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AN EVALUATION OF DATA WEIGHTING FOR THE ICCAT NORTHERN SWORDFISH MANAGEMENT STRATEGY EVALUATION

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SUMMARY

Management Strategy Evaluation requires the identification of the Operating Model specifications whose uncertainty brings about the greatest amount of uncertainty into the subsequent management advice. This study used a systematic approach to test three methods of describing the uncertainty in data weighting of the length compositional and the catch per unit effort data for the Northern Swordfish Management Strategy Evaluation. Method 1 held the CPUE lambda at 1.0 and varied the length compositional lambda. Method 2 held the length compositional lambda at 1 and varied the CPUE lambda. Method 3 varied both the CPUE and length compositional lambdas simultaneously and required fewest number of combinations. The greatest amount of variation in the estimates of SSB0, SSB_{2017} and SSB_{2017}/SSB0 resulted from using Method 2. However, it was noted that not all nine lambda variations were necessary to capture an adequate amount of uncertainty.

RÉSUMÉ

L'Évaluation de la Stratégie de Gestion implique l'identification des spécifications des Modèles Opérationnels dont l'incertitude engendre la plus grande part de l'incertitude dans l'avis de gestion consécutif. Cette étude utilisait une approche systématique pour tester trois méthodes de description de l'incertitude dans la pondération des données de composition par tailles et des données de capture par unité d'effort pour l'Évaluation de la Stratégie de Gestion de l'espadon du nord. La méthode 1 maintenait le lambda des données de CPUE à 1,0 et faisait varier le lambda des données de composition par tailles. La méthode 2 maintenait le lambda des données de composition par tailles à 1 et faisait varier le lambda des données de CPUE. La méthode 3 faisait varier simultanément tant les lambdas des données de CPUE que des données de composition par tailles et nécessitait le plus petit nombre de combinaisons. La plus grande part de variation dans les estimations de SSB_0, SSB_{2017} et SSB_{2017}/SSB_0 résultait de l'utilisation de la méthode 2. Il a toutefois été noté que les neuf variations du lambda n'étaient pas toute nécessaires pour refléter une part adéquate de l'incertitude.

RESUME

La evaluación de estrategias de ordenación requiere la identificación de las especificaciones del modelo operativo cuya incertidumbre aporta la mayor cantidad de incertidumbre al posterior asesoramiento en materia de ordenación. Este estudio utiliza un enfoque sistemático para probar tres métodos de describir la incertidumbre en la ponderación de los datos de composición por tallas y de los datos de la captura por unidad de esfuerzo para la evaluación de estrategias de ordenación para el pez espada del Atlántico norte. El Método 1 mantenía la lambda de la CPUE en 1,0 y variaba la lambda de la composición por tallas. El Método 2 mantenía la lambda de la composición por tallas en 1 y variaba la lambda de la CPUE. El Método 3 variaba las lambdas de la CPUE y de la composición por tallas simultáneamente y requería menor número de combinaciones. La mayor cantidad de variación en las estimaciones de SSB0, SSB_{2017} y SSB_{2017}/SSB0 se producía al usar el Método 2. Sin embargo, se observó que no eran necesarias las nueve variaciones de lambda para reflejar una cantidad adecuada de incertidumbre.

KEYWORDS

Management Strategy Evaluation, operating model, data weighting

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1. Introduction

A Management Strategy Evaluation (MSE) Operating Model (OM) is a mathematical–statistical model (usually models) used to describe the fishery dynamics in simulation trials, including the specifications for generating simulated resource monitoring data when projecting forward in time. Multiple models will usually be considered to reflect the uncertainties about the dynamics of the resource and fishery (Anon. 2018). Management Strategy Evaluation (MSE) requires the identification of the Operating Model (OM) specifications whose uncertainty brings about the greatest amount of uncertainty into the subsequent management advice. Using a grid-based design, plausible values for these parameters are arrived at and used to create a matrix of possible states of nature of the fishery under study. Often times the number of parameters required to thoroughly describe the model uncertainty can result in grids that are sometimes unnecessarily large and cumbersome to work with. It is for this reason that efficiency in grid design is an important aspect to the overall MSE process.

Creative uses of data weighting might be necessary to enable the models to mimic plausible dynamics, but given their potential influence on the conclusions of the MSE such manipulations of data should be documented, examined and communicated to stakeholders (Sharma et al. 2020). The objective of this evaluation was to determine the most efficient manner in which to build the northern Swordfish (NSWO) MSE grid of uncertainty so as to take into account the uncertainty in the weighting of the of the observations of CPUE and length compositions (LTHC) with the least number of combinations that still capture the range of uncertainty. Results should also inform us with regard to which of the two sources of data results in the greatest uncertainty in the resulting metrics. This study uses three different methods to distribute the weighting across the length compositional (LTHC) and the catch per unit effort (CPUE) observational data by fitting the same baseline model using various pairings of lambda across the two data types. These results of this are intended to show the effects of using the various pairings of lambdas on LTHC and CPUE on B0, B_{2017}, and B/B0.

2. Methods

The most recent version of Stock Synthesis (version 3.30) is used for this study along with a new configuration that incorporates discards and a release mortality. The baseline model set all CPUE CV's to 0.30, lambdas to 1.0 and did not add any "added variance" (AV) to the CV's. All LTHC were set to an effective sample size (ESS) to 2 and an AV was calculated using the Francis method with the r4ss package. In an assessment model that is constructed with the purposes of providing actual management advice, the added variance on the LTHC (which is equivalent to adjusting the weighting) is often adjusted (using a standardized routine such as "the Francis method") so that the signal from the LTHC is not over or under represented in the final fit of the model. However, this step is not practical when using the model as an MSE operating model (as in this case). As such, all added variances on the LTHC were fixed at the values used in the base model. The stock-recruitment steepness parameter was fixed 0.75 and natural mortality at 0.20 for all model configurations considered.

Three methods to distribute weighting between LTHC and CPUE were considered. Method 1 held the CPUE lambda at 1.0 and varied the LTHC lambda. Method 2 held the LTHC lambda at 1.0 and varied the CPUE lambda. The values of variable lambdas examined were 0.05, 0.1, 0.2, 0.5, 1, 2, 5, 10, and 20 (**Table 1**). This method required 18 model configurations (9 for LTHC and 9 for CPUE) to complete.

Method 3, termed the proportional lambda method, varied the lambdas on LTHC and CPUE simultaneously while still keeping the same proportional weighting between the two. The method utilizes the observation that LTHC and CPUE together account for nearly all of the weighted observational data in the model. This allows the convenience of disregarding the lambdas on the other observational data. (**Table 1**). This resulted in 9 model configuration

The effects of these two methods was examined through the examination of spawning stock biomass (SSB) in 1950 (B0), 2017 (B_{2017}) and SSB/SSB0. The percent change in these metrics from the base case scenario were also examined.

3. Results

Comparison of base models. A comparison of trends in SSB and SSB/SSB0 for the baseline model of the three methods are shown in **Figure 1.** Visual inspection of the trends confirms that the differences between baseline models of the three methods is negligible. Thus, a continuation of the comparisons can proceed without further consideration of any differences between methods that needs to be taken into account.

Method 1. In general, when compared to the base model, increasing the lambda on the LTHC lead to similar estimates of SSB0 (**Figure 2A**). Percent differences between the base model (where lambda on the LTHC and CPUE = 1) and models across LTHC lambdas ranged from a minimum of 0.1% at lambda = 2, to a maximum 1.2% at lambda = 0.05 (**Table 2, Figure 2B**). In general, when compared to the base model, increasing the lambda on the LTHC lead to similar estimates of SSB_{2017} (**Figure 2C**). Percent differences between the base model (where lambda on the LTHC and CPUE = 1) and models across LTHC lambdas ranged from a minimum of -0.2% at lambda = 2, to a maximum 4.3% at lambda = 0.05 (**Table 2, Figure 2D**). Similar to SSB0 and SSB_{2017}, estimates of SSB/SSB_{2017} were similar across the range of LTHC lambdas (**Figure 2E**). Percent differences between the base model (where lambda on the LTHC and CPUE = 1) and models across LTHC lambdas ranged from a minimum of -0.3% at lambda = 2, to a maximum 3.3% at lambda = 20 (**Table 2, Figure 2F**).

Method 2. Increasing the lambda on the CPUE lead to increased estimates of SSB0 (**Figure 3A**). Percent differences between the base model (where lambda on the LTHC and CPUE = 1.0) and models across CPUE lambdas ranged from a minimum of 1.4% at lambda = 20, to a maximum -9.4% at lambda = 0.05 (**Table 2**, **Figure 3B**). Estimates of SSB_{2017} generally trended up as lambda on the CPUE was increased from 0.05 to 1.0 but there after showed smaller differences (**Figure 3C**). Percent differences between the base model and models across CPUE lambdas ranged from a minimum of -1.0% at lambda = 10, to a maximum -20.7% at lambda 0.10 (**Table 2, Figure 3D**). Estimates of SSB_{2017}/SSB) followed the same trends as SSB0 and SSB_{2017}, trending up as lambda on the CPUE lambda was increased (**Figure 3E**). Percent differences between the base model and all models across CPUE lambdas ranged from a minimum of -0.10% at lambda = 5, to a maximum -14.2% at lambda = 0.1 (**Table 2**, **Figure 3F**).

Method 3. Estimates of SSB0 remained relatively unchanged across all models using Method 2 (**Figure 4A**). Percent differences between the base model (where lambda on the LTHC and CPUE = 1.0) and models across proportional lambdas ranged from a minimum of 0.1% at LTHC = 0.09/CPUE lambda = 0.9, to a maximum 1.8% at LTHC = 2/CPUE lambda = 0.4 (**Table 2**, **Figure 4B**). Estimates of SSB_{2017} also remained relatively unchanged across all models using Method 2 (**Figure 4C**). Percent differences between the base model (where lambda on the LTHC and CPUE = 1.0) and models across proportional lambdas ranged from a minimum of 0.8% at LTHC = 0.35/CPUE lambda = 0.7, to a maximum 4.3% at LTHC = 0.05/CPUE lambda = 1.0 (**Table 2**, **Figure 4D**). Estimates of SSB_{2017}/SSB0 also remained relatively unchanged across all models using Method 2 (**Figure 4E**). Percent differences between the base model (where lambda on the LTHC and CPUE = 1.0) and models across proportional lambdas ranged from a minimum of 0.2% at LTHC = 0.35/CPUE lambda = 0.7, to a maximum 3.1% at LTHC = 0.05/CPUE lambda = 1.0 (**Table 2**, **Figure 4E**).

Overall, Method 2 (setting the LTHC lambda to 1.0 and varying the CPUE lambda) resulted in greatest ranges of all three metrics examined (**Table 2**). The ranges in the three metrics for Method 2 were approximately five times those of both Method 1 and Method 3. The range of possible values for SSB_{2017}/SSB0 for all Method 1, Method 2, Method 3 and all methods combined are shown in **Figure 5**. By definition, all configurations begin at the same level (i.e. SSB2017/SSB0 = 1.0). However, the range in 2017 results in the stock being overfished to not overfished.

4. Discussion

The results of this study determined that Method 2 (varying the CPUE lambdas) was more a more useful approach than either Method 1 (varying on the LTHC lambdas) or Method 3 (proportional weighting). However, the NSWO MSE Technical Team also noted that not all nine of the lambda variations of Method 2 were necessary to include in the uncertainty grid. Based these results the NSWO MSE Technical Team determined that the most efficient path forward was to use the (1) LTCH lambda = 1 and CPUE lambda 1; (2) LTCH lambda = 1 and CPUE lambda 20; and (3) LTCH lambda = 1 and CPUE lambda 0.05.

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Table 1. Combinations of lambdas on the CPUE and length compositional (LTHC) data for the two methods used for this work.

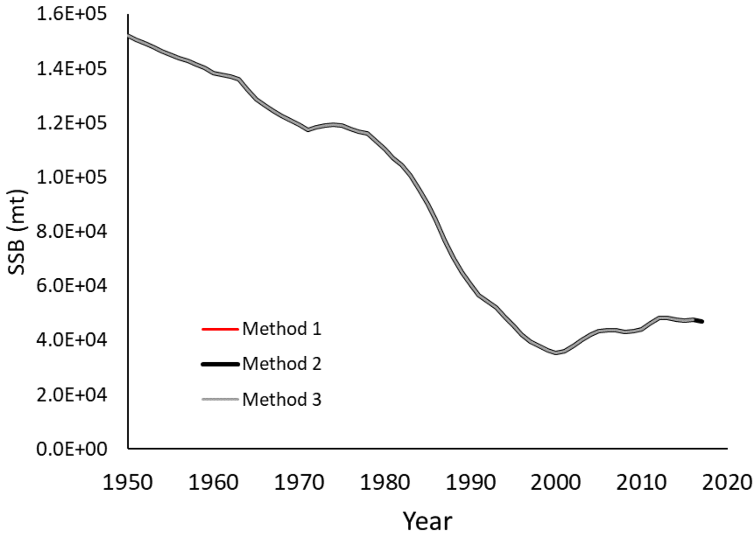
Method 1				Method 2				Method 3			
Run#	CPUE lambdas	LTHC lambdas	Rel Wt THC:CPUE	Run#	CPUE lambdas	LTHC lambdas	Rel Wt THC:CPUE	Run#	CPUE lambdas	LTHC lambdas	Rel Wt LTHC:CPUE
1	1	0.05	0.05	10	20	1	0.05	19	1	0.05	0.05
2	1	0.10	0.10	11	10	1	0.10	20	0.90	0.09	0.1
3	1	0.20	0.20	12	5	1	0.20	21	0.80	0.16	0.2
4	1	0.50	0.50	13	2	1	0.50	22	0.70	0.35	0.5
5	1	1	1	14	1	1	1	23	1.00	1	1
6	1	2	2	15	0.50	1	2	24	0.50	1	2
7	1	5	5	16	0.20	1	5	25	0.40	2	5
8	1	10	10	17	0.10	1	10	26	0.30	3	10
9	1	20	20	18	0.05	1	20	27	0.20	4	20

Table 2. Percent differences between each run and the associated base model (runs 5, 14 and 23) and associated minimum, maximum, average, standard deviation and range.

Method 1	1	2	3	4	5	6	7	8	9					
Lambda_CPUE	1	1	1	1	1	1	1	1	1					
Lambda_LTHC	0.05	0.1	0.2	0.5	1	2	5	10	20	MIN	MAX	AVG	SD	Range
SSB0	1.2%	-0.3%	-0.1%	-0.3%	0.0%	0.1%	0.5%	-0.2%	-0.2%	0.1%	1.2%	0.1%	0.5%	1.1%
SSB 2017	4.3%	1.0%	0.9%	-1.0%	0.0%	-0.2%	2.2%	3.1%	3.1%	-0.2%	4.3%	1.7%	1.8%	4.5%
SSB/SSB0	3.1%	1.3%	1.0%	-0.6%	0.0%	-0.3%	1.7%	3.3%	3.3%	-0.3%	3.3%	1.6%	1.6%	3.6%

Method 2	10	11	12	13	14	15	16	17	18					
Lambda_CPUE	0.05	0.1	0.2	0.5	1	2	5	10	20					
Lambda_LTHC	1	1	1	1	1	1	1	1	1	MIN	MAX	AVG	SD	Range
SSB0	-9.4%	-7.6%	-5.8%	-2.3%	0.0%	1.8%	2.1%	1.8%	1.4%	1.4%	-9.4%	-2.3%	4.7%	10.8%
SSB 2017	-17.0%	-20.7%	-15.2%	-5.4%	0.0%	3.8%	2.0%	-1.0%	-3.6%	-1.0%	-20.7%	-7.1%	9.3%	-19.7%
SSB/SSB0	-8.4%	-14.2%	-10.0%	-3.2%	0.0%	2.0%	-0.1%	-2.7%	-4.9%	-0.1%	-14.2%	-5.2%	5.4%	-14.1%

Method 3	19	20	21	22	23	24	25	26	27					
Lambda_CPUE	1	0.9	0.8	0.7	1	0.5	0.4	0.3	0.2					
Lambda_LTHC	0.05	0.09	0.16	0.35	1	1	2	3	4	MIN	MAX	AVG	SD	Range
SSB0	1.2%	0.1%	0.2%	0.6%	0.0%	1.8%	1.8%	1.7%	1.5%	0.1%	1.8%	1.1%	0.7%	1.7%
SSB 2017	4.3%	1.7%	1.1%	0.8%	0.0%	3.8%	3.8%	3.1%	1.9%	0.8%	4.3%	2.6%	1.4%	3.6%
SSB/SSB0	3.1%	1.6%	0.8%	0.2%	0.0%	2.0%	1.9%	1.4%	0.4%	0.2%	3.1%	1.4%	1.0%	3.0%



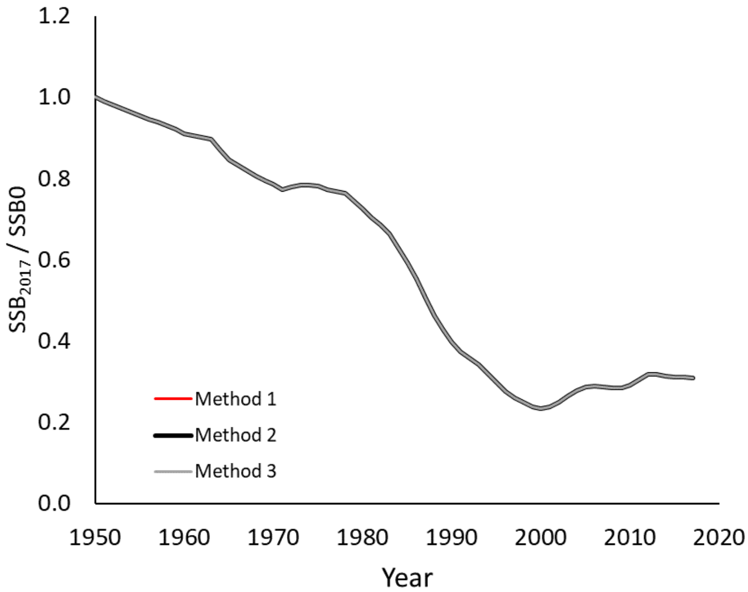


Figure 1. Trends in SSB (top) and SSB2017 / SSB0 (bottom) from the three base models used in this study where the paired lambdas were either LTHC = 1 and CPUE = 1 (red line), or LTHC = 0.6 and CPUE = 0.6 (black line).

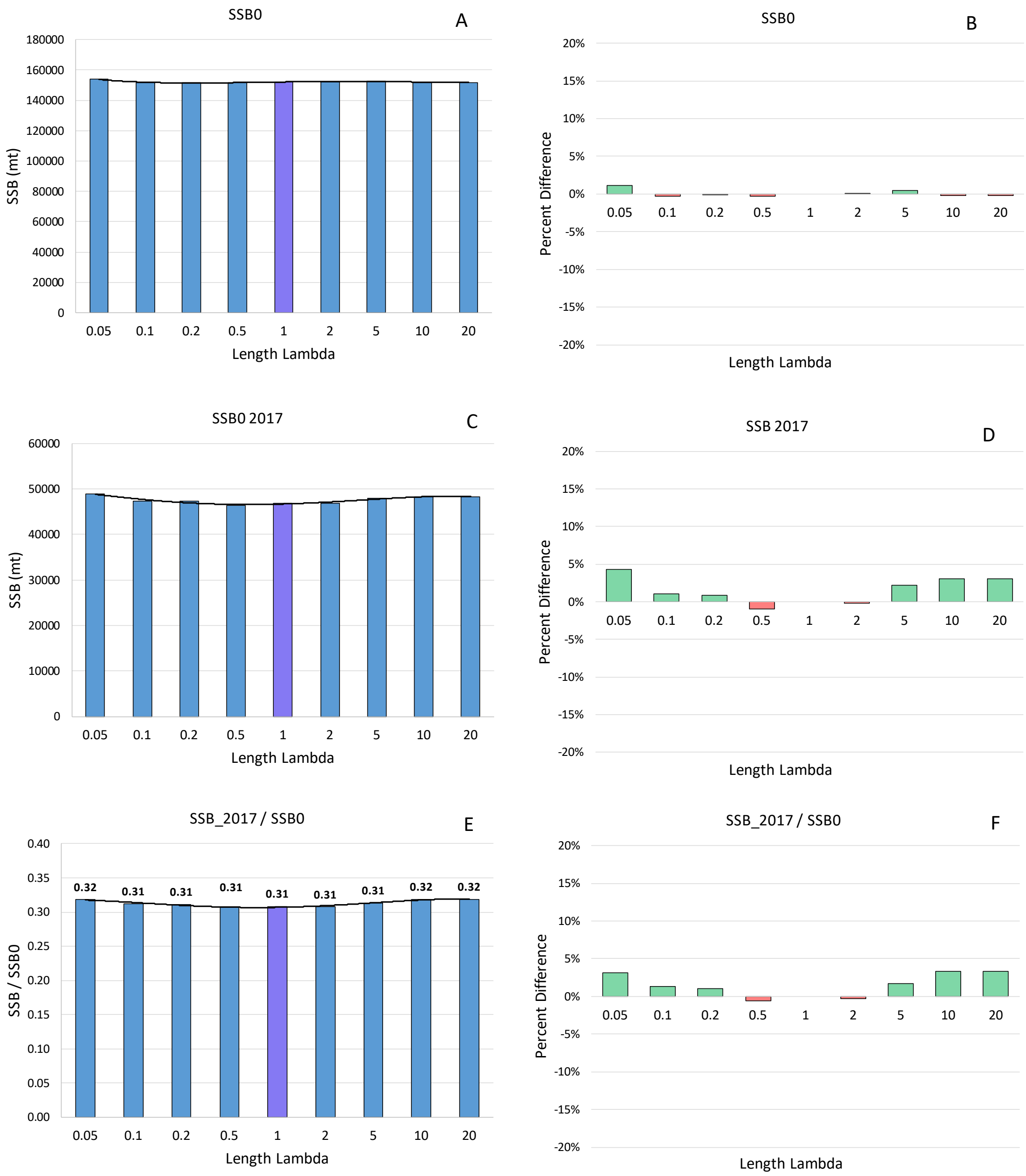


Figure 2. Estimate of spawning stock biomass in 1950 (A) and percent differences between base case (B) across the range of length composition lambdas; estimate of spawning stock biomass in 2017 (C) and percent differences between base case across the range of length composition lambdas (D); Estimates of spawning stock biomass in 2017 relative to estimates of spawning stock biomass in 1950 ($SSB/SSB0_{2017}$) (E) and percent differences between base case (F) across the range of length composition lambdas. Black line is a smoothed curve fit. Purple bar is the base model.

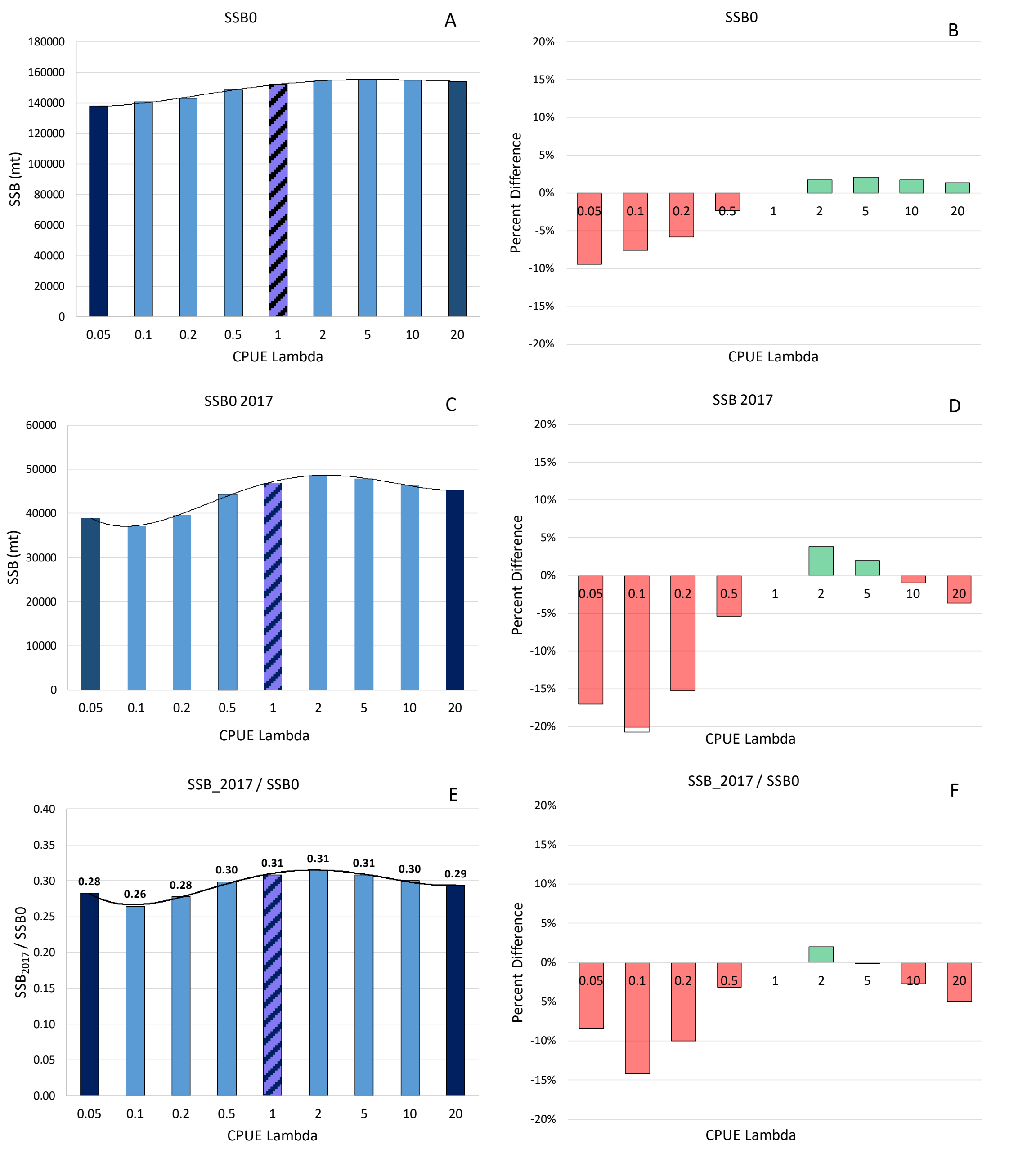


Figure 3. Estimate of spawning stock biomass in 1950 (A) and percent differences between base case (B) across the range of CPUE lambdas; estimate of spawning stock biomass in 2017 (C) and percent differences between base case across the range of CPUE lambdas (D); Estimates of spawning stock biomass in 2017 relative to estimates of spawning stock biomass in 1950 ($SSB/SSB0_{2017}$) (E) and percent differences between base case (F) across the range of CPUE lambdas. Black line is a smoothed curve fit; purple hashed bar is base model and dark bars (including the purple hashed are the values used in the uncertainty grid.

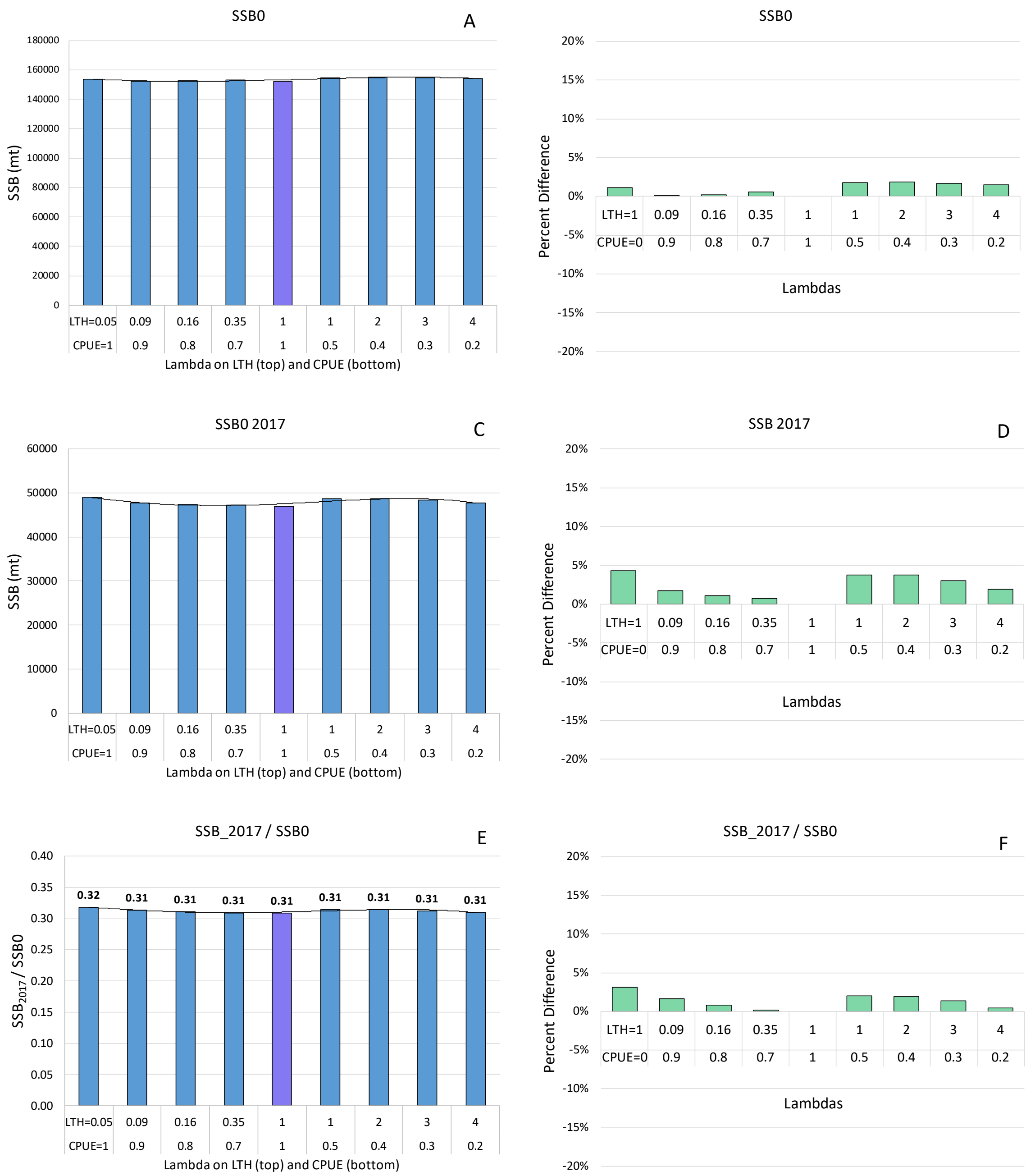


Figure 4. Estimate of spawning stock biomass in 1950 (A) and percent differences between base case (B) across the range of proportional length compositional and CPUE lambdas; estimate of spawning stock biomass in 2017 (C) and percent differences between base case proportional length compositional and CPUE lambdas (D); Estimates of spawning stock biomass in 2017 relative to estimates of spawning stock biomass in 1950 ($SSB/SSB0_{2017}$) (E) and percent differences between base case (F) proportional length compositional and CPUE lambdas. Black line is a smoothed curve fit.

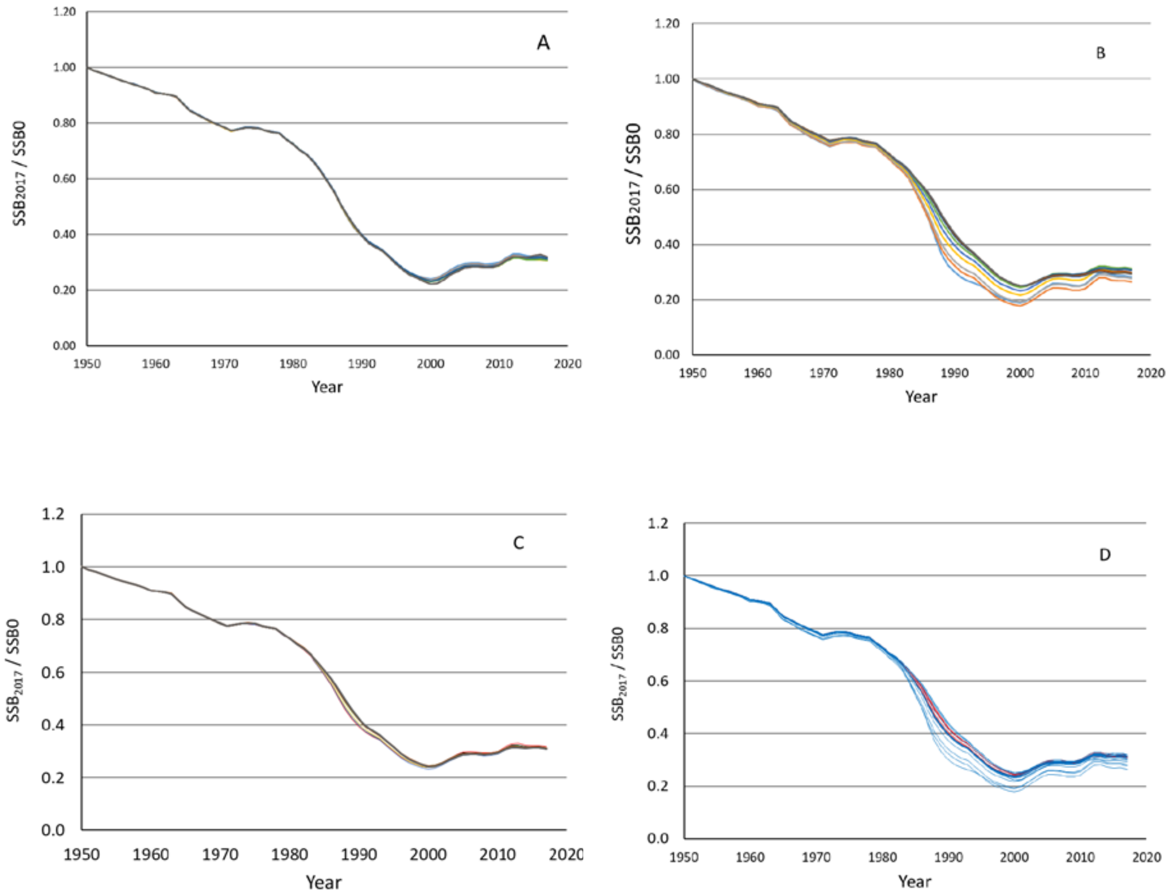


Figure 5. SSB2017 / SSB0 for the methods that change only the lambda on the length compositions (A), change only the CPUE lambda (B), proportional method (C) and trends for all three methods overlaid (D).