SCRS/2021/100 Collect. Vol. Sci. Pap. ICCAT, 78(7): 262-277 (2021)

SUMMARY OF FITS TO CPUE INDICES FOR THE UPDATED NORTH ATLANTIC SWORDFISH OPERATING MODEL UNCERTAINTY GRID

Adrian Hordyk[1]

SUMMARY

Fits to the catch-per-unit-effort (CPUE) indices and the length composition data are shown for the 10 national fleets and 5 survey fleets used in the conditioning of operating models (OMs) for the North Atlantic swordfish fishery. Plots of the fits to these input data are shown for the three levels of relative weighting to the CPUE and length composition data. Other than this axis of relative weighting, the three levels of natural mortality (M) had the largest influence on the fits to the data. In general, the overall error in the fits to the CPUE indices, summarized as root mean square error, and to the length composition data was lowest for the OMs where M = 0.3. The estimated stock status for these OMs was the highest (mean spawning biomass relative to spawning biomass at maximum sustainable yield >2), although the variability in the estimates was also the highest for this level.

RÉSUMÉ

Les ajustements aux indices de capture par unité d'effort (CPUE) et aux données de composition par taille sont présentés pour les 10 flottilles nationales et les 5 flottilles de prospection utilisées dans le conditionnement des modèles opérationnels (OM) pour la pêcherie d'espadon de l'Atlantique Nord. Les diagrammes des ajustements à ces données d'entrée sont présentés pour les trois niveaux de pondération relative des données de CPUE et de composition par taille. À part cet axe de pondération relative, les trois niveaux de mortalité naturelle (M) avaient la plus grande influence sur les ajustements aux données. En général, l'erreur globale dans les ajustements aux indices de CPUE, résumée comme l'erreur quadratique moyenne, et aux données de composition par taille était la plus faible pour les OM dans lesquels M = 0,3. L'état du stock estimé pour ces OM était le plus élevé (biomasse reproductrice moyenne par rapport à la biomasse reproductrice au niveau de la production maximale équilibrée >2), bien que la variabilité des estimations était également la plus élevée pour ce niveau.

RESUMEN

Se muestran los ajustes a los índices de la captura por unidad de esfuerzo (CPUE) y los datos de composición por tallas para las 10 flotas nacionales y 5 flotas de prospección usadas en el condicionamiento de los modelos operativos (OM) para la pesquería de pez espada del Atlántico norte. Los gráficos de los ajustes a estos datos de entrada se muestran para los tres niveles de ponderación relativa de la CPUE y los datos de composición por tallas. Aparte de este eje de ponderación relativa, los tres niveles de mortalidad natural (M) tuvieron la mayor influencia en los ajustes a los datos. En general, el error global en los ajustes a los índices de CPUE, resumido como error cuadrático de la media raíz, y a los datos de composición por tallas, fue el más bajo para los OM donde M = 0,3. El estado estimado del stock para estos OM era el más alto (biomasa reproductora del stock media relativa a la biomasa reproductora en el nivel del rendimiento máximo sostenible > 2), aunque la variabilidad en las estimaciones era también la más elevada para este nivel.

KEYWORDS

Management Strategy Evaluation, Fishery Management, Catch/effort

---

[1] Blue Matter Science Ltd, 2150 Bridgman Avenue, North Vancouver, BC, CANADA, V7P2T9
adrian@bluematterscience.com

1 Introduction

The North Atlantic swordfish (hereafter swordfish) fishery is undergoing a Management Strategy Evaluation (MSE) process. A first step in an MSE is the development of a set of operating models (OMs), with each OM representing an alternative hypothesis for the dynamics of the fishery. The Swordfish Species Working Group (hereafter the Group) has chosen to use the approach of an OM uncertainty grid, where the key fishery uncertainties are captured by means of alternative levels in several axes of uncertainty. As is usual in an MSE process, the uncertainty grid has been revised several times. The current uncertainty grid has six axes of uncertainty each with 2 or 3 levels (**Table 1**). A full factorial design of these factors and levels results in an uncertainty grid of 216 OMs (see Hordyk et al., 2021 for details).

Swordfish was last assessed in 2017 (Anon., 2017). In addition to the catch data from 8 longline fleets, there were two primary data streams used in the stock assessment: 1) indices of abundance derived from catch-per-unit-effort (CPUE) data from 6 national fleets, and 2) length composition data from 7 national fleets. The data from the Canada longline fleet was split into two stanzas: Early (1962 - 1970) and Late (1979 - 2016) due to changes in fishing practices that were believed to have changed catchability. Similarly, data from the Japan longline fleet was split into three phases: Early (1974 - 1998), Mid (2006 - 2010), and Late (2011 - 2015) due to changes in fishing practices in these periods. Five additional survey indices were developed from the age-specific (ages estimated from length data) CPUE from the Spain longline fleet (Age-1, -2, -3, -4, and -5+) (**Table 2**).

The 216 OMs were conditioned with the Stock Synthesis 3 assessment software (Methot & Wetzel, 2013). An important part of the MSE process is to evaluate the fits of the conditioned OMs to the input data. Cases where the fits to the data are poor may indicate combinations of fixed parameters and data assumptions that are unlikely to reflect the true stock dynamics, and may suggest that the problematic OMs are removed and the uncertainty grid revised.

This paper summarizes the fits of the OMs in the uncertainty grid to the CPUE index and the length composition data used in the OM conditioning.

2 Methods

The fits to the CPUE indices are summarized graphically with time-series plots of the observed indices and the predicted indices from the 216 operating models. The time-series plots are faceted by the CPUE lambda axis of uncertainty (three levels: 0.05, 1, and 20) and the axis for the 1% increase in catchability. This was done because the CPUE lambda axis represents alternative weightings of the CPUE data and is therefore expected to impact the fit to the CPUE indices, and the OMs that included the 1% increase in catchability had different indices to those without. The plots were color-coded by the three levels of natural mortality (*M*) as this was the factor that in general had the largest impact on the fits to the CPUE indices. The root mean squared error (RMSE) for each level of *M* was included in each panel to summarize the error in the fits to the CPUE indices.

The fits to the length frequency data were summarized as barplots of the observed length composition data for each fleet, aggregated over all years, with lines indicating the model fits for the 216 OMs in the uncertainty grid. The length composition plots were faceted by the CPUE lambda axis of uncertainty, and color-coded by the three levels of *M*, the factor that had the largest impact on the fits to the length composition data.

Detailed reports of the fits to the data for each of the 216 OMs, including the statistical properties of the fits to the CPUE and length composition data are available in the OM-specific diagnostic reports available on the North Atlantic Swordfish MSE homepage (https://iccat.github.io/nswo-mse/).

3 Results

There was relatively little difference in the fits to the length composition data for the Spain fleet across the three levels of CPUE lambda and three levels of M, although, as expected, the fits to the length composition data were better when the CPUE data was down-weighted (CPUE lambda = 0.05) (**Figure 1**).

For the US fleet, the OMs with the 1% annual increase in catchability and *M* = 0.1 had a lower RMSE (**Figure 2**). Although there was less variability in the OMs where the CPUE indices were up-weighted (CPUE lambda = 20), the predicted indices tracked the observed index better when the CPUE indices were down-weighted (**Figure 2**).

There was little variability in the predicted length compositions in the OMs where CPUE data was down-weighted (**Figure 3**). Most of the variability in the fits to the length composition when CPUE data was up-weighted could be explained by the 3 levels of M (**Figure 3)**.

The variability in the fits to the length composition data was more apparent for the Canada-Late fleet, where the lowest level of *M* (0.1) resulted in a considerable mismatch between the observed and predicted length data across all three levels of CPUE lambda (**Figure 4**). The OMs that included the environmental covariate had a lower RMSE for this fleet, with the lowest RMSE occurring in the OMs where the CPUE and length composition data both had a lambda of 1 and natural mortality was 0.3 (**Figure 5**).

There was very little difference in the fit to the Canada-Early index across the three levels of CPUE lambda and the three levels of *M* (**Figure 6**).

The fits to the length composition data from the Japan-Early fleet varied considerably across the three levels of M, especially for the lowest level of natural mortality (0.1) (**Figure 7**). The fits to the CPUE indices were similar across the three levels of CPUE lambda, and similar across the three levels of *M* (**Figure 8**).

For the Japan-Mid fleet, the fits to the length composition data were similar across the three levels of *M* when CPUE lambda = 0.05, but highly variable when the CPUE data was up-weighted, especially at the highest levels of *M* (**Figure 9**). Similar to the Japan-Early, the fits to the CPUE indices were similar across the three levels of CPUE lambda, although the OMs where the CPUE data was up-weighted (CPUE lambda = 20) had the lowest overall RMSE (**Figure 10**).

The fits to the length composition data from the Japan-Late fleet were similar across the 3 levels of *M*, although there was increased variability in the fits where the OMs where CPUE lambda was 20 (**Figure 11**). Similar to the Japan-Early and Japan-Mid, the fits to the CPUE indices were similar across the three levels of CPUE lambda (**Figure 12**).

The fits to the length composition data were very similar across the three levels of *M* when the CPUE indices were down-weighted (**Figure 13**). There was more variability when the CPUE indices were up-weighted, particularly for *M* = 0.1 (**Figure 13**). Similarly, the OMs with *M* = 0.1 had the highest RMSE for the fits to CPUE indices (**Figure 14**).

For the Chines-Taipei fleet there was a poor fit to the length composition data across the three levels of CPUE lambda and the three levels of *M*, especially when *M* = 0.1 (**Figure 15**). In contrast, the fits to the length compositions from Morocco fleet were similar across the three levels of CPUE lambda and the three levels of *M* (**Figure 16**). For the fits to the Morocco index, the OMs with *M* = 0.1 had the lowest RMSE, except for when the CPUE indices were down-weighted (**Figure 17**).

The fits to the age-specific CPUE indices from the Spain fleet had the lowest RMSE when *M* =0.1, with RMSE generally increasing with increasing values of *M* (**Figure 18**, **Figure 19**, **Figure 20**, **Figure 21**, **Figure 22**). The lowest RMSE was for the Age-5+ Survey when the CPUE lambda = 20 and the 1% annual increase in catchability was included in the indices, with a slightly different fit but identical RMSE across the three values of *M* (**Figure 22**).

4 Discussion

The results show that the three levels of *M* result in considerable differences to the fits to the CPUE indices and the length composition data, particularly for the length data from the Canada-Late, Japan-Early and -Mid, and Chinese-Taipei fleets (**Figure 5**, **Figure 7**, **Figure 9**, and **Figure 15** respectively). The fits to the length composition data appeared worst for these stocks for the OMs where *M* was at the lowest level (0.1). These OMs also had the lowest estimated stock status (mean SB/SB_{MSY} ~ 1) with the higher values of *M* resulting in estimates of stock status that were considerably higher (Hordyk et al., 2021).

As expected, the three levels of CPUE lambda resulted in variability in the fits to the CPUE and length composition data, with better fits to the CPUE indices as the relative weight to these data was increased. The OMs with higher weights on the CPUE indices resulted in lower estimates of stock status, and less variability in the estimates of the biological reference points and stock status (Hordyk et al., 2021). This result suggests that there is tension between the CPUE and length composition data that cannot be easily resolved, particularly across the three levels of natural mortality.

5 Acknowledgements

The Swordfish Species Working Group, particularly Kyle Gillespie, Rui Coelho, Alex Hanke, Daniela Rosa, and Michael Schirripa are thanked for their input and feedback on this work. This work was carried out under the provision of the ICCAT Science Envelope and the ICCAT – EU Grant Agreement – Strengthening the scientific basis for decision-making in ICCAT. The contents of this paper do not necessarily reflect the point of view of ICCAT or other funders and in no ways anticipate ICCAT future policy in this area.

References

Anon. (2017). Report of the 2017 ICCAT Atlantic Swordfish Stock Assessment Session. SCRS/2017/008. *Collect. Vol. Sci. Pap. ICCAT*, *74*(3), 841–967.

Hordyk, A., Schirripa, M., & Rosa, D. (2021). Updates to the Operating Model Uncertainty Grid for the North Atlantic Swordfish MSE SCRS/2021/099. *Collect. Vol. Sci. Pap. ICCAT*.

Methot, R. D., & Wetzel, C. R. (2013). Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research*, *142*, 86–99. https://doi.org/10.1016/j.fishres.2012.10.012

Table 1. The six axes of uncertainty (columns) and the levels for each factor (rows) in the operating model (OM) uncertainty grid for the North Atlantic Swordfish MSE. The full factorial design of these factors and levels results in a grid of 216 OMs.

Natural Mortality (M)	Recruitment variability (sigmaR)	Steepness (h)	CPUE Lambda	1% Annual Increase in Catchability	Environmental Covariate
0.1	0.2	0.60	0.05	FALSE	FALSE
0.2	0.6	0.75	1	TRUE	TRUE
0.3		0.90	20		

Table 2. The range of years for the CPUE index and length composition data for the 10 commercial fleets and 5 survey indices for the North Atlantic swordfish fishery.

Fleet	Data Year Range	
	CPUE Index	Length Composition
Spain	-	1977 – 2015
US	1992 – 2015	1970 – 2015
Canada – Late	1979 – 2016	1988 – 2015
Canada – Early	1962 – 1970	-
Japan – Early	1974 – 1998	1971 – 2006
Japan - Mid	2006 – 2010	2007 – 2009
Japan - Late	2011 – 2015	2011 – 2014
Portugal	1999 – 2016	1986 – 2015
Chinese-Taipei	-	1995 – 2015
Morocco	2005 – 2016	2003 – 2015
Age-1 Survey	1982 – 2015	-
Age-2 Survey	1982 – 2015	-
Age-3 Survey	1982 – 2015	-
Age-4 Survey	1982 – 2015	-
Age-5+ Survey	1982 – 2015	-

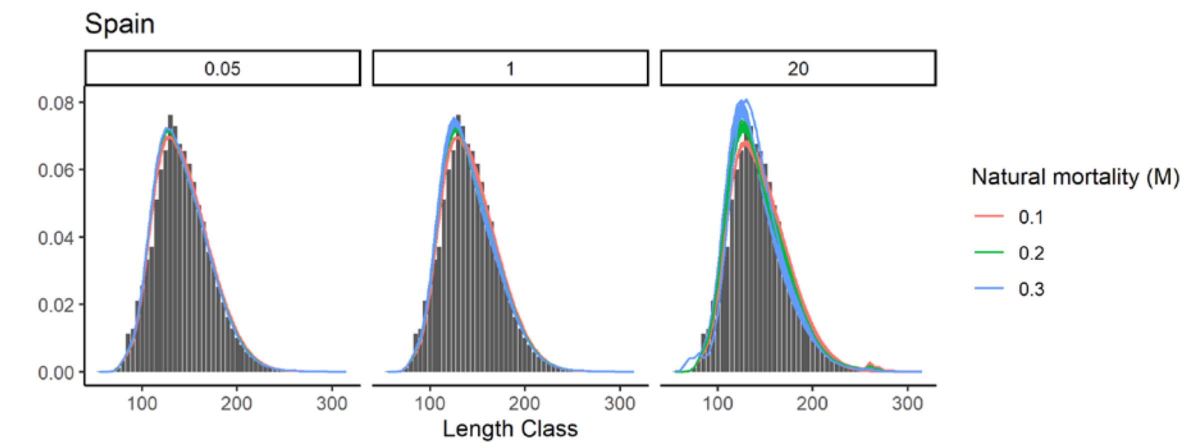

Figure 1. Fits of the length composition data, aggregated over all years, for the three levels of CPUE lambda (columns) and three levels of natural mortality (M; colours) for the Spain fleet.

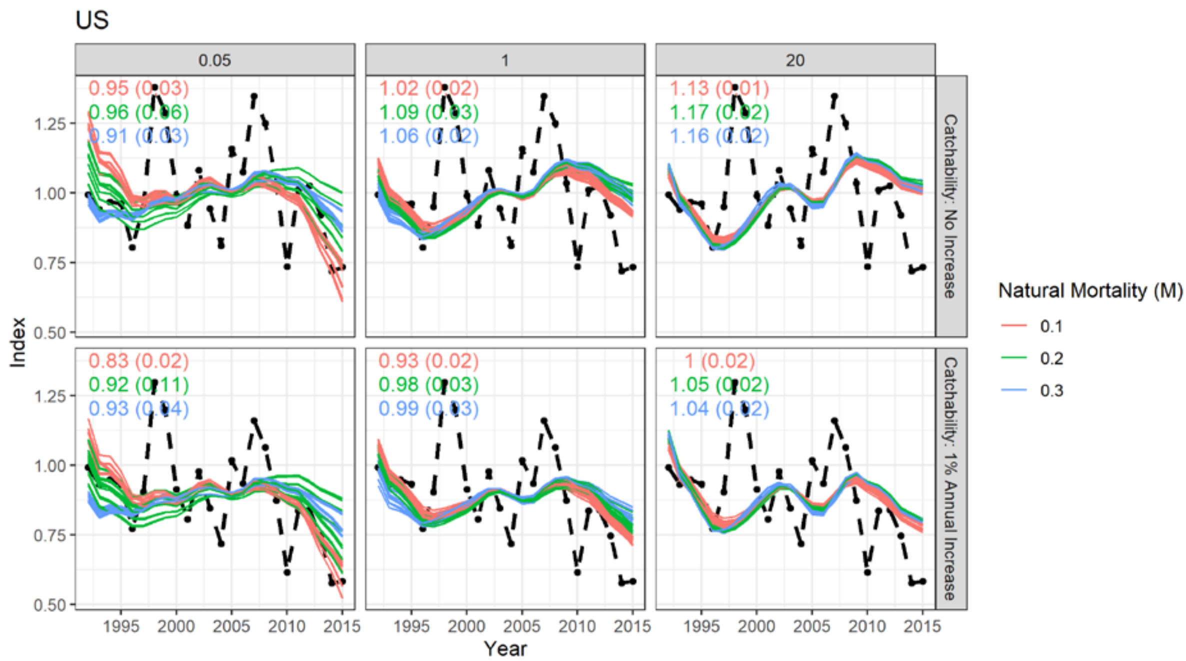

Figure 2. The CPUE index (dashed black line) for the US fleet without (top row) and with (bottom row) the assumed 1% annual increase in catchability and the three levels of CPUE lambda (columns). The predicted indices from the 216 OMs in the uncertainty grid are shown as coloured lines indicating the 3 levels of natural mortality (*M*). The numbers in the top left of each panel are the root mean square error (standard deviation).

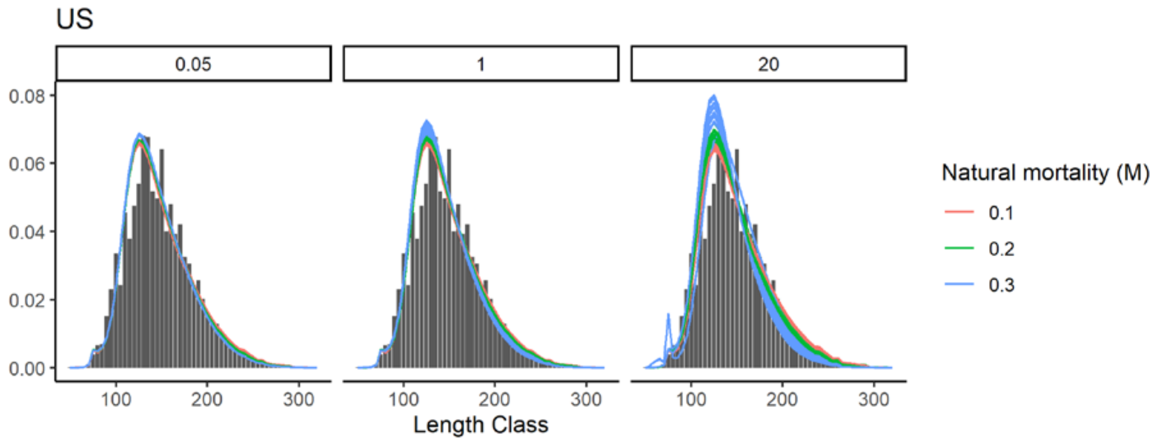

Figure 3. Fits of the length composition data, aggregated over all years, for the three levels of CPUE lambda (columns) and three levels of natural mortality (M; colours) for the US fleet.

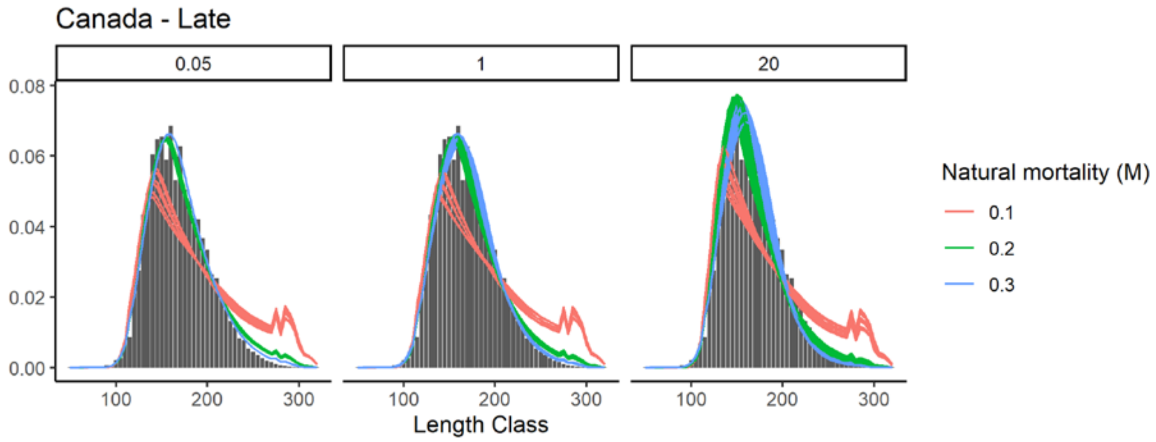

Figure 4. Fits of the length composition data, aggregated over all years, for the three levels of CPUE lambda (columns) and three levels of natural mortality (M; colours) for the Canada - Late fleet.

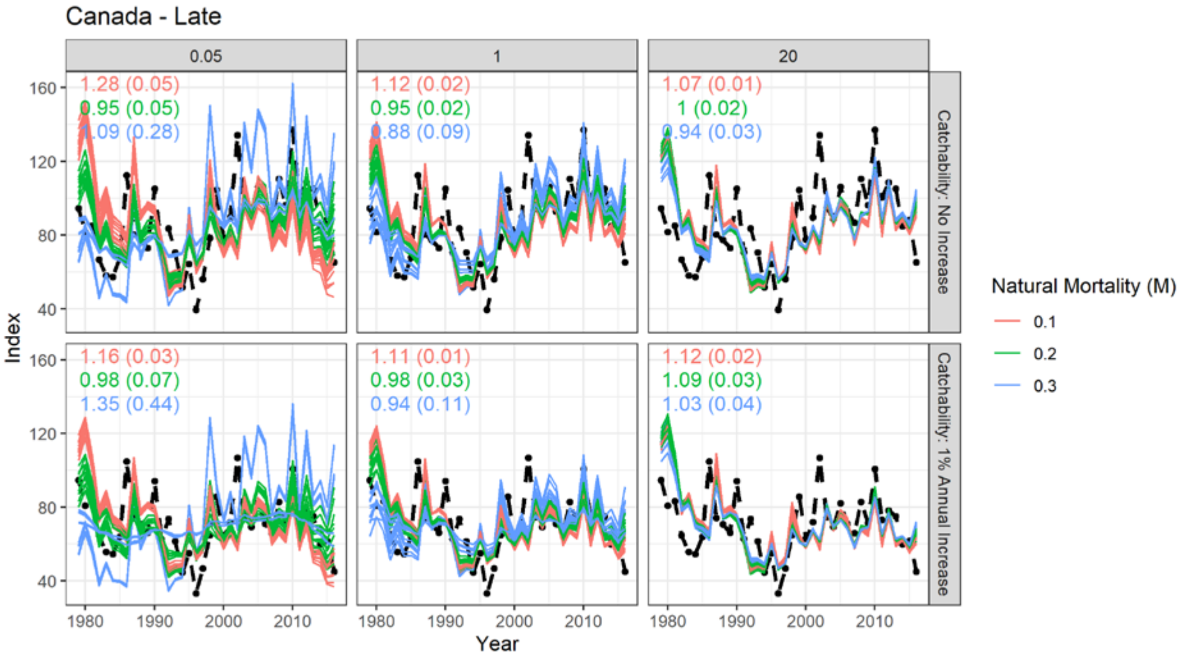

Figure 5. The CPUE index (dashed black line) for the Canada - Late fleet without (top row) and with (bottom row) the assumed 1% annual increase in catchability and the three levels of CPUE lambda (columns). The predicted indices from the 216 OMs in the uncertainty grid are shown as coloured lines indicating the 3 levels of natural mortality (*M*). The numbers in the top left of each panel are the root mean square error (standard deviation).

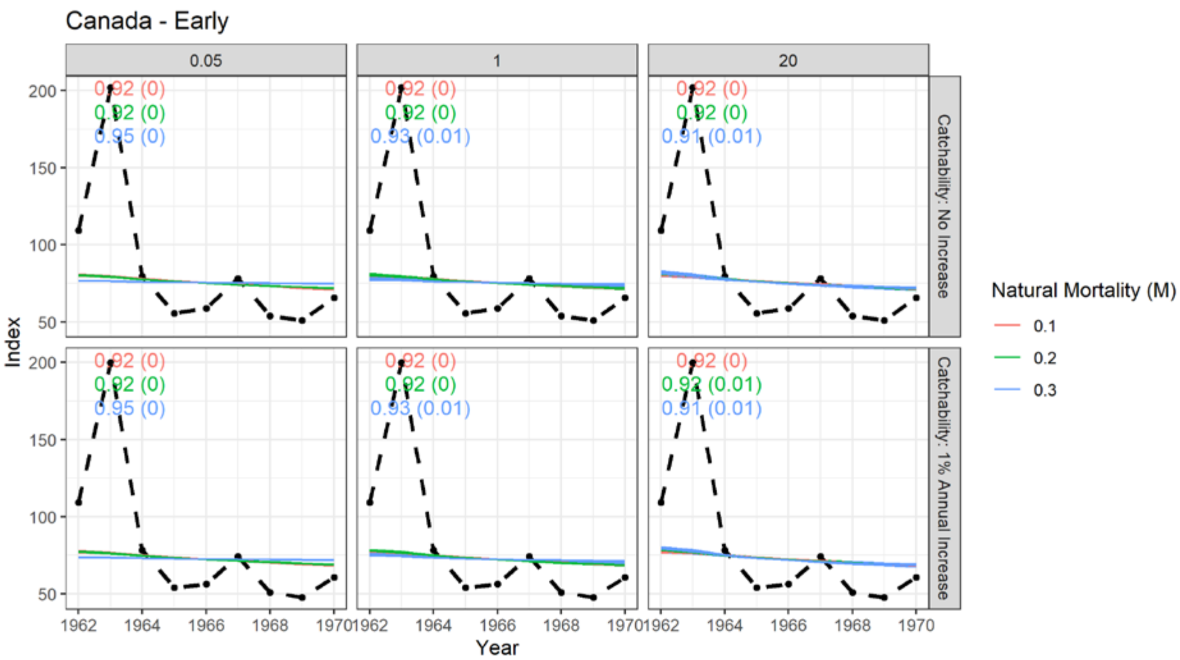

Figure 6. The CPUE index (dashed black line) for the Canada - Early fleet without (top row) and with (bottom row) the assumed 1% annual increase in catchability and the three levels of CPUE lambda (columns). The predicted indices from the 216 OMs in the uncertainty grid are shown as coloured lines indicating the 3 levels of natural mortality (*M*). The numbers in the top left of each panel are the root mean square error (standard deviation).

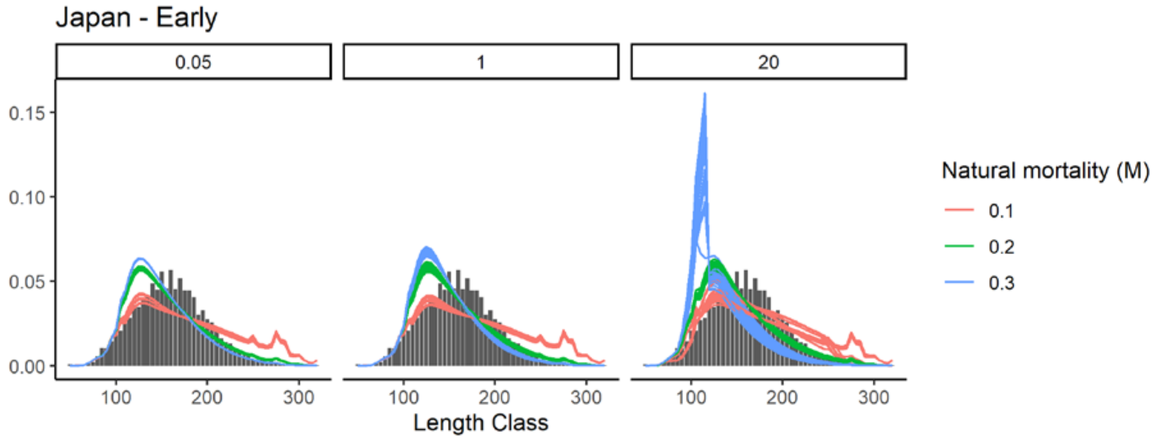

Figure 7. Fits of the length composition data, aggregated over all years, for the three levels of CPUE lambda (columns) and three levels of natural mortality (M; colours) for the Japan - Early fleet.

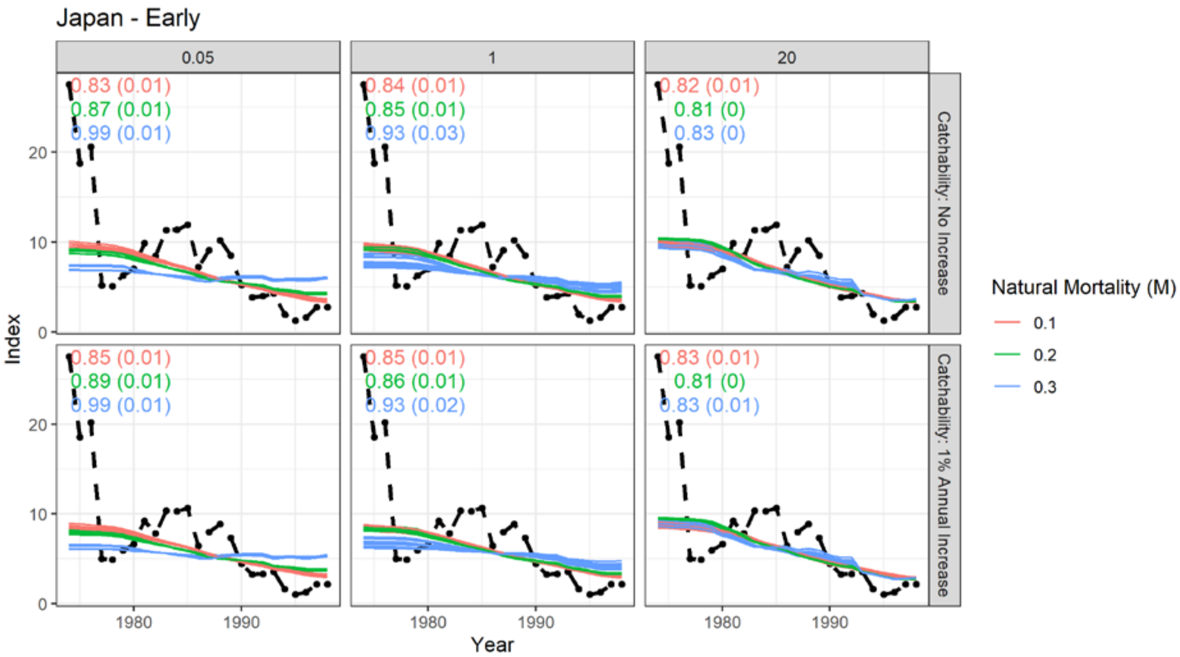

Figure 8. The CPUE index (dashed black line) for the Japan - Early fleet without (top row) and with (bottom row) the assumed 1% annual increase in catchability and the three levels of CPUE lambda (columns). The predicted indices from the 216 OMs in the uncertainty grid are shown as coloured lines indicating the 3 levels of natural mortality (*M*). The numbers in the top left of each panel are the root mean square error (standard deviation).

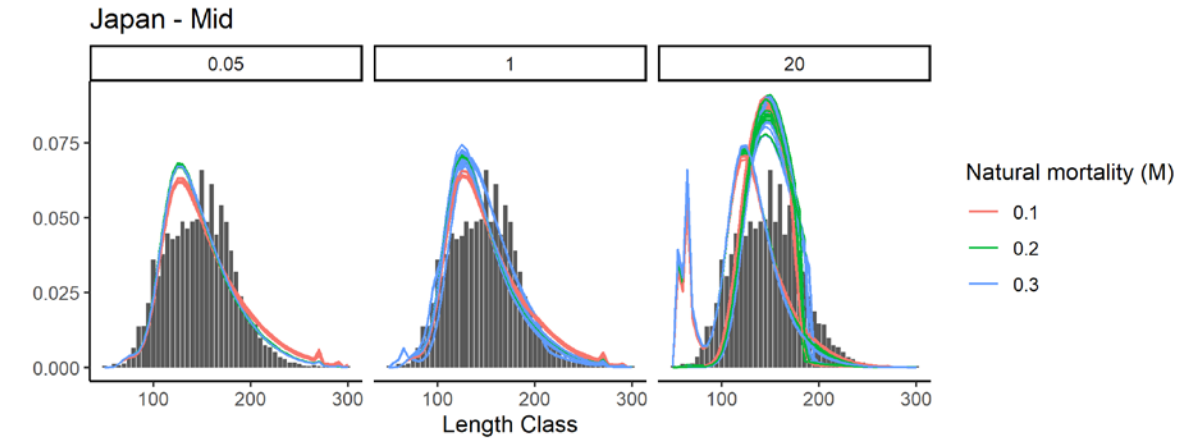

Figure 9. Fits of the length composition data, aggregated over all years, for the three levels of CPUE lambda (columns) and three levels of natural mortality (M; colours) for the Japan - Mid fleet.

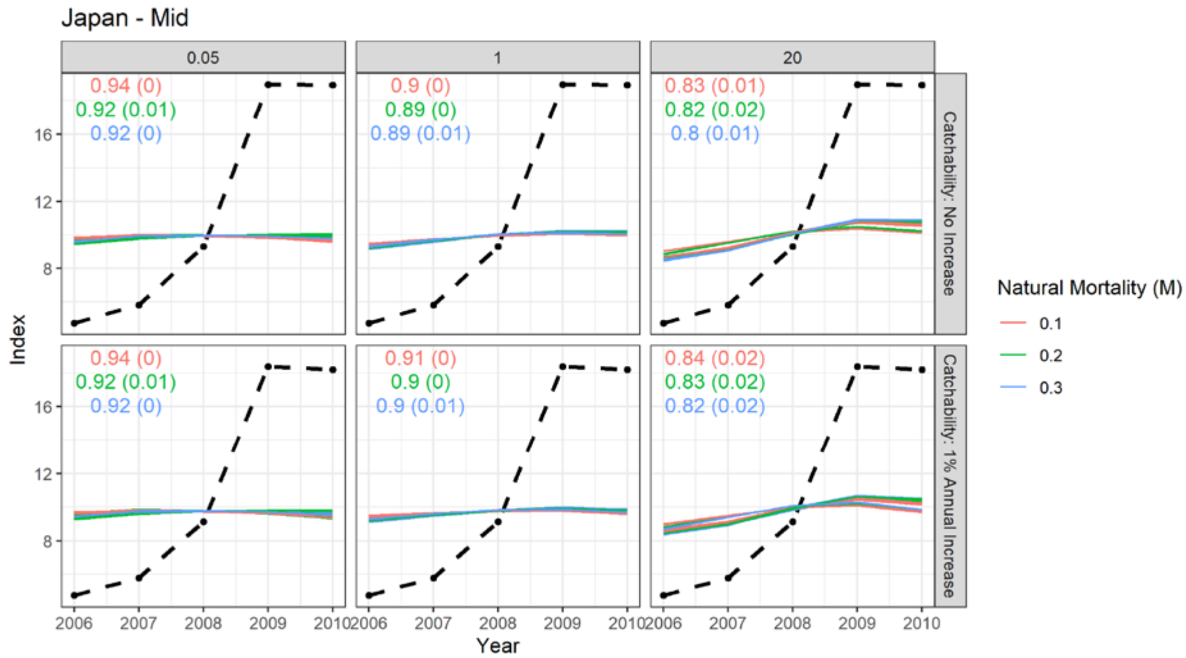

Figure 10. The CPUE index (dashed black line) for the Japan - Mid fleet without (top row) and with (bottom row) the assumed 1% annual increase in catchability and the three levels of CPUE lambda (columns). The predicted indices from the 216 OMs in the uncertainty grid are shown as coloured lines indicating the 3 levels of natural mortality (*M*). The numbers in the top left of each panel are the root mean square error (standard deviation).

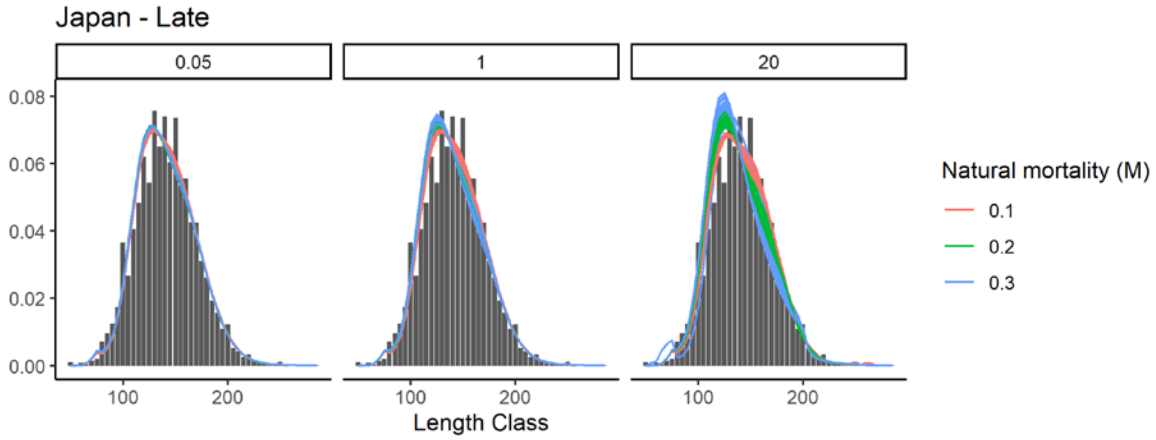

Figure 11. Fits of the length composition data, aggregated over all years, for the three levels of CPUE lambda (columns) and three levels of natural mortality (M; colours) for the Japan - Late fleet.

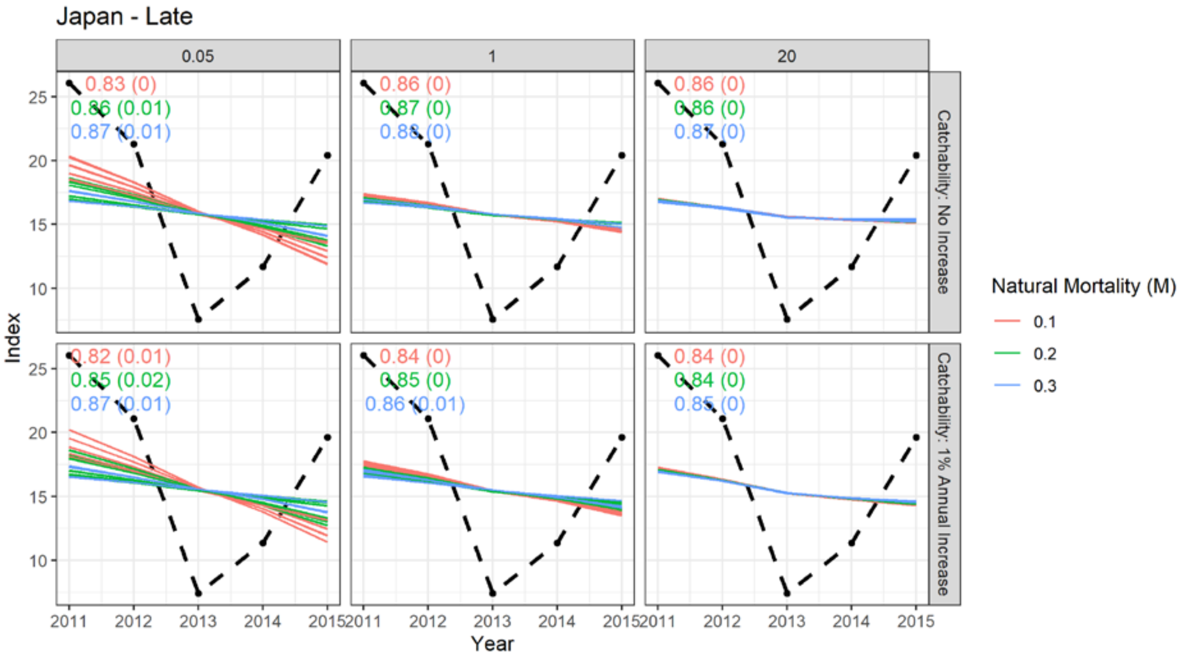

Figure 12. The CPUE index (dashed black line) for the Japan - Late fleet without (top row) and with (bottom row) the assumed 1% annual increase in catchability and the three levels of CPUE lambda (columns). The predicted indices from the 216 OMs in the uncertainty grid are shown as coloured lines indicating the 3 levels of natural mortality (*M*). The numbers in the top left of each panel are the root mean square error (standard deviation).

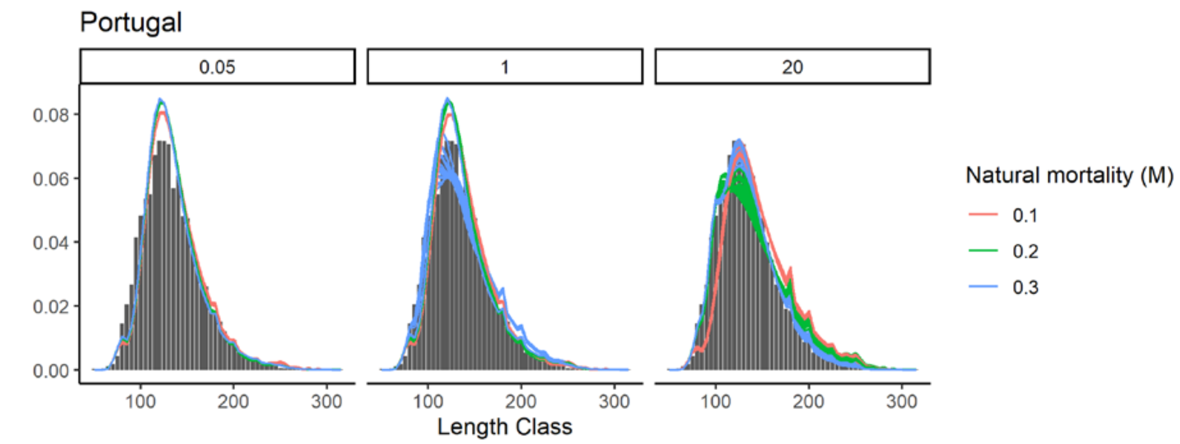

Figure 13. Fits of the length composition data, aggregated over all years, for the three levels of CPUE lambda (columns) and three levels of natural mortality (M; colours) for the Portugal fleet.

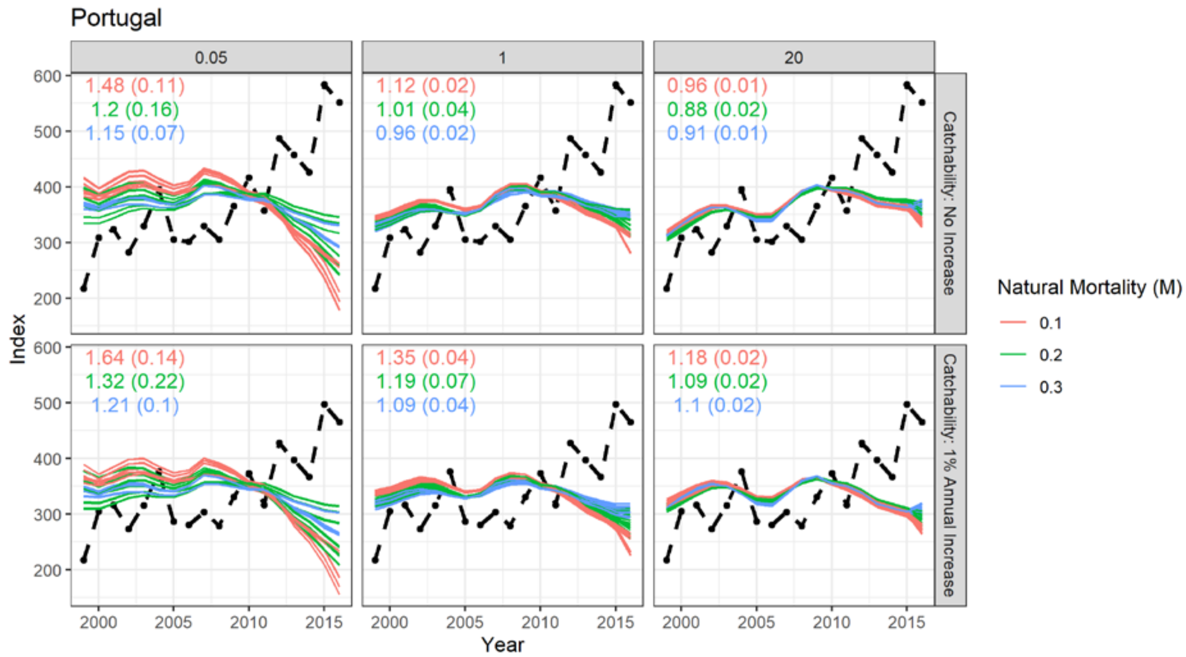

Figure 14. The CPUE index (dashed black line) for the Portugal fleet without (top row) and with (bottom row) the assumed 1% annual increase in catchability and the three levels of CPUE lambda (columns). The predicted indices from the 216 OMs in the uncertainty grid are shown as coloured lines indicating the 3 levels of natural mortality (*M*). The numbers in the top left of each panel are the root mean square error (standard deviation).

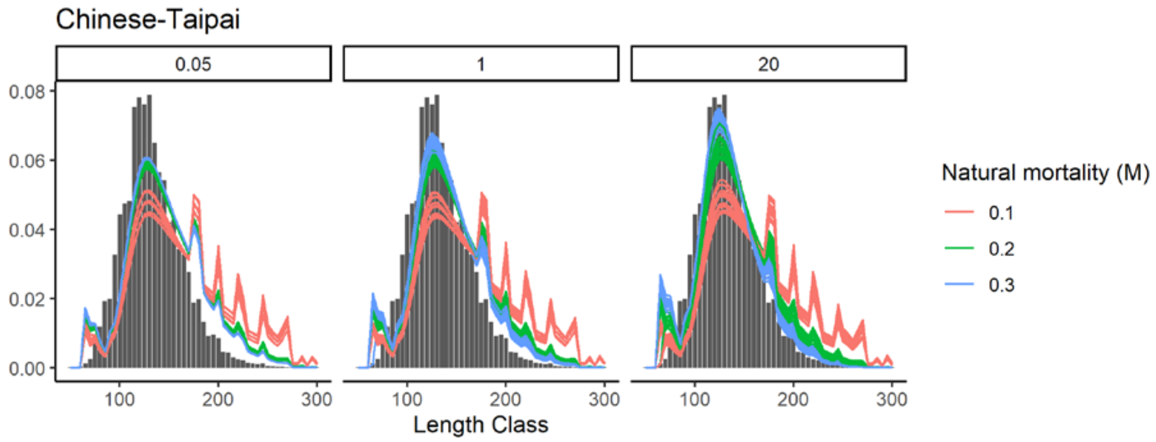

Figure 15. Fits of the length composition data, aggregated over all years, for the three levels of CPUE lambda (columns) and three levels of natural mortality (M; colours) for the Chinese-Taipei fleet.

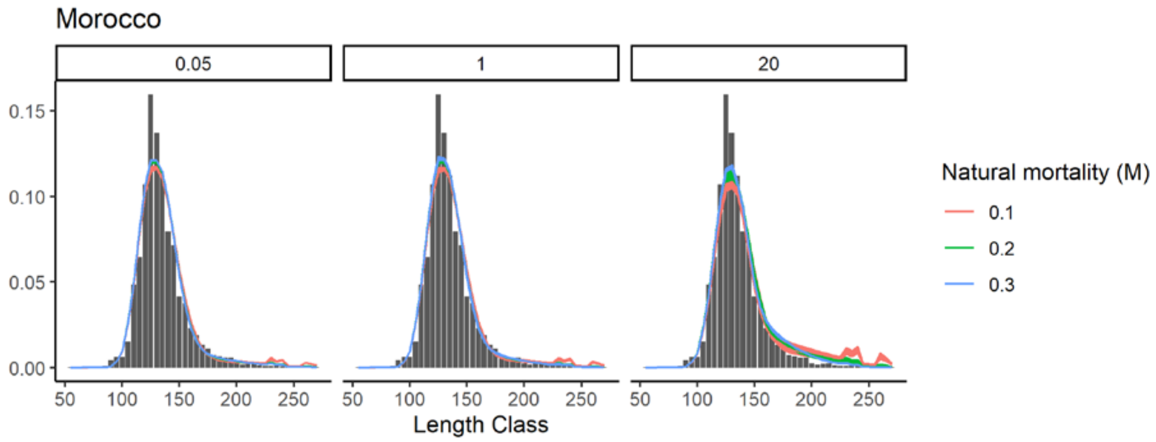

Figure 16. Fits of the length composition data, aggregated over all years, for the three levels of CPUE lambda (columns) and three levels of natural mortality (M; colours) for the Morocco fleet.

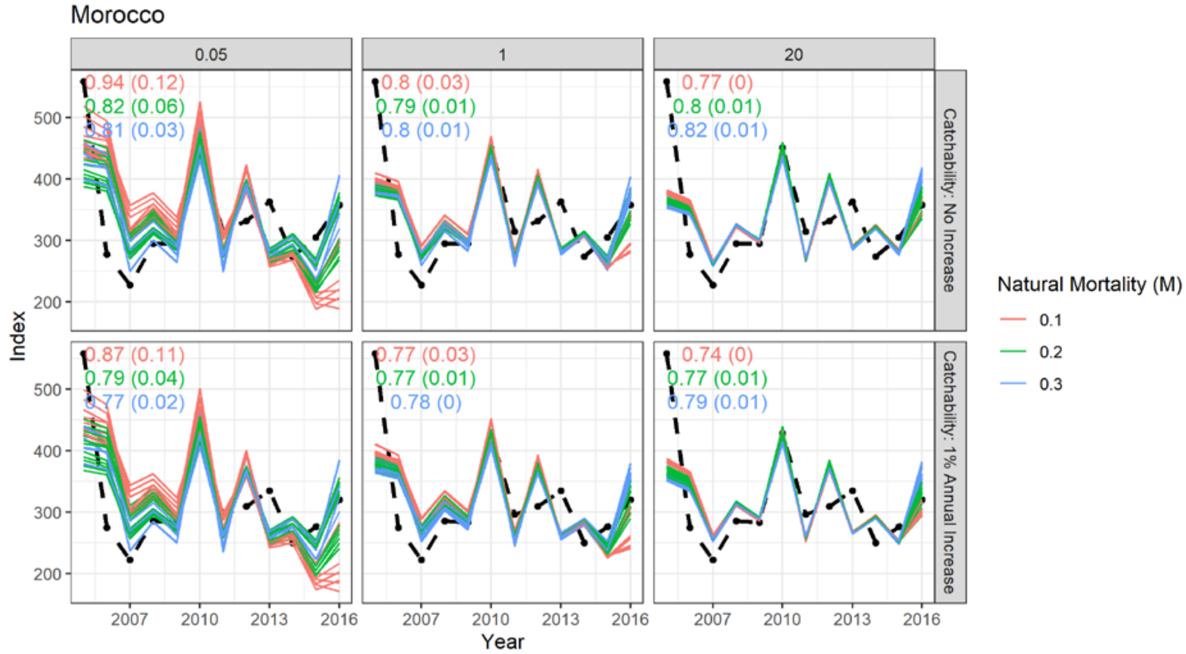

Figure 17. The CPUE index (dashed black line) for the Morocco fleet without (top row) and with (bottom row) the assumed 1% annual increase in catchability and the three levels of CPUE lambda (columns). The predicted indices from the 216 OMs in the uncertainty grid are shown as coloured lines indicating the 3 levels of natural mortality (*M*). The numbers in the top left of each panel are the root mean square error (standard deviation).

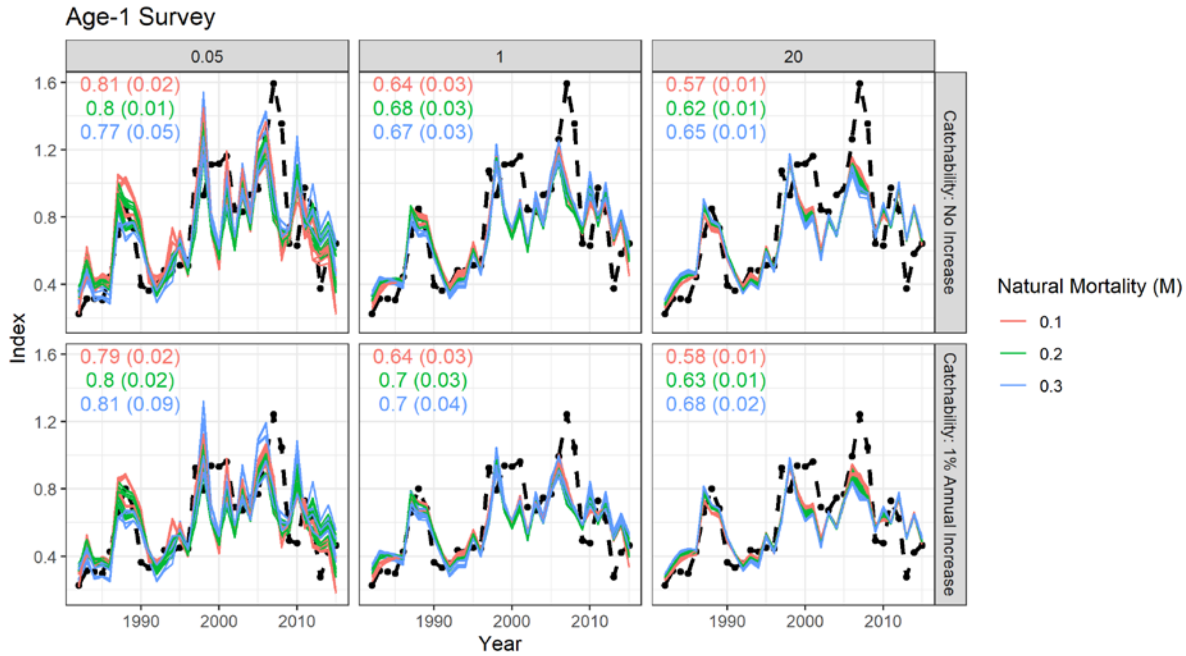

Figure 18. The CPUE index (dashed black line) for the Age-1 Survey fleet without (top row) and with (bottom row) the assumed 1% annual increase in catchability and the three levels of CPUE lambda (columns). The predicted indices from the 216 OMs in the uncertainty grid are shown as coloured lines indicating the 3 levels of natural mortality (*M*). The numbers in the top left of each panel are the root mean square error (standard deviation).

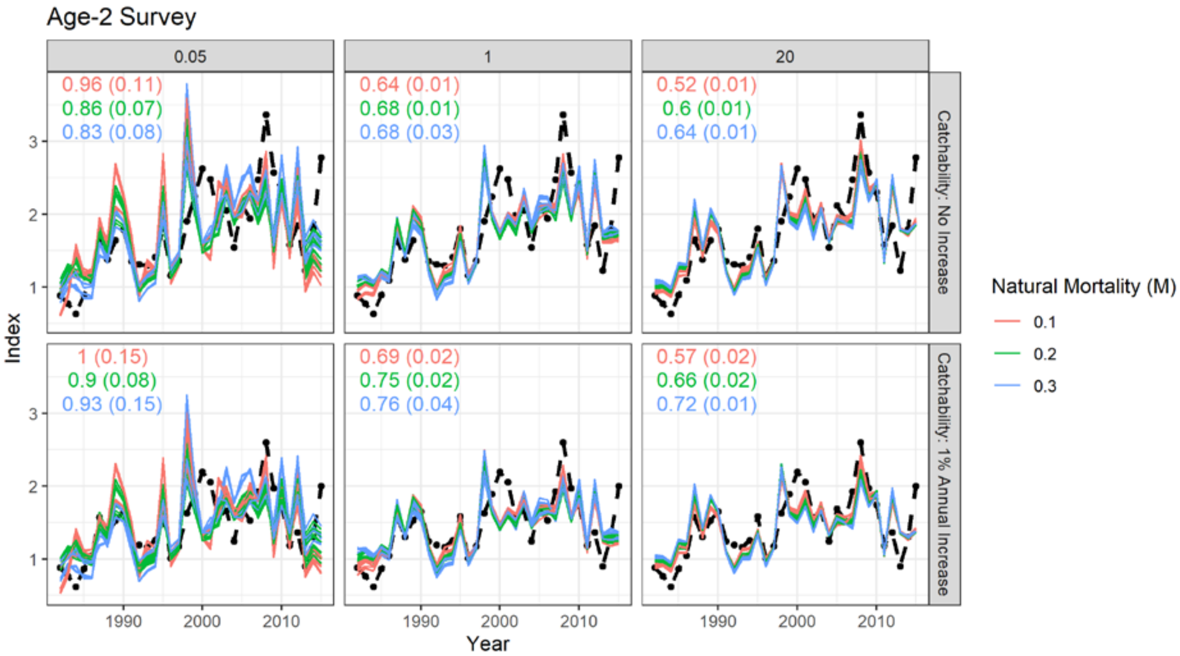

Figure 19. The CPUE index (dashed black line) for the Age-2 Survey fleet without (top row) and with (bottom row) the assumed 1% annual increase in catchability and the three levels of CPUE lambda (columns). The predicted indices from the 216 OMs in the uncertainty grid are shown as coloured lines indicating the 3 levels of natural mortality (*M*). The numbers in the top left of each panel are the root mean square error (standard deviation).

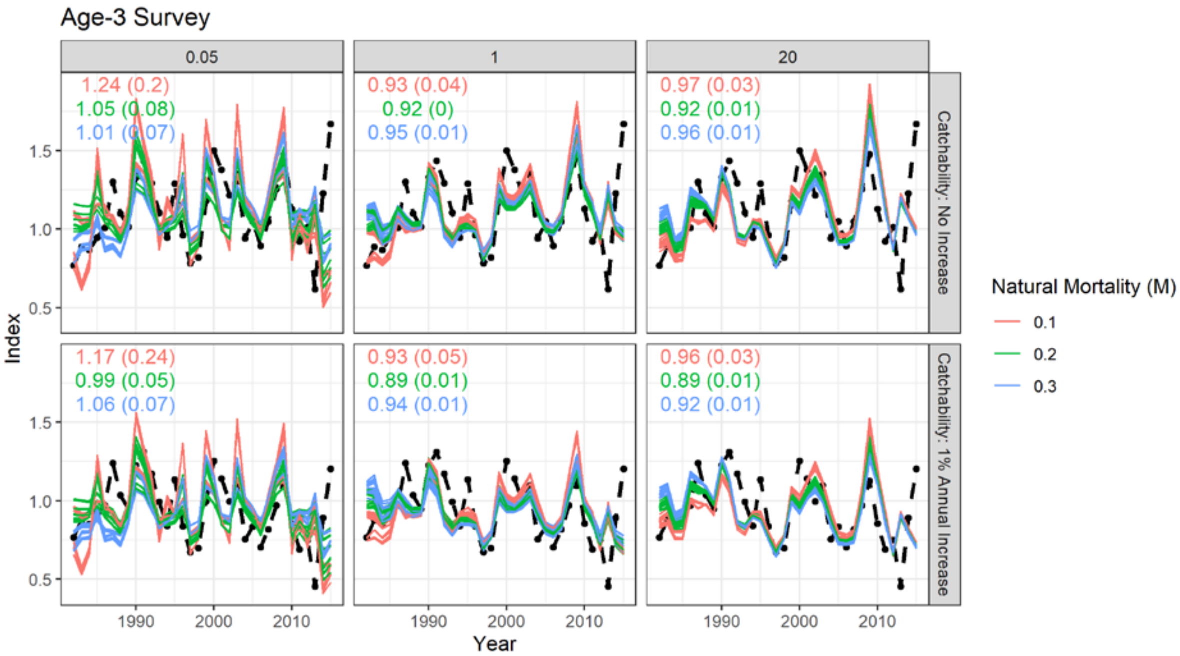

Figure 20. The CPUE index (dashed black line) for the Age-3 Survey fleet without (top row) and with (bottom row) the assumed 1% annual increase in catchability and the three levels of CPUE lambda (columns). The predicted indices from the 216 OMs in the uncertainty grid are shown as coloured lines indicating the 3 levels of natural mortality (*M*). The numbers in the top left of each panel are the root mean square error (standard deviation).

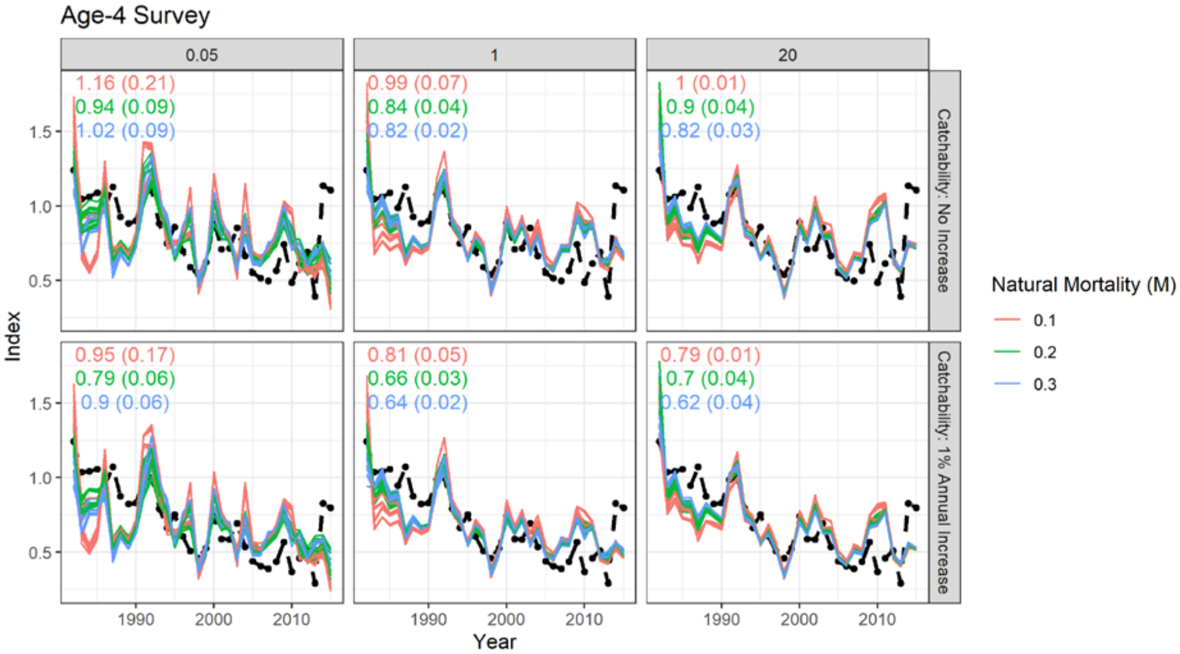

Figure 21. The CPUE index (dashed black line) for the Age-4 Survey fleet without (top row) and with (bottom row) the assumed 1% annual increase in catchability and the three levels of CPUE lambda (columns). The predicted indices from the 216 OMs in the uncertainty grid are shown as coloured lines indicating the 3 levels of natural mortality (*M*). The numbers in the top left of each panel are the root mean square error (standard deviation).

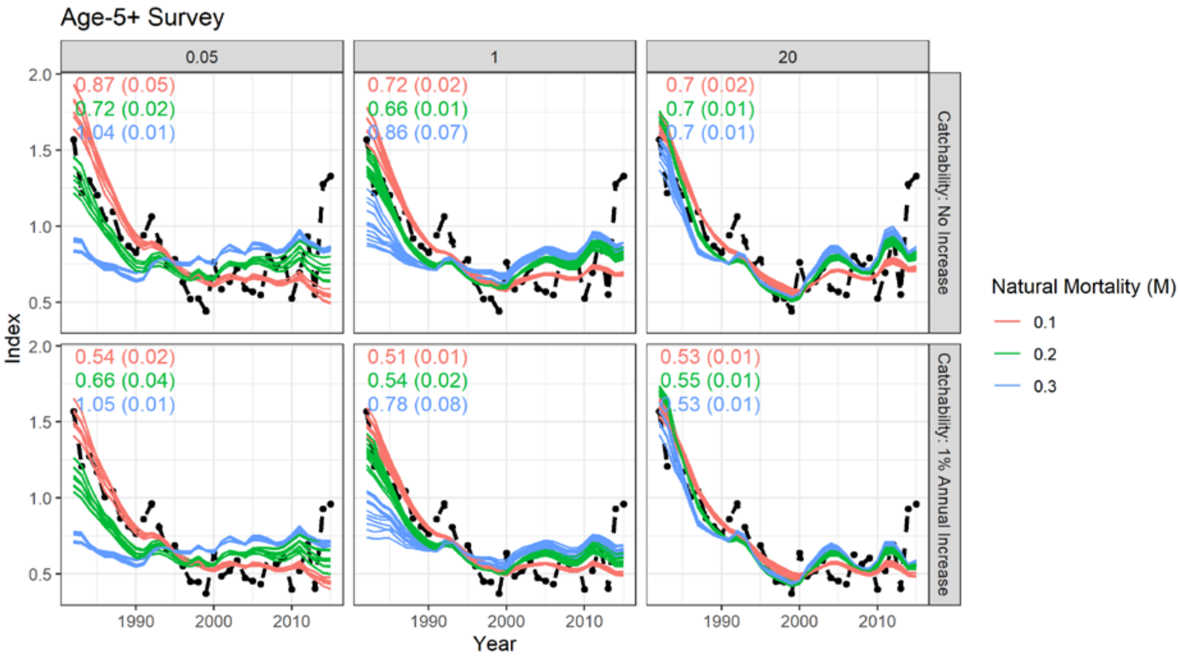

Figure 22. The CPUE index (dashed black line) for the Age-5+ Survey fleet without (top row) and with (bottom row) the assumed 1% annual increase in catchability and the three levels of CPUE lambda (columns). The predicted indices from the 216 OMs in the uncertainty grid are shown as coloured lines indicating the 3 levels of natural mortality (*M*). The numbers in the top left of each panel are the root mean square error (standard deviation).