Development of updated Operating Models for the IJsselmeer/Markermeer

For the stocks of pikeperch, perch, bream and roach

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Wageningen University & Research report C046/23

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Summary

This report presents the ongoing work and initial testing for the operating models (OM) utilized for the 2023 management strategy evaluation (MSE) analysis of four commercially important fish stocks (pikeperch, perch, bream, roach) within the IJssel/Markermeer complex. In recent years, these stocks have witnessed a concerning decline prompting the Ministry of Agriculture, Nature, and Food Quality to take management decisions based on the best available scientific information. With the goal of long term sustainability while allowing the highest possible commercial catches, an MSE analysis of the IJssel/Markermeer stocks was conducted in 2019/2020. Following the results of the previous MSE, an update of the OM's is essential to optimize the outcomes of both past and current management objectives and to signal the need adjustments when needed.

These operating models provide virtual representations of stock population dynamics enabling simulation testing for various management procedures (MPs). Through this approach, it becomes possible to predict (with certain levels of uncertainty) future stock populations and conduct risk assessments of current management policies. The OM's use data from scientific surveys, commercial catches and estimated catches from birds with the purpose of achieving adequate fish stocks for commercial benefit while ensuring sufficient nourishment for bird populations. Commercial and bird catches were modelled in the OM's as separate 'fleets' with differing levels of selectivity at age for both catch sources for the different stocks. Age structured models were constructed with spawning stock biomass used to predict annual changes in recruitment.

OM's were conditioned using the available data inputs as well as three sets of priors (initial biomass, level of stock depletion, the steepness of the stock recruitment relationship) to set up a pool of possible trajectories for the stocks to best explain historical populations while providing the basis for future projections. These stock trajectories underwent several rounds of selection to choose the output which best represented historical catches and biomass trends.

The pikeperch OM showed a considerable level of uncertainty regarding the current stock status. The recent increase in commercial catches was only explained by a considerable rise in fishing mortality, though relatively high recruitment in recent years has been suggested from the open water survey. Several alternative OM's were also given consideration for this stock. The bream OM relied on a smoothened biomass index from the open-water survey to project the OM over the historical period, which, after selection of stock trajectories, showed a stock which has declined significantly since the 1990's. Fishing pressure for this stock, was seen as currently well above Fmsy, although lower than the highest period between 2007-2010. Initial future projections for this stock under different levels of exploitation were also explored. The perch OM suggests a gradual decrease in spawning stock biomass (SSB) in recent years, though these results change depending on two alternative scenarios regarding high or low bird catches. Fishing pressure for this OM is seen as currently above Fmsy and higher than historical levels. Potential future scenarios under different fishing pressures were also investigated for this stock. The roach OM, like with bream, uses a smoothened biomass index from the open-water survey. The OM for this stock, however, is currently ongoing with no projection of historical SSB levels or fishing pressure.

This analysis faced challenges due to limited information and conflicts between catch and survey data which posed difficulties for models to reconcile. These conflicts left the roach OM, in particular, unresolved. To address these issues, plans are underway for an external review and more rigorous investigation of the data sources and implementation of the OM's scheduled for early 2023. Additionally robustness tests for management procedures are also planned to ensure the reliability and effectiveness of the models.

1 Introduction

In a management strategy evaluation (MSE) analysis, the operating model (OM, **Figure 1**) is the component of the framework that represents the dynamics of the system (here fish stocks, birds and fishing fleets) with an appropriate description of the attached sources of variability (e.g. in biological processes) and uncertainty (e.g. on stock status). The OM is generally conditioned on data, which involves 1) defining a set of likely population dynamics and fleet related parameters, 2) the corresponding historical stock development, and 3) defining assumptions on those values for the simulation period (future years) for each of the processes and their variability. In the MSE simulations, an observation model collects information, with observation error, from the OM to feed data into a method used to derive indicators on stock status. These stock indicators are then used in a management rule to define the catches or exploitation level that should be implemented by the manager for the following year. On this basis (and with possible implementation error), the OM is updated (i.e. projected one year ahead in the simulation).

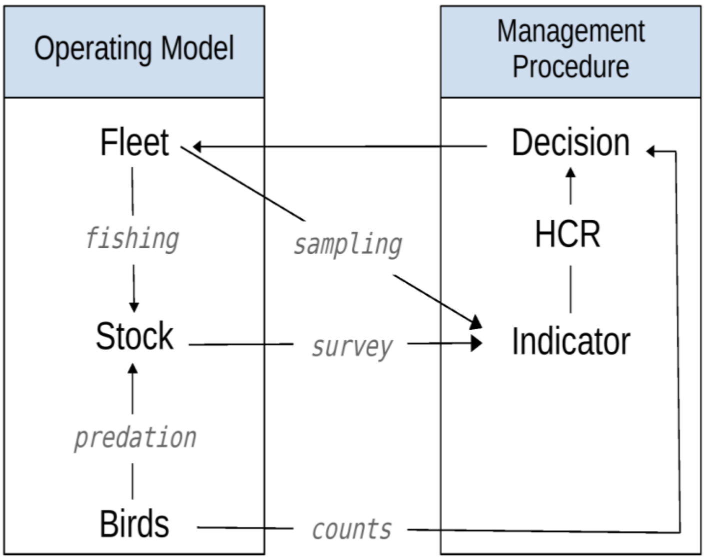

***Figure 1**: Schematic representation of the simulation model constructed for the MSE analysis of candidate management procedures for IJsselmeer fish stocks.*

For the stocks located within the IJsselmeer/Markermeer complex, only 'data-limited' assessments are possible. As a result, a standard stock assessment for these stocks is not possible which creates a greater challenge to produce precise estimates of stock dynamics such as spawning stock biomass (ssb) and fishing pressure. A more flexible MSE approach was thus chosen to evaluate these stocks. The MSE tool in development consists of 1) proposing a set of likely population dynamics parameters, with values chosen by considering the species life histories, 2) reconstructing past stock development based on these parameters, and 3) selecting likely trajectories, based on their consistency with the different sources of information available for the stocks (mainly catches and survey). This approach has been termed the "feasible trajectory" approach (Bentley and Langley 2012).

In this report, we present preliminary updates to the OMs for the four stocks considered in the IJsselmeer/Markermeer complex: bream, perch, pikeperch and roach. These are, to a large extent, modifications of the OMs presented in earlier work (Tien et al. 2020a, 2020b), but are also based on some new methodological developments conducted during the previous year. The new developments include a change in the time referential used (now years match with fishing seasons, to better correspond to the way management is implemented), the definition of new criteria for the selection of the feasible trajectories (making more use of the available data) and the definition of alternative OMs for sensitivity testing.

2 Data

Data is routinely collected on the IJsselmeer fish stocks and fishing fleets. Information on biology, related to growth, maturity and other aspects of the stocks biology, is obtained from samples taken both during the open water survey and the landing operations. The information on total catches together with the observations of changes in abundance provided by the open water survey, constitute the main sources of information on the dynamics and exploitation of the stocks used in this study.

2.1 Fleet catch data

The estimates of the annual landings from all 4 fisheries considered over the period 2012-2020 are shown in **Figure 2**. The time series were constructed by collating data from different sources (logbooks since 2007, PO1 between 2003 and 2016, and PVIS2 before 2003). In the case of bream and roach, part of the landings from the seine fishery are not sold at the auction where market sampling takes place, leading to unaccounted catches for 1992-2005 period. For these two fisheries, there is therefore a large uncertainty in the magnitude of these landings in the earlier part of the time series. Based on the estimates provided by some fishermen, an assumption was made on the amount of bream not sold via the auction, which was used as the basis for an alternative time series of historical landings. For roach, while the full range of data is shown, only the catch information from 2008 onwards is used in the analysis due to uncertainty regarding catches in the years prior.

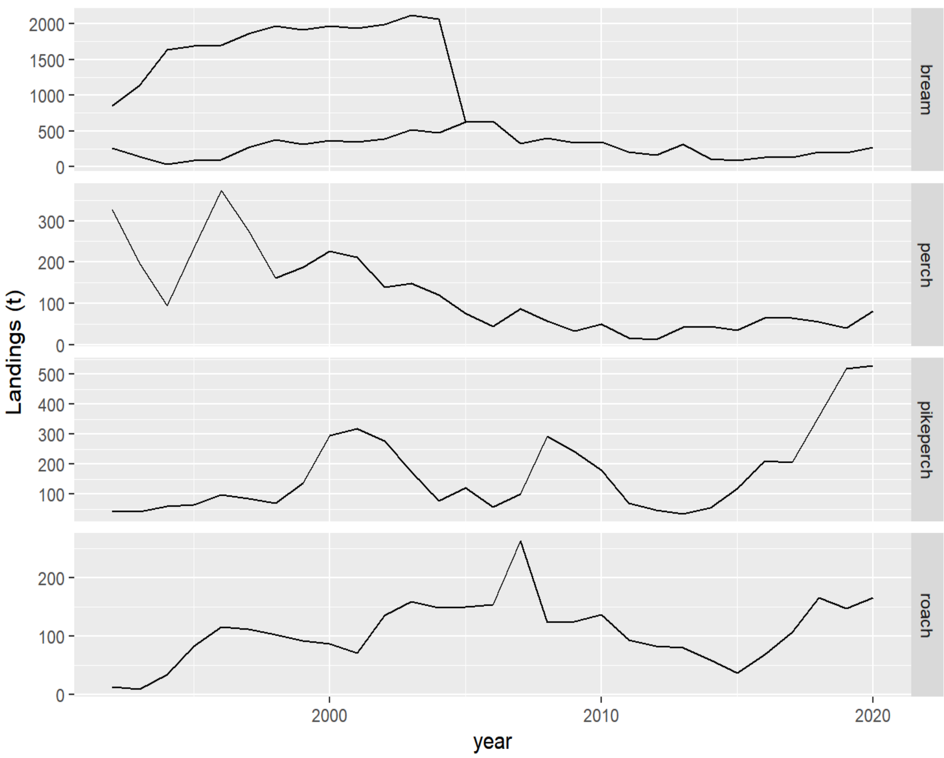

Figure 2*: Annual estimated commercial catches by the IJsselmeer fisheries from each stock. Note that for bream both minimum (bottom line in top panel) and maximum (top line) estimates are provided for the period 1992-2005.*

[1] Coöperatieve Producentenorganisatie Nederlandse Vissersbond - IJsselmeer U.A.
[2] Productschap Vis

2.2 Bird catch estimates

Estimates of fish intake per stock for the whole of the bird population based around the IJsselmeer and Markermeer is an important source of mortality. These estimates were constructed during the development of the previous set of operating models (Tien et al. 2020a). They were based on the annual bird colonies census, combined with calculations on the range of lengths of each fish species that each bird species could ingest, the energetic needs of adult and chicks per year, and the trends in abundance of the suitable fish ages, to obtain an overall estimate of fish consumption by the bird community of the IJsselmeer. This estimate ignores the availability of other fish stocks, and any preferential choice among the four fish stocks by each bird species. Nevertheless, it provides an approximate measure of the fish biomass in the selected length and age range that the bird population could be expected to require to maintain its current levels.

This data source has not been updated from the previous calculations, and covers the 1992-2018 period (Figure 3), but updated figures will be available in 2023. An assumption was thus made that bird intake for years 2019-2020 was equal to the average of the 2016-2018 period. The same values were used in future projections, as the initial objective is for the procedures to ensure that fishing activity still allows bird populations to have the resources for them to remain at the 2016-2018 level. One exception is perch, where a strong relationship was found between the strength of recruitment and bird predation on the stock (Tien et al. 2020a), an aspect that warrants accounting for this relationship in any future projection. Calculated bird catches for perch in the past are currently estimated to be higher than those taken by the fleets and is assumed to be linked to the strength of recruitment, as indicated by the abundance of age 0 fish in the survey. A decision was made to consider perch consumption by the bird population be determined by the strength of recruitment, which was quite variable for this stock.

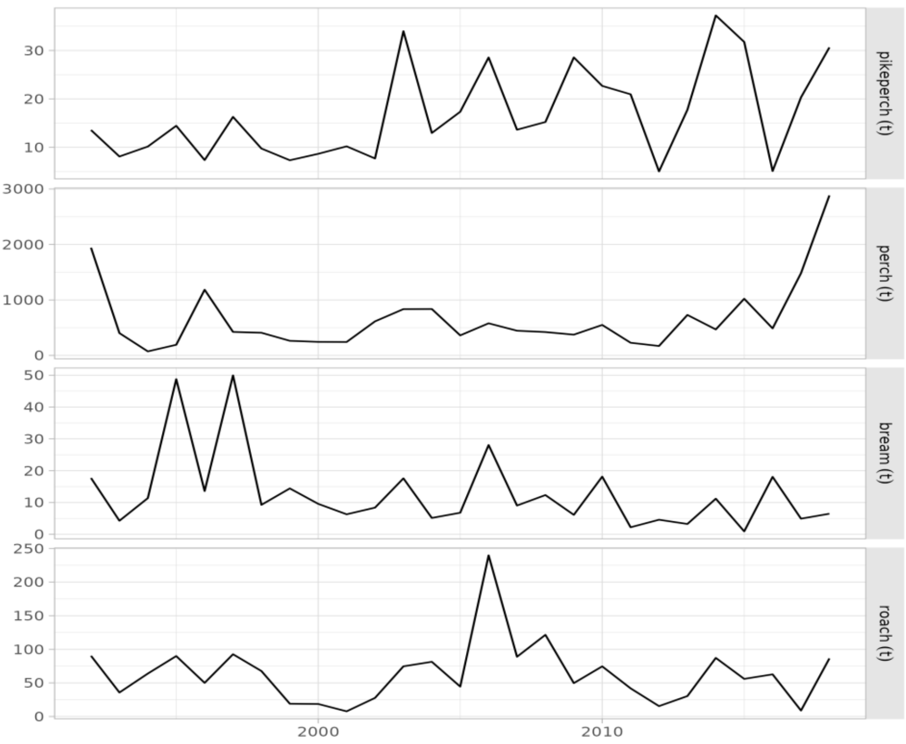

Figure 3*: Annual estimated catches by the IJsselmeer bird populations from each stock.*

2.3 Survey

An annual survey is carried out using trawling gear, which provides a fishery-independent view of changes in abundance for a wide range of ages across the four stocks (Volwater et al. 2022). From this, trends in surveyed biomass are computed.

Changes in abundance of age-0 fish are used to generate a series of recruitment deviates for the stock-recruits relationship in each OM run. A weighting factor is then applied, sampled from a uniform probability distribution, that determines the strength by which the recruitment series is reflected in the survey signal on age-0 abundance (Figure 4).

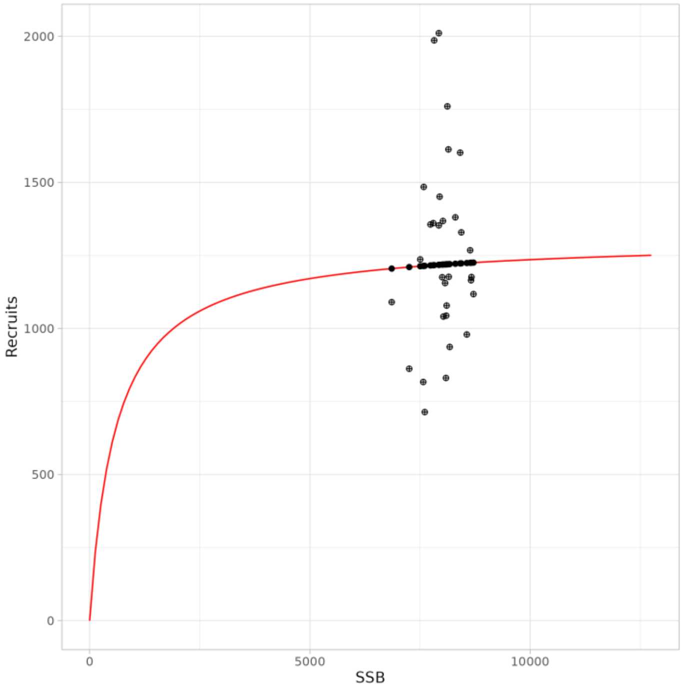

***Figure 4**: Example iteration of the stock-recruitment relationship obtained from prior distributions for pikeperch (line), with black dots on the line showing the expected recruitments for the estimated biomasses over the OM conditioning years (1992-2022). Points away from the line show the estimated recruitment once deviances, which are derived from the survey age 0 abundances, are added.*

2.4 Selectivity patterns for the fishery, the survey and the removals by the birds

Trends in the stock biomass sampled by the survey are used to condition the OM through an age structure provided by the assumed selectivities shown in **Figure 5**. The trends in surveyed biomass are used in two different ways in the OMs, depending on the stock. The selectivity-at-age for the bird predation, the commercial fishery and for the scientific survey used in the OMs of the four stocks are presented in **Figure 5**. The values used for the development of the OMs were taken from the previous MSE work (Tien et al. 2020a, 2020b) and were not re-estimated this year.

For the fishery and the survey, the selectivities were based on the length frequency distribution from the respective data sets, as well as expert knowledge on the expected behaviour of the respective gears. The selectivity at length was later converted into selectivity at age using the established von Bertalanffy growth curves for each species.
Selectivity of the overall bird population was based on the proportion of removal per bird species and the respective prey length range for each bird species. This was used to compute a selectivity at length for all the species combined, finally converted into selectivity at age.

There is work ongoing to update the selectivity curves for the four stocks and new values will be used in 2023.

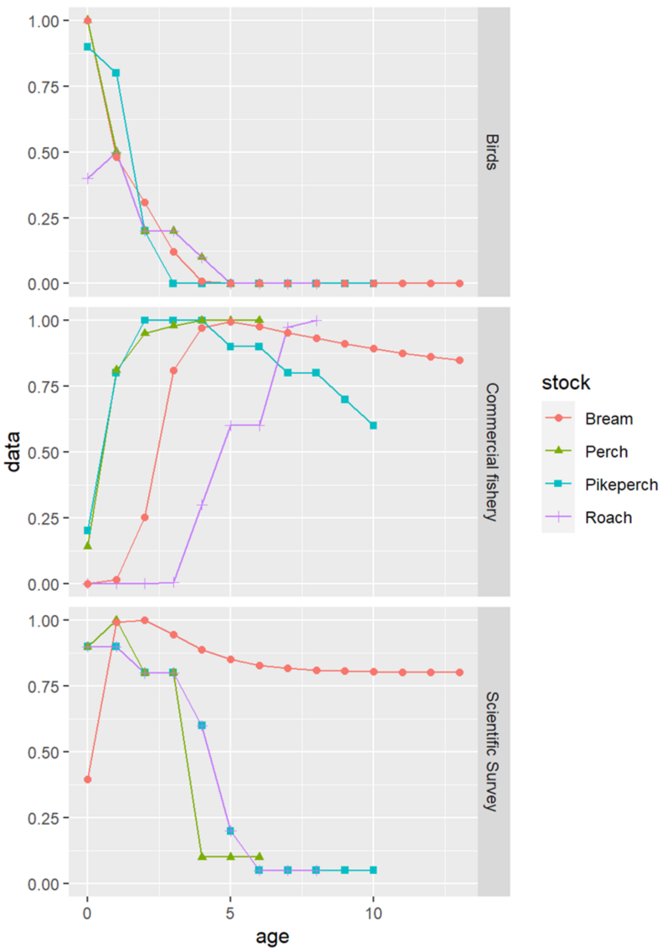

Figure 5: *Selectivity-at-age for the bird predation, commercial fishery and the survey, used for the OMs of the four fish stocks.*

2.5 Biology

2.5.1 Growth

Age observations obtained during the annual survey are length-stratified, so a maximum of 20 individuals of each species are aged for each 1 cm length bin. Fitting a growth model to these data is likely to introduce some bias in the estimated parameters due to non-random sampling (Goodyear 2019). Although a number of methods have been proposed to correct for this potential bias, none of them appear to be totally satisfactory (Perreault, Zheng, and Cadigan 2020), and require a considerable effort to implement. Von Bertalanffy growth models were fitted for the four stocks using weighted nonlinear least squares, with weights being defined by the number of fish caught in the survey in each length bin. A single model was fitted for the whole time series, as the number of samples precluded estimating changes in time in growth. Model fitting was carried out using the models and algorithms available in the **FSA** R package (Ogle et al. 2022).

2.5.2 Maturity, weight at age, natural mortality

The proportion of fish mature-at-age, weight-at-age and natural mortality-at-age used in the OMs of the four stocks are presented in **Figure 6**. Out of the four stocks, bream shows the longest period before maturity while pikeperch displays the highest mean weight at age. Natural mortality is assumed to be highest for bream from age 0-1 but transitions to relatively low natural mortality for older ages. All stocks were assumed to show a constant rate of natural mortality by age 3 (**Figure 6**). More detailed information how this data was derived can be found in the previous IJssel/Markermeer evaluations (Tien et al. 2020a, 2020b).

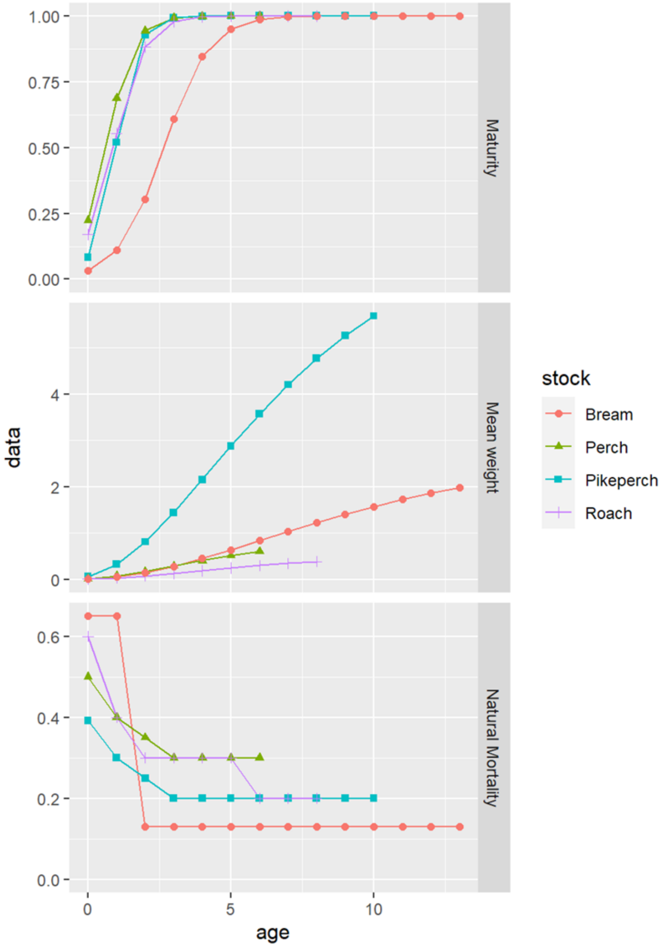

Figure 6*: Maturity, weight and natural mortality-at-age used for the OMs of the four stocks.*

3 Methods

3.1 Operating Model

The operating models are age-structured, with recruitment driven by spawning stock biomass. Population abundances at the start of the time series (1992) are assumed to be at an unknown level of depletion (dep) over their carrying capacity or potential unfished biomass (K). Abundance at age for a given year is given by:

$$N_{a,y} = \begin{cases} \frac{4sR_0B_y}{(B_0(1-s)+B_y)(5B_0-1)} e^{\epsilon_y - \sigma_R^2/2} & \text{if } a = 0 \\ N_{y-1,a-1}e^{-Z_{y-1,a-1}} & \text{if } 1 \leq a \leq x \\ N_{y-1,x-1}e^{-Z_{y-1,x-1}} & \text{if } 1a = x \end{cases}$$

where $N_{a,y}$ is the number of fish of age a at the start of year y, $Z_{a,y}$ is the total mortality of individuals of age a during year y:

$$Z_{a,y} = M_{a,y} + F_{a,y}$$

$M_{a,y}$and $F_{a,y}$ are the instantaneous rates of natural and fishing mortality at age a and in year y, respectively. Total F is determined by the partial fishing mortalities imposed by individual fisheries:

$$F_{a,y} = \sum_{f=1}^{f=F} E_{f,y}\, S_{f,a,y} \alpha_f B_y^{\beta_f}$$

where $E_{f,y}$ is the effort of fishery f in years y, $S_{a,y}$ is the selectivity of fishery f on age a, B_y is the total biomass in the middle of the period of activity of fishery f, and α and β are the cachability coefficients for fishery f.

Recruitment is predicted through a Beverton and Holt relationship (Methot et al, 2011), where R_0 is the expected recruitment at virgin biomass levels, B_y is the spawning biomass in year y, s is the steepness of the stock-recruit relationship, B_0 is the unfished spawning biomass, and ϵ_y is the recruitment deviance for year y.The catches by fishery at age and year, $C_{a,y}$, are given by the Baranov catch equation:

$$C_{a,y,f} = \frac{F_{a,y,f}}{Z_{a,y,f}} N_{a,y}(1 - e^{-Za,y,f})$$

The yearly time step used in the model refers to the April to March period, so as to match the timing of the fishery and of management regulations.

3.2 Conditioning

The process by which an operating model makes use of the available data, combined with the chosen priors and assumptions, is termed conditioning. The model is expected to be able to explain past observations as a way to ensuring it provides a reasonable representation of the system for future projections. The methodology employed here combines a series of prior distributions for the main population parameters, and a set of selection criteria that compare the generated dynamics with observed data.

The *feasible trajectories* estimator presented by Bentley and Langley (2012) is suited for the construction of the operating models used in these evaluations. This method allows the incorporation of different levels of complexity and knowledge, and can be implemented with relative efficiency using tools already available in the FLR toolset (Kell et al., 2007). The method consists in creating a pool of possible population trajectories from the combination of various priors for population parameters (carrying capacity, initial depletion and stock-recruit steepness) and state variables (biomass and population structure) derived from those priors. A hindcast projection is carried out based on one or more sources of data that reflect the changes in population dynamics over the period over which data is available. For the IJsselmeer stocks, these primary data sources are the SSB trends computed from survey, or the total catch series computed from landing data and other information. The choice of data source used to infer feasible trajectories for each stock has been made based on the ability of the data source to inform stock dynamics.

A set of MSY and depletion reference points are directly generated by the combination of prior values for K and stock-recruitment steepness, and the fitted fishery selectivities. A large set of trajectories is selected based on feasibility criteria specific to each stock (Section 3.2.2). The values of specific variables in the generated stock trajectories are compared with likelihood functions that reflect how feasible those values are. For example, a population that has collapsed in the past, despite catch and survey data indicating otherwise, is excluded from the set of trajectories. In contrast with the original implementation from Bentley and Langley (2012), the set of trajectories is not dynamic, due to the computational approach of the FLR libraries employed. Instead, a large number of possible trajectories is created and then filtered. The number of stock trajectory replicates required is largely dependent on the acceptance rate that the selection criteria impose. To obtain 500 trajectories in the final operating model, a much higher number of initial populations (for example, 10,000) would be required if only a low percentage of them are accepted. A teo stepo process was applied, where initial runs with 10,000 to 15,000 iterations would be used to obtain the acceptance rate. This was then used to calculate the necessary number of model runs in order to achieve the required 500+ iterations.

The methodology used for these stocks in the past (Tien et al. 2020a, 2020b) has been refined by the addition of extra selection criteria. The code has also been improved in its efficiency and flexibility.

3.2.1 Priors

Initial priors were constructed for three parameters in the operating models that determine the scale of the stocks, their initial abundance, and their productivity: 1) virgin biomass (B_0), 2) the level of depletion of the stock at the start of the selected data period (*dep*), and 3) the steepness of the stock-recruitment relationship (s) (**Table 1**).

Uniform distributions were used for both virgin biomass and depletion. The upper limits of the distribution for virgin biomass for each stock were set using an extrapolation to the whole lake area of the largest densities recorded by the open water survey. The lower limits were set as a multiplier of the largest annual catches. For pikeperch, for example, the prior used was $U(150{,}15000)$. Inital depletion used some arbitrary limits that reflected the overall understanding of the stock status at the start of the series, and the comparison between observed catches and survey abundances. Initial ranges were set as $U(0.20{,}0.80)$. Comparisons of these priors with posterior distributions appear to indicate that values outside of this range would be very unlikely. This is evidenced from the catch and index of abundance trajectories, which provide information on the value of initial biomass and are derived from the product of carrying capacity and initial depletion.

A prior for the steepness of the stock-recruitment relationship, was set based on life-history correlations and data from other stocks of the same species, as obtained from the *FishLife* database (Thorson, Cope, and Patrick 2014).

Table 1: Prior distributions for carrying capacity. K; also assumed here to be the same as virgin biomass (B0), initial depletion from fishing (dep), and steepness of the stock recruitment relationship (h) employed in the conditioning of operating models for the four stocks. U refers to a uniform distribution, while B denotes a beta distribution, bounded or unbounded. Further details on the rational behind the priors chosen can be found in Tien et al. 2020a, 2020b.

	K	dep	h	deviances weight (kd)
pikeperch	U(1500, 15000)	U(0.2, 0.8)	B(1.91, 1.28), bound to 0.55-0.85	U(0.01, 1)
perch	B(2,2) * 55500	U(0.4, 0.8)	U(0.4, 0.8)	U(0.01, 0.4)
bream	B(2,2) * 62000	U(0.2, 0.8)	B(1.91, 1.28), bound to 0.55-0.85	U(0.01, 1)
roach	B(2,2) * 14400	U(0.2, 0.8)	B(1.91, 1.28), bound to 0.55-0.85	U(0.01, 0.4)

3.2.2 Selection criteria

- In contrast with Bentley and Langley (2012), feasible trajectories were selected by applying simultaneously (and not sequentially) a set of selection criteria. There were four categories of criteria applied for each stock:
- criteria related to the catches: in general, the OM should be able to produce at least the catches observed in the past
- criteria related to biomass trend: the biomass in the OM should have a trend that is similar to the trend in the biomass index from the survey
- criteria related to changes in fishing effort: the trajectories with unrealistic effort increase from one year to the next were not retained
- criteria related to exploitation rate (catches divided by biomass): OM trajectories corresponding to too high exploitation rates (>80%) were considered not realistic, as such high exploitation levels would have inevitably led to population collapses, which was never observed for those four stocks (although some are believed to be at low levels).

Due to the specificities of each stock in terms of data and stock dynamics, the four types of criteria were implemented in slightly different ways for the four stocks, as detailed in the results section.

3.3 Model validation

Model validation is the determination of the degree to which a model or a simulation, and their associated simulations, are accurate representations of the real world from the perspective of the intended use.

Formal model validation methods, for example various types of cross-validation, do not extend easily to the methodology employed here for OM conditioning. A cross-validation exercise requires the sequential removal of individual data points used in the model fitting (Carvalho et al. 2017), followed by the model fitting procedure being run without them. A measure of stability of the model results to individual data points can then be obtained.

This cross-validation procedure could be carried out on the main data used to project the initial populations, once they are created from the selected values of virgin biomass, depletion, and stock-recruitment steepness. But as the population projection uses aggregated target values per time-step (either total catch in a year or the change in abundance reported by the survey) individual data points cannot be removed, and blocks of data per time step would be removed instead. This procedure is yet to be finalised.

A cross-validation exercise could instead be conducted on the data used in model trajectory selection, but the statistical value of such exercise remains to be determined. In contrast with traditional model fitting, intended to provide a best estimate of model parameters and population values, OM conditioning is concerned with the characterization of the overall dynamics of the system, its variability, and uncertainty in our knowledge and ability to predict it. Only if some particular data sources, or individual values within those, were suspected to having an unduly influence in the final conditioned OM, would a cross-validation exercise be justified. The method requires a large number of simulations being carried out, which take a significant amount of computations time (e.g. over 8 hours for a single stock using multiple computing cores, multiplied by the number of data points).

4 Results

4.1 Pikeperch

The candidate base case OM for pikeperch is presented in **Figure 7**. The model presents a large uncertainty in current stock status, although recent increases in catches can only be explained by a significant increase in fishing mortality. This is likely to affect the decisions that any MP will take in the short term. MP performance evaluation should be more robust to this uncertainty in the medium and long term. The open-water survey indicates that large recruitments have taken place in recent years. Whether future recruitment variability remains as high as that apparent in the last decade will also be an important factor determining MP performance in the short term. The possible ability of MPs to benefit from those larger reproductive rates, and to respond to subsequent drops, will be an important robustness test for this stock

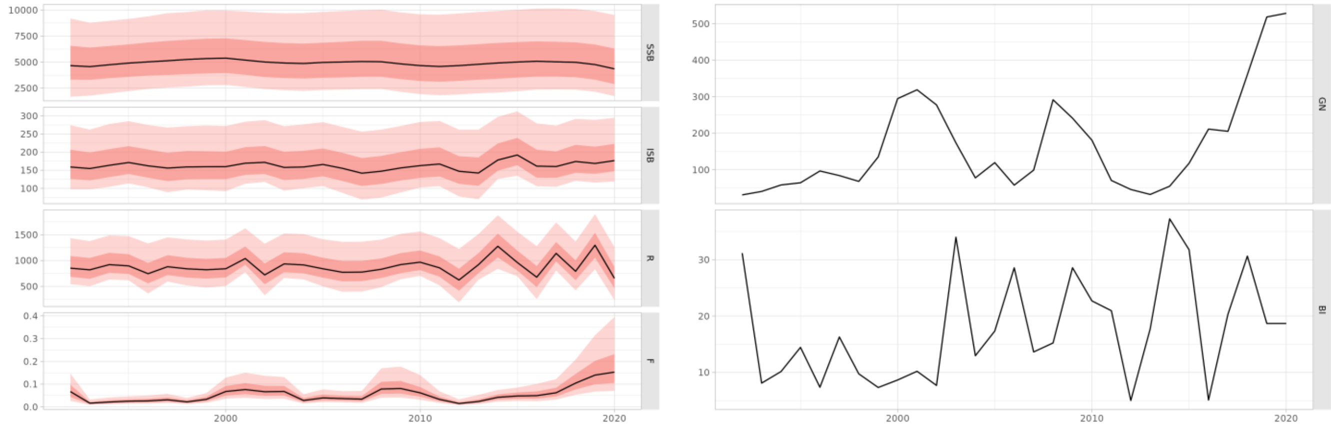

***Figure 7**: Time series of population dynamics (spawning biomass, immature biomass, recruitment, and fishing mortality) and catches by fishery (gillnets and birds) for the conditioned pikeperch base case operating model.*

From the wide priors assigned to the three main unknown parameters (carrying capacity, depletion, and stock-recruit steepness), the procedure selected a narrower range of values as feasible for the first two (**Figure 8**). The operating model conditioning selection was able to accept around 6% of the proposed prior combinations. A number of proposed populations could not explain the observed catches (**Figure 9**a) or could do so only by imposing unrealistic harvest rates, greater than 80% (**Figure 9**c). The scenarios with such unrealistic harvest rates were filtered out (**Figure 9**d). The most determining selection criteria is the agreement with annual biomass trends detected by the trawl survey (**Figure 9**b and e).

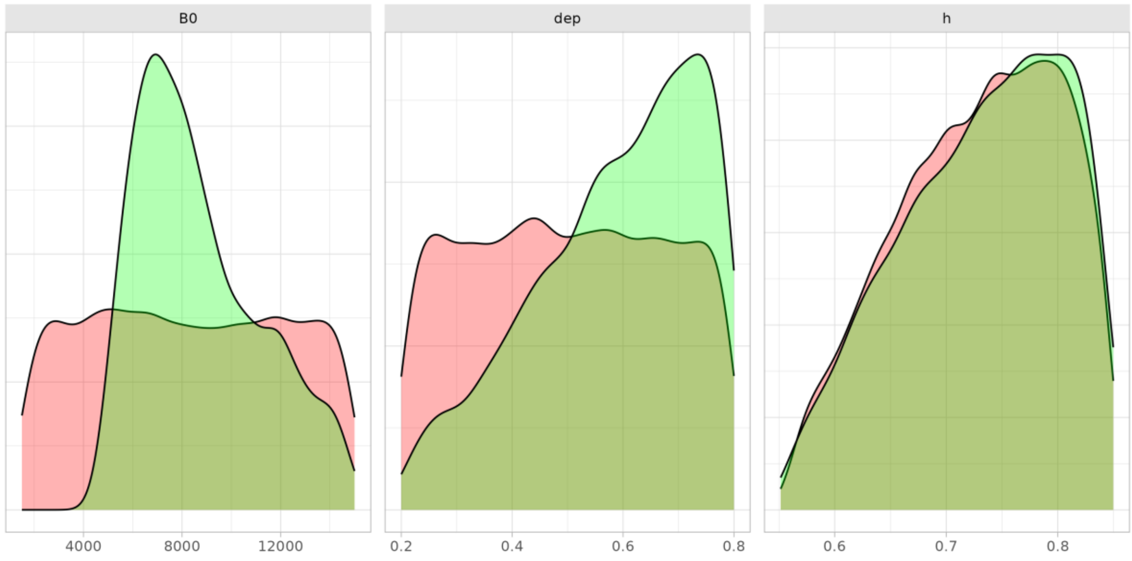

***Figure 8**: Comparison of the prior and posterior distributions for the three main population parameters (virgin biomass, B0, initial depletion level, dep, and stock-recruitment steepness, h.*

Four specific selection criteria were applied to the pikeperch population simulation runs, after the population was projected from its initial depleted status by extracting the total reported catch:

1. Catch every year is on target, with a 1% error allowance from total catch records, U(0.99, 1).
2. Changes in biomass of ages 0 to 3 matches those in survey, N(0, 0.10).
3. Annual harvest rate, defined as total catch over the biomass available to the fleets given their selectivity, falls between 0 and 0.80, U(0, 0.80).
4. Effective effort increases to a maximum of 400% from one year to the next, U(0, 4).

The application of these selection criteria to the base case OM, leads to a 6% acceptance ratio. The change in biomass reported by the survey is the dominant factor that limits which initial populations are incorporated into the OM (**Figure 9**).

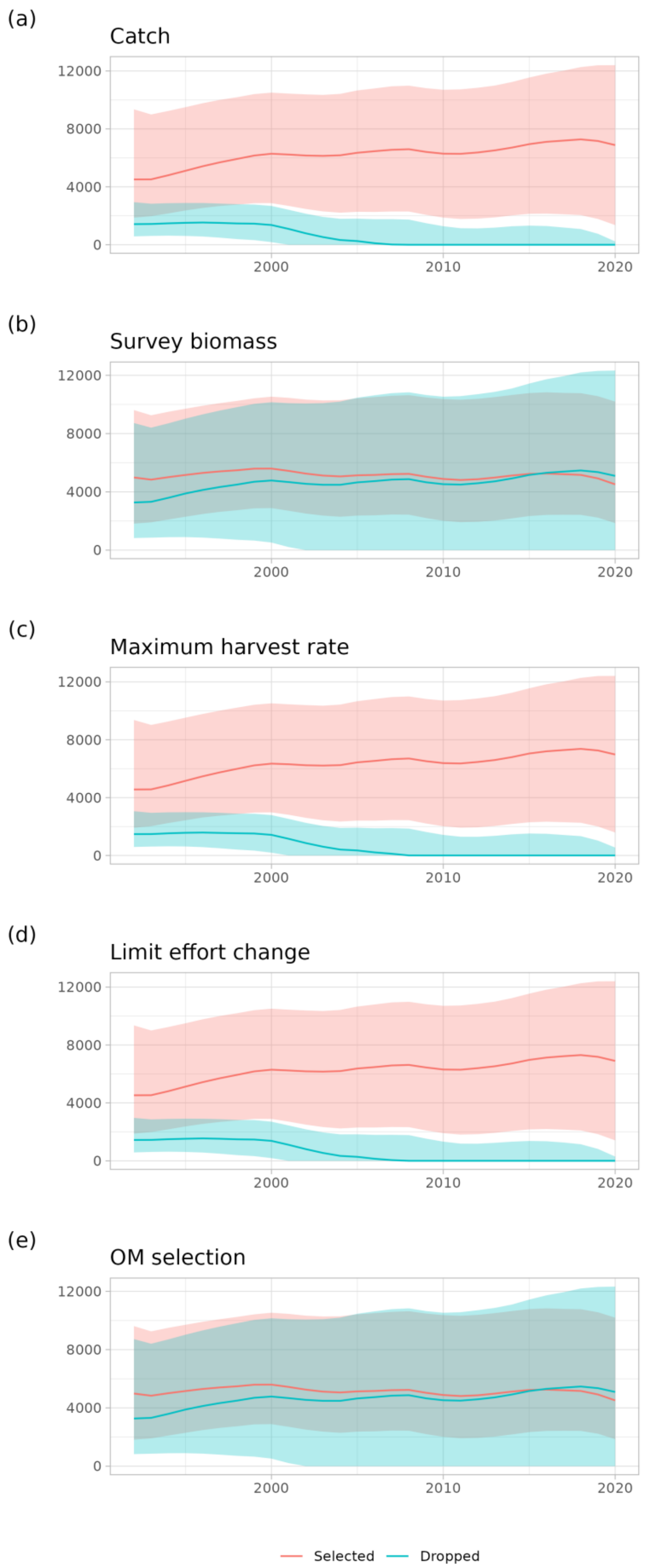

Figure 9*: Selection of population trajectories by each of the selection criteria (a-d) and overall OM selection (e).*

4.1.1 Alternative operating models

Three alternative operating models have been tested for pikeperch. They incorporate other population processes that have been raised as credible hypothesis, and could become part of the set of OM which for robustness tests are undertaken (i.e. those on which the candidate MPs are tested to understand their robustness to these alternative OM dynamics). **Figure 10** presents the base case run together with those of the three following alternatives:

- Variable age 0 M. Natural mortality of age 0 individuals was linked to recruitment strength, as determined by the age 0 in the open water survey. This reflects a process of density dependence, apparent in the weak cohort signal between ages 0 and 1 for pikeperch in the survey data.
- Decrease in productivity. Primary productivity in the IJsselmeer has decreased over the last 2 or 3 decades, as nutrient inflow has been substantially curtailed. An annual decrease of around 3% has been applied to the carrying capacity of the pikeperch stock to account for lower K values
- Senescence M. Natural mortality in the last two ages in the model (9 and 10+) is increased from 0.20 to 0.25 and 0.30, to reflect a possible onset of senescence. The abundance of larger pikeperch was a problematic issue in previous simulations (Tien et al. 2020a). This uncertainty is induced by the limited sampling of old individuals, which could be explained by both their absence from the lake, or the inability of both fleets and survey to catch them.

The alternative conditioned models (**Figure 10**) present a range of alternative hypothesis on the stock dynamics that will provide useful when carrying out robustness test of candidate MPs. The incorporation on early-life density dependence (Variable age 0 M) does not appear to have a large effect in the range of population trajectories the OM algorithm selects (top row). In contrast, the other two hypothesis do alter the view on stock productivity and stock status. Future trends in productivity will have to be considered when evaluating MPs under the relevant alternative OM.

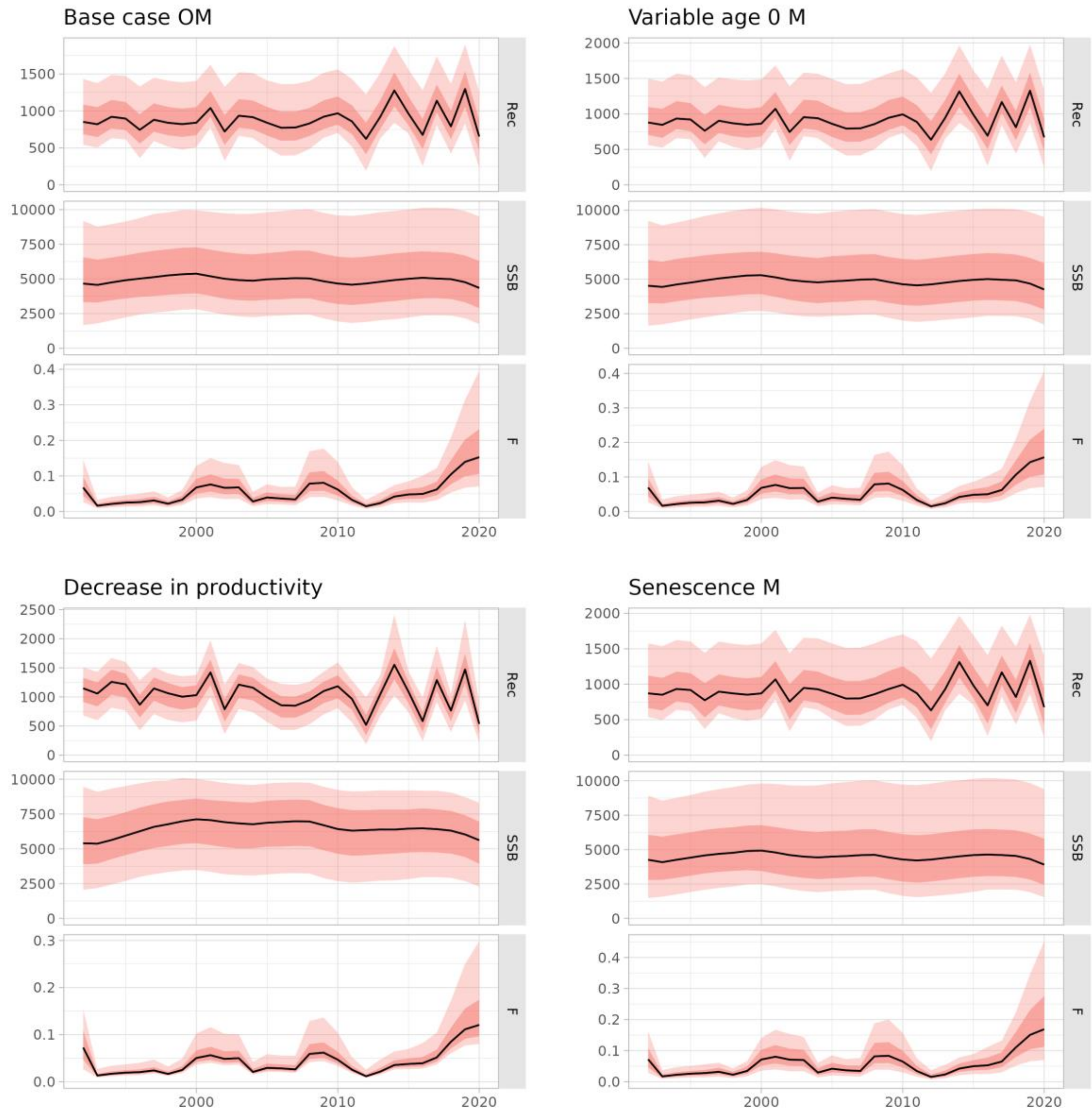

***Figure 10**: Comparison of the time series of population dynamics (recruitment, spawning biomass, and fishing mortality) for the four conditioned pikeperch base case operating models.*

4.2 Bream

4.2.1 Initial projection of the OM

Priors were defined for a total of 10,000 replicates (iterations) of the stock. Recruitment deviances were based on the survey index at age 0 (**Figure 11**). This index shows a strong declining trend for the period 1992-2020. Within the same period, the survey also indicates a general decline in the stock. The declining trend in the recruitment index is likely to be largely due to a decrease in the spawning stock biomass. In the operating model, density dependence is accounted for implicitly by the stock-recruitment model, with a decrease in recruitment strength linked with decreased overall stock size. Therefore, this trend should not be present in the recruitment deviances (which only represent stochastic deviations from the stock-recruitment model). The recruitment deviances were therefore generated based on the differences between annual age 0 index values and a lowess smoother of the index (instead of the mean of the index for other stocks).

Figure 11: *Age 0 index from the survey for bream (and smoother, panel (a)) and historical recruitment deviances generates based on the differences between yearly index and smoother (panel (b)).*

After initializing the population (creating a stock at the start of the data period, 1992, for each value of K and dep), the stock was projected forward until the final data year (2020) by imposing an annual rate of change in stock biomass equal to the annual rate of change in the biomass index from the survey. A smoother was first applied to the survey index to filter out the short term variation and keep only the longer term trend (Figure 12).

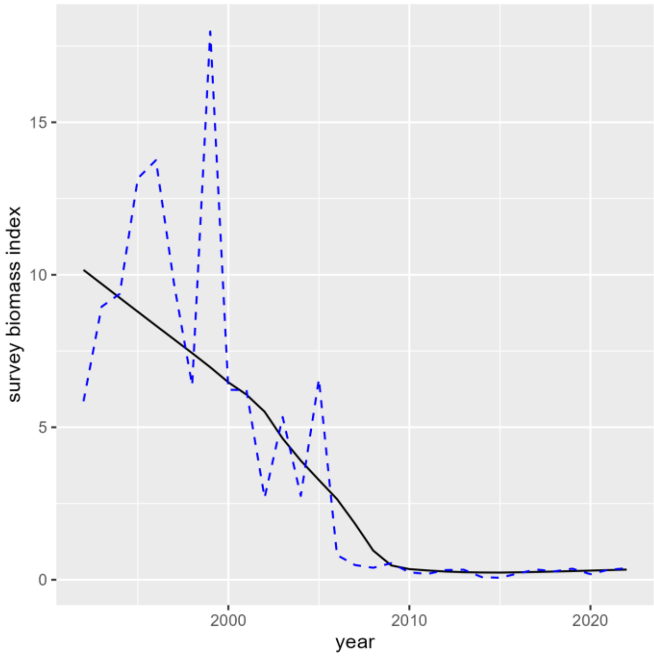

Figure 12: *Biomass index from the survey and smoother used to project the Bream OM over the historical period.*

4.2.2 Selection of feasible trajectories

The iterations in the projected OM that have plausible trajectories were selected based on a number of criteria :

- The modelled catches should be in agreement with the catch data available. The catch information for bream prior to 2005 is very uncertain, as there was no good report of the catches from the seine fishery. Rather than catch data, there are two available scenarios for that time period (a Cmax and a Cmin scenario). The selection of plausible trajectories based criteria related to the catch was therefore done separately for two time periods : 1998 to 2002 for the period with the two catch scenarios and from 2015 to 2020 for the recent period with accurate data. For the earlier period, over the 5 years : - the annual catch should never be lower than the Cmin values - the annual catch should on average be lower than 1.5 times the Cmax value - for the recent period, the catch should be on average at least the reported catch, but not more than twice the reported catch

- Trend in the stock biomass should be close to the trend in the biomass index from the survey. - the harvest rate (catch/stock biomass) should not be high that 80% for more than 3 year over the OM projection period - fishing effort cannot increase by more than 4 times from one year to the next.

Amongst those criteria, the least restrictive was the one related to the biomass trend, which was met for all iterations (**Figure 13**). The criteria related to harvest rate was also not very selective, as nearly 100% of the iterations remained selected. The criteria related to effort increase was more selective (leaving just under 50% of the iterations). The most selective criteria was the combination of the 4 catch related criteria, which when applied jointly, selected just under 20% of the iterations. The combination of all criteria selected 1,521 iteration (15.2% acceptance rate), out of which 500 were selected randomly to form the definitive OM.

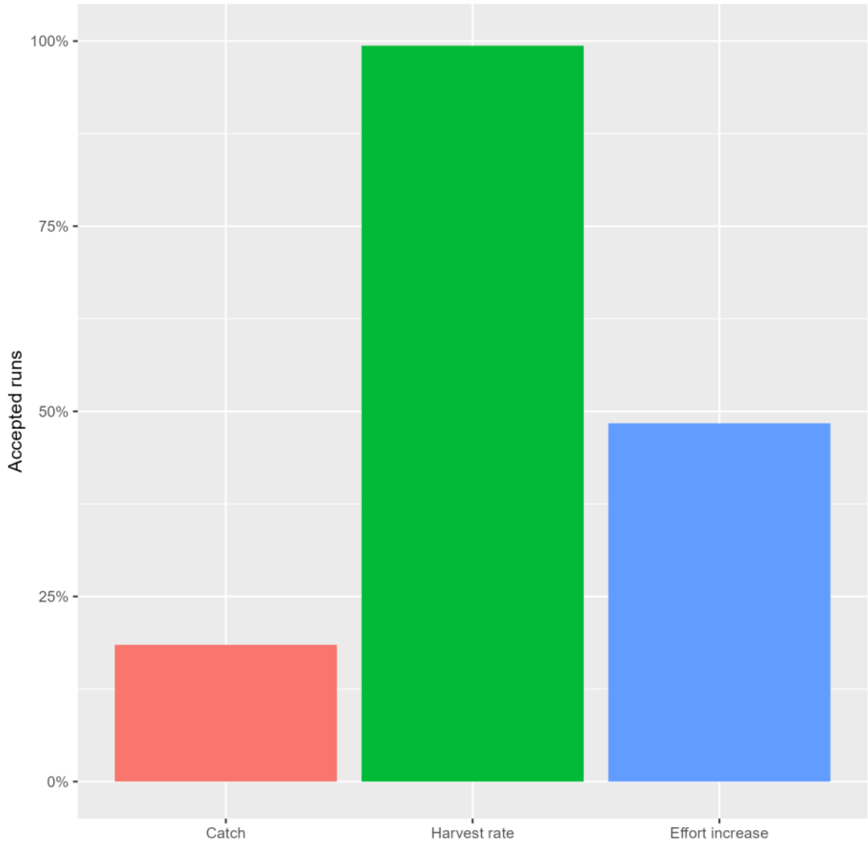

***Figure 13**: Proportion of the iterations that have plausible trajectories for each of the criteria defined for Bream.*

Figure 14 shows the distribution of the priors (values for the initial 10,000 iterations) and posteriors (values of the 1,521 iterations remaining after selection of plausible trajectories) for the population dynamic parameters. The prior for virgin biomass, B0, had a wide distribution, ranging from very small values up to 60,000t. This parameter is strongly revised for (posterior have a much narrower distribution than priors) by the selection of feasible trajectories, with a mode of the posterior distribution close to 37 000t, and all values lower than 20 000t being removed from the OM. The posterior distribution for the initial depletion rate is also narrower than the prior, with a mode at 0.50 and values lower than 0.25 and higher than 0.70 being removed. For steepness, high values – h between 0.70 and 0.85- were selected. The distribution of the parameter limiting recruitment variability was less revised by the feasible trajectory selection than the other parameters.

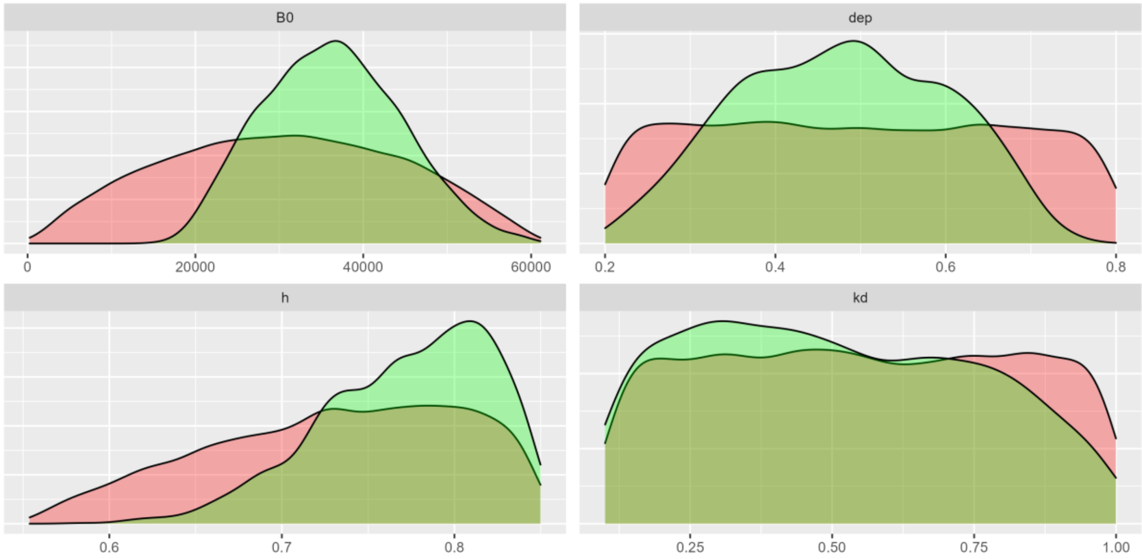

Figure 14*: Prior and posterior values (red and green respectively) of the population dynamics parameters from which the OM is derived. K : carrying capacity, : dep : population depletion rate in the first year; h : steepness of the stock-recruitment model, kd : d.*

4.2.3 OM trajectories

The OM for bream represents a stock that decreases from biomass levels above SBmsy at the start of the period to levels far below SBmsy, close to 0, since 2010 (**Figure 15**). The status at the start of the simulation period, 2020, is that of a severely depleted stock, with stock biomass at 2.5% to 7.5% of SBmsy. The level of exploitation increased from F well below Fmsy in the first 5 years, to F up to 9 times Fmsy from 2007 to 2010. F subsequently decreased but remained well above Fmsy. The starting conditions for the projections correspond to F/Fmsy in 2020 between 3 and 7.

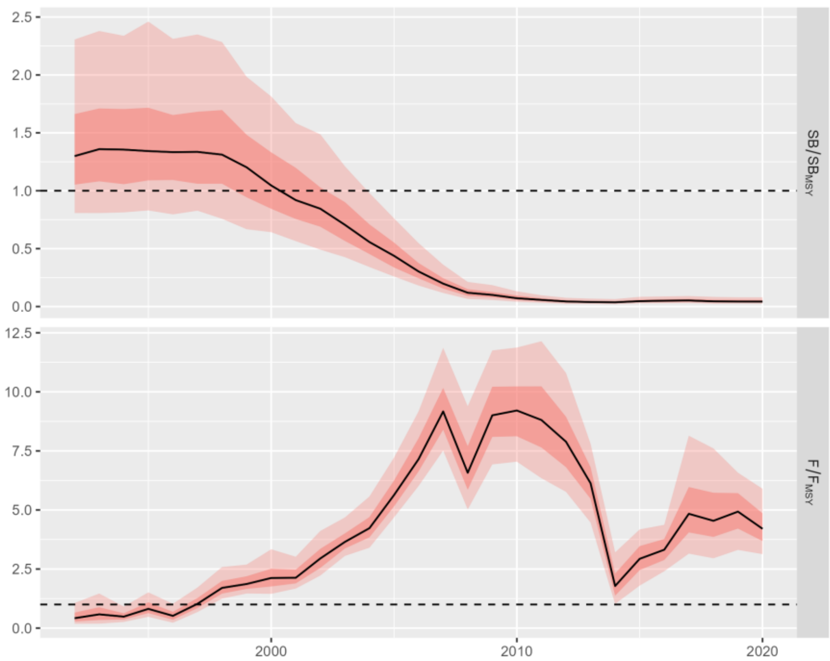

Figure 15*: Trajectories of SB/SBmsy and F/Fmsy in the bream OM (left panels) and stock status at the start of the simulation period (right panels).*

4.2.4 OM dynamics

In order to investigate the possible future trajectories in the OM, a series of simple runs (i.e. no management procedures) were conducted: future F at 0, future F at Fmsy, future effort at 2/7 of the latest effort value (2020). This latter scenario is meant to approximate the recent management decision of a reduction from 7 to 2 fishing days for the seine fishery in 2022 (which is assumed here to be implemented one year earlier). In the three scenarios, fishing mortality is reduced in 2021 compared to 2020 (F(0-13); **Figure 16**). In the scenario applying a reduction of effort, F decreases first to level close to Fmsy, and then further decreases to close to 0. The stock size recovers slowly to levels close to SBmsy (roughly the 2000 levels) by around 2035 for the scenarios with F=0 and with effort reduction, but remain under Fmsy for the whole simulation period for the scenarionF=Fmsy. Catches remain very low for the scenarios with F=0 and with effort reduction, and increase to around 700t at the end of the simulation period for F=Fmsy.

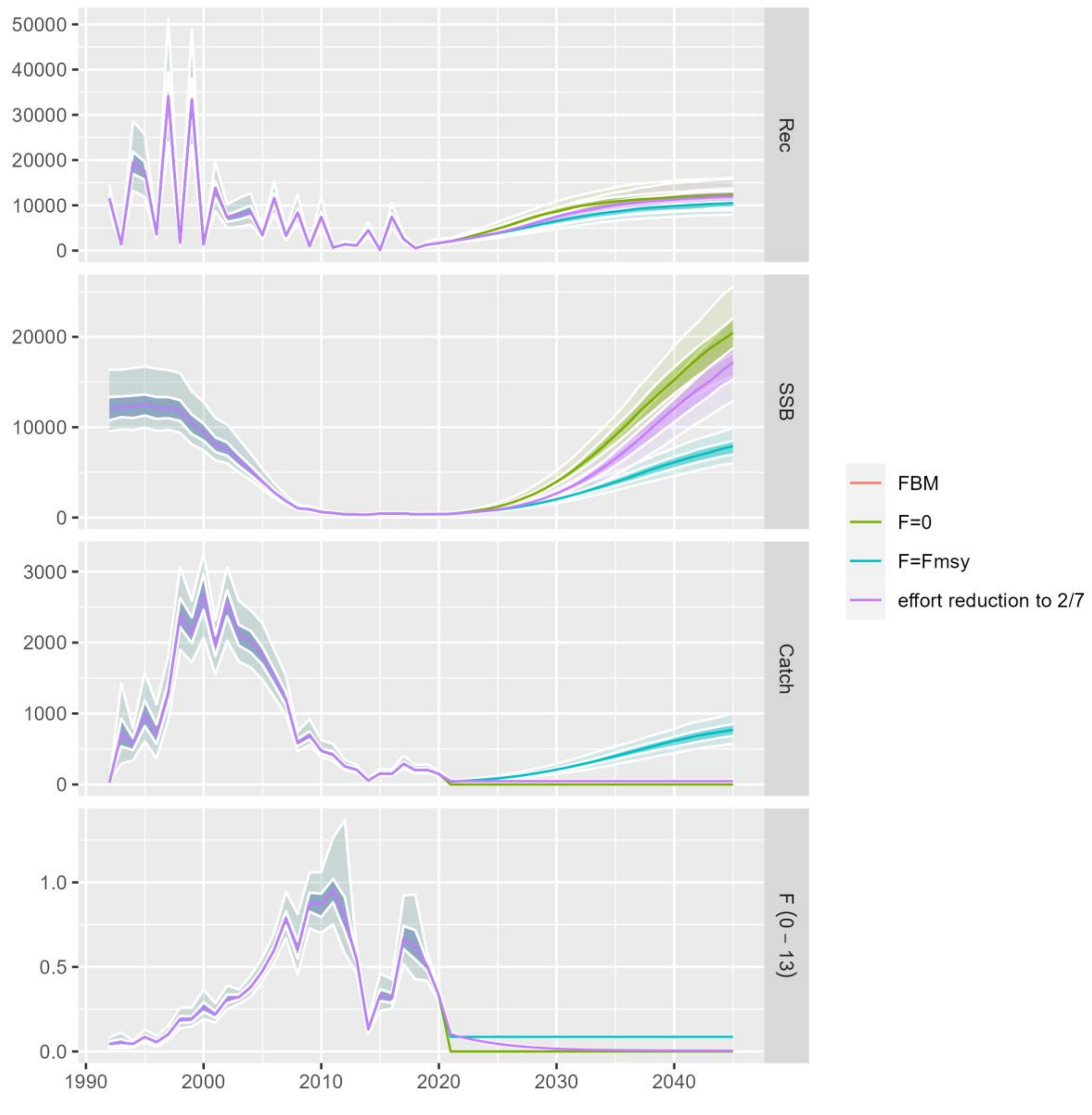

***Figure 16**: Projection of the bream OM under three different fishing mortality or effort scenarios.*

4.3 Perch

An important aspect for perch is that estimates of possible bird catches are larger than those reported from the fishing fleets. These bird catches contribute substantially more to the total fishing effort for perch than they do for the other fish species. A clear relationship can be observed between recruits and the catches by birds (**Figure 17**).

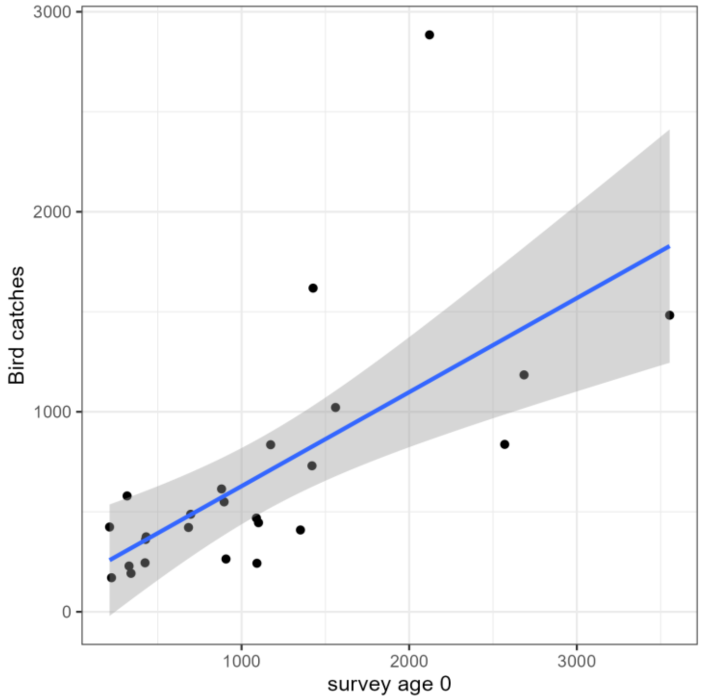

Figure 17*: Relationship between calculated catches of perch by the bird population in the IJsselmeer and the recruitment index obtained from age 0 abundances in the open water survey.*

Bird catch of perch is estimated to have increased dramatically over the last two years of the series (**Figure 18**, top graph). This has a notable effect on the conditioning and forecasting, as the last value in this series is used to set values for the most recent years (2019-2020). An update of all input data, to be carried out in 2023, should allow a revision of these values. Meanwhile, using this initial time series, two OMs have been assembled for perch. The first one has bird catches at the originally estimated level up to 2018, and years 2019 and 2020 are estimated to be the mean of the years 2016-:2018. An alternative time series does not follow for the extreme catches in 2018, but instead estimates the years 2018-2020 to be the mean of the years 2015-2017.

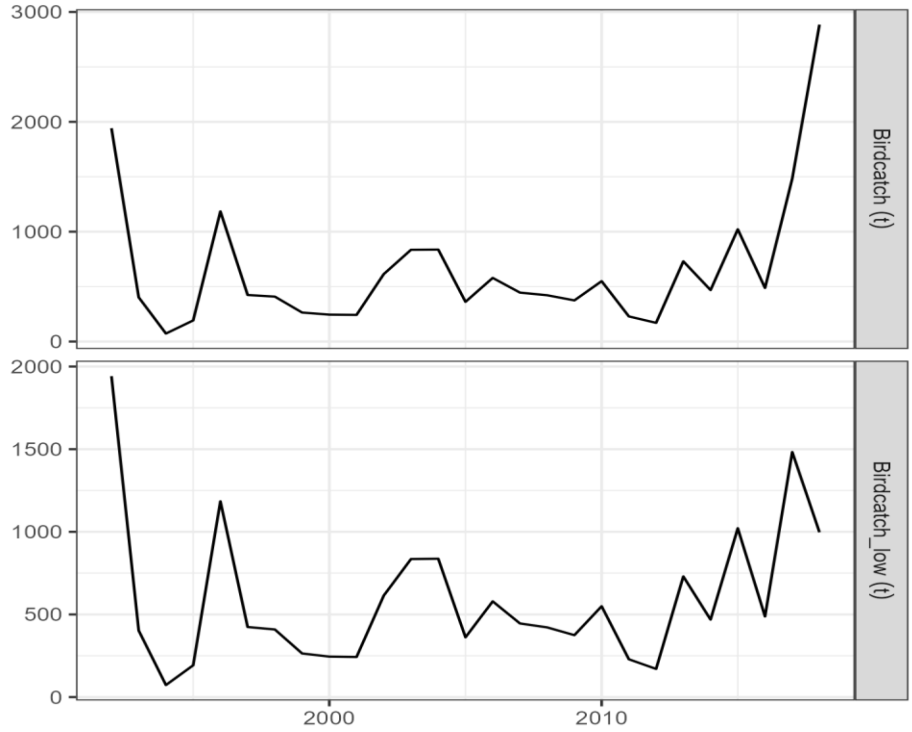

Figure 18*: Top graph; original estimated bird catch series for perch in the Ijsselmeer. Bottom graph: Alternative bird catch series in which the high 2018 bird catches are replaced by the average of the 3 years before it (2015-2017).*

4.3.1 Selection of feasible trajectories

A total eight selection criteria are being used to select feasible trajectories for perch:

1. Catch every year is on target, with a 5% error allowance from total catch records, U(0.99, 5) (**Figure 19**; "Catch")
2. The differences between the log(biomass) over the ages 0 to 3 in the official survey and the log(biomass) from the generated survey of the OM should not differ by greater than log(8) over the whole time series. This value was chosen so that this criterion would not be excessively restrictive, and that enough iterations would be accepted (**Figure 19**, "Biomass").
3. The direction of change between the yearly log(biomass) over the ages 0 to 3 in the official survey and the log(biomass) from the generated survey of the OM should not differ over two periods:
4. The time series is divided into two periods: a) 1992-2005, associated with a decline in biomass and b) 2005-2020, associated with an increase in biomass. Only iterations matching the decrease over the period 1992-2005 are retained (**Figure 20**, "Biomass trend 1992:2005").
5. The next check is if the harvest rate (Catch/Biomass) of any year is between set boundaries. A maximum harvest rate of 0.6 was allowed. Also, a minimum harvest rate of lower than 0.002 was allowed for a maximum of 10 years in any iteration. This resulted in two selection criteria (Figure 18, "Maximum harvest rate" and **Figure 20**, "Minimum harvest rate")
6. Any iteration exhibiting an annual rate of change in effort which was over four times the level of the previous year, was discarded (**Figure 20**, "Limit effort change").
7. Changes in numbers at age 2 in the official survey matches those in OM, N(0, 0.10). Age two was chosen because the effect of recruitment has somewhat dissipated once fish enter that age class and because the survey has high selectivity for that age class (**Figure 20**, "Index age 2") which was thought to be more reliable than ages 0-1.
8. Model runs requiring unrealistic levels of fishing mortality, F greater than 4, to explain catches, where eliminated. **Figure 20**, "Feasible Fbars").

All criteria limited, to some extent, the choice of feasible trajectories. For the simulation that were done using the lower catches by birds in 2018, the combination of all criteria selected 1,569 iterations (15.7 acceptance rate), of which 500 were randomly selected to form the base OM. **Figure 20** presents the trajectories selected by each criteria for this OM using the lowered bird catches.

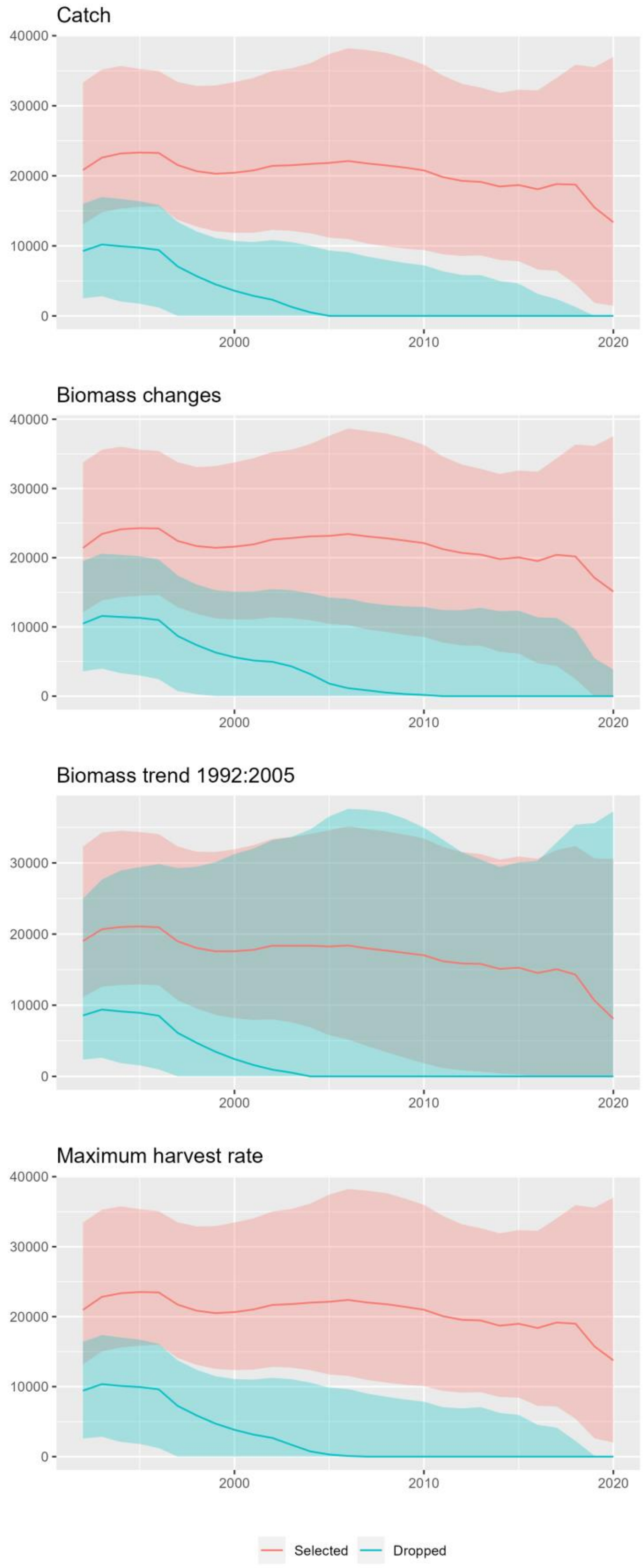

Figure 19: *Selection of possible population trajectories (as SSB) for each of the eight selection criteria, plus random draw of 500 runs.*

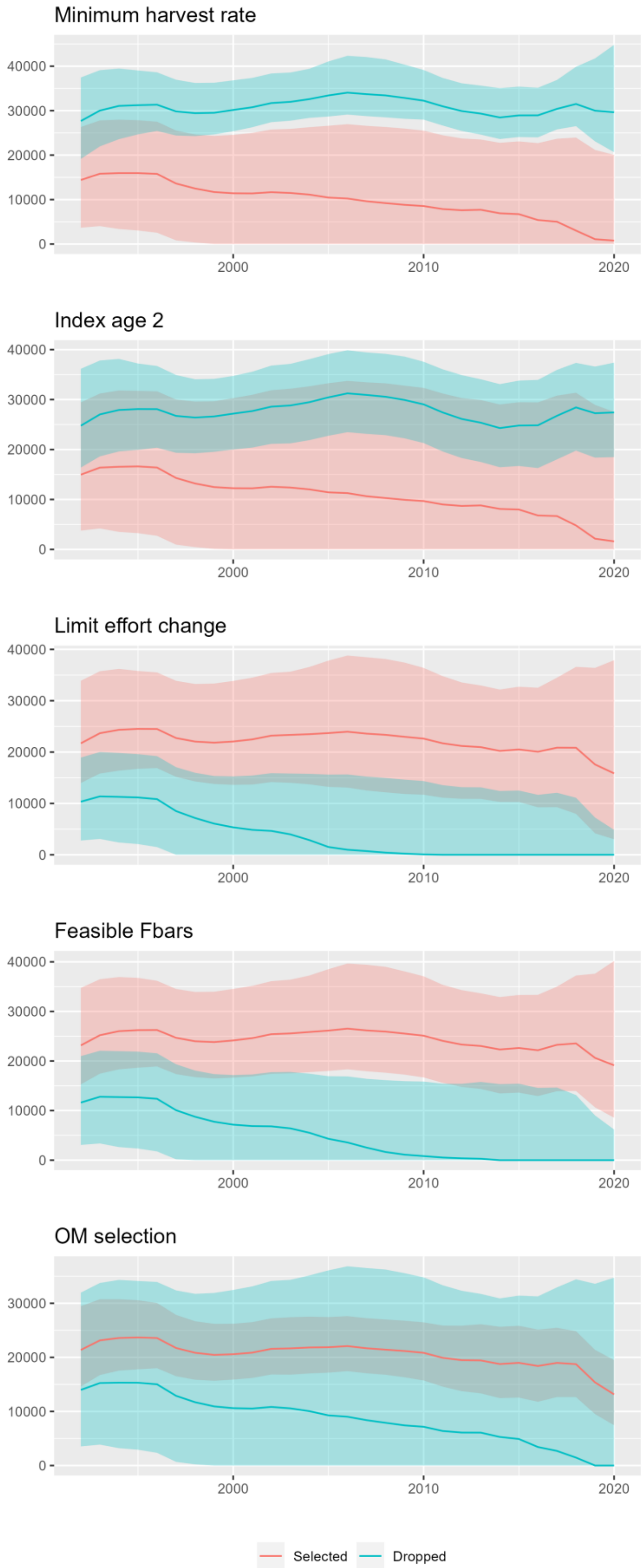

Figure 20*: Selection of possible population trajectories (as SSB) for each of the eight selection criteria, plus a random draw of 500 runs.*

4.3.2 Prior vs posterior parameters

Figure 21 shows that the data and model structure are able to narrow the possible values for virgin biomass, while both steepness and depletion are not being updated. Prior depletion levels might have to be revisited if alternative sources of data could be used to narrow it down. Uncertainty in initial depletion will translate into large uncertainty in stock status at the start of the simulation.

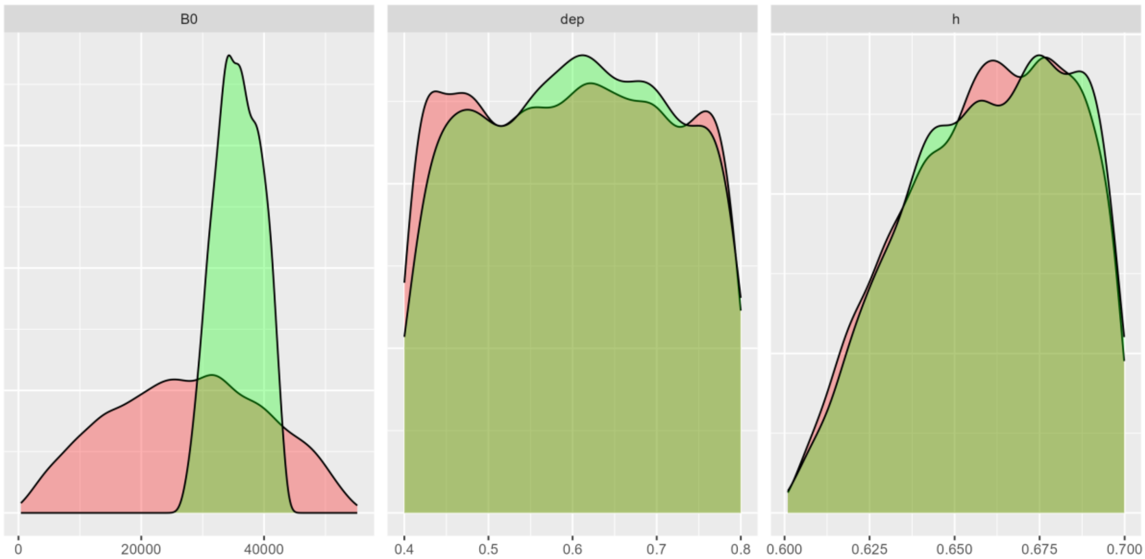

***Figure 21**: Comparison of the prior and posterior distributions for the three main population parameters (virgin biomass, B0, initial depletion level, dep, and stock-recruitment steepness, h.*

4.3.3 Stock status

The alternative bird catch series led to contrasting views on current stock status. The high catches caused a decrease in the population size in the most recent years (**Figure 22**), which is less pronounced when the bird catch series with the lower estimate for 2018 is used (**Figure 23**).

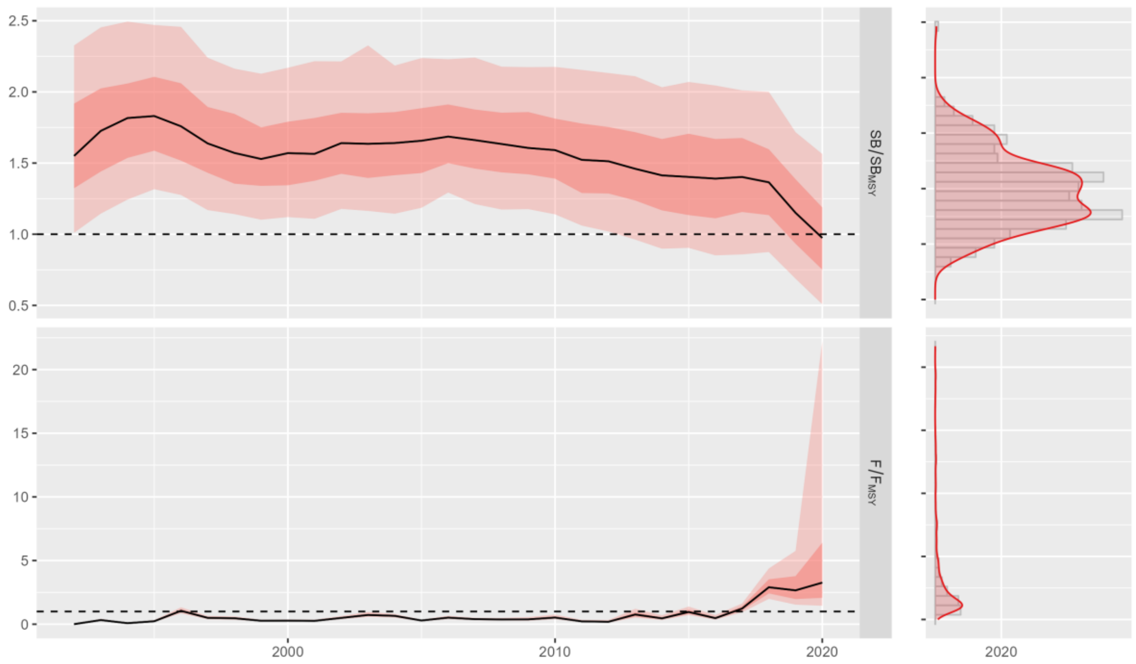

Figure 22*: Selection of possible population trajectories (SSB) for perch with the scenario for high bird catches.*

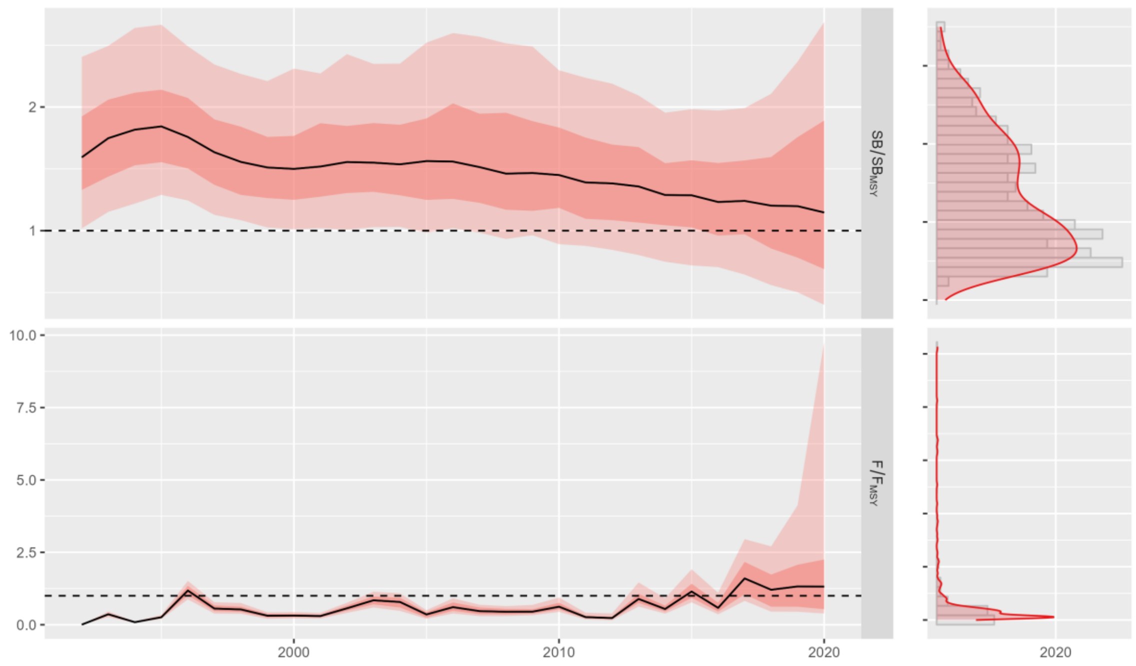

Figure 23*: Selection of possible population trajectories (SSB) for perch with the scenario for low bird catches.*

4.3.4 OM dynamics

In order to investigate the possible future trajectories in the OM's with the original bird catches and lowered bird catches, an exploratory projection was run under a 0 catch assumption for both the bird fisheries and the commercial fisheries; future F was put at 0 for both the bird fisheries and the commercial fishery. These future projections are thus controlled by a constant F (**Figure 24**).

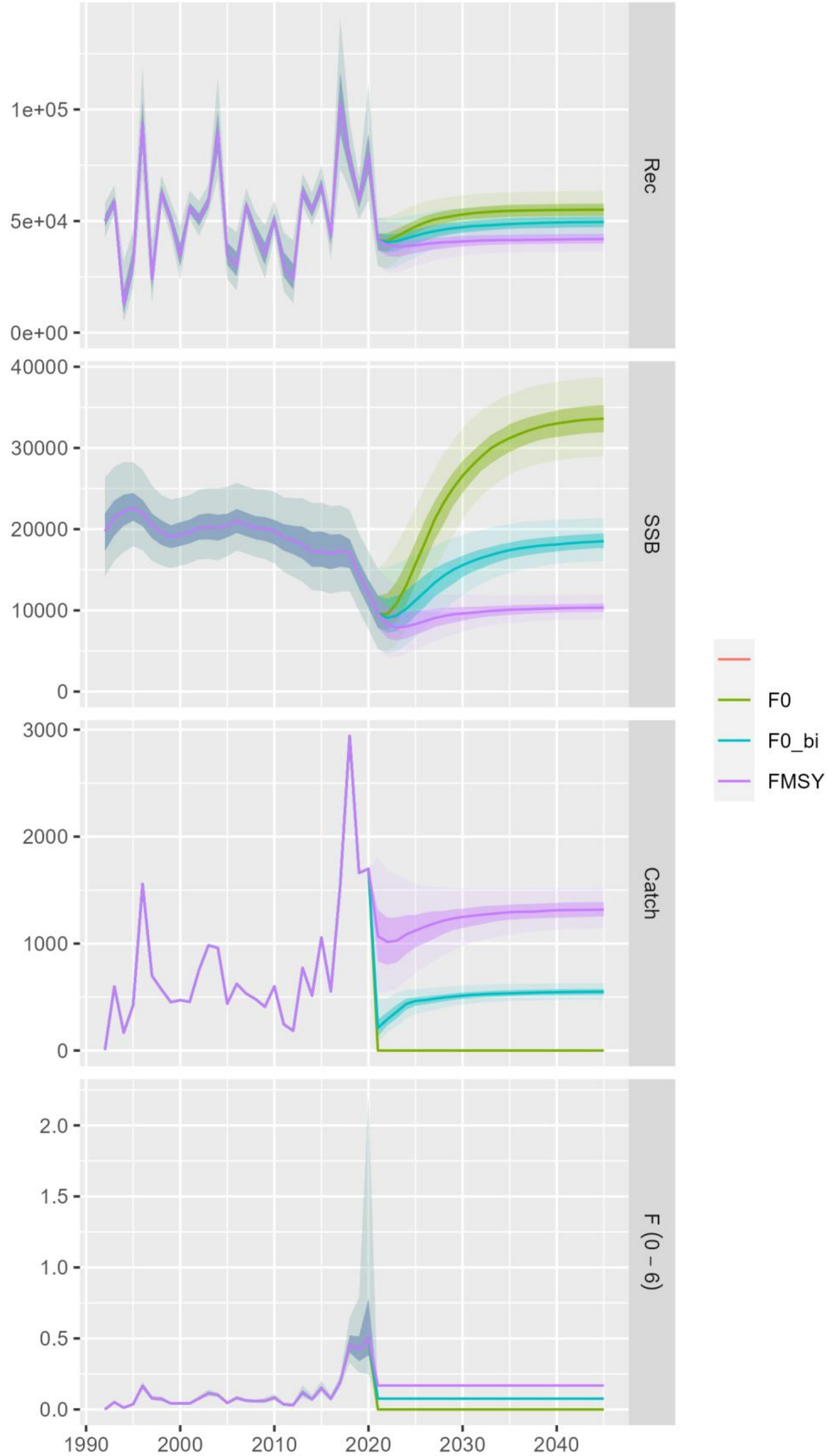

Figure 24: *Population trajectories for both OMs. F0 refers to the scenario of the default bird catch estimates and F0_low refers to the scenario under lowered bird catch values in recent years. In the projections F is put at a constant value of 0.*

4.4 Roach

The candidate OM for roach is still in development due to challenges regarding historical catches and scientific survey results. Fishery catch data (**Figure 25**) from 1992 suggests a peak in gillnet catches in 2007 (263 t) followed by an 8-year decline to 2015 (38 t). The subsequent years show and increase in gillnet catches with the year 2020 displaying relatively high catches compared to historical dataset (**Figure 26**). Estimated bird catches for roach averaged 39 % less than the annual fishery catches since 1992. The scientific survey index for adult roach suggests a general decrease in catch per unit effort (CPUE) within the data collection period (**Figure 26**a). The current challenge for the roach OM involves reconciling the patterns observed from the fishery catch data (**Figure 26**) with the trend seen in the scientific surveys (**Figure 26**a).

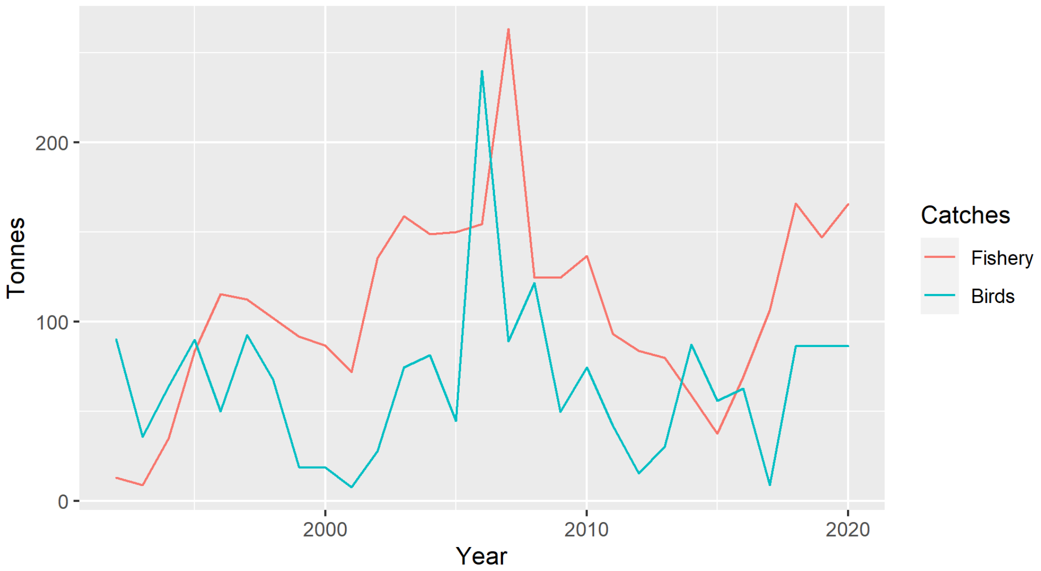

***Figure 25**: Historical catch data from the IJsselmeer gillnet fishery and estimated bird catches from 1992-2020.*

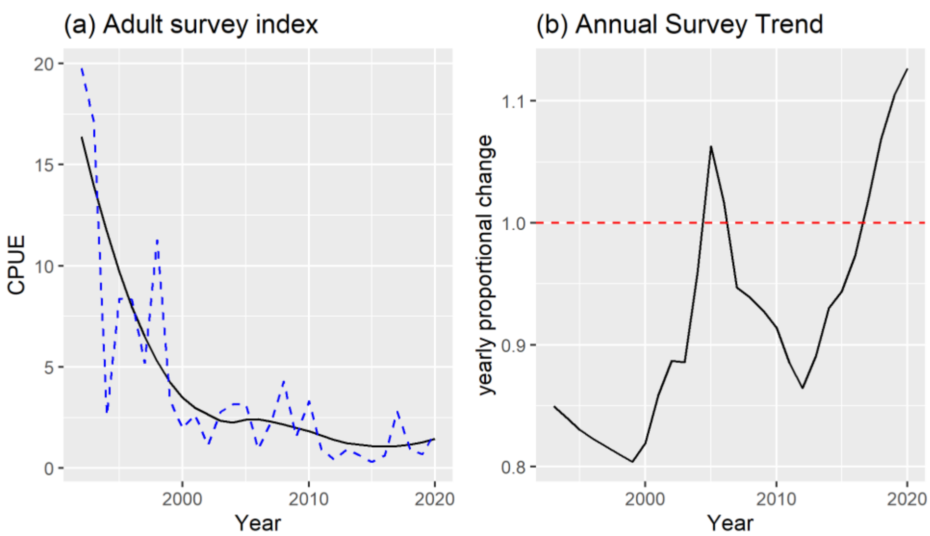

***Figure 26**: Adult survey index for roach. A loess smoother with a 0.75 span (black solid line) was used to infer long term trends(a). The proportional annual rate of change from the smoothened data (b). A value below 1 reflects a relative decrease while a value above 1 shows an increase in the biomass trend.*

4.4.1 Simulation

The distribution of priors for virgin biomass (B0; range = 95 - 14365 t), initial depletion rate (dep; range = 0.20- 0.79), and steepness of the stock-recruitment model (h; range = 0.55 - 0.85) were defined using 15,000 iterations (**Figure 27**). The simulation initializes the population in 1992 and projects the stock to 2020 (data collection period) by imposing an annual rate of change in the stock biomass equal to the annual rate of change in the biomass index from the scientific survey. To account for unrealistic annual variability observed in the data, a LOESS (locally weighted smoothing) smoother was applied to the survey data (**Figure 27**a) to obtain the yearly trend used in the simulation (**Figure 27**b). The selection of feasible trajectories, and report of OM dynamics for roach will be delayed to 2023.

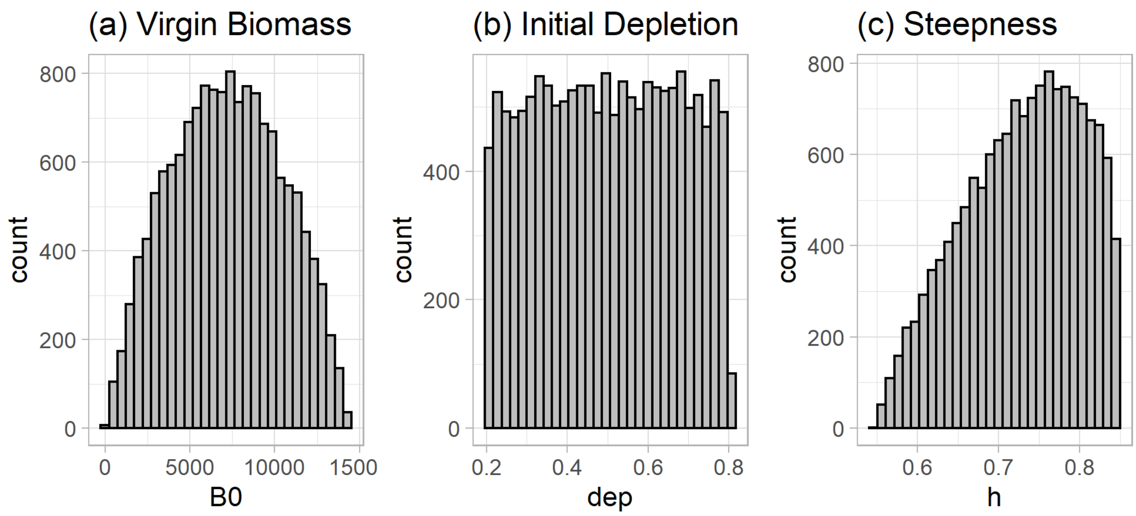

***Figure 27**: Prior probabilities for virgin biomass (a), initial depletion (b) and steepness for the stock recruitment relationship (c) for the roach stock.*

5 Discussion

In 2022, an initiative was undertaken to update the operating models for the four key fish stocks of management interest in the IJsselmeer/Markermeer complex (pikeperch, perch, bream and roach). The feasible trajectories methodology (Bentley and Langley 2012), which is based on a combination of informed priors and model selection derived from available data, was applied and adapted to each stock. Refinements to the method, such as additional and more rigorous selection criteria, should lead to models that are better at extracting trends and information from the data. Conflicts between survey and catch data proved challenging in this latest evaluation.

A few other issues require further investigation such as the conditioning of the roach OM which was left unresolved. Contradictions between different data sources require particular solutions that will be reviewed in detail during the first quarter of 2023. This process will include an external reviewer with ample experience in MSE and OM building to provide feedback on the approach and implementation.

This review process will also lead to the definition of robustness tests, a set of alternative formulations of the OM in the projection years. Different hypothesis on environmental, biological or fleet dynamics, deemed to be likely or possible, can then be used to test the robustness of management procedures tested under the base case OM. For example, future trends in productivity of the lakes will be obtained from other research projects.

6 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 C046/23
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: 13 July 2023

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

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