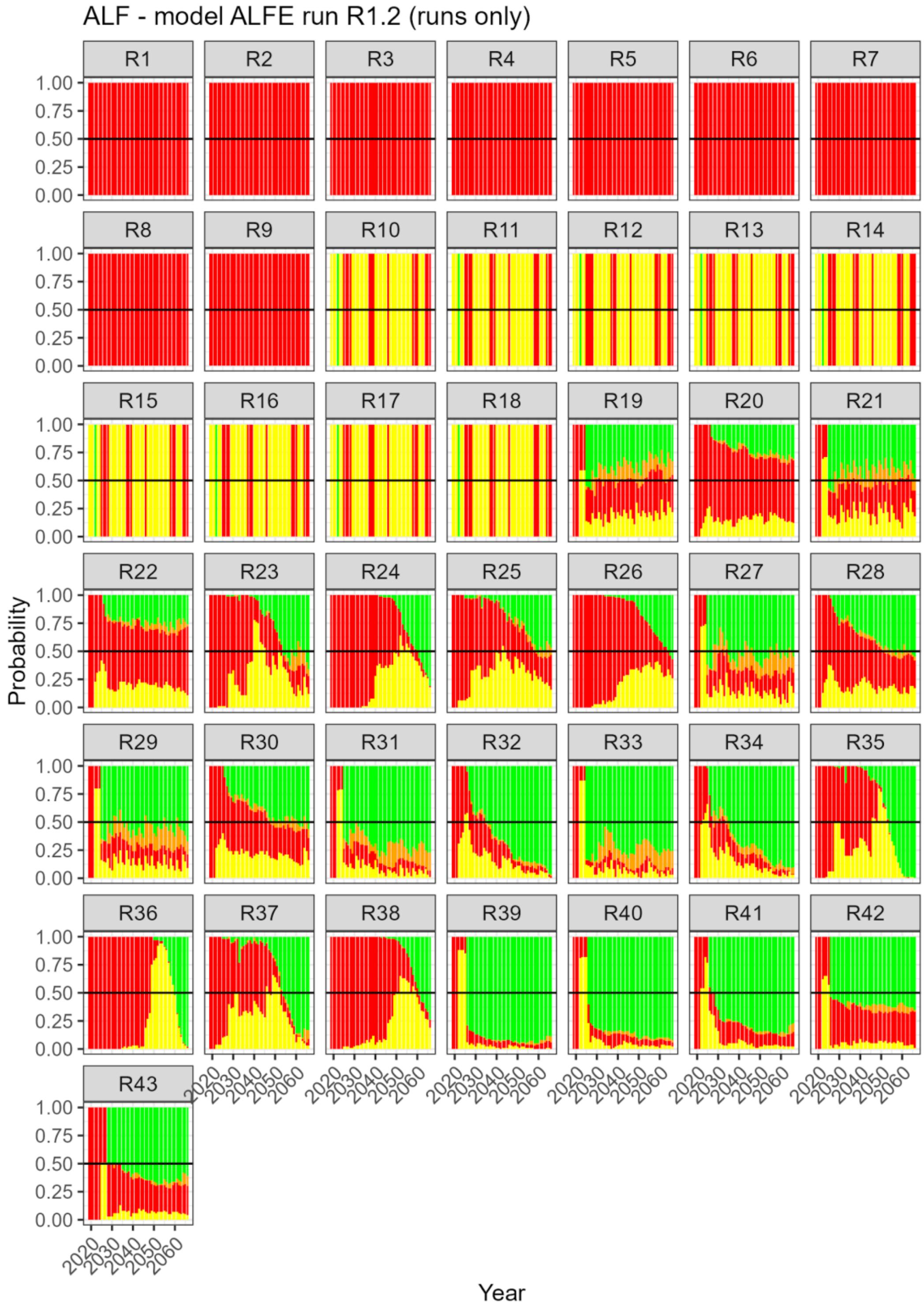

Figure H.2: Kobe time plot for the simulation scenarios for the east alfonsino stock model R1.2 (M = 0.2) simple MSE runs which do not re-estimate parameters. Only runs which have the same TAC plateau of 1400 t are represented. The proportion of the simulations in each quadrant of the Kobe matrix (see Figure E.3 for the definition of the colours) in each year of the projection period are depicted. The horizontal line represents the 50% probability.

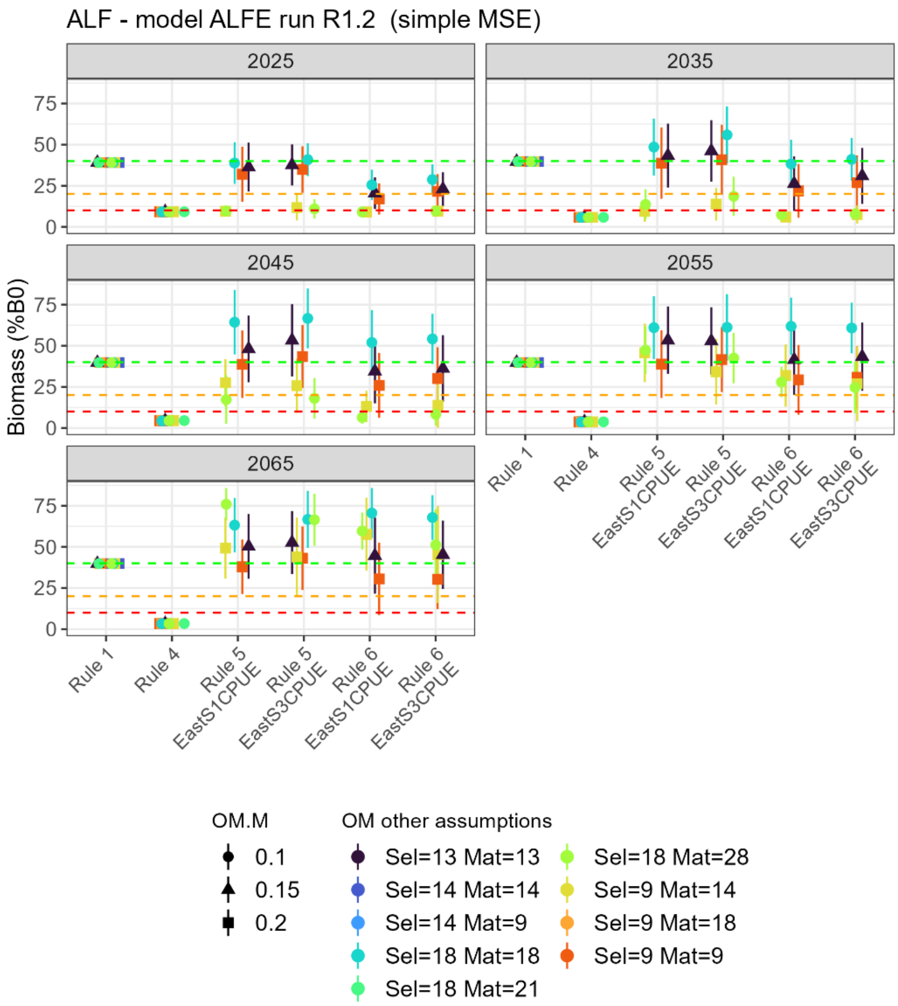

Figure H.3: Spawning stock biomass status as a percentage of initial biomass and 95% credible interval every 10 years for the different simulations for the east alfonsino stock model R1.2 (M = 0.2) simple MSE runs which do not re-estimate parameters. Only runs which have the same TAC plateau of 1400 t are represented. 40% B_0 is plotted in green, 20% B_0 in orange, and 10% B_0 in red.

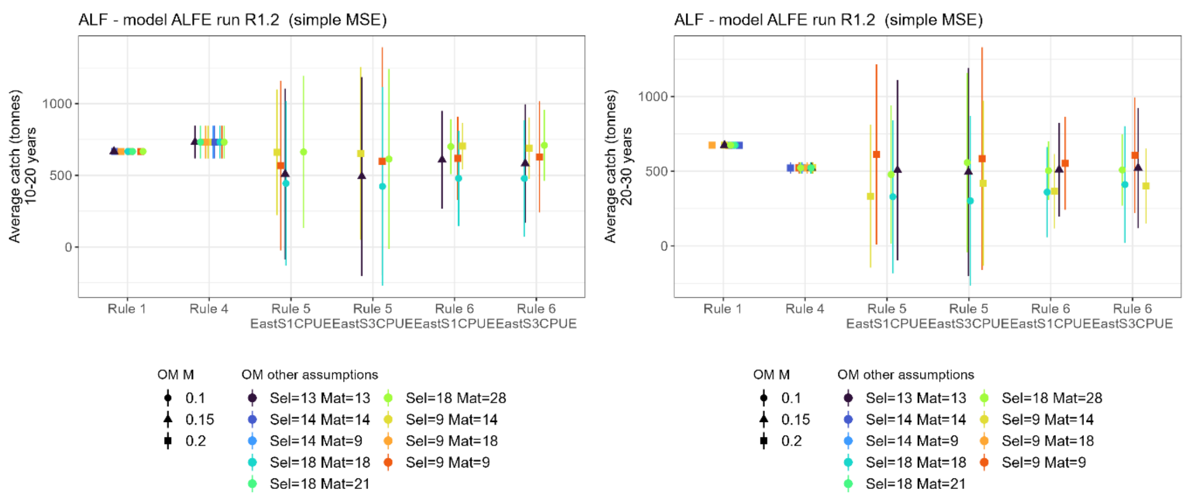

Figure H.4: Predicted total allowable catch (TAC) in tonnes in the medium (10-20 years) and long term (20-30 years for the different simulations for the east alfonsino stock model R1.2 (M = 0.2) simple MSE runs which do not re-estimate parameters. Only runs which have the same TAC plateau of 1400 t are represented.

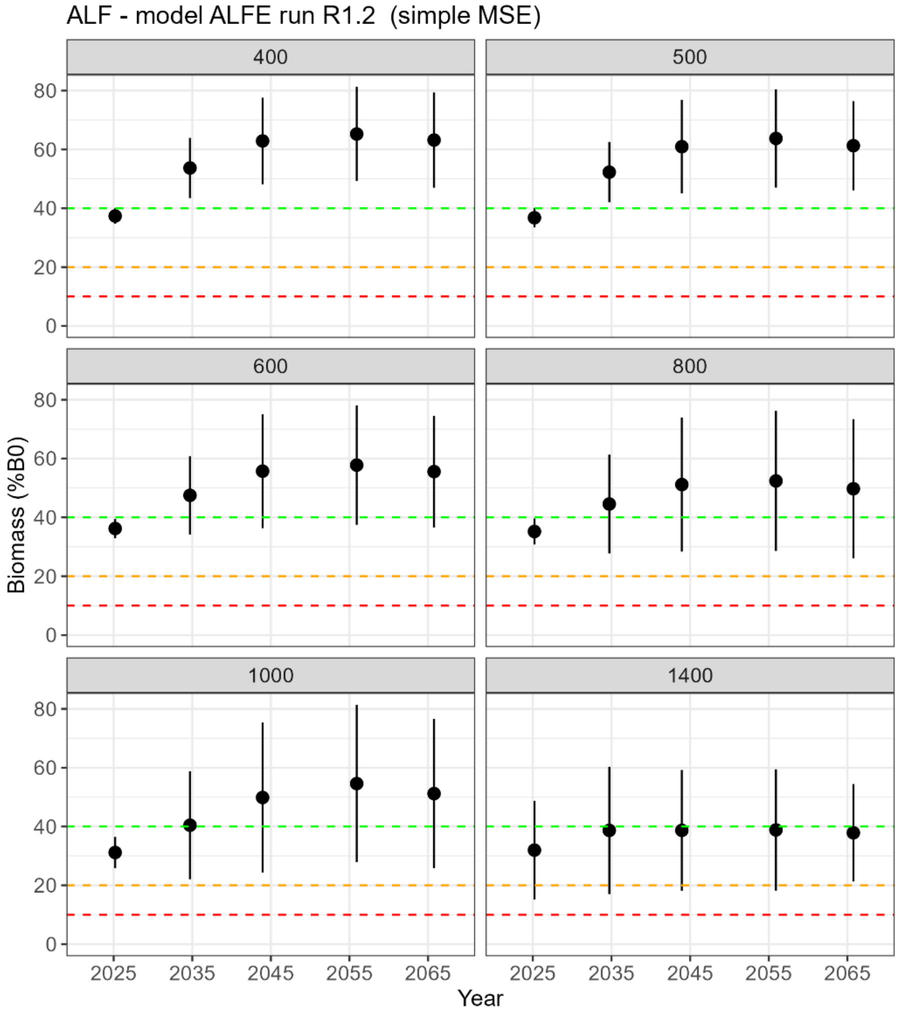

Figure H.5: Spawning stock biomass status as a percentage of initial biomass and 95% credible interval over time for simulations for the east alfonsino stock model R1.2 (M = 0.2) simple MSE runs which do not re-estimate parameters. Only R19 and R39 to R43 are represented: they all use Rule 5, CPUE series S1, and identical OM and EM, varying only the TAC on the plateau of Rule 5, showed in the facets in tonnes. 40% B_0 is plotted in green, 20% B_0 in orange, and 10% B_0 in red.

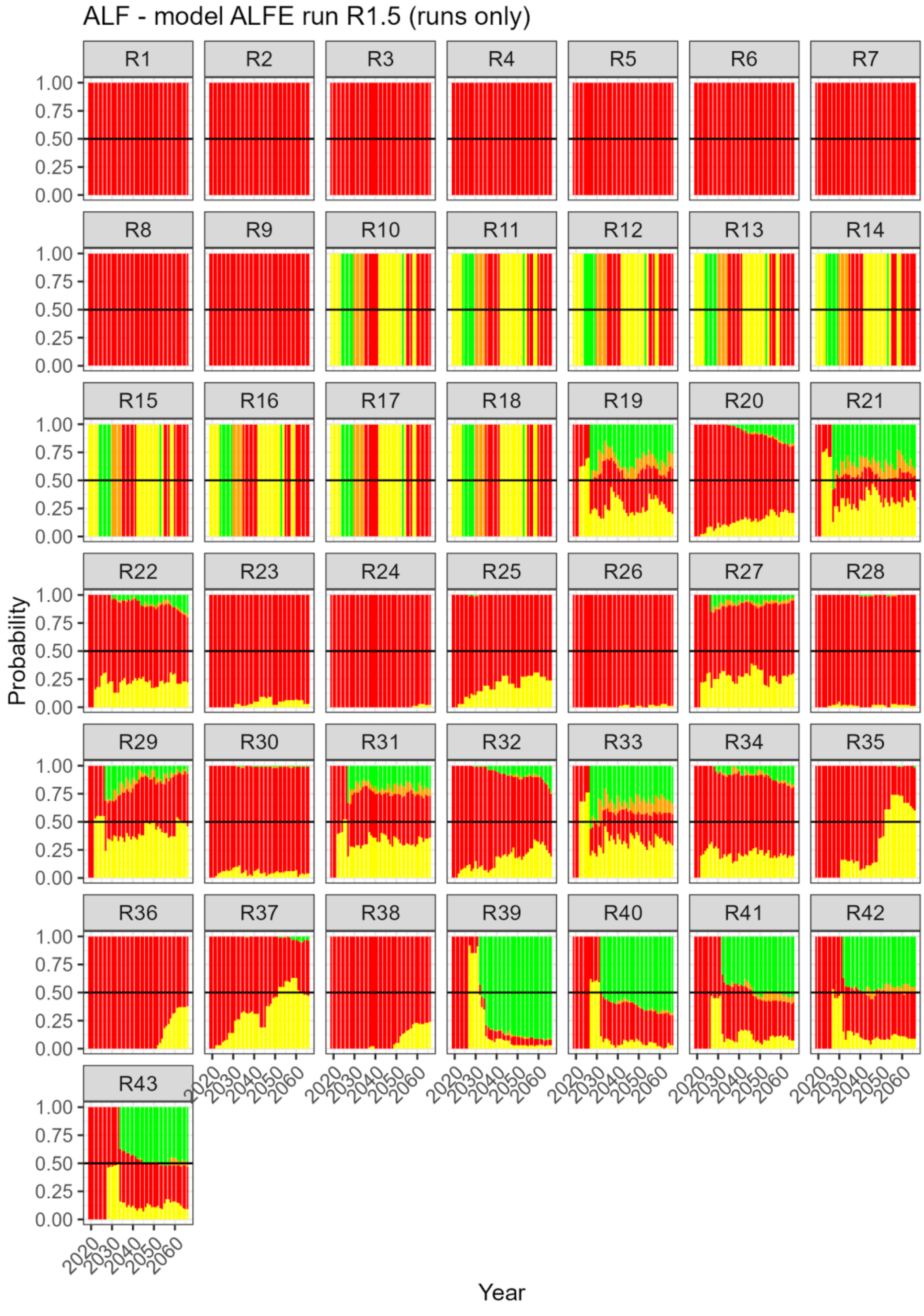

Figure H.6: Kobe time plot for the simulation scenarios for the east alfonsino stock model R1.5 (M = 0.1) simple MSE runs which do not re-estimate parameters. Only runs which have the same TAC plateau of 1400 t are represented. The proportion of the simulations in each quadrant of the Kobe matrix (see Figure E.3 for the definition of the colours) in each year of the projection period are depicted. The horizontal line represents the 50% probability.

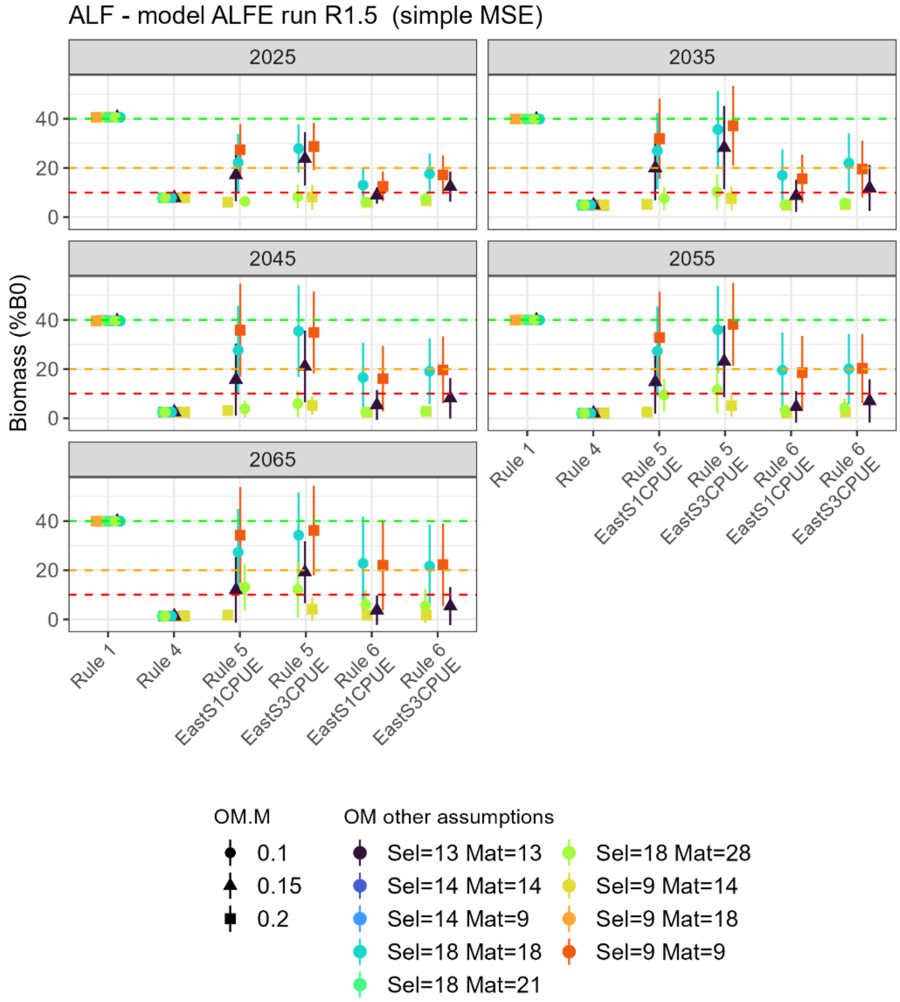

Figure H.7: Spawning stock biomass status as a percentage of initial biomass and 95% credible interval every 10 years for the different simulations for the east alfonsino stock model R1.5 (M = 0.1) simple MSE runs which do not re-estimate parameters. Only runs which have the same TAC plateau of 1400 t are represented. 40% B_0 is plotted in green, 20% B_0 in orange, and 10% B_0 in red.

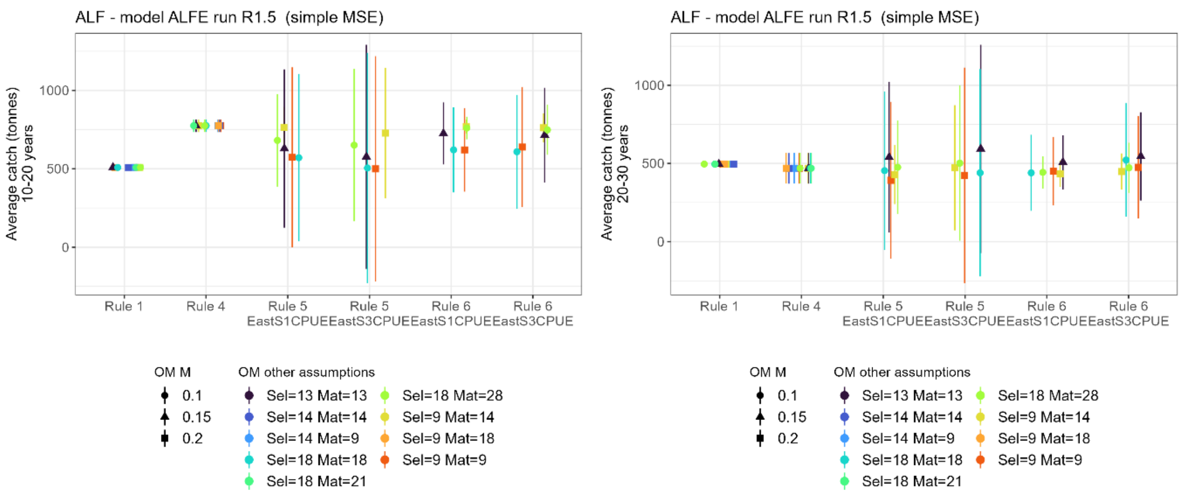

Figure H.8: Predicted total allowable catch (TAC) in tonnes in the medium (10-20 years) and long term (20-30 years for the different simulations for the east alfonsino stock model R1.5 (M = 0.1) simple MSE runs which do not re-estimate parameters. Only runs which have the same TAC plateau of 1400 t are represented.

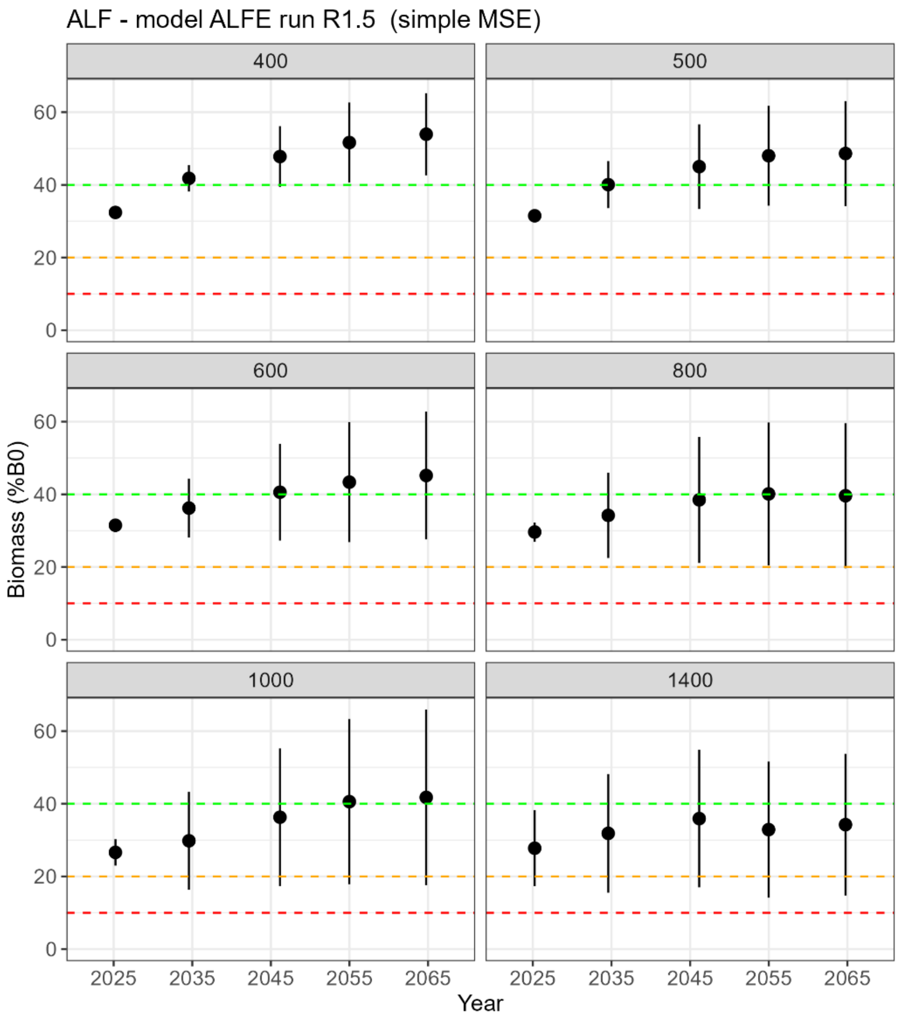

Figure H.9: Spawning stock biomass status as a percentage of initial biomass and 95% credible interval over time for simulations for the east alfonsino stock model R1.5 (M = 0.1) simple MSE runs which do not re-estimate parameters. Only R19 and R39 to R43 are represented: they all use Rule 5, CPUE series S1, and identical OM and EM, varying only the TAC on the plateau of Rule 5, showed in the facets in tonnes. 40% B_0 is plotted in green, 20% B_0 in orange, and 10% B_0 in red.

17. Appendix I – Terms of Reference for project PAM-2024-03

Project title: Development of Harvest Strategies for key SIOFA fish stocks

Project Code: PAM-2024-03

Terms of Reference

17.1 Introduction

The SIOFA Precautionary Approach and Management (SIOFA-PAM) programme will further enhance the scientific advice of the SIOFA Scientific Committee (SC) for the SIOFA Meeting of the Parties (MoP), in particular towards ensuring the sustainable management of fish stocks and the environmental impacts associated with fishing.

The SIOFA-PAM programme has three main projects that focus on development of a framework to ensure the sustainable management of fish stocks and managing the environmental impacts associated with fishing activities within the SIOFA Area. These aim to guide, inform, and enhance resource protection and to improve sustainable resource management measures, especially in the context of the information-limited fisheries. A fourth project provides for expert review and advice across the three main projects.

The specific projects of SIOFA-PAM will be to:

PAM-2024-01: Develop the SIOFA Precautionary Approach Framework. This project involves establishing a framework for high, medium, and lower information stocks to apply the precautionary approach within the SIOFA Area. This framework will provide guidelines and principles to help ensure that fisheries management decisions are made in a precautionary manner using the best scientific evidence available, consistent with the Objectives (Article 2) and General Principles (Article 4) of the SIOFA Agreement (SIOFA, 2006).

PAM-2024-02: Determine Biological Reference Points (BRPs) for key SIOFA fish stocks. This project focuses on developing and scientifically evaluating BRPs for the key fish stocks within the SIOFA Area, based on the best available scientific data and methods.

PAM-2024-03: Develop harvest strategies for key SIOFA fish stocks. Building upon previous workshops and ongoing efforts by the SC and MoP, this project aims to develop formal harvest strategies for key SIOFA fish stocks.

PAM-2024-04: Expert Review Panel for the Development of the SIOFA Precautionary Approach and Management. Provide external expert review and advice to the project teams and SIOFA for the work and outcomes of the three main projects.

17.2 Methods

This project will undertake simulation and technical scientific analyses of key SIOFA fish stocks to develop harvest strategies, including consideration of appropriate management controls, harvest control rules, and scientific data collection and analyses. These will be tested under different scenarios to assess their effectiveness and trade-offs between different management objectives.

This project will address the setting of management objectives (MoP 11 Report, Annexes N and O), BRPs, monitoring strategy, Harvest Control Rules (HCRs), Management Strategy Evaluations, and other scientific analyses or elements considered appropriate for key SIOFA fish stocks (e.g., orange roughy and toothfish). The conclusions and outcomes from this project should also be consistent with the final SIOFA Precautionary Approach Framework (PAM-2024-01).

This project will provide technical advice to the Scientific Committee and Meeting of the Parties, including the scientist-fisheries manager joint meetings and workshops, on harvest strategies for e.g. orange roughy and toothfish to support the adoption and use of harvest strategies by the Meeting of the Parties (SIOFA MoP10 Report Para 88) as per the timeline for the implementation as described in Annex K of the SC9 report.

The project will take into consideration other Regional Fisheries Management Organizations (RFMOs) approaches, as well as any SC and MoP requirements.

As a part of this project, the consultants will present preliminary methods, draft reports and results developed during the project to an Expert Panel (see Project PAM-2024-04) and a project Advisory Panel for review, as well engage in project workshops when developing the outputs. Interim and final results will be submitted and presented to SC in 2025 and 2026 respectively.

17.3 Project Objectives

1. To consider monitoring strategies and develop harvest control rules and undertake management strategy evaluations designed to help ensure sustainable fisheries within the SIOFA Area, including:
    a. Harvest control rules that are suitable for a range of different levels of available data.
    b. Management strategies that consider the trade-offs between different harvest control rules, levels of risk, and achievement of management objectives.
    c. Breakout rules and default breakout actions.
2. Evaluation of different stock assessment options, based on the level of data available, for key SIOFA fish stocks, and specifically including orange roughy and toothfish.
3. Evaluate how additional objectives such as bycatch, fisheries impacts, benthic impacts, etc., could be included as part of harvest strategies.

17.4 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 concerned CCPs.
5. SIOFA Agreement (SIOFA, 2006). https://siofa.org/sites/default/files/documents/SIOFA-Agreement-Digital-ENG.pdf

17.5 Key project indicators

1. Follow the project timeline as detailed in this agreement, including the submission of deliverables.
2. Collect any necessary data as early as possible, e.g. by submitting a data request to the SIOFA Secretariat.
3. Attend the project initialisation meeting with the project Expert Panel (composed by external experts) and Advisory Panel (composed by 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 that will assist the consultant(s) to access and interpret reports, data, and to provide advice on relevant analyses for the project.
4. Present preliminary results during the project, as required, to the project Expert Panel and 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 variation to the project.
6. Submit deliverables on time and appropriately formatted, as required. Each deliverable will be going 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 (i.e. EU), with appropriate corresponding logos in prominent positions, 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.

17.6 Deliverables

1. Attend (virtually) the project Advisory Panel meetings for Project PAM-2024-03. Additional attendance may be required at the project Advisory Group meetings for the closely related projects PAM-2024-01 and PAM-2024-02
2. Produce support materials and engage in discussions during 2 planned SIOFA Workshops (virtual) to be organized during the project timeline (tentatively Jan/Feb 2025 and Nov/Dec 2025).
3. Presentation of methods and results to the SIOFA SC annual meetings (March 2025 and 2026)
4. 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 Expert Panel, Advisory Group, 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.

5. A Final Report that follows the guidelines and format available at https://github.com/SIOFASecretariat/SIOFA_Reporting_templates and includes any final review comments from the SIOFA Scientific Committee on the final Draft Report. The Final Report will also be submitted to the 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.

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.

17.7 Acceptance of Draft and Final Reports

1. Draft and Final Reports must be submitted in English to the SIOFA Secretariat (Project Coordinator).
2. Draft and Final Reports will be reviewed by SIOFA 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 contract milestones will be subject to acceptance of the submitted reports by SIOFA.

17.8 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.

17.9 Work timeline and payment schedule

The funds for this project, budgeted under the SIOFA-PAM EU Grant (https://siofa.org/eu-grants), allow for a maximum total budget of 40 000 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	30 September 2024	First instalment payment (30% of the total contract sum)

Presentation of preliminary results	18–27 March 2025	Presentation of preliminary methods and results to the SC10 meeting (virtual)
Delivery of draft report	31 December 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.
Presentation of final results	March 2026	Presentation of final results to the SC11 meeting (virtual)
Delivery of final report	1 April 2026	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

17.10 Submission of applications

1. A current CV that summarises the applicant(s) relevant educational background and professional experience.
2. A brief proposal (indicatively 1-3 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 3.
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 8th of September 2024, Reunion Island time, will be considered.

17.11 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.

17.12 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).

17.13 CONTACTS

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

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