Determination of Biological Reference Points (BRPs) for key SIOFA fish stocks (SIOFA PAM-2024-02) Final Project Report

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Executive Summary

This document presents the development of Biological Reference Points (BRPs) for key fish stocks managed by the Southern Indian Ocean Fisheries Agreement (SIOFA), as part of the SIOFA project PAM-2024-02. The project addresses the need for science-based benchmarks to evaluate stock health and guide sustainable management in a predominantly data-limited environment.

We propose robust BRPs in alignment with related projects (PAM-2024-01 and PAM-2024-03) and incorporate advice and insights from the SIOFA Expert and Advisory Panels.

BRPs include target reference points (TRPs), limit reference points (LRPs), and trigger points, ensuring stock sustainability within biological and operational boundaries. BRPs linked to indicators based on biomass, fishing mortality, and CPUE have been evaluated.

Most SIOFA species have little information, which complicates BRP development, requiring approaches that balance scientific rigor with practical implementation needs. Interim BRPs were established for the key species, orange roughy, alfonsino, and toothfish, shaped by workshops and recommendations from SIOFA's 10th and 11th Meetings of Parties (MoP10, MoP11). Work to validate and refine these BRPs has prioritized data collection, risk assessment methods, and simulations.

Management with BRPs involves comparing them with information derived for stocks such as stock assessments, catch rate, or length data. We review stock assessment methods and the types of BRPs that may plausibly be applied to SIOFA stocks. We also review methods for developing BRPs, and the approaches used in a range of RFMOs and national jurisdictions.

A tiered framework is proposed based on data availability and assessment type that addresses zero, low, medium, and high-information stocks, incorporating international best practices and life-history data from diverse sources. It maintains consistency with other regional fisheries bodies (particularly CCAMLR for toothfish), to provide benefits through shared knowledge and coordinated management. It considers climate change, regime shifts, environmental variability, and dynamic BRP adjustments.

Assessment methods, BRP types, control parameters, and reference point values will need to vary substantially between stocks. We propose reference point approaches for each SIOFA species and stock, with multiple options that may be used as alternatives or in conjunction with one another.

The study provides a foundation for sustainable fisheries management in the SIOFA region, helping to ensure the health of fish stocks and the long-term viability of the fisheries sector.

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1. Introduction

1.1 SIOFA Management Context

The Southern Indian Ocean Fisheries Agreement (SIOFA) manages diverse deep-sea fisheries resources across a vast area. Most species under SIOFA management are characterized by limited data availability, creating unique challenges for developing robust biological reference points.

1.2 Project Objectives

This project (PAM-2024-02) aims to develop suitable Biological Reference Points (BRPs) for key SIOFA fish stocks, working in close collaboration with related projects PAM-2024-01 (policy settings and management approach) and PAM-2024-03 (harvest control rules).

The specific objectives are:

1. Provide analyses supporting the development of suitable BRPs for key SIOFA fish stocks (Appendix A of the SIOFA Fisheries Overview 2024, Table 1) and propose interim default BRPs for low, medium, and higher information stocks. Specifically, evaluate the potential use of standard biological reference points, such as $B_{40\%}$ and $B_{20\%}$, MSY, SB_{MSY}, SB_0, $SB_{F=0}$, SB/SB_{MSY}, $SB/SB_{F=0}$, SB/SB_0, F_{MSY}, F/F_{MSY} and $F_{40\%}$, as well as CPUE equivalents and any other appropriate reference points (see Table 2 for definitions).

2. Review methods for risk calculation and uncertainty quantification

3. Determine conditions for BRP revision or re-evaluation

1.3 Project Terms of Reference (see Appendix C)

ToR 1: Provide analyses that will support the development of suitable BRPs for key SIOFA fish stocks and propose interim default BRPs for low, medium, and higher information stocks:

a. The analysis should include consideration of target ranges, threshold regions, and limit reference points.

b. Provide example case studies to illustrate their implementation, including examples of different choices of BRPs for the same species or SIOFA species that are harvested in other Regional Fisheries Management Organizations (RFMOs).

ToR 2: Review methods for the calculation and interpretation of risk and the quantification of uncertainties related to them. For stocks where quantitative risk analyses are not possible, provide options on how to establish appropriate default reference points and how these may be improved to be stock specific reference points.

ToR 3: Determine the conditions for when/if the BRPs would need to be revised or reevaluated (e.g., identify changes in available information or regime shifts).

1.4 Collaboration and Integration

This project has been carried out in close collaboration with projects PAM-2024-01, which identifies the appropriate policy settings and management approach, and PAM-2024-03 which informs some of the harvest control rules and biological reference points tested (Figure 1). It also incorporates feedback from the review panel, covered under PAM-2024-04. The same modelling frameworks have been 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).

Collaboration more broadly within SIOFA was supported by three virtual meetings:
The first workshop, WS2025-PAM (3 February 2025, SIOFA Secretariat, 2025b), introduced the

consultants, outlined the terms of reference for the PAM projects, and discussed the planned methods. Participants recommended prioritizing low-information stocks, considering SAFE methodology where appropriate, and ensuring climate change robustness in harvest control rules. The workshop emphasized coordination with neighbouring organizations and requested additional workshops for stakeholder consultation before final reports to the Scientific Committee in 2026.

The second workshop, WS2025-PAM2 (6 August 2025, SIOFA Secretariat, 2025a), principally discussed the draft report for project WS2025-PAM-01. The workshop endorsed the draft Precautionary Approach Framework's three-component architecture: Information Classification System (high, medium, low and zero information tiers), Three-Zone Stock Status System, and Management Procedures as the default approach. Participants recommended focusing initially on the main SIOFA species listed in CMM 17(2024), refining zone definitions based on biological reference points, and ensuring coordinated development across all PAM projects. The workshop requested draft Terms of Reference for a third joint MoP-SC workshop.

The third workshop, WS2025-PAM3 (7 October 2025, SIOFA Secretariat, 2025c), focused on the draft report for project WS2025-PAM-02. Key outcomes included: adding common mora to target species while excluding squid; maintaining CCAMLR consistency for toothfish management; endorsing a Green/Amber/Red flag system for management advice; requesting trigger levels for low-catch species; noting CPUE unreliability for orange roughy due to hyperstability; and acknowledging ongoing alfonsino aging protocol development.

Final reports for the 3 main PAM projects were provided in draft form by 31 December 2025, with final reports delivered by 1 April 2026.

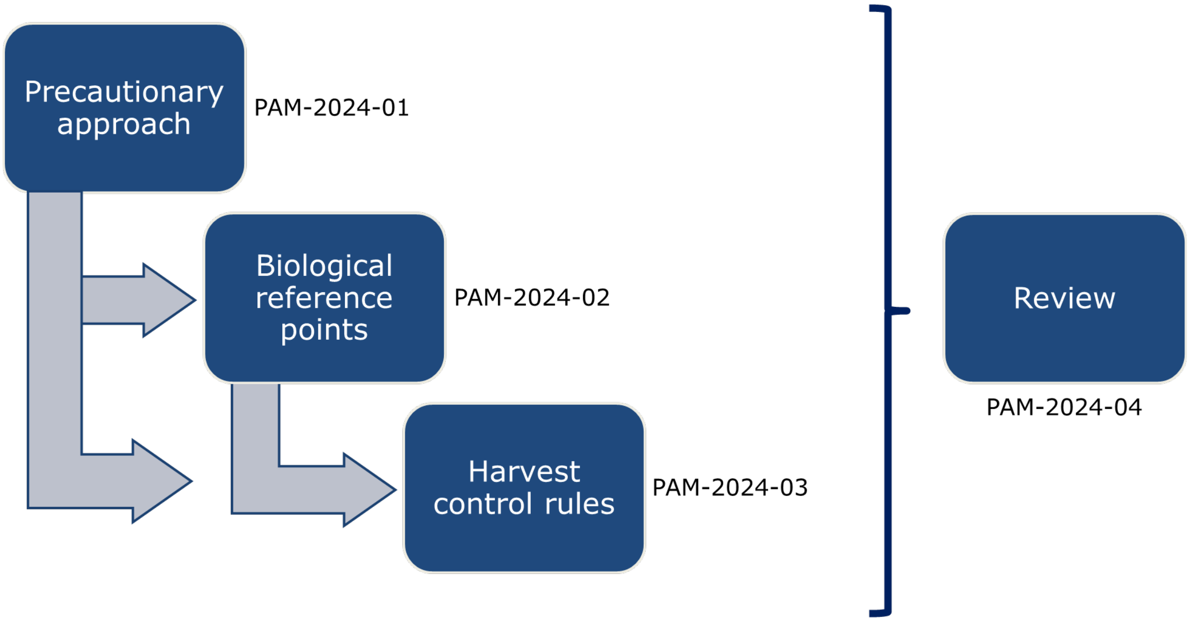

Figure 1: Schematic diagram showing relationships between PAM projects.

2. Harvest strategies and reference points

Indicators and performance measures are key components of a harvest strategy. The types of indicators, performance measures and reference points used in harvest strategies depend upon the state of knowledge of the stocks and fishery and the nature of the assessments undertaken.

Indicators are used to provide information on the state of the stock or fishery. They can be an output from a stock assessment such as biomass or fishing mortality, or an empirical indicator such as an estimate of catch per unit effort. Reference points are established at specific values of indicators that have management implications.

Performance measures are used to provide information on the predicted performance of management strategies against pre-determined management objectives. They measure outcomes of interest to managers and stakeholders, such as mean catch, variability of catch, and the probability of breaching an LRP.

2.1 BRPs (Biological reference points)

A biological reference point (BRP) is "a benchmark against which to assess the performance of management in achieving an operational objective" (FAO, 1997), and each BRP is associated with a metric or indicator. Such indicators may indicate the biomass or abundance of the stock, the fishing mortality or exploitation rate, or catch itself. The relationship between the indicator and the benchmark summarizes a stock's biological status and is used to inform fisheries managers about stock health (NZ Ministry of Fisheries, 2011).

Target Reference Points (TRPs) represent desired outcomes of fishery management, such as the optimum yield as determined through fisheries governance processes. Under the SIOFA Precautionary Approach Framework, TRPs are defined as the biomass level that management aims to maintain or achieve. Target reference points are generally based on optimizing the benefits obtained from a fishery given a maximum level of risk. The benefits considered are usually, but not necessarily, limited to yields in terms of weight. The indicator should fluctuate around its TRP.

Limit Reference Points (LRPs) set boundaries that are intended to constrain harvesting within safe biological limits (United Nations, 1995). Under the SIOFA Precautionary Approach Framework, LRPs identify the boundaries of undesirable states that should be avoided with high probability, such as the minimum biomass level below which stocks are considered to be in a biologically unsafe condition. Limit reference points are based on the biology of a species and represent a level at which the risk to the stock becomes unacceptably high (Sainsbury, 2008). The risk of the indicator breaching its LRP should be low.

Trigger Reference Points are sometimes defined in addition to TRPs and LRPs. It is useful to differentiate between BRPs, which represent objectives, and the operational control points at which management measures might change (Cox et al., 2013; Taylor et al., 2024). Trigger RPs reflect points at which a predetermined management decision is initiated (Sainsbury, 2008), but do not in themselves represent desirable or undesirable states of the stock.

The operational framework for trigger reference points in SIOFA, including tiered trigger types and management responses by information class, is set out in PAM-2024-01. From a BRP perspective, we recommend that low-catch SIOFA species lacking a formal assessment use catch-based triggers, consistent with PAM-2024-01 Table 2(a) for low- and zero-information stocks. The trigger should be set as a fixed proportion of an agreed reference catch (e.g. the mean or maximum of a recent historical period); exceedance prompts SC review of the stock’s information classification, data needs, and the potential for precautionary management measures, rather than imposing an automatic catch limit.

3. Assessment Methods

Each indicator that is used with BRPs and in harvest strategies is estimated using an assessment method. Here we review the assessment methods used to produce indicators and describe their characteristics. We consider their suitability for quantifying the associated uncertainties in a SIOFA context.

Integrated assessment models are seen as the gold standard for determining stock status. However, species with low and moderate information may be difficult to assess using standard methods. In all cases, analysts should be careful to select methods that are appropriate for the species of interest (Dowling et al., 2019).

A key aspect of any stock assessment process is full characterisation of the available data. This will be a key step in the development of BRPs, selection of assessment methods, and assessment of stocks against those BRPs.

3.1 Integrated analysis

Integrated analysis methods (Fournier and Archibald, 1982; Maunder and Punt, 2012) are the preferred approach for conducting stock assessments (Punt et al., 2020). These may use Stock Synthesis (Methot Jr and Wetzel, 2013) but equivalent analyses can be carried out using other assessment packages such as (but not limited to) Casal2 (Casal2 Development Team, 2023; Doonan et al., 2016) or developed with R-TMB (Kristensen, 2025).

Minimum data requirements are flexible because, by definition, integrated analysis incorporates multiple data types using maximum likelihood or Bayesian methods. Assessments for data-limited species should where possible be based on the same approaches as those for data-rich stocks, recognizing that the range of uncertainty will be greater (Punt et al., 2020). Many stock assessment models and estimation methods can be applied in a data-limited context as well as in data-rich cases, and this has been identified as best practice (Punt, 2023). For example, Stock Synthesis was found to perform relatively well at estimating stock status when using only catch and length frequency data (SS-CL), along with life history parameters (Rudd et al., 2021). Simple Stock Synthesis (SSS; Cope, 2013) was similarly found to perform well in comparison to many other approaches (Pons et al., 2020). SSS requires only historical catch and life history information.

The flexibility of these approaches allows them to provide various types of metrics and BRPs, but particularly depletion-based RPs based on proportions of B_0. With a reliable estimate of the stock recruitment relationship (steepness / h) they can also provide MSY-based RPs. The recommended BRPs may depend on the specific characteristics of an individual stock.

3.2 Surplus production

These approaches are best applied using Bayesian methods (Kokkalis et al., 2024). Minimum data requirements include a time series of fishery removals and an index of abundance, usually based on CPUE or survey data. Additional information such as life history parameters is useful to establish a prior distribution for the production curve. SPM models can provide MSY-based RPs or depletion-based RPs.

3.3 Empirical methods: CPUE only

In the absence of a reliable time series of catch data, time series of CPUE can be used to estimate population trends, and managers can choose to designate parts of the time series as target and/or limit reference points. Standardization of the CPUE is highly recommended (Hoyle et al., 2024). Development of CPUE indices requires a time series of catch and effort data together with appropriate metadata about fishing strategy, and preferably with the same vessels (or vessels with temporal overlap) throughout the time series. The method is not suitable for species that aggregate in a way that leads to hyperstability, or where CPUE is not proportional to abundance for other reasons (e.g., serial depletion).

Equivalent approaches can be based on other time series, such as survey-based abundance indices or population size estimates. Hence, the minimum data requirement is a time series of data that can be assumed to indicate relative stock status.

Where possible, CPUE should be examined at finer spatial scales (e.g. seamount, block, or grid cell) in addition to the stock-wide aggregate. Finer-scale CPUE trends can reveal localised depletion, progressive exploration of new fishing grounds, or contraction and dispersal of spawning aggregations — signals that may be masked in aggregate indices and that are of particular relevance for SIOFA's aggregation-forming species such as orange roughy and alfonsino. Monitoring at fine spatial scales can support earlier detection of changes in stock status than a stock-wide index alone.

3.4 Length-based methods

Length-based methods for fish stock assessment use length frequency data to estimate population parameters and stock status without requiring age information. They can estimate key parameters such as total mortality rates, growth rates, exploitation levels, and relative stock size by analysing the size structure of catches over time. They rely on the principle that fishing and natural mortality progressively deplete larger size classes, so that length composition distributions contain information about mortality patterns and population dynamics. In most cases they assume that length-data are representative of the whole stock and that effective selectivity is asymptotic, so may be unsuitable when there is spatial size partitioning or strongly size-selective fishing.

3.4.1 LB-SPR (Length-based assessment of spawning potential ratio)

Length-based SPR (Hordyk et al., 2015; Prince et al., 2015a) is one of the most commonly used methods for data-limited fisheries (Canales et al., 2021). It is generally easier and cheaper to collect length frequency than landings data, and the resulting data are often more reliable. LB-SPR estimates SPR, an indicator of stock status. It also estimates the ratio F/M, an indicator of exploitation rate, which can be used to infer F based on estimates of M.

Information requirements are a) at least one year of catch size composition, b) the life history ratio (LHR) – *M/K*, c) estimates of asymptotic size (L_∞), and d) estimates of size at maturity (L_m). Direct estimates of life history parameters may be difficult to obtain in a data-limited situation. However, estimates from meta-analyses are increasingly available (e.g., Horswill et al., 2025; Prince et al., 2023; Thorson, 2020; Thorson et al., 2017).

LB-SPR can be used in association with SPR-based BRPs or F-based BRPs.

3.4.2 LBB (Length-based Bayesian approach)

The length-based Bayesian approach (Froese et al., 2018) estimates stock status relative to MSY-based reference points using only length frequency data and basic life history parameters. It applies Bayesian inference with priors informed by life history theory to estimate relative stock biomass (B/B_{MSY}), fishing mortality (F/F_{MSY}), and related population parameters from time series of length frequency data. It works by analysing how the size structure of catches changes over time, with Bayesian priors constraining parameters like selectivity and fishing mortality to biologically plausible ranges based on relationships between growth, mortality, and body size. LBB provides probabilistic estimates of whether a stock is overfished or experiencing overfishing. Minimum data requirements include at least one year (preferably more) of representative length measurement data, along with estimates of asymptotic length, growth rate, natural mortality, and length at maturity. The life history parameters that can be obtained from literature or empirical relationships when direct estimates are unavailable.

3.4.3 LIME (Length-based Integrated Mixed Effects)

The LIME model is an extension of length-only approaches to account for time-varying recruitment and fishing mortality (Rudd and Thorson, 2018). LIME can fit to multiple data types and does not require equilibrium assumptions. This may allow the method to perform better than other length-based methods (Pons et al., 2020). LIME estimates annual values of F and SPR. Minimum data requirements include a single year of length frequency data and basic biological information, but LIME models can fit to multiple years of length data, catch, and an abundance index if available.

3.4.4 LBPA (Length-based pseudo-cohort analysis)

The Length-Based Pseudo-cohort Analysis (LBPA) model estimates parameters using multiple length frequency samples. Using more than one length frequency sample is assumed to reduce the effects of the equilibrium conditions assumed in the model (Canales et al., 2021). This method is relatively new and not yet widely used (12 citations of Canales et al., 2021 in Google Scholar). However, in simulations by the developers of the method it generally outperformed LBSPR. Data requirements are similar to LBSPR.

3.4.5 Simple length-based indicators

Where length-frequency data are available from commercial catches, simple length-based indicators (LBIs; Froese 2004; ICES WKLIFE V 2015) can serve as auxiliary stock status indicators within a traffic-light monitoring framework, providing low-cost signals of growth overfishing and size structure truncation to complement life-history-based BRPs. Key indicators include the proportions of mature fish and individuals near optimal harvest length in the catch (Pmat, Popt; Froese 2004), ratio-based indicators such as Lmean/Lopt and Lc/Lmat (ICES WKLIFE V 2015; Froese *et al.* 2018), and the mean length of the largest 5% of individuals (Lmax 5%; Probst *et al.* 2013; reference points in Miethe *et al.* 2019). These indicators do not constitute formal BRPs — they cannot directly quantify stock biomass or fishing mortality relative to MSY benchmarks — and their validity depends on catch length distributions being representative of the exploited population, a key assumption violated where fishing targets known aggregation sites, as is characteristic of orange roughy and alfonsino. ICES WKProxy further cautioned that Lopt-based reference points may be unreliable for deep-sea species with M/K ratios that deviate substantially from the assumed value of 1.5. LBIs are therefore not recommended as primary indicators for the core deep-water SIOFA species but may be more appropriately applied to tropical and elasmobranch species where gear selectivity is closer to asymptotic and length-frequency sampling is more representative of population size structure; in all cases their applicability should be evaluated on a species-by-species basis prior to adoption.

3.5 Catch only methods

Catch-only methods (COMs) are data-limited stock assessment methods that rely primarily on time series of catch or landings to estimate stock biomass status (Free et al., 2020). They can take a graphical, empirical, mechanistic, or ensemble approach. As indicated by the name, minimum data requirements are a full time series of catch or landings data.

However, simulation testing and the history of their application indicate that these approaches in general perform poorly at determining stock status, although ensembles of multiple methods generally performed better than individual methods. A major reason for their poor performance is simply the lack of information about stock status contained in the shape of a catch history alone. Use of these methods is not recommended (Free et al., 2020; Ovando et al., 2022; Punt, 2023).

3.6 PSA (Productivity−Susceptibility Analysis)

PSA is a semi-quantitative approach that evaluates species vulnerability by scoring two main dimensions: productivity (the species' ability to recover from depletion) and susceptibility (exposure to fishing pressure). Productivity factors include growth rate, age at maturity, fecundity, and natural mortality. Susceptibility factors include overlap with fishing areas, selectivity of fishing gear, and post-capture mortality. Species are plotted on a two-dimensional graph, with those in the upper right quadrant (low productivity, high susceptibility) considered highest risk.

PSA is relatively straightforward, and useful for efficient species prioritization with limited data. However, vulnerability assessments are indicative, non-quantitative, and mainly useful for comparison among species subject to the same fishery. It is also difficult to assess cumulative effects across fisheries. As a result, this method is not amenable for use with reference points (Baéz et al., 2025).

PSA methods have been applied in the SIOFA context but found to be prone to misclassifying compared to more quantitative approaches such as SAFE (Georgeson et al., 2020). PSA should therefore be used as a screening tool to prioritise species for further assessment rather than as a basis for setting BRPs; species ranked at high vulnerability should be progressed to a quantitative method before reference-point-based management is applied.

3.7 SAFE (Sustainability Assessment for Fishing Effects)

The SAFE method (Zhou and Griffiths, 2008) takes a more quantitative approach, estimating fishing impact and comparing it to sustainability reference points based on basic life-history parameters. The proportion of each species' population that is vulnerable to capture is assessed against risk-based biological reference points (BRPs) developed from empirical equations that relate life history traits to natural mortality (M) (Griffiths et al., 2019): the maximum sustainable fishing mortality (F_{MSM}), which is a proxy for F_{MSY}, F_{LIM}, the instantaneous fishing mortality rate that corresponds to the limit biomass B_{LIM}, and the lowest fishing mortality that would render a species extinct (F_{CRASH}). These F-based reference points constitute the BRPs provide by SAFE.

One drawback of the SAFE method in the SIOFA context is the requirement for species and effort distribution data at high spatial resolutions. Logbook and observer programmes should provide sufficient effort and catch information for some SIOFA species. However, the availability of fishery independent survey data represents a significant data gap for species distribution information. SAFE is also intended for use with individual fisheries, which will be problematic for species caught by multiple fisheries.

Minimum data requirements include species distribution maps or habitat models, fishing effort data that include spatial distribution and intensity, basic life history parameters (growth, reproduction, natural mortality), and information about total mortality.

3.8 EASI-Fish (Ecological Assessment of Sustainable Impacts of Fisheries)

The EASI-Fish method (Griffiths et al., 2019) was developed to estimate the cumulative impacts of fishing for data-limited bycatch species. It uses a risk-based framework with standardized protocols for data collection and analysis. The method estimates a proxy for fishing mortality (F) based on the 'volumetric overlap' of each fishery with the distribution of each species. F is then used in length-structured per-recruit models to assess population vulnerability status against proxies for conventional biological reference points such as F/F_{MSY} (Baéz et al., 2025).

EASI-Fish is better suited than SAFE for the cumulative effects of multiple fisheries. It allows for population structure via a length-based model. It also uses conventional reference points such as F_{MSY} and $B_{40\%}$. As with SAFE, the per-recruit reference points produced by EASI-Fish can be used directly as BRPs, with the added advantage that cumulative impacts across multiple fisheries are accounted for.

While EASI-Fish was designed for data-limited settings, minimum data requirements still include detailed information on life history information such as natural mortality, growth, and maturity, as well as fishery susceptibility. These parameters are often very uncertain. It also requires spatial information about overlaps between fishing effort and the stock distribution, which may be poorly known.

3.9 SEFRA (Spatial Ecological Framework for Risk Assessment)

The SEFRA method (Sharp, 2017) was developed in New Zealand to assess the population-level risk to non-target species arising from direct incidental mortality in commercial fisheries. The method is based on a detailed Bayesian model. It accounts for variation in fishing impacts due to spatial variation in both population densities and effort, combined with information about productivity based on demographic parameters. The framework considers connectivity between areas, cumulative impacts, and the effectiveness of spatial management measures like marine protected areas. Its primary output is a risk ratio. An independent review (Lonergan et al., 2017) considered it to be a high quality method and a very useful tool, although some aspects would benefit from further development. In SEFRA the reference point is the Population Sustainability Threshold (PST), a modified Potential Biological Removal derived from r_{max} and a calibration coefficient that defines the desired population recovery objective. The PST functions as a limit reference point for fishery-related mortality, and the risk ratio (estimated mortality / PST) is the indicator. SEFRA was developed primarily for protected species (seabirds, marine mammals) rather than fish stocks.

Like EASI-Fish, SEFRA deals with cumulative impacts of multiple fisheries. Minimum data requirements include detailed spatial information on fishing effort, species distributions, and habitat types to identify spatial patterns of risk. It requires fishery observer data to estimate vulnerability (the probability of interaction per encounter). It also requires life history information such as growth, natural mortality, and maturity to define population growth rate and the population sustainability threshold.

Detailed information on species distributions is unavailable for many SIOFA species, which is a limitation of all these approaches. Given its Bayesian framework, SEFRA may have the most potential for dealing with multiple sources of uncertainty in an integrated and consistent way. Nevertheless, the approach is complex. The main concern in a SIOFA context is that it may be difficult to implement.

SAFE, EASI-Fish and SEFRA are quantitative methods that deliver formal reference points directly: SAFE estimates F and compares it to F_{MSM}, F_{LIM} and F_{CRASH} derived from life history (Zhou & Griffiths 2008; Zhou et al. 2011); EASI-Fish estimates F via volumetric overlap and uses length-structured per-recruit models to evaluate conventional reference points such as F_{MSY} and SPR-based proxies (Griffiths et al. 2019); SEFRA estimates total fishery-related mortality and compares it to a Population Sustainability Threshold (PST) derived from r_{max} (MPI 2017; Sharp 2018). For these methods, the BRPs are intrinsic to the assessment and require no additional interpretation. PSA, in contrast, is a semi-quantitative screening tool that produces only relative vulnerability scores against arbitrary attribute thresholds (Hobday et al. 2011). PSA categories should not be treated as formal BRPs; rather, “high” vulnerability rankings should trigger data collection and progression to a quantitative method capable of supporting reference-point-based management.

3.10 CPUE by seabed area analogy

The CPUE by seabed area method (Agnew et al., 2009; CCAMLR Secretariat, 2021) estimates biomass in a data-limited site by using the biomass estimated in a data-rich site and assuming the same relationship between CPUE and density of fish in the data-limited site. As fishing data become available this simple ‘seabed area’ approach scales biomass by the ratio of the Catch Per Unit Effort (CPUE; e.g., the kg of fish caught per km of fishing line) in the data-rich site to that in the data-limited site, such that the biomass B in site *x* can be estimated as $B_x = C_x A_x B_r / C_r A_r$, where C represents CPUE, A seabed area, and *r* the reference site.

Minimum data requirements are very low: density estimates from one or more comparator sites, and an estimate of the habitat area of the data-limited site of interest. This method is used for toothfish in the SIOFA region.

4. Methods for developing BRPs

Many alternative reference points are available. Target reference point options are summarised in Table 3, and limit reference point options in Table 4, with detailed discussion below, including the pros and cons of each approach.

4.1 MSY-based

Stocks may be managed to target reference points that achieve maximum sustainable yield, such as B_{MSY} and F_{MSY}. These maximise the long-term catch from a fishery. LRPs may be based on a proportion of B_{MSY}, such as 0.4 B_{MSY}.

However, there are drawbacks associated with the use of MSY-based reference points. They generally require relatively long time series of data on catch and relative abundance to estimate the production function. In age-structured and size-structured models, B_{MSY} estimates are strongly influenced by the steepness and natural mortality parameters, which are very difficult to estimate reliably. They are also sensitive to estimates and/or assumptions about selectivity, which may be uncertain. MSY-based targets do not consider the increasing costs of fishing as stocks are fished down, unlike MEY-based targets (see below).

LRPs based on MSY may correspond to very low biomass levels where stock dynamics are uncertain, and they may therefore be associated with high risk to the sustainability of the population.

4.2 MEY-based

This approach is advocated by Australian harvest strategy policy (DAWR, 2018a). Managing to maximise economic returns generally results in more profitable fisheries than the associated B_{MSY} or B_{MSY} proxy target, while avoiding overexploitation. B_{MEY} is always higher than the associated B_{MSY} or B_{MSY} proxy, and it is also more complex to determine.

4.3 Ratios of current to unfished levels

A proportion of B_0 such as $B_{40\%}$ can be used as a proxy for B_{MSY}. B_0 can be estimated from age structured, size structured, or surplus production models, or using data-limited methods. B_0 may be more reliably estimated than B_{MSY}, but it may still be difficult to estimate.

$B_{40\%}$ is commonly used as a proxy for the target reference point B_{MSY}. Alternative rates can be used, usually in the range 30% to 60%, with higher levels used for less resilient species, but with levels as high as 75% for prey species within CCAMLR.

$B_{20\%}$ is a commonly used default limit reference point, based on the threshold of recruitment overfishing (Myers et al., 1994), with higher levels recommended for less productive stocks.

Sainsbury (2008) notes that there is good empirical support for 20% B_0 avoiding recruitment overfishing for productive stocks, but recommends higher defaults as best practice because (a) 20% B_0 "does not avoid recruitment overfishing for low productivity stocks, (b) it may not provide adequate protection for other fishing impacts that are likely to be slowly reversible or irreversible (e.g. genetic modification, reduced age structure with consequences to the quality of spawning, changed ecological role such as in food-web dynamics, ease of population recovery from the limit), and (c) it is less robust to uncertainty in estimation and model specification, including to changes in the climate or ecosystem (Ludwig et al., 1993).”

Sainsbury (2008) recommends using the greatest of the following 3 quantities:

- “B_{lim}, the biomass below which average recruitment declines or stock dynamics are highly uncertain.” [This is consistent with the ICES definition which uses the spawning biomass where average recruitment is not impaired (ICES, 2022). Sainsbury does not specify the amount of recruitment decline but indicates that 50% R_0 is too low. A stock recruitment relationship implies that expected recruitment will always decline with spawning biomass to some degree, so a threshold must be chosen. We suggest an average recruitment of 67% R_0, i.e., at least 2/3 of R_0.]
- “0.3 $B_{F=0}$, where $B_{F=0}$ is the biomass expected to be present at a specific time in the absence of fishing. B_0 is commonly used as an unchanging proxy for $B_{F=0}$, but this is becoming increasingly unsatisfactory because the underlying assumption of stationarity is less tenable under the emerging understanding of natural ecosystem dynamics and the system-level effects of climate change and other anthropogenic effects. Instead, a dynamic, time-varying estimate of B_0 should be used. This can be provided by model calculations based on the expected stock dynamics in the absence of a fishery, by reference to unfished sites, or a combination of both. For stocks that naturally exhibit large fluctuations in productivity, the quantity 0.3 B_0 can give very low levels of absolute biomass during periods of low productivity. In these cases, an additional limit reference point is required, which should be no lower than 0.2 of the median long-term unfished biomass”. [Use of dynamic B_0 is impractical for the low information stocks typical of SIOFA].
- “The biomass from which rebuilding to the target reference point could be achieved in a period no greater than one generation time for the species plus 10y”.

When considering an appropriate percentage of B_0, factors that may indicate higher percentages include low productivity, high longevity, depensation, ecosystem role, and lack of information.

- Less productive stocks (i.e., those with low steepness) experience recruitment overfishing at higher stock levels (Mace et al., 2002; Musick, 1999).
- Longevity and generation time affect both recovery potential and assessment uncertainty. Species that take decades to mature will require human generations to recover from low levels, and more precautionary limits may be needed to reduce the risk of this occurring.
- Allee effects (depensation) can occur at low stock levels rather than compensation (Barrett and Huynh, 2025; Liermann and Hilborn, 2001; Perälä et al., 2022). Recent developments in analysis methods suggest that they are more common in fisheries than previously believed (ICES, 2022; Perälä and Kuparinen, 2017).
- Species that serve important roles in the ecosystem may require higher levels in order to maintain those functions.
- Higher levels are also supported for little known species (Caddy and Mahon, 1995; Mace, 1994).

Consistency with CCAMLR management requires the use of 20% B_0 as an LRP for Patagonian toothfish, and 20% B_0 is commonly used in RFMOs. Most jurisdictions use a default value of 20% B_0, with higher values for less productive species.

For species where ratios are appropriate, we recommend 20% B_0 as a default LRP. We recommend 30% B_0 for species that are less productive, particularly long-lived, may experience depensation close to the 20% B_0 level, are little-known, or serve an ecosystem role that requires higher biomass.

Quantitative thresholds for these criteria are not currently defined in the literature, and to our knowledge no simulation testing has been published that establishes life-history values at which a 30% B0 LRP outperforms 20% B0. As draft thresholds for the criteria above, we propose: longevity — generation time ≥ ~30 years; depensation — any documented or strongly suspected case; little-known — Information classification “Zero” under the PAM-2024-01 framework (although this is moot because biomass indicators are not applicable to Zero information stocks). Quantitative thresholds for low productivity and ecosystem role are harder to specify objectively. Steepness, although central to resilience at low biomass, cannot be reliably estimated from typical fishery data and is usually fixed or borrowed from meta-analyses (Lee et al. 2012; Conn et al. 2010), so it should not be used as the primary productivity criterion. Ecosystem role typically requires expert judgement.

Simulation testing — building on the operating models developed under PAM-2024-03 — is recommended to refine these draft thresholds. Stock-specific recommendations are given in Table 11 and Appendix A.

4.4 Empirical

4.4.1 CPUE-based proxy B_{MSY}

In cases where the relationship between CPUE and biomass (or abundance) can be assumed proportional, it may be reasonable to use certain CPUE levels as reference points. Standardized CPUE is strongly preferred, because unstandardized CPUE is more likely to vary due to factors not associated with biomass.

CPUE-based reference points are easy to understand and communicate. They can be applied to data-limited stocks. They are based on observable quantities that do not rely on assessment model assumptions.

Note, however, that empirical indicators based on CPUE must be treated with caution since catchability (given fishing behaviour and gear efficiency) can change substantially over time. They also do not guarantee a specific level of stock biomass, which is often unknown when using this methodology.

A particular concern is hyperstability, in which CPUE remains high while biomass declines. This can occur when fish aggregate to spawn or feed, when vessels target sonar-detected aggregations, or when fishing concentrates on the most productive grounds as the stock contracts (serial depletion). SIOFA species such as orange roughy and alfonsino are particularly susceptible. CPUE-based reference points should not be used for stocks where hyperstability is suspected; in such cases, length-based, life-history-based, or risk-based reference points are preferred.

A further concern is effort creep, which occurs when gear, vessel technology, or access to information improves over time. CPUE-based reference points should make allowances for effort creep.

A historical period when both CPUE and catches were relatively high may provide a suitable CPUE level to use as a target: ‘high CPUE’ represents a single year, while $CPUE_{t1\text{-}t2}$ represents mean CPUE across a period. Similarly, with $CPUE_0$ as a proxy for B_0, x% $CPUE_0$ can be used as a TRP.

Similarly, limit reference points can be developed from periods when the stock was considered in an undesirable state but later recovered. $CPUE_{low}$ represents a single year, while the more precautionary approach is to take the average across a period ($CPUE_{t1-t2}$). Similarly, with $CPUE_0$ as a proxy for B_0, x% $CPUE_0$ can be used as an LRP.

4.5 Per recruit based

Per-recruit or "dynamic pool" reference points are estimates of the lifetime expectation of the contributions of a single recruit to various metrics such as yield, biomass (or spawning stock biomass), or egg production.

Spawning-potential-per-recruit (SPR) is the potential contribution to spawning biomass over the lifetime of a single recruit at a given constant level of F. $F_{X\%SPR}$ is the fishing mortality rate associated with an SPR of X% (Mace, 1994).

Calculation of fishing mortality reference points using SPR requires natural mortality (M), growth, maturity, and fishery selectivity. A stock-recruitment relationship, and therefore steepness, is not required.

SPR default targets of 40% and 50% have been proposed (summarised by Sainsbury, 2008), and are widely used (e.g., Jaugeon et al., 2023). However, the value of x% to use as an F_{MSY} proxy should be adapted to the species characteristics rather than using a constant percentage of SPR, because SPR_{MSY} is a declining function of stock productivity (Zhou et al., 2021; Zhou et al., 2020). In New Zealand, SPR reference points of $F_{30\%SPR}$, $F_{40\%SPR}$, $F_{45\%SPR}$, and $F_{\geq 50\%SPR}$ are recommended as targets for high, medium, low, and very low productivity species respectively (NZ Ministry of Fisheries, 2011). A similar approach is used in Canada (Barrett et al., 2024) and recommended by Sainsbury (2008). Guidelines for allocating stocks to these categories are provided in Table 5. Alternatively, Zhou et al. (2020) provide a model-based approach for predicting SPR_{MSY} and F_{MSY} from life history parameters, for situations where there is not enough information to calculate F_{MSY}. Note that the recommendations of Zhou et al. (2020) tend to be less conservative for long-lived species because they consider productivity only in terms of resilience, i.e., steepness. We have chosen to follow the conventional recommendation in Table 5.

Earlier approaches include the use of $F_{0.1}$, the fishing mortality rate at which the slope of the yield per recruit curve as a function of fishing mortality is 10% of its value at the origin. $F_{0.1}$ was once widely used as a target reference point, but in practice stocks have often declined (Sainsbury, 2008). F_{max} is the F that maximizes yield-per-recruit, but it is never less than F_{MSY} and is not a precautionary proxy. F = M uses the F equal to the natural mortality rate (M) as a proxy for F_{MSY} (Francis, 1974). However, this often overestimates F_{MSY} (Zhou et al., 2012).

$F_{20\%SPR}$ (i.e., SPR=0.2) can be used as a proxy for a state in which finfish recruitment rates are likely to be impaired (Mace and Sissenwine, 1993; Prince et al., 2015b), but this level of fishing pressure is seen as too high to act as a default LRP (Sainsbury, 2008). As noted for SPR targets, the value of x% to use as an F_{LIM} proxy should be adapted to the characteristics of the species. Mace and Sissenwine (1993) proposed $F_{30\%SPR}$ as a default LRP but indicated that it would not be conservative enough for 20% of stocks they examined. A generally applicable approach is to use 1.5 F_{TARGET} as the LRP.

4.6 Based on productivity-related parameters and constant F

Where productivity-related parameters and fishing selectivity are known and a biomass target is agreed upon, a target long term constant fishing mortality (F_{TARGET}) can be calculated that achieves a 50% probability of being at the target biomass, regardless of whether B_0 is known. This F_{TARGET} can then be applied to an existing estimate of current vulnerable biomass. The associated LRP is normally calculated as 1.5 F_{TARGET}.

This principle is included in the CCAMLR trend analysis rule, whereby if the CPUE trend is not declining, the catch limit for CCAMLR research blocks is calculated as the CPUE biomass estimate x gamma (where gamma = 0.04). The CPUE biomass estimate is derived from either a tag-based Chapman estimate or a CPUE by seabed area equivalent with other areas that have full stock assessments.

4.7 Risk-based thresholds

Risk-based reference points proposed for bycatch species include F_{LIM}, F_{MSM}, and F_{CRASH} (Zhou et al., 2020; Zhou et al., 2011). F_{MSM} can be used as a target reference point, and F_{LIM} as a limit reference point. Table 6 sets out the formulae for these reference points based on life-history parameters.

F_{MSM} is the instantaneous fishing mortality rate that corresponds to the maximum number of fish in the population that can be fished in the long term. The latter is the maximum sustainable fishing mortality (MSM) at B_{MSM} (biomass that supports MSM), similar to target species MSY.

F_{LIM} is the instantaneous fishing mortality rate that corresponds to the limit biomass B_{LIM}, where B_{LIM} is assumed to be half of the biomass that supports a maximum sustainable fishing mortality (0.5 B_{MSM}). F_{LIM} is generally calculated from F_{MSY} as $F_{LIM} = 1.5\ F_{MSY}$.

F_{CRASH} is the minimum unsustainable instantaneous fishing mortality rate that, in theory, will lead to population extinction in the long term. This is the fishing mortality corresponding to the slope at the origin of the stock-recruitment relationship (i.e. the extinction threshold). F_{CRASH} is too high to be a suitable limit reference point (Zhou et al., 2021).

Zhou et al. (2021) recommended representing biomass RPs such as B_{LIM} and B_{MSM} in terms of vulnerable biomass rather than spawning biomass, because it simplifies the assessment of data-limited stocks. They also recommended default limit RPs of 25% B_0 rather than 20%, because 25% unfished vulnerable biomass may be closer to 20% SB_0. Many stocks become vulnerable to fishing gear before maturation, and the uncertainty associated with low information stocks requires additional precaution. The corresponding F-based LRP is 1.5 F_{MSY}.

For stocks using risk-based assessment the combined LRP (cF_{LIM}) derived from multiple methods should be used as an interim LRP.

Where species interactions and ecological sustainability are essential elements in fisheries management, a relatively low fishing mortality benchmark such as F_{MSY} should be considered as an LRP, e.g., for keystone predator or prey species.

Zhou et al. (2021) recommended combining the results of multiple methods for calculating risk-based reference points, depending on data availability. Method 1 determines F_{MSY} from life history parameters, method 2 uses demographic analysis. Method 3 uses the intrinsic population growth rate from the literature.

4.7.1 Life history parameters (method 1)

This method estimates BRPs from models of the relationship between life history parameters and biological reference points. Parameters to predict F_{MSY}, F_{proxy} ($F_{0.1}$ or $F_{x\%SPR}$), and $F_{0.5r}$ for teleosts and elasmobranchs were provided by Zhou et al. (2012), who found that natural mortality was the most important life history parameter: the best predictor for F_{MSY} was 0.87 M for teleosts, and 0.41 M for elasmobranchs. Predictions of spawning biomass per recruit RPs SPR at MSY (SPR_{MSY}) were provided by Zhou et al. (2020) based on the combination of life history parameters (including combinations of maximum lifespan, age- and length-at-maturation, growth parameters, natural mortality) and taxonomic class, together with gear selectivity (e.g., see Table 5).

4.7.2 Demographic analysis (method 2)

This method uses the Euler-Lotka equation. Its application may require borrowing LHPs from other regions and making assumptions about some parameters.

4.7.3 Intrinsic population growth rate from literature (method 3)

Where available, this is a simple approach that can be applied at low cost and with little effort. The intrinsic population growth rate r is not used directly as a BRP. Rather, F-based reference points are derived from r using the relationship $F_{MSY} = 0.5r$ (denoted $F_{0.5r}$; Zhou et al. 2012) with the corresponding limit reference point $F_{LIM} = 1.5F_{MSY} = 0.75r$. Where r has been estimated from demographic analysis in published studies, these values can be used directly without repeating the Euler-Lotka calculation of Method 2, though the two approaches often yield similar results because published r estimates are frequently derived from demographic models.

4.8 Climate change

4.8.1 Alternative Approaches for Incorporating Climate Variability

The challenge of establishing biological reference points under changing environmental conditions presents SIOFA with several methodological alternatives. The existence of time variation in biological parameters is well established in fisheries science. However, methods for dealing with the resulting time variation in reference points are still under development (Bessell-Browne et al., 2025; Goethel et al., 2023). Figure 2 provides an overview of various approaches and how they relate to the management cycle.

Static Reference Points

The conventional approach maintains fixed biological reference points based on historical equilibrium assumptions. This method assumes stable long-term average productivity and uses a constant B_0 (virgin biomass) as the baseline for calculating reference points such as $B_{40\%}$ and $B_{20\%}$.

Dynamic B_0 Approach

This method acknowledges temporal variability by using $B_{F=0}$, the biomass that would have resulted under current conditions if no fishing had occurred (MacCall et al., 1985). This approach allows factors other than fishing to affect population size through time and provides a mechanism to account for changing productivity when the specific driver of the change is unknown.

Time-Varying Parameter Models

These incorporate explicit temporal variation in biological parameters including recruitment, natural mortality, growth, weight-at-age, length-weight relationships, fecundity and maturity, allowing reference points to adjust continuously with changing conditions.

Regime Shift Approaches

This framework accounts for large and persistent shift in the ecosystem state, with the system not expected to return to its original state, essentially resetting reference points following identified breakpoints in productivity (e.g., Wayte, 2013). A regime shift is considered to have occurred when there has been a large and persistent shift in the ecosystem state, with the system not expected to return to its original state (Rocha et al., 2015).

SPR-Based Approaches

Spawning Potential Ratio (SPR) reference points offer a potentially more stable alternative to biomass-based reference points. They focus on per-recruit indicators that may be less sensitive to recruitment variability while still capturing changes in growth, maturity, and natural mortality patterns. However, they also respond more slowly to population changes.

Including climate change in the harvest control rules

Harvest control rules can include climate conditioning (e.g., Duplisea et al., 2021; Mormede et al., 2025), whereby the expected effect of climate on productivity (such as future recruitment) is included as a discounting factor to the harvest control rule. 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. These rules eventually break down (or might be altogether erroneous) but potentially reduce the need for management intervention in a changing climate.

Including climate change in the breakout rules

Climate considerations can be included in breakout rules, as recommended elsewhere (e.g., Carruthers, 2024 in ICCAT). These can be included in two ways: if there is deviation between the models and the data collected (for climate reasons or any other reason), or if there is a change in the climate data which might lead to change in the productivity of the stocks managed. They should be included as an additional backstop, regardless of the approach taken.

4.8.2 Critical Issues and Trade-offs

Data Requirements and Implementation Challenges

An important constraint for SIOFA stocks is that data requirements tend to be larger for approaches that attempt to deal with climate change, given the implicit need to estimate more parameters. Time-varying parameters will be difficult to estimate for SIOFA stocks, which are largely data-limited . This limitation severely restricts the practical application of more sophisticated approaches.

Risks with Dynamic Approaches

While dynamic B_0 methods can provide benefits including less inter-annual variation in catch limits and maintenance of higher harvest rates when declines are attributed to environmental conditions, they introduce conservation concerns. Critically, allowing for environmental change may also lead to lower stock sizes, and higher exploitation rates at low stock sizes compared to static B_0, by partly attributing biomass changes to environmental factors.

An important risk is the potential 'ratcheting down effect', particularly for LRPs (Bessell-Browne et al., 2025), where dynamic B_0 can progressively reduce LRP levels, effectively lowering the conservation threshold to near zero and raising concerns about stock collapse if declines are misattributed.

Attribution Uncertainty

A challenge lies in correctly identifying causality. Incorrectly attributing changes in biological parameters to climate instead of fishing can lead to adverse outcomes. This attribution problem is compounded by uncertainty about whether a change in productivity is lasting and difficulty in predicting future productivity without understanding the underlying mechanisms.

Species-Specific Considerations

Importantly, the implications of adopting a dynamic B_0 approach differ significantly among species, meaning a one-size-fits-all solution is not appropriate (Bessell-Browne et al., 2024). Careful case-by-case evaluation is needed.

Communication and Implementation Complexity

Dynamic reference points can be challenging to implement due to the additional uncertainty they introduce (Eddy et al., 2023). More complex models can also be difficult to communicate to stakeholders, potentially impacting social license (Silvar-Viladomiu et al., 2022).

4.9 Conclusions on methods for developing BRPs

Given the data limitations characteristic of SIOFA stocks and the substantial risks associated with misattribution of productivity changes, a pragmatic tiered approach is recommended:

Static Framework with Climate Monitoring

For most SIOFA stocks, particularly data-limited species, maintain static reference points while establishing robust monitoring systems to detect productivity changes, achieved through performance indicators. This approach provides precautionary management while building the data foundation necessary for future adaptive strategies.

Secondary Considerations:
1. Productivity-Based Reference Points: Where growth and maturity data are available, productivity-based reference points (e.g., F_{TARGET}) should be considered as they may provide greater stability than biomass-based indicators under recruitment variability while remaining responsive to changes in somatic growth and natural mortality.

2. In data-limited situations, use current catch rates as reference points. CPUE-based reference points should not be used for stocks where catch rates may be hyperstable — for example, those that aggregate to spawn or feed, or where vessels target sonar-detected aggregations — as CPUE may remain high while biomass declines. For such stocks, length-based, life-history-based, or risk-based reference points should be used instead.

3. Also develop risk-based reference points (F_{LIM} = 1.5 F_{TARGET}) based on multiple methods.

4. Selective Dynamic B_0 Application: For data-rich stocks, cautiously explore dynamic B_0 approaches through Management Strategy Evaluation, ensuring that consistent methods between targets and limits are maintained to avoid the potential for ‘perverse’ behaviour when one RP is dynamic and the other static (Bessell-Browne et al., 2024).

5. Climate-Ready Management Framework: Rather than immediately implementing dynamic reference points, focus on developing "climate-ready" harvest strategies that include:

- Regular review triggers for reference point revision
- Explicit protocols for identifying regime shifts
- Precautionary buffers that account for increasing environmental uncertainty
- Enhanced data collection to support future transition to adaptive approaches

While dynamic limit and target reference points can make fisheries management more adaptive to environmental change, there are significant risks. These relate particularly to the accurate attribution of biomass changes, the potential for reduced absolute stock sizes, and the 'ratcheting down' of conservation limits. These require careful consideration and robust testing before implementation in data-limited contexts.

We suggest prioritising adaptive capacity within the current framework while maintaining precautionary management standards. This will allow SIOFA to respond to climate variability without compromising conservation objectives or accepting the substantial uncertainties inherent in dynamic approaches given current data limitations.

5. International Context and Best Practices

5.1 Regional Fisheries Body Comparison

Biological reference points vary considerably across CCAMLR[1] and comparable Regional Fisheries Management Organizations (RFMOs), reflecting different management philosophies, data availability, and species characteristics.

Note that in almost all cases, biomass-based reference points (B_0, B_{MSY}) are based on spawning biomass (SB_0, SB_{MSY}).

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[1] CCAMLR is formally a conservation body established under the Antarctic Treaty System with a mandate broader than fisheries management, but it functions as the competent authority for fisheries conservation and management in the CCAMLR Convention Area.

Required probabilities of being above the target or remaining above the limit are included below where the organisation specifies them explicitly. For most of the bodies reviewed, probability requirements are not formally attached to the reference-point definitions themselves but are introduced through harvest control rules or management strategy evaluation when the reference points are operationalised.

1. CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources)

Toothfish-specific BRPs:

- Precautionary approach aims to keep the breeding population at 50% of its initial size, out to 35 years in the future.
- TRP is 50% B_0 (spawning biomass) – 50% probability
- LRP is 20% B_0 — no more than 10% probability of falling below over 35 years (i.e. > 90% probability of being above)
- Data-limited areas use CPUE-by-seabed area analogy and Chapman mark-recapture estimation to determine current local vulnerable biomass and apply a constant F (0.04) exploitation rate rule.

2. SPRFMO (South Pacific Regional Fisheries Management Organisation)

SPRFMO manages three main fisheries: jack mackerel, flying squid, and deepwater species, including orange roughy.

- TRPs should be B_{MSY} or proxy.
- TRPs under development, stock assessments remain highly uncertain.
- B_{min} recommended for use as proxy for B_0 for jack mackerel, but not yet agreed

3. WCPFC (Western and Central Pacific Fisheries Commission)

Main target species

- Depletion-based indicators and reference points ($SB/SB_{F=0}$)
- Hierarchical approach based on data availability
- TRPs based on $SB/SB_{F=0}$, proportions vary by species
- LRPs 20% $SB_{F=0}$ for most species

Data-limited species:

- Discussions of biological LRPs for billfish and sharks ongoing, none accepted.
- A hierarchical framework has been proposed for billfish LRPs – see Brouwer and Hamer (2021).

4. ICCAT (International Commission for the Conservation of Atlantic Tunas)

MSY-based framework:

- TRPs based on B_{MSY} (0.8-1.2)
- LRPs at 0.4 B_{MSY}
- Kobe Framework visualization with phase plots and strategy matrix

Data-limited methods:

- Harvest Control Rules recommended for both depleted and healthy stocks
- Interim probabilistic reference points used with biomass dynamic models

5. IOTC (Indian Ocean Tuna Commission)

- Interim limit reference points established in 2015:
    1. TRPs of B_{MSY} and F_{MSY} for all main target species (albacore, yellowfin, swordfish, bigeye, skipjack)

2. LRPs for ALB, YFT and SWO of 0.4 B_{MSY}, 1.4 F_{MSY}
3. LRPs for BET of 0.5 B_{MSY}, 1.3 F_{MSY}
4. LRPs for SKJ of 0.4 B_{MSY}, 1.5 F_{MSY}
5. For marlin and sailfish, catch limit is based on historical mean catch, which triggers management action if exceeded over 3 consecutive years, Resolution 18/05. Indian Ocean Tuna Commission (IOTC 2018).

- Bigeye MP established in 2022
- Swordfish MP established in 2024
- Skipjack MP established in 2024 with TRP of 40% SB_0 and LRP of 20% SB_0
- No BRPs established for sharks

6. NAFO (Northwest Atlantic Fisheries Organization)

Groundfish, redfish, shrimp

Precautionary approach framework:

- TRPs: Long-term objectives to maintain SSB in 'safe zone' at or near B_{MSY}
- LRPs: B_{LIM} varies by species, often 30% B_{MSY}
- Three biomass zones – critical (below B_{LIM}), cautious (between B_{LIM} and $B_{TRIGGER}$), and healthy (above $B_{TRIGGER}$)
- Interim milestones for stocks below B_{LIM}

7. ICES

ICES has a tiered approach to reference points.

Category 1 (High information)

- TRP: F_{MSY}, B_{MSY}
- LRP: B_{PA}, B_{LIM}, F_{PA}, F_{LIM}, where B_{LIM} is the lowest observed SSB, or the lowest SSB where R was not impaired. B_{PA} includes a safety margin above B_{LIM}.

Category 2: Assessment but with uncertain BRPs.

- Proxies for MSY, PA RPs

Category 3: Survey based

- Empirical RPs relative to index averages or trends

Category 4: Catch only

- Historical catch proxies

Category 5: Qualitative only

- None

Category 6: Bycatch / minor

- None

5.2 Australian comparison

Sourced from the Commonwealth Fisheries Harvest Strategy Policy Framework (DAWR, 2018a), and the Guidelines for the Implementation of the Commonwealth Fisheries Harvest Strategy Policy (DAWR, 2018b).

The target reference point for key commercial fish stocks is the stock biomass required to produce maximum economic yield from the fishery (B_{MEY}). For multispecies fisheries, the biomass target level for individual stocks may vary in order to achieve overall maximum economic yield from the fishery. In cases where stock-specific B_{MEY} is unknown or not estimated, a proxy of 0.48 times the unfished biomass, or 1.2 times the biomass at maximum sustainable yield (B_{MSY}), should be used. Where B_{MSY} is unknown or poorly estimated, a proxy of 0.4 times the unfished biomass should be used. Alternative target proxies may be applied provided they can be demonstrated to be compliant with the policy objective. The target is to be maintained "on average" (implied 50% probability).

All stocks must be maintained above their biomass limit reference point (B_{LIM}) at least 90 per cent of the time. Where information to support selection of a stock-specific limit reference point is not available, a proxy of 20% unfished biomass should be used. In all cases, the species' role in the proper functioning of the marine ecosystem should be considered and the LRP must be no less than 20% unfished biomass.

In the case of less productive stocks (such as some sharks), more conservative biomass LRPs may be adopted, B_{30} being advocated as best practice (Sainsbury, 2008). If B_{MSY} can be reliably estimated and B_{MSY} is above B_{40}, then $0.5B_{MSY}$ may be an appropriate alternative.

An LRP above the proxy value of 20% B_0 may be prescribed for other reasons, such as where a stock is a key forage species. Where such situations arise, the reference points selected should be tested to ensure the stock is not exposed to an unacceptable risk of recruitment impairment.

The development of constant escapement strategies (for example to regularly adjust fishing mortality to maintain a constant stock size) may be considered for highly variable stocks, provided it can be demonstrated that these can deliver on the policy objectives.

Quantitative assessment of a stock may not be possible for reasons such as cost or paucity of data. In such cases, LRPs based directly on biomass may not be appropriate. The LRP for such stocks may be a specified indicator level that acts as a proxy for B_{20}, such as a specified level of catch per unit effort (CPUE). If such approaches are adopted for use in harvest strategies to manage the risk of recruitment impairment, they should be tested to ensure they meet the requirements of the Harvest Strategy Policy

5.3 New Zealand comparison

Sourced from the 'Harvest Strategy Standard for New Zealand Fisheries' (Ministry of Fisheries, 2008) and the 'Operational Guidelines For New Zealand's Harvest Strategy Standard' (NZ Ministry of Fisheries, 2011).

The Harvest Strategy Standard consists of three core elements:

- A specified target about which a fishery or stock should fluctuate;
- A soft limit that triggers a requirement for a formal, time-constrained rebuilding plan; and
- A hard limit below which fisheries should be considered for closure.

Targets should be based at minimum on MSY-compatible reference points: B_{MSY}, F_{MSY} or proxies. Targets may also allow for economic, social, cultural and ecosystem considerations, which will generally result in targets equal to the MSY-compatible reference points, or better (i.e., above B_{MSY}, below F_{MSY}).

A limit represents a point at which further reductions in stock size (or proxies) are likely to ultimately lead to an unacceptably high risk of stock collapse and/or a point at which current and future utility values are diminished or compromised. Limits (both hard and soft) should be set well above extinction thresholds. They should act as upper bounds on the zone where depensation may occur. They should be set at levels from which a stock is likely to recover in reasonable time.

The probability of biomass declining below 20% B_0 should be no greater than 10% (Francis 1992 risk criterion). The target is a level around which the stock is expected to fluctuate (≥50% probability).

5.4 Common Themes and Best Practices

Based on this comparison of approaches, several common factors emerge. All organizations reviewed are affected by data limitations. Data limitations comparable to those faced by SIOFA also affect many national jurisdictions, and the methods reviewed here draw on both RFB/RFMO and domestic-fishery experience. Most use tiered systems based on data availability. TRPs are typically set at B_{MSY} or a proxy. LRPs are typically set at 20% of B_0 or 40% of B_{MSY}. SPR-based approaches can be useful but need to be adjusted for the productivity of the species rather than using default proportions of SPR. Life history-based RPs provide useful species-specific starting points. Approaches are increasingly being developed and refined.

6. Species-Specific Biological Reference Points

6.1 Current interim BRPs

SIOFA has made considerable progress towards management based on BRPs and HCRs, having held a series of harvest strategy workshops: the Workshop on harvest strategy pre-assessment (WSHSPA-2023) in March 2023, the Joint MoP-SC Workshop on Harvest Strategy Management Objectives (WS2023-HSMO) in November 2023, and the Joint MoP-SC Workshop on the Development of Harvest Strategies (WS2024-HSS) in June 2024.

The 10th Meeting of Parties (MoP10) (SIOFA, 2023a) endorsed interim BRPs for three key species, as recommended by SC8 (SIOFA, 2023b):

- **Orange roughy**: TRP = 40% B_0, LRP = 20% B_0
- **Alfonsino**: TRP = 40% B_0, LRP = 20% B_0
- **Toothfish**: TRP = 50% B_0, LRP = 20% B_0 (consistent with CCAMLR)

For orange roughy and alfonsino, the interim TRP was set at 40% of unfished biomass (B_0), while for toothfish the interim TRP was set to 50% of unfished biomass to be consistent with CCAMLR. For both species a requirement was set for a 50% probability of being above the target. The interim LRPs for all species were set to 20% of B_0, with 90% probability of remaining above the limit.

MoP11 in July 2024 also 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.

6.2 Consideration of reference points by species

BRPs are required for low, medium, and higher information stocks, to enable evaluation of stock status against these reference points. Specific guidance is required for the primary and secondary species identified by SC in 2023 - see Appendix A of the SIOFA Fisheries Overview 2024 (SIOFA Secretariat, 2024). These species (see Table 1) are considered target species. This list includes species and species groups (billfish, tuna, yellowfin tuna) that are managed by the Indian Ocean Tuna Commission. These will not be further considered here.

Within this species list, the WS2025-PAM2 workshop (SIOFA Secretariat, 2025a) recommended giving priority to determining limit reference points (LRP) for the main SIOFA species as listed in Annex 1 of CMM 17 (2024) (see Table 6 of the CMM); the species list is reproduced in Table 7. These species were Patagonian toothfish; orange roughy; alfonsino; brushtooth lizardfish & scads; shallow-water (<200m) *Carangoides* spp., snappers, emperors and groupers; deep water (>200m) snappers, lutjanids, hapuka; oilfish; squid. Note that squid species are not included in the list of primary and secondary species and little information is available about the fishery, so it has not been addressed here. Although both lists omit mora / ribaldo (*Mora moro*), it is a target species of the longline bottom fishery in SIOFA, and it is regularly reported on by SIOFA (SIOFA Secretariat, 2025e), so it is addressed here.

To obtain the most relevant life history information available for each species, both published and unpublished, we explored information sources such as FishBase (Froese and Pauly, 2024), Google Scholar, and meta-analyses across species (Prince et al., 2023; Thorson, 2020; Thorson et al., 2017).

Information was prioritised according to criteria that include sample sizes, analytical methods, whether the data come from the same stock, and whether the data come from the same or a related species. The population dynamics of many species vary spatially, so biological parameter values derived from one region may not be appropriate for a model of the same species in a different region. Changes and improvements in analytical methods can be particularly important: e.g., alfonsino ages can differ by a factor of 2 depending on the use of sectioned vs whole otoliths, which substantially affects estimates of the Brody growth coefficient K (indicating somatic growth rate), natural mortality M, age at 50% maturity t_{mat}, maximum observed age t_{max}, and productivity.

6.2.1 Outcomes

Detailed information for each species is reported in Appendix A, including biology, SIOFA fisheries, current stock assessment status, and data availability. Life history parameters from all species are summarised in Appendix B.

The characteristics of potential BRPs have been explored in Section 2.1, based on a review of relevant literature.

A tiered framework, based on data availability and assessment type, is required for the diverse species managed by SIOFA. Generic approaches across all species are not feasible due to varying data quality and stock characteristics.

This framework (Table 8) develops TRPs and LRPs based on the best available information.

The assessment types listed in Table 8 are organised by the data and method used to derive reference points, rather than by the form of management procedure under which they would be applied. They map approximately onto the three-tier Management Procedure structure set out in PAM-2024-01: integrated and simplified integrated analyses support Tier 1 (full, model-based) management procedures; productivity-and-constant-F, CPUE index, LB-SPR and LIME approaches support Tier 2 (simplified, empirical) management procedures; and catch-only approaches support Tier 3 (qualitative, knowledge-based) management procedures. Two points warrant specific note. First, the quantitative risk-based methods (SAFE, EASI-FISH, SEFRA) deliver formal F-based or PST-based reference points directly and can in principle support Tier 2 management procedures where their outputs drive an empirical HCR, or Tier 3 where they support structured triage only. Second, CPUE-based approaches under Tier 2 require that CPUE be reasonably proportional to biomass; for aggregation-forming species (e.g. orange roughy, alfonsino) this assumption may not hold and length-based, life-history-based, or risk-based alternatives should be considered, consistent with PAM-2024-01's Tier 2 guidance.

Based on the information above and the PAM-2024-01 Conceptual Framework (consultation draft), Table 9 classifies stocks according to information availability. Information to support these classifications, and details of the available data for individual species, are provided in Appendix A and in Table 10. Based on these classifications and the types of assessment that can be applied (covered in Section 2), we propose the reference point approaches in Table 11. For some stocks, multiple reference points are proposed as alternative management options or to be used in conjunction with each other.

Appendix A summarises the above information for each species. It places them in the context of the current BRP framework, addresses BRP development considerations, and recommends BRPs.

There will be a need to update the calculation of BRPs as new information becomes available. The skillsets and expertise required to conduct this work vary between methods. Some approaches will require the ability to simulate management procedures. Others may require expertise in standardization of catch and effort data or spatial analysis of length data. A general requirement is experience in the analysis of fisheries data and an understanding of the nature of SIOFA fisheries.

Interim BRPs should be reviewed by the SC when any of the following conditions are met: (i) a new or updated stock assessment becomes available; (ii) the stock's information classification changes (either upward or downward); (iii) revised life-history parameters (e.g. natural mortality, steepness, growth) materially alter the productivity estimates underpinning the current BRPs; (iv) a regime shift or persistent environmental change is detected through monitoring indicators; or (v) at minimum every five years, regardless of new information, to confirm that the BRPs remain appropriate.

Simulations developed for the stocks of interest (orange roughy and alfonsino) in the context of PAM-2024-03 have been used as a starting point for the testing of BRPs.

Examples of the types of results generated by reference point simulation are provided in Table 12. For more details, see the report for project PAM-2024-03.

7. Conclusions and Recommendations

7.1 Key Findings

1. Tiered Approach Viability: A tiered framework based on data availability and assessment type has been proposed for the diverse species managed by SIOFA. Generic approaches across all species are not feasible due to varying data quality and stock characteristics.

2. Species-Specific Requirements: Control parameters and reference point values will need to vary substantially between stocks. Stock-specific robustness testing is needed for effective BRP implementation.

3. Data Limitations as Primary Constraint: Most SIOFA species are low or zero information, requiring approaches that balance scientific rigor with practical implementation needs.

4. International Alignment: Consistency with other management bodies (particularly CCAMLR for toothfish) provides benefits through shared knowledge and coordinated management.

5. Species-level BRPs: Recommendations of potential reference points are provided for each species and stock, with multiple options that may be used as alternatives or in conjunction with one another.

7.2 Recommendations

The following recommendations consolidate guidance distributed throughout the report. Stock-specific reference points are summarised in Table 11, and example simulation outputs in Table 12.

R1. Tiered framework. Apply BRPs through the tiered framework set out in Table 8, matching assessment type and information class to the reference point options in Tables 3 and 4.

R2. Default LRP and elevated LRP for less productive stocks. Adopt 20% B_0 as the default LRP, and 30% B_0 for stocks meeting the qualitative criteria in Section 4.3 (low productivity, longevity, depensation, ecosystem role, or little-known). As draft quantitative thresholds we propose: generation time ≥ ~30 years; any documented or strongly suspected depensation; or PAM-2024-01 information classification of "Zero". Steepness should not be used as the primary productivity criterion as it cannot be reliably estimated from fishery data despite its importance for resilience. Simulation testing is recommended to refine these draft thresholds.

R3. F-based reference points. Where productivity-related life-history parameters and selectivity are available, calculate a constant F_{TARGET} corresponding to the agreed biomass target and apply F_{LIM} = 1.5 F_{TARGET}. For data-limited and bycatch species, derive F-based reference points from life-history parameters using the risk-based methods of Zhou et al. (2011, 2020) summarised in Table 6, combining results from multiple methods where possible (cF_{LIM}).

R4. Length-based reference points. For low-information stocks with adequate length-frequency data, apply simple length-based indicators and LB-SPR where appropriate. These methods are unsuitable for deep-water aggregating species such as orange roughy and alfonsino, but may be useful for tropical and elasmobranch stocks.

R5. CPUE-based reference points. Where standardised CPUE can reasonably be assumed proportional to biomass, CPUE-based reference points (e.g. $CPUE_{t1-t2}$, x% $CPUE_0$) provide a practical option for data-limited stocks. CPUE-based reference points should not be used where hyperstability is suspected (e.g. orange roughy, alfonsino). CPUE should also be examined at finer spatial scales (e.g. seamount, block) to detect localised depletion, exploration of new grounds, or dispersal of spawning aggregations; such signals may warrant management action independent of the stock-wide assessment.

R6. BRPs from risk-based ERA methods. SAFE, EASI-FISH and SEFRA are quantitative and deliver formal F-based or PST-based reference points directly; their outputs can be used as BRPs without additional interpretation. PSA is a screening tool only and should not be used to define BRPs — species ranked at high vulnerability under PSA should be progressed to a quantitative method (e.g. SAFE) before reference-point-based management is applied.

R7. Trigger reference points for low-catch species. Apply catch-based triggers to low-catch species lacking a formal assessment, consistent with the framework in PAM-2024-01. Exceedance prompts SC review of information classification, data needs, and potential precautionary measures rather than an automatic catch limit.

R8. Stock-specific BRPs. Adopt the species-specific reference points proposed in Table 11 and detailed in Appendix A as the operational starting point for SC consideration. Multiple reference points are proposed for some stocks, to be used as alternatives or in combination.

R9. Climate change. Maintain static reference points as the primary approach, supported by indicator-based monitoring of productivity change. Reserve dynamic B_0 approaches for data-rich stocks evaluated through MSE.

R10. Conditions for revising BRPs. Review interim BRPs when (i) a new or updated assessment becomes available; (ii) the stock's information classification changes; (iii) revised life-history parameters materially alter productivity estimates; (iv) a regime shift or persistent environmental change is detected; or (v) at minimum every five years.

R11. International alignment. Maintain consistency with CCAMLR for toothfish and align with broader RFB/RFMO best practice for other species.

7.3 Final Remarks

Development of biological reference points for SIOFA species is an important step toward sustainable fisheries management in the Southern Indian Ocean. Data limitations present significant challenges, but a tiered approach provides a precautionary framework.

Continued collaboration is needed, along with sustained data collection and assessment improvement. Adaptive management will allow BRPs to evolve as knowledge increases, providing a foundation for long-term sustainability.

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10. Tables

Table 1: List of species identified by the SIOFA SC as primary and secondary species in SIOFA fisheries and considered as target species for the purposes of this overview. The PAM-01 Framework provides interim definitions: Primary species (coloured orange): species for which management tools and measures are in place and the achievement of stock management objectives is expected. Secondary species (coloured blue): all other species comprising ≥5% of total catch (3–5 year average), or ≥2% for "less resilient" species (e.g., sharks, based on ERA). ETP: species defined as endangered, threatened, or protected under national legislation, international agreements, or IUCN Red List

FAO Code	Common name	Scientific name
BYS	Splendid alfonsino	*Beryx splendens*
ORY	Orange roughy	*Hoplostethus atlanticus*
CDL	Cardinal fishes	*Epigonus spp*
OIL	Oilfish	*Ruvettus pretiosus*
HAU	Hapuka	*Polyprion spp.*
LIB	Brushtooth lizardfish	*Saurida undosquamis*
RUS	Indian scad	*Decapterus russelli*
KZJ	Threadfin bream	*Nemipterus bipunctatus*
UPM	Goldfin goatfish	*Upeneus moluccensis*
DCC	Shortfin scad	*Decapterus macrosoma*
LTQ	Sky emperor	*Lethrinus mahsena*
TOP	Toothfish	*Dissostichus eleginoides*
NGU	Yellow spotted trevally	*Carangoides fulvoguttatus*
NGY	Bludger	*Carangoides gymnostethus*
NGX	Carangoides species	*Carangoides spp*
LEC	Escolar	*Lepidocybium flavobrunneum*
SSO	Smooth oreo dory	*Pseudocyttus maculatus*
BIS	Bigeye scad	*Selar crumenophthalmus*
YBS	bigeye barracuda	*Sphyraena forsteri*
EMN	Marbled coral groper	*Plectropomus punctatus*
LUB	Emperor red snapper	*Lutjanus sebae*
LJB	Two-spot red snapper	*Lutjanus bohar*
BOE	Black oreo	*Allocyttus niger*
ORD	Oreos nei	*Oreosomatidae*
GRV	Macrourids	*Macrourus spp*
ANT	Violet cod	*Antimora rostrata*
BIL	Billfish*	*Istiophoridae*
TUN	Tuna *	*Thunnini*
YFT	Yellowfin tuna	*Thunnus albacares*

Table 2: Glossary of reference points and other terms used in this document.

Term	Definition
B	Spawning stock biomass, also SB and SSB
B_0	Initial unexploited spawning stock biomass
B_{LIM}	Spawning stock biomass at the limit reference point
B_{MIN}	The minimum biomass level observed in a fishery
B_{TARGET}	Target spawning stock biomass, defined as either B_{MSY} or a proxy such as 40% B_0
B_{MSY}	Equilibrium biomass at F_{MSY}. Usually spawning stock biomass.
$B_{x\%}$	X% of unfished biomass.
$B_{F=0}$	Biomass at any point in time that would have resulted if no fishing had occurred. Also known as dynamic B_0.
B/B_{MSY}	Biomass relative to biomass at maximum sustainable yield.
B/B_0	Biomass relative to unexploited biomass
$B/B_{F=0}$	Biomass relative to the biomass that would have been present in the absence of all fishing.
CPUE	Catch per unit of 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.
E_{TARGET}	The long-term constant harvest rate that would result in the spawning stock biomass being at B_{TARGET} on average
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 (*U*), where the annual fishing exploitation rate (*U*) is calculated using the formula U=1-exp(-F)
F_{MAX}	Fishing mortality rate that corresponds to the maximum yield per recruit
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/F_{MSY}	Fishing mortality relative to fishing mortality at MSY.
$F_{x\%}$	The long-term instantaneous fishing mortality rate that would result in the spawning stock biomass being at x% B_0 on average.
$F_{x\%SPR}$	Fishing mortality rate associated with a spawning potential ratio (SPR) of x%
F_{TARGET}	The long-term instantaneous fishing mortality rate that would result in the spawning stock biomass being at B_{TARGET} on average
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 per ratio model
LRP	Limit reference point
MSY	Maximum sustainable yield
M	Natural mortality rate
SPR	The ratio of SSB-per-recruit (φ) at a given constant long-term F and the φ without fishing (φ_0)
TAC	Total allowable catch
TRP	Target reference point
VulnB	Vulnerable biomass

Table 3: Potential target reference points

TRP	Group	Information class	Comments
X% B_{MSY}	Target & Bycatch	High	Choose the level of x based on an evaluation.
x% F_{MSY}	Target & Bycatch	High	Choose the level of x based on an evaluation.
x% B_0	Target & Bycatch	High	Choose the level of x based on an evaluation.
x% $B_{F=0}$	Target & Bycatch	High	Choose the level of x based on an evaluation.
F_{TARGET}	Target & Bycatch	High and medium	Determine F using a simulation.
F_{SPRMSY}	Target & Bycatch	Medium or low	Choose the level of x based on an evaluation
SPR x% $B_{F=0}$	Bycatch	Medium or low	Choose the level of x based on an evaluation.
x% $CPUE_0$	Target & Bycatch	High or medium	Choose the start of a reliable CPUE series and the level of x.
$B_{F=0,\ t1–t2}$	Target & Bycatch	High	Choose a time period where the stock was considered in a desirable state.
$B_{t1–t2}$	Target & Bycatch	High	Choose a time period where the stock was considered in a desirable state.
$CPUE_{t1–t2}$	Target & Bycatch	High or medium	Choose a time period where the stock was considered in a desirable state.

Table 4: Potential limit reference points (modified from Table MI-1 in WCPFC Scientific Committee 2021).

LRP	Information class	Comments
x% F_{MSY}	High	Choose the level of x based on an evaluation.
x% B_0	High	Choose the level of x based on an evaluation.
x% $B_{F=0}$	High	Choose the level of x based on an evaluation.
SPR x% $B_{F=0}$	Medium or low	Choose the level of x based on an evaluation.
x% F_{TARGET}	High or medium	Choose the level of x based on an evaluation.
x% $CPUE_0$	High or medium	Choose the start of a reliable CPUE series and the level of x.
x% $CPUE_{t1–t2}$	High or medium	Choose a time period where the stock was considered in a desirable state.
$B_{F=0,\ t1–t2}$	High	Choose a time period where the stock was considered in an undesirable state (and should be avoided in future) but recovered back to suitable levels.
$B_{t1–t2}$	High	Choose a time period where the stock was considered in an undesirable state (and should be avoided in future) but recovered back to suitable levels.
$CPUE_{t1–t2}$	High or medium	Choose a time period where the stock was considered in an undesirable state (and should be avoided in future) but recovered back to suitable levels.
$B/B_{F=0}$_ low	High	Choose a low year where the stock was considered in an undesirable state (and should be avoided in future) but recovered back to suitable levels.
B_low	High	Choose a low year where the stock was considered in an undesirable state (and should be avoided in future) but recovered back to suitable levels.
CPUE_low	High or medium	Choose a low year where the stock was considered in an undesirable state (and should be avoided in future) but recovered back to suitable levels. Note $CPUE_{t1–t2}$ is more precautionary.
F_{LIM}	Low	Use as an interim LRP until a more reliable indicator can be generated.

F_{CRASH}	Low	Use as an interim LRP until a more reliable indicator can be generated.

Table 5: Guidelines for categorising productivity levels for exploited fish species, based on FAO (2001), NZ Ministry of Fisheries (2011), and Barrett et al. (2024). M is natural mortality; r is the intrinsic rate of natural increase; K is the Brody growth coefficient; t_{mat} is the average age of maturity; t_{max} is the expected maximum age in the absence of fishing, approximated by the formula corresponding to the age at which a cohort drops to 1% of its original number; and G is the average generation time approximated by the formula given.

Parameter	Productivity			
	Very low	Low	Medium	High
M	< 0.1	< 0.2	0.2–0.5	> 0.5
r		< 0.14	0.14–0.35	> 0.35
K		< 0.15	0.15–0.33	> 0.33
t_{mat} (years)	> 15	> 8	3.3–8	< 3.3
t_{max} (years) (t_{max}=4.6/M)		> 25	14–25	< 14
G (years) (G=t_{mat}+1/M)	> 25	> 10	5–10	< 5

Table 6: Methods used to calculate LRP benchmarks for fishing mortality indicators F_{MSM}, F_{LIM} and F_{CRASH} using life history parameters (Zhou et al., 2011). ω is a coefficient linking fishing mortality to natural mortality. It was estimated as 0.87 (SD=0.05) for teleosts and 0.41 (0.09) for elasmobranchs based on a meta-analysis across multiple species comparing fishing mortality RPs to M and other LHPs (Zhou et al., 2012). Updated from Clarke and Hoyle (2014) using recommended good practices from (Maunder et al., 2023).

Method	Formula for F_{MSM}	Formula for F_{LIM}	Formula for F_{CRASH}	Parameters	Source of M formula
1	$r/2$	$0.75r$	r	r = intrinsic population growth rate	
2	ωM	$1.5\omega M$	$2\omega M$	M	An existing estimate
3	ωM	$1.5\omega M$	$2\omega M$	$M=5.4/t_m$ where t_m is the maximum observed age	Hamel and Cope (2022)
4	ωM	$1.5\omega M$	$2\omega M$	$M = 4.1181K^{0.73}L_\infty^{-0.33}$, where L_∞ and K are von Bertalanffy growth parameters.	Then et al. (2015)
5	ωM	$1.5\omega M$	$2\omega M$	$M=1.55K$, where K is the Brody growth coefficient.	Hamel and Cope (2022)
6	ωM	$1.5\omega M$	$2\omega M$	$M=1.817/GSI$ where t_{mat} is average age at maturity	Hamel (2015)
7	ωM	$1.5\omega M$	$2\omega M$	$M=3W^{0.288}$	Lorenzen (1996)

Table 7: Established fisheries in the SIOFA area in 2024. From Annex 1 of SIOFA CMM 17 (2024).

Targeted species/fisheries	Fishing gear	Participants	Area
Patagonian toothfish	Set longlines, traps	Australia, EU (Spain), France (Overseas Territories), Japan, Korea	Designated fishing footprints of Australia, EU (Spain), Japan, and France (Overseas Territories). SIOFA sub-areas 3b and 7
Orange roughy	Bottom trawl	Australia, Cook Islands, Japan, China, Mauritius	Designated fishing footprints of Australia, Cook Islands, Japan. Underwater topographic features in SIOFA sub-areas 1, 2, 3a, 3b, 4, 5 and 6.
Alfonsino	Midwater trawl	Australia, Cook Islands, Japan, Korea,	Designated fishing footprints of Australia, Cook Islands and Japan. Underwater topographic features in SIOFA sub-areas 1, 2, 3a, 3b, 4, 5 and 6.
Brushtooth lizardfish and scads	Trawl (nei), single boat otter board trawl	Thailand	Designated fishing footprint of Thailand.
Shallow-water (<200m), Carangoides spp., snappers, emperors and groupers	Set longline, hook and line (handlines), bottom trawl, traps	EU (France), Mauritius, Thailand, Comoros	Designated fishing footprint of Thailand. SIOFA sub-area 8 (mainly Saya de Malha Bank)
Deep water (>200m) snappers, lutjanids, hapuka	Set longline, dropline	Australia, China, EU (Spain)	Designated fishing footprints of the EU (Spain) and Australia. SIOFA Subareas 2, 3a, 3b and 4.
Oilfish	Pelagic longline, dropline	Chinese Taipei, Seychelles	Southwest Indian Ocean
Squid	Light Seining, Squid Jigging	China	To be confirmed as per footnote 4

Table 8: Hierarchical approach for defining BRPs based on the type of assessment applied to the stock. For RPs set to x% or y%, choose level of x or y based on an evaluation. For TRPs, default x=40%. For LRPs, default y is 20% for SSB and 25% for vulnerable biomass; default z is 150%; default w is 50%.

Assessment type	TRP	LRP	Minimum data requirements
Integrated analysis, steepness well-determined	B_{MSY}, F_{MSY}	y% B_0, z% F_{MSY}	Steepness, Growth, M, catch, CPUE
Integrated analysis, steepness not well-determined	x% B_0, F_{TARGET}	y% B_0, z% F_{TARGET}	Growth, M, catch, CPUE
Simplified integrated analysis (e.g., SS-CL, SSS, surplus production model)	x% B_0, F_{TARGET}	y% B_0, z% F_{TARGET}	Catch, size frequency or index of abundance
Productivity & constant F	F_{TARGET}	z% F_{TARGET}	Biomass
CPUE index only	mean $CPUE_{t1\text{-}t2}$	w% mean $CPUE_{t1\text{-}t2}$	CPUE, preferably standardized
LB-SPR	SPR_{TARGET}, F_{SPRMSY}	z% F_{SPRMSY}	Sizes, growth curve
LIME	F_{TARGET}	z% F_{TARGET}	Sizes, growth curve
Risk-based (e.g. SAFE. EASI-Fish, SEFRA)	F_{MSM}	z% F_{MSM}	
Catch only	$Catch_{t1\text{-}t2}$	1.5 $Catch_{t1\text{-}t2}$ & 0.5 $Catch_{t1\text{-}t2}$	Catch

Table 9: Proposed classification of the stocks under consideration, based on the draft PAM-2024-01 approach and results of the PAM-2024-03 analyses for alfonsino, using reference points proposed in Table 11. Orange roughy areas are WSR (Walters Shoal Ridge), LWSR (Long Walter's Shoal Ridge), and SWIOR (South-West Indian Ocean Ridge).

Species	Area	Information quality	Stock status	Source / data
Orange roughy	WSR	High	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	Under watch	Deterministic catch and CPUE model
Hapuka	All	Low	Unknown	Unstandardised CPUE
Mora	All	Low	Under watch	Decreasing unstandardised CPUE
Oilfish	All	Low	Under watch	Standardised & unstandardised CPUE opposing trends

Table 10: Number of length observations in the SIOFA observer database by species and year, for all species listed in Table 1. Additional species(*) were included where more than 1000 samples were collected.

FAO code	Common name	Scientific name	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
ANT	Blue antimora	*Antimora rostrata*	0	0	0	316	0	658	1162	1083	563	615	4397
BIS	Bigeye scad	*Selar crumenophthalmus*	0	0	0	0	0	19	0	1613	675	19	2326
BOE	Black oreo	*Allocyttus niger*	0	0	0	0	0	0	0	0	0	0	0
BYS	Splendid alfonsino	*Beryx splendens*	792	500	9608	39863	24013	32229	17536	14433	25024	28973	192971
CDL	Cardinal fishes nei	*Epigonus spp*	0	0	0	0	0	0	0	0	70	200	270
DCC	Shortfin scad	*Decapterus macrosoma*	0	0	0	0	0	3052	1014	6952	5455	4230	20703
EDR*	Pelagic armourhead	*Pseudopentaceros richardsoni*	56	0	338	1650	13	0	87	63	80	0	2287
EMN	Marbled coral grouper	*Plectropomus punctatus*	0	0	0	0	0	96	65	128	65	57	411
GRV	Grenadiers nei	*Macrourus spp*	0	0	0	279	27	12	517	592	298	1	1726
KZJ	Delagoa threadfin bream	*Nemipterus bipunctatus*	0	0	0	0	0	5803	8558	11892	12427	4380	43060
LEC	Escolar	*Lepidocybium flavobrunneum*	0	0	0	0	0	1	0	4159	7041	1496	12697
LIB	Brushtooth lizardfish	*Saurida undosquamis*	0	0	0	0	0	6056	5327	9720	9690	5096	35889
LJB	Two-spot red snapper	*Lutjanus bohar*	0	0	0	0	0	205	225	32	93	120	675
LTQ	Sky emperor	*Lethrinus mahsena*	0	0	0	0	0	0	0	0	0	0	0
LUB	Emperor red snapper	*Lutjanus sebae*	0	0	0	0	0	13	105	58	1	50	227
MCH*	Bigeye grenadier	*Macrourus holotrachys*	0	0	0	150	60	1183	1339	776	1073	1851	6432
NGU	Yellow spotted trevally	*Carangoides fulvoguttatus*	0	0	0	0	0	231	3306	200	751	2163	6651
NGX		*Carangoides spp*	0	0	0	0	0	1851	490	0	0	0	2341
NGY	Bludger	*Carangoides gymnostethus*	0	0	0	0	0	0	49	53	69	7	178
OIL	Oilfish	*Ruvettus pretiosus*	0	14	10	0	0	3	4	8240	16675	2678	27624
ORD	Oreos nei	*Oreosomatidae*	0	0	0	0	0	0	0	0	0	0	0
ORY	Orange roughy	*Hoplostethus atlanticus*	283	0	0	0	9727	9605	6799	42	4312	1300	32068
RFA*	Whiteleg skate	*Amblyraja taaf*	0	0	0	0	7	542	846	789	539	936	3659
RIB	Common mora / Ribaldo	*Mora moro*	51	0	0	20	8	687	701	907	668	442	3484
RUS	Indian scad	*Decapterus russelli*	0	0	0	0	0	8457	13511	19751	14582	4400	60701
SSO	Smooth oreo dory	*Pseudocyttus maculatus*	82	0	0	0	0	0	0	0	90	100	272
TOP	Patagonian toothfish	*Dissostichus eleginoides*	0	0	0	792	254	4954	5552	3291	4378	5389	24610
TUD*	African scad	*Trachurus delagoa*	0	0	0	0	0	0	0	1882	920	373	3175
TUJ*	Arabian scad	*Trachurus indicus*	0	0	0	0	0	0	0	640	280	463	1383
UPM	Goldband goatfish	*Upeneus moluccensis*	0	0	0	0	0	0	0	1619	0	0	1619
WHA	Hapuku wreckfish	*Polyprion oxygeneios*	6	0	136	10	0	24	527	281	6	7	997
HAU	Hapuka	*Polyprion spp.*	0	0	0	0	0	0	0	0	0	0	0
WRF*	Wreckfish	*Polyprion americanus*	0	0	96	0	32	111	1951	585	227	184	3186
YBS	Bigeye barracuda	*Sphyraena forsteri*	0	0	0	0	0	0	0	0	0	0	0

Table 11: 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 brackets is the required probability of being above the target or limit. B_0 = initial biomass, SSB = spawning stock biomass, VulnBcurrent = 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)	50% B_0 (p>50%)	30% B_0 (p>90%)
	Fishing mortality	F = 0.024	F = 0.036
	$VulnB_{current}$ (acoustics)	C = 0.024 $VulnB_{current}$ (p>50%)	C = 0.036 $VulnB_{current}$ (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 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. F_{TARGET} should be calculated once ageing and modelling have been updated.

Table 12: Potential F_{TARGET} for the base case Walter Shoal Ridge (WSR) orange roughy stock under various definitions 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

11. Figures

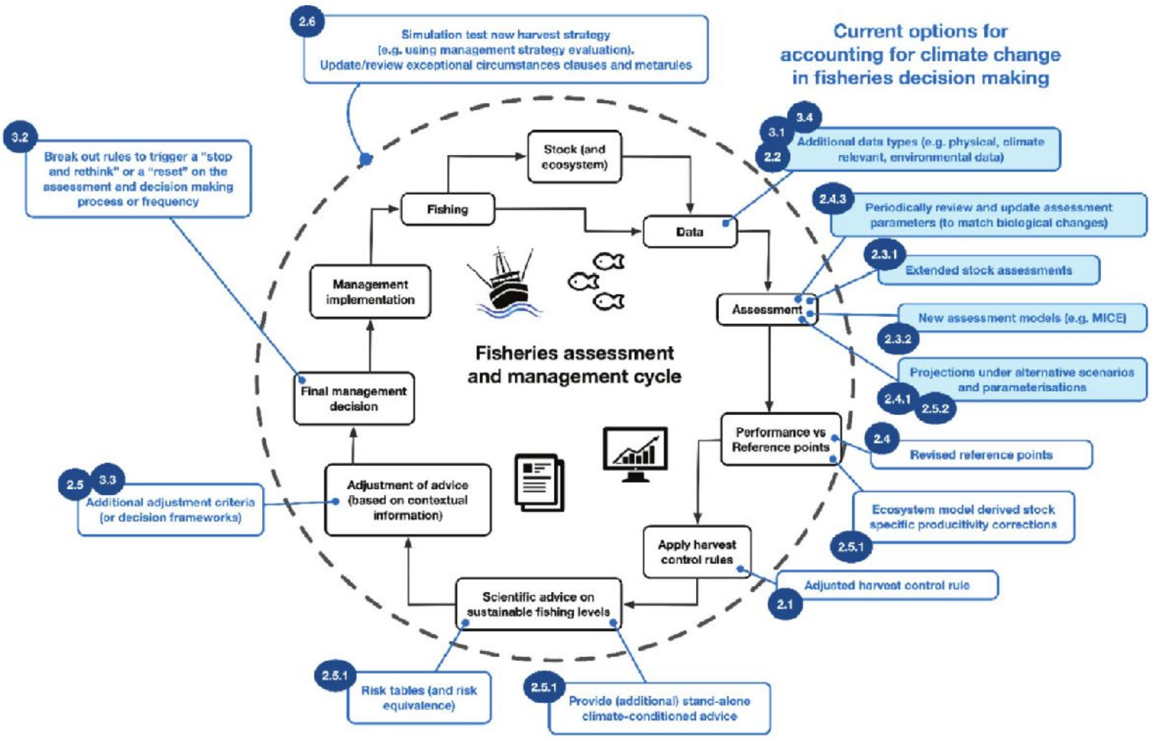

Figure 2: How approaches for incorporating climate into harvest strategies connect to the management cycle, and how climate change impacts may be incorporated. Numbers next to each option link to the section of Bessell-Browne et al. (2025) in which they are discussed. Categorized as data and assessment-related options (shaded) and other approaches (unshaded). Figure reproduced from Bessell-Browne et al. (2025), Licensed under Creative Commons Attribution License (CC BY).

12. Appendix A: Individual species

12.1 Main fisheries

12.1.1 TOP – Patagonian toothfish (Dissostichus eleginoides)

Biology: Large, long-lived notothenioid species reaching 2.3m and 50+ years age (Andrews et al., 2011), representing one of the most valuable fish species globally. Inhabits continental slopes and underwater topographic features at depths of 300-3,850m. Complex life cycle with pelagic eggs and larvae, demersal settlement at ~10cm/1 year, shallow juvenile habitat (<300m) until age 6-7, followed by ontogenetic migration to progressively deeper waters. Sexual maturity around 70-95cm length and 6-9 years age. Slow growth (K=0.04-0.08) and late maturation create high vulnerability to overfishing. Patagonian toothfish dominant species with first reported Antarctic toothfish (*D. mawsoni*) catches in 2021.

SIOFA Fisheries and management: Premium target species in demersal longline fisheries managed under CMM 01(2023) and CMM 15(2023). Small amount of trap usage. 100% observer coverage mandatory with tagging programs coordinated with CCAMLR. Two primary management areas: William's Ridge fishery and Del Cano Rise, both of which are adjacent to CCAMLR areas. TACs range 50-300 tonnes depending on area and exploratory status. Movement patterns are uncertain.

These are straddling stocks which makes it difficult to assess them independently of CCAMLR and to assign them independent reference points. It is a high priority to maintain consistency with the approaches used in CCAMLR.

SIOFA has adopted Management Objectives and Performance measures for defined toothfish management areas (MoP11 Report, Annex O).

The first objective is to maintain the stock (or a suitable proxy) at 50% B_0, or fluctuating around this level (i.e., with a 50% probability). The second is to ensure that the stock is above a limit reference point (LRP) of 20% B_0 with a 90% probability. A harvest strategy to achieve these objectives has not been defined yet. 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).

Current Stock Assessment Status: Preliminary assessment for Del Cano Rise fishery using depletion analysis and standardized CPUE trends (Sarralde et al., 2020) was highly uncertain but suggested possible stock reduction below biomass target levels.

Subsequently, an assessment of the Del Cano Rise and South Indian Ridge current stock size was developed based on CPUE by seabed area analogy, together with the CCAMLR ramp rule developed for research blocks (Selles et al., 2024). This was designed to develop an interim ad-hoc harvest control rule to be updated annually while the data needed for assessment are collected. 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.

A separate fishery characterization was completed for the Williams Ridge fishery in subarea 7 (Ziegler and Miller, 2022). Stock status was classified as uncertain pending updated assessment following improved data collection. Catches from the Williams Ridge fishery are included in stock assessments for Heard Island and McDonald Island that are presented to CCAMLR.

Data Availability:. Comparatively good data quality. Standardized CPUE for Del Cano Rise, although not considered useful due to catch-effort data quality limitations, which may be resolved in future data by protocol changes. Limited tagging data, with 26 recaptures 2019-2022. Length frequency data available from biological sampling programs.

Current BRP Framework (although B_0 and current stock size are considered unknown):

- **Interim TRP**: 50% B_0 (consistent with CCAMLR management)
- **Interim LRP**: 20% B_0
- **Probability Requirements**: 50% above target, 90% above limit
- **Sensitivity Analysis Requirements**: Evaluate 50-60-70% probability for TRP of 40-50-60% B_0

BRP Development Considerations:

- CCAMLR consistency essential for cross- jurisdictional management coordination
- Stock connectivity between SIOFA and CCAMLR areas requires coordinated reference point approaches
- Life history vulnerability requires conservative approaches
- Extensive tagging and data sharing programs, but tag returns not sufficient to inform abundance estimation.
- Predator interactions (killer whale depredation) affect fishery dynamics and BRP interpretation

Recommendations:

- Maintaining consistency with CCAMLR requires continued use of interim TRPs
- **Recommended TRP**: 50% B_0
- **Recommended LRP**: 20% B_0
- Recommended interim constant F exploitation rate: 0.04 (CCAMLR ramp rule)
- **F-based TRP and LRP**: Develop alternative F_{TARGET} and F_{LIMIT} values based on a) productivity-related parameters and b) the recommended TRP and LRP
- **Risk-based TRP and LRPs**: Based on M=0.13 or 0.155, F_{MSM} = 0.11 or 0.13, F_{LIM} = 0.17 or 0.20 (although these might not be consistent with the TRP).

12.1.2 ORY - Orange Roughy (*Hoplostethus atlanticus*)

Biology: Exceptionally long-lived deep-sea species (maximum age 200+ years) inhabiting depths of 180-1,800m. Extremely slow growth (K=0.033-0.045) and very late maturation (22-40 years) (Hoyle and Mormede, 2025). Aggregates for spawning around seamounts and steep topographic features (Branch, 2001). Limited seasonal migration between feeding and spawning areas, with little movement between management areas (Edmonds et al., 1991). Steepness is assumed to be 0.57, based on life history correlates (Wiff et al., 2018), although this estimate is very uncertain.

SIOFA Fisheries: Major target species for bottom trawl fisheries. Two primary management areas with different stock status: Walter's Shoal Ridge, Long Walter's Shoal Ridge, and South-West Indian Ocean Ridge. Annual catches average around 1000 tonnes, mostly in SIOFA areas 2 and 3b.

Data Availability: Acoustic survey data provide the main abundance information, although trends are sometimes contradictory between hill complexes. High observer coverage in recent years provides detailed biological sampling and age structure data. Standardized CPUE does not provide useful abundance information due to the aggregated nature of the stock when targeting occurs (Hoyle and Mormede, 2025).

Current Stock Assessment Status: Three sets of fully Bayesian age-based stock assessment models were developed in 2025: 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, acoustics surveys, length frequencies, and age frequencies.

For orange roughy, B/B_0 was estimated for Walter Shoal Ridge (WSR) and for Long Walter Shoal Ridge (LWSR). Results for both areas suggested that biomass was above the target and limit reference points at 40% and 20% B_0 respectively, although these estimates are highly uncertain

(Mormede and Hoyle, 2025a; Mormede and Hoyle, 2025b). The acoustics data were sparse for some hills whilst they showed a large decline in biomass for other hills, warranting caution.

These assessments also calculated F-based interim target reference points F_{40}, based on the long-term exploitation rate that achieves a 50% probability of being above 40% B_0. Results indicated that F for WSR had often been above the F-based TRP, whereas for LWSR, F had largely been below the F-based TRP. The assessments did not calculate F-based limit reference points.

The Long Walter Shoal Ridge stock represents an extended version of 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 status of the South-West Indian Ocean Ridge stock was unknown (Mormede and Hoyle, 2025b). 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.

BRP Development Considerations:
Options are limited for stocks that currently lack assessments, because it is challenging to develop empirical indicators. Orange roughy CPUE cannot be used to provide a reliable index of abundance, due to hyperstability that is difficult to resolve. Orange roughy are fished when aggregated, and vessels generally set their nets after identifying a suitable plume of fish with their sounders. Much of the search process is unrepresented in the data available for standardization, so CPUE is based on catch per haul duration. This is likely proportional to the density of the spawning aggregation rather than the density of the stock as a whole on the fishing ground (Hoyle and Mormede, 2025), and these aggregation densities are likely to be largely independent of the overall stock density.

Use of age and length data to estimate fishing mortality based on catch curves is also problematic. Fishing on spawning aggregations means that age and length data are not representative of the population, since immature fish are not available, and the proportion of fish spawning may change with age and size. Moreover, the equilibrium assumptions that are implicit in many catch curve and length-based methods tend to negatively bias mortality estimates when stocks have not reached equilibrium. This is the case for orange roughy, because generation times are substantially longer than the length of time since fishing began.

The main alternative source of information about biomass and population trends is acoustic surveys (Macaulay, 2022). However, these surveys have been episodic through time, and their spatial distribution has been limited, with most (17) in the WSR area and only a few in the North Ridge (3), North Walter's (4), Seamounts (1), and South Ridge (1) areas. They also survey only part of the aggregated spawning subset of any stock, with the proportion believed to be affected by environmental factors and the time of year.

Orange roughy steepness indicates that expected recruitment is significantly reduced to 57% R_0 at 20% B_0. Generation time of 22-40 years indicates very long recovery times if the stock goes below the LRP. Species attributes of low productivity and particularly long life indicate use of 30% B_0 as LRP. There may also be higher risk of Allee effects in a species that forms large aggregations for spawning (de Mitcheson, 2016).

Recommendation

- Adopt TRP at 50% B_0 and LRP at 30% B_0. The higher LRP is supported by orange roughy life history characteristics: low steepness (0.57), which implies recruitment is significantly reduced at 20% B_0; exceptionally long generation times (22–40 years), indicating very slow recovery if the stock falls below the LRP; and spawning aggregation behaviour, which may increase the risk of Allee effects. The TRP of 50% B_0 maintains a 20% buffer between target and limit, providing adequate management response space, and is consistent with the TRP adopted for toothfish. Both values fall within the sensitivity range endorsed by MoP11 for further evaluation.

- **Alternative TRP and LRP**: Develop F_{TARGET} and F_{LIMIT} based on productivity-related parameters and recommended TRP and LRP. Based on the WSR base case assessment (Mormede & Hoyle 2025), the corresponding F_{TARGET} at 50% B_0 with p>50% is approximately 0.024.
- **Risk-based TRP and LRPs**: Based on M=0.045, F_{MSM} = 0.039, F_{LIM} = 0.059. Note that these values are higher than the model-based F_{TARGET} and F_{LIM}, reflecting the additional constraint imposed by the biomass-based reference points at 50/30% B_0.

12.1.3 BYS - Splendid Alfonsino (*Beryx splendens*)

Biology: Schooling benthopelagic species with global distribution in temperate and tropical waters. Found at depths of 25-1,300m, but more commonly at 400-600m, generally in aggregations over rocky bottoms and underwater topographic features. Maximum length reaches 70cm. Growth is slow (K=0.068) and maturation late (~9 years) (Brouwer et al., 2021). Natural mortality is currently estimated as 0.2 (sensitivity range 0.15 to 0.25) (Brandão et al., 2020; Shotton, 2016).

However, the estimates of growth rate, age at maturation, and natural mortality are based on ageing using whole otoliths, which tend to provide considerably younger age estimates than sectioned otoliths (Andrews, 2023). Ageing with sectioned otoliths has been validated for alfonsino spp. using bomb radiocarbon (Andrews, 2023; Friess and Sedberry, 2011). Ageing of sectioned otoliths indicates that alfonsino are likely to be very long-lived (60+ years) (Andrews, 2023). Applying the methods of Hamel and Cope (2022) to t_{max} of 60 years would imply M=0.09. Growth curves based on this new information are likely to indicate slower growth and older ages at maturation and full selectivity.

SIOFA Fisheries: Primary target species in midwater trawl fisheries around seamounts and underwater features, with two management areas in the east and west. Annual catches range from 3000-5000 tonnes with significant year-to-year variability reflecting effort allocation and quota constraints. Fishing effort has decreased from 2015 peaks, with up to three vessels participating in recent years. Mainly caught in western SIOFA Area (subareas 2, 3a, 3b).

Data Availability: Age composition and growth parameters from across the SIOFA area have been established (Brouwer et al., 2021), but are based on whole otoliths. The SC is currently conducting work to develop an aging protocol for alfonsino, based on both morphometrics and sectioned otoliths, which if successful is likely to provide an alternative and larger set of age data, and lead to updated growth curves and estimates of maximum age.

Observer length frequency data from the Cook Islands fleet are available from 2004 (SIOFA Secretariat, 2025d) with over 200,000 samples. Alfonsino segregate by size with depth, with larger fish found in deeper water (Shotton, 2016), which will need to be allowed for in analyses of both size and age data. Females tend to be larger than males (Salmerón et al., 2021; Shotton, 2016).

Catch and effort data are available, and standardized CPUE time series are available from 2013-2018 (Brandão and Butterworth, 2020), although the authors caution that problems with data quality affect the utility of these data as an index of abundance (SIOFA Secretariat, 2025d). Data quality is limited by lack of pre-2013 baseline information, and by the fact that catch data are aggregated daily rather than reported haul-by-haul. In addition, alfonsino fishing mainly uses aimed bentho-pelagic trawling, in which the gear is not deployed until the skipper has located a catchable fish aggregation with the echo-sounder (Shotton, 2018; Shotton and Heaphy, 2024). Alfonsino aggregate in association with underwater topographic features such as seamounts, particularly during spawning (SIOFA Secretariat, 2025d). Standardized CPUE will therefore be hyperstable and may be only weakly related to stock abundance, because it omits the effort involved in locating aggregations.

Alternative data sources may be developed, such as search effort metrics based on time spent searching per aggregation found, distance travelled between successive sets, or proportion of features checked that have alfonsino. Potential spatial indicators include the number of discrete features / areas fished, sequential depletion patterns, or repeated fishing success on the same features. Depletion methods may be considered based on catch extracted per location. Inferences of abundance per seabed area may be considered based on stocks in other parts of the world.

There are no tagging, trawl survey, or acoustic survey data. The SIOFA Scientific Committee is considering the feasibility of using acoustic methods to survey alfonsino (SIOFA Secretariat, 2025d). There is uncertainty about the utility of acoustic surveys given uncertainty about the proportion of the stock sampled, and how estimates may be affected by alfonsino scattering in response to disturbance (Shotton and Heaphy, 2024).

Current Stock Assessment Status: An age-structured production model for alfonsino was last carried out in 2020, fitted to catch histories, standardised CPUE times series and length frequency data (Brandão et al., 2021; Brandão et al., 2020). Due to data limitations, only deterministic models were applied, and the selectivities of the different fleets were assumed to be identical. The stock status for both West and East management units was estimated at about 60% of B_0, with no current over-fishing. However, the reliance on CPUE is problematic given the likelihood that CPUE is hyperstable. Outcomes are sensitive to natural mortality, and the likely substantial changes to ageing will tend to reduce the M estimate. The associated updates to the age composition data may offset this effect on the assessment.

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.

A stock assessment for alfonsino is scheduled for 2026.

BRP Development Considerations:

- Current interim BRPs: TRP = 40% B_0, LRP = 20% B_0
- Stock assessment indicates healthy status, but methods are likely to change considerably with the 2026 assessment. Initial investigations as part of project PAM-2024-03 indicated status might be lower than previously estimated.
- CPUE indices are likely hyperstable, and biomass indicators based on acoustic methods appear difficult to develop given alfonsino behaviour.
- Methods suitable for low information stocks will be required, such as risk-based reference points based on updated life history information:
    - F_{MSY} = 0.87 M, and F_{LIM} = 1.5 F_{MSY}
    - Demographic analysis
    - Intrinsic growth rate from life history traits.
- Tiered BRP approaches will be required given uncertainty about assessment methods.

Recommendation

- Tiered BRPs: develop TRPs and LRPs based on the available information. For example:
    - If assessments are feasible: TRP = 40% B_0, LRP = 20% B_0
    - If acoustic methods can be developed: Develop F_{TARGET} and F_{LIMIT} based on productivity-related parameters and recommended TRP and LRP.

  - Risk-based TRP and LRPs: Based on M=0.2 or 0.09, F_{MSM} = 0.17 or 0.078, F_{LIM} = 0.26 or 0.12.

- Classify as low information stock.
- Detailed analyses of existing data (catch, size, age), allowing for spatial complexity and covariates such as depth effects.

12.1.4 OIL - Oilfish (Ruvettus pretiosus)

Biology: Large pelagic species complex from Gempylidae family reaching 200-300cm in length. Maximum age poorly understood with estimates around 42 years for oilfish. Maximum age of 42 implies M = 0.13. Butterworth et al. (2021) propose M = 0.11. Inhabits open ocean environments at depths of 100-800m with complex vertical migration patterns. All biological parameters have very poor reliability (rank: 0-1) with no SIOFA-specific studies. Very little known about growth and reproductive biology globally, with proposed parameters from other regions including K=0.11 yr^{-1}, L_∞=90cm, but noting significant inconsistencies with maximum sizes observed elsewhere. Extremely high wax ester content (20-25% body weight) creates significant flesh quality issues making it unsuitable for many commercial markets.

SIOFA Fisheries: Target fisheries confined to western edge of SIOFA area near African continental shelf, primarily in subareas 1 and 3b, with first reported catches in 2013 (SIOFA Secretariat, 2025f). Recent 5-year average (2018-2022) annual catch 1,353 tonnes (combined with escolar). Fishing effort and catches increased substantially from 2015, then stabilized at higher levels than other main SIOFA species. Targeted using pelagic (drifting) longlines, with small amounts from midwater trawls and gillnets. Chinese Taipei is the only CCP participating in the target oilfish fishery. Also caught as incidental catch in longline fisheries across broader SIOFA area targeting tuna and other pelagic species. Significant catches occur in cells overlapping both the SIOFA area and adjacent EEZs, requiring coordinated management.

Data Availability: Low to moderate. CPUE standardized 2017-2023 for Chinese Taipei fleet (Lu et al., 2025). Standardized CPUE increasing for oilfish in parallel with effort increases, whilst the unstandardised CPUE shows a general decrease over time (SIOFA Secretariat, 2025f). Often misidentified or aggregated with escolar in catch records. Acoustic surveys not feasible, no trawl surveys conducted, no tagging programs implemented. Length frequency data available from 2021 (~28000). Age frequency data unavailable.

Current Stock Assessment Status: No stock assessments available and no management units defined. SIOFA Scientific Committee recommended interim catch limit corresponding to 5-year average, but no further management advice agreed. No harvest strategy developed. Market demand fluctuations significantly affect targeting patterns, with 2021 catch decline attributed to reduced market demand causing vessels to switch to tuna targets.

BRP Development Considerations:

- No current BRPs established due to lack of stock assessments
- High market value volatility affects fishery behaviour
- Species aggregation with escolar in longline catches, and uncertainty about reporting quality, complicates stock-specific BRP development.
- Taiwanese data appears to distinguish oilfish from escolar – more information is needed to characterise this dataset.
- Cross-EEZ catches necessitate coordinated reference point frameworks
- Life history parameter uncertainty requires conservative precautionary approaches
- Need for ageing and ageing validation to develop biological parameters.

- Biological research needed to separate species biology and population dynamics.
- Need to better understand spatial dynamics of oilfish fishing and the factors that affect CPUE, such as aggregation, the nature of the search process, and risks of serial depletion.
- Empirical BRPs may be feasible based on standardized Taiwanese CPUE.
- SAFE methodology application may be feasible given spatial information from Taiwanese tuna longline catches.
- Butterworth et al. (2021) recommended constant catch approach until more data available

Recommendation

- TRP and LRP: Consider developing F_{TARGET} and F_{LIMIT} based on productivity-related parameters.
- TRP and LRP: Consider TRP: x% mean $CPUE_{2017\text{-}2023}$, LRP: y% $CPUE_{2017\text{-}2023}$. The appropriate levels of x and y should be determined using simulation.
- Risk-based TRP and LRPs: Based on M=0.13, F_{MSM} = 0.11, F_{LIM} = 0.17.

12.1.4.1 LEC - Escolar (Lepidocybium flavobrunneum)

Biology: Large pelagic species reaching 180cm length and 12-15 years age. Moderate productivity with estimated natural mortality M=0.4-0.6 and maturation at 3-4 years. High lipid content creates flesh quality issues similar to oilfish.

SIOFA Fisheries: Historically bycatch but increasing of commercial importance.

Data Availability: Moderate. CPUE standardized 2017-2023 for Chinese Taipei fleet (Lu et al., 2025). Standardized CPUE increasing for escolar in parallel with effort increases. Often misidentified or aggregated with oilfish in catch records. Species identification generally reliable among experienced operators. Length frequency data available from 2021 (~13000).

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation:

- Risk-based TRP and LRPs: Based on M=0.5, F_{MSM} = 0.43, F_{LIM} = 0.65.

12.1.5 Ribaldo / common mora (*Mora moro*)

Biology: A large-eyed, generally grey, species of deep-sea fish, the only species in its genus. It is distributed worldwide in temperate oceans at depths of 300-2500 m (Cohen, 1986), into the upper continental slope, and grows up to a length of about 80 cm. Average lengths recorded in the SIOFA Area are around 57 cm, for an average weight of about 5.6 kg (source: SIOFA Observer database 2004-2022). Little is known about its reproductive biology, but it may be a winter and early spring spawner in the northern Atlantic (Cohen, 1986). Max age of 39 years from Chatham Rise, New Zealand (Sutton et al., 2010). Probably feeds on fishes, crustaceans, molluscs and other invertebrates (Cohen, 1986).

SIOFA Fisheries: a target species of the bottom longline fishery in SIOFA. Primary targets in this fishery are toothfish (*Dissostichus* spp.) and hapuka (*Polyprion* spp.), mostly in Subareas 1, 2, 3a and 3. Participating CCPs are the EU (Spain) and Australia.

Data Availability: Catch and effort data are available, with catches reported since 2013. Unstandardized CPUE includes both targeted and bycatch effort and is likely to depend on the target of each operation. Standardized indices are not available. Length frequency data are available annually since 2019 (~3500 in total), as are weight data from the same fish, and a total of 1319 otoliths. No tagging data are available.

Current Stock Assessment Status: No stock assessments available and no management units defined.

BRP Development Considerations:

- No current BRPs established due to lack of stock assessments
- Life history parameter uncertainty requires conservative precautionary approaches
- Need for ageing and ageing validation to develop biological parameters but defaults can be inferred from NZ ageing.
- Need to better understand spatial dynamics of bottom longline fishing; the factors that affect sizes; and the factors that affect CPUE, such as aggregation, the nature of the search process, and risks of serial depletion. Fishery characterisation required.
- Butterworth et al. (2021) recommended constant catch approach until more data available.
- Length-based assessment (LIME / LB-SPR) may be possible using the available length data.

Recommendation

- Risk-based TRP and LRPs: Based on M=0.14, F_{MSM} = 0.12, F_{LIM} = 0.18.

12.2 Brushtooth lizardfish and scads

12.2.1 LIB - Brushtooth Lizardfish (Saurida undosquamis)

Biology: Mid-sized demersal species with high productivity – rapid growth (K=0.124-0.51) and short lifespan (6-8 years maximum), reaching 38-42 cm. Early maturation (1-2 years) and high natural mortality (M=0.35-2.63) indicate high productivity and resilience to fishing pressure. Maximum age of 8 (Chang et al., 2022) implies M=0.675 (Hamel and Cope, 2022). Biological parameters estimated from regional studies outside SIOFA area (Chang et al., 2022; Froese and Pauly, 2024; Thresher et al., 1986).

SIOFA Fisheries: Target species in coastal trawl and handline fisheries, particularly around islands and shallow banks. Annual catches …

Data Availability: Low. High productivity suggests robust population dynamics, but lack of systematic monitoring prevents abundance index development. Observer length samples available since 2019 (~5100-9700 p.a.*). No significant catch and effort data.

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- TRP and LRP: Consider developing F_{TARGET} and F_{LIMIT} based on productivity-related parameters
- Risk-based TRP and LRPs: Based on M=0.675, F_{MSM} = 0.6, F_{LIM} = 0.9.

12.2.2 DCC - Shortfin Scad (Decapterus macrosoma)

Biology: Small pelagic schooling species with presumed high productivity based on family characteristics. Maximum length ~35cm with rapid growth (K=0.50-1.60) and early maturation typical of small carangids. Forms large schools in coastal and oceanic waters.

SIOFA Fisheries: Target species in purse seine and ring net fisheries. Important baitfish for tuna longline operations. Annual catches variable and poorly documented in SIOFA databases, often aggregated with other small pelagics.

Data Availability: Low. No dedicated CPUE standardization studies identified. Schooling behaviour creates hyperstability issues complicating abundance index interpretation. Species identification generally reliable within experienced fishing operations. Length frequency data available from 2019 (~1000-7000 p.a.).

Current Stock Assessment Status: No stock assessments available and no management units defined.

12.2.3 RUS - Indian Scad (Decapterus russelli)

Biology: Small pelagic schooling species with rapid growth (K=0.58-1.42) and short lifespan (5-12 years). High productivity with early maturation (1-2 years) and high natural mortality (M=2.63) indicates strong resilience to fishing pressure when properly managed. M estimate appears high and may need review since tmax=12 implies M = 0.45 (Hamel and Cope, 2022).

SIOFA Fisheries: Major commercial target supporting large-scale purse seine and ring net fisheries. Annual Indonesian catches exceed 180,000 tonnes, though SIOFA-specific catch data limited. Important for food security and export markets.

Data Availability: Low. Despite large catch volumes, no SIOFA-specific CPUE standardization studies identified. Species identification generally reliable, but effort standardization complicated by diverse gear types and fishing strategies.

Significant length frequency data available from 2019 (~4400 to 20000 p.a.).

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- Risk-based TRP and LRPs: Based on M=0.45 or 2.63, F_{MSM} = 0.39 or 2.3, F_{LIM} = 0.59 or 3.4.

12.2.4 BIS - Bigeye Scad (Selar crumenophthalmus)

Biology: Small pelagic schooling species with high productivity. Maximum length ~38cm with rapid growth (K=0.6-0.9) and early maturation. Short lifespan typical of small carangids with high natural mortality supporting resilient population dynamics.

SIOFA Fisheries: High-value live bait fishery worth $100+ per dozen for tuna longline operations. Also targeted for human consumption in purse seine fisheries. Annual catches highly variable depending on oceanographic conditions affecting schooling patterns.

Data Availability: Low to moderate. High commercial value justifies better data collection than other small pelagics, but schooling behaviour creates significant hyperstability issues in CPUE interpretation. Short time series of catch and effort data available (since 2020). Effort standardization complicated by diverse capture methods. A small amount of length frequency data is available (~2300).

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- Risk-based TRP and LRPs: Based on K=0.75, F_{MSM} = 1.0, F_{LIM} =1.5.

12.3 Shallow-water (<200m) Carangoides spp., snappers, emperors and groupers

12.3.1 NGX - Carangoides Species (Carangoides spp.)

Biology: Species complex including 15+ species with highly variable life histories. Size ranges 25-120cm, lifespans 8-25 years, productivity varies from high (small coastal species) to moderate (large reef species). Systematic uncertainties complicate management.

SIOFA Fisheries: Mixed fishery complex with various gear types targeting different species assemblages. Commercial importance varies by area and species composition. Total annual catches estimated 100-500 tonnes but poorly documented.

Data Availability: Very Low. Taxonomic challenges prevent species-specific assessment. Most catch data reported at genus level, limiting abundance index development. Short time series of catch and effort data available (since 2019). Some length frequency data available (~2300).

Current Stock Assessment Status: No stock assessments available and no management units defined.

12.3.2 NGY - Bludger (Carangoides gymnostethus)

Biology: Medium-sized carangid reaching 90cm length and 12-18 years age. Estimated moderate productivity (M=0.22-0.32) with maturation at 3-4 years. Inhabits coastal waters and coral reefs, often in mixed schools with other carangids.

SIOFA Fisheries: Target species in coastal multispecies fisheries using various gear types. Important for local food security and small commercial operations. Catch data quality poor due to species aggregation in reporting.

Data Availability: Low. No dedicated assessment studies identified. Species identification challenges with other Carangoides species prevent meaningful abundance index development. No significant length frequency data (~180) or catch and effort data.

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- Risk-based TRP and LRPs: Based on M=0.22 or 0.32, F_{MSM} = 0.19 or 0.28, F_{LIM} = 0.29 or 0.42.

12.3.3 LJB - Two-spot Red Snapper (Lutjanus bohar)

Biology: Large long-lived snapper reaching 63cm length and 55+ years age. Low productivity with slow growth (K=0.10) and complex maturation patterns (females 9.4 years, males 1.5 years). Natural mortality M=0.08-0.12 indicates vulnerability.

SIOFA Fisheries: High-value species in reef fisheries but declining catches reflect overexploitation in many areas. Important for local food security and commercial operations. Annual catches estimated 10-50 tonnes across SIOFA region.

Data Availability: Moderate potential. High-quality Great Barrier Reef biological studies provide assessment framework, but SIOFA-specific data limited. Species identification reliable due to distinctive coloration. Small amounts of length frequency data available (~700). No significant catch and effort data.

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- Risk-based TRP and LRPs: Based on M=0.08 or 0.12, F_{MSM} = 0.07 or 0.10, F_{LIM} = 0.10 or 0.16.

12.3.4 LTQ - Sky Emperor (Lethrinus mahsena)

Biology: Large reef-associated species reaching 65cm length and 27+ years age. Moderate growth rate with late maturation typical of large lethrinids. Inhabits coral reefs and adjacent sandy areas to 100m depth. Maximum age of 27 implies M = 0.2 (Hamel and Cope, 2022)

SIOFA Fisheries: Target species in reef-based handline and spear fisheries around islands and atolls. High value species ($15-25 per kg) supporting artisanal and small commercial operations. Annual catches 10-50 tonnes across SIOFA region.

Data Availability: Low. Limited assessment data despite commercial importance. Effort standardization complicated by diverse gear types and fishing locations. Species identification generally reliable due to distinctive morphology. No significant length frequency data or catch and effort data.

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- Risk-based TRP and LRPs: Based on M=0.2, F_{MSM} = 0.17, F_{LIM} = 0.26.

12.3.5 EMN - Marbled Coral Grouper (Plectropomus punctatus)

Biology: Medium-sized grouper reaching 80-96cm length and 15-25 years age. Moderate productivity with estimated natural mortality M=0.15-0.25 and maturation at 4-6 years. Protogynous hermaphrodite vulnerable to fishing pressure on spawning aggregations. Maximum age of 25 implies M = 0.22 (Hamel and Cope, 2022)

SIOFA Fisheries: High-value target species ($20-40 per kg) in live reef fish trade and local commercial fisheries. Primary gear includes handlines and fish traps around coral reefs. Annual catches estimated 20-100 tonnes.

Data Availability: Low. No dedicated CPUE standardization studies identified for Indian Ocean populations. Species identification challenges with other Plectropomus species complicate catch reporting accuracy. Small amounts of length frequency data available (~400). No significant catch and effort data.

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- Risk-based TRP and LRPs: Based on M=0.22, F_{MSM} = 0.19, F_{LIM} = 0.28.

12.3.6 LUB - Emperor Red Snapper (Lutjanus sebae)

Biology: Large long-lived snapper reaching 62.8cm length and 34-40 years age. Low productivity with slow growth (K=0.14-0.19) and late maturation (9 years). Natural mortality estimates M=0.104-0.122 indicate vulnerability to overfishing. Maximum age of 40 years implies M = 0.135.

SIOFA Fisheries: Premium commercial target worth $25-50 per kg in export markets. Major fishery increases documented in Seychelles: from 283 tonnes (1987-2003) to 693 tonnes (2004-2006). Primary gear includes handlines and bottom longlines.

Data Availability: Low. Comprehensive Seychelles stock assessment (1977-2006) (Grandcourt et al., 2008) provides methodological framework. Species identification generally reliable. Very small amounts of length frequency data (~230). No significant catch and effort data.

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- Risk-based TRP and LRPs: Based on M=0.135, F_{MSM} = 0.12, F_{LIM} = 0.18.

12.3.7 NGU - Yellow Spotted Trevally (Carangoides fulvoguttatus)

Biology: Large carangid reaching 120cm length and 15-20 years age. Moderate productivity with estimated natural mortality M=0.20-0.30 and maturation at 3-5 years. Inhabits coral reefs and adjacent pelagic waters throughout Indo-Pacific.

SIOFA Fisheries: Target species in reef-based handline fisheries and bycatch in pelagic operations. High value species supporting artisanal and recreational fisheries around islands. Annual catches poorly documented.

Data Availability: Low. No species-specific CPUE standardization studies for Indian Ocean populations. Catch data typically aggregated at genus level with other Carangoides species. Schooling behaviour complicates abundance interpretation. Some length frequency samples available since 2019 (~6700).

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation:

- Risk-based TRP and LRPs: Based on M=0.25, F_{MSM} = 0.22, F_{LIM} = 0.33.

12.4 Deep water (>200m) snappers, lutjanids, hapuka

12.4.1 HAU, WHA, WRF - Hapuka (Polyprion spp.)

Biology: Large reef-associated species complex including hapuku wreckfish (*P. oxygeneios*) and wreckfish (*P. americanus*). Hapuku wreckfish can reach at least 52 (Wakefield et al., 2010), and wreckfish at least 80 years of age (Lytton et al., 2016). Maximum ages of 52 and 80 imply M estimates for WHA and WRF of 0.104 and 0.068 respectively. Can reach 180 cm in length and 100 kg. Slow growth (K=0.06-0.10, reliability 4) and late maturation (10-13 years, reliability 3) indicate high vulnerability to fishing pressure. Complex life cycle with juveniles pelagic for 1-2 years before settling to deep reefs and seamounts at 100-800m depth. Movement studies show potential for significant migrations between fishing areas, complicating stock structure assessment.

SIOFA Fisheries: Caught primarily in western SIOFA area (subareas 2, 3a, 3b) using bottom longlines targeting seamounts and deep reefs. Recent 5-year average (2018-2022) annual catch 82 tonnes across all Polyprion species. Catches significantly increased in 2020 with corresponding effort increases, but both subsequently decreased substantially. Wreckfish (*P. americanus*) is the most commonly caught species in recent years. No directed fisheries, primarily taken as bycatch in mixed demersal fisheries, though high commercial value ($20+ per kg) creates potential for targeted effort.

Data Availability: Low to moderate. CPUE data cannot be considered reliable abundance index due to the inclusion of all operations catching hapuka including bycatch. CPUE is not standardized. High-quality Australian and New Zealand assessment data available for regional biological parameters, but there is limited SIOFA-specific information. Species identification is generally reliable due to distinctive morphology, but aggregation at genus level in catch reporting prevents species-specific analysis. Observer coverage provides biological data for improved parameter estimation. Some length frequency data are available for WHA (~1100) and WRF (~3200).

Current Stock Assessment Status: No stock assessments available. No harvest strategy developed. SIOFA Scientific Committee recommended interim catch limit corresponding to 5-year average annual catch, but no further management advice agreed. Species identification challenges between hapuku wreckfish and wreckfish complicate species-specific management approaches.

BRP Development Considerations:

- No current BRPs established - requires initial development using regional parameter borrowing. Sources from Australia/New Zealand provide baseline.
- Vulnerable life history suggests conservative BRP levels.
- Species complex requires either group-level BRPs or species-specific approaches with improved identification.
- High commercial value justifies enhanced data collection to refine BRPs.

- Stock structure research required to define appropriate management units.
- Association with seamount habitats requires consideration of localized depletion patterns in assessment and BRP design.
- SIOFA SC recommends maintaining catches at present levels (5-year average 2018-2022).

Recommendation

- Risk-based TRP and LRPs: Based on M=0.10 and 0.068, F_{MSM} = 0.09 and 0.058, F_{LIM} = 0.14 and 0.088.

12.4.2 CDL - Cardinal Fishes (Epigonus spp.)

Biology: Deep-water complex of 4-6 species (*E. lenimen*, *E. telescopus*, others) inhabiting 200-2,000m depths across the SIOFA area. Life spans vary dramatically among species with black cardinal fish (*E. telescopus*) exceeding 100 years, while smaller species live 15-25 years. Natural mortality estimates range 0.15-0.25 yr^{-1} (reliability rank: 3), growth parameters K=0.10-0.15 yr^{-1} (rank: 2), asymptotic length 20-30cm (rank: 2). Maturation occurs at 5-8 years, representing moderate productivity relative to other deep-sea species. Species identification challenges significantly complicate biological understanding.

SIOFA Fisheries: Currently taken as bycatch in bottom trawl and longline fisheries targeting orange roughy and toothfish across SIOFA subareas. No directed fisheries exist, but there is increasing commercial interest as traditional target species become restricted. Catch volumes poorly documented due to aggregation in "mixed finfish" categories. Annual catches estimated 100-500 tonnes but data quality uncertain.

Data Availability: Low. No species-specific CPUE standardization studies available. Scientific observer biological data collection sporadic (2012-2022) with limited sampling. Major data gaps include species-specific catch recording, effort allocation, and validated life history parameters. No significant length frequency data available (~270).

Current Stock Assessment Status: No stock assessments available and no management units defined.

BRP Development Considerations:

- Requires group-level approach due to species identification challenges
- Interim F/F_{LIM} >1 recommended as LRP until enhanced identification protocols developed
- Precautionary approach warranted: Target reference points should incorporate high uncertainty buffers
- Enhanced species identification protocols essential for future stock-specific BRPs

Recommendation:

- None at this stage.

12.5 Other species

12.5.1 KZJ - Threadfin Bream (Nemipterus bipunctatus)

Biology: Small demersal species inhabiting coastal waters to 100m depth. Limited biological information available - estimated maximum length ~30cm with presumed moderate productivity based on family characteristics. Feeds primarily on benthic invertebrates.

SIOFA Fisheries: Target species in small-scale coastal fisheries using bottom trawls, handlines, and fish traps. Important for local food security in Indian Ocean island nations. Commercial catch data poorly documented.

Data Availability: No species-specific CPUE studies identified. Catch reporting typically aggregated at family level with other Nemipteridae. Requires improvements in species identification and catch documentation. Many length frequency samples available (~43,000).

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- None at this stage

12.5.2 UPM - Goldfin Goatfish (Upeneus moluccensis)

Biology: Small tropical demersal species reaching ~25cm length. Life history parameters poorly known for Indian Ocean populations - maturation estimated around 1 year based on Mediterranean studies. Benthic forager using barbels to locate prey in sand and mud substrates.

SIOFA Fisheries: Incidental catch in coastal multispecies fisheries. Low individual value but contributes to subsistence and local commercial fisheries. Catch volumes and fishing effort poorly documented.

Data Availability: No Indian Ocean-specific biological or fisheries studies identified. Species identification challenges with other *Upeneus* species prevent meaningful abundance assessment. 1600 length frequency samples.

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- None at this stage

12.5.3 SSO - Smooth Oreo Dory (Pseudocyttus maculatus)

Biology: Long-lived deep-sea species reaching 60-68cm length and 86 years age. Very slow growth (K=0.06) and late maturation (25-30 years) (McMillan et al., 2021) indicate high vulnerability to fishing pressure. Inhabits depths of 200-1,500m.

SIOFA Fisheries: Bycatch in orange roughy and alfonsino trawl fisheries. No directed fisheries but growing commercial interest. Annual catches estimated 50-200 tonnes but often aggregated with other oreo species in reporting.

Data Availability: Low. Major challenge from species aggregation in catch reporting - most data recorded as "oreos nei" preventing species-specific analysis. High-quality New Zealand biological studies available but limited SIOFA-specific assessment data. Very few length frequency samples available (272).

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- Risk-based TRP and LRPs: Based on M=0.063, F_{MSM} = 0.055, F_{LIM} = 0.082.

12.5.4 BOE - Black Oreo (Allocyttus niger)

Biology: Extremely long-lived deep-sea species reaching 35-47cm length and 153 years age. Very slow growth (K=0.044) and very late maturation (27 years) (McMillan et al., 2021) make among the most vulnerable fish species to fishing pressure.

SIOFA Fisheries: Bycatch in orange roughy and alfonsino trawl fisheries. No directed fisheries due to small size and low commercial value. Annual catches estimated 20-100 tonnes but typically aggregated with other oreo species.

Data Availability: Low. Species aggregation problem - most catch data recorded as "oreos nei" preventing species-specific analysis. Extreme longevity demands precautionary management despite data limitations. No length frequency samples available.

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- Risk-based TRP and LRPs: Based on M=0.035, F_{MSM} = 0.031, F_{LIM} = 0.046.

12.5.5 ORD - Oreos nei (Oreosomatidae)

Biology: Family complex including multiple species with extreme longevity characteristics. Warty oreo documented to 140 years (McMillan et al., 2021). All species show very slow growth and late maturation patterns.

SIOFA Fisheries: Mixed bycatch in deep-sea trawl fisheries. Some commercial potential but limited by small individual size and aggregated reporting. Annual catches estimated 100-500 tonnes across multiple species.

Data Availability: Very Low. Fundamental challenge from family-level aggregation in catch reporting. Individual species assessment impossible without improved identification protocols. Represents critical systematic challenge for SIOFA management. No length frequency samples available.

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- Risk-based TRP and LRPs: Based on M=0.039, F_{MSM} = 0.034, F_{LIM} = 0.050.

12.5.6 YBS - Bigeye Barracuda (Sphyraena forsteri)

Biology: Large predatory species reaching 75cm length and 8-10 years age. High productivity with estimated natural mortality M=0.6-0.8 and early maturation (2-3 years). Inhabits coral reefs and adjacent pelagic waters throughout Indo-Pacific.

SIOFA Fisheries: Target species in reef-based spear and handline fisheries. Important for subsistence and local commercial operations around islands. Annual catches poorly documented, estimated 10-50 tonnes across SIOFA region.

Data Availability: Low. Limited assessment studies despite widespread distribution and commercial importance. Species identification generally reliable due to distinctive morphology. Effort standardization complicated by diverse gear types and fishing locations. No length frequency samples available.

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- Risk-based TRP and LRPs: Based on M=0.7, F_{MSM} = 0.6, F_{LIM} = 0.9.

12.5.7 GRV - Macrourids (Macrourus spp.)

Biology: Deep-sea species complex with moderate longevity (25-41 years) and slow growth (K=0.047-0.069). Distribution studies available for M. carinatus from BANZARE Bank show patchy habitat associations.

SIOFA Fisheries: Important bycatch in toothfish longline fisheries. No directed fisheries but increasing commercial interest. Annual catches estimated 50-200 tonnes, primarily *M. carinatus* and *M. whitsoni*.

Data Availability: Low to moderate. High-quality toothfish observer data includes macrourid bycatch information, but species-specific identification challenges limit assessment potential. Slow growth indicates vulnerability requiring precautionary management. Limited length frequency samples available (~1700).

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- Risk-based TRP and LRPs: Based on M=0.13, F_{MSM} = 0.11, F_{LIM} = 0.17.

12.5.8 ANT - Violet Cod (Antimora rostrata)

Biology: Deep-sea species with broad depth range (150-3,000m) and moderate longevity (23-42 years). Very slow growth (K=0.01-0.047) indicates vulnerability to fishing pressure. Wide distribution across Atlantic, Pacific, and Indian Oceans.

SIOFA Fisheries: Bycatch in deep-sea longline and trawl fisheries. Some commercial potential but limited catch volumes. Primary occurrence in toothfish fisheries as non-target species.

Data Availability: Low. Limited assessment data despite wide distribution. Good quality biological studies from Ross Sea and North Atlantic, but SIOFA-specific information lacking. Species identification generally reliable due to distinctive morphology. Some length frequency samples available (n=4400).

Current Stock Assessment Status: No stock assessments available and no management units defined.

Recommendation

- Risk-based TRP and LRPs: Based on M=0.13, F_{MSM} = 0.11, F_{LIM} = 0.17.

13. Appendix B: Detailed Life History Parameters

Biological Parameters Table

Species	**Scientific Name**	**M (yr^{-1})**	**L∞ (cm)**	**K (yr^{-1})**	**t_{mat} (yrs)**	**t_{max} (yrs)**	**Productivity**	**Data Quality**	**Primary Source**
DEEP-SEA SPECIES									
Splendid alfonsino	*Beryx splendens*	0.2*	80.6 (Butterworth et al 2021) 43.1 – 65.6 (FishBase) 61.3*	0.068*	6† 9*	61 to possibly 72#	Low	Medium	* whole otoliths, unvalidated (Brouwer et al., 2021) # sectioned otoliths, bomb ^{14}C (Andrews, 2023) † Brandão et al. (2021)
Orange roughy	*Hoplostethus atlanticus*	0.035-0.064 (Butterworth et al 2021)	51-56 (Hoyle & Mormede 2025)	0.033-0.044 (Hoyle & Mormede 2025)	22-40 (Butterworth et al 2021)	>100-250 (Butterworth et al 2021)	Low	High	SIOFA/CCAMLR (2020-25)
Cardinal fishes	*Epigonus* spp	0.15-0.25*	20-30*	0.10-0.15*	5-8*	15-25*	Medium	Low	Estimated/FishBase
	Epigonus telescopus		75			104 Tracey et al 2000			
	Epigonus robustus		22						
Oilfish	*Ruvettus pretiosus*	0.11	90, 200-300#	0.11, 0.94*		42		Very Low	#FishBase

Species	Scientific Name	M (yr^{-1})	L∞ (cm)	K (yr^{-1})	t_{mat} (yrs)	t_{max} (yrs)	Productivity	Data Quality	Primary Source
			162.4*						* Western north Atlantic (Daniels, 2023)
Hapuka/Wreckfish	*Polyprion* spp	0.05-0.08*	150-160	0.06-0.10	10-13	60+, 52, 80	Low	Low	NZ aquaculture
Smooth oreo	*Pseudocyttus maculatus*	0.05-0.08*	60-68	0.06	25-30	86	Low	Medium	NZ Fisheries (2020-23)
Black oreo	*Allocyttus niger*	0.03-0.05*	35-47	0.044	24-30	153	Low	Medium	NZ Fisheries (2020-23)
TROPICAL/SUBTROPICAL									
Brushtooth lizardfish	*Saurida undosquamis*	0.35-2.63	38.05-42.00	0.124-0.51	1-2	6-8	High	Medium	Multiple
Indian scad	*Decapterus russelli*	2.63	24-25	0.58-1.42	1-2	5-12	High	Medium	Indonesian/Mumbai
Threadfin bream	*Nemipterus bipunctatus*	NA	~30	NA	NA	NA	Unknown	Very Low	FishBase only
Goldfin goatfish	*Upeneus moluccensis*	NA	NA	NA	~1	NA	Unknown	Very Low	Mediterranean only
Shortfin scad	*Decapterus macrosoma*	High*	~35	0.50-1.60	~1-2*	NA	High	Low	FishBase/estimates

Species	Scientific Name	M (yr^{-1})	L∞ (cm)	K (yr^{-1})	t_{mat} (yrs)	t_{max} (yrs)	Productivity	Data Quality	Primary Source
Sky emperor	*Lethrinus mahsena*	Low*	~65	NA	NA	27	Low	Low	FishBase/Al-Husaini
Bigeye scad	*Selar crumenophthalmus*	High*	~38	0.6-0.9	NA	NA	High	Low	FishBase
LARGE PELAGICS									
Patagonian toothfish	*Dissostichus eleginoides*	0.13-0.155	145-165	0.04-0.08	8-12	45-50	Low	High	CCAMLR (2020-24)
Escolar	*Lepidocybium flavobrunneum*	0.4-0.6*	150-180	0.2-0.3*	3-4*	12-15*	Medium	Low	Estimated
Bigeye barracuda	*Sphyraena forsteri*	0.6-0.8*	65-75	0.4-0.6*	2-3*	8-10*	High	Low	Indian Ocean studies
CARANGIDS & GROUPERS									
Yellow spotted trevally	*Carangoides fulvoguttatus*	0.20-0.30*	90-120	0.15-0.25*	3-5*	15-20*	Medium	Low	Australian studies
Bludger	*Carangoides gymnostethus*	0.22-0.32*	80-90	0.18-0.28*	3-4*	12-18*	Medium	Low	South African
Carangoides species	*Carangoides* spp	0.18-0.40	25-120	0.15-0.45	2-5	8-25	Medium	Low	Genus estimates
Marbled coral grouper	*Plectropomus punctatus*	0.15-0.25*	80-96	0.12-0.18*	4-6*	15-25*	Medium	Low	Indian Ocean

Species	Scientific Name	M (yr^{-1})	L∞ (cm)	K (yr^{-1})	t_{mat} (yrs)	t_{max} (yrs)	Productivity	Data Quality	Primary Source
Emperor red snapper	*Lutjanus sebae*	0.104-0.122	48.3-62.8	0.14-0.19	9	34-40	Low	High	NW Australia/Seychelles
Two-spot red snapper	*Lutjanus bohar*	0.08-0.12*	63	0.10	9.4♀/1.5♂	55+	Low	High	Great Barrier Reef
OTHER SPECIES									
Oreos nei	*Oreosomatidae*	Low*	43-60	0.05-0.06	27-34	86-210	Low	Medium	NZ (pre-2020)
Grenadiers	*Macrourus* spp	0.10-0.12	78-100	Low*	12-16	43-65	Low	Medium	Ross Sea/Falklands
Violet cod	*Antimora rostrata*	Low*	82-143	0.01-0.047	15-20*	23-42	Low	Medium	Ross Sea/N Atlantic

14. Appendix C: Terms of Reference for the Project PAM-2024-02

SIOFA | APSOI
Southern Indian Ocean Fisheries Agreement
Accord relatif aux Pêches dans le Sud de l'Océan Indien

Project title: Determination of Biological Reference Points (BRPs) for key SIOFA fish stocks

Project Code: PAM-2024-02

Terms of Reference

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 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.

2. Methods

The determination of Biological Reference Points (BRPs) is a critical component of fisheries stock assessment/evaluations, the Precautionary Approach Framework (PAF) and development of Harvest Control Rules (HCRs). They will be developed so that they can be used to inform fisheries managers about stock's status relative to the BRPs and hence the overall management objectives.

The need for simultaneous consideration of biological reference points and actions to be taken if they are exceeded is made in both the FAO Code of Conduct for Responsible Fisheries (SIOFA Agreement Article 1d) and Article 6 of the United Nations agreement relating to the conservation and management of straddling fish stocks and highly migratory fish stocks (SIOFA Agreement Article 1b).

The current interim BRPs (MoP10 Report, paragraphs 77 and 78) will be reviewed, including the strengths and weaknesses of each BRP. Further, the project will propose interim default BRPs for low, medium, and higher information stocks to enable evaluation of the status of stocks against these reference points. And specifically with guidance for the primary and secondary species identified by SC in 2023 (see Appendix A of the SIOFA Fisheries Overview 2024). The conclusions and outcomes from this objective will be consistent with the PAM-2024-01 and PAM-2024-3 projects, as appropriate.

The development of the BRPs will consider the relationship between MSY/MSY proxies and relevant factors such as the stock productivity, stock status, and the exploitation patterns of SIOFA fisheries. Suitable proxies for stock status and BRPs should be considered and be consistent with the operational guidelines that will be developed in project PAM-2024-01. Example case studies will be used to illustrate their implementation, including examples of different choices of BRPs for the same species or SIOFA species that are harvested in other Regional Fisheries Management Organizations (RFMOs).

The BRPs 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.

3. Project Objectives

1. Provide analyses that will support of the development of suitable BRPs for key SIOFA fish stocks (Appendix A of the SIOFA Fisheries Overview 2024) and propose interim default BRPs for low, medium, and higher information stocks.
   Specifically, evaluate the potential use of standard biological reference points, such as B40% and B20%, MSY, SBMSY, SB0, SBF=0, SB/SBMSY, SB/SBF=0, SB/SB0, F, FMSY, F/FMSY and F40%, as well as CPUE equivalents and any other appropriate reference points (e.g. as listed in Table 1):
   a. The analysis should include consideration of target ranges, threshold regions, and limit reference points.
   b. Provide example case studies to illustrate their implementation, including examples of different choices of BRPs for the same species or SIOFA species that are harvested in other Regional Fisheries Management Organizations (RFMOs).

2. Review methods for the calculation and interpretation of risk and the quantification of uncertainties related to them. For stocks where quantitative risk analyses are not possible, provide options on how to establish appropriate default reference points and how these may be improved to be stock specific reference points.

3. Determine the conditions for when/if the BRPs would need to be revised or reevaluated (e.g., identify changes in available Information or regime shifts).

Table 1: Potential limit reference points (Reproduced from Table MI-1 in WCPFC Scientific Committee 2021).

LRP	Group	Assessment type	Comments
x% F/F_{MSY}	Target & Bycatch	Data rich	Choose the level of x based on an evaluation.
x% $B/B_{F=0}$	Target & Bycatch	Data rich	Choose the level of x based on an evaluation.
x% B_0	Target & Bycatch	Data rich	Choose the level of x based on an evaluation.
SPR x% $B_{F=0}$	Bycatch	Medium data or data poor	Choose the level of x based on an evaluation.
x% $CPUE_0$	Target & Bycatch	Data rich or medium data	Choose the start of a reliable CPUE series and the level of x.
$B/B_{F=0,\ t1-t2}$	Target & Bycatch	Data rich	Choose a time period where the stock was considered in an undesirable state (and should be avoided in future) but recovered back to suitable levels.
B_{t1-t2}	Target & Bycatch	Data rich	Choose a time period where the stock was considered in an undesirable state (and should be avoided in future) but recovered back to suitable levels.
$CPUE_{t1-t2}$	Target & Bycatch	Data rich or medium data	Choose a time period where the stock was considered in an undesirable state (and should be avoided in future) but recovered back to suitable levels.
$B/B_{F=0}$_ low	Target & Bycatch	Data rich	Choose a low year where the stock was considered in an undesirable state (and should be avoided in future) but recovered back to suitable levels.
B_low	Target & Bycatch	Data rich	Choose a low year where the stock was considered in an undesirable state (and should be avoided in future) but recovered back to suitable levels.
CPUE_low	Target & Bycatch	Data rich or medium data	Choose a low year where the stock was considered in an undesirable state (and should be avoided in future) but recovered back to suitable levels. Note CPUEt1−t2 is more precautionary.
$F/F_{lim} > 1$	Bycatch	Data poor	Use as an interim LRP until a more reliable metric can be generated.
$F/F_{crash} > 1$	Bycatch	Data poor	Use as an interim LRP until a more reliable metric can be generated.

See also Table 7 from WCPFC-SC17-2021/MI-WP-08.

4. Relevant SIOFA information

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

3. SIOFA reporting templates. Available at: https://github.com/SIOFASecretariat/SIOFA_Reporting_templates
4. SIOFA reports:
   a. SIOFA SC, SC Working Group, and National Reports. Scientific Committee Meeting | SIOFA (https://siofa.org/)
   b. SIOFA MoP reports. Meeting of the Parties | SIOFA (https://siofa.org/)
   c. SIOFA technical and scientific reports (public reports and abstracts of restricted reports are available from https://siofa.org/, and full restricted reports will be made available by the SIOFA Secretariat to the project consultant upon request and after the approval of relevant CCPs.
5. SIOFA Agreement (SIOFA, 2006). https://siofa.org/sites/default/files/documents/SIOFA-Agreement-Digital-ENG.pdf

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.

6. Deliverables

1. Attend (virtually) the project Advisory Panel meetings for Project PAM-2024-02. Additional attendance may be required at the project Advisory Group meetings for the closely related projects PAM-2024-01 and PAM-2024-03
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.

7. Acceptance of Draft and Final Reports

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

8. Intellectual Property clause and confidentiality

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

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

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

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

9. Work timeline and payment schedule

The funds for this project, budgeted under the SIOFA-PAM EU Grant (https://siofa.org/eu-grants), allow for a maximum total budget of 30,000 Euro (including all costs and any travel related expenses).

The consultant shall follow the timeline described in Table 2 below.

Table 2: 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

Milestone	Date	Activities
		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

10. Submission of applications

11. A current CV that summarises the applicant(s) relevant educational background and professional experience.
12. 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.
13. Any proposed exclusions to the intellectual property clause or variations to the work timeline and payment schedule.
14. The proposed consultancy price (including all consultant expenses and project related costs), noting that the available budget for this work indicated in Section 3.
15. Identification of any project risks and associated mitigation and management required to successfully complete the project.
16. 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
17. 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.

18. 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.

19. 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).

20. Contacts

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

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