AN ASSESSMENT OF WESTERN ATLANTIC SAILFISH FOR 2016

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SUMMARY

An initial assessment of the Western Atlantic sailfish stock was conducted in advance of the full 2016 SCRS Sailfish Stock Assessment meeting. The fully integrated assessment framework Stock Synthesis was used to construct several variations of an age-structured stock production model, each of which consisted of one fishing fleet and ten indices of abundance. Profile analysis on natural mortality and the steepness parameter of the stock-recruitment function demonstrated that neither parameter was well determined from the data. The steepness parameters was generally estimated at a very high value (h = 0.97) and with a very tight distribution (SD = 0.04). This resulted in unrealistically narrow confidence intervals around the resulting estimated trends in biomass. In an attempt to alleviate this issue, mcmc analysis was conducted while (1) fixing natural mortality and (2) steepness at plausible values. The resulted suggested that fishing mortality in 2014 was generally below the F_{MSY} benchmark and that biomass was either slightly or considerably above the B_{MSY} benchmark.

RÉSUMÉ

Une évaluation initiale du stock du voilier de l'Atlantique Ouest a été réalisée avant la réunion SCRS d'évaluation complète du stock de voilier de 2016. Le cadre d'évaluation entièrement intégré Stock Synthesis a été utilisé pour construire plusieurs variantes d'un modèle de production de stock structuré par âge, chaque variante étant composée d'une flottille de pêche et de dix indices d'abondance. L'analyse du profil de la mortalité naturelle et le paramètre de la pente à l'origine de la relation stock-recrutement (steepness) ont démontré qu'aucun des deux paramètres n'était bien déterminé à partir des données. Les paramètres de steepness ont généralement été estimés à une valeur très élevée (h = 0,97) et avec une distribution très étroite (SD = 0,04). Cela a entraîné des intervalles de confiance irréalistes et étroits en ce qui concerne les tendances estimées de la biomasse en résultant. En vue de résoudre ce problème, une analyse mcmc a été menée en fixant (1) la mortalité naturelle et (2) la steepness à des valeurs plausibles. Les résultats donnaient à penser que la mortalité par pêche en 2014 était généralement inférieure au niveau de référence de F_{PME} et que la biomasse était légèrement ou considérablement supérieure au niveau de référence de B_{PME}.

RESUMEN

Se llevó a cabo una evaluación inicial de stock de pez vela del Atlántico occidental antes de la reunión de evaluación completa de stock de pez vela del SCRS de 2016 Se utilizó el marco de evaluación plenamente integrado Stock Synthesis para construir diversas variaciones de un modelo de producción de stock estructurado por edad, compuestas cada una de ellas de una flota pesquera y diez índices de abundancia. El análisis del perfil de mortalidad natural y del parámetro de la inclinación de la función stock-reclutamiento mostraba que ninguno de los dos parámetros estaba bien determinado por los datos. Los parámetros de inclinación se estimaron generalmente en un valor muy elevado (h = 0,97) , con una distribución muy estrecha (SD = 0,04). Esto tuvo como resultado unos intervalos de confianza estrechos no realistas en las tendencias estimadas resultantes de la biomasa. En un intento de solventar este problema, se realizó un análisis mcmc, (1) fijando la mortalidad natural y (2) la inclinación en valores plausibles. El resultado sugiere que mortalidad por pesca en 2014 se situaba generalmente por debajo del nivel de referencia de F_{RMS} y que la biomasa se hallaba considerable o ligeramente por encima del nivel de referencia B_{RMS}.

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KEYWORDS

Stock assessment, mathematical models, fishing mortality

Introduction

An effort was undertaken to develop several assessment models for Western Atlantic sailfish. Previous assessment were somewhat inconclusive as to the status of the stock and estimates of maximum sustainable yield (MSY). Noteworthy changes to the data include changes in landings, especially the year 2009 (**Figure 1**), and changes in the direction in the trend of several indices of abundance (**Figure 2**). Of the ten indices of abundance available for consideration, four showed a decreasing trend, five an increasing trend, and one no obvious trend. Based upon these basic observations, it was evident from the start of the analysis that there would be a high degree of uncertainty in the estimated model parameters and the thus the status of the stock. This would be consistent with previous assessments.

Methods and Materials

It was noted from the ICCAT Manual that “there is no existing growth model adopted by ICCAT for Atlantic sailfish”. Since some sort of growth model was necessary to construct the age-structured assessment model the one published by Chiang *et al.* 2004 was used here. This was thought to be the most reliable estimate of growth, however it needs to be noted that this growth is for sailfish in the Indo-Pacific region. Chiang *et al.* 2004 did not publish a combined sex growth model, so the average of the males and female specific curves were used. The length-weight equation was also taken from the ICCAT Manual, as was the maturity schedule as described by Arocha and Marcano (2006). Fish were assumed to 50% mature at age_1 and fully mature thereafter. Natural mortality was taken from the ICCAT manual and assumed to be M = 0.15 for all ages. The manual suggests a range of 0.15 to 0.30, “however, based upon body size, behaviour, and physiology, estimates of adult fish would likely be fairly low (Anon. 1994, 1998).”

All indices that were available by the data deadline (April 30, 2016) as indicated in the Billfish Work Plan for 2016, plus one that arrived post deadline, were used for this analysis. Those data sets shown in **Table 1**.

The flag-specific CPUEs were weighted by the catch that flag and gear represented. This was done in an effort to mimic the methods used in the previous assessment. The Brazilian Rod & Reel had no catch associated with it in the ICCAT Task 1 files. Also, that index had very large residual mean square error in test fits and was preventing the model from converging and inverting the hessian. Given these two attributes this index was removed from the “base” model. The weighting was done across all year and no attempt was made to consider year-specific weightings. This is why the US Rod & Reel fleets have lambdas of 1.0, because even though currently this flag/gear does not account for much of the landings, it did in the early years of the fishery. There are other, just as justifiable, methods to weight the CPUE’s by catch.

The Stock Synthesis modelling platform was used to estimate historic trends in population trends. Three parameters were considered (natural mortality, virgin recruitment, and stock-recruitment steepness) plus fifty-five recruitment deviations (1960-2014).

Candidate Models

Four candidate model configurations and associated assumptions were considered for the base model:

Model_1: Unweighted CPUE; no recruitment deviations
Model_2: Unweighted CPUE; with recruitment deviations
Model_3: Catch weighted CPUE; no recruitment deviations
Model_4: Catch CPUE; with recruitment deviations

Each candidate model used a fixed value of natural mortality of M = 0.20 and an estimated value of steepness using an informative prior (h = 0.70, SD = 0.14) with a full beta distribution (**Figure 3**).

Important to any model fitting exercise is the robustness of the parameter fits to the data. While it is often the case that some value is estimated for each estimated parameter, it is important to try and quantify the goodness of this fit. One way to achieve this is through likelihood profile analysis. Profile analysis seeks to determine whether or not a parameter is estimated with a decidedly marked minimization of the overall model likelihood. In this case, the critical parameters are the steepness of the stock-recruitment function, and the rate of natural mortality. For the profile analysis on natural mortality, M was fixed at 0.20 and steepness fixed at a range of values from 0.2 to 0.99. In the same way, steepness was fixed at its estimated value of 0.3 and M fixed at a range of 0.10 to 0.30. The value of the model fit likelihood is then plotted to determine how decisive the parameter estimate is.

Uncertainty surrounding parameter estimates and derived quantities was achieved using Markov chain Monte Carlo (MCMC) techniques. The two parameters of the greatest interest in the model would be natural mortality and the steepness parameter. Because no information is available on the true value of either of these parameters, one would allow both of these parameters to be estimated so that the total uncertainty would be propagated throughout the model results. However in the case of blue marlin M and steepness were highly correlated, which means that it is inappropriate to allow both to be estimated at the same time. This problem was overcome by fixing M at five likely values but at different probabilities. Forty percent of the runs were made at M =0.2, 20 percent each at M = 0.15 and 0.25, and ten percent each at M = 0.10 and 0.30. After estimating the posterior mode of each candidate model, MCMC simulation was applied to numerically sample chains of length 501,000 from the posterior distribution. Each chain was thinned (500 for M = 0.1 and 0.3, 250 for M = 0.15 and 0.25, and 125 for M = 0.2) to eliminate the with-in chain autocorrelation, and first 1000 thinned iterations were excluded to eliminate potential dependence on initial conditions. This resulted in 4000 runs for M = 0.2, 2000 runs each at M = 0.15 and 0.25, and 1000 each at M = 0.1 and 0.3. Posterior and derived posterior values from these 10,000 runs were finally pooled to characterize the uncertainty in both M and steepness. The posterior distributions from the above described MCMC process were described for virgin (maximum) recruitment (R0), steepness, terminal year F/F_{MSY} and B/B_{MSY}, F_{MSY}, and total yield at MSY. A similar approach was taken for the steepness parameter.

Results

The selection of which of the four candidate model to continue to work with was based on examination of the resulting trends in historic spawning output. While it is recognized that this is generally not good practice, the wide differences in the model results suggest that in this case using this criteria is not in violation of good practices. Model_1 resulted in a declining trend but with no recognition of the recent upturn in many of the indices (**Figure 4, upper left**). The resulting confidence intervals around the historic trend in biomass were infinitesimal, making this model quite implausible for management purposes. Model_2 always resulted in a declining trend but went to nearly zero biomass after the year 2000, which did not seem plausible either (**Figure 4, upper right**). Furthermore, Model_2 model did not converge properly, so confidence intervals around estimates of spawning output were not available. Model_3 resulted in a historic biomasses varying very little from those estimated for the virgin conditions after the year 2000, which did not seem to fit what is known about the exploitation of this stock (**Figure 4, lower left**). Model_4 resulted in historic trends in spawning output that were in line with what is believed to be known about the history of exploitation (**Figure 4, lower right**). While justifying model selection based on examination of resulting trends is generally not good practice, in this case it seemed acceptable given the large differences in the four choices. Model_4 was selected as the best choice from which to continue the analysis.

Profile Analysis

Profile analysis was conducted on the natural mortality and steepness parameters. The results indicated that the CPUE data fit beset at the highest values of both natural mortality (**Figure 5**) and steepness (**Figure 6**). The lack of a “trough” shape in the results suggest that neither of the two parameters were well estimated, which lead to the conclusion that further efforts should consider fixing these parameters at values thought to be plausible and that alternative values should be explored.

For both natural mortality and steepness the negative log-likelihood values by each of the CPUE series were also examined. Overall, there was conflict within the signals that best fit each CPUE time series, even within the same CPC. For instance, while the U.S. longline index fit best (i.e. had the lowest –log(likelihood)) at the lowest values of M, the U.S. Rod & Reel index fit best at the highest values (**Figure 5, bottom**). Regarding steepness, while the Venezuelan longline index fit best at lower values of steepness, the Venezuelan Rod & Reel index fit best at high values (**Figure 6, bottom**).

Estimates of steepness were very close to the upper limit of 1.0 with very little variation (**Figure 7, top**). This resulted in a very tight distribution around the estimate of virgin recruitment (R0) (**Figure 7, bottom**). Since out of a total of three parameters (not including recruitment deviations) two of them had very tight distributions, the resulting uncertainty around the management benchmarks was deceivingly low (**Figure 8**). So low that the results were questionable and not in line with the lack of knowledge of the species.

To try and better characterize the model uncertainty the growth parameters were modelled, rather than fixed, with informative priors in hopes that the model would incorporate the additional uncertainty into the overall uncertainty of stock status. However, results of this – mcmc analysis resulted in the posterior distributions being quite far from the initial values (**Figure 9**). The conclusion is that the model did not provide estimates of stock status from within the prior distributions, but rather from growth values well outside (and thus not very plausible) values.

As a consequence of the results from the paragraph above, in order to try and capture realistic uncertainty while maintaining realistic values of critical parameters, the continued analysis was forced to fix the values of M and steepness and collect the resulting posteriors. The distributions for this analysis for natural mortality are shown in **Figure 10** and for steepness in **Figure 11**. Because for each value of M and steepness 500,000 mcmc runs were made, the shape of the distribution of the prior can be modified by thinning the -mcmc's for each parameter value at different levels.

The resulting distribution of various critical parameters and derived quantities (MSY, R0, steepness, F/F_{MSY} in 2014 and B/B_{MSY} in 2014) when fixing at various levels and allowing steepness and R0 to be estimated are shown in **Figure 12**. Likewise, the values of the same parameters and derived quantities when fixing h at various levels and estimating M and R0 are shown in **Figure 13**. We then ask ourselves, do we have more confidence in our estimates of natural mortality or in our estimates of steepness? If we believe we know natural mortality better than we know steepness then we would tend to draw our management advice from **Figure 12** and from the Kobe plot given in **Figure 14**. If, on the other hand, we believe we are more certain about our estimates of steepness than we are about our estimates of natural mortality we would want to draw our advice from **Figure 13** and from the Kobe plot shown in **Figure 15**. In either case, the uncertainty around the estimates of stock status still seem unrealistically low relative to our knowledge of the biology of sailfish and the degree of conflict in the indices.

Table 1. Indices of abundance considered for the Stock Synthesis assessment model for western sailfish, 2016.

Fleet Number	*Flag*	*Gear Type*	*Years*	*Numbers/ Biomass*	*Catch Weight*
1	Fishery (All flags)	All gear types	1950-2014	Biomass	1.00
2	Brazil	Rod & Reel	1996-2014	Numbers	0.00
3	Brazil	Longline	1978-2012	Numbers	0.52
4	Japan	Longline	1994-2014	Numbers	0.42
5	US	Longline (observer)	1992-2014	Numbers	0.13
6	US	Rod & Reel (Rec Billfish Survey)	1972-2014	Numbers	1.00
7	US	Rod & Reel (Mar Rec Fish Survey)	1981-2014	Numbers	1.00
8	Venezuela	Longline (observer)	1987-2014	Numbers	0.34
9	Venezuela	Rod & Reel	1961-2001	Numbers	0.03
10	Venezuela	Gillnet	1991-2014	Biomass	0.41
11	Spain	Longline	2001-2014	Biomass	0.61

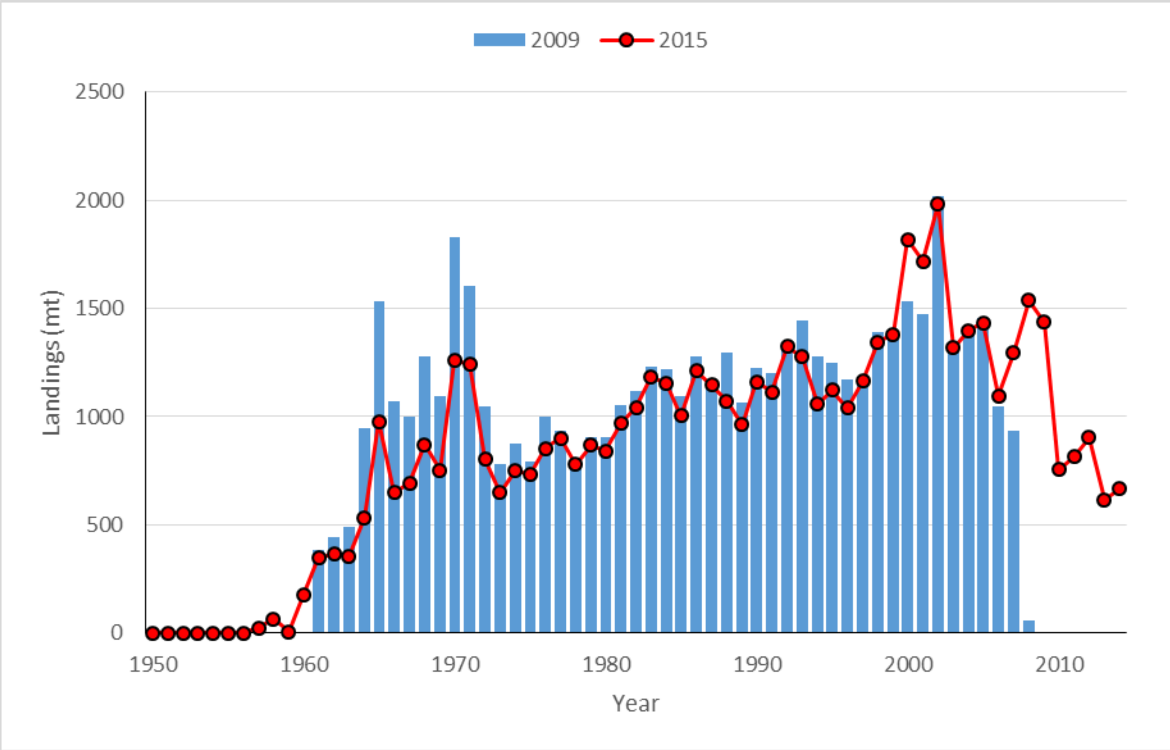


Figure 1. Landings of western sailfish from the 2009 assessment (bars) and the 2016 assessment (line), 1950-2015.

Figure 2. Indices of abundance for western sailfish from the 2009 assessment (blue) and the 2016 assessment (orange).

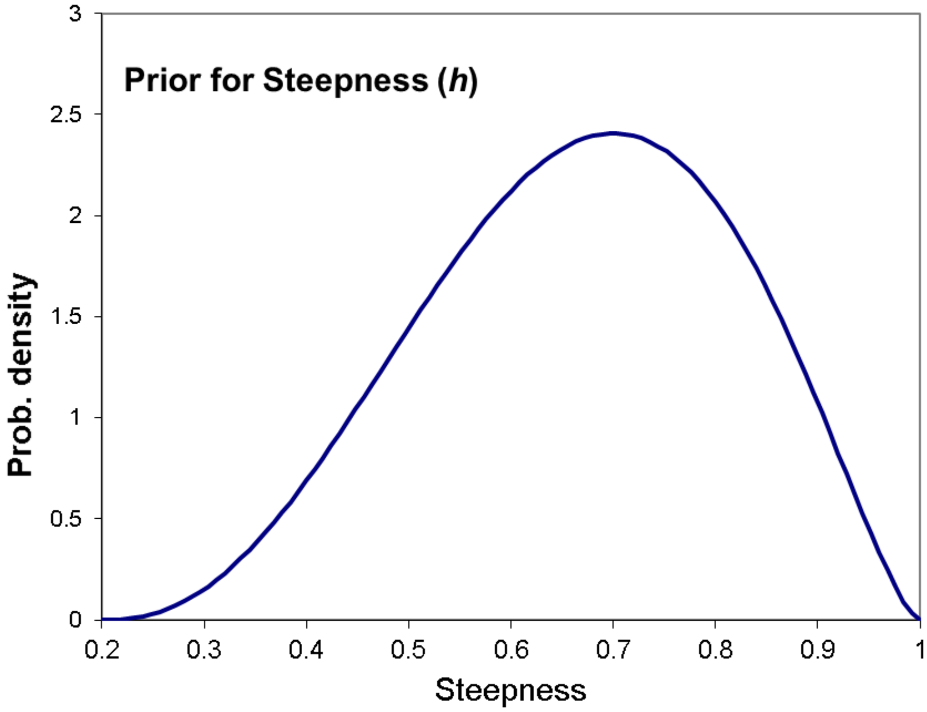


Figure 3. Prior distribution used for estimating steepness parameter, mode = 0.70, standard deviation = 0.14, full beta distribution.

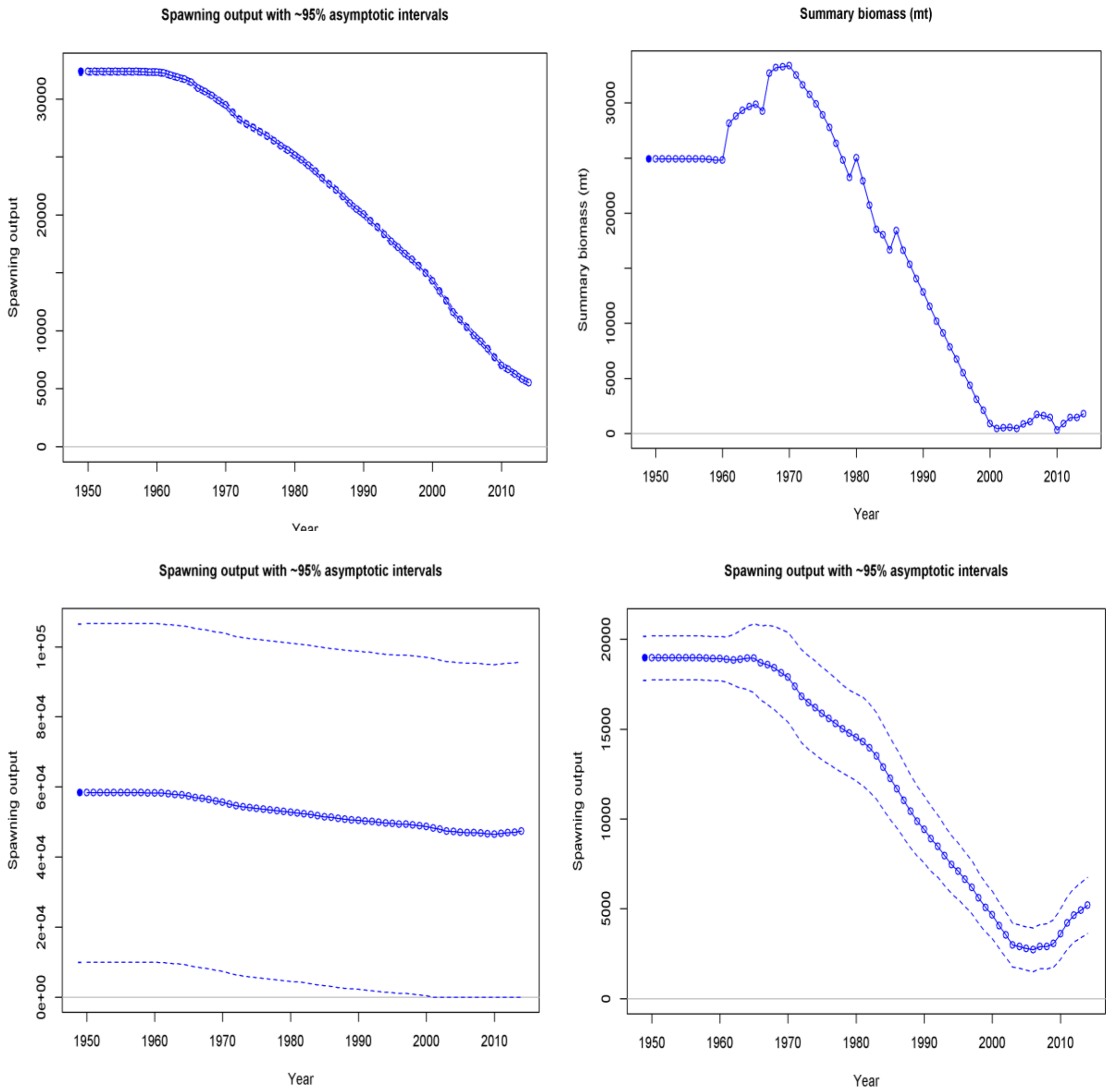


Figure 4. Estimated trends in spawning output (or summary biomass) from each of the four candidate models (upper left, Model_1; upper right, Model_2; lower left, Model_3, lower right Model_4.

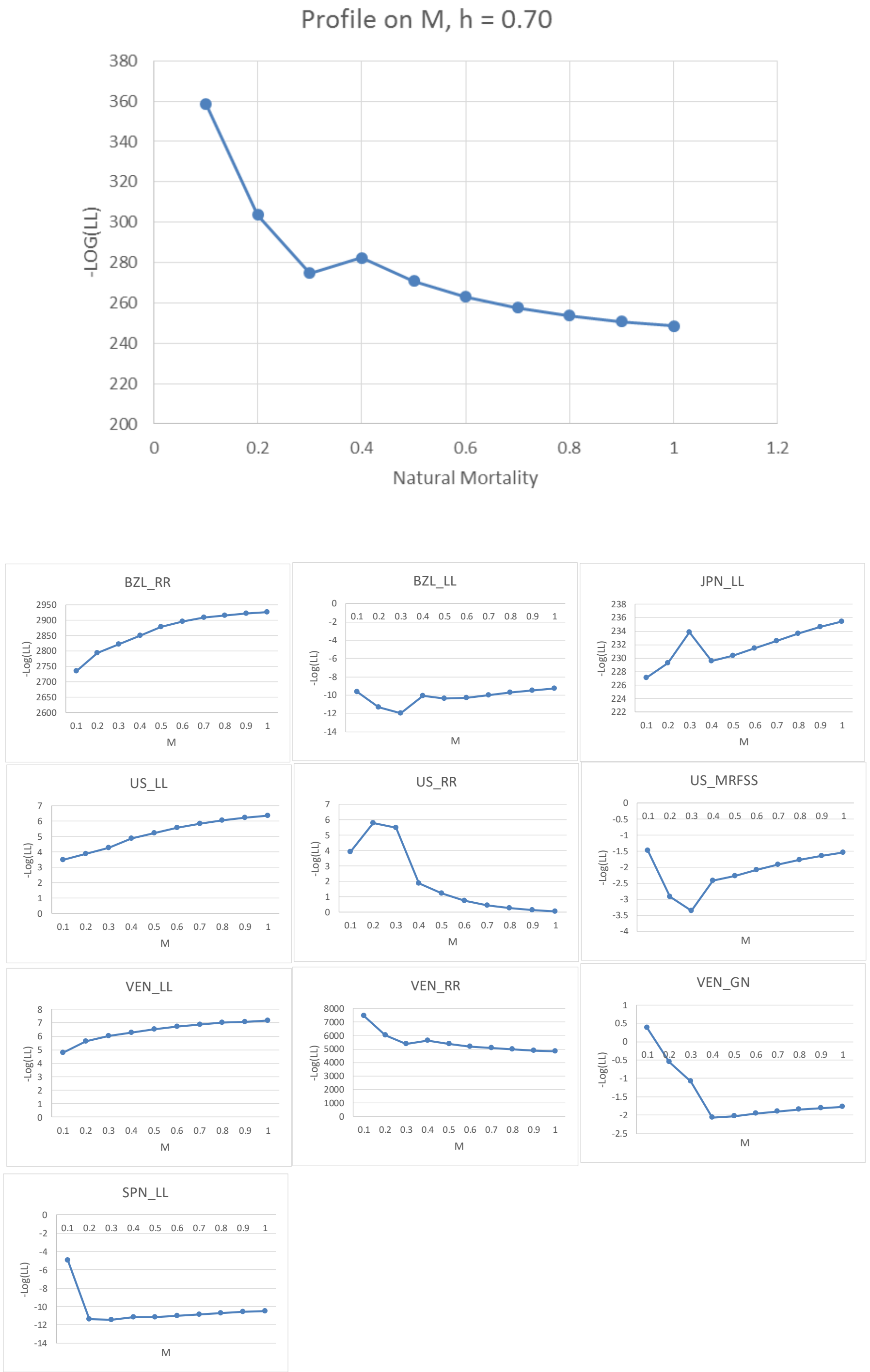


Figure 5. Results of profile analysis of Model_4, fixing steepness = 0.70 and profiling across natural mortality.

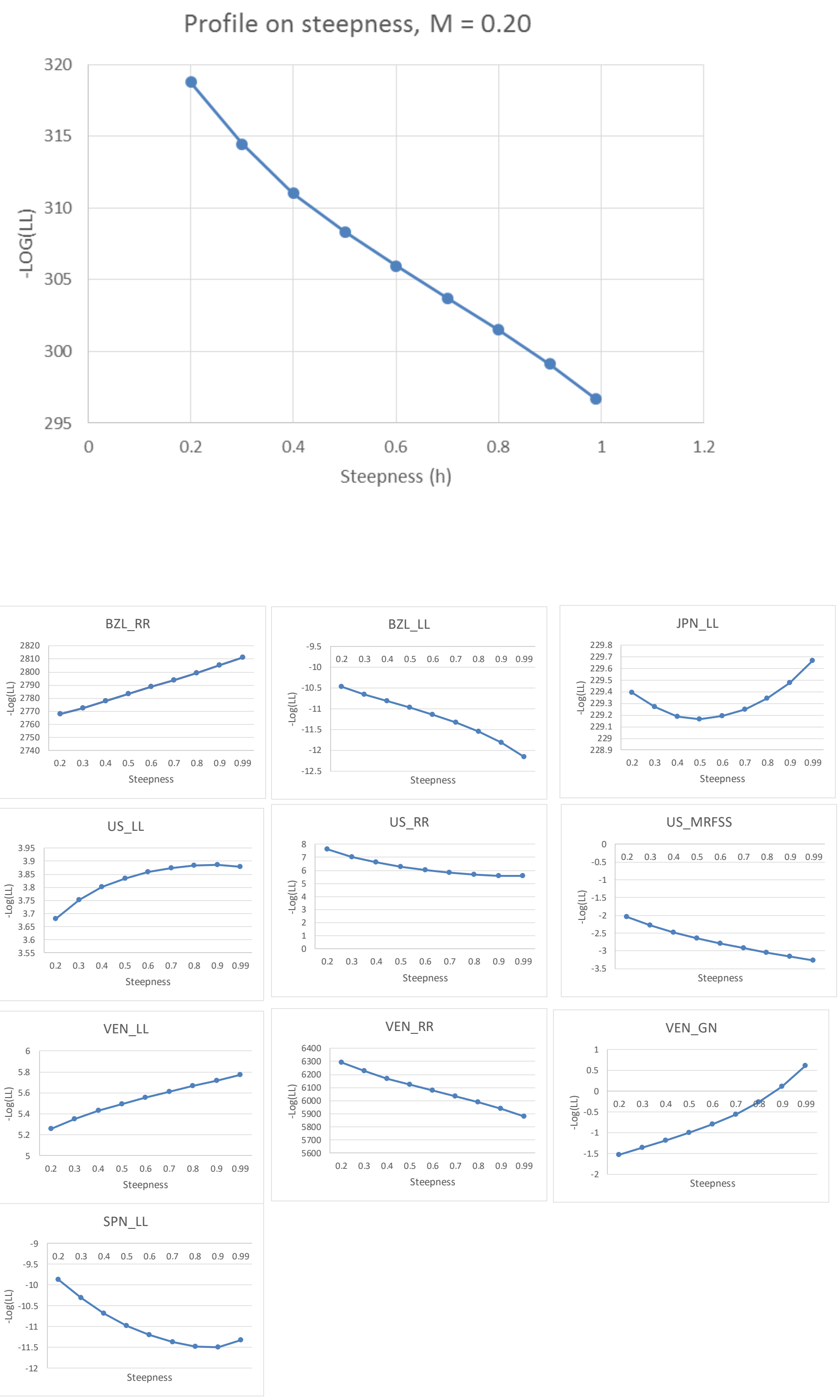


Figure 6. Results of profile analysis of Model_4, fixing M = 0.20 and profiling across steepness.

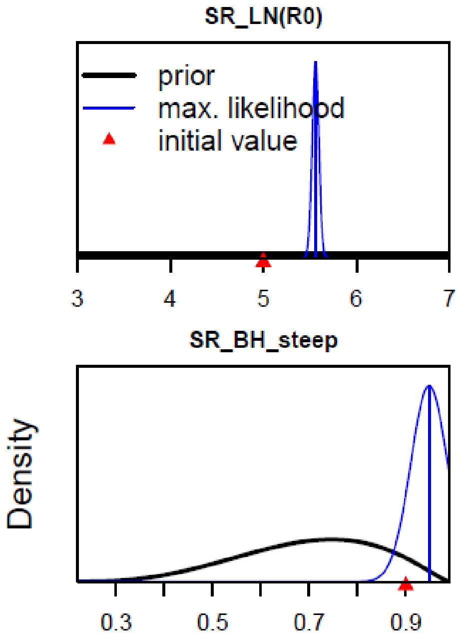


Figure 7. Prior, maximum likelihood and initial values for R0 (top) and steepness (bottom).

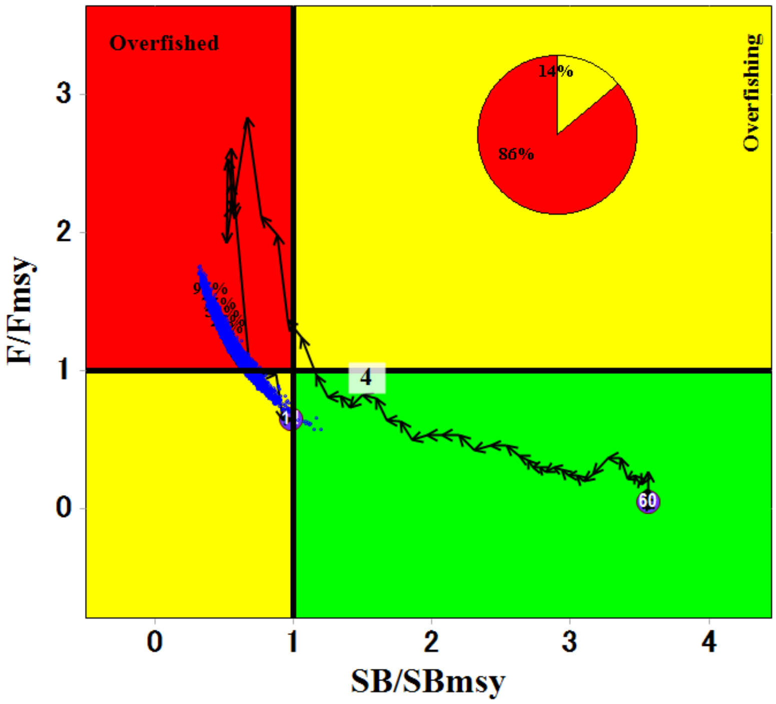


Figure 8. Kobe plot for Model_4.

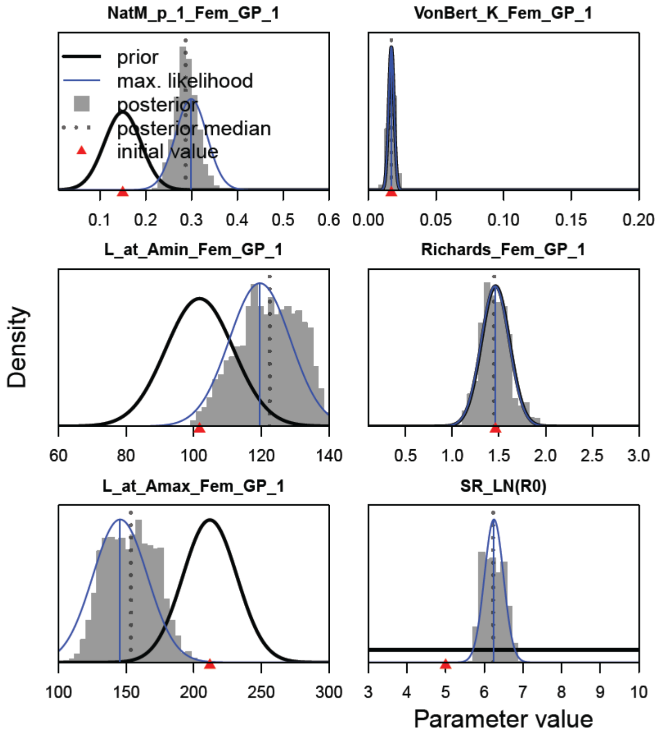


Figure 9. Prior, maximum likelihood, posterior and posterior median, and initial values for Model_4 when growth was allowed to be estimated along with M and steepness.

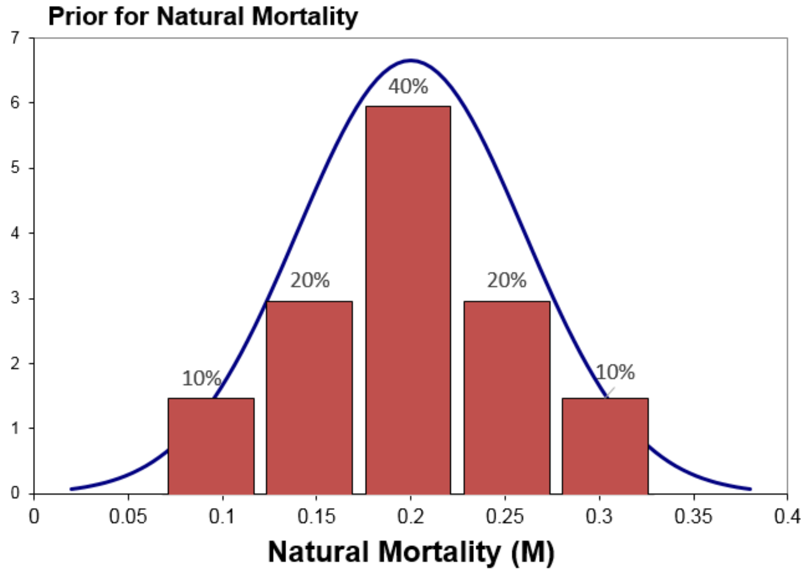


Figure 10. Distribution of M values and the percentage of samples taken for each M value to arrive at the final set of posterior runs.

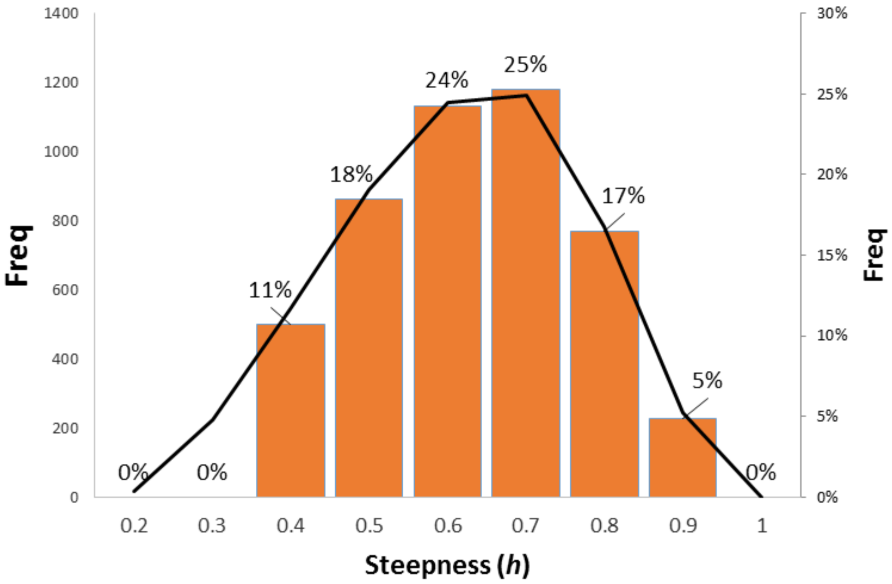


Figure 11. Distribution of steepness values and the percentage of samples taken for each M value to arrive at the final set of posterior runs.

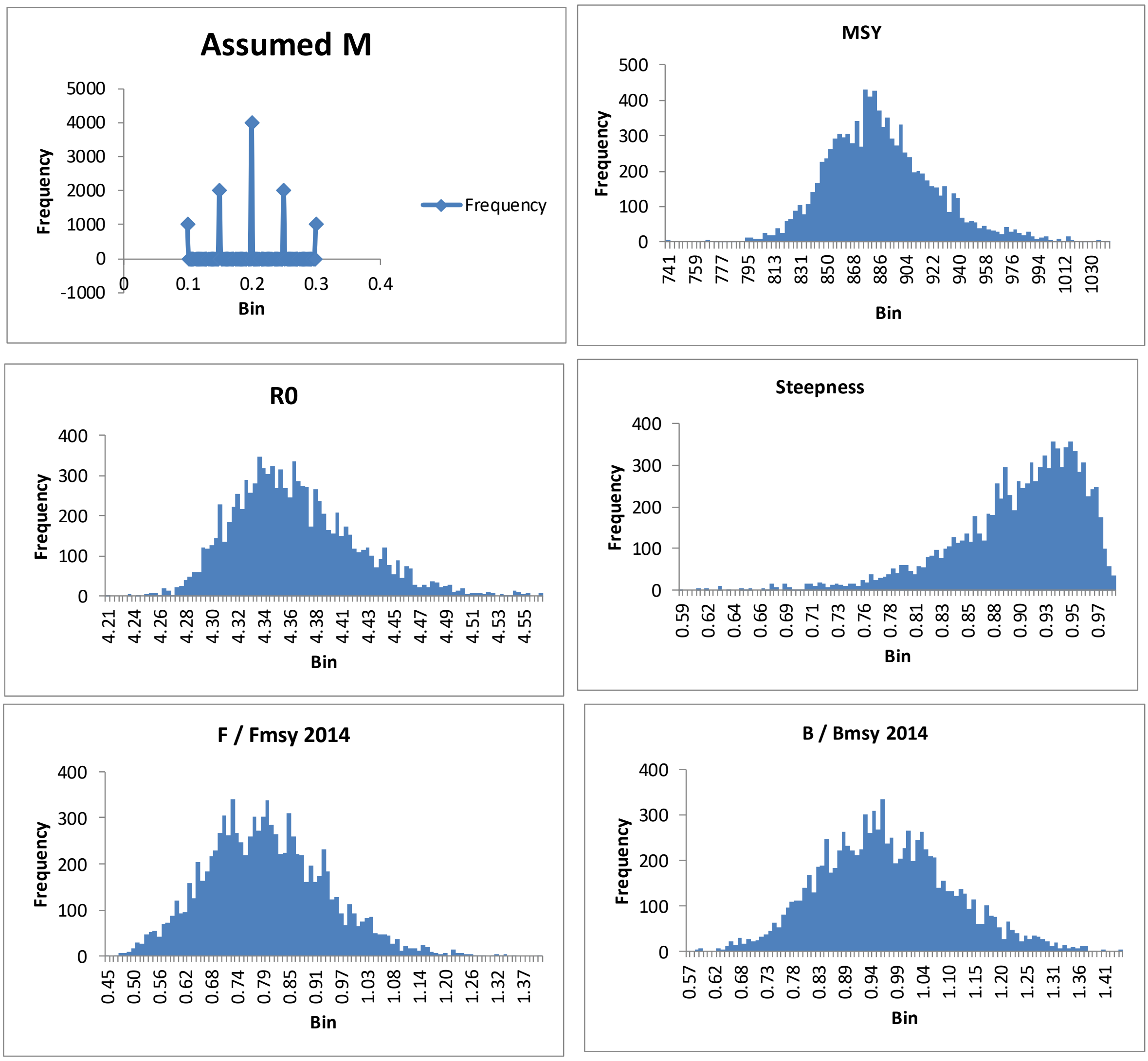


Figure 12. Distributions of fixed (M) and estimated parameters from fitting Model_4 at various levels of M and allowing R0 and steepness to be estimated.

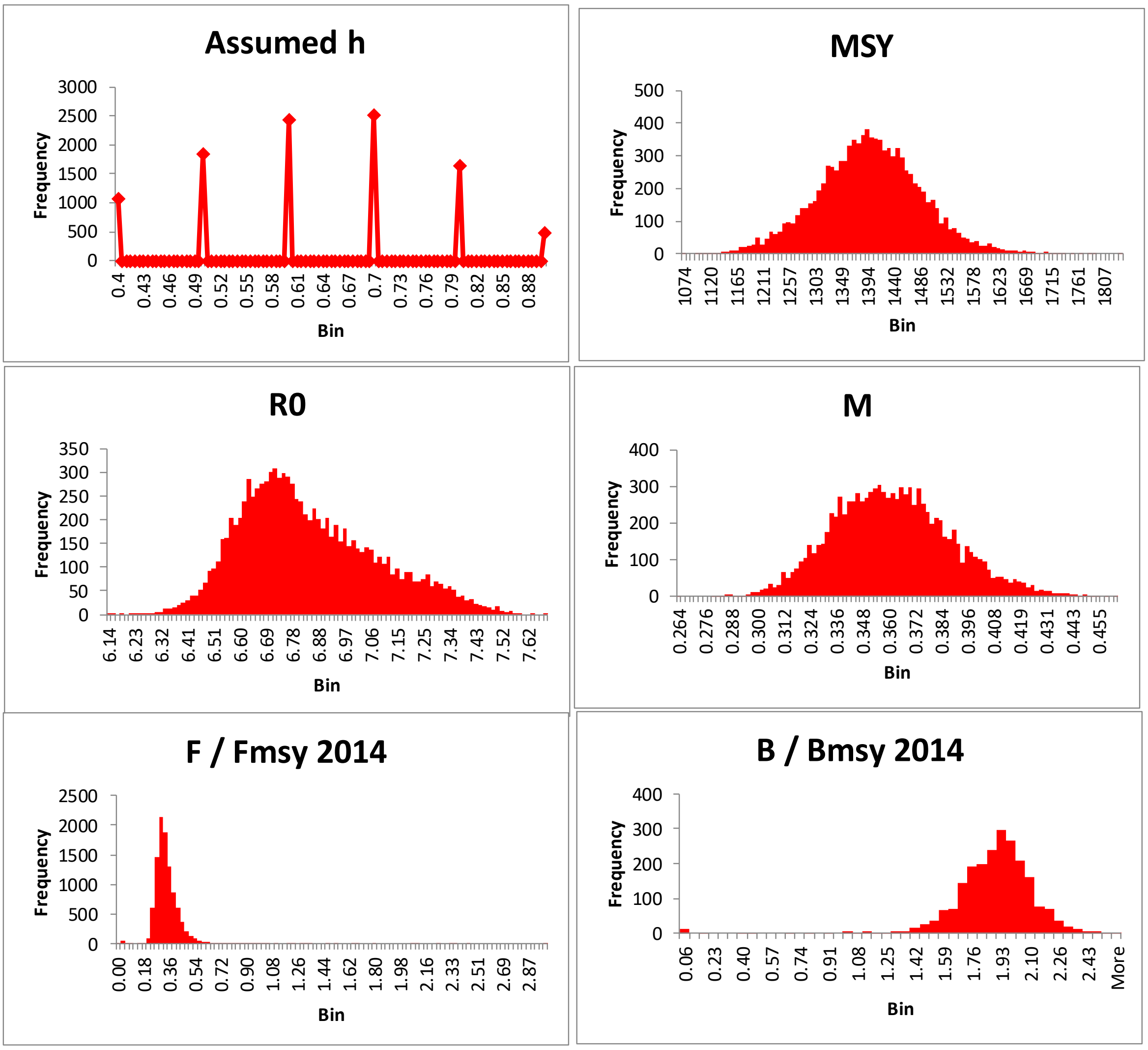


Figure 13 . Distributions of fixed (steepness) and estimated parameters from fitting Model_4 at various levels of M and allowing R0 and M to be estimated.

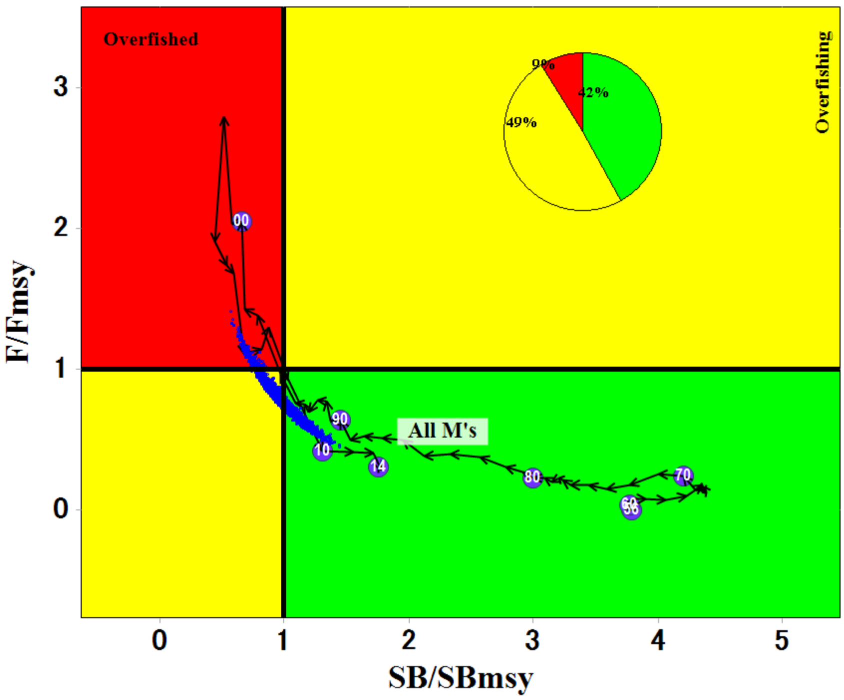


Figure 14. Kobe plot for Model_4, assumed values of M and estimating steepness.

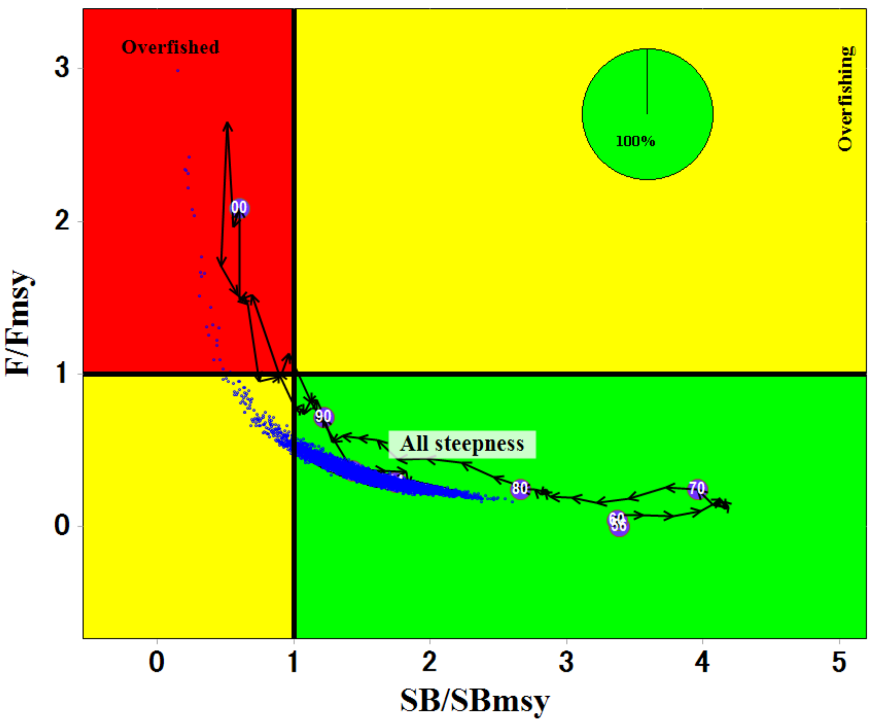


Figure 15. Kobe plot for Model_4, assumed values of steepness and estimating natural mortality.

Appendix 1

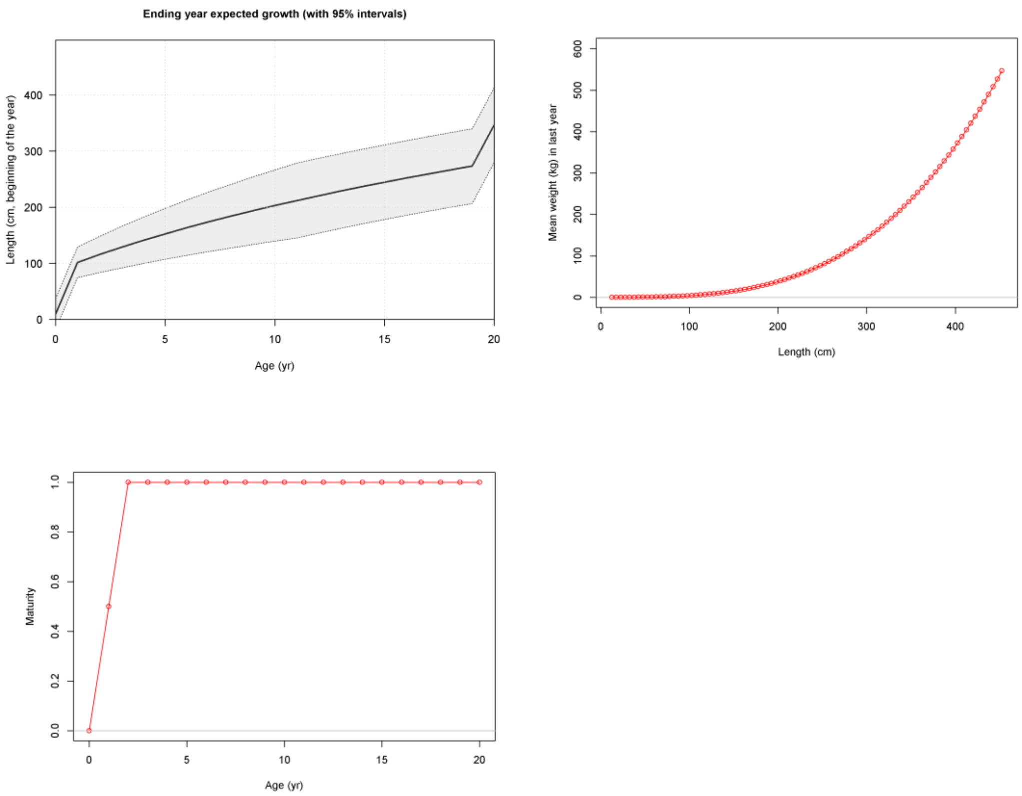


Figure 1. Biological factors of growth (upper left), length-weight (upper right), and maturity (lower left) used for Stock Synthesis western sailfish assessment, 2016.

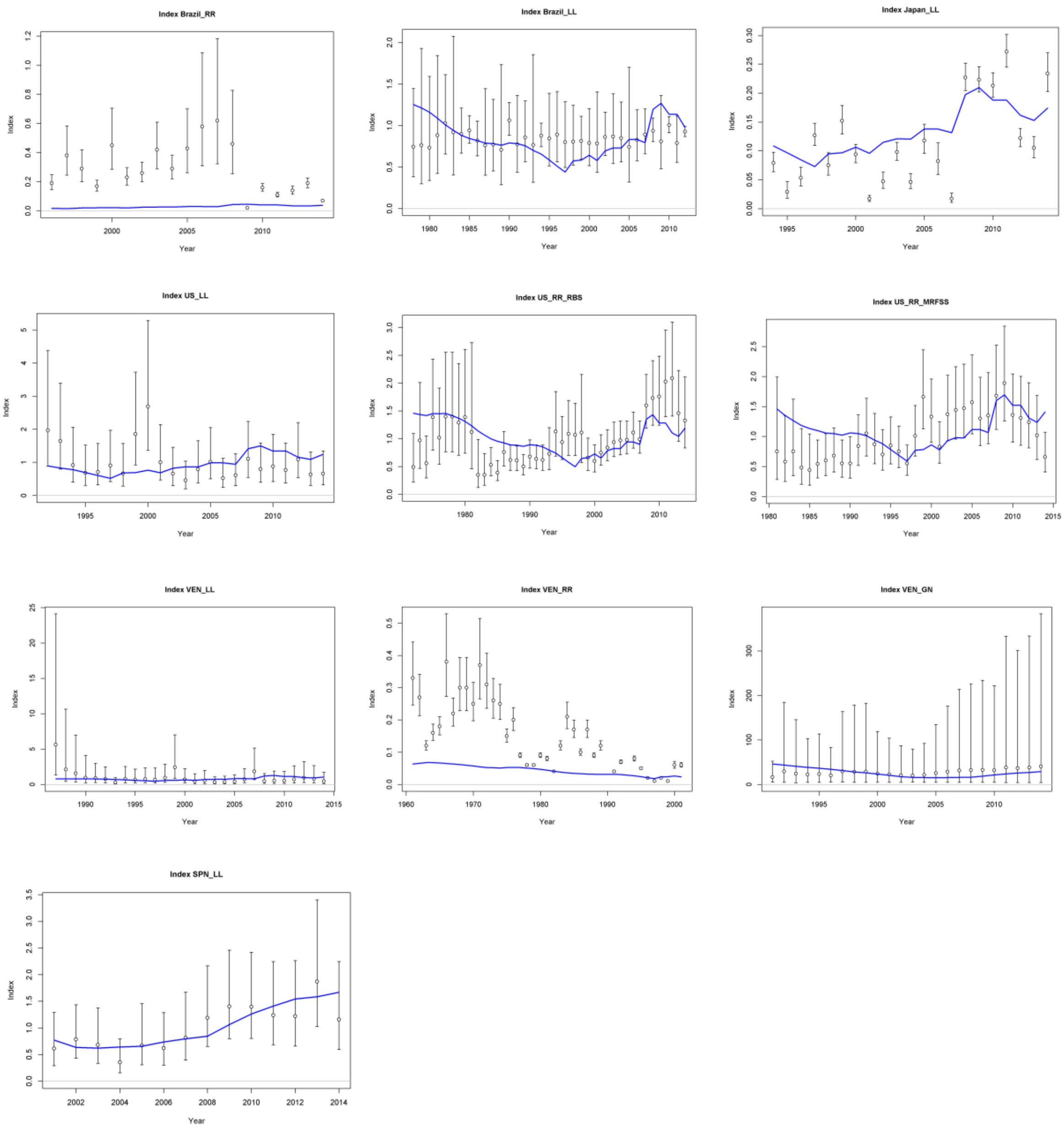
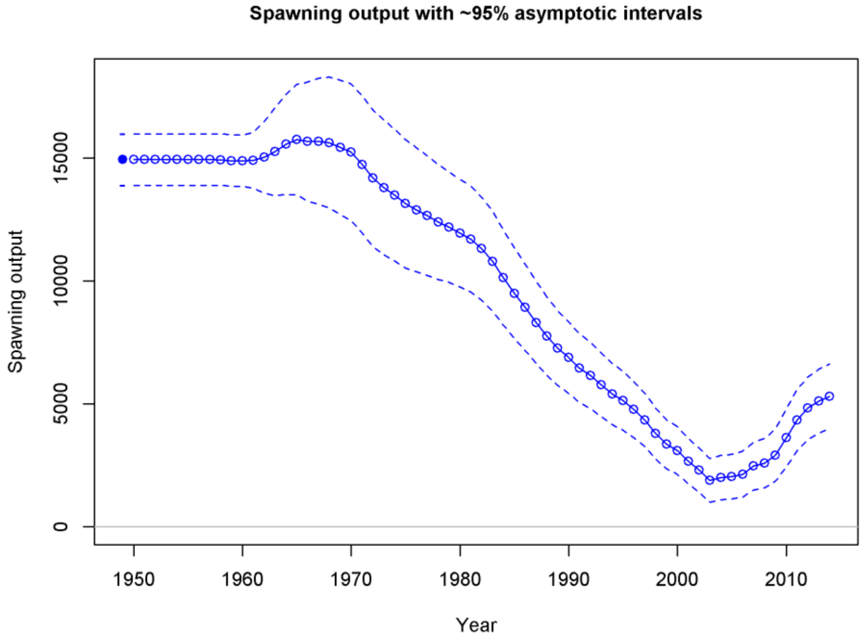


Figure 2. Fit to the indices of abundance used for Stock Synthesis western sailfish assessment, 2016.



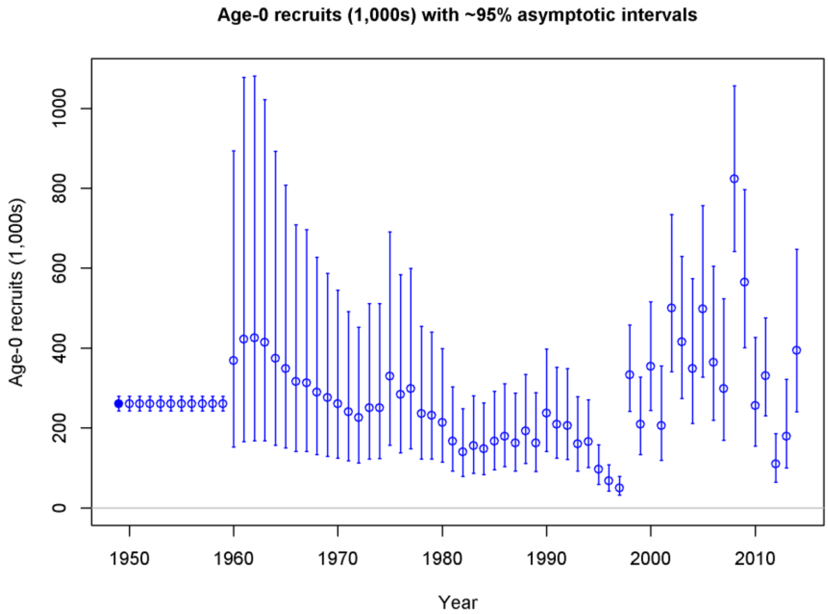


Figure 3. Reconstruction of historic spawning stock biomass (top) and annual recruitment from Stock Synthesis western sailfish assessment, 2016.

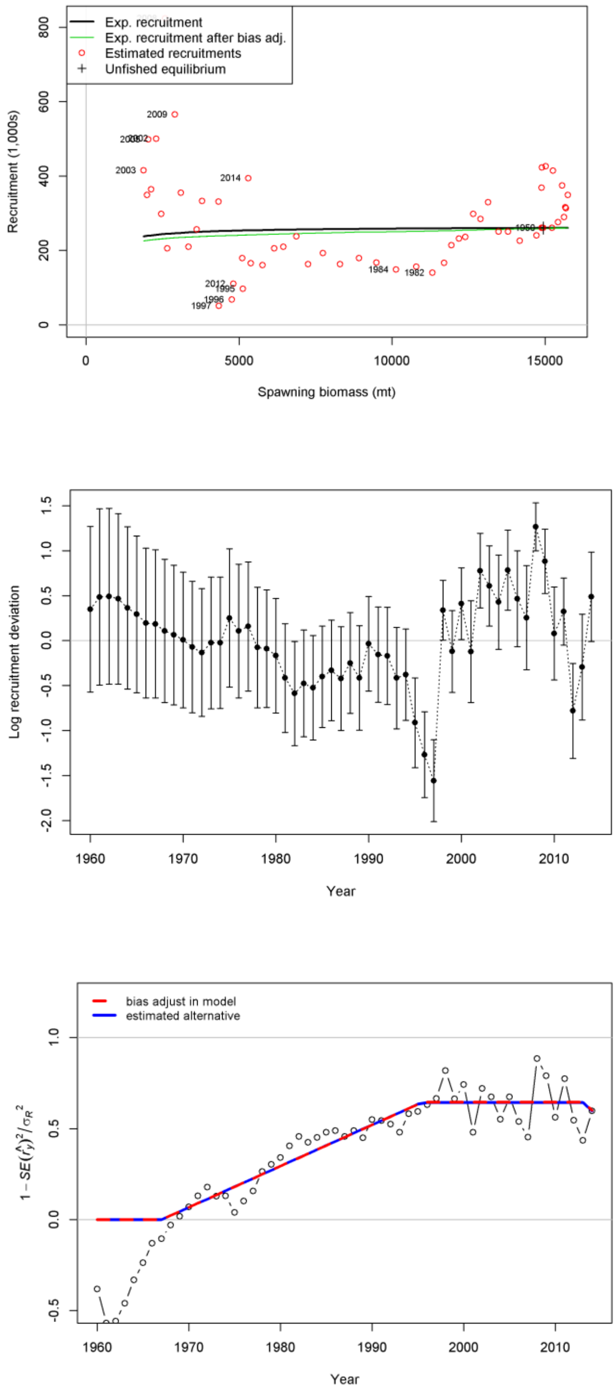


Figure 4. Estimated spawner-recruit function (top), annual recruitment deviations (middle), and bias correction (bottom) from Stock Synthesis western sailfish assessment, 2016.