A Preliminary Stock Synthesis Model Conducted for the WCNPO Striped Marlin

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Abstract

A preliminary base-case model in Stock Synthesis 3.30 for striped marlin (*Kajikia audax*) is described. The base-case model covers 1975-2017 for the Western Central North Pacific Ocean (WCNPO) region as determined by the Billfish Working Group at the January 2019 working group meeting. It includes all the data available for the WCNPO region as of the January Billfish WG data preparatory meeting. The preliminary base-case model converged, model fits to CPUE and length composition data were reasonable. Ending year (2017) stock status relative to maximum sustainable yield (MSY) reference points obtained from the preliminary SS3 model run indicated that the fishing mortality rate in 2017 was above the fishing mortality rate at maximum sustainable yield. The preliminary SS3 model run also indicated that stock spawning biomass, was below the stock spawning biomass at maximum sustainable yield.

Introduction

This document details a preliminary base-case model for the WCNPO striped marlin. The preliminary base-case model was a product of collaboration by a modeling sub-group of the ISC Billfish WG.

Methods

Definition of Fisheries

Data are available for thirty different fleets in the WCNPO: 23 catch time series and 7 CPUE indices. The fleet names and numbers are detailed in Table 1. The data available for each fleet are shown in Figure 1.

Catch

The 23 time series of catch for the WCNPO model were divided into early and late periods to coincide with divisions of the CPUE indices (Table 1, 1). Three ISC countries contributed catch time series: Japan, Taiwan, and the US. In addition, catch from countries reporting to the WCPFC and IATTC were obtained from each RFMO, respectively. The CV for catch was set to 0.05 for all fleets.

Relative Abundance Indices

The seven CPUE indices available for inclusion in the WCNPO model are detailed in Table 1. The CPUE indices were assumed to be linearly proportional to biomass where catchability (q) occurs in the first month of the quarter assigned.

The CVs for each CPUE index were assumed to be equal to their respective calculated SEs on the log scale. The minimum CV was scaled to a minimum of 0.20. If the input SE was greater than these values, it was left unchanged.

Length Composition

Length composition data were available for nine WCNPO fleets (Figure 1). These data were available in quarterly time steps. Data were fit using a multinomial error structure.

Initial Base-case Model Description

The assessment was conducted with Stock Synthesis (SS) version 3.30.08.03-SAFE released 29 September 2017, using Otter Research ADMB 11.6 (Methot and Wetzel 2013). The model was set up as a single area and sex and four seasons (quarters). Age at recruitment was calculated based upon the model estimated average selectivity at age based upon the quarterly selectivity at length. The maximum age of striped marlin was set to 15 years. Sex aggregated specific biological parameters were used, with age-specific natural mortality (Table 2). The model used a Beverton-Holt spawner-recruit relationship with steepness (h) fixed at 0.87 and sigmaR (σ_r) fixed at 0.6.

The population was assumed to be in equilibrium prior to 1975, with an estimated equilibrium exploitation catch of 2500 mt per quarter (5000 mt annual total).

Main recruitment deviations were estimated from 1994-2017. The early period (prior 1994) of recruitment deviations represents a data-poor period where there is little information to drive recruitment.

The population model and the fishery length data had one cm length bins from 50-230+ cm. The population had 16 annual ages from age 0 to 15+. There were no age data. Fishery length data were used to estimate selectivity patterns, which controlled the size distribution of the fishery removals. All fleets with length data were estimated as six parameter double normal (dome-shaped) selectivity patterns except for Japan drift gillnet length data, which was estimated as a two parameter asymptotic logistic selectivity pattern. Survey selectivity patterns mirrored their respective catch fleets (Table 3

Table).

Model estimated time series of total biomass (B in metric tons, mt = 1000 kg), age 1+ total biomass (B_{1+} mt), female spawning biomass (SSB mt), and recruitment (R in 1000s of fish) were tabulated on an annual basis. Annual exploitation rate (F) was calculated as Catch/B_{1+}. Stock status indicators were calculated based upon MSY-based reference points as proxies.

Convergence Criteria and Diagnostics

The model was assumed to have converged if the standard error of the estimated parameters could be derived from the inverse of the negative hessian matrix. Parameter estimates hitting bounds of the prior was also indicative of poor model fit.

Profiling the likelihood on R_0, where the R_0 is fixed at a range of values around the maximum likelihood estimate and then the likelihood is estimated, was used to identify influential data components (Lee *et al.,* 2014). Finally, residual plots and plots of the observed vs expected data were examined to evaluate goodness-of-fit.

Results

The base-case model ran in about 25 minutes, and had a total likelihood of 749.05. The inverse Hessian was positive definite, which allowed for the estimation of parameter standard deviations and suggests that the model converged. The maximum gradient component was 0.0003, which is greater than the target value 0.001, suggesting good parameter estimation.

Profiling on R_0 showed that the length composition data and CPUE indices showed different minimum likelihood solution (Figure 2).

Fits to the abundance indices were relatively good, with no substantial divergences between the expected and estimated CPUEs (Figure 3). Fits to the length composition data were also relatively good, although several problems are evident in the fitting to the US Hawaii longline length composition data (F16) (Figure 4).

A pattern of large positive and negative recruitment deviations suggests either some problem in the estimation of recruitment or strong periodic recruitment pulses (Figure 5).

Model estimates of age 1+ SSB show a relatively flat trend with a slight decrease form 1975-1999, and a slight increase from 2000 to 2016. (Figure 6). Initial female spawning stock biomass was estimated to be approximately 97,000 mt.

Results of this preliminary model showed that, relative to MSY, the stock is likely in an overfished condition and overfishing is likely occurring (Figure 7).

Acknowledgements

Steven Teo (NOAA SWFSC) and Jon Brodziak (NOAA PIFSC) assisted answering questions on Stock Synthesis modelling.

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Tables

Table 1. List of fleets with Catch and CPUE indices provided for the 2019 Western Central North Pacific Ocean Striped Marlin Stock Assessment.

Catch Index	Abundance Index	Fleet Name	Time Series
F1	S1	JPNLL_Q1A1_Late	1994-2017
F2	-	JPNLL_Q1A2	1975-2017
F3	-	JPNLL_Q1A3	1975-2017
F4	-	JPNLL_Q2A1	1975-2017
F5	S2	JPNLL_Q3A1_Late	1994-2017
F6	-	JPNLL_Q4A1	1975-2017
F7	-	JPNLL_Q1A4	1975-2017
F8	-	JPNLL_Q2A2	1975-2017
F9	-	JPNLL_Q3A2	1975-2017
F10	-	JPNLL_Q4A2	2000-2016
F11	-	JPNLL_Q4A3	1975-2017
F12	-	JPNLL_Others	1975-2017
F13	-	JPNDF_Q14	1975-2017
F14	-	JPNDF_Q23	1975-2017
F15	-	JPN_Others	1975-2017
F16	S3	US_LL	1987-2017
F17	-	US_Others	1987-2017
F18	S4	TWN_DWLL	1967-2017
F19	S5	TWN_STLL	1958-2017
F20	-	TWN_Others	1958-2017
F21	-	WCPFC_Others	1975-2017
F22	S6	JPNLL_Q1A1_Early	1975-1993
F23	S7	JPNLL_Q3A1_Early	1975-1993

Table 2. Key life history, recruitment, and selectivity parameters used in the striped marlin stock assessment model. The column labeled "Estimated ?" identifies if the parameters are expected to be estimated within the assessment model (Estimated), fixed at a specific value, i.e., not estimated (Fixed).

Parameter (units)	Value	Estimated?
Natural mortality (M, age-specific yr)	$M_0 = 0.54$, $M_1 = 0.47$, $M_2 = 0.43$, $M_3 = 0.40$, $M_{4+} = 0.38$	Fixed
Length_at_min_age (EFL cm)	$L(A_{min}) = 104$	Fixed
Length_at_max_age (EFL cm)	$L(A_{max}) = 214$	Fixed
VonBert_K	$k = 0.24$	Fixed
$W=aL^b$ (kg)	$a = 4.68 \times 10\text{-}6$	Fixed
	$b = 3.16$	
Size at 50-percent maturity (EFL cm) and maturity ogive slope parameter	Female: $L_{50} = 161$, $\beta = -0.08$	Fixed
Stock-recruitment steepness (h)	$h = 0.87$	Fixed
Unfished log-scale recruitment ($\text{Ln}(R_0)$)	-	Estimated
Standard deviation of recruitment (σR)	$\sigma R = 0.6$	Fixed
Initial age structure	-	Estimated
Recruitment deviations	-	Estimated
Selectivity	-	Estimated
Catchability	-	Estimated

Table 3. Table of selectivity functions for each catch and abundance time series.

Fleet	Selectivity Function
F1	Double-normal
F2	Double-normal
F3	Mirror F2
F4	Double-normal
F5	Double-normal
F6	Double-normal
F7	Mirror F2
F8	Mirror F4
F9	Mirror F5
F10	Mirror F6
F11	Mirror F6
F12	Mirror F4
F13	Asymptotic lognormal
F14	Asymptotic lognormal
F15	Mirror F4
F16	Double-normal
F17	Mirror F16
F18	Double-normal
F19	Mirror F18
F20	Mirror F14
F21	Mirror F4
F22	Mirror F1
F23	Mirror F5
S1	Mirror F1
S2	Mirror F5
S3	Mirror F16
S4	Mirror F18
S5	Mirror F18
S6	Mirror F1
S7	Mirror F5

Figures

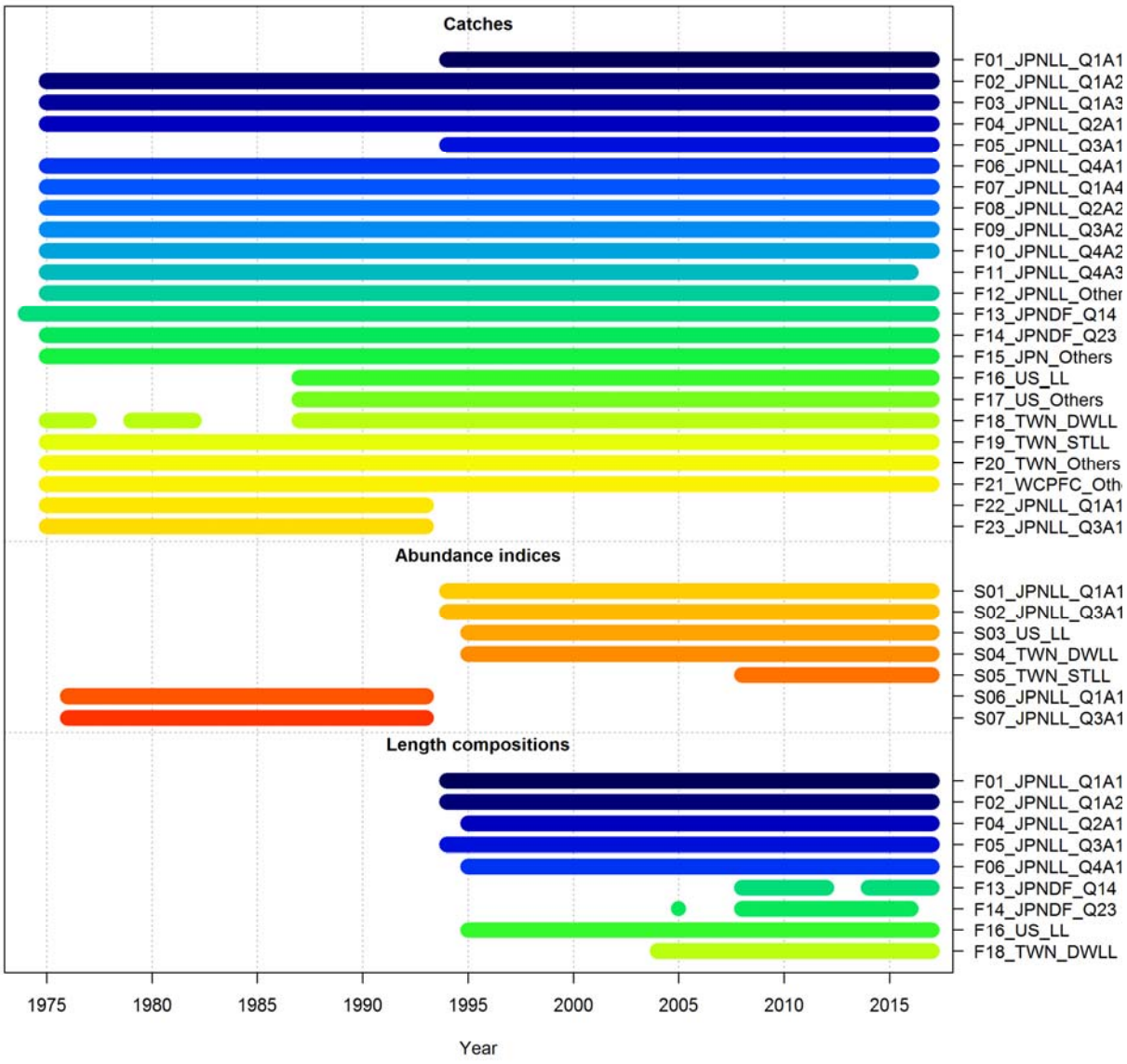

Figure 1. Catch, abundance, and length composition data available for the WCNPO Stock Synthesis striped marlin assessment model.

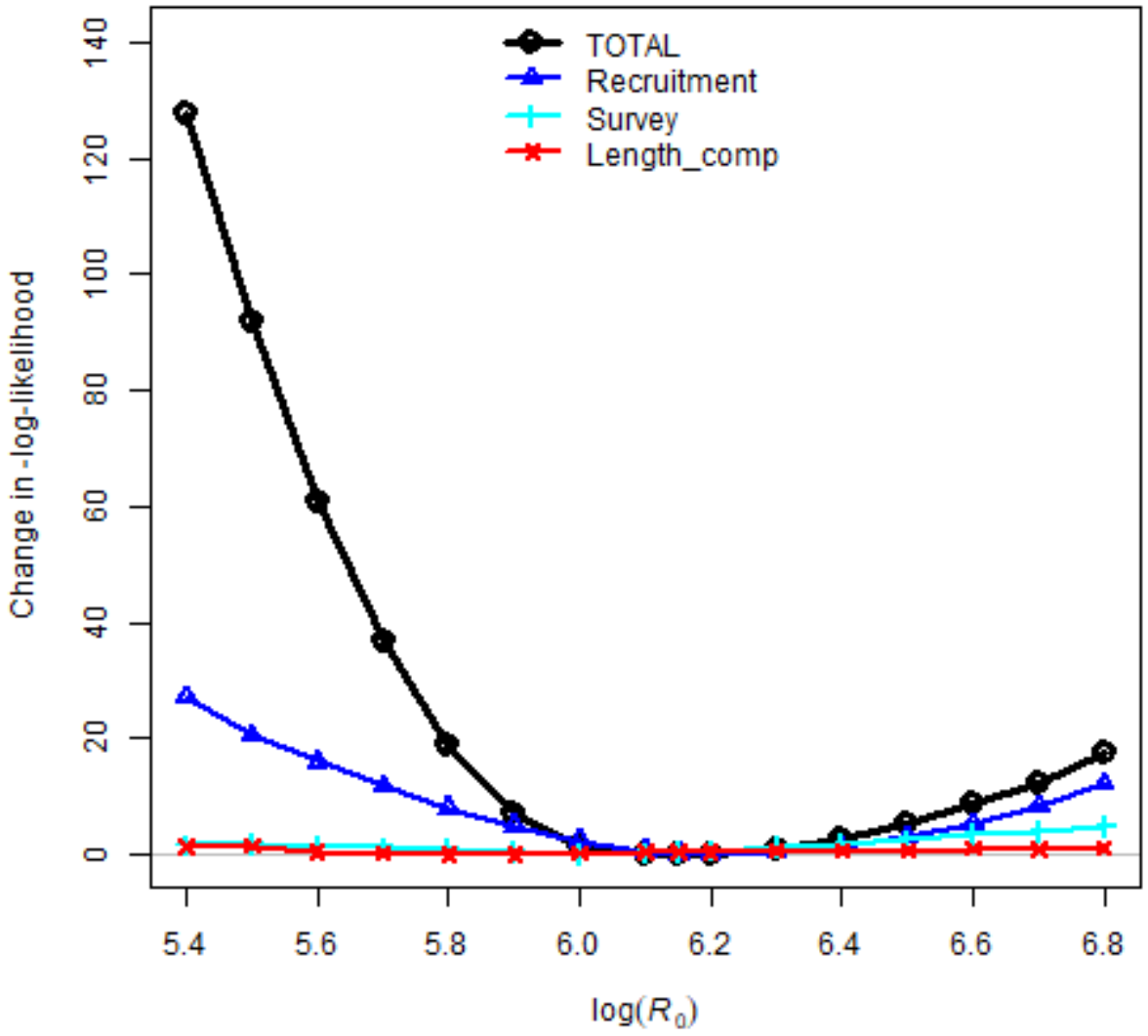

Figure 2. Likelihood profile on log(R_0) by likelihood component in the preliminary base-case model.

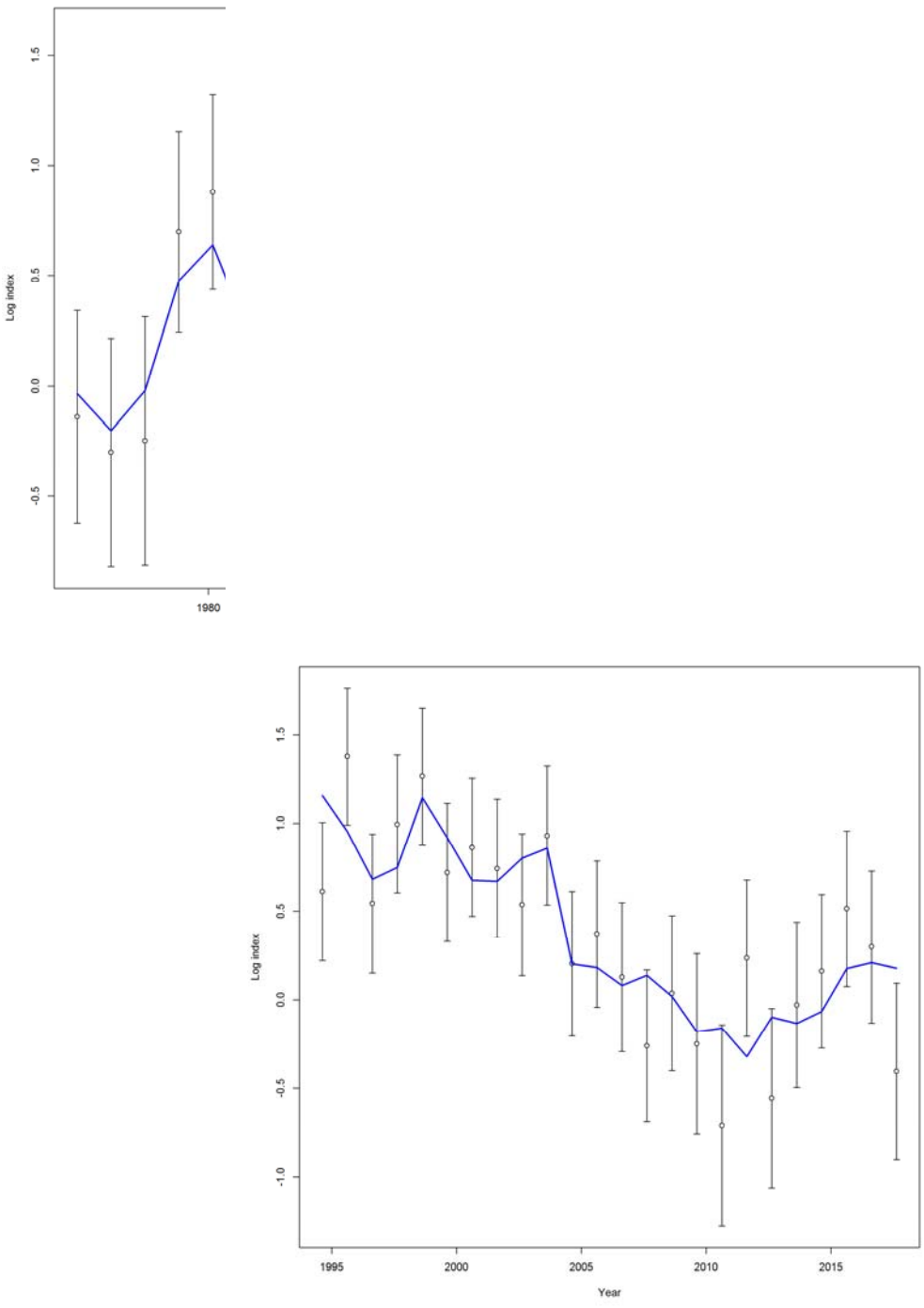

Figure 3. Model-estimated (blue line) versus observed (open circle) log(CPUE) for the indices from Japan Quarter 3 in Area 1 for the early (top panel) and late (bottom panel) periods in the preliminary base-case model. Error bars are input log(SE).

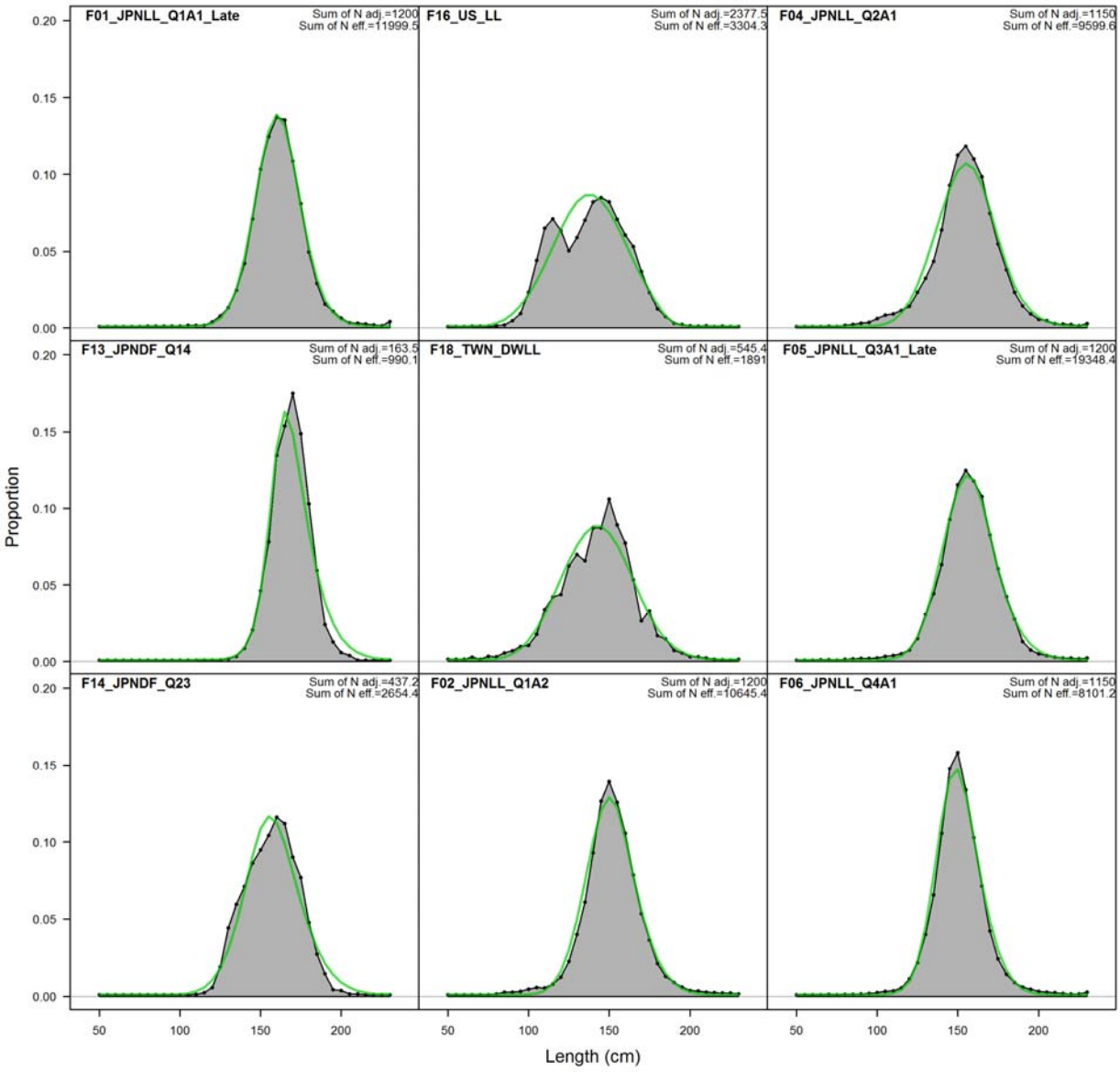

Figure 4. Length composition data observed (black line and grey shading) and initial base-case model-estimated selectivity (green line), aggregated across time by fleet.

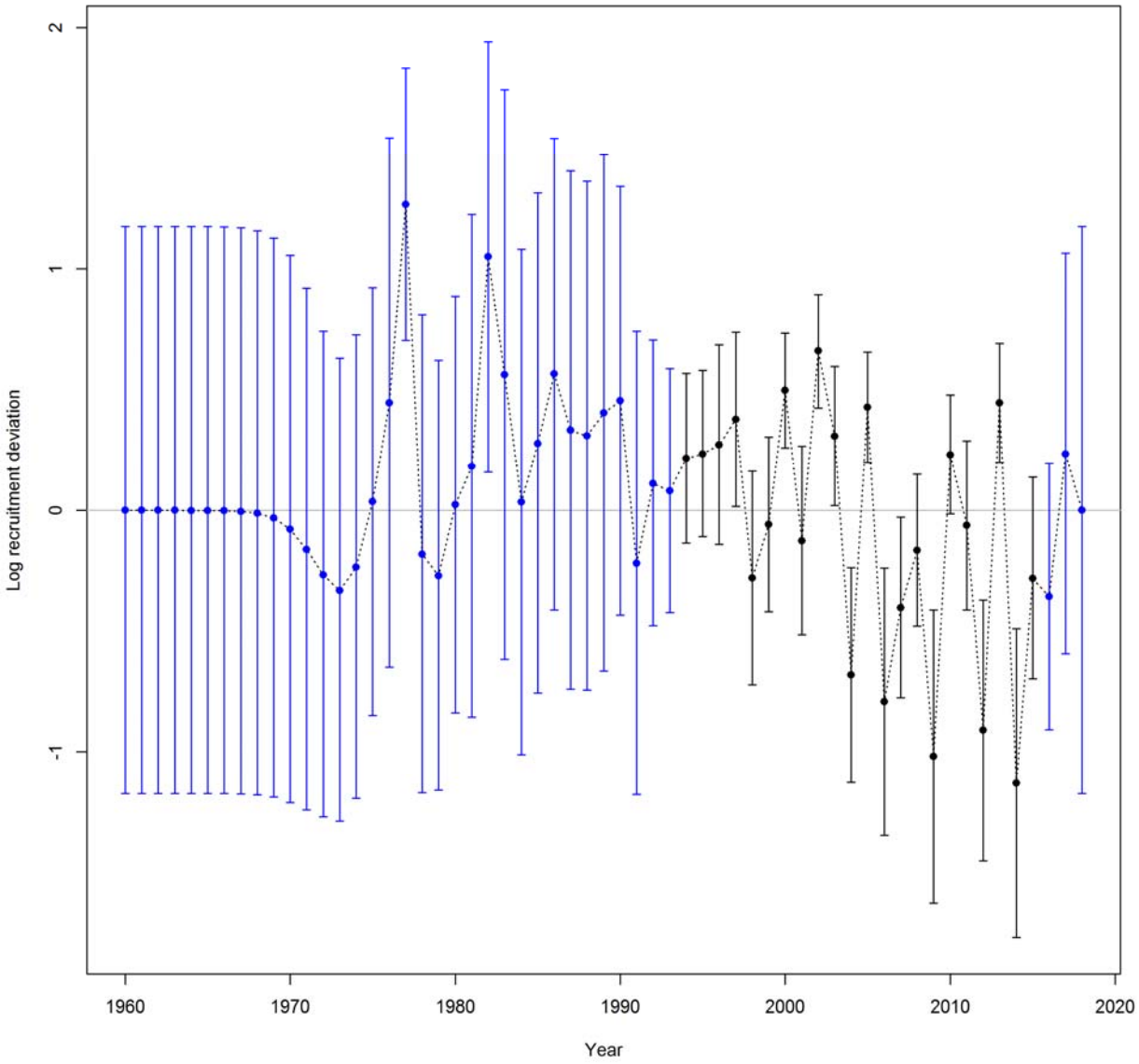

Figure 5. Residual recruitment deviations estimated from the preliminary base-case model. Blue circles indicate early recruitment deviations prior to 1994.

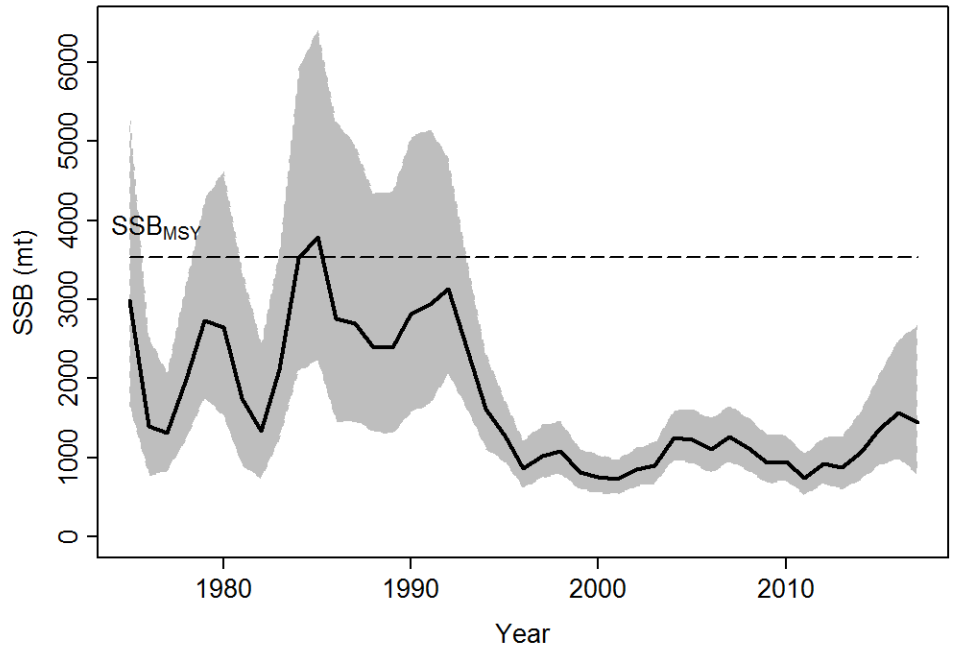

Figure 6. Annual estimates of female spawning stock biomass (black line) with 95% confidence intervals (grey shaded area).

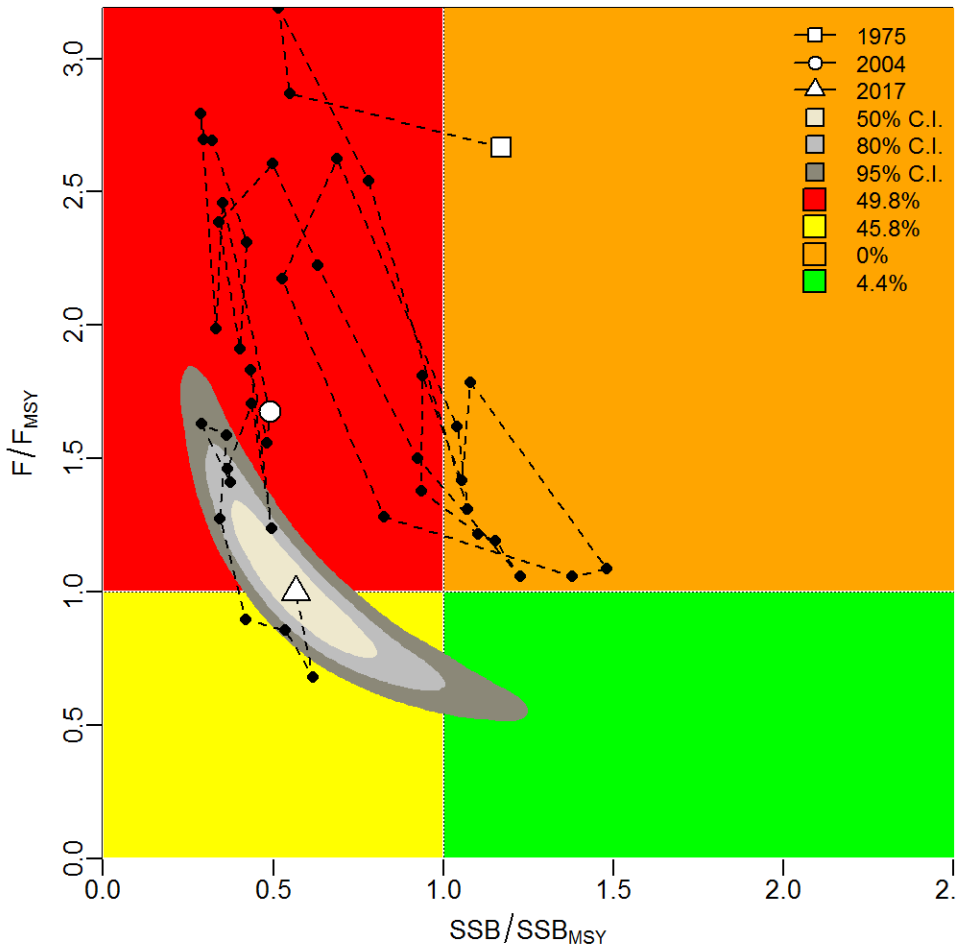

Figure 7. Kobe plot of the trends in estimates of relative fishing mortality and spawning stock biomass for the preliminary base-case Stock Synthesis striped marlin assessment model from 1975-2017.