SCRS/2020/159 Collect. Vol. Sci. Pap. ICCAT, 77(3): 654-668 (2020)

MIGRATING THE NORTH ATLANTIC SWORDFISH STOCK ASSESSMENT MODEL TO AN UPDATED VERSION OF STOCK SYNTHESIS WITH ANALYSIS OF THE CURRENT MINIMUM SIZE REGULATION

Michael J. Schirripa[1], Adrian Hordyk[2]

SUMMARY

Updates to the modeling platform used to assess the North Atlantic swordfish stock (Stock Synthesis) have been made. In order to take advantage of this update and to be fully aware of any changes to the assessment the update might have, a comparison between the older version of Stock Synthesis (version 3.24) and the updated version (version 3.30) was made. The updated version of the software gave essentially identical results than did the previous version. This updated model was used to assess the outcomes of having a full retention fishery, the current minimum size regulation with 0% discard mortality, and with a, 88% discard mortality. The model using full retention resulted in a lower retained maximum sustainable yield than the 0% discard mortality, but higher than the model assuming 88% discard mortality. Furthermore, the model using full retention required a larger stock size to account for the observed landings, but lower than the model assuming 88% discard mortality. These results are only valid under the assumption that selectivity of undersized fish does not change because of the size regulation.

RÉSUMÉ

Des mises à jour de la plate-forme de modélisation utilisée pour évaluer le stock d'espadon de l'Atlantique Nord (Stock Synthesis) ont été effectuées. Afin de tirer parti de cette mise à jour et d'être pleinement conscient de toute modification de l'évaluation qu'elle pourrait entraîner, une comparaison entre l'ancienne version de Stock Synthesis (version 3.24) et la version mise à jour (version 3.30) a été réalisée. La version actualisée du logiciel a donné des résultats essentiellement identiques à ceux de la version précédente. Ce modèle mis à jour a été utilisé pour évaluer les résultats d'une pêcherie avec rétention totale, la réglementation actuelle sur la taille minimale avec une mortalité des rejets de 0% et une mortalité des rejets de 88%. Le modèle utilisant la rétention totale a donné une production maximale équilibrée inférieure à la mortalité des rejets de 0%, mais supérieure au modèle postulant une mortalité des rejets de 88%. En outre, le modèle utilisant la rétention totale a nécessité une taille de stock plus importante pour tenir compte des débarquements observés, mais inférieure à celle du modèle postulant une mortalité des rejets de 88%. Ces résultats ne sont valables que dans l'hypothèse où la sélectivité des poissons sous-taille ne change pas en raison de la réglementation sur la taille.

RESUMEN

Se han realizado actualizaciones a la plataforma de modelación utilizada para evaluar el stock de pez espada del Atlántico norte (Stock Synthesis). Con el fin de aprovechar esta actualización y para ser plenamente consciente de cualquier cambio que la actualización pueda producir en la evaluación, se realizó una comparación entre la versión anterior de Stock Synthesis (versión 3.24) y la versión actualizada (versión 3.30). La versión actualizada del software producía esencialmente resultados idénticos a los de la versión anterior. Este modelo actualizado se utilizó para evaluar los resultados de contar con una pesquería de retención total, con la reglamentación actual de talla mínima con mortalidad por descarte del 0 %, y con una mortalidad por descarte del 88 %. El modelo que utilizaba la retención total tuvo como resultado un rendimiento máximo sostenible menos retenido que el de mortalidad por descarte del 0 %, pero superior al del modelo que asumía una mortalidad por descarte del 88 %. Además, el modelo que usaba la retención total requería un mayor tamaño del stock para tener en cuenta los desembarques observados, pero menor que el modelo que asumía una mortalidad por descarte del 88 %. Estos resultados son válidos únicamente en el supuesto de que la selectividad de peces de talla inferior a la regulada no cambia a causa de la reglamentación sobre talla.

[1]NOAA Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami FL 33149 USA. Michael.Schirripa@noaa.gov

[2] Blue Matter Science, 2150 Bridgman Avenue North Vancouver, BC, Canada, V7P2T9 adrian@bluematterscience.com

KEYWORDS

Swordfish, Stock assessment, Population modeling

1. Introduction

The latest ICCAT North Atlantic Swordfish assessment was conducted in 2017 (Anon. 2017). At that time the latest version of the modeling platform used to assessment the stock, Stock Synthesis (Methot and Wetzel, 2013), was version 3.24P (SS3). Since then, an updated version of the software, version 3.30 (SS) has been released. Before fully migrating from SS3 to SS the Swordfish Species Group felt it wise to attempt to replicate the model configured in SS3 with one using SS. To ensure that the migration of the SS3 model to the SS model provided the same results given the same data and assumptions, the SS3 model was directly translated to the SS model and the results compared.

Accomplishing this task outside the assessment process would free up valuable time at either the data preparatory and/or assessment meetings so that other matters could receive more attention.

One aspect of the Swordfish fishery not included in the 2017 assessment model is that of the minimum legal size limit adopted in 1991 (ICCAT Recommendation 1990-2). This regulation gave each CPC the choice of adopting a minimum size limit of 125 cm LJFL with an 11% allowance for undersized fish, or 119 cm LJFL with no allowance for undersize fish.

> *In order to protect small swordfish, the Contracting Parties take the necessary measures to prohibit the taking and landing of swordfish in the entire Atlantic Ocean weighing less than 25 kg live weight (125 cm lowerjaw fork length); however, the Contracting Parties may grant tolerances to boats which have incidentally captured small fish, with the condition that this incidental catch shall not exceed 15 percent of the number of fish per landing of the total swordfish catch of said boats.*

The effectiveness of a minimum size regulation is directly proportional to the degree of discard mortality of the released fish is likely to incur. The greater the discard mortality the less effective the minimum size regulation is, to the extent that it can actually make the fishery less productive. As the most recent swordfish assessment model was chosen as the operating model (OM) for the swordfish Management Strategy Evaluation (MSE) effort these two tasks provided an opportunity to migrate the current swordfish assessment model, Stock Synthesis version 3.24 (SS3) to the latest version of Stock Synthesis 3.30 (SS).

2. Methods

The latest ICCAT swordfish assessment of 2017 was conducted using SS3 v3.24 model. This assessment model used seven fleets (and three sub-fleets) which were found to account for over 95% of the total swordfish landings: Canada (early 1962-1970, late 1979-2015) Chinese Taipei, E.U. Spain, E.U. Portugal, Japan (early 1974-1998, mid 2006-2010, and late 2011-2015) Morocco, and the U.S. The initial migration of the assessment model from Stock Synthesis SS3 v3.24 (SS3) to version 3.30.16 (SS) was accomplished via the use of a translation program written by the software authors. This program reads in the model files associated with the the v3.24 and outputs the same model configuration in v3.30 format. A comparison between the two models was conducted using various estimated management quantities common to each model.

Landing data for this work were provided by the Task 1 data maintained the ICCAT Secretariat. The dead discards reported in the Task 1 data are included in the overall accounting of removals input to the assessment model. Live discards are modeled separately and subjected to a user defined discard mortality.

In order to conduct any study of the effects of a minimum size regulation, estimates of discards, the lengths of the discards and the discard mortality are critical. The ICCAT Secretariat does not produce the amounts of live discards in their Task 1 tables. While information regarding the amount of fish discarded, both live and dead, would be very helpful to this effort, this data was not available at the time of this study. The accuracy of this analysis would be greatly enhanced if estimates of live and dead discards in terms of weight or numbers were made available final.

Length-based selectivity were estimated within the assessment for each fleet. A “knife edge” retention curve was put into place starting in 1993 to coincide with the timing of the minimum size regulation. Each fleet was assigned a minimum legal size of either 119 or 125 cm LJFL, below which all fish were assumed discarded and subject to the defined discard mortality.

At the time of this study, complete estimates of the amount of live and dead discards or rates of discarding were not available and thus could not be used as observational data to fit the model to. Inspection of the freely available ICCAT Secretariat Task 1 data reveals that either only a few flags report dead discards, or, few generate dead discards (**Table 2**). In an attempt to work around this lack of data, discards were estimated within the model 1993-2017 with information derived from each fleets landings, length compositions that included discarded fish and explicitly modeling the fleets length-based selectivity and the minimum legal size. “Dummy” values for discards were input as data, however the lambda on these values was set to zero. In this way, the “dummy” values had no influence on the model fit, but the model still created expected values (i.e. estimated discards). Discards before the establishment of the minimum legal size were considered to be zero. Until more information can be obtained on pre-regulation discards and lengths, this assumption is necessary.

Lengths of landed and discarded swordfish are mostly collected through biological sampling programs conduct by each CPC. Representatives from each of the individual CPCs included in the assessment were ask to verify how their length compositions were reported: retained only, or retained as well as discarded (**Table 2**). Also verified was which option of the regulation was being used; either the 119 cm LJFL with no tolerance or 125 cm LJFL with tolerance (**Table 2**). All but two of the CPC’s included in the SWO assessment model report both retained and discarded swordfish lengths (**Table 2**). The capabilities of the model did not allow for the modeling of the 15% tolerance of undersized fish for those CPCs choosing the 125 cm minimum size. For these fleets a cut off of 119 cm LJFL was used.

Three models were constructed and used for comparison. The models were fit for years 1950-2015 with an additional two years of “carry over” landings to serve the management schedule. The first model assumed full retention of all fish. The second model incorporated the current minimum limit and a 0% release mortality. The third model incorporated the same minimum size limit but with an 88% release mortality. For each model, natural mortality was held constant at M = 0.20, steepness was held constant at h = 0.75 and that virgin recruitment (R0), annual recruitment deviations and selectivity parameters was estimated.

3. Results

The results produced by the SS model were essentially identical to those produced by the SS3 model (**Figure 1**). The appearance of a single line this figure is because the results of the SS3 and SS models are virtually identical. All management benchmarks (derived quantities based on MSY, SPR, etc.) also were identical (**Table 1**). Consequently, and changes to the results of the next swordfish assessment can be directly attributable to changes other than from the migration to the SS modeling platform.

Length composition of swordfish aggregated across year by fleet (and sub-fleet) show the variation in the distribution of lengths across fleets (**Figure 2**). Distributions range from mostly smaller fish for Morocco to mostly larger fish for Canada. From these different distributions, it can be seen that the minimum legal size regulation likely has differential effects on different fisheries based on where and how they fish. Given the seasonal migratory nature of swordfish and subsequent segregation by size, (larger fish tend to migrate further poleward than do smaller fish, Schirripa et al. 2017), it is likely that fishing conducted nearer to the equatorial regions would be more effected than those fishing the more northern latitudes.

The average percentage of swordfish below the minimum size across all years post-regulations (i.e. 1993 and beyond) are given in **Table 3**. Inspection of the data shows that Canada encounters the least percentage (5% for 125 cm LJFL) of sublegal fish while Portugal the highest percentage (for 119 cm LJFL). It should be noted that the Portuguese fleet fishes a very large area (between -40 and 40 degrees latitude) relative to Canadian fishery (north of 40 degrees latitude). The percentage of swordfish below the current minimum sizes of 119 cm LJFL and 125 cm LJFL by year and fleet are shown in **Figure 3**. Inspection of the figure reveals that for the fleets of Spain, the US and Japan-early the percentage of fish encountered below the minimum sizes has generally not changed pre- and post-regulation. This suggests that these fishermen have not altered their fishing practice in response to the minimum size regulation. The lengths of fish caught by the Portuguese fleet, on the other hand, shows a downward trend, an indication that perhaps this flag has altered fishing practices to avoid the sub-legal swordfish. This conclusion must be made with caution however, as the percentage of fish below the minimum size is also influenced by the incoming year class strengths and/or the loss of larger fish. If the minimum size regulation is having the desired effect, stronger year classes strengths would be expected, which would likely increase the fleets encounter rate with sub-legal fish.

The estimated selectivities and fixed retention curves show that the effect of the minimum size regulation affects each fishery differently. The selectivity of the Canadian fleet suggests that the minimum size regulation would result in relatively few discards (**Figure 4, top**). The estimated selectivity of Spain suggests that a larger proportion of fish would be discarded (**Figure 4, middle**) and the selectivity of the US fleet (**Figure 4, bottom**) suggests that a large majority of swordfish would be discarded.

Trends in spawning stock biomass for the period under assessment for the three models were similar, however, because the landings were the same and held constant for each model, higher discard mortality necessitated that the population start out at a larger size (**Figure 5A**). Similarly, the three ending spawning biomass were similar, just arrived at through different starting spawning biomasses. Because the values of steepness and natural mortality were held constant for each model, the regenerative properties of the model populations did not change. Thus, the only manner in which the estimation process could account for the increase in fishing mortality due to discarding was to increase the overall population size. The estimation process accounted achieved this through increasing the estimate of virgin recruitment (**Figure 5B**). The overall Trends in F/F_{MSY} were essentially identical up to the year 1993, after which the model assuming 88% discard mortality diverged and increased to a value to that reflected the increase in mortality due to discarding (**Figure 5C**). While the derived quantity F_{MSY} did not change between models, the increase in the annual estimated F did increase, thus increasing the ratio of F/F_{MSY}. Of the four derived quantities examined, the trends n SSB/SSBMSY were the most similar between models (**Figure 5D**). Unlike F_{MSY}, which is not dependent on absolute population size, SSB_{MSY} does changes with the estimate of absolute population size. Thus, unlike F/F_{MSY}, the ratio of SSB/SSB_{MSY} does not show the same change over time. What does change is the absolute value of the catch associated with SSB_{MSY}.

The three models performed quite differently relative to traditional management objectives (**Table 4**). The model using the minimum size and 0% discard mortality was estimated to require the smallest initial population size to account for the amount of observed catch common to all three models (**Figure 6A**). At the same time, this model derived the largest total yield (all fish killed) and retained yield (all fish landed) at maximum sustainable yield (for this model total and retained yield were identical by definition) (**Figure 6B**). The model using a full retention of all fish required a larger initial population size than the 0% discard mortality model (**Figure 6A**) while at the same time deriving a lower total/retained yield than did the model using a minimum size and 0% discard mortality (**Figure 6B**). This is because the catch of the full retention model was made up of smaller fish that were being discarded in both of models using the minimum size.

The model using the minimum size and a, 88% discard mortality not only required the largest initial population size (**Figure 6A**) but also derived the highest amount of total yield (all fish killed and landed), and the lowest amount of retained yield (landed fish).

4. Discussion

A minimum size regulation can be used to achieve management objectives by altering fishing practices in several ways. One way is releasing the under sized fish, which is what was modeled in this study. This practices is only effective however if the released fish experience little or no release mortality. Studies thus far estimate that release mortality for swordfish in a longline fishery can be up to 88 percent (Coelho et al. 2019). Another way a minimum size regulation can alter fishing practices is to persuade the fishery to relocate their activity in an effort to reduce encounters with under sized fish, usually in either time or space. This practice is only effective however if the target species segregate at some time by size (or, to some extent, age). This can be seen in the length compositions from the US versus those from Canada. Larger swordfish tend to migrate further north in the summer than do smaller swordfish (Schirripa et al. 2017). Critical to the interpretation of these results is the assumption that the fishing fleets did not change their fishing practices to avoid undersized fish. Changes in practice to avoid undersize fish include, but not limited to, changing the area where the fishery is conducted, change in gear type, or any other practice that would change the vulnerability of undersized fish.

This study shows that a minimum legal size for the North Atlantic swordfish can result in management objective trade-offs. While the full retention fishery reduces the waste associated with dead discards, the yield at maximum sustainable yield was the lowest of the three models, resulting in reduced catch. While the model using a minimum size and 0% discard mortality resulted in the highest maximum sustainable yield and lowest amount of waste, a discard mortality of 0% is difficult, if not impossible, to achieve. If the minimum size limit changes the encounter rate of undersized fish, even with a relatively high release mortality the minimum size regulation result in increased safety and yield, but may depend on fishing fleets to operate only in certain areas and/or at certain times. The assumed natural mortality, steepness of the stock-recruitment relation and discard mortality are the key uncertainties in this analysis, and further evaluation is required to elucidate the impact of this assumption on the fishery dynamics and the performance of candidate management procedures.

References

Anonymous. Report of the 2017 ICCAT swordfish Assessment (Madrid, Spain 3-7 July, 2017). (available here): 85 p.

Coelho, R. and Muñoz-Lechuga, R., 2019. Hooking mortality of swordfish in pelagic longlines: comments on the efficiency of minimum retention sizes. Reviews in Fish Biology and Fisheries, 29(2), pp.453-463.

Methot, R.D. and Wetzel, C.R. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fish. Res. 42:86-99.

NOAA Fisheries Toolbox, 2011. Stock Synthesis, Version 3.23b. http://nft.nefsc.noaa.gov

Schirripa, M.J., Abascal, F., Andrushchenko, I., Diaz, G., Mejuto, J., Ortiz, M., Santos, M.N. and Walter, J., 2017. A hypothesis of a redistribution of North Atlantic swordfish based on changing ocean conditions. Deep Sea Research Part II: Topical Studies in Oceanography, 140, pp.139-150.

Table 1. Task 1 catch/landings (nomenclature was changed from "catch" to "landings" but denote the same quantity) and dead discards reported by the flags (fleets) used in the North Atlantic swordfish stock assessment

CATCH																										
Flag	Type	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Canada	C	2234	1676	1610	739	1089	1115	1119	968	1079	959	1285	1203	1558	1200	1081	1334									
	DD					5	52	35	50	26	33	79	45	106	38	61	39	9	15	8	111	59	12	8	11	21
	L														203	267		1300	1346	1551	1489	1505	1604	1579	1548	1188
Chinese Taipei	C	974	3337	3365	3395	3074	1433	1453	1650	1448	1474	1511	775	884	549	774	809	701	498	616						
	DD																			5	144		52	62	5	129
	L																				545	697	484	626	626	494
EU.España	C	14930	15625	19622	16355	14865	11354	10660	12419	11240	11196	10338	11810	11833	12210	12544	10533	12132	11740	9585						
	DD																							7		
	L																			1747	12064	9874	9936	11355	10641	9729
EU.Portugal	C	1961	1599	1997	2092	1344	1157	1158	1137	1242	1153	1386	1785	1407	1404	1206	1018	1177	1286	858						
	DD																									
	L																	88		608	1067	1563	1493	1657	1710	2337
Japan	C	6386	5634	4666	3696	2717	2584	1868	2	1																
	DD								598	567	319	263														
	L								951	685	833	924	1263	1189	1746	3046	2537	2118	2376	1756	1801	984	1521	1087	1016	1357
Maroc	C	2628	2690	1775	3196	5167	3419	3357	2822	3549	3602	3629	3588	2857	2399	1959	2387	2311	2573							
	DD																									
	L																			1809	1572	1832	1832	1330	2010	1900
U.S.A.	C	147	114	100	106	22	49	34	3006	2260	2584	2534														
	DD	408	708	526	589	467	443	500	492	308	264	282	276	227	185	220	205	148	138	223	217	120	137	137	90	107
	L	3636	3252	3926	3624	3361	3169	3053					2395	2160	1873	2463	2387	2730	2274	2551	3393	2824	1809	1581	1408	1270

Table 2. Fleet number, flag, partition of lengths reported and the minimum legal size used by each of the fleets (and sub-fleets) used in the North Atlantic swordfish stock assessment.

Fleet	Length Type	Min.Size
Spain	Retain/Discard	125
US	Retain/Discard	119
Canada_early	Retain/Discard	125
Canada_late	Retain/Discard	125
Japan_early	Retain/Discard	125
Japan_mind	Retain/Discard	125
Japan_late	Retain/Discard	125
Portugal	Retain/Discard	125
Chinese_Taipei	Retained	119
Morraco	Retained	125
Other	N/A	N/A

Table 3. Average percentage of swordfish observed under the minimum size post-regulation (1993+).

Fleet	<=119 cm	<=125 cm
Spain	27	42
US	5	20
*Canada	1	5
Japan-Early	20	29
Japan-Mid	21	30
Japan-Late	20	32
*Portugal	34	49
Chinese-Taipai	21	32
Morocco	15	41

Table 4. Derived management quantities for the SS model assuming full retention of swordfish, the current minimum size regulation and 0% discard mortality and the current minimum size regulation with an 88% discard mortality. Total yield reflects all fish killed (retained + killed via discard mortality) while retained yield reflects only those fish retained.

Derived Quantity	Full Retention	Discard Mortality = 0%	Discard Mortality = 88%
SSB Unfished	134,751	127,708	147,608
Recruitment Unfished	977	926	1,071
SSB@MSY	33,992	30,919	36,788
F@MSY	0.12	0.13	0.12
Total Yield@MSY	11,620	12,181	12,592
Retained Yield@MSY	11,620	12,181	11,410

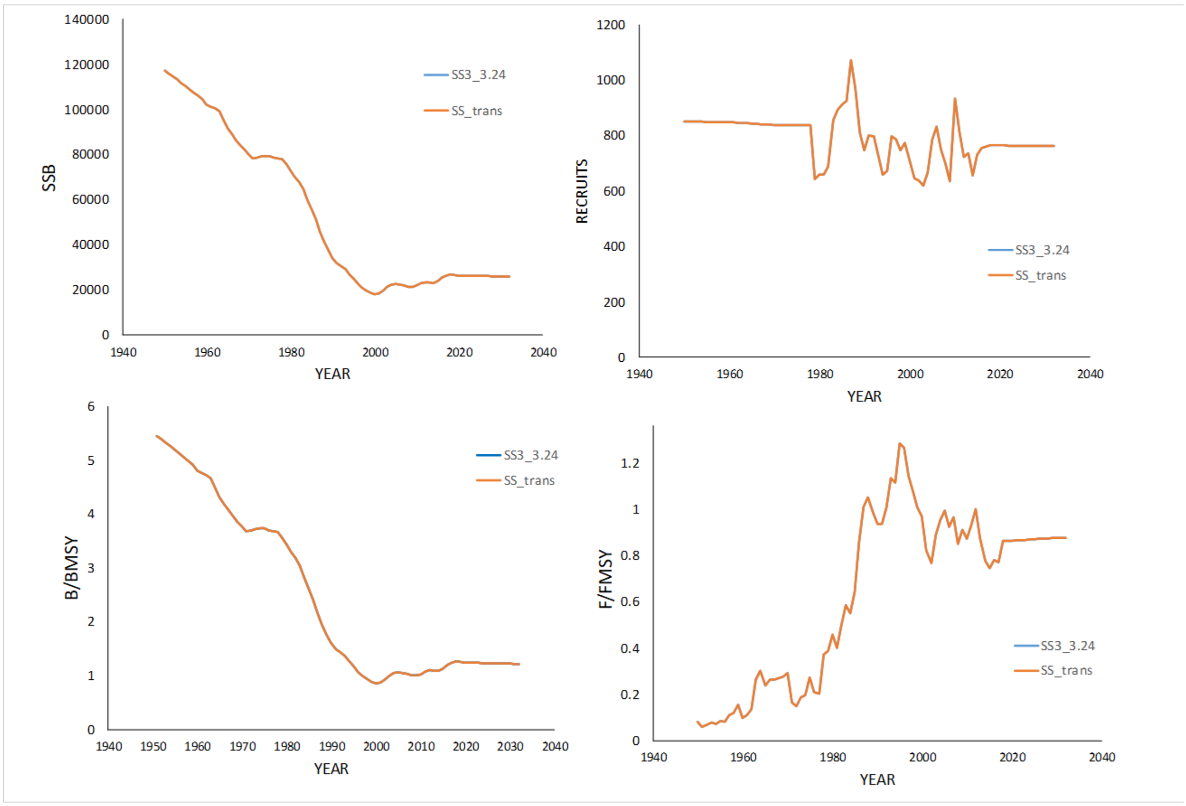

Figure 1. Comparison between estimates spawning stock biomass (SSB, upper left), number of recruits (upper right), B/Bmsy (lower left) and F/Fmsy (lower right) using Stock Synthesis v3.24 (blue) and Stock Synthesis v3.30 (SS_trans, orange). Note that both lines

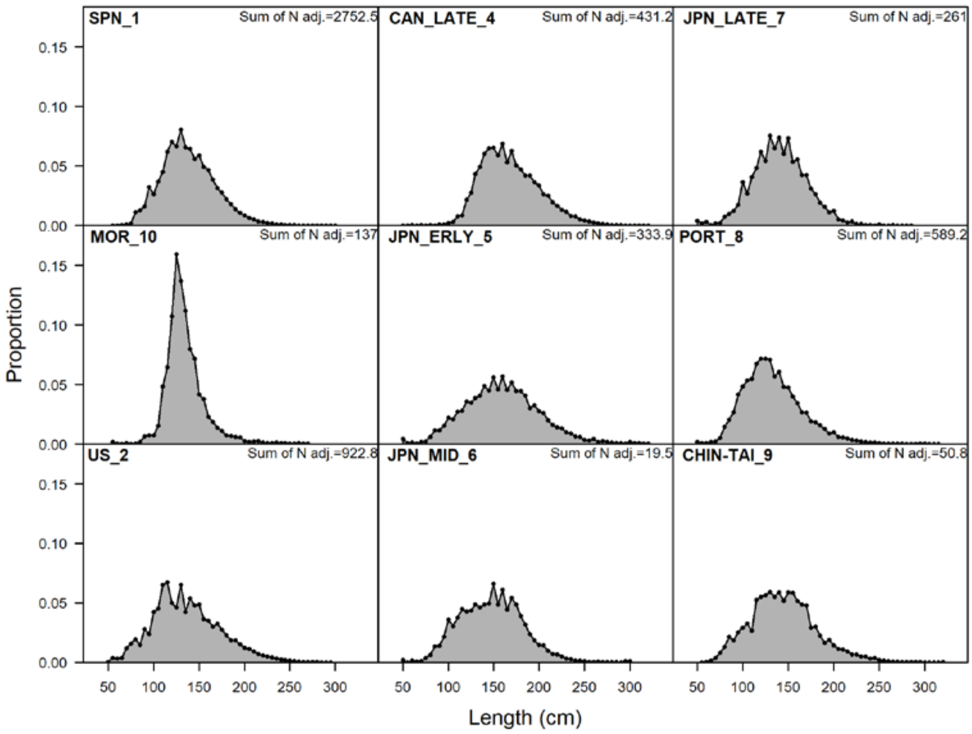

Figure 2. Length composition of Swordfish aggregated across year by fleet and sub-fleet.

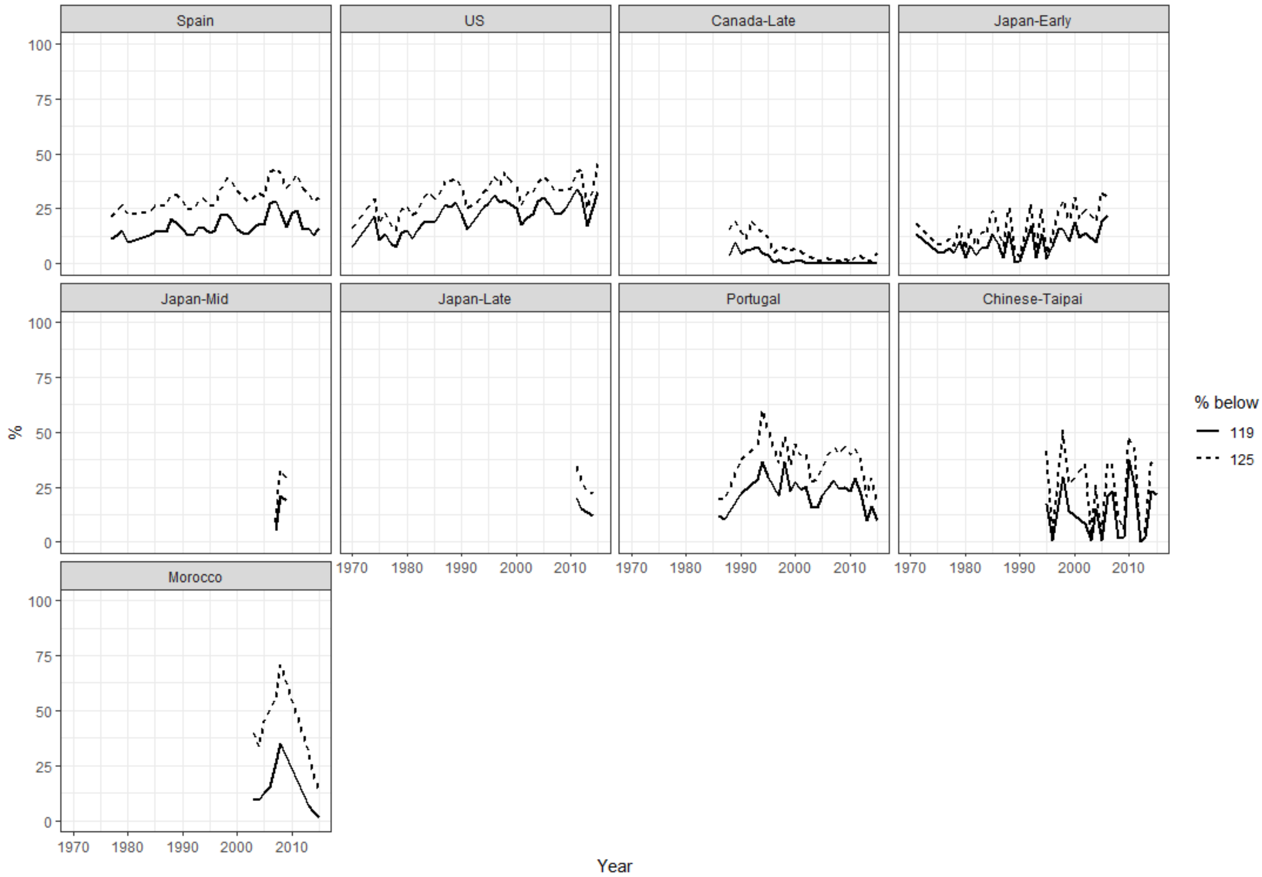

Figure 3. Percentage of Swordfish lengths below the minimum size of 119 cm LJFL (solid line) and 125 cm LJFL (dashed line) by year and flag.

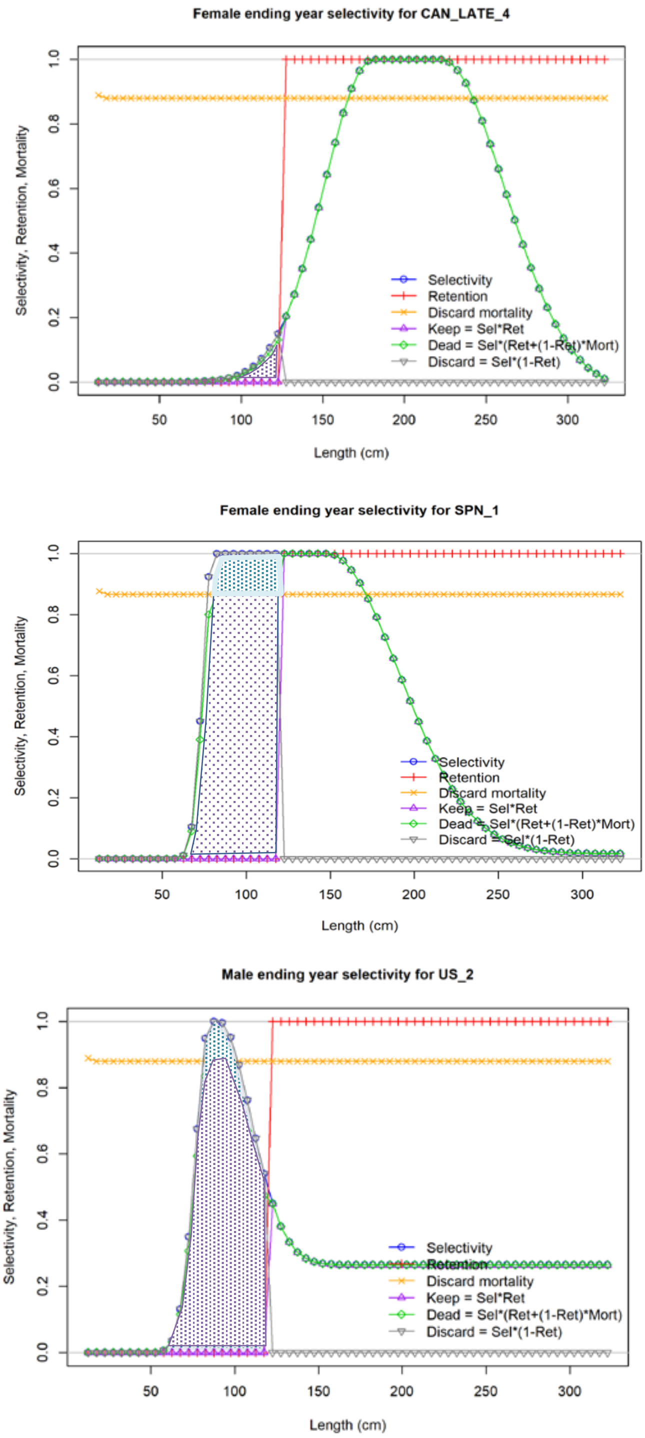

Figure 4. Estimated selectivities from the fisheries of Canada (top), Spain (middle) and the US (bottom). The filled/yellow areas represent lengths and percentage of fish discarded dead, and the filled/blue areas the lengths and amount fish discarded and survive.

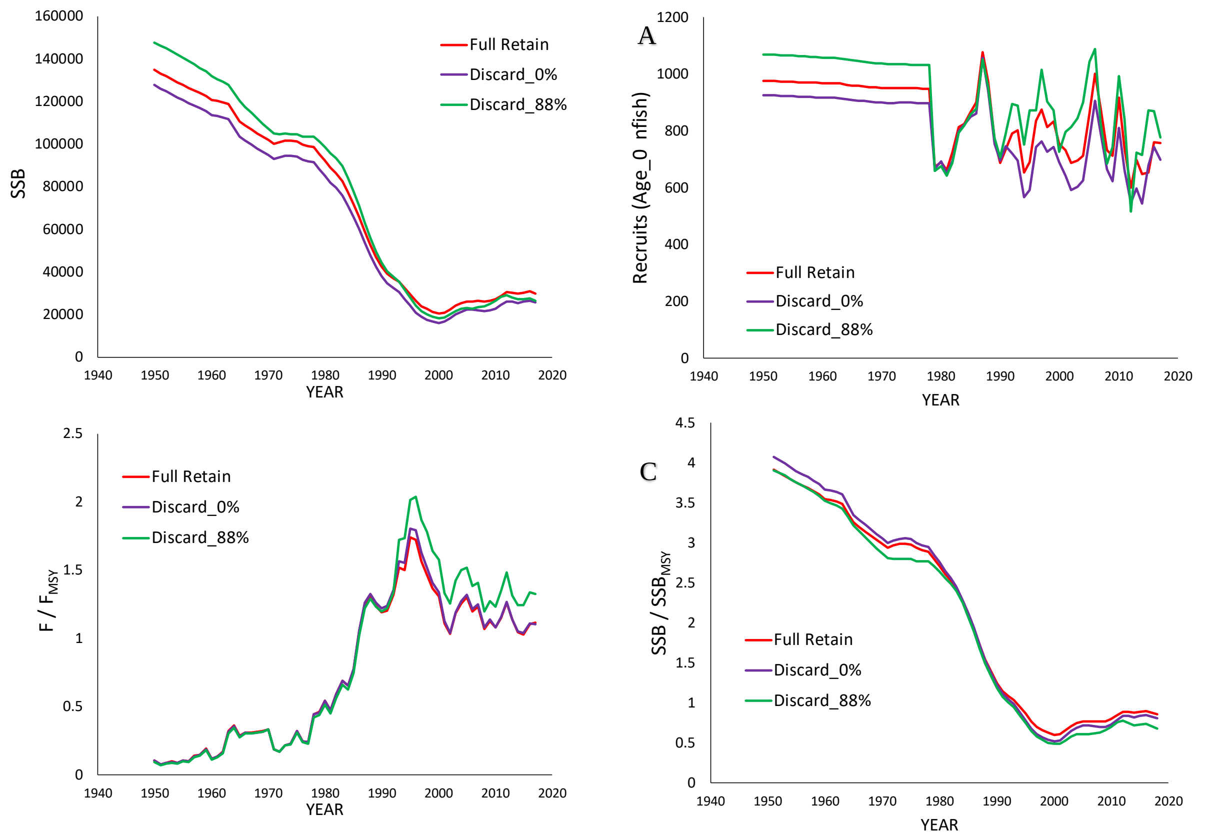

Figure 5 . Comparison between estimates spawning stock biomass (A), number of recruits (B), F/F_{MSY} (C) and SSB/SSB_{MSY} (D) from the models assuming full retention (red), a minimum size regulation with 0% discard mortality (purple) and 88% discard mortality (green).

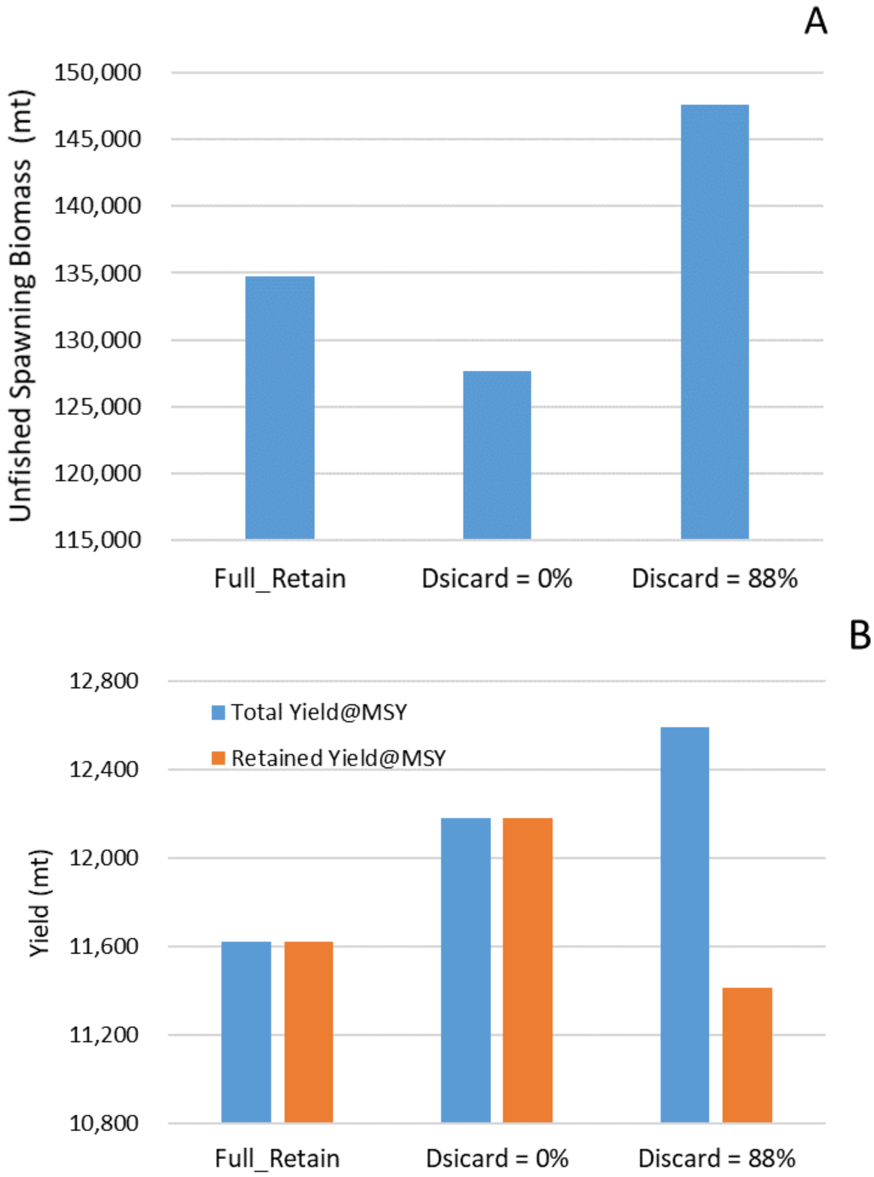

Figure 6. Unfished spawning biomass (top, A), total yield (all fish killed) in weight and retain yield (fish landed) in weight (B) for the three models examined.