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A COMPARISON OF THE 2008, 2012 AND 2017 ASSESSMENTS OF THE NORTH ATLANTIC SHORTFIN MAKO SHARK

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SUMMARY

The 2017 ICCAT stock assessment for north Atlantic shortfin mako suggested a substantial deterioration of the estimated stock status compared with the 2008 and 2012 stock assessments. ICCAT is updating catch projections in May 2019 to evaluate if further management measures are needed to ensure the sustainability of the North Atlantic shortfin mako fishery. This paper compares the data, methods and results of the three most recent assessments as background to the discussions to be held during the Shortfin Mako Stock Assessment Update Meeting in May 2019.

RÉSUMÉ

L'évaluation du stock de requin-taupe bleu de l'Atlantique Nord réalisée par l'ICCAT en 2017 a suggéré une détérioration substantielle de l'état estimé du stock par rapport aux évaluations précédentes de 2008 et 2012. L'ICCAT est en train d'actualiser les projections des captures en mai 2019 dans le but d'évaluer la nécessité de mesures de gestion supplémentaires afin de garantir la durabilité de la pêcherie de requin-taupe bleu de l'Atlantique Nord. Le présent document compare les données, les méthodes et les résultats des trois plus récentes évaluations comme base pour les discussions qui auront lieu lors de la réunion de mise à jour de l'évaluation du stock de requin-taupe bleu en mai 2019.

RESUMEN

La evaluación del stock de marrajo dientuso del Atlántico norte de ICCAT de 2017 sugería un deterioro sustancial del estado estimado del stock en comparación con las evaluaciones de stock anteriores de 2008 y 2012. ICCAT está actualizando las proyecciones de captura en mayo de 2019 para evaluar si son necesarias más medidas de ordenación para garantizar la sostenibilidad de la pesquería de marrajo dientuso del Atlántico norte. Este documento compara los datos, métodos y resultados de las tres evaluaciones más recientes como base para las discusiones de la reunión de actualización de la evaluación de stock de marrajo dientuso que se celebrará en mayo de 2019.

KEYWORDS

Sharks, stock assessments, population dynamics, potential yield, exploitation.

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1. Introduction

Shortfin mako shark is a highly migratory species distributed in all of the world's oceans from 50ºN to 50ºS. They are an important by-catch in tuna longline fisheries. Concerns over shark stock status generally (http://www.fao.org/ipoa-sharks/background/sharks/en/) have increased and the FAO has adopted a shark international plan of action (Shark IPOA http://www.fao.org/ipoa-sharks/background/about-ipoa-sharks/en/) in 1999. As indicated in the FAO Shark IPOA, "*sustainable fisheries for sharks are possible, but have to be very closely managed with small yields compared to standing stocks*".

In the Atlantic, the International Commission for the Conservation of Atlantic Tunas (ICCAT) has the mandate to manage fisheries catching sharks. The Standing Committee on Research and Statistics (SCRS) has provided cautionary advice on shortfin mako shark most recently based on stock assessments conducted in 2004, 2008, 2012 and 2017. The 2004 stock assessment was the first conducted for the species and very preliminary, it is not discussed in the text, but the results are presented in **Table 1.**

The 2008 stock assessment concluded: *Estimates of stock status for the North Atlantic shortfin mako shark obtained with the different modeling approaches were much more variable than for Atlantic blue sharks. For the North Atlantic, multiple model outcomes indicated stock depletion to about 50% of virgin biomass (1950s levels) and levels of F above those resulting in MSY, whereas others estimated considerably lower levels of depletion and no overfishing. In light of biological information that places the point at which BMSY is reached with respect to the carrying capacity at levels higher than for blue sharks and many teleost stocks, there is some non-negligible probability that the stock could be below the biomass that supports MSY and above the fishing mortality rate associated with MSY. A similar conclusion was reached by the Committee in 2004, and recent biological data show that the productivity for this species is lower than previously believed*".

The conclusion of the 2012 stock assessment was more positive: "*The results indicated in general that the status of the North and South Atlantic stocks is healthy and the probability of overfishing is low; however, they also show apparent inconsistencies between estimated biomass trajectories and input CPUE trends, producing wide confidence intervals in estimated trajectories and other parameters.[…] Taking into consideration results from the modeling approaches used in the assessment, the associated uncertainty, and the relatively low productivity of shortfin mako sharks, the Working Group recommends, as a precautionary approach, that the fishing mortality of shortfin mako sharks should not be increased until more reliable stock assessment results are available for both the northern and southern stocks*".

The 2017 assessment concluded: "*The models agree that the northern stock was overfished and was undergoing overfishing. The results obtained in this evaluation are not comparable with those obtained in the last assessment in 2012 because the input data and model structures have changed significantly. The catch time series are different (they now start in 1950 vs. 1971 in the 2012 assessment) and were derived using different assumptions; the CPUE series have been decreasing since 2010 (the last year in the 2012 assessment models); some of the biological inputs have changed and are now sex specific; and additional length composition data became available. Additionally, in 2012 only the BSP1 production model and a catch-free age-structured production model were used. This updated assessment represents a significant improvement in our understanding of current stock status for North Atlantic shortfin mako*". Our objective in this paper is to document in more detail the similarities and differences in the 2008, 2012 and 2017 stock assessments.

2. Data used

Figure 1 shows the catch estimates used in the 2008, 2012 and 2017 north Atlantic mako shark assessments. Reporting of shark catches by species improved in the mid 1990s and in 2008, the working group estimated total shortfin mako catches assuming that the ratio of shortfin to the target species observed after the mid 1990s also applied in earlier years. This resulted in considerably higher catch estimates for 1971 to the early 1990s and similar estimates afterwards. These estimates were also used in the 2012 stock assessment, which also included recovered catch series from several nations. In 2017, the working group revised Task I estimates again with additional recovered catch series, which resulted in higher estimates for 1986 to 1995, but lower than 2012 estimates obtained using the ratio estimate. Higher catches during 1971 – 1994 would imply higher resilience of the stock given the observed CPUEs. The alternate catch series used in the 2017 assessment (called C2 in the assessment report; based on ratios of shark catches to the main target species) is between the series used in the 2012 and 2017 assessments for 1971 to the mid 1990s, then slightly higher than all previous series for the late 1990s to the last year in the assessment. The series used in the SS3 assessment and the production model assessments are the same.

Nine CPUE indices were examined during the 2008 stock assessment, but only the Japanese, USA and Spain longline logbook CPUE series were used in the assessment (**Figure 2**). The overall conclusion in the 2008 assessment was that caution was advisable, but there were no clear indications of stock decline.

Four CPUE indices examined during the 2008 assessment are not discussed in the 2012 assessment[3]: US LPS, US-Tourn, CAN-LL and CH-TA-LL while the Portuguese LL was provided for the first time and added **(Figure 3**). Six CPUE indices were evaluated in 2012 and four were used in the assessment, the same three as in 2008 with the Portugal longline added. The indices showed either stability or an increasing trend (particularly the Spanish LL index) albeit with substantial variability (e.g the Portugal LL). These CPUE indices supported the relatively more positive view in the 2012 assessment report.

The four CPUE indices used in the 2012 assessment were retained in the 2017 assessment with the addition of the CH-TA-LL which was deemed adequate for inclusion (**Figure 4**). All the CPUE indices show a decline from the early 2010s to 2015, some to a greater extend than others (e.g. Portugal). These CPUE indices are consistent with the more negative view in the 2017 assessment.

Figures 5 to 8 show each index as it was used in successive assessments. The CPUE indices used in the 2008 assessment had been rescaled compared to the indices used in the 2012 and 2017 assessments by taking the mean of the overlapping years among all indices used in 2008 (**Figure 5**). The series used in successive assessment overlap one another. The most recent US longline logbook series shows a decrease by slightly more than half from 1986 to 2015. The CPUE series for the Japanese longline series differ from one assessment to the other (**Figure 7**) but they generally agree in being higher at the beginning of the series, following by a decline until about 2000, increasing thereafter until about 2010. The most recent series shows wide fluctuations without a clear trend with the most recent value (2015) among the lowest observed. The Spanish longline series (**Figure 7**) are reasonably consistent from one assessment to the other, except for the first five years in the series used in the 2012 assessment. The trends are consistent with those in the Japanese series, a decrease from the early 1990s through to 2000, followed by an increase to 2010 and then another decrease. The CPUE index from the Portuguese longline was used in the 2012 and 2017 assessments (**Figure 8**). The 2017 series is similar to the 2012 series during 1999 to 2004, but diverges substantially afterwards. While the series used in the 2012 assessment essentially showed no trend, the series used in the 2017 assessment shows a three fold increase from 1999 to 2006 followed by a 2-fold decrease from 2006 to 2014 and a steep decline in 2015.

3. Stock assessment methods

Several assessment modeling approaches (Bayesian surplus production models, age-structured production modeling, catch-free age structured production models and integrated modeling (SS3)) each with several model configurations tested have been used to assess shortfin mako shark since 2008. Until 2017, most of the production models considered observation errors, but no process errors. With the introduction of BSP2, JAGS and JABBA, modeling assumed both observation and process errors. In 2017, a length-age integrated model, Stock Synthesis 3 (SS3) was also used. Table 1 provides a summary of the data (catch and CPUE indices) and models used in the 2004, 2008, 2012 and 2017 stock assessments and gives a summary of the results (ratios of reference points and status) for each stock assessment.

4. Assessment results

Some results of the 2008 Bayesian Surplus Production base case assessment are shown in **Figure 9**. **Figure 10** shows the 2008 estimates of B/B_{MSY} and F/F_{MSY} for the various Bayesian Surplus Production model configurations tested. Fishing mortality is estimated to be consistently above F_{MSY} while about half of the biomass estimates are at or above B_{MSY} and half below B_{MSY}. The fit to the indices (**Figure 9** panel c) is not very good: the estimated biomass declines steadily while most CPUE indices reached a minimum around the year 2000 and increased thereafter. The report indicates that increases in CPUE indices may be due to causes other than increase in biomass of shortfin mako shark.

Fits to the indices were similarly poor in the 2012 Bayesian Surplus Production continuity run. The 2012 assessment tried to reconcile declining biomass trends from modelling with observed increases in most CPUE

[3] Updating of CPUE indices is the responsibility of individual CPC scientists and some indices may be removed after evaluation during data preparatory meetings.

indices after 2000. In all 16 Bayesian Surplus Production configurations were tested. "*The 16 models gave very consistent results (Table 18, Figure 46). All found that the median of the current stock abundance was above BMSY. All found the median F was less than FMSY, except for the run that used estimated catches from effort before 1997. Figure 46 also indicated the 80% credibility intervals. The continuity run was also more pessimistic than most of the runs, presumably because of the lower mean in the prior for r*" (page 8 of the 2012 report). **Figure 11** shows the biomass and fishing mortality results relative to MSY reference points for the 16 configurations tested. Absolute estimates of biomass appear to be in the same order of magnitude as those in the 2008 assessment (i.e. biomass in 1971 in the order of 200000t) but much lower fishing mortality.

The Kobe plot in the 2017 Executive Summary in the SCRS report is shown in **Figure 12**. The results of 9 models are shown, four BSP2JAGS, 4 JABBA and 1 SS3. All models, except SS3 indicate that the stock is overfished and that overfishing is occurring. The SS3 results suggest that fishing mortality is too high (overfishing occurring) but that the biomass is about at B_{MSY}. Given the high fishing mortality, the stock would be expected to decline below B_{MSY} in the near future.

Discussion

Data and information on shortfin mako shark and on the fisheries catching it have improved considerably since the first tentative assessment in 2004. Currently, two series of catch estimates and five longline CPUE indices of stock size are used. Of those relative stock size indices, the Japanese and US longline series have always been included, the Spanish index was added in 2008, the Portuguese in 2012 and Chinese Taipei in 2017. More stock size indices were available, but after evaluation, only those indicated above were used in the assessment.

The US longline index has remained very consistent in successive assessments (**Figure 5**), but the Japanese longline series has changed from one assessment to the next (**Figure 6**). The Spanish index in the two most recent assessments is very consistent for the period 1996-2015 (**Figure 7**), but the trends in 1990-1994 differ in those assessments. Similarly, for Portugal (**Figure 8**), the series show different trends in the 2012 and 2017 assessments.

The various model runs in the 2008 assessment (**Figure 10**) indicated that overfishing was occurring (all the ratios F/FMSY are above 1) while there was approximately a 50:50 chance that the stock was overfished (half of the ratios B/BMSY are below 1 and half above 1). The results of the various model runs made during the 2012 assessment were more optimistic (**Figure 11**): of the 16 runs, the biomass ratios were all above 1 and only one of the F ratios was above 1. The results of the 2017 assessment are completely the opposite (**Figure 12**) with all F ratios considerably above 1 and only one B ratio close to 1 (the estimate from SS3).

It is difficult to reconcile the results of the 2017 assessment using all indices simultaneously with model runs that use each index individually **(Figure 13**). In that case, the biomass ratios are greater than 1 for all years for all CPUE series, except for the US and CH-TA longline indices in 2014 and 2015.

The incorporation of process error in the 2017 surplus production models improved considerably the fit to the stock size indices although such models do not capture the biological characteristics of shortfin mako shark productivity. Surplus production models assume that the biomass next year is related to the biomass this year, plus growth (including recruitment), minus catch and natural mortality. The shortfin mako shark fishery is based essentially on immature fish; this means that the component of surplus production related to somatic growth of fish already recruited to the fishery is included in surplus production models, but the recruitment component related to the offspring production by the mature component is not included. For a species like shortfin mako shark that produces 12 pups or less per spawning event, the production of recruits is expected to be closely related to the abundance of mature females.

While there remains uncertainties in stock size estimates, we conclude that the 2017 assessment better reflects stock and exploitation trends than previous assessment did.

Acknowledgements

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Table 1: Summary of the data, models and results of the 2004, 2008, 2012 and 2017 stock assessments. **BSP**=Bayesian Surplus Production model, **CFASPM**=Catch free Age-Structured Production Model, **ASPM**=Age-Structured Production Model, **SS**=Stock Synthesis 3, **BSP2JAGS**=Bayesian Surplus Production Model incorporating both observation and process error using Just Another Gibbs Sampler (JAGS), **JABBA**=Just Another Bayesian Biomass Assessment.

STOCK ASSESSMENT										
YEAR	2004		2008			2012		2017		
CATCH										
Type	Task I + tuna ratios [a]		Task I + tuna ratios [a]			Task I + tuna ratios [h]		C1: Task I + tuna ratios [l]	C2: target spp ratios [m]	
Period	1971-2002		1971-2006			1971-2010		1950-2015	1971-2015	
CPUE	JP LL, US LL		JP LL, US LL, ESP LL			JP LL, US LL, ESP LL, POR LL		JP LL, US LL, ESP LL, POR LL, CH TA LL		
MODELS	**BSP**	**CFASPM**	**BSP**	**CFASPM**	**ASPM**	**BSP**	**CFASPM**	**BSP2JAGS**	**JABBA**	**SS**
STATUS										
B/B_{MSY}	0.84 [b]		0.95; 0.72-1.67 [d]	1.26-1.65 [f]		1.15.-1.72 [i]	1.63-2.16 [k]	0.63-0.85 [n]	0.57-0.76 [n]	0.95 [o]
B_{cur}/B_0		0.24-0.36 [c]			0.45, 0.73 [g]					
F/F_{MSY}	0.58 [b]		3.77; 1.20-4.53 [e]	0.48-0.70 [f]		0.25-1.63 [j]	0.16-0.62 [k]	1.93-3.58 [n]	3.75-4.38 [n]	4.37 [o]
Overfished?	Maybe	Maybe	Near	No	Unknown	No	No	Yes	Yes	Near
Overfishing?	No		Yes	No	Unknown	No	No	Yes	Yes	Yes

[a] Task I includes ICES and FAO statistics to fill gaps; Tuna ratios are of sharks to tunas (including swordfish and billfish)

[b] Only run that converged

[c] Range of five runs

[d] Base run (run d) followed by range from all other runs, most close to 1.0

[e] Base run (run d) followed by range from all other runs, most 3 to 4

[f] Range of 2 runs

[g] Mode and mean, respectively of run D

[h] Task I with historical catch series from several nations recovered

[i] Range of 16 runs

[j] Range of 16 runs. 1.63 is the only value >1

[k] Range of 12 runs

[l] Task I with additional historical catch series from several nations recovered

[m] Based on ratios of shark catches to catches of the main target species

[n] Range of 4 runs (2 with C1 catch, 2 with C2 catch)

[o] Based on run 3 (using C1 catch)

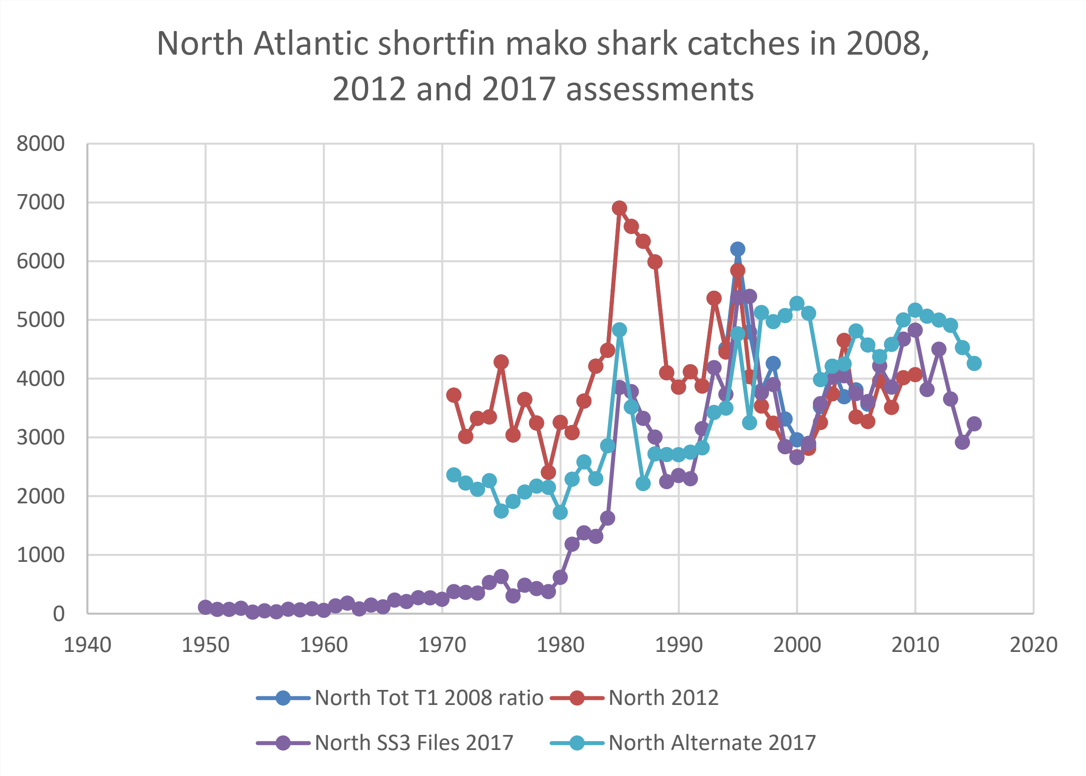

Figure 1. Estimates of catches used in the 2008, 2012 and 2017 stock assessments of north Atlantic shortfin mako.

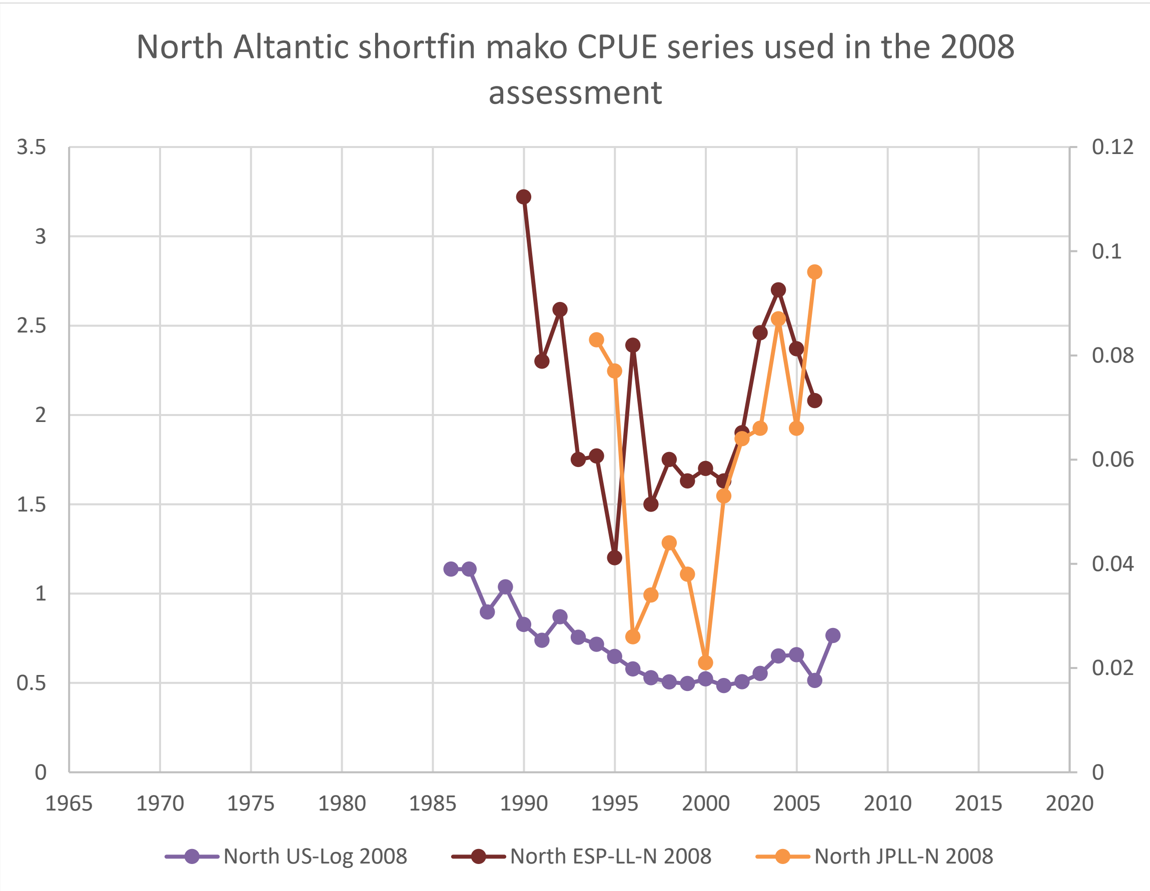

Figure 2. CPUE indices used in the north Atlantic shortfin mako shark assessment in 2008.

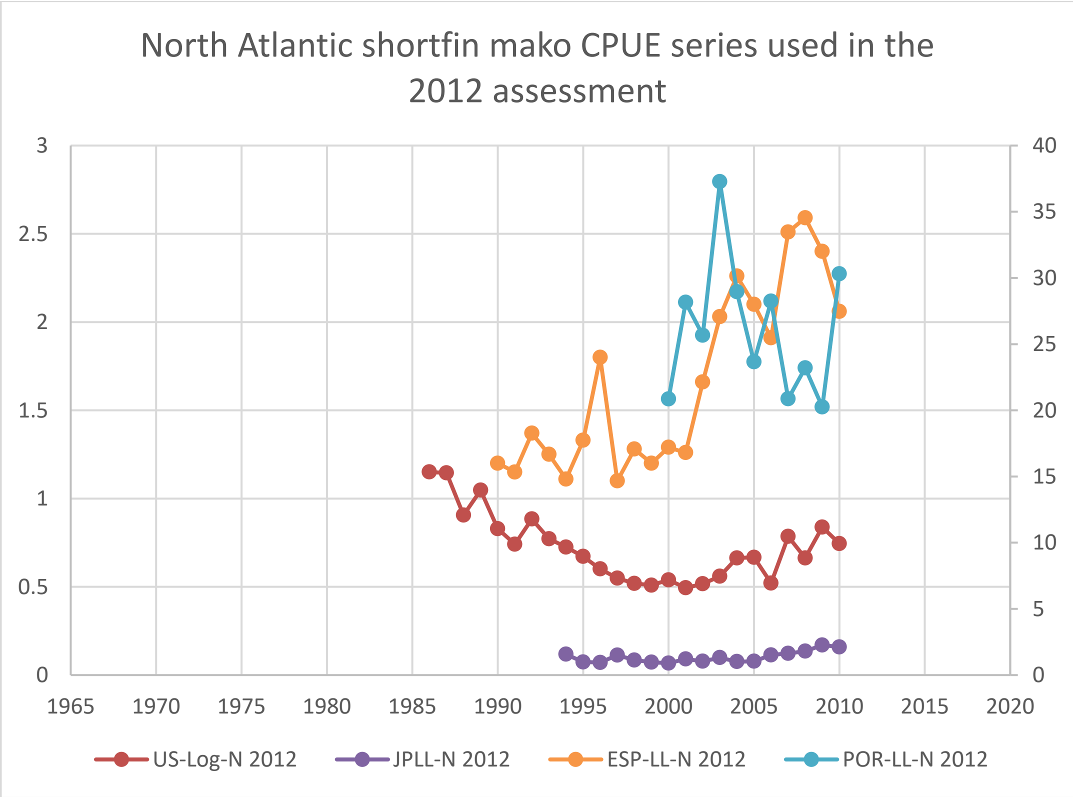

Figure 3. CPUE indices used in the north Atlantic shortfin mako shark assessment in 2012. Note that the Portugal longline index uses the right-hand vertical axis.

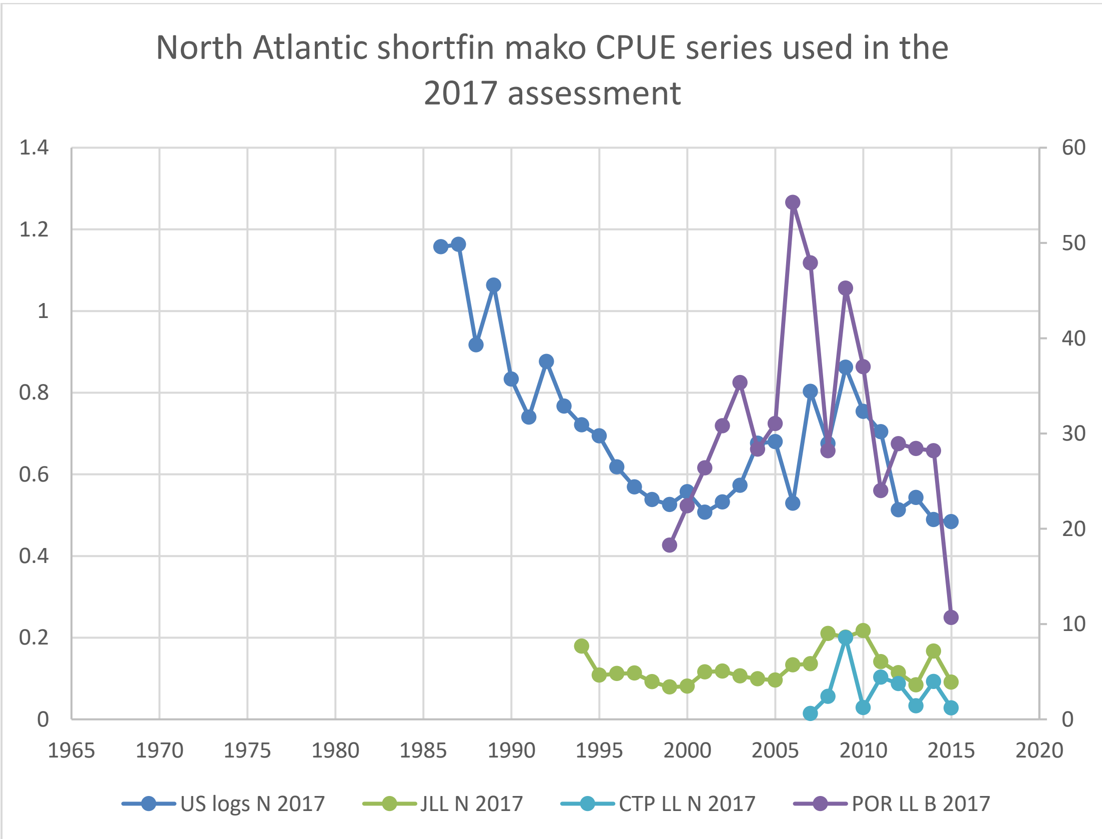

Figure 4. CPUE indices used in the north Atlantic shortfin mako assessment in 2017. Note that the Portuguese and Spanish longline indices use the right-hand vertical axis.

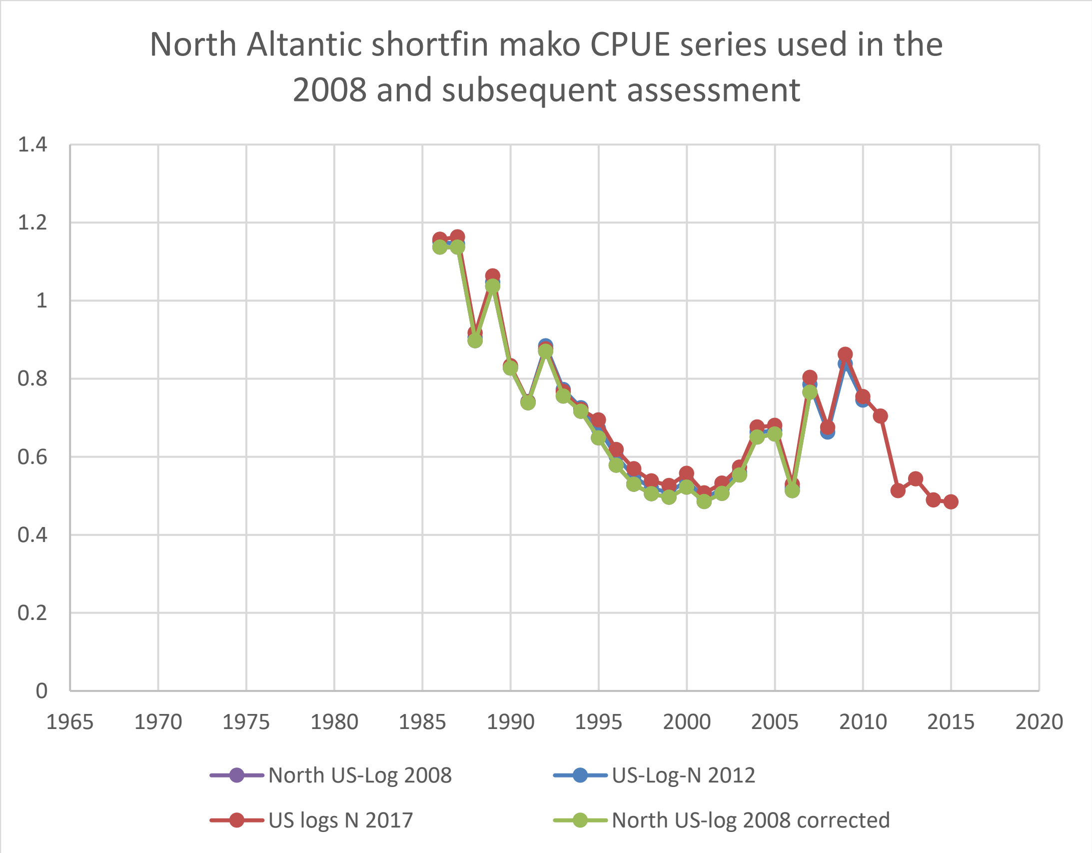

Figure 5. CPUE index from the US longline logbooks used in the 2008, 2012 and 2017 stock assessments.

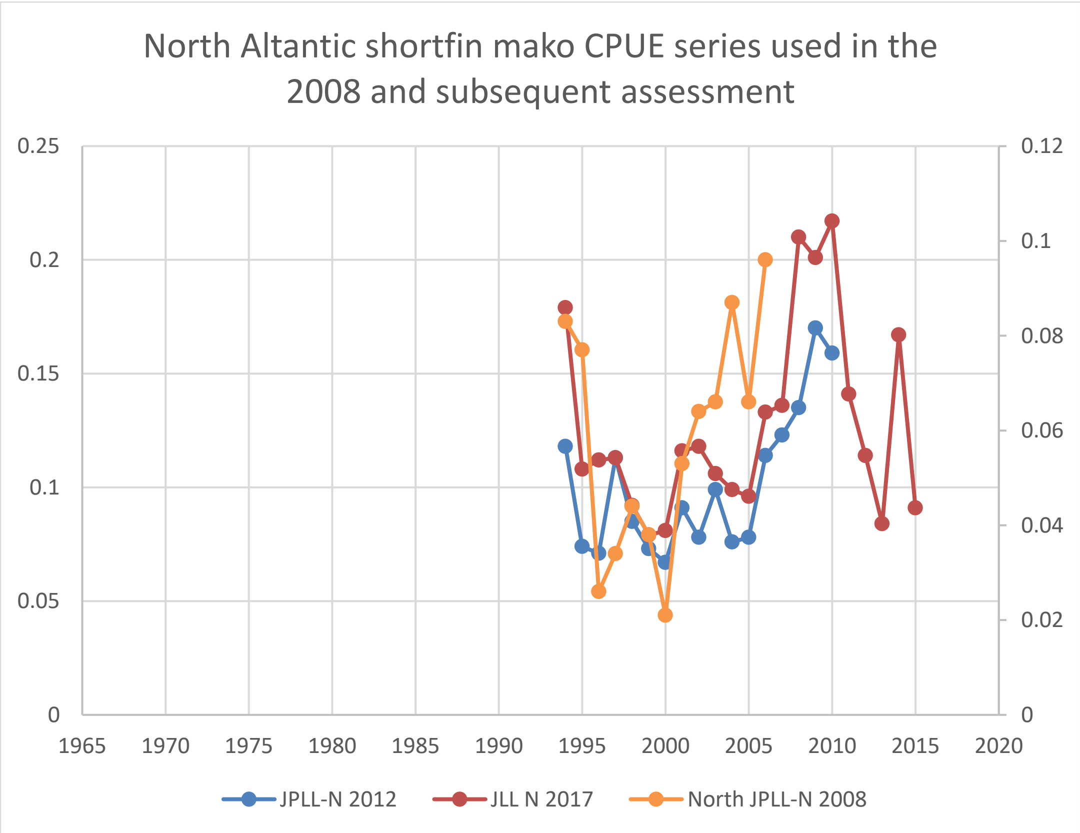

Figure 6. CPUE index for the Japanese Longline used in the 2008, 2012 and 2017 stock assessments.

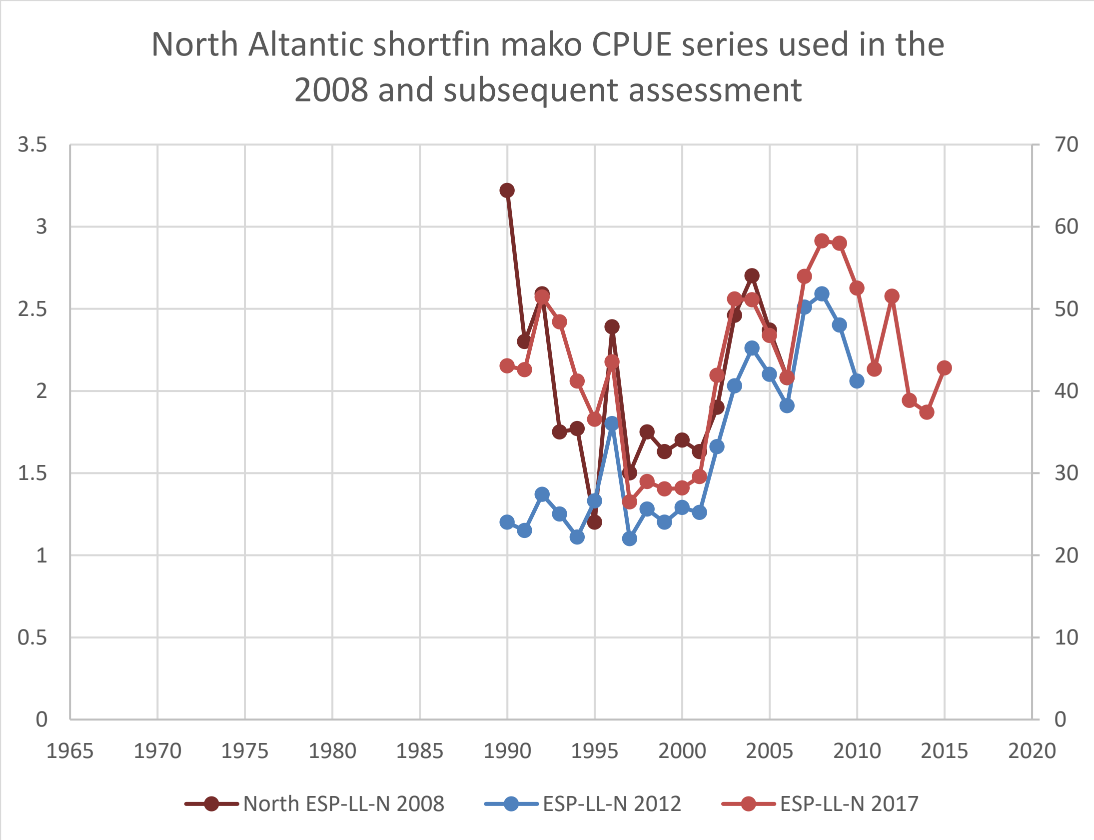

Figure 7. CPUE index for the Spanish longline used in the 2008 and 2012 stock assessment with the 2017 estimates added. Note that the 2017 estimates use the right-hand vertical axis.

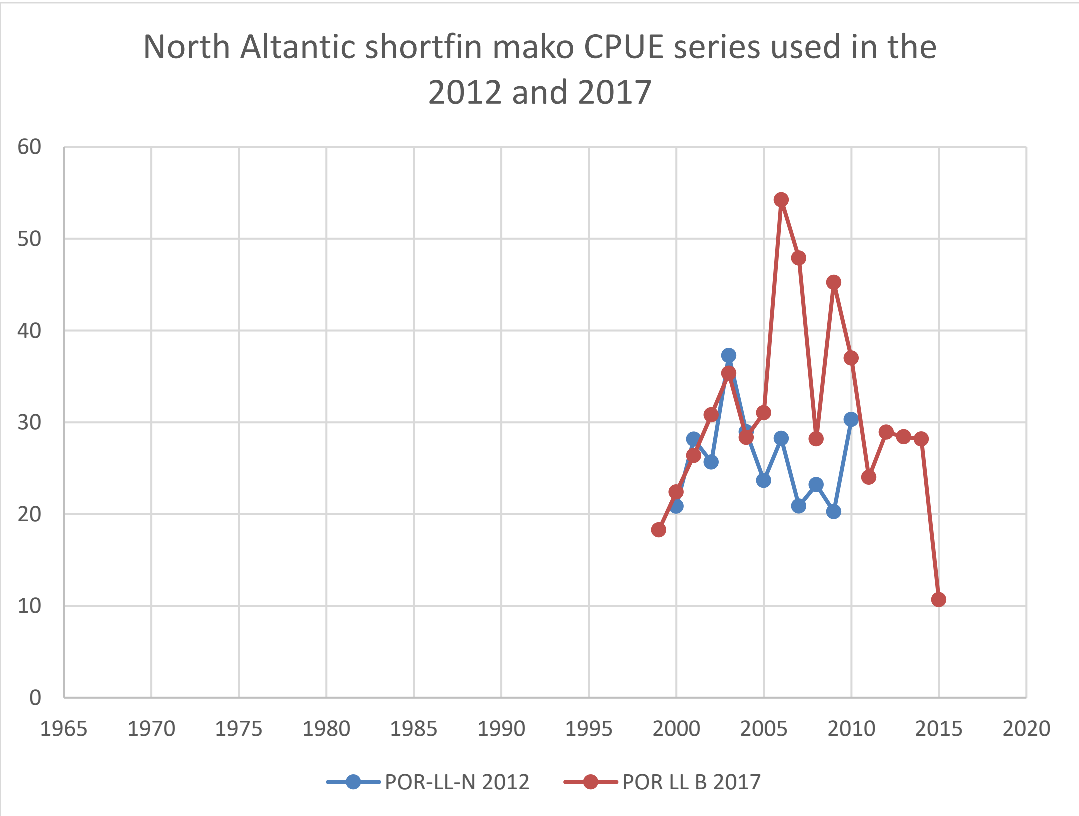

Figure 8. CPUE index for Portuguese longlines used in the 2012 and 2017 stock assessments.

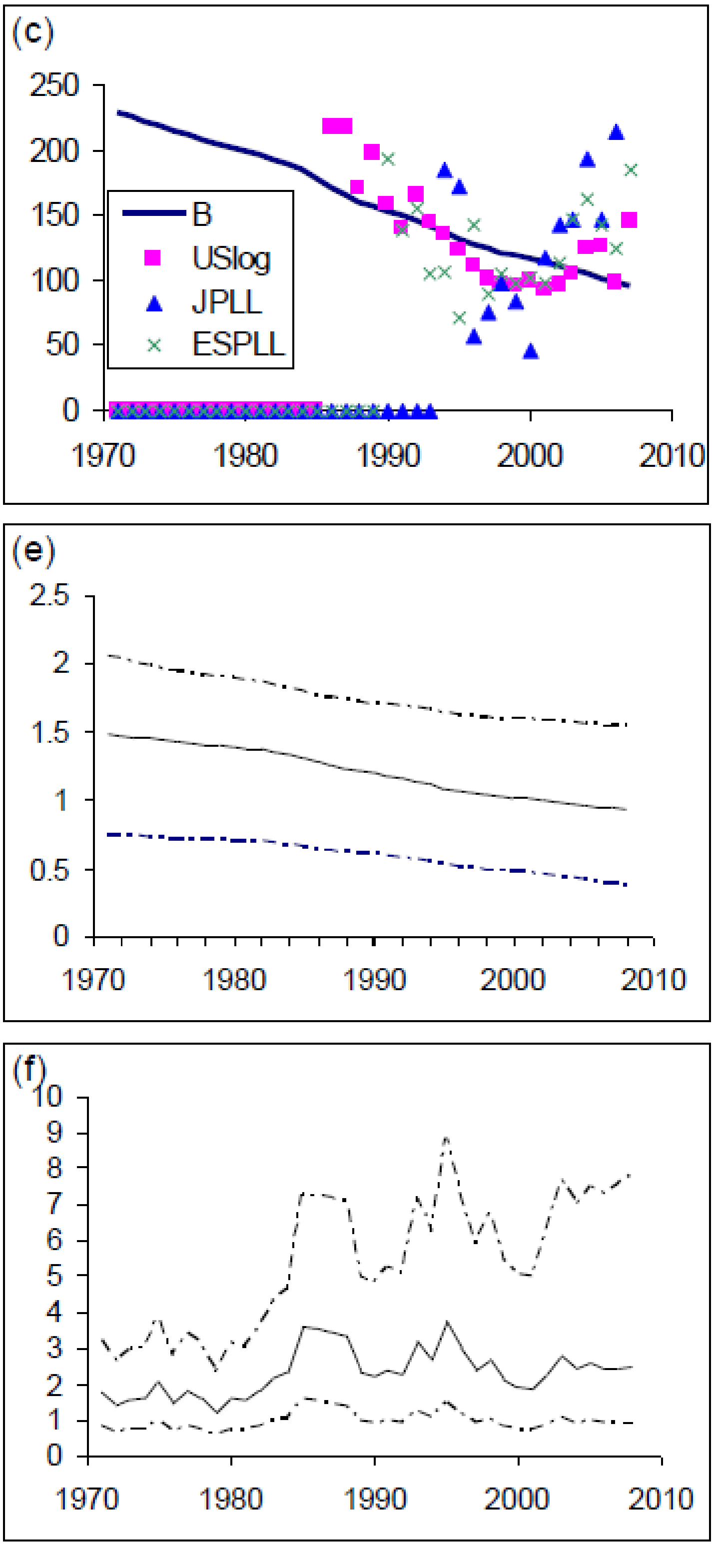

Figure 9. Panels from the base case Bayesian Surplus Production model from Figure 13 of the 2008 shortfin mako assessment report. Panel c) shows the biomass trend and the fit to the CPUE indices used, panel e) shows the temporal trend of B/BMSY and panel f) shows the temporal trend in fishing mortality.

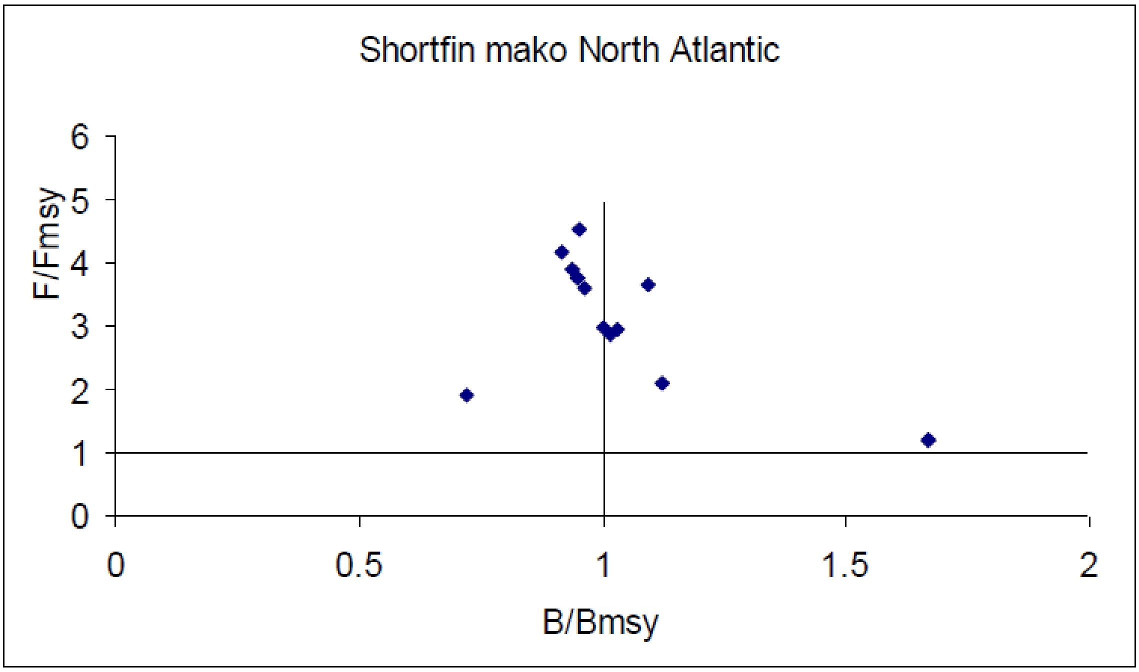

Figure 10. Upper panel of Figure 14 of the 2008 shortfin mako assessment report showing the 2008 estimates of B/BMSY and F/FMSY for the various Bayesian Surplus Production model configurations tested.

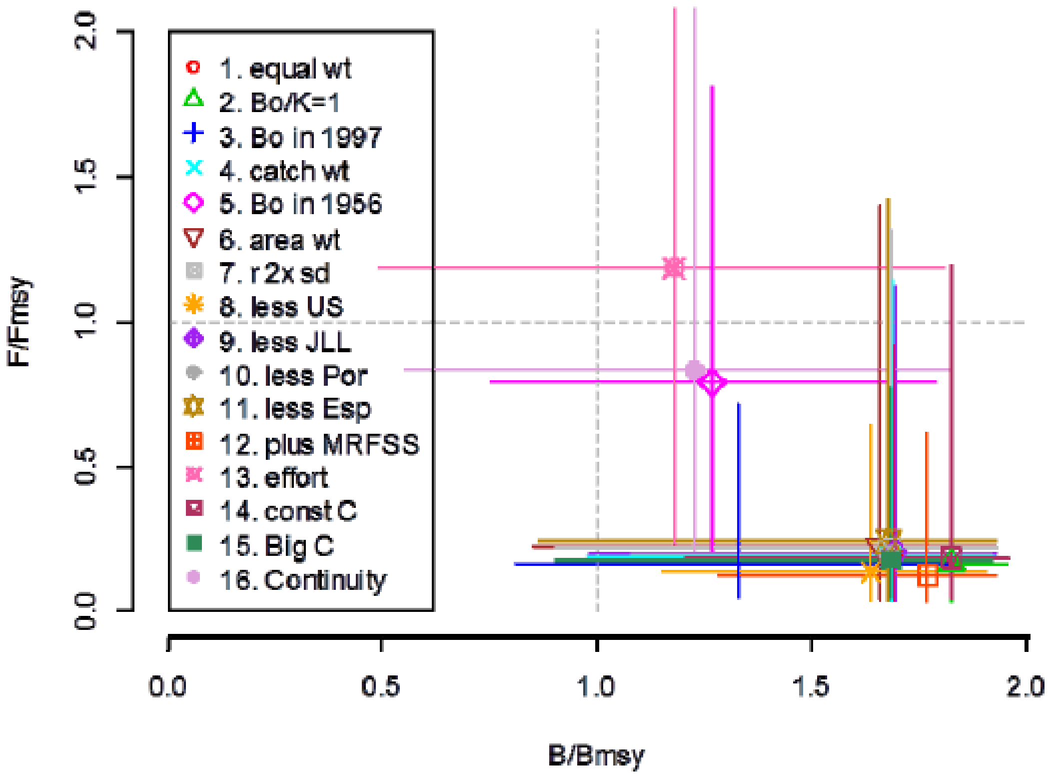

Figure 11. This is figure 46 of the 2012 assessment report, showing the median biomass estimates relative to BMSY and the median fishing mortality relative to FMSY with 80% credibility intervals from the 16 Bayesian Surplus Production model configurations tested.

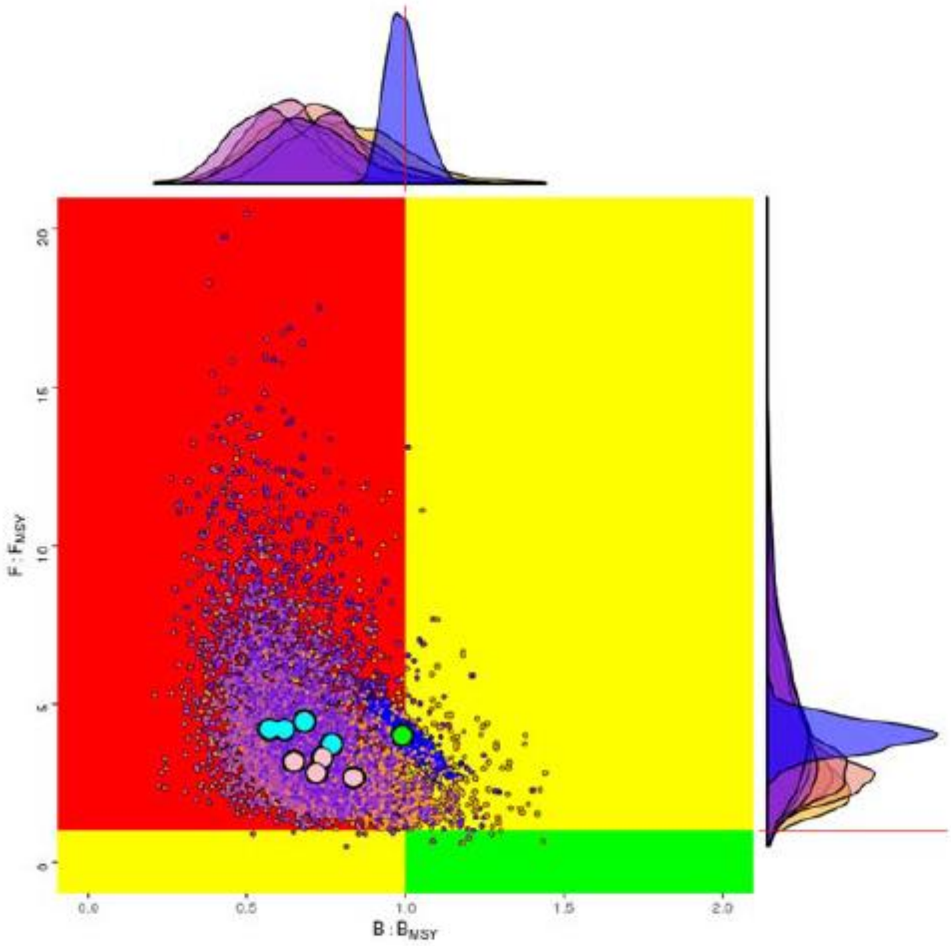

Figure 12. This is figure SHK-Figure 9 from the SCRS report in 2017. Stock status (2015) of North Atlantic shortfin makos based on Bayesian production models (4 BSP2JAGS and 4 JABBA runs) and 1 length-based, age-structured model (SS3). The clouds of points are the bootstrap estimates for all model runs showing uncertainty around the median point estimate for each of nine model formulations (BSP2JAGS: solid pink circles; JABBA: solid cyan circles; SS3: solid green circle). The marginal density plots shown are the frequency distributions of the bootstrap estimates for each model with respect to relative biomass (top) and relative fishing mortality (right). The red lines are the benchmark levels (ratios equal to 1).

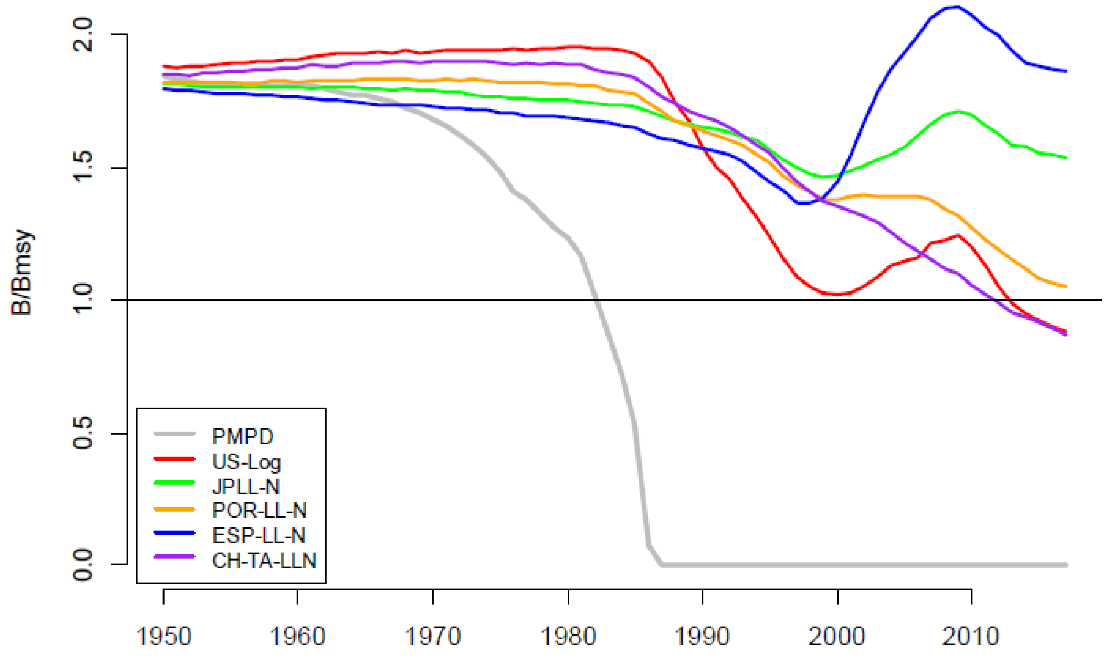

Figure 13. This is figure 4 from the 2017 assessment report. North Atlantic BSP2-JAGS diagnostic model runs, including post-model pre-data (PMPD), and each abundance index of abundance fitted separately.