AN OPERATING MODEL FOR NORTH ATLANTIC SWORDFISH: AN OUTPUT FROM THE CAPACITY BUILDING TRAINING WORKSHOPS IN MSE ANALYSIS

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SUMMARY

*This document presents the development of an example for an Operating Model for the North Atlantic swordfish (*Xiphias gladius*) stock. This was developed within the Capacity Building courses in MSE analysis conducted by ICCAT in 2018. A grid of Stock Synthesis models was constructed based on identified structural uncertainty in the current stock assessment. Each population model run, carried out using the same input data, has a different combination of assumed parameters and variables. The current grid results in 288 model runs, of which 173 converged, producing alternative population trajectories and productivity estimates, which are briefly explored.*

RÉSUMÉ

Ce document présente le développement d'un exemple de modèle opérationnel pour le stock d'espadon de l'Atlantique Nord (Xiphias gladius). *Celui-ci a été mis au point dans le cadre des cours de renforcement des capacités en analyse MSE organisés par l'ICCAT en 2018. Une grille de modèles de Stock Synthesis a été construite sur la base de l'incertitude structurelle identifiée dans l'évaluation actuelle des stocks. Chaque scénario du modèle de population, exécuté en utilisant les mêmes données d'entrée, a une combinaison différente de paramètres et de variables postulés. La grille actuelle donne lieu à 288 scénarios du modèle, parmi lesquelles 173 ont convergé, produisant des trajectoires de population et des estimations de la productivité alternatives, qui sont abordées succinctement.*

RESUMEN

*Este documento presenta el desarrollo de un ejemplo de un modelo operativo para el stock de pez espada del Atlántico norte (*Xiphias gladius*). Se desarrolló en el marco de cursos de creación de capacidad en análisis de MSE impartidos por ICCAT en 2018. Se construyó una matriz de modelos Stock Synthesis basándose en la incertidumbre estructural identificada en la actual evaluación del stock. Cada ensayo del modelo de población, llevado a cabo utilizando los mismos datos de entrada, tiene una combinación diferente de parámetros y variables asumidos. La actual matriz tuvo como resultado 288 ensayos del modelo, de los cuales 173 convergieron, produciendo estimaciones de productividad y trayectorias de la población alternativas para el stock, que se exploran brevemente.*

KEYWORDS

Capacity building, Management Strategy Evaluation (MSE), North Atlantic, Operating Model (OM), Swordfish

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1. Introduction

1.1 Background

The International Commission for the Conservation of Atlantic Tunas (ICCAT) has committed to develop Management Strategy Evaluation (MSE) (Rec [15-07]) to evaluate precautionary management reference points and robust harvest control rules. This was then included as one of the main goals of the SCRS Science Strategic Plan 2015-2020.

Recommendation [15-07] identified albacore north, bluefin tuna, swordfish north and tropical tunas as priority stocks and established a work plan and timetable for the development of the MSE. Changes to the timetable were adopted in 2017 by the SCRS which also defined the major steps of the technical work to be completed as part of the MSE (Anon., 2017a). For the northern albacore MSE, the SCRS provided advice on a variety of HCRs in 2017 (Anon., 2017a) and the Commission adopted an interim harvest control rule in 2017 (Rec [2017-04]). Work regarding bluefin tuna has started in 2016, while northern swordfish and tropical tunas work was expected to begin in 2018. A timetable chart in the 2017 SCRS report (Anon., 2017a) reflected the earlier dates that the SCRS could provide enough information to the Commission to consider harvest control rules for each stock: 2019 for Bluefin tuna, 2020 for northern swordfish and 2021 for tropical tunas.

Considering the advances, current and expected, in MSE development, ICCAT planned and carried out a series of three Capacity Building Courses aiming to enhance the participation of the ICCAT SCRS scientific community in MSE. Following the participation of the authors in these courses (see acknowledgments section for specific funding provided), this working document objective is to present an output exercise showing an example developed for an operational model (OM) for North Atlantic Swordfish.

1.2 North Atlantic Swordfish assessment

The OM being developed here is based of the population and fishery models used for the assessment of the stock status of North Atlantic swordfish (Anon., 2017a), presented at 2017 Swordfish Stock assessment meeting. The Stock Synthesis 3 (Methot & Wetzel, 2013) population model is age-based (with ages 0-25) and separated by sex. Information from 16 fisheries was used, including length composition data for eight of them. Standardized CPUE series was available from 14 fleets. For complete details of the base case stock assessment model please refer to Schirripa (2017) and Anon. (2017b). A summary of the population trajectories estimated by the base case model are presented in **Figure 1**.

2. Operating model conditioning

2.1 Software implementation

The software that has been developed for conditioning of the SS3-based OM for Indian Ocean albacore (Mosqueira, 2017) has been extended to work on the model structure applied to North Atlantic swordfish. This is based on the FLR Project R library for quantitative fisheries science (Kell et al. 2007). Currently, all the code for this work (condition the OM, load and inspect the results, and future projections and simulations) is hosted at the OwnCloud for the MSE Capacity Building courses.

2.2 Structural uncertainty grid

It is expected that by the end of 2018 there should be a development of the operating model (OM) framework, defining a set of OM models describing the major axes of uncertainty and the initial conditioning of these alternative OMs for North Atlantic swordfish. Considering the workplan for swordfish MSE in 2018, at the 2018 ICCAT Bluefin tuna and North Atlantic swordfish management strategy evaluation meeting, the Swordfish working group (SWO WG) discussed and proposed several uncertainties that could be incorporated into these OMs (Anon., 2018).

For the present work and as an exercise for the Capacity Building courses, the authors decided to construct a small grid of model runs based on a selection of the identified uncertainties by the SWO WG. A summary of the grid of uncertainties considered for the conditioning of the OM is presented in **Table 1**. This grid results in a total of 288 model runs, of these 115 models failed to converge, most likely due to unreasonable combinations of parameters and data that lead to a failure in convergence. A total of 173 model runs converged and constitute the operating model. OM population trajectories are presented in **Figure 2**. For exploration of the implications of the various assumed parameters in the models, the distribution of estimates for virgin biomass (B_0) in the OM grid are presented in **Figure 3**. Below is a detailed description of the uncertainties considered and initial inspection of results.

2.2.1 Steepness

Steepness (h) from Beverton and Holt stock-recruitment function is often a very influential parameter which is difficult to estimate in most stock assessments, however in the 2017 North Atlantic assessment it was estimated to be 0.88 (Anon., 2017b). For the grid three possibilities of fixed steepness were considered, to reflect uncertainty in this parameter using plausible values (0.6, 0.75 and 0.9). The distribution of estimates of B_0 in relation to h are presented in **Figure 4**.

2.2.2 Natural Mortality

Natural mortality (M) is a common unknown in species biology and, in combination with Stepness, is one of the parameters that is often more influential in the stock assessment models. In the base case 2017 stock assessment, natural mortality was constant for all ages and sexes at 0.2. A total of 3 possibilities were considered for M in this grid to reflect plausible lower and higher values (0.1, 0.2 and 0.3). The distribution of estimates of B_0 in relation to M are presented in **Figure 5**.

2.2.3 Effective sample size

The effective sample size (ESS) alters the relative weighting of length samples and CPUE series in informing the model about stock dynamics and the effects of fishing at length. Particularly in cases where there are conflicts between CPUE and size distribution data, ESS can have implication for the stock assessment models as more or less relative weight will be given to each data source. In the 2017 swordfish base case assessment model, a fleet specific effective sample size was used. For the OM grid, and in order reflect different assumptions in regarding those data sources, two values were used for the relative weight of length sampling data in the total likelihood, through changes in the effective sampling size parameter, of 2 and 20, for all fleets. The distribution of estimates of B_0 in relation to ESS are presented in **Figure 6**.

2.2.4 Catchability increase

Two scenarios were considered for the effective catchability (q) of the CPUE fleets. On the first one it was assumed that the fleets have not improved their ability to fish for swordfish over time, and/or that any increase through time was captured by the CPUE standardization process (0% increase). This reflects the base case as used in the 2017 stock assessment. For the OM grid, one additional scenario was considered, specifically with a 1%/year increase in catchability by changing the CPUE indices to reflect this. With this alternative we therefore assume that the CPUE standardization processes cannot fully account for the increases in catchability. The distribution of estimates of B_0 in relation to q increase are presented in **Figure 7**.

2.2.5 Environmental effects

In the base case stock assessment model, catchability was made a function of the Atlantic Multidecadal Oscillation (AMO) for some fisheries. In the grid, two scenarios were considered for the environmental effects. For one it was assumed that the AMO has an effect in catchability in some fisheries, as in the base case. While in the alternative scenario it was considered that there was no environmental effect for any of the fisheries, affecting the catchability. The distribution of estimates of B_0 in relation to environmental effects are presented in **Figure 8**.

2.2.6 Recruitment deviations

Two values were considered for the true variability of recruitment in the population (sigmaR), specifically 0.2 and 0.6. The base case in the stock assessment model considered a value of 0.2, and for this OM grid we posed a second hypothesis. The distribution of estimates of B_0 in relation to sigmaR are presented in **Figure 9**.

2.2.7 CPUE variance

Given that GLMs of CPUEs can often have CVs that are seemingly under estimated, a variance reweighting was used on each of the CPUE time series in the base case model the 2017 stock assessment. For the OM grid two extreme scenarios were used, with CPUE CVs set to 0.3 and 0.6 for all fleets. The distribution of estimates of B_0 in relation to CPUE variance are presented in **Figure 10**.

Despite in many cases the varied parameter values being greater and lower than the base case parameter value the distribution of B_0 is usually skewed to the right (B_0 estimates are mostly higher than in the base case). Additionally, for some parameter levels there is an indication that B_0 estimations may have hit a lower bound. Further analysis is required to understand the factors that led to those estimations.

3. Final remarks and future steps

This work started on the basis of the Capacity Building workshops for MSE organized in 2018 by ICCAT. This working paper provides an example for a north Atlantic swordfish OM grid that was developed both at and between those courses. The grid provided reflects mostly structural uncertainties that have been identified at the time of the 2017 North Atlantic swordfish assessment and in the 2018 ICCAT inter-sessional BFT/NSWO MSE meeting.

In the future, it could be interesting to further develop this work as an ongoing scientific process. It is further noted that while the objectives for the 2018 North swordfish are mostly related with the development of the OM, for 2019 the main objectives are to develop and start the evaluation of alternative MPs (**Table 2**). In the case of North Atlantic swordfish there are already conservation measures adopted by ICCAT, notably by the setting of TACs (total allowable catches) and MLS (minimum landing sizes), so the evaluation of those would also be important.

As such, future steps for this work could include:

- Consideration of additional structural uncertainties or additional parameter values of the uncertainties already considered;
- Further analysis of the estimates of the operating model, e.g., further checking for unreasonable results;
- Computing an initial set of reference projections, e.g. constant catch and constant fishing mortality;
- Testing the effectiveness of the current conservation measures applied to swordfish, e.g. minimum landing sizes.

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Table 1. Summary of the North Atlantic swordfish stock assessment base case model and operating model grid.

Variable	Stock assessment base case model	Operating model grid		
Steepness	0.88 (estimated)	0.6	0.75	0.9
Natural mortality	0.2	0.1	0.2	0.3
SigmaR	0.2	0.2	0.6	
CPUE CV	Fleet specific	0.3	0.6	
ESS	Fleet specific	2	20	
Catchability increase	0%	0%	1%/year	
Environmental effects	AMO effect in some fisheries	AMO effect in some fisheries	No environmental effects	

Table 2. Roadmap adopted by ICCAT with regards to implementation of MSE for priority stocks. The red circles reflect the earlier dates at which the SCRS could provide initial advice and recommendations regarding evaluation of alternative MPs.

MSE Calendar SCRS	2018 ALB-N	2018 BFT	2018 SWO-N	2018 TROP	2019 ALB-N	2019 BFT	2019 SWO-N	2019 TROP	2020 ALB-N	2020 SWO-N	2020 TROP	2021 SWO-N	2021 TROP
Development of OM framework			X	X									
Conditioning of OM				X							X		X
Development of OM alternatives			X					X					
Finalization of diagnostics and improvements of MP evaluations	X												
Re-evaluation of performance of MPS in light of definition of exceptional circumstances	X												
Development of MPs		X			X	X	X	X					X
Evaluation of MPs		X				X	X		X		X		X
Independent review of MSE process	X	X							X	X	X		
Production of documentation for stakeholders explaining results of MSE for BFT						X			X	X			X

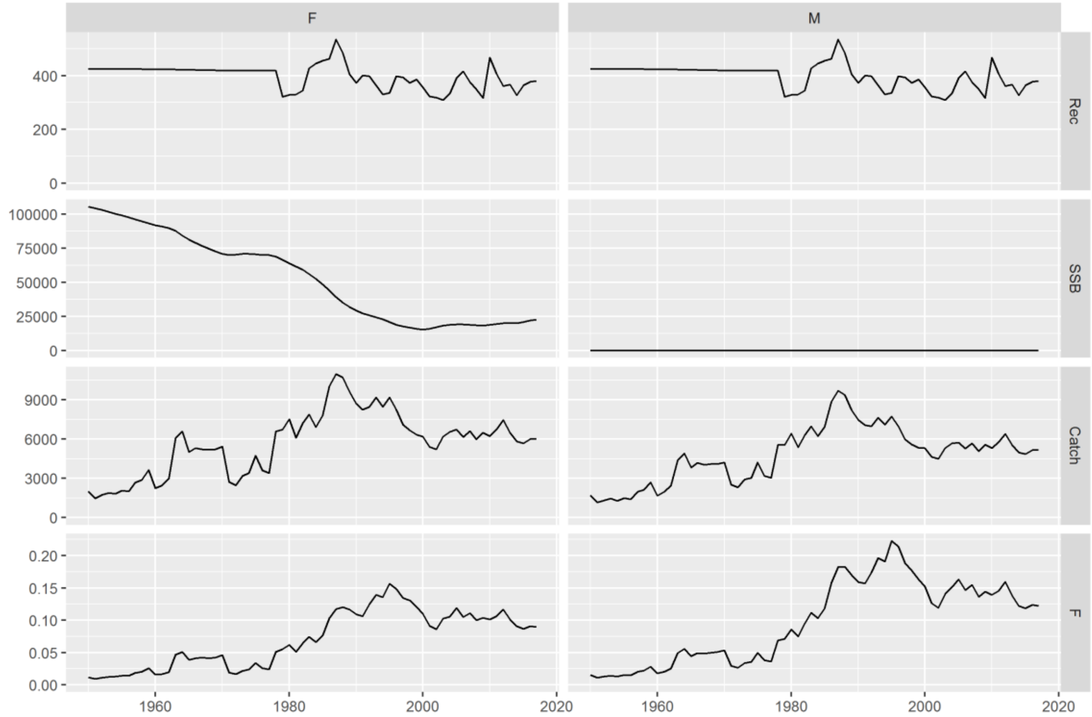

Figure 1. Population trajectories (recruitment, SSB, catch and F) estimated by the 2017 Stock Synthesis stock assessment of North Atlantic swordfish.

Figure 2. Population trajectories (recruitment, SSB, catch and F) estimated by operating model grid for North Atlantic Swordfish. The black line shows the median value, while the darker and lighter ribbons show the 50% and 90% quantiles, respectively.

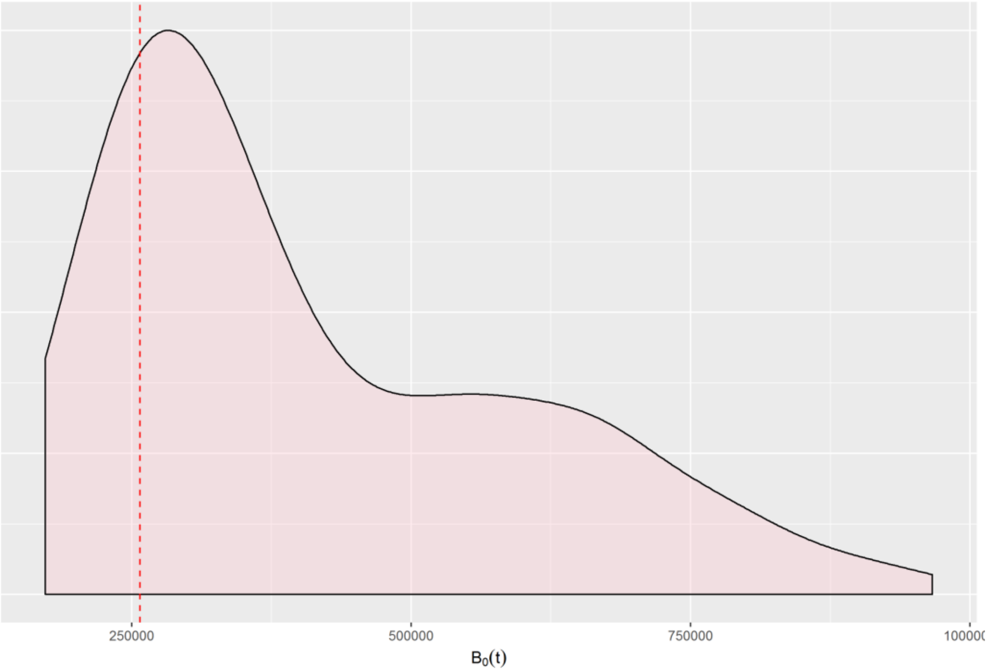

Figure 3. Distribution of the 173 estimated values of virgin biomass (B_0) in the operating model grid for North Atlantic Swordfish. The red dotted line shows the value estimated from the stock assessment base case model run.

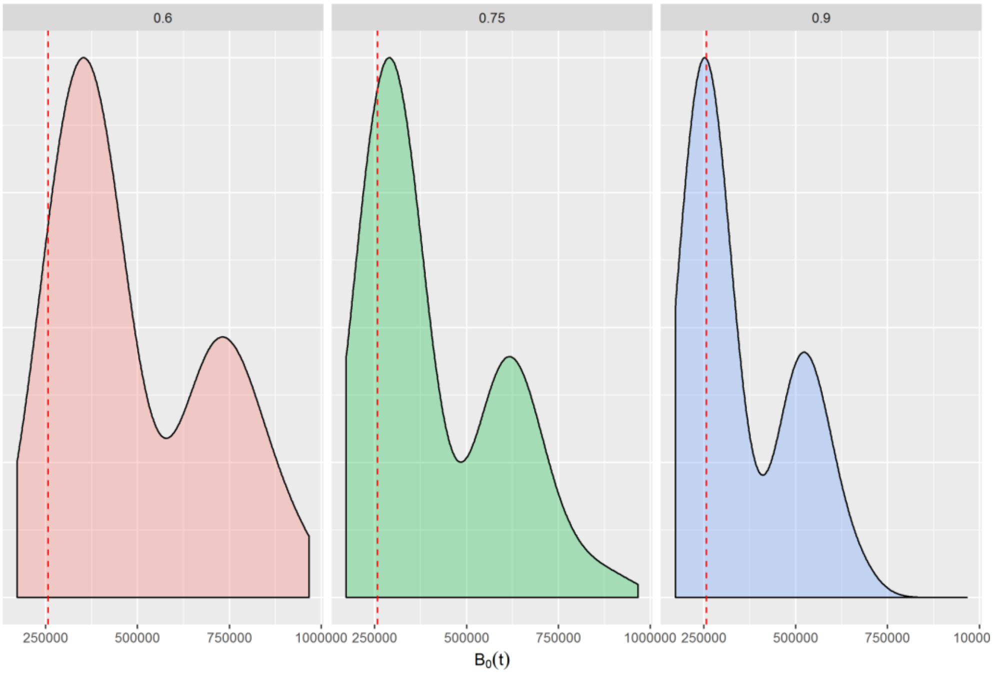

Figure 4. Distribution of the 173 estimated values of virgin biomass (B_0) in the operating model grid for North Atlantic Swordfish by assumed (fixed) values of steepness (0.6, 0.75 and 0.9). The red dotted lines show the values estimated by the stock assessment base case model runs.

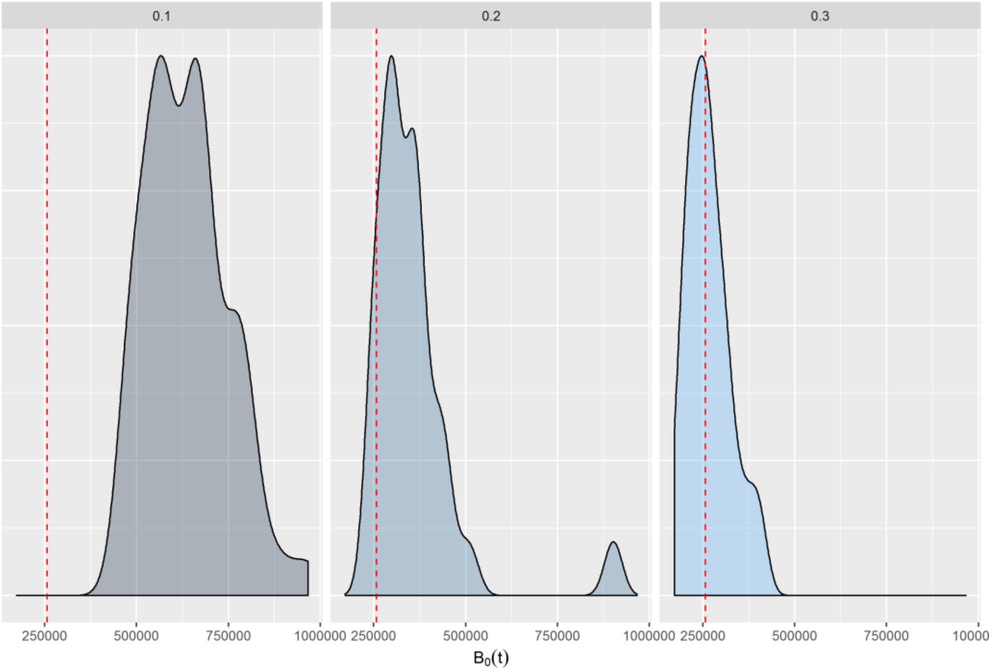

Figure 5. Distribution of the 173 estimated values of virgin biomass (B_0) in the operating model grid for North Atlantic Swordfish by natural mortality (0.1, 0.2 and 0.3). The red dotted lines show the values estimated by the stock assessment base case model run.

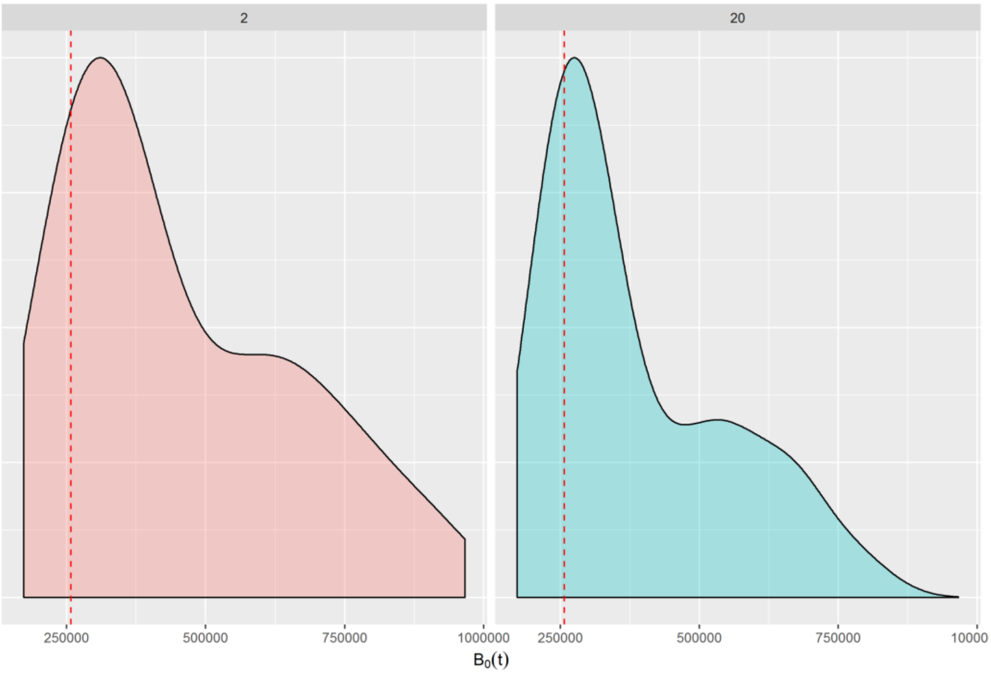

Figure 6. Distribution of the 173 estimated values of virgin biomass (B_0) in the operating model grid for North Atlantic Swordfish by effective sample size (2, 20). The red dotted lines show the values estimated by the stock assessment base case model run.

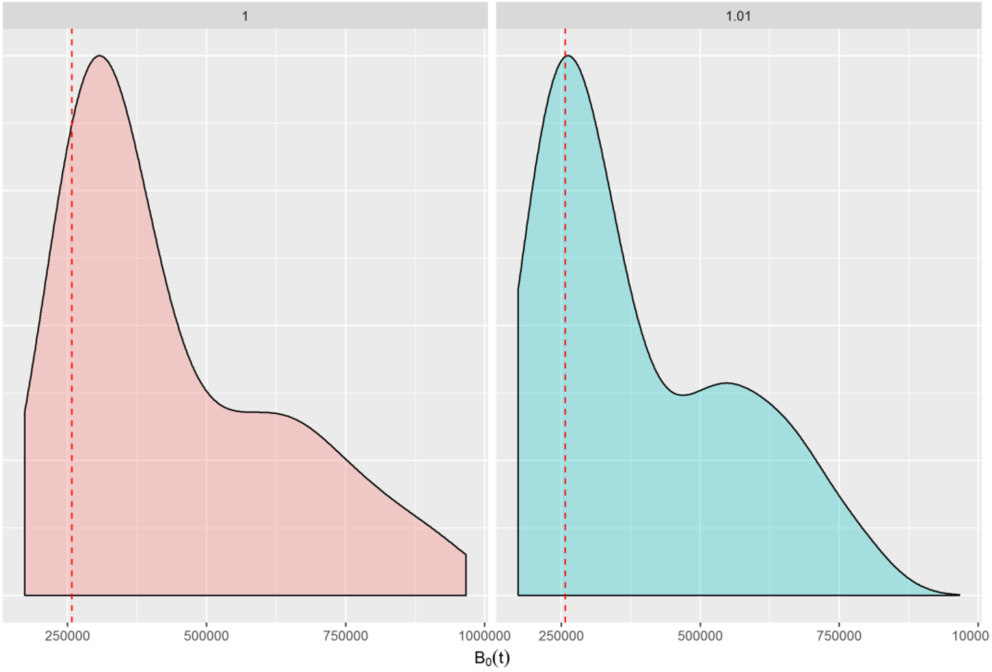

Figure 7. Distribution of the 173 estimated values of virgin biomass (B_0) in the operating model grid for North Atlantic Swordfish by catchability increase (1 – 0% increase; 1.01 – 1% increase/year). The red dotted lines show the values estimated by the stock assessment base case model run.

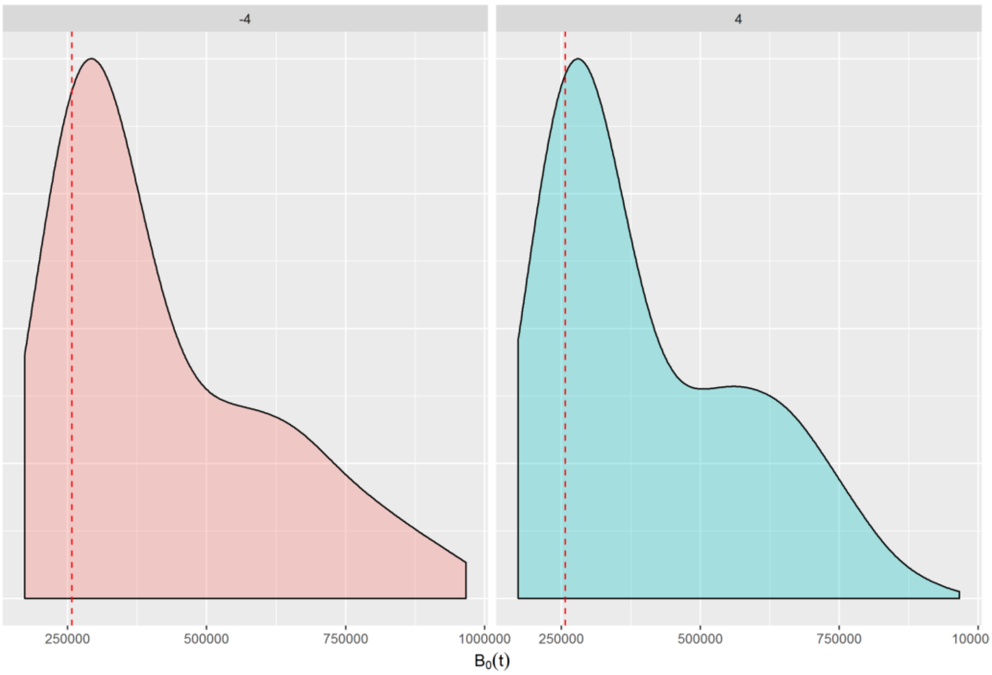

Figure 8. Distribution of the 173 estimated values of virgin biomass (B_0) in the operating model grid for North Atlantic Swordfish by environmental effect (right panel – Atlantic Multidecadal Oscillation effect on some fisheries; left panel – no environmental effect). The red dotted lines show the values estimated by the stock assessment base case model run.

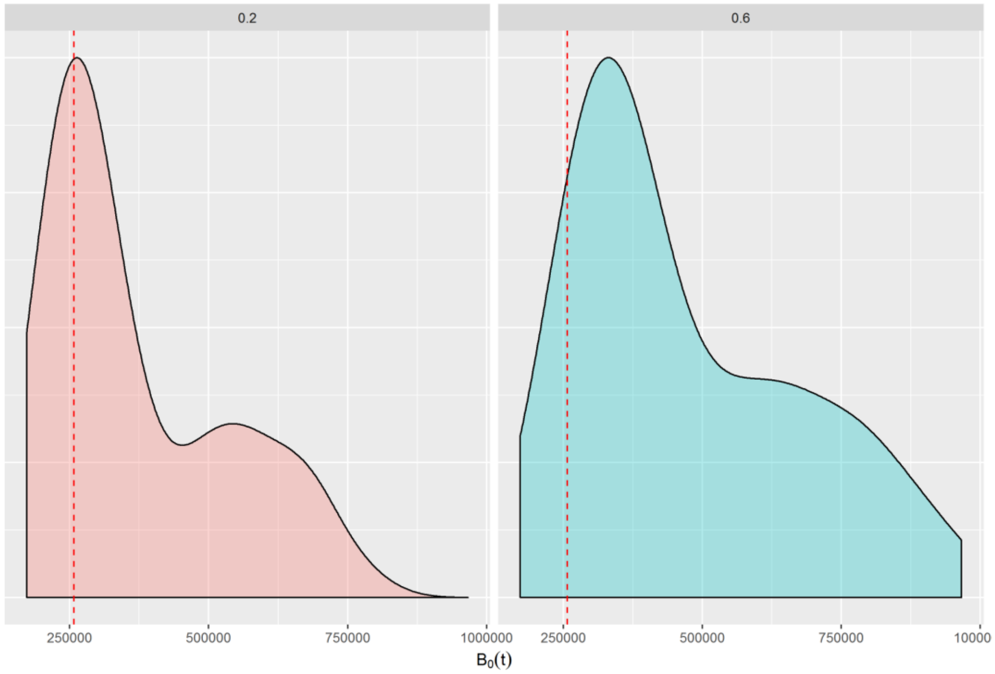

Figure 9. Distribution of the 173 estimated values of virgin biomass (B_0) in the operating model grid for North Atlantic Swordfish by recruitment deviation (0.2, 0.6). The red dotted lines show the values estimated by the stock assessment base case model run.

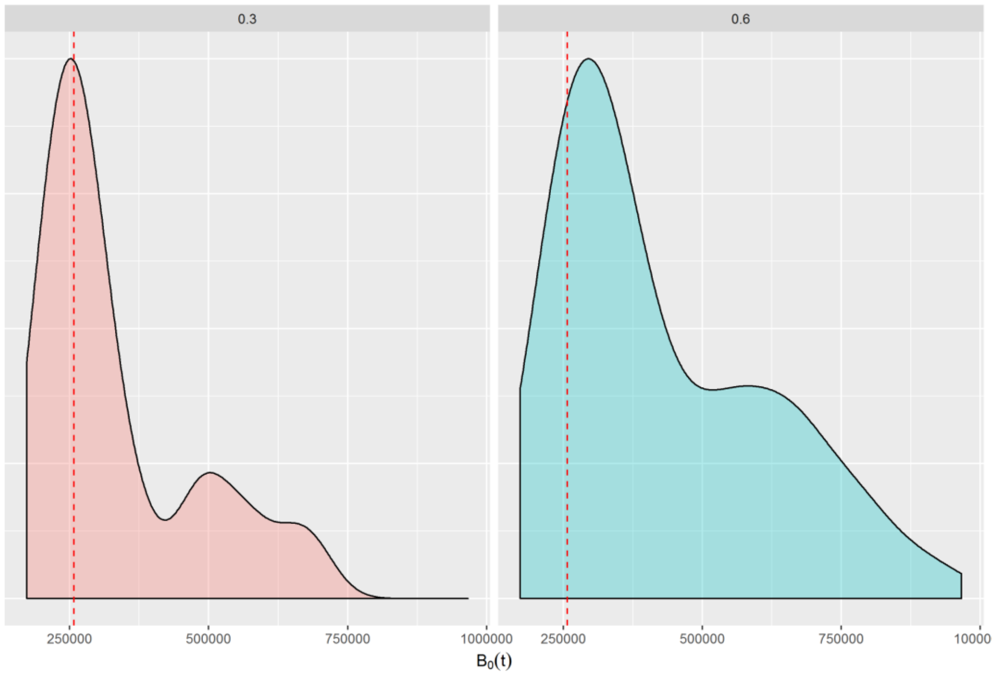

Figure 10. Distribution of the 173 estimated values of virgin biomass (B_0) in the operating model grid for North Atlantic Swordfish by CPUE variance (0.3, 0.6). The red dotted lines show the values estimated by the stock assessment base case model run.