Development, implementation and initial testing of candidate management procedures for the IJsselmeer/Markermeer

For the stocks of pikeperch, perch, bream and roach

Author(s): Iago Mosqueira, Thomas Brunel, Jasper Bleijenberg and Justin Tiano

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Summary

This report presents the work that was carried out in 2022 to develop a new set of candidate management strategies for the pikeperch, perch, bream and roach fisheries in the IJsselmeer – Markermeer complex. The management procedures proposed here are based on stock indicators that can be derived from the two main sources of data available for these stocks: 1) changes in abundance obtained from the scientific survey, and 2) landings quantities and composition from the commercial fisheries within the complex. The status indicators derived from these data are used in harvest control rules, set to propose a total allowable catch for the following year. These new developments build upon the experience from the previous Management Strategy Evaluation analysis (Tien et al. 2020a&b), and extends the set of options available. This report provides a brief demonstration of the application of the updated management tools on the pikeperch and bream operating models.

1 Introduction

A management procedure (MP) is an established system that outlines the necessary steps for regulating a fishery. These steps start with the collection of data, from scientific observations and the associated fisheries, followed by a model-based or model-free method to compute indicators of stock status that informs a decision rule. The metric for stock status can be obtained by the application of a statistical model, or from the calculation of more simple indicators from either or both surveys and catch data. Management Strategy Evaluation (MSE) provides a framework in which alternative MPs can be evaluated through simulation accounting for the expected degree of error or bias in data collection, system dynamics and implementation. The MSE simulations use an operating model (OM) which serves as a modelled representation of the possible dynamics of the system, and in which uncertainty regarding our knowledge of the system is central (Figure 1).

It is important to note that the main objective of the MSE analyses is to provide insight into the relative performance of different MP, rather than provide a realistic representation of the system being modelled. The complexities of real-world natural and human systems are challenging to accurately represent in these models. The MSE approach, nevertheless, allows the testing of various management strategies in a controlled (modelled) environment, providing decision makers with a range of options for which to explore their comparative performance, trade-offs and risks.

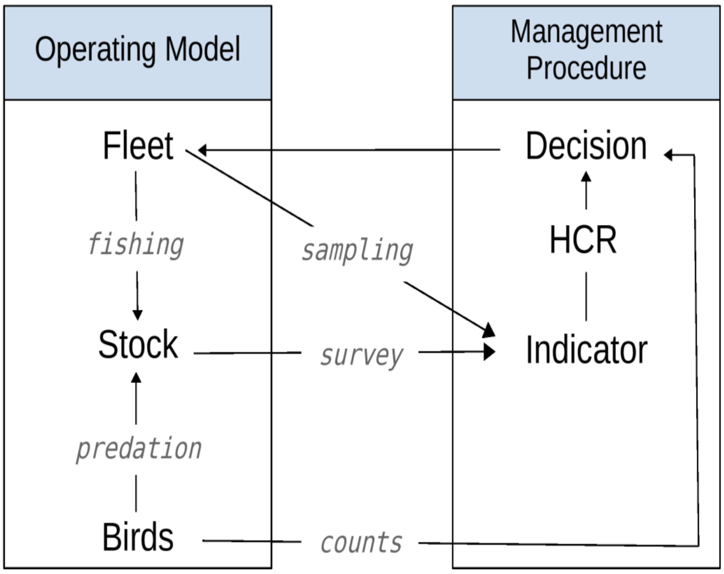

Figure 1: *Schematic representation of the simulation model constructed for the MSE analysis of candidate management procedures for IJsselmeer fish stocks.*

Previous testing of MPs for IJsselmeer stocks focused on two potential procedures:

1. A model-free MP, in which changes in stock status was inferred from the yearly trend in biomass of each stock, derived from the open-water survey. A decision on an updated catch level was then made based on the slope of the index over the last five years, and the distance of a weighted mean of the index biomass to a given target level. This target level was found by tuning the MP parameters to the required management objective, probability and time frame.
2. A model-based MP, that estimated changes in stock status relative to an F_{MSY} proxy using the samples of the lengths of fish in the commercial catches as input. The LBSPR (Length-Based Spawning Potential Ratio) estimator (Hordyk et al. 2016) was tested, but it required a significant quantity of additional information, substituted in many cases by assumed values, such as those on the life-history of the species. It also assumed a shape of the selectivity curve of the fleet or fleets exploiting the stock that did not match that of the main fleets in

the IJsselmeer. The method proved too sensitive to small changes in the right-hand tail of the length-frequency distribution of catches-at-length. A small number of large fish, which is usually not targeted or often caught by the fleets, could sometimes be present in the catch samples, and quickly disappearing from those same samples, which lead to large changes in the estimate of exploitation status, F/F_{MSY}.

As a result, a wider range of MPs has been explored while paying special attention to stock status estimators that could make the best use of the available data. The candidate MPs proposed here make use of the main sources of information available on stock status and dynamics: the biomass index from the open-water survey, and data on the commercial catches and their length distribution. The Harvest Control Rules (HCRs) tested provide a recommendation on a maximum catch level, or total allowable catch (TAC), to be applied by the fishing fleets acting on the stocks. At the moment, no assumptions are being made on possible implementation scenarios, so the initial analyses shown here assume that this TAC will be taken fully, and will not be exceeded.

These candidate MPs do not cover the full range of possible management and estimation tools. Instead, they provide a first indication of the ability of each procedure at managing these stocks. Based on the results of the performance evaluation, alternative MPs could still be proposed at a later stage. Combinations of multiple stock status indicators, for example, could prove to be a suitable option in this kind of data-limited situations.

Data-limited status indicators are generally sensitive to the quality of a single source of information. In comparison, complex stock assessment models integrate multiple data sources, in a statistically-sound manner. In general, it is possible to manage a stock using limited data as long as the quality of the signal on status and abundance they provide is constant in terms of bias and noise. Robustness to large levels of observation uncertainty can usually only be gained by following a less risky strategy, thus limiting exploitation so as to ensure stock survival.

2 Data collection

The first element of a management procedure is the collection of the data that will inform any evaluation of stock status and trends, referred to as the ‘observation error model’ (OEM). The MPs evaluated here all follow the current data collection procedures. The sources of data explicitly used in these procedures include the following:

- Data on total landings or catches by species and year.
- Samples of lengths, maturity and age in the landings.
- Survey of stock biomass and abundances at length/age.

Certain data sources which are being collected but are not currently used in the operating models, could potentially be used in future iterations. For example, more precise estimates of effort are only available for a very short period (2016-2018) but could eventually help establish the relationship between fish availability and catches. Collection and validation of this information is encouraged if the dynamics of the fleet are to be considered in more detail in the future.

3 Status indicators

The collected data is used by model-based or model-free methods to estimate or calculate an indicator of stock status, either in terms of abundance or exploitation level.

3.1 Survey-based biomass index

Stock specific catches-per-unit effort (CPUE; kg/sampled ha) from the survey are used as an indicator of changes in stock biomass. This was calculated from the estimated catches-at-age in the survey and the weight-at-age (both generated by the OEM).

3.2 Relative harvest rate

Harvest rate, which is the ratio of the total catch over the stock biomass, is a measure of fishing pressure frequently used in stock assessment models and management rules. It provides an alternative measure to instantaneous fishing mortality on the strength of exploitation of a stock. The concept of *relative harvest rate*, the ratio of total catch to a relative indicator of stock size (such as a survey index), has been proposed and tested recently for management on stocks for which a stock assessment is unavailable (Fischer et al. 2022). This stock status estimator makes use of the two main data sources on the IJsselmeer stocks:

1. The total catch estimates obtained from landings.
2. The annual open-water trawl survey.

Harvest rate rules have the potential to be more robust than those built around length-based indicators, as they are less influenced by changes in selectivity, recruitment or environmental factors. Here, we define the relative harvest rate using the biomass index from the survey as indicator of changes in stock size.

3.3 Length-based indicators (LBIs)

In data-limited fisheries, information is often not available or reliable enough to fully estimate the current status of a stock regarding is exploitation ($F/\ F_{MSY}$) and conservation (SSB/SSB_{MSY}) level. Statistical catch-at-age models, generally considered the best method for estimating stock status and productivity, require a long and reasonably precise time series of catch and weights at age, as well as indices of abundance known to reflect well the changes in the population caused by fishing. When this information is not sufficient for those models, which is true for the majority of fish stocks worldwide, other methods can provide useful estimates of changes in abundance. Length-based indicators and estimates have a long history, based on the known effect of fishing on the distribution of lengths in a fish population (Kell et al. 2022). Statistics summarizing the overall distribution, can be computed from the length frequency distribution of fish from either commercial catches or surveys. These are commonly called length-based indicators (LBIs) and can be used in tandem with reference points based on life history parameters to inform on stock status.

The theory behind their value is based on the fact that, in a heavily exploited stocks, less individuals survive to the larger sizes compared to lightly exploited stocks (Miethe et al. 2019). Consequently, absolute values of the LBI to its reference ratio can be useful proxies for stock status, but changes in the length distribution derived from these LBIs can also be used to track trends in stock abundance.

Two examples of applying LBIs to inform the decision-making process for a stock can be found in (Jardim et al. 2015) and (Miethe et al. 2019) where they apply LBIs to stocks with varying life histories, by using the computed values as inputs for harvest control rules. The performance of these HCRs was evaluated using MSE. In that context, several LBIs have been incorporated into the FLR toolset (Fisheries Library in R; (Kell et al. 2007)) for utilization at developing MPs for the IJsselmeer stocks. With their respective reference values LBIs are able to convey information about the status of a stock. The chosen LBIs have been selected from those explored and tested in a recent analysis (Kell et al. 2022), as well as those considered by ICES for data-limited stocks (ICES 2022). Figure 2 describes potential LBI indicators, their calculation, and the corresponding reference points for the assessment of stock status.

LBI statistics

Indicator	Calculation	Reference point	Indicator ratio	Expected value	Property
lmaxy	Length class with maximum biomass in catch	Lopt = 2/3 L∞	lmaxy/Lopt	=1	Optimal yield
bheqz	Von Bertellanfy Z value for total mortality		bheqz	<0.3	Optimal fishing mortality
lbar	Mean length	L50 (length at 50% maturity)	lbar/L50	>1	Optimal yield
lmean	Mean length of individuals > lc50	LF=M = 0.75*lc50 + 0.25L∞	lmean/LF=M	=1	Maximal sustainable yield
lmean	Mean length of individuals > lc50	Lopt = 2/3 L∞	lmean/Lopt	~1	Optimal yield
lmean	Mean length of individuals > lc50	Lmat (Length at maturity)	lmean/Lmat	>1	Conservation (immatures)
l25	25th percentile	L50 (Length at 50 % maturity)	l25/L50	>1	Conservation (immatures)
lc50	Length at 50% of modal abundance	L50	lc50/L50	>1	Conservation (immatures)
lmax5	Mean length of largest 5%	L∞	lmax5/Linf	>0.8	Conservation (large individuals)
l95	95th percentile	L∞	l95/Linf	>0.8	Conservation (large individuals)
pmega	Proportion of individuals above Lopt + 10%		pmega	>0.3	Conservation (large individuals)

Figure 2: *Length based indicators and their corresponding reference points.*

Length-based indicators have the potential to manage data-limited fisheries efficiently, and tend to be well accepted as they are simple to compute (Kell et al. 2022). The relationship between those quantities and the processes causing changes in their values are generally intuitive. An exploration of a range of LBIs was thus conducted to better understand their capacity to inform decision making for management of the IJsselmeer stocks.

3.3.1 LBI implementation and simulation-testing

To assess the performance of the LBIs for the IJsselmeer stocks, the indicators were applied to three hypothetical stock trajectories (Figure 3). These were based on a population with the life history characteristics of pikeperch and under various past histories of exploitation:

1. The first trajectory (F_{MSY}) represents a scenario for which the F value (mortality due to fishing) imposed on a stock grows to 1.5 times F_{MSY} over 24 years. After which a reduction in F is imposed leading to a decrease to 0.5 times F_{MSY} over the next 15 years followed by a subsequent increase from half of F_{MSY} to 0.9 times that value.
2. The second trajectory (one-way) displays F as a steady upward trend. Over a period of 60 years, fishing mortality increases progressively from 0.5 times the F_{MSY} value to three times that amount, with the addition of a multiplicative noise modelled as following a normal distribution,$N(0.02,0.001)$.
3. The third trajectory (nocon) contains very little contrast, with a random low F, $N(0.25,0.01)$.

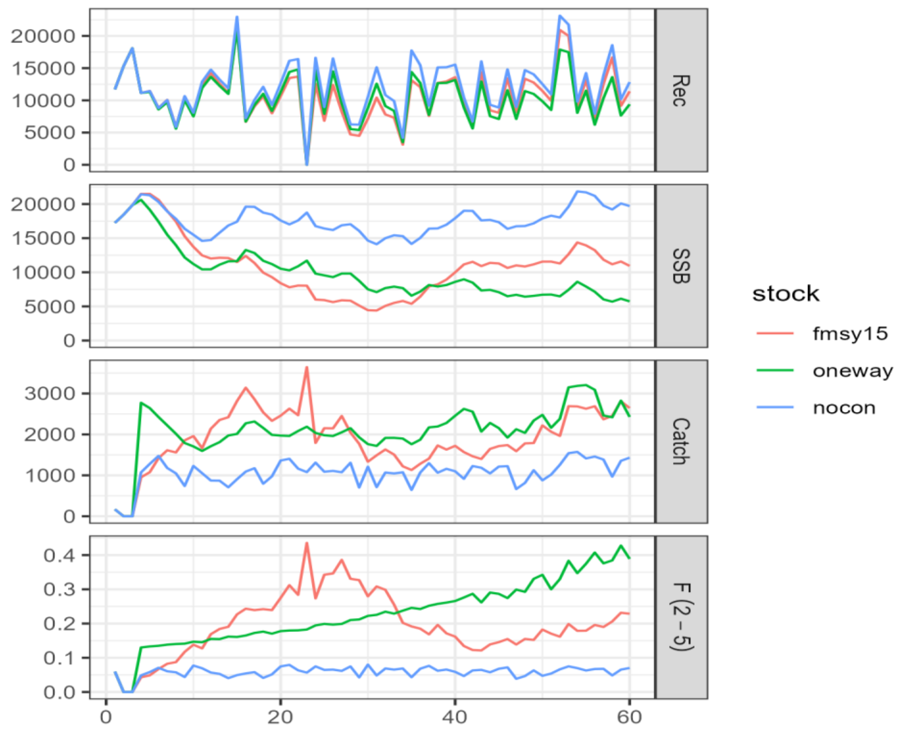

Figure 3: *Stock trajectories for the three simulations.*

Figures 4, 5 and 6 (F_{MSY}, one way and nocon scenarios respectively) show plots of the time series of status given by the indicator-reference ratio against the actual stock trajectory that leads to them. The tested length-based indicators should be able to discriminate between years when status is positive or negative so that management action is triggered correctly.

Each of these trajectories lead to differences in relative stock status over the time series, which the LBIs attempt to estimate (Figures 4, 5 and 6).

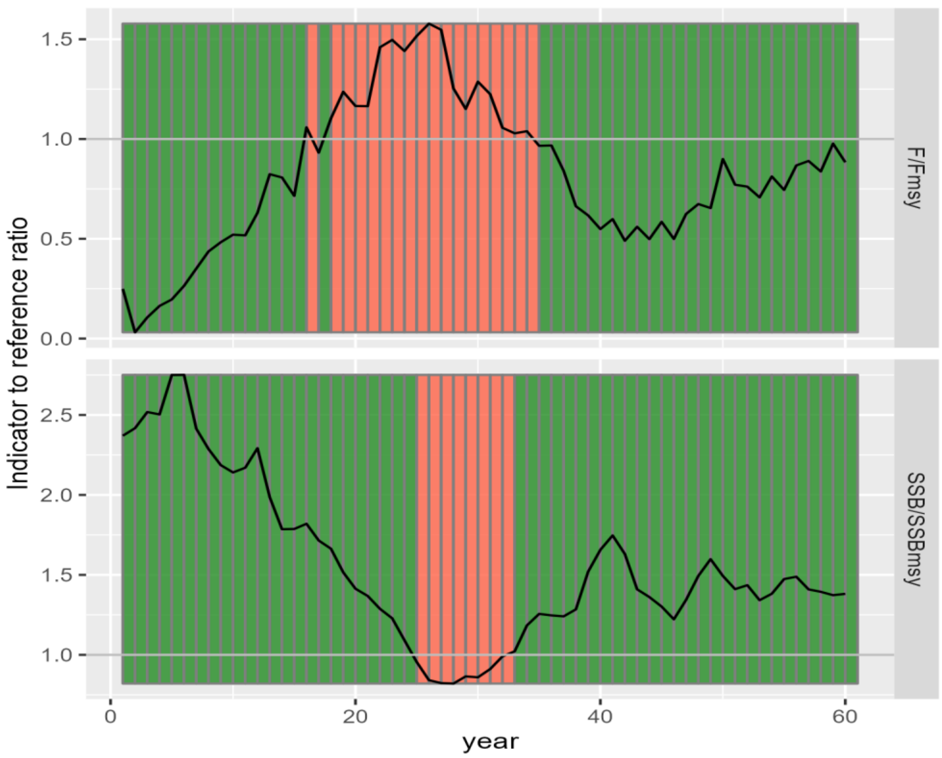

Figure 4: *Status of the stock for the F_{MSY} simulation.*

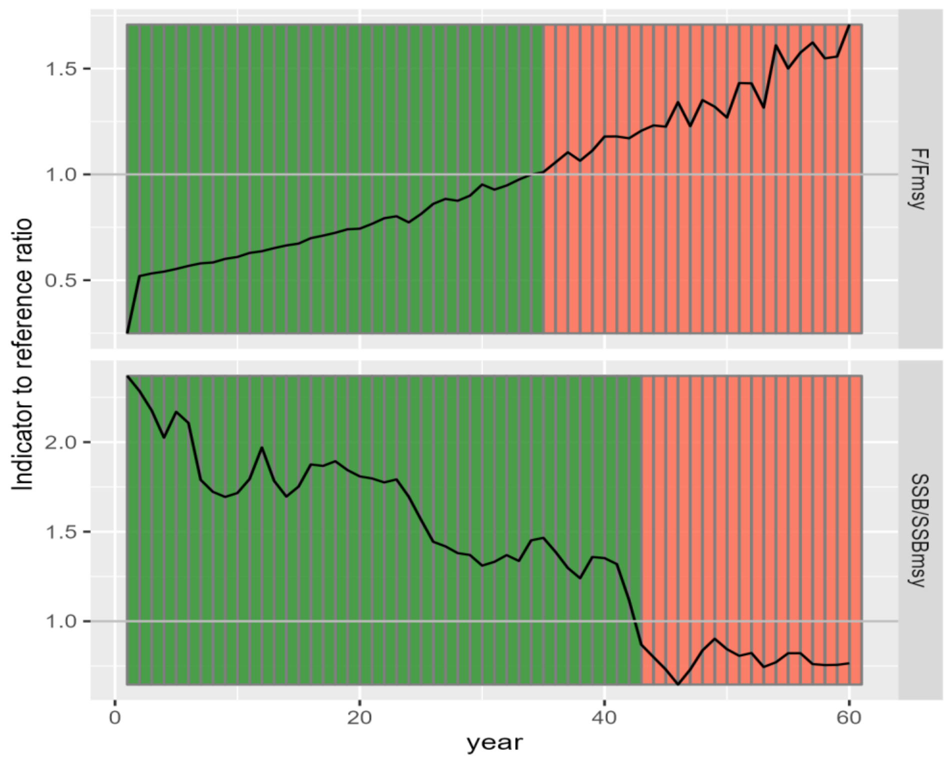

Figure 5: *Status of the stock for the one way simulation*

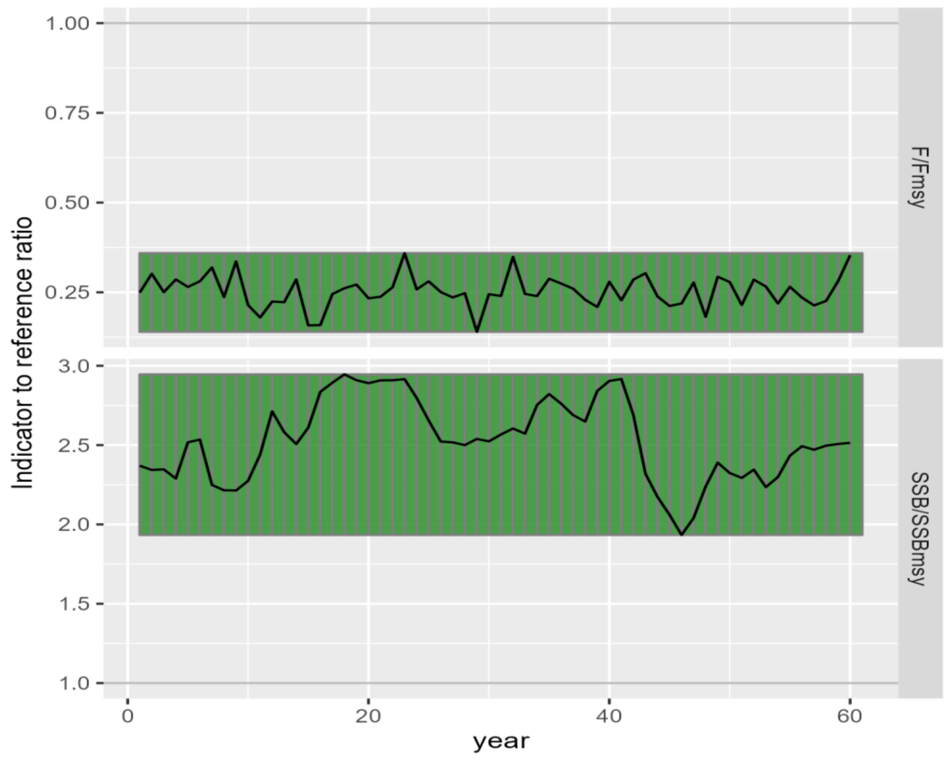

Figure 6: *Status of the stock for the nocon simulation.*

The ability of the proposed LBIs to inform on stock status was evaluated by comparing their status estimate with the actual status of the simulated stock relative to a reference point. The receiver operating characteristic (ROC) curve (Krzanowski and Hand, 2009) was computed for each indicator to assess their ability to determine if the stock was over-exploited, falling on one side of the reference point boundary, and thus management action should be taken. The higher the Area Under the Curve (AUC), the better its performance.

3.3.2 Results

The set of LBIs tested (Figure 2) showed varying abilities to provide a reliable inference on stock status and changes to it.

3.3.2.1 F_{MSY} trajectory

For the F_{MSY} trajectory, the best performing LBIs are l95 and Pmega (Figure 2). With L95, the 95th percentile of the length distribution strongly follows the trend in SSB over SSB_{MSY} (Figure 7). Its reference is Lopt (defined as 2/3 * Linf). The performance as visualized in the ROCs corresponds with the situation as depicted with lower figures. The red color indicates overfishing. Pmega is the ratio of lengths that exceed Lopt by 1.1 times. This LBI does not have a reference point established, but the ratio is generally expected to be at least 30 percent of the population to ensure the conservation of large individuals.

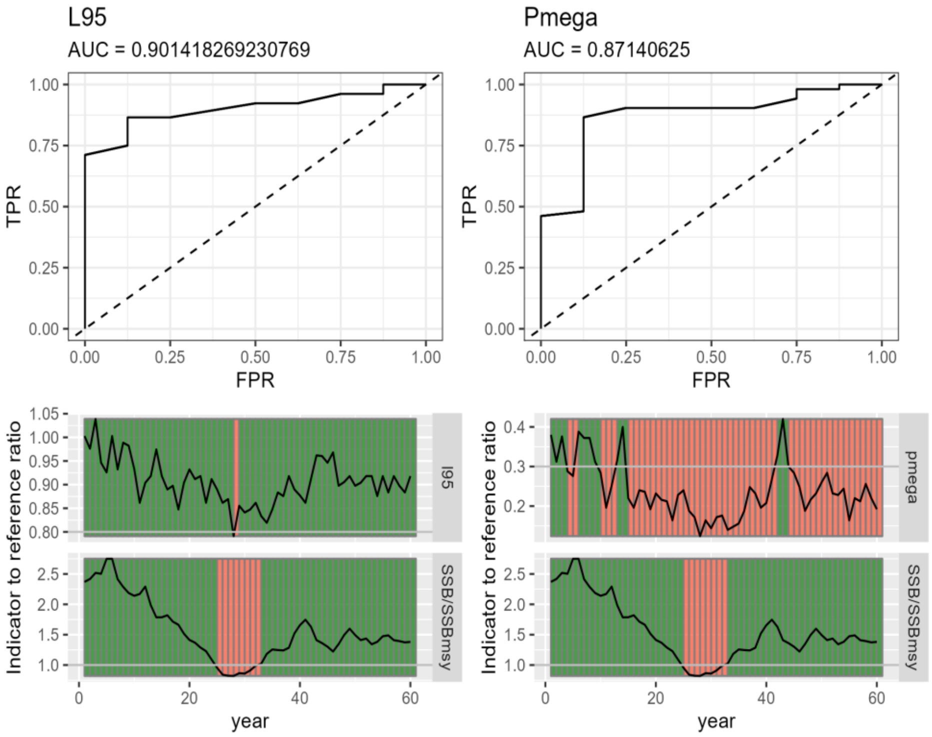

Figure 7: *F_{MSY} scenario. Performance of L95 and Pmega LBI indicators.*

The LBIs that perform less well in this situation are the Lc50 and lmaxy indicators (Figure 2). For Lc50 (length at 50% of modal abundance) this might be the case because the mode of the fish abundance at length fluctuates more than other indicators with recruitment. The reference for Lc50 is the mean length of individuals at 50 percent maturity. Currently this parameter value is estimated from the maturity at age, but this can be a life history parameter input as well (Figure 8).

For Lmaxy (the length class with maximum biomass in the catch)its value is easily shifted by the growth of a strong year classes and can shift easily between years. The reference point for this LBI is Lopt, as indicated in Figure 2 has the Lopt value as reference.

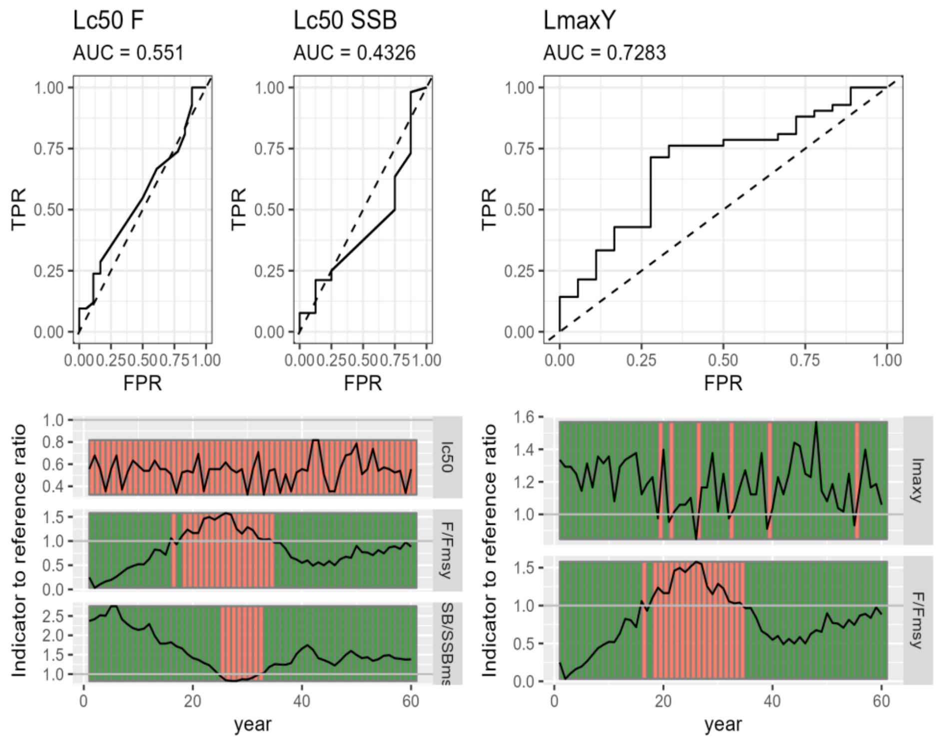

Figure 8: *F_{MSY} scenario. Performance of Lc50, compared with both F (Lc50 F) and SSB Lc50 SSB) reference values, and of the and the LmaxY over Lopt indicator.*

3.3.2.2 One way trajectory

For the one-way trajectory, the best performing LBIs are also Pmega, and L95 (Figure 9). The performance of these indicators for this trajectory are poorer than for the F_{MSY} trajectory, which contains more information of stock dynamics as it includes both decline and recovery phases. The length distribution might therefore be a little less fiercely impacted on a yearly basis and as such the noise around the LBI is relatively bigger. Nevertheless, these LBIs perform relatively well in respect to the higher AUC values in this scenario.

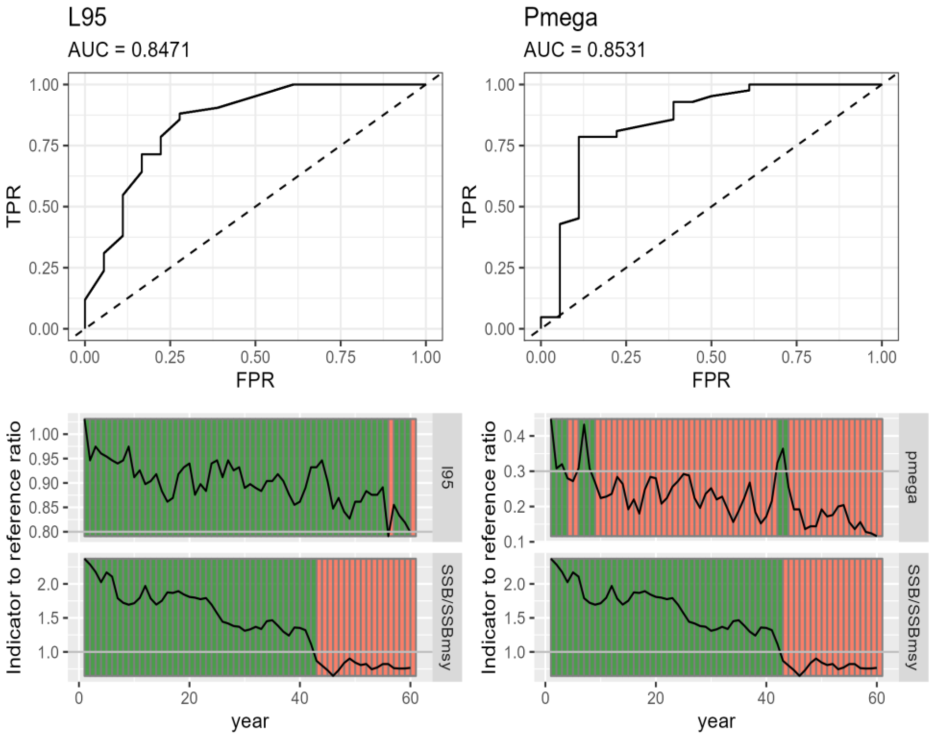

Figure 9: *one way scenario. Performance of L95 and Pmega LBI indicators.*

The second and third worst LBI-reference ratios are L25 and bheqz Figure 10). L25 is the length at the 25th percent quantile of the length distribution. This indicator behaves similarly to lc50 and can be influenced by the strength of recruitment. Bheqz estimates the Von Bertalanffy Z value for total mortality. The calculation of this value relies on an internal estimation of Lc50, calculating Z as:

$$z = \left(k(L_{\infty} - L)\right)/(L - L_{c50})$$

where L is the mean length weighted by the relative abundance and k (the von Bertalanffy growth parameter). The bheqz LBI is generally variable, but this noise seems to affect the performance most when the fishing pressure gradually increases. Though not shown in this report, under the F_{MSY} trajectory, the bheqz LBI performed reasonably well.

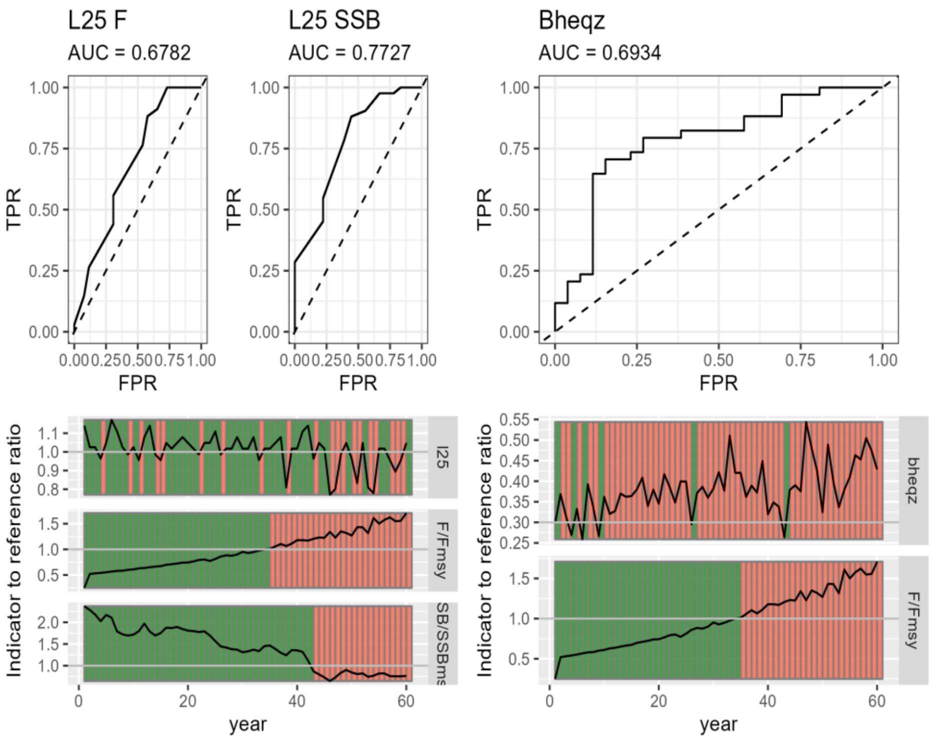

Figure 10: *one way scenario. Performance of L25, compared with both F (L50 F) and SSB (L50 SSB) reference values, and Bheqz LBI indicators.*

3.3.2.3 No contrast trajectory

All years in the no-contrast OM trajectory present a positive stock status. With this trajectory, most LBI-reference ratios are quite far away from the reference values, showing a relatively positive performance for the LBI. For example with Lmaxy (Figure 11), no gradation in performance can be deduced from the visualizations for the good performing LBI reference ratios.

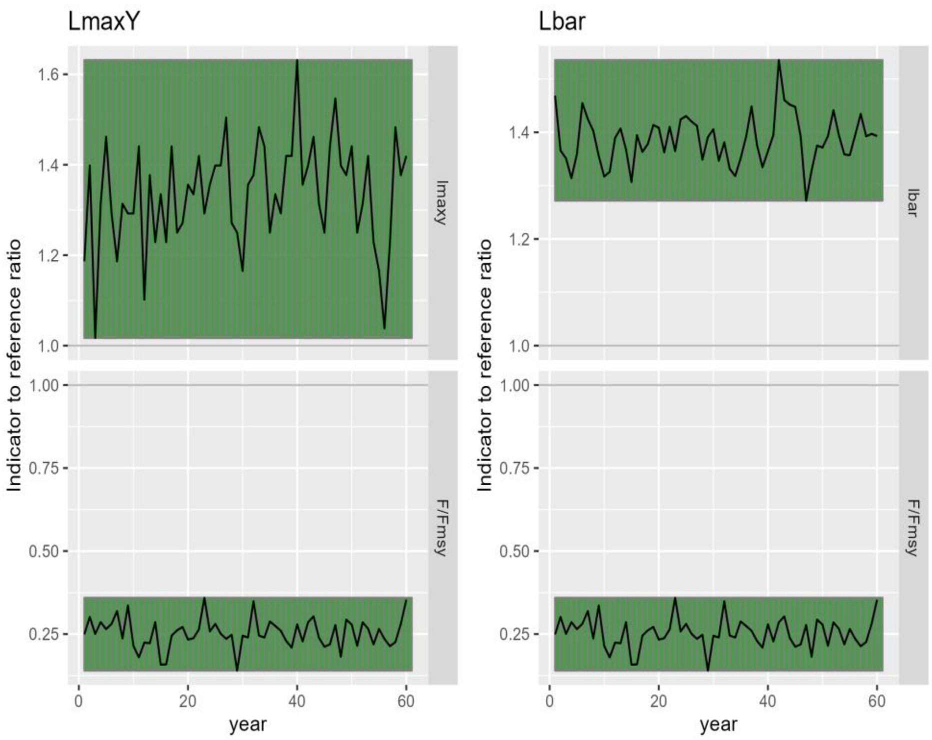

Figure 11: *no contrast trajectory. Performance of LmaxY and Lbar LBI indicators.*

However, it is possible to get a sense of bad performing LBI indicators. Similarly to other scenarios, the LC50 LBI perform the worse, followed by Pmega in this situation (Figure 12). Both have some contrast in the indicator-reference ratio, and they vary greatly compared to F/ F_{MSY} and SSB/SSB_{MSY}.

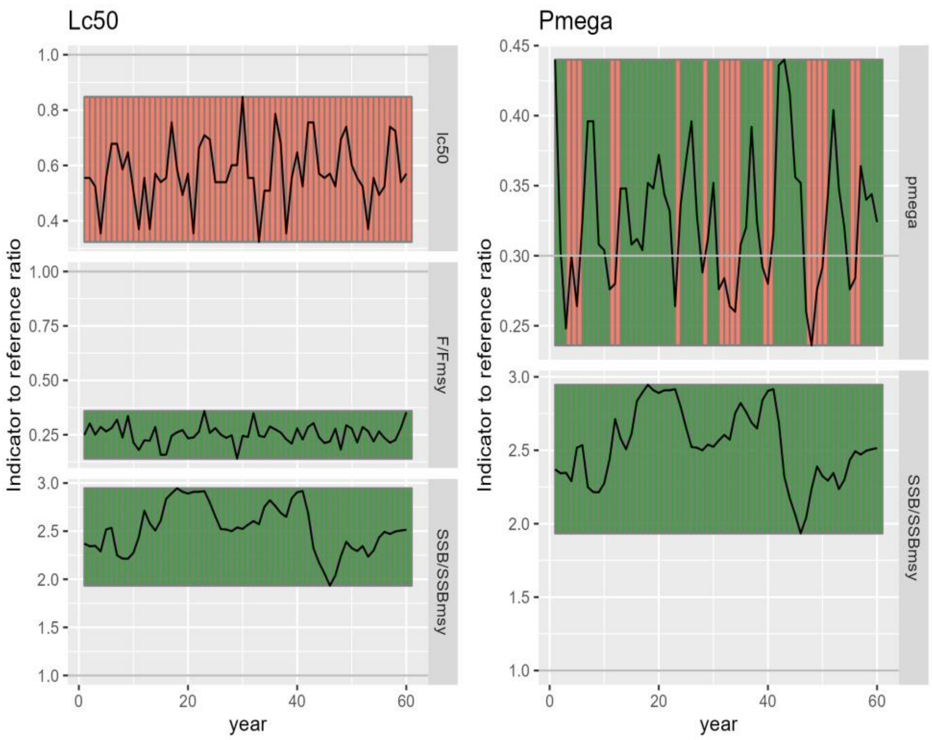

Figure 12: *no contrast trajectory. Performance of Lc50 and Pmega LBI indicators.*

4 Harvest control rules

The following Harvest Control Rules (HCR) were chosen to match the possible status estimators presented above. These serve as an initial selection of possible functional forms, although limitations exist on what HCRs can or should be used with a given status estimator.

4.1 Harvest rate HCR

The relative harvest rate estimator is connected to a hockey-stick shaped HCR, implemented as proposed by Fischer et al. (2022) :

$$TAC_{y+1} = I_y \cdot H_{target} \cdot BSG \cdot \lambda$$

where the biomass safeguard (BSG) is defined as

$$\mathrm{BSG} = min\left(1, \frac{I_y}{I_{trigger}}\right)$$

In this case, the TAC for the coming year is defined as the product of the survey index I_y and the target harvest rate value, H_{target}. In addition, the biomass safeguard (BSG) is applied, which reduces the target harvest rate when the index falls below an index trigger value, $I_{trigger}$. The BSG essentially imposes a hockey-stick functional form on the control rule, similar to the ICES MSY advice rule. The response parameter λ can be used to scale the entire harvest control rule, and adjust its performance to any desired criteria through the tuning process.

The two control points in the HCR, H and Itrigger, can be defined empirically. The proxy proposed by Fischer et al. (2022) for $I_{trigger}$ is the lowest observed stock index, multiplied by an uncertainty buffer of 1.4 in the absence of better knowledge. The reference level for harvest rate, H_{target}, can be defined as the mean of the past relative harvest rate values for years in which the stock was considered exploited at below MSY ($F < F_{MSY}$; based, for instance, on the exploitation level proxies derived from a length-based indicator). A reference level can also be chosen based on the perception of various stakeholders regarding a specific period when catch and catch rates both appear to be reasonable and stable.

In the context of this MSE analysis, tuning can be used to find the optimal value for one of the control parameters (typically H_{target}), while the other is fixed a priori, following the approach of Fischer et al. (2022).

4.2 Trend based HCR

The survey biomass index was used in the so-called 'trend based HCR', as developed by the Commission for the Conservation of the Southern Bluefin Tuna (Hillary et al. 2015). In this HCR, the slope in the biomass index (in log space) is calculated over the last 5 years of data (linear regression of the index vs years). This slope is then used to define a TAC multiplier to be applied to define the next TAC :

$$TAC_{y+1} = TAC_y \begin{cases} 1 - k_1 \times |\text{slope}|^{\gamma} & \text{slope} < 0 \\ 1 + k_2 \times \text{slope} & \text{slope} \geq 0 \end{cases}$$

The parameters in this HCR are the values k_1 and k_2 which represents the responsiveness for the TAC change to the slope in the index, and γ, which allows for non linear relationship between TAC change and the index slope.

4.3 CPUE-based rule

The CPUE rule (ITOC 2018) bases the decision of future TAC on the recent trend in a stock size index, combined with the distance between the current index value and a tunable target (Figure 13). It was originally developed for application on commercial CPUE indices in tuna fisheries. The index used here is the survey biomass index, as in the previous HCR. Future TAC is calculated as a proportion, (TAC_{mult}), of the current TAC, which is defined as

$$TAC_{mult} = 1 + k_a Sl + k_b D$$

Where Sl is the slope of the survey biomass index over the last 5 years, D is the difference between current index value and the target value, and k_a and k_b are parameters of the relative weight assigned to the previous two quantities (Figure 13).

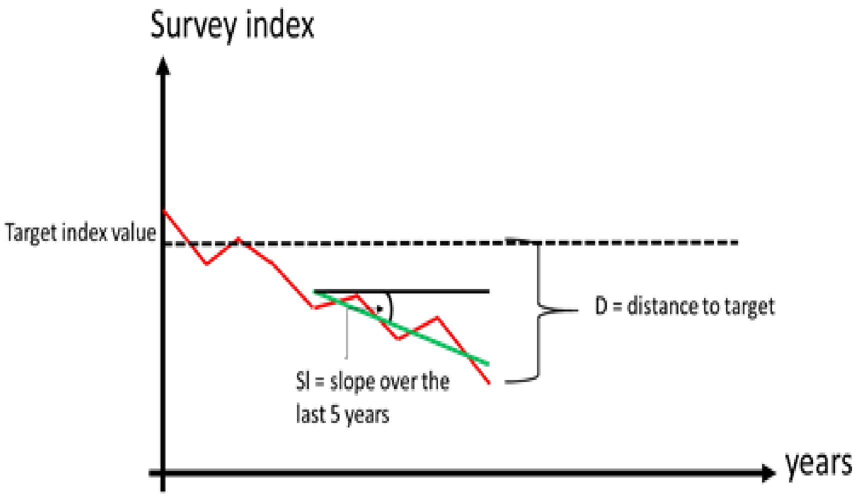

Figure 13: *The CPUE rule is based on the recent slope in the survey index (SI) and the distance to the target index value (D).*

4.4 Target HCR

The harvest control rule to be used in combination with the various length-based indicators is the target harvest control rule of Hoshino et al. (2020), which is commonly applied to mean length in the catch (MLC). TAC is adjusted up or down if the average of recent MLC values is above or below the target value for the MLC. In this rule the future TAC is calculated as a proportion, TAC_{mult}, of the current TAC, which is defined as

$$TAC_{mult} = \begin{cases} 0.5 \times \left[\frac{(MLC_{recent})}{(MLC_{limit})}\right]^{2r} & \text{if} \quad MLC_{recent} < MLC_{lim} \\ \left[0.5 \times \left(1 + \frac{(MLC_{recent} - MLC_{limit})}{(MLC_{target} - MLC_{limit})}\right)\right]^{r} & \text{if} \quad MLC_{recent} \geq MLC_{lim} \end{cases}$$

where MLC_{recent} is the average of the recent MLC values (for example over the last 5 years), MLC_{target} and MLC_{limit} are the target and limit reference values for MLC, and r is a reactivity parameter (for values of r greater or less than 1, the HCR will increase/reduce the effort by a value larger or smaller than $r = 1$).

Educated guesses can be used to choose the initial parameter values for target and limit mean length, but optimal values for these parameters can also be obtained by multidimensional; tuning.

4.5 Limits to yearly changes in TAC (change cap)

All the harvest control rules can be tested with an additional catch stability mechanism that, after the first year, limits the proposed TAC not to change from the previous value by more than a given percentage (upwards and downwards). The current runs have been carried out without any limit, but those can easily be implemented and their effect on management performance, and possible catch stability, can be tested.

4.6 Banking and borrowing

Management of the fishing activity of the main fleets is expected to be based on various measures that limit or allow expansion of fishing effort. Advice based on maximum catch cannot be directly translated to changes in the level of effort in the fishery. Constant catchability is rarely a reasonable assumption (Marchal et al. 2003), as multiple factors related to both stock dynamics and fishing activity have an effect on the catch that can be obtained applying the same level of fishing effort. For example, changes in fish distribution as abundance increases or decreases, and the subsequent adaption of fishers to those changes, are both bound to alter the effort to catch relationship.
Given the limitations on the data available on the effective effort of the fishery, and on their potential catchability, the operating model cannot be expected to be able to model and predict fishing effort, or use it for the provision of management advice.

If a management authority is required to convert catch-based advice into limitations on fishing effort, a correction mechanism can be established by which deviations from the expected catch, either positive or negative, are used to correct the advice in the following year. This inter-annual quota flexibility permits modifications of the advice obtained from the application through effort of a catch-based harvest control rule. If the catches obtained under the effort limits derived from the catch advice where lower than the recommended TAC, future catches can be increases by some amount (e.g. 10%) to compensate for that loss, while if they were higher, future TAC is lowered in the same way. This is similar to the banking and borrowing mechanism applied in some stocks (see for example Oliveira (2013)), but is directly triggered by the disparity between TAC and realised catch. In many cases, this mechanism is used to allow for flexibility to respond to market and social considerations in the application of TAC limits, thus the name of banking and borrowing.

These mechanisms are often incorporated to existing management procedures, and their effect evaluated through simulation. In this case, the compensation scheme is part of the management procedure, and corrects the catch advice returned by the harvest control rule before any implementation error. Evaluations of such rule have been carried out, but results are still preliminary. Initial values for the correction level have been set at 10%, so that a TAC cannot be increased or decreased by more than that amount, and always only up to the difference between observed and predicted catches.

5 Evaluation and tuning of the management procedures

The process for tuning management procedures consists in searching for the value of one or more HCR control points that would lead to the required management objective. It is in essence what was performed in previous analyses (Tien et al. 2020a, 2020b). Preliminary MSE tuning runs have been conducted for a single example of HCR to ensure the procedure works as expected, but complete results will only be presented once the final set of OMs has been finalized, and a set of tuning management objectives has been agreed.

5.1 Performance statistics

The effectiveness of management procedures is evaluated based on a number of dimensions related to both stock conservation and productivity. These dimensions are determined by the management objectives and interest of all stakeholders (Punt et al. 2014). A series of performance statistics that provide a precise quantification of those objectives need to be defined beforehand. For this, the existing set of performance statistics from the previous analysis (Tien et al. 2020a, 2020b) was reviewed and deemed suitable for the updated MSE. The following list presents these metrics under three categories: 1) conservation of fish stocks, 2) conservation of bird populations, and 3) fishery's yield. The name for each statistic employed in different output tables and plots can be found in parenthesis.

1. Conservation
   - Mean spawner biomass relative to unfished (SB_0).
   - Mean spawner biomass relative to the spawner biomass at MSY (SSB_{MSY}).
   - Mean fishing mortality relative to the fishing mortality at MSY (F_{MSY}).
   - Probability of being in the Kobe green quadrant, where $F < F_{MSY}$ and $SB > SB_{MSY}$ (green).
   - Mean biomass relative to B_{lim}, defined as 10% of virgin (B_{lim}).
   - Probability of mean biomass being less or equal to B_{lim} (PB_{lim}).
   - Biomass-weighted mean length (BWML).
2. Birds
   - Probability that the fish biomass available to birds fulfils their needs (PBVBi).
   - Fish biomass available to birds (BVBi).
3. Yield
   - Mean catch over the years (C).
   - Average annual variability in catch (AAVC).
   - Percentage of inter-annual change in catch (IACC).

These performance statistics are computed for one or more time periods, as averages across years to avoid the effect of process variability in their estimates. Calculations are carried out separately for each stock, and do not, for example, compute aggregated yields or the combined biomass available to the bird populations.

5.2 Tuning management procedures

The candidate management procedures have control parameters which will impact the overall performance of the MP. These control parameters can be automatically adjusted so that the management procedures meet the objectives set by the managers. This process is called “tuning” and is carried out by iteratively testing different values for the control parameter that is deemed to be the most appropriate, until the resulting management procedure meets the tuning objectives.

In these preliminary tests, tuning was carried out for the Harvest Rate HCR for both pikeperch and bream for illustrative purposes. Ultimately, the management procedures will be tuned for all four stocks, and the performance of the tuned MP will be evaluated to highlight their respective capabilities and trade-offs. The management objectives will need to be clearly defined and agreed upon together with the managers. For the purpose of demonstrating the tuning process in this report, the following management objective was chosen: to achieve, over the medium to long term (years 2035 to 2044), a 60% probability of being simultaneously at an exploitation level at or below the fishing mortality associated with Maximum Sustainable Yield (F_{msy}) AND a stock size at or above the biomass level necessary to deliver in the long term the Maximum Sustainable Yield (B_{msy}).

The work conducted in 2022 focused mainly on methods development. The full set of simulations and tuned MP’s will be presented at the end of 2023. Here, we show only a limited number of runs, for illustrative purposes, using the pikeperch and bream stocks as examples.

5.3 Pikeperch

The update set of operating models for pikeperch was used for testing the new MPs: one that responds to changes in the relative harvest rate, and another one than responds to trends in the survey estimates of biomass. Tuning was set initially to achieve a 60% probability of both fishing mortality and spawning biomass being at the corresponding MSY levels (F/F_{MSY} and SB/SB_{MSY}).

An example run (Figure 14) shows the population and fishery trajectories of this initial tuned run for the relative harvest rate MP (Section 4.1).

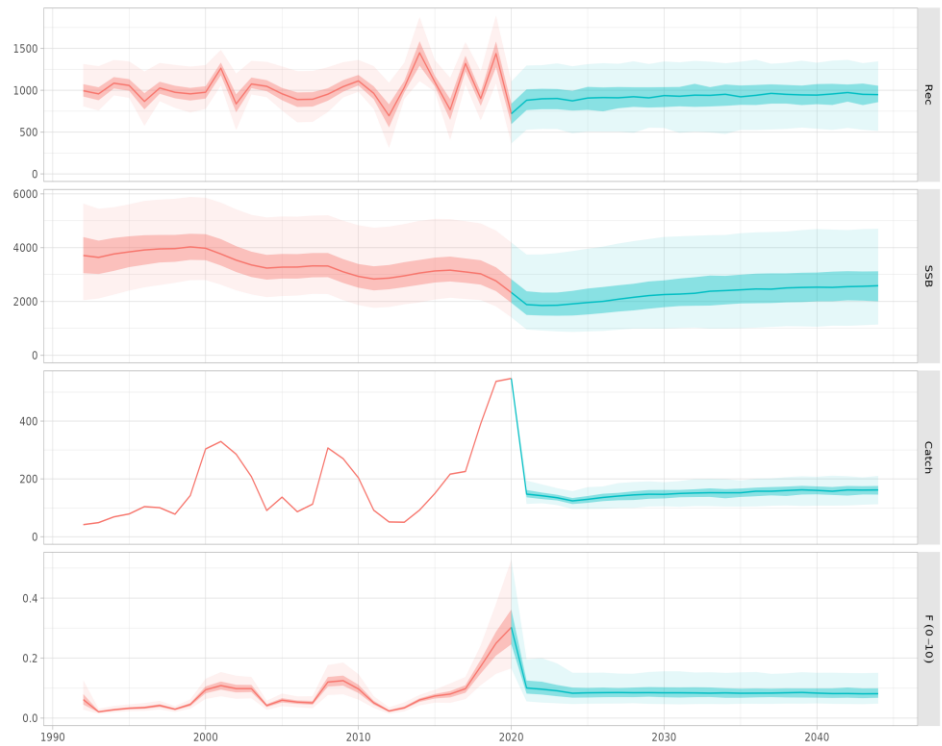

Figure 14: *Example of tuned MP for pikeperch. The MP is based on the harvest rate indicator and HCR (Section 4.1), tuned to obtain a 60 percent probability of being in the Kobe green in the 2035-2044 period.*

This MP has then been applied to a set of alternative OMs that reflect a number of alternative scenarios on past and/or future population and fishery dynamics. For example, the possible impact of cannibalism on age 0 pikeperch following a large recruitment event, or a linear decrease in overall productivity leading to a reduction in the expected maximum biomass and recruitment of pikeperch.

5.4 Bream

Prior to applying any MP, the bream OM was projected one year ahead (to 2021), imposing a decrease in fishing effort by 2/7 in order to approximate the effect of the reduction in the number of fishing days from the seine fishery from 7 days to 2 days. In reality this reduction occurred in 2022, not 2021 as implemented here. However, this was done so the starting conditions for the simulation reflect the recent management decision, which is important for some of the MPs which use last year's catch as starting point to set future TACs, by applying annual multipliers.

The implementation of MPs on the bream OM was tested using the following MPs: trend HCR applied using the survey index (Section 4.2) and Target HCR applied using the mean length in the catches (Section 4.4).

Those MP were not tuned, and HCR parameters were set manually so that the MPs led to a stock recovery, for illustrative purposes. The implementation of both MPs is shown in figure 15. This results in either future catches remaining at the current low level (trend MP) or being reduced further (target MP). This leads to fishing mortality levels that allow for the stock to recover to high levels at the end of the simulation period but without reaching an equilibrium.

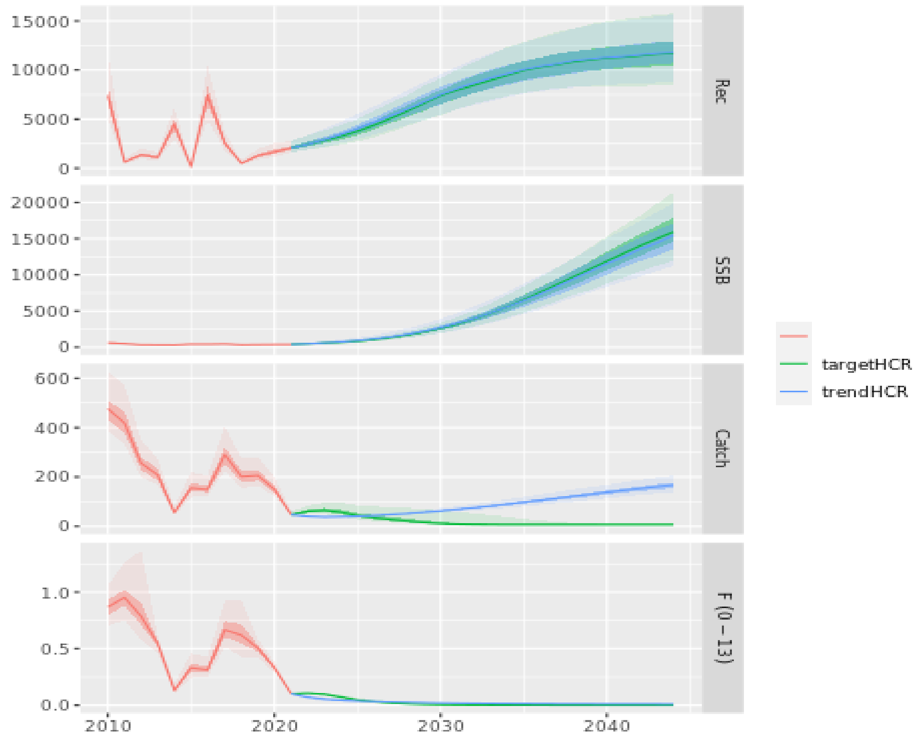

Figure 15: *Implementation of two management procedures on the bream OM (green: target HCR implemented based on the mean length in the catch indicator, blue: trend HCR implemented based on the survey index.*

An attempt at tuning an MP was also made, using the harvest rate MP (Figure 16). The tuning was conducted with the objective to find the target harvest rate value that leads to a 60% probability of being in the green portion of the Kobe plot for the period 2035 to 2044. The target harvest rate that achieved this criteria was 6.625. The corresponding MP has a similar effect on the stock as the 2 MPs above. The tuned harvest rate MP however had a strong initial reduction in the catch, and a subsequent increase to higher levels than for the 2 other MPs.

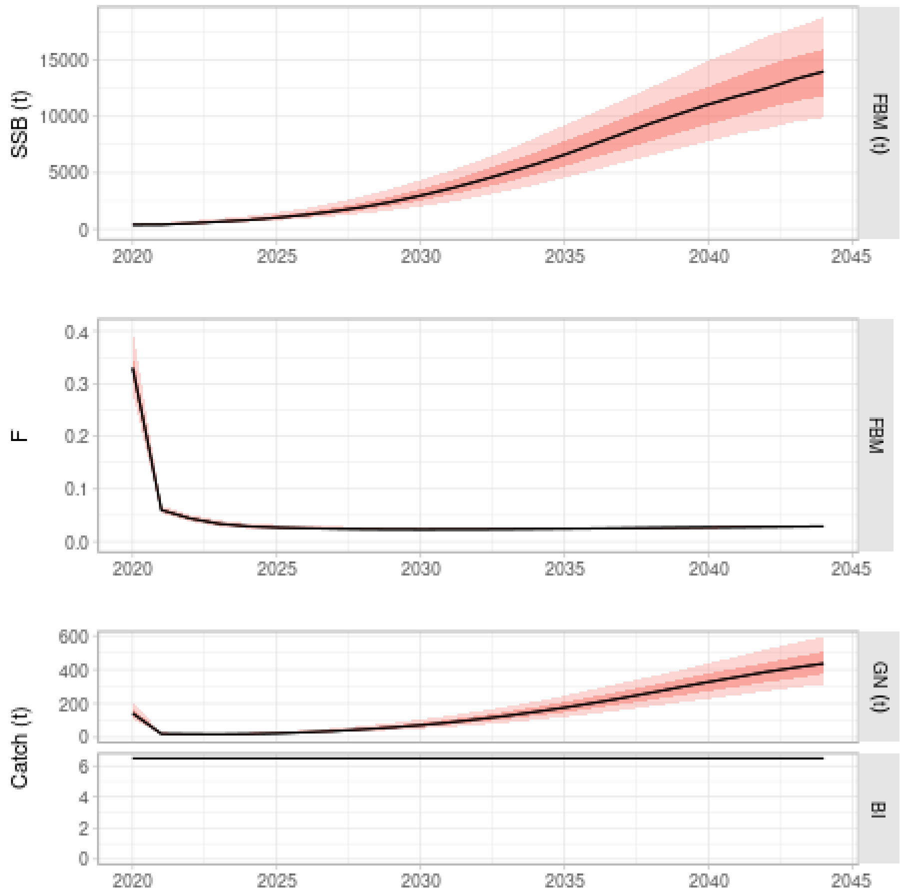

Figure 16: *Implementation of the harvest rate MP, tuned to achieve a 60 percent probability of being in the green area of the Kobe plot over 2035 - 2044. Top two panels show the SSB and fishing mortality for the bream stock, while the bottom ones present the catches by fishery (commercial and birds).*

6 Risks and precision of alternative management objectives

The previous MSE exercise proposed two candidate management objectives, and various probability levels, for which MPs could be tuned (Tien et al. 2020a, 2020b). One considered the probability of the stocks being exploited at sustainable levels by setting to achieve a 50% probability of the stock being exploited at or below F_{MSY} in the period 2026 to 2028. The other considered the risk of overexploitation, and was set to achieve risk levels smaller than 5% for the stock biomass falling below the limit reference point (B_{lim}), which was set at 10% of the calculated virgin biomass.

Further exploration of the OM characteristics has led to reconsider the use of performance indicators based on the tails of the uncertainty envelope. Extreme quantiles of the distribution of stock biomass is poorly determined in the data-limited approach employed to condition the IJsselmeer fish stock OMs. Both prior distributions and selection criteria can be expected to be robust in determining the central tendency of those values (Bentley and Langley 2012) but are less reliable for the values required to apply the risk criteria employed in the past (Butterworth et al. 2010).
The proposed tuning process would now be targeted to achieving a given probability of the stock being exploited at levels expected to be sustainable in the long term, for example a 50% or 60% probability of fishing mortality, or a sufficient proxy, being at or below the MSY level. Risks of biomass falling below levels in which severe impairment of recruitment could be expected, or some other appropriate minimum limit reference point, will still be monitored. If a strategy is deemed too risky, a higher probability of achieving the target level can be applied, and the updated risks further explored.

The approach followed in 2023 will thus consist of defining management objectives - jointly with the managers - based on MSY criteria (e.g. 60% probability of being in the green area of the Kobe plot over 2035 - 2044, as used here for illustrative purposes). For each tuned MP, the biological risk (probability of $SSB<SSB_{lim}$) will be calculated, and if the risk is deemed to high (e.g. higher that 5%), tuning will be redone for a more conservative management objective (e.g. 70% probability of being in the green area of the Kobe plot), and both runs will be presented.

The trade-off between expected sustainability and associated risks will be explored together with those related to expected catch and catch rate levels, availability of food for the bird populations, and possible size composition of the fish population.

7 Discussion

In the simulations, the dynamics of the birds populations and of their predation on the different fish stocks are only modelled for perch, where an empirical relationship between birds catches and perch recruitment is used to simulate future predation. For the rest of the stocks, the birds are modelled as a separate "fishing fleet", with a specific selection pattern. The assumption is made that the future catches of "bird fleet" are constant, equal to the average of the most recent three years of data. By doing so, the fisheries management procedures are tested while "reserving" the necessary amount of fish to sustain the bird populations their current levels. However, there are certain limits to these assumptions. A constant catch by the birds implies that the "effort" of the birds fleet will need to be adjusted to any change in fish stock size. If a fish stock becomes small, it is likely that the birds will switch to other prey species, rather than increase their time targeting that specific stock (in which case the catches by the birds may decrease). Conversely, if a fish stock becomes very abundant, it could receive more targeting by the birds, and therefore, their catches may increase. Finally, smelt, one of the preferred prey species for the birds, is currently at low levels, but if its abundance was to recover to earlier levels, this may cause a substantial reduction of bird-mediated predation pressure on the IJsselmeer fish stocks in this analysis.

The current configuration of the OMs for the four stocks does not accurately model fishing effort. Effort is an internal variable in the OM that is required by the function used to do the projections. However, this function works based on relative changes in effort, and therefore any dimensionless or fictional effort values - with the corresponding catchabilities - would be suitable for the projections. Aiming at using a realistic measure of the fishing effort in the model would require quite an undertaking, involving identifying an appropriate measure of effort, assessing the relationship between effort and the resulting fishing mortality.

For these reasons, it is rather uncommon for MSEs to test management strategies based on effort management. Here, as in most cases, the MPs tested deliver advice on TAC. If such an MP is chosen to be basis for management in the future, it will be required that managers translate the scientific advice delivered as a TAC, into a measure of fishing effort (likely the duration of the fishing season). This will inevitably lead to discrepancies between the advised TAC and the actual catches, which may (depending on the magnitude of these discrepancies) alter the performance of the MP. This additional source of uncertainty can be incorporated in the MSE tool, for example by the addition of random "management implementation errors", that would represent the uncertainty in translating a TAC advice into a number of fishing days. These issues will need to be discussed by the managers.

In the EU marine fisheries, it is also common practice for countries to bank or borrow quota from on year to the next : they can decide not to catch their full quota, and use the remainder the following year, or to go over the quota and repay the following year their over shoot. Such a scheme could be envisaged here, and a way to compensate for the potential differences between TAC advice and realized catches. The effect of such a scheme on the performance of the MPs can easily be tested to see for instance if it partially compensates for the potential decrease in performance due to the translation of the TAC into fishing effort.

Finally, although it cannot be included into the current MSE models, analyses of past relationships between different measures of effort and the catches throughout the fishing season will be carried out to provide a basis for the managers to translate TAC into fishing effort.

For clarity, short-term objectives often refer to the first 5 years of the simulation, medium-term refers to the following 10 years, and long-term refers the succeeding years after.

MSEs rarely considers short-term management objectives because the projections in the short term (e.g. 5 years) are highly influenced by the stock status at the start of the simulation. In general, this is estimated with a higher uncertainty than earlier years in stock assessments models. Furthermore, the latest estimates of recruitment from the stock assessment model (which also have higher uncertainty) and the assumption on upcoming recruitments in the projection years, have a strong influence on stock status in the short term.

MSEs are generally more suitable for longer term-objectives that are characterized with higher certainty. This is because after a number of years in the simulations, stock status becomes independent of the starting conditions, and a dynamic equilibrium is reached. This equilibrium represents the steady-state of the stock (and its variation) that can be expected when the management strategy is implemented consistently over a long period of time. The concept of MSY is based on the same idea: F_{MSY} is the fishing mortality that leads, on average and in the long term, to maximum sustainable yield.

No proper stock assessments are available for the four Ijsselmeer/Markermeer stocks, to inform the MSE on the state of the stock at the start of the simulation. Although the process of configuring an OM for these stocks relies on the same population dynamics equations as most stock assessment models and uses data that could be used in a stock assessment, the data is constrained much less stringently in MSE compared to classical stock assessment models. However, while the objective of stock assessments are to provide absolute estimates of stock size and fishing mortality, the MSE OM configuration as devised there, which is based on the feasible trajectories, aims at selecting likely population dynamics parameters that are compatible with the trends observed in the data. These Oms may not form a strong foundation for short-term management objectives, but they are better suited to model long term behavior, where population dynamics take precedence over initial stock status. Overall, it is recommended in light of the finalized MSE work to come in 2023 and the caveats for short term MSE projections, the management goals that are formulated consider the long-term objectives only.

8 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. The organisation has been certified since 27 February 2001. The certification was issued by DNV.

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Justification

Report C045/23
Project Number: 4318100385

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved: Benoit Berges
Colleague scientist

Signature:

Date: 12 July 2023

Approved: Dr. Ir. T.P. Bult
Director

Signature:

Date: 12 July 2023

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