The Southern Indian Ocean Fisheries Agreement (SIOFA) 5th Meeting of the Parties
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MoP5-Prop01
Orange Roughy Biological Reference Points and Harvest Control Rules (HCR)

*Relates to agenda item: **9*** Proposal ☒ Other Document ☐ Info Paper ☐

Delegation of the Cook Islands

Abstract

This paper provides a basis for the Meeting of the Parties to establish reference points for the management of orange roughy fisheries in the SIOFA region. Newly estimated biological parameters including M and B_{msy} for SIOFA orange roughy were provided in 2018 and used to estimate B_{MSY}. This is very uncertain and could be close to or even less than 20%B_0 it was considered to be too risk prone to be used as a target or limit reference point. New reference points that meet the Marine Stewardship Council standards are proposed. The paper also proposes a dynamic Harvest Control Rule (HCR) that could be used specifically for orange roughy. The Cook Islands welcomes feedback from all Contracting Parties on the recommendations.

Recommendations *(proposals only)*

1. The Cook Islands recommends adoption of a Limit Reference Point of 20%B_0 and a target biomass range of 30-50% B_0 for orange roughy stocks.
2. The Cook Islands recommends adoption of a dynamic HCR that will maintain an orange roughy stock at 40%B_0.

Introduction.

The Cook Islands are pleased to submit a discussion paper on the establishment of reference points for the management of orange roughy fisheries in the SIOFA region for the consideration by the Meeting of Parties. The paper also proposes Harvest Control Rules (HCR) that could be used.

In 2017, Innovative Solutions Ltd (ISL) was contracted to provide a stock assessment for orange roughy in the Walters Shoal region (WSR), and to apply the New Zealand HCR to other orange roughy stocks in the SIOFA area.

At SAW01 stock assessments (SAWG(2018)-01-05, SAWG(2018)—01-06) were carried out for all orange roughy stocks in the SIOFA area and subsequently presented to the Scientific Committee. Although these assessments considered the application of harvest control rules based on the newly estimated biological parameters including M and B_{msy} for SIOFA orange roughy, this was not reviewed by the SC.

The Scientific Committee has requested (SC03 para 234) further direction from the Meeting of the Parties on the establishment of reference points as it is not possible to develop advice on status or specific catch limits without these reference points.

This discussion paper consist of two parts: (i) Technical Guidelines, which contain guidance on calculations of biological reference points to be used as inputs to setting fishing targets, and (ii) Implementation Guidelines, which include sections on developing or using HCR for SIOFA orange roughy.

Contracting Parties are invited to consider this discussion paper and provide comments to the Cook Islands.

1. Technical Guidelines

Deterministic MSY calculations and reference points for SIOFA Orange Roughy

Article 4 of the Agreement Principle (d) requires that '*the fishery resources shall be managed so that they are maintained at levels that are capable of producing the maximum sustainable yield, and depleted stocks of fishery resources are rebuilt to the said levels;*

To develop a harvest strategy for a fishery-stock combination it is important to take into account the differences in the types, amounts and quality of data available for calculating biological reference points. This means the principle of maintaining the resources at B_{MSY} will need to be applied in different ways for different fisheries depending on the available data.

In the case of potential reference points for SIOFA orange roughy stocks, we note that deterministic B_{MSY} has **not** been found to be a useful reference point for New Zealand orange roughy stocks as it is highly dependent on the stock-recruitment relationship and is therefore very uncertain (see Cordue 2014a). Little is known about the stock recruitment relationship for any of the New Zealand stocks and even less for SIOFA stocks.

If a Beverton-Holt stock recruitment relationship is assumed for the SIOFA WSR stock then B_{MSY} is highly dependent on the steepness parameter (Table 1). It is not sensitive to the range of M values that can be expected for the stock (Table 1). It is also insensitive to the maturity parameters (Table 2).

Table 1 B_{MSY} (%B_0) calculated for combinations of M (natural mortality) and h (steepness in a Beverton-Holt stock recruitment relationship). In the base model M = 0.045 and h = 0.75 (the default value used in New Zealand). For these calculations the maturity parameters were assumed to be the mean median values for the five assessed New Zealand stocks (a_{50} = 37 years, a_{to95} = 12 years[1]). Growth and length-weight parameters determined from orange roughy caught on Sleeping Beauty were used.

				h
M	0.65	0.75	0.90	0.95
0.036	28	23	16	11
0.045	28	24	15	11
0.054	28	23	15	11

Table 2 B_{MSY}, MSY, and U_{MSY}[2] calculated for three alternative pairs of maturity parameters. Base model parameters were used for other parameters in each case.

Maturity (a_{50}, a_{to95})	**B_{MSY} (%B_0)**	**MSY (%B_0)**	**U_{MSY}**
30 years, 10 years	23.9	2.14	0.086
37 years, 12 years	23.6	2.25	0.091
45 years, 20 years	23.3	2.27	0.093

Given that B_{MSY} is very uncertain and could be close to or even less than 20%B_0 we consider it to be too risk prone to be used as a target or limit reference point (and U_{MSY} not suitable as a target or limit exploitation rate).

A management strategy evaluation (MSE) has been carried out for a generic New Zealand orange roughy stock to determine an appropriate limit reference point, target biomass range, and HCR for use in managing orange roughy stocks (Cordue 2014b). The proposed management strategy was designed to be consistent with New Zealand's Harvest Strategy Standard and the Certification Requirements of the Marine Stewardship Council Sustainability Standard. Unusually, this MSE did not address social or economic interests in an explicit way but focussed solely on the sustainability of the target stock in order to meet specific MSC requirements.

The first step was to estimate stock recruitment steepness (the percentage of virgin recruitment, on average, produced when the stock is at 20% of virgin biomass, B_0) by performing extra stock assessment runs for the Mid-East Coast New Zealand stock. Of the four stocks assessed in 2014, this was the only stock which had the year class strengths (YCS) estimated from age data on cohorts spawned at low stock size (and hence information on how average recruitment changes at low stock size). Assessment runs were done for Beverton-Holt and Ricker stock-recruitment relationships. The results were similar for both, with median steepness (for the combined posterior) equal to 0.6 with a 95% CI of 0.31-0.95.

The large level of uncertainty in steepness, as well as the form of the stock-recruitment relationship, creates a high degree of uncertainty in the estimates of B_{MSY}. For the Beverton-Holt model, the median estimate and 95% CI of B_{MSY} were 26% B_0 and 12–39% B_0; and for the Ricker model they were 42% B_0 and 37-47% B_0. As there was no basis for choosing between the Beverton-Holt and Ricker stock-recruitment relationships, we conclude that the mid-point of the target range to be about 40% B_0.

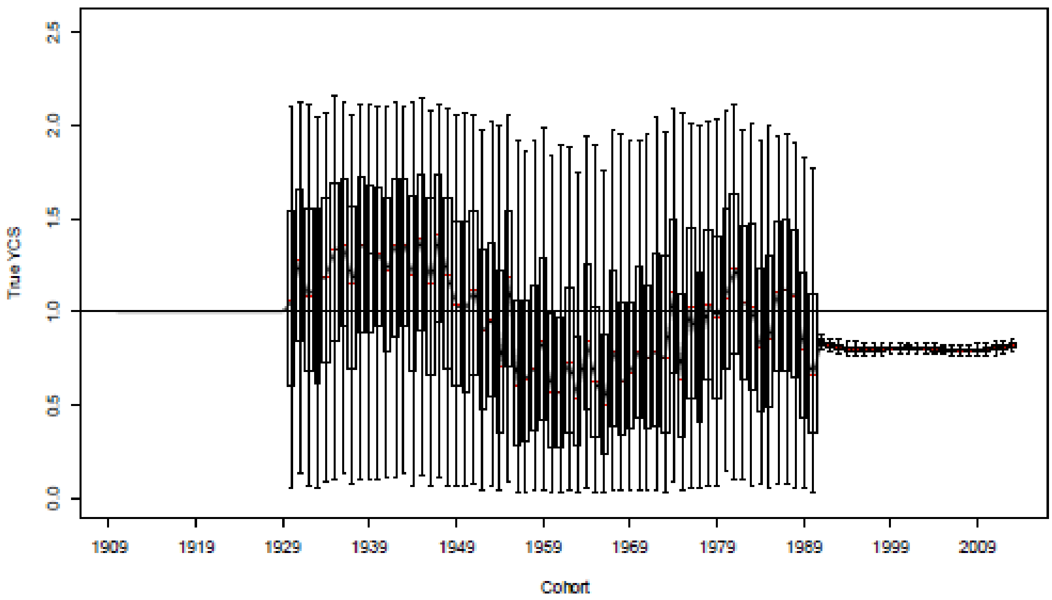
[1] a_{50} is the age at which half of the population is mature; a_{to95} is the number of years from age at 50% maturity to age when 95% of the population is mature.
[2] U_{MSY} is the annual rate of exploitation of the stock at B_{MSY}

The limit biomass reference point was defined to be the greater of 20% B_0 or 50% B_{MSY}. Under this definition, the Bayesian estimate of the limit reference point was 20% B_0 with a very high level of certainty.

Experimentation with various HCRs showed that spawning biomass, even when managed with a (perfectly) constant *F*, was prone to large long-term fluctuations, because of the low natural mortality and low recruitment. Therefore, a fairly wide target range was needed to accommodate these long-term fluctuations and a breadth of 20% B_0 was proposed. Taken with the mid-point of 40% B_0, this gave a target biomass range of 30 to 50% B_0 (with a limit reference point of 20% B_0). With narrower biomass target ranges, the natural variability in the stock abundance and recruitment made it difficult to keep the stock within the range for a sufficiently high proportion of the time.

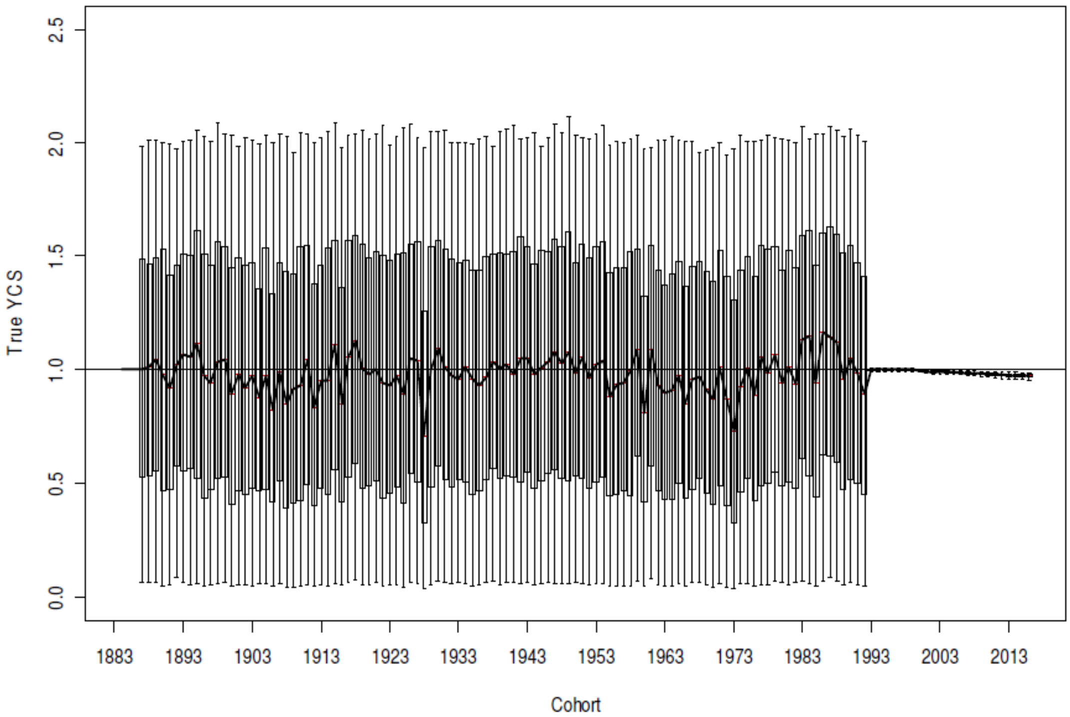
Recruitment (YCS) was estimated for the four New Zealand stocks, and three of the four estimated relatively high YCS during the 1920-40s, followed by a recruitment decline to around 50% or less of the long-term mean YCS by the 1960s, suggesting recruitment to the fisheries after the biomass fish-down was around half of what was expected from the initial size of the stocks (Figure 1) The high recruitment estimated for the 1920-40s also caused the estimated biomass to increase towards the start of fishery in three of the four stocks. When combined with the age at recruitment estimates, the models indicate that recruitment to the spawning stocks moved to below average levels in the mid-1970s (Mid-East Coast), early 1980s (Challenger Plateau), and around 1990 (East & South Chatham Rise).

Figure 1 Recruitment in New Zealand Orange Roughy Stocks (ESCR)



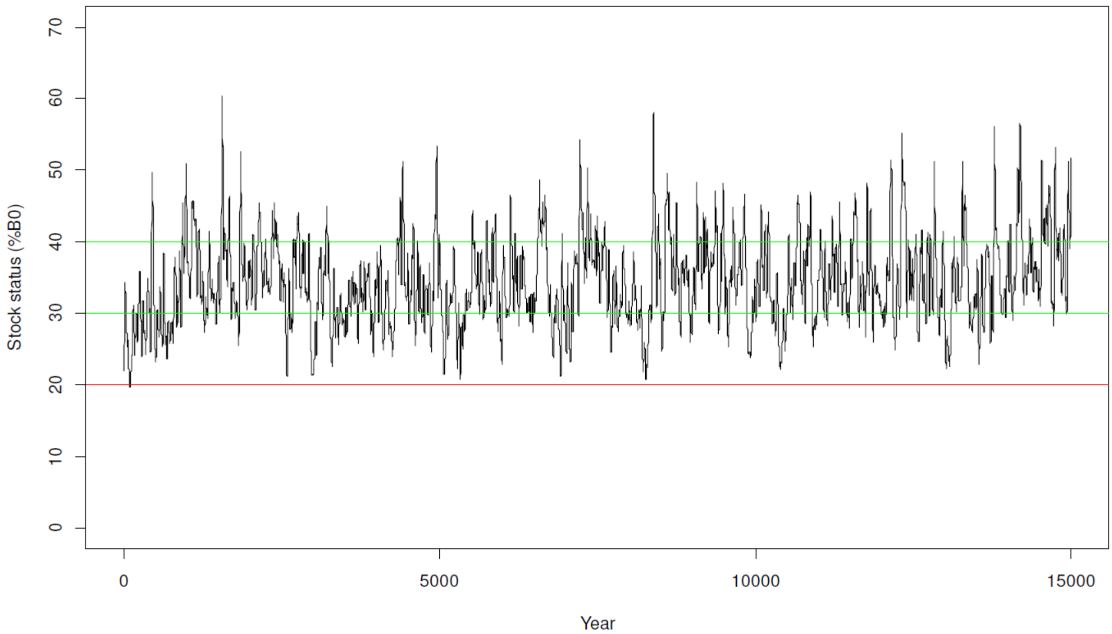
The YCS for the WSR assessment in SIOFA shows a substantially different pattern to New Zealand. There is relatively little variation in recruitment over time, i.e. there is essentially deterministic recruitment (Figure 2).

Figure 2 Recruitment in Walters South Stock in SIOFA



The stochastic recruitment seen in New Zealand orange roughy stocks has a significant impact in the MSE as it results in variation in spawning stock biomass even in the absence of fishing. When fishing at a constant $F_{35\%Bo}$ the mid season spawning biomass is very variable (Figure 3).

Figure 3 New Zealand Orange Roughy example of time series of stock status when fishing at constant F35%Bo



A MSE for SIOFA orange roughy would show less variability in spawning stock biomass. However, there is currently only one age composition data set for the WSR stock though collection of age frequency data for other stocks is in the Scientific Committee Workplan. A MSE could be undertaken in 2019-2020 with more data, but it would likely have the same result.

As the Management Strategy Evaluation carried out for New Zealand orange roughy stocks was reviewed and accepted by both New Zealand and the MSC, and is very robust, we believe that it should be accepted by the MoP.

It is recommended that the reference points used in New Zealand for orange roughy are adopted for SIOFA: a limit reference point of 20% B_0 and a target biomass range of 30–50% B_0 (see Cordue 2014b). The associated target exploitation rate range is $U_{30\%B0}$–$U_{50\%B0}$ (where $U_{x\%B0}$ is the exploitation rate that delivers a deterministic equilibrium spawning biomass of x% B_0).

2. Implementation Guidelines

Harvest Control Rules

Two interpretations of what is a harvest control rule (HCR) have developed. The initial understanding was that a HCR defines one or more management actions that would be taken when the state of the fishery falls below a pre-defined or pre-agreed threshold. For example, if an estimate of the biomass (e.g. the spawning biomass) of an exploited stock was below the agreed threshold, fishing would be stopped, or fishing effort would be reduced in a pre-agreed and non-negotiable manner. The intention was that if a management action that was required in response to a particular condition of the stock could be agreed before the stock arrived in that state then this would avoid delays or disagreements in implementing a management response caused by different stakeholders trying to negotiate differing responses that reflected their current interests.

The relevant point is that decision makers are free to agree on any criterion/criteria that would trigger implementation of the HCR. For example, these could include:

- Insufficient mature females, i.e. spawning stock biomass, in the current stock
- Low biomass
- Catch rates that are uneconomic
- The advent of particular inclement oceanographic conditions
- Or whatever.

Those who accept regulation of their fishery by a HCR are also free to negotiate what response to a threshold trigger should be, e.g.

- Close the fishery for the rest of the season
- Close the fishery until some agreed stock condition occurs – i.e. there is a recovery of its biomass
- Close, or reduce the harvest from, the fishery until there is a market recovery
- Implement some form of catch restriction
- Implement some form of effort restriction
- Agree that no new entrants should be permitted in the fishery until some condition is satisfied
- Etc.

This type of HCR has more commonly been implemented in fisheries under national jurisdiction. Experience has shown that when the level of the target stock occurs that (should) trigger the implementation of the pre-agreed HCR various parties can exert pressure to lower the threshold levels that had previously been agreed upon arguing financial and/or social pressures, which may be consistent with interpretations of the Ecosystem Approach to Fisheries Management.

The second application of a HCR is more restrictive and is well accepted in RFMOs such as SPRFMO with the jack mackerel fishery. It is the response that should/must occur when the biomass or spawning stock biomass state of a stock falls below a defined reference point or level. The concept of reference points for fisheries management has been around for over two decades (Caddy & Mahon 1995).

The New Zealand Orange Roughy harvest control rule

Harvest control rules (HCRs), based on the range and limit reference points, were tested in simulations, sufficiently long to ensure stochastic equilibrium had been reached, and to check the HCR performed adequately with regard to maintaining the biomass within the target range with little possibility of ever being below the limit reference point. With an appropriate HCR, stock status should remain within the target biomass range most of the time when measured over the long-term, and should avoid dropping below the limit reference point.

In a static HCR, there is a simple functional relationship between estimated stock status and fishing mortality, *F*, where a low stock status results in management action to give a low *F* and *vice versa*. For example, the TAC could be set as a fixed proportion (such as the natural mortality rate, 4.5%) of the current spawning biomass estimate. In a dynamic HCR, there is an initial functional relationship and an additional rule by which that relationship can change over time that makes the HCR more responsive to change in stock status (or whatever indicator is being used).

A dynamic HCR was developed, based on an earlier, 'slope' HCR which had *F* increasing from 0 at 10% B_0 to 0.045 at 30% B_0 and remaining constant thereafter (0.045 was the assumed value of *M* in the stock assessments, so the earlier HCR was an '$F = M$' strategy).

This HCR was modelled within the MSE which estimates that it will maintain stock status around 42% B_0 and within the management target range 97% of the time. It also estimates that, under this HCR, the stock will not decline below 20% B_0. Under this HCR, catch limits would be set based on an F_{mid} of 0.045. This means that if a stock is estimated to be at 40% B_0, the midpoint of the target range, the recommended catch would be based on F = 0.045 (i.e. 4.5% of the current vulnerable biomass). If a stock is estimated to be within the target range, the recommended catch limit would be estimated, based on the slope of the HCR within this range (i.e. between 0.034 at 30% B_0 and 0.056 at 50% B_0). When the stock status is estimated to be greater than 40% B_0, the HCR allows removal of more catch to return the stock to 40% B_0. Conversely, when the stock size is estimated to be at the lower bound of the management target range, the recommended catch limit would be reduced to 75% of F_{mid} (i.e. to F = 0.034) to provide for the stock size to increase back towards 40% B_0.

The new dynamic HCR is considerably more complex and risk averse than the static HCR: first, *F* further increases within the target biomass range of 30–50% B_0 as stock status increases (Figure 4), and second, there is an added dynamic component. The dynamic element operates by scaling the slope of the HCR when outside the target reference range. If estimated stock status is below the lower bound of the target biomass range then *F* is scaled down below that indicated by the slope. The scaling down of *F* occurs every time that a stock assessment estimates stock status to be below the lower bound. There is a specified limit to the scaling down that may not be exceeded (see Appendix 1 in Cordue 2014b). There is also an equivalent scaling up if the estimated stock status is above the upper bound of the target reference range (in this case the threshold is set at 60% B_0 rather than the upper bound itself). This is a complex HCR and is fully explained in Cordue, (2014b). It is also an HCR that needs to be informed by appropriately frequent stock assessments.

The exploitation rate from the HCR (U_{HCR}) depends on estimated stock status (*ss*):

U_{HCR}	$= 0.05625$	for $ss > 50\% B_0$
	$= 0.1125\, ss$	for $30\% B_0 < ss \leq 50\% B_0$
	$= 0.16875\,(ss - 0.1)$	for $10\% B_0 < ss \leq 30\% B_0$
	$= 0$	for $ss \leq 10\% B_0$.

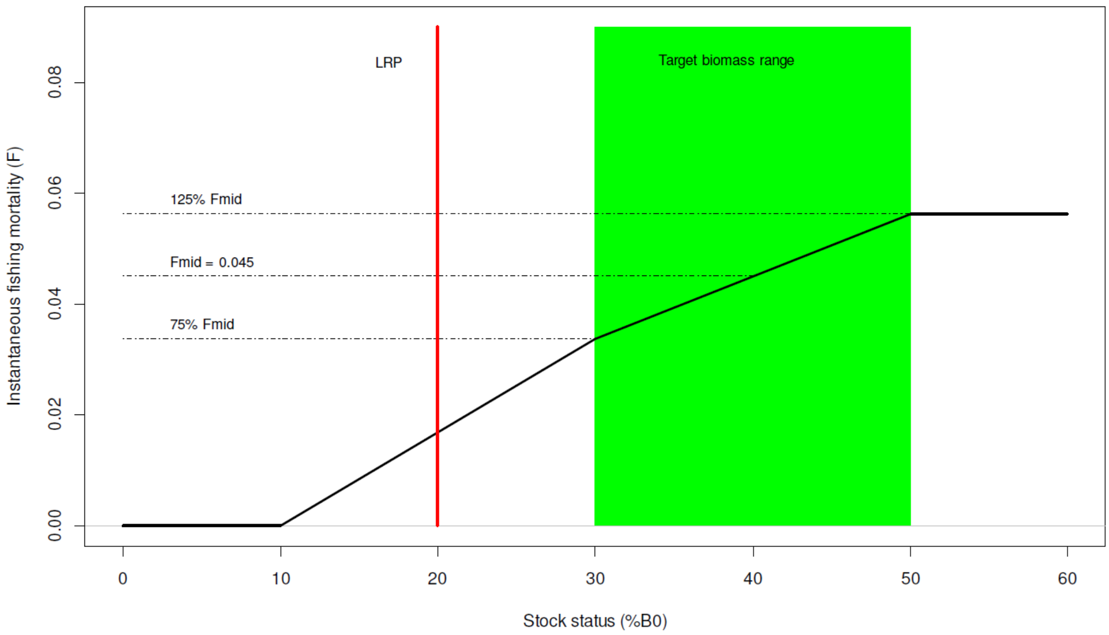


Figure 4 Proposed harvest control rule. The target biomass range is 30-50% B0 and the limit reference point is 20% B0. Instantaneous F (or an exploitation rate) is calculated using the ramped line shown from the current estimate of stock status.

The dynamic aspect of the HCR was robust to uncertainty in parameter estimates (e.g., *h* and *M*, recruitment variability and correlation) and errors in assumptions (e.g., the form of the stock–recruit relationship, and errors in assumptions such as the form of the stock recruitment relationship or bias in the estimators of stock status and/or current biomass). The dynamic rescaling of the functional relationship essentially allows the HCR to be more responsive to changes in stock status as the HCR becomes progressively more conservative as stock status falls. Similarly, if the stock size increases, then the HCR progressively increases the fishing mortality rate.

The main specifications of the HCR (dynamic HCR10 of Cordue 2014b), are: the limit reference point of 20% B_0, target biomass range of 30 to 50% B_0, initial F_{mid} of 0.045, slope within the target range: *p* = 25%; which declines to zero at 10% B_0; and fixed rescaling points: *lower* = 30% B_0, *upper* = 60% B_0. In the simulations, stock assessments were specified to occur every 3 years.

The final HCR developed was found to be robust to the uncertainty in steepness and natural mortality, as well as one-off and multiple violations in major assumptions. The analyses concluded that the HCR should perform well unless there is a severe violation of the assumptions made in the evaluation, and steepness and/or natural mortality are excessively low.

This HCR which meets the MSC standard is seen as the most appropriate for SIOFA orange roughy stocks given the current stock status estimates from the 2018 assessments, where 4 of the data-rich stocks are estimated to be above 70% B_0 (Figure 5, Table 3), and no rebuilding plan is required. Adopting this harvest strategy should ensure sustainable utilisation.

Figure 5 WSR Snail Trail (Kobe Plot)

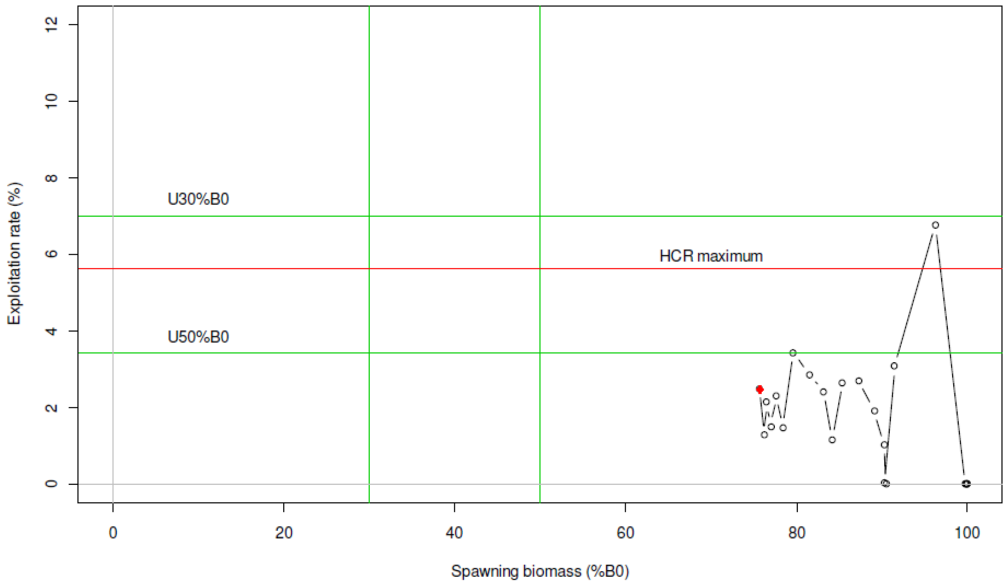


Table 3 Current Stock Status for 3 data rich SIOFA stocks

		B_0 (000 t)	B_{17} (000 t)	ss_{17} (%B_0)
N. Walters	Low	9.7	8.5	88
	Middle	13	12	91
	High	19	17	94
Seamounts	Low	24	17	70
	Middle	31	24	77
	High	45	38	84
M. Ridge	Low	55	46	84
	Middle	75	66	88
	High	108	99	92

Recommendations

The Meeting of the Parties adopts the following reference points for orange roughy:

1. A limit reference point of 20% B_0
2. A target biomass range of 30–50% B_0

The Meeting of the Parties adopts the dynamic HCR where:

The exploitation rate from the HCR (U_{HCR}) depends on estimated stock status (ss):

U_{HCR}	$= 0.05625$	for $ss > 50\% \; B_0$
	$= 0.1125 \; ss$	for $30\% \; B_0 < ss \leq 50\% \; B_0$
	$= 0.16875 \; (ss - 0.1)$	for $10\% \; B_0 < ss \leq 30\% \; B_0$
	$= 0$	for $ss \leq 10\% \; B_0$.

The Meeting of the Parties requests the SC to consider reference points for other fisheries in SIOFA and suitable Harvest Control Rule for these fisheries.

References

Caddy, J.F., Mahon, R. (1995), Reference Points for fisheries management. FAO Fisheries Technical Paper No. 347. Rome, FAO, 1995,83p.

Cordue, P.L. 2014 a. The 2014 orange roughy stock assessments. *New Zealand Fisheries Assessment Report 2014/50*. 135 p.

Cordue, P.L. 2014 b. A management strategy evaluation for orange roughy. ISL Client Report for Deepwater Group Ltd. 42 p.