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INITIAL EVALUATION OF ALTERNATIVE ASSUMPTIONS OF DISCARD MORTALITY ON THE ESTIMATED STOCK DYNAMICS FOR NORTH ATLANTIC SWORDFISH

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SUMMARY

The conditioning model used to generate the operating models (OM) for North Atlantic swordfish assumed that all fish that were caught were accounted for in the landings, and did not explicitly model discard mortality on sub-legal fish. Recent research has been focused on a better understanding of the impact of the minimum size limit and discard of sub-legal fish on the fishery dynamics, and a new base case OM was developed that accounted for the minimum size limit ad discard mortality. This paper examines the impact of alternative assumptions of discard mortality on the estimated fishery dynamics and the performance of a set of reference candidate management procedures. The results demonstrate that, while the assumed discard mortality rate has an impact on the stock dynamics, it may not be consequential in terms of relative performance of the candidate management procedures and the selection process for identifying the candidate management procedure that is most appropriate for the North Atlantic swordfish fishery.

RÉSUMÉ

Le modèle de conditionnement utilisé pour générer les modèles opérationnels (OM) pour l'espadon de l'Atlantique Nord postulait que tous les poissons capturés étaient pris en compte dans les débarquements, et ne modélisait pas explicitement la mortalité par rejet des poissons sous-taille. Les recherches récentes visaient à mieux comprendre l'impact de la taille minimale et des rejets de poissons sous-taille sur la dynamique de la pêche, et un nouveau cas de base de l'OM a été élaboré qui tient compte de la taille minimale et de la mortalité par rejet. Ce document examine l'impact des postulats alternatifs de mortalité par rejet sur la dynamique estimée de la pêche et la performance d'un ensemble de procédures de gestion potentielles de référence. Les résultats montrent que, si le taux de mortalité des rejets a un impact sur la dynamique du stock, il n'est pas forcément conséquent en termes de performance relative des procédures de gestion potentielles et du processus de sélection pour identifier la procédure de gestion potentielle la plus appropriée pour la pêche de l'espadon dans l'Atlantique Nord.

RESUMEN

El modelo de condicionamiento utilizado para generar los modelos operativos (MO) para el pez espada del Atlántico norte asumía que todos los peces que se capturaban se tenían en cuenta en los desembarques, y no modelaba explícitamente la mortalidad por descarte de los peces de talla inferior al a regulada. Las investigaciones recientes se han centrado en comprender mejor el impacto del límite de talla mínima y el descarte de peces de talla inferior a la regulada en la dinámica de la pesquería, y se ha desarrollado un nuevo caso base de OM que tiene en cuenta el límite de talla mínima y la mortalidad por descarte. Este documento examina el impacto de los supuestos alternativos de mortalidad por descarte sobre la dinámica estimada de la pesquería y el desempeño de un conjunto de procedimientos de ordenación candidatos de referencia. Los resultados demuestran que, aunque la tasa de mortalidad por descarte asumida tiene un impacto en la dinámica del stock, puede no tener consecuencias en términos de desempeño de los procedimientos de ordenación candidatos y ni en el proceso de selección para identificar el procedimiento de ordenación candidato más apropiado para la pesquería de pez espada del Atlántico norte.

KEYWORDS

Management Strategy Evaluation, operating model, closed-loop simulation, minimum size limits, candidate management procedures

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1. Introduction

An operating model (OM) uncertainty grid has been developed for the North Atlantic swordfish fishery, with the aim of using a management strategy evaluation (MSE) framework to evaluate the performance of alternative candidate management procedures (cMPs). The uncertainty grid was developed by modifying keep uncertainties from the base case OM, including alternative life-history parameters and assumptions related to the data used to condition the model. An analysis of the impact of the axes of uncertainty on the estimated stock status and the relative performance of a set of cMPs revealed that the uncertainties in natural mortality (*M*) and steepness of the stock-recruitment relationship (*h*) were most consequential (Hordyk 2020).

The conditioning model used to generate the base case OM and the 288 OMs in the uncertainty grid assumed that all fish that were caught were accounted for in the landings, and did not explicitly model discard mortality on sub-legal fish. Recent research has been focused on a better understanding of the impact of the minimum size limit and discard of sub-legal fish on the fishery dynamics. A new analysis of the swordfish reported landings data has made it possible to evaluate the impact of the minimum size limit and discards of sub-legal fish in the conditioning of the operating models. (Schirripa and Hordyk, 2020). This analysis evaluated the impact of accounting for the size limit and discard mortality and compared the results of the OM conditioning to the base case OM that did not account for discarding.

To compare against the base case OM, Schirripa and Hordyk (2020) developed a model that accounted for the minimum size and discarding (hereafter MS_OM), and assumed a discard mortality rate of 88% as it is the most plausible value supported by data (Coelho and Muñoz-Lechuga, 2019). The assumed discard mortality rate remains a key uncertainty, and further evaluation is required to evaluate the impact of this assumption on the fishery dynamics and the performance of candidate management procedures.

This paper describes an analysis that examines the impact of alternative assumptions of discard mortality on the estimated fishery dynamics and the performance of a set of reference candidate management procedures. A small uncertainty grid is built using the MS_OM from Schirripa and Hordyk (2020) is used as a base case, and modifying the assumed values for *M*, *h*, and the discard mortality rate. First, the estimated fishery dynamics are reported in terms of spawning biomass (SB) relative to spawning biomass corresponding to maximum sustainable yield (SB_{MSY}) for each level of *M*, *h* and discard mortality rate. Then, a MSE framework is used to evaluate the performance of 5 reference management procedures to determine the conditions where the assumed discard mortality rate is most consequential in terms of performance and selection of cMPs. The results from this preliminary analysis can be used by the Swordfish Species Working Group to determine the key uncertainties and prioritise future research that is focused on the issue of discard mortality and alternative minimum size limits.

2. Methods

An uncertainty grid was developed with three levels of *M* (0.1, 0.2, and 0.3), three levels of *h* (0.6, 0.75, and 0.90) (the same as the OM uncertainty grid; Hordyk (2020)) and four assumed levels of discard mortality (0, 0.5, 0.88, and 1). These levels of discard mortality rate bracket assuming all discarded fish survive (0) and all discarded fish are killed (1). The 36 OMs were conditioned using Stock Synthesis 3 v3.30 (Methot and Wetzel 2013), with *M*, *h* and discard mortality for all fleets fixed at their respective values for each OM.

Results of the predicted stock dynamics under these alternative conditions are summarized as time-series plots of the estimated SB/SB_{MSY} for each operating model.

The 36 OMs were also evaluated with respect to their impact on the performance of the following set of reference management procedures:

1. Current Catch (curC) – the TAC is fixed at the level of the most recent catch;
2. Perfect FMSY (FMSYref) – the TAC is calculated each year so that $F = F_{MSY}$;
3. Index Target 1 (Ind_1) – the TAC is calculated each year based on the ratio of the index to a target level with a maximum annual change in TAC of 5%;
4. Index Target 2 (Ind_2) – Same as Ind_1 but with a maximum annual change in TAC of 10%;
5. Surplus Production Model (SP_MSY) – A surplus production model is used to set the annual TAC to the level corresponding with fishing at the estimated F_{MSY}.

These reference management procedures were selected as they cover a range of typical candidate management procedures that may be proposed for the swordfish fishery (Ind_1, Ind_2, and SP_MSY) and hypothetical management options that are expected to have widely different performance (curC and FMSYref). More details on the reference management procedures are found in Hordyk (2020).

Performance of the reference management procedures was evaluated against 3 criteria:

1. The probability that spawning biomass (SB) is greater than SB_{MSY} throughout the projection period;
2. The average short-term catch (first 10-years of the projection period) relative to the highest catch obtainable with a fixed-F policy;
3. The average long-term catch (last 10-years of the projection period) relative to the highest catch obtainable with a fixed-F policy.

These performance metrics were selected to evaluate the type of metrics that are generally used for evaluating performance: biological sustainability and short- and long-term catches. They do not represent the metrics that will be used to select candidate management procedures in the full MSE process for the swordfish fishery.

The five reference management procedures were evaluated for each of the 36 OMs, with 20 simulations per OM and a 50-year projection period. Within each OM, the simulated stock dynamics were identical across the 20 simulations during the historical period, with stochastic recruitment deviations and index observation error in the projection years.

The results are summarised with plots of the performance metrics for each OM.

3. Results

3.1 Estimated Stock Dynamics

The estimated SB/SB_{MSY} was relatively similar throughout the time-series for the OMs with steepness of 0.6 and 0.75 (**Figure 1**). The assumed rates of discard mortality had a greater impact on the estimated SB/SB_{MSY} for the OMs where h=0.9, particularly in the early years and in the most recent years of the 68-year time period (**Figure** 1).

The alternative assumed rates of discard mortality had almost no impact on the estimated stock status in 2017 for the OMs where M=0.3 and h=0.6 and 0.75 (**Figure 2**). For the OMs with h=0.6 and 0.75, the estimated stock status tended to be more optimistic as the assumed discard mortality increased (**Figure 2**). The pattern was more varied for the OMs with h=0.9, where the estimated stock status tended to by more pessimistic as discard mortality increased. An exception was the OM with M=0.1 and h=0.9, where assumed discard mortality of 0 resulted in the lowest estimate of SB/SB_{MSY}, with the estimate increasing for discard mortality = 0.5 and then declining again as discard mortality was increased (**Figure 2**).

3.2 Performance of Reference Management Procedures

Increased values in the assumed discard mortality rate tended to result in higher probability of SB >SB_{MSY} most operating models (**Figure 3**). In the OM where M=0.3 and h=0.9, the alternative values of discard mortality had almost no impact on the probability of SB >SB_{MSY} (**Figure 3**). Despite the difference in absolute performance across the OMs with different assumed discard mortality, the ranking of the reference management procedures remained consistent, with the surplus production assessment method (SP_MSY) consistently resulting in the highest probability of SB >SB_{MSY} (**Figure 3**). Similarly, the relative performance of the two index-targeting methods was generally consistent, with Ind_1 typically resulting in higher probability of SB >SB_{MSY} than Ind_2 (**Figure 3**).

The ranking of the reference management procedures was more varied for the performance metric evaluating the average short-term yield with respect to the M and h values (**Figure 4**). However, within each M and h combination, the ranking of the reference management procedures remained consistent, indicating that the assumed discard mortality rate did not impact the relative performance and selection of the management methods (**Figure 4**).

The average long-term yield varied more across the OMs and the levels of discard mortality (**Figure 5**). In general, the SP_MSY method resulted in the highest average long-term yield, and average long-term yield tended to be lower as the discard mortality increased (**Figure 5**). The Ind_2 method has the lowest long-term yield in all cases. Similar to the other performance metrics, the assumed discard mortality rate did not impact the relative ranking of the reference management procedures (**Figure 5**).

4. Discussion

This preliminary analysis evaluated the impact of a range of assumed discard mortality rates on the estimated stock dynamics and the relative performance of a set of reference management procedures. The results demonstrate that the alternative values of discard mortality have an impact on the predicted stock dynamics and estimated stock status. Similarly, the absolute performance of the reference management procedures was impacted by the assumed discard mortality, with varied absolute performance across the assumed levels of M and h.

However, the ranking of the reference management procedures, in terms of which methods performed best and worst, was relatively consistent across the four levels of discard mortality. These results suggest that, while the assumed discard mortality rate has an impact on the stock dynamics, it may not be consequential in terms of relative performance of the candidate management procedures and the selection process for identifying the cMP that is most appropriate for the North Atlantic swordfish fishery. This in turn suggests that it may be appropriate to use the discard mortality rate of 88%, which appears most supported by the data, as the default assumption for the swordfish OMs, and it may not be necessary to include additional discard mortality rates in the uncertainty grid.

5. Acknowledgements

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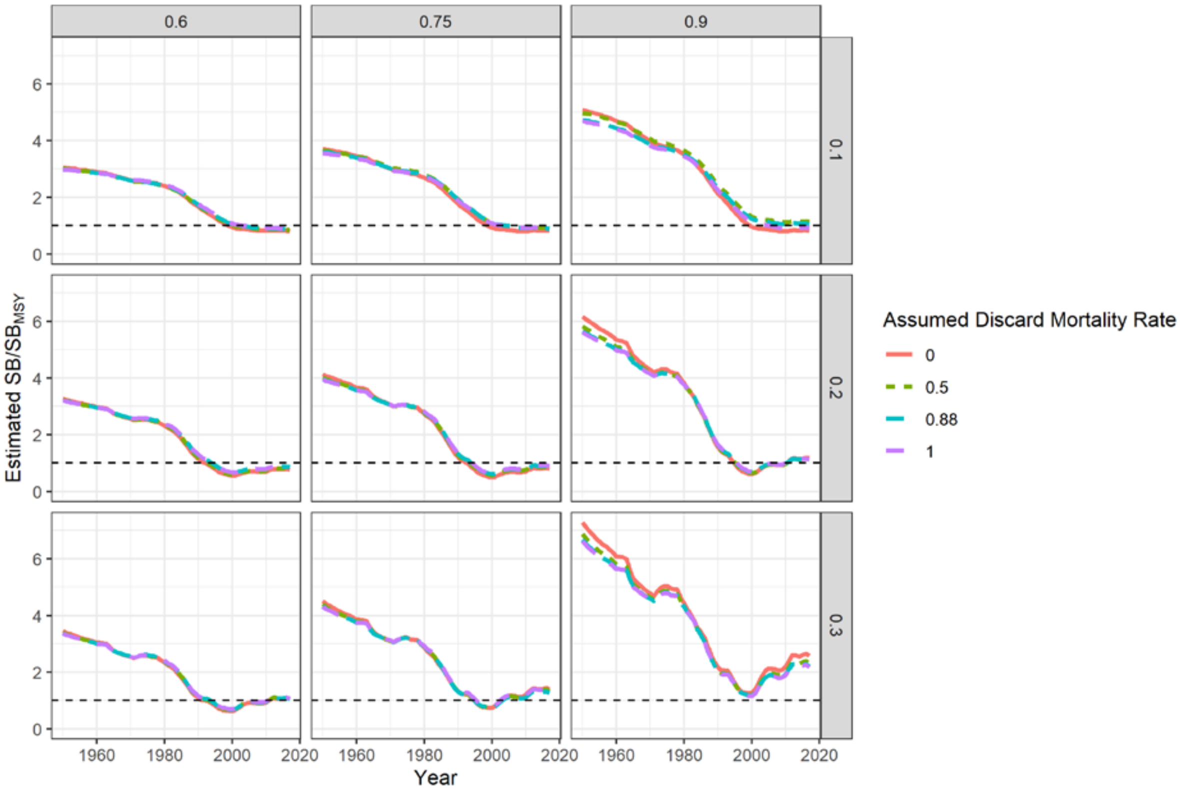

Figure 1. The estimated spawning biomass (SB) relative to spawning biomass corresponding to maximum sustainable yield (SB_{MSY}) for the four levels of assumed discard mortality (colors), the three levels of natural mortality (rows), and three levels of steepness (columns).

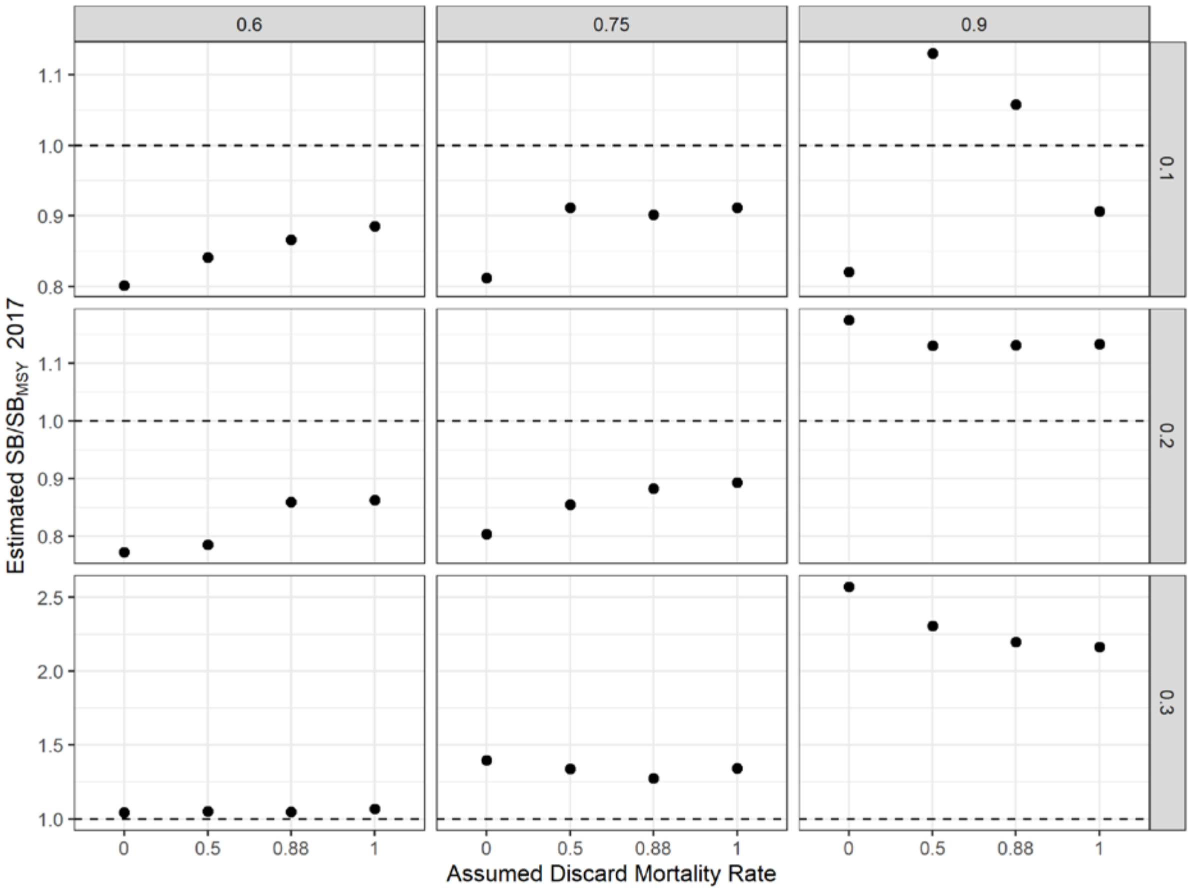

Figure 2. The estimated spawning biomass (SB) relative to spawning biomass corresponding to maximum sustainable yield (SB_{MSY}) for the most recent year (2017) for the four levels of assumed discard mortality (x-axis), the three levels of natural mortality (rows), and three levels of steepness (columns).

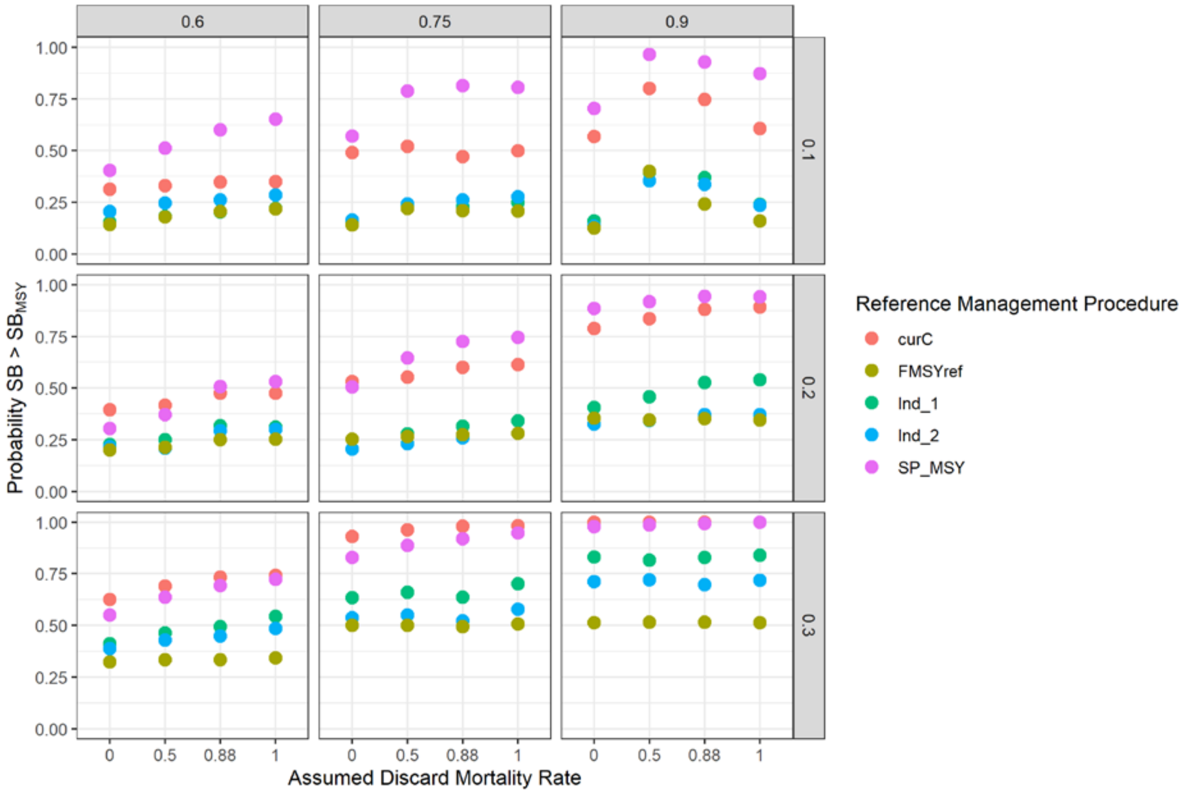

Figure 3. The probability spawning biomass (SB) is greater than the spawning biomass corresponding to maximum sustainable yield (SB_{MSY}) for the four levels of assumed discard mortality (x-axis), the 5 reference management procedures (colors), and the three levels of natural mortality (rows), and three levels of steepness (columns).

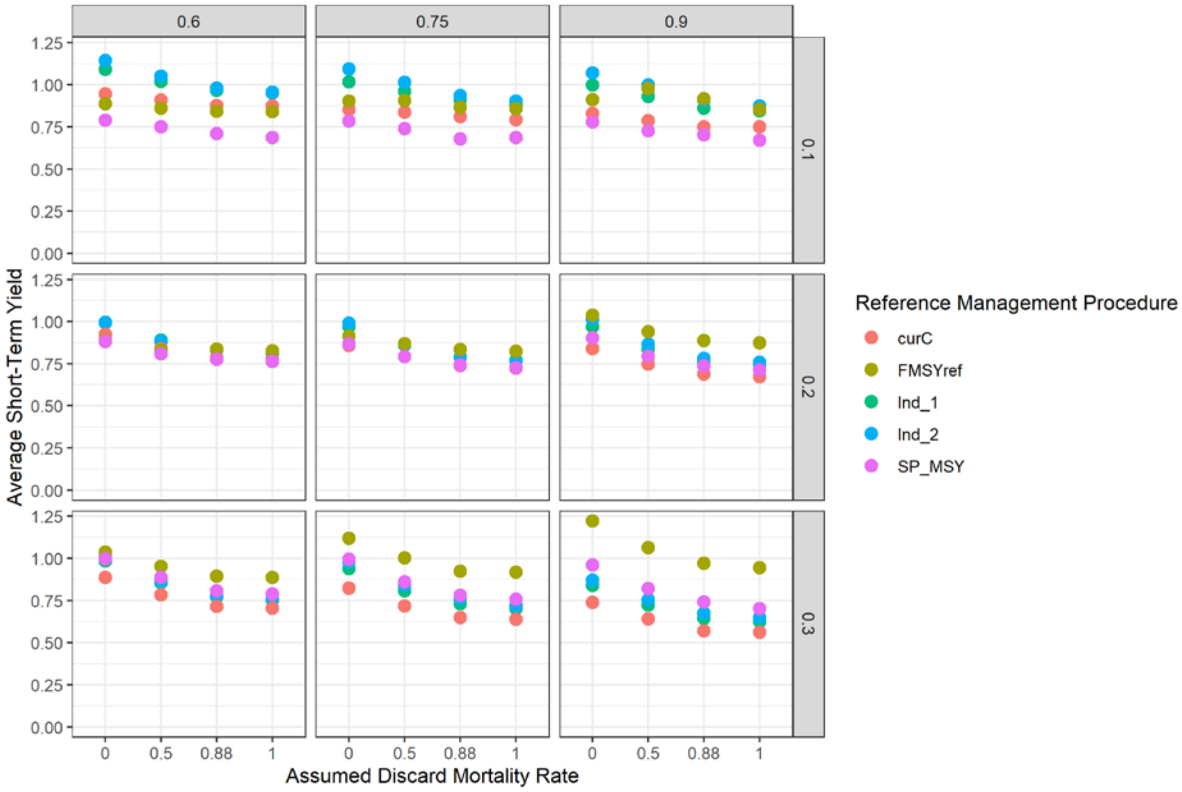

Figure 4. The average relative short-term yield for the four levels of assumed discard mortality (x-axis), the 5 reference management procedures (colors), and the three levels of natural mortality (rows), and three levels of steepness (columns).

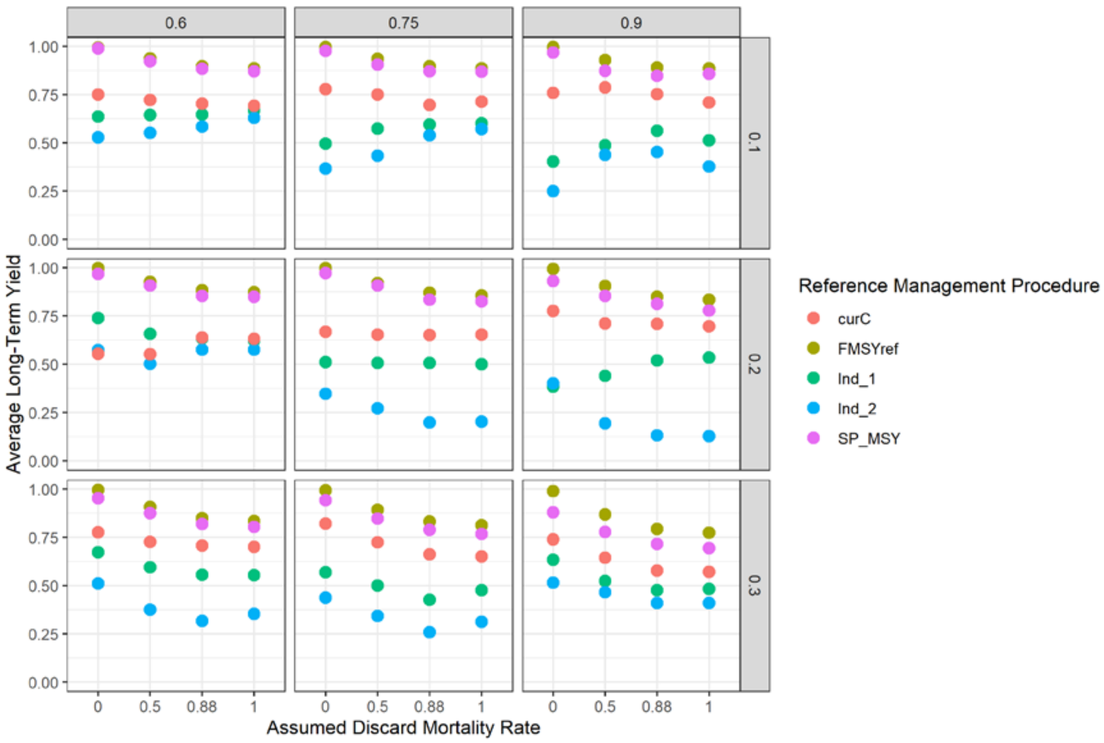

Figure 5. The average relative long-term yield for the four levels of assumed discard mortality (x-axis), the 5 reference management procedures (colors), and the three levels of natural mortality (rows), and three levels of steepness (columns).