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Stock Synthesis settings of control file for the stock assessment of blue shark in the North Pacific [1]

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Summary

This working paper summarizes the contents of the Stock Synthesis (SS3) control file and explains the procedure of model configuration and parameterization for selecting a base case model that will be used in the stock assessment of blue shark in the North Pacific Ocean in 2022. First, the version update was conducted for the control file used in the previous stock assessment in 2017. Second, the updated control file was reconfigured by updating biological parameters and changing the model structures. Third, the fitting of the annual abundance indices and length composition data were adjusted using a two-step data-weighting approach (adjusted the CV of CPUE and conducted the down-weighting of the sample size of length composition data using variance adjustment factors of relevant fleets). Fourth, the bias-adjustment parameters of the stock recruitment relationship were updated following the suggested SS3 output, and the sigma-R was tuned by repeatedly changing the value based on the recruitment deviations and standard error of the recruitment deviations.

Introduction

Blue shark (*Prionace glauca*) is widely distributed from tropical to temperate waters around the globe and is the most abundant species of oceanic pelagic shark (Nakano and Steven, 2008). The stock assessment of blue shark in the North Pacific Ocean was conducted in 2017 by the ISC SHARK working group (WG) (ISC, 2017) using the Stock Synthesis (SS3) modeling platform (Method and Wetzel, 2013) and data from 1971 to 2015 (ISC, 2017). In the SS model, parameters and model structures are configured by the control file of SS3. The control file comprised of following sections: biological parameters such as growth and maturity; spawner-recruit parameters such as steepness and recruitment deviations; fishing mortality (*F*) parameters such as initial-*F* and estimation method of *F*; selectivity parameters such as selectivity patterns; variance adjustment factors for the coefficient of variation (CV) of survey data and length composition data; lambda of likelihood components (Method et al., 2020).

The objective of this working paper is to summarize the contents of the control file of SS for selecting a base-case model candidate that will be used in the stock assessment of blue shark in the North Pacific Ocean in 2022.

Materials and Methods

The version of SS3 was updated from V3.24 to V3.30.18 (finally updated to the latest version V3.30.19 as of April 26 in 2020) for the SS3 files of the base-case model used in the previous stock assessment in 2017 (Kai et al., 2022). Then, the control file of SS3 was updated using newly available biological parameters and was configured using new spawner-recruit parameters, fishing mortality parameters, selectivity parameters, variance adjustment factors, and lambda of likelihood components.

A major change to the model configuration is the assumed shape of the stock-recruitment relationship (SR). A low-fecundity SR (Taylor et al., 2013) was used in the previous stock assessment to explain the lower survival ratio prior to the recruitment after partition. Although the application of low-fecundity SR is theoretically reasonable for elasmobranchs, the WG decided that more research is needed before this SR option is fully operationalized in ISC stock assessments for sharks. In particular, the parameters (α and β) of low-fecundity SR were based on strong assumptions relating to the unfished stock-recruitment relationship in the previous stock assessment in 2017. The Working group (WG), therefore, determined to use the Beverton-Holt-SR in the stock assessment in 2022 (ISC, 2022). In addition, the period of main recruitment deviation was changed from 1990-2013 to 1971-2020 because there were a few years of size data before 1990. Sigma-R of SR relationships was tuned by repeatedly changing the value using the following equation:

$$Sigma\text{-}R = \sqrt{Var(devs.) + Mean(devs.se^2)} \quad (1)$$

where *devs*. and *devs.se* indicates recruitment deviations and standard error of the recruitment deviations, respectively.

The values of Sigma-R were calculated by using the r4ss object (Taylor et al., 2021).

All the selectivity curves were assumed to be double normal with defined initial and final selectivity levels (No 24) except that high-seas drift-net fishery (F11: SM_MESH) and US Hawaii shallow set fishery (F18: US_HW_SH). Since F11 has only one year of sex-combined length composition data with different sizes of length bins, generalized composition data was used. A more flexible cubic spline selectivity function with sex-specific offset was used for the F18 in order to achieve a better fit to the bimodal distribution seen in the length composition data for this fishery. The time block of selectivity was set to F8 (JPN_LG_MESH_EARLY) to explain the distinct historical shift of the body size through the change in the operational area and/or target fish. The time varying selectivity applied to F19 (TAIW_LG) to improve the fits to the size data and the same setting was used for this fleet in the previous assessment. At the final stage of SS3 conditioning, selectivity parameter of "top_logit" for all fleets except for F8 and F18 was fixed at -6.0 to reduce the high correlation of parameters because the parameter has no impact on the outcomes of the SS3.

Data weighting for CPUE and length composition data were conducted using a two-step data weighting approach; calculated the variance adjustment factors for fleet-specific relative abundance indices (CPUE) and fleet-specific length composition data (Francis 2011; Courteney et al. 2016). The CPUE was weighted using the CV (Courteney et al. 2016). The procedure is as follows: 1) The mean annual CV (CV_{mean}) is calculated for each CPUE series; 2) The root mean square error (RMSE) on the natural log scale of CPUE is calculated using the following equation:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\{\log(\mathrm{CPUE}_i) - \log(\widehat{\mathrm{CPUE}_i})\}^2} \quad (2)$$

where N is total number at year i of input CPUE time series (CPUE_i) for each fleet, $\widehat{\mathrm{CPUE}_i}$ is an average estimated CPUE from a LOESS smoother. Since it is commonly known that the CVs on the arithmetic scale are approximately equal to the standard errors (SEs) on the natural log scale, the RMSE can be regarded as a minimum average CV (CV_{min}) for each CPUE series (i.e., $CV_{\mathrm{min}} \approx RMSE$); 3) If the $CV_{\mathrm{mean}} < CV_{\mathrm{min}}$, the variance adjustment for each CPUE series in SS was conducted by adding the value to the average CV (CV_{mean} + variance adjustment) and scaled up to 20% CV in order to maintain a certain level of variance for each CPUE. If the $CV_{\mathrm{mean}} > CV_{\mathrm{min}}$, the variance of the CPUE series was not adjusted in the SS3.

The length composition data was weighted based on down weighting, which was implemented by reducing the variance adjustment factors in the control file of SS3 to reduce the effect of the large sample size of fleet-specific length composition data. The values of variance adjustment factors of all fleets were set to 0.002161 (50/23142), where 50 is a criterion, and 23,412 is the average sample size of fleet4 (F4: JPN_KK_SH). The representative fleet (F4) was designated based on the wide operational area in the main distributed area of blue shark, large amount of the catch from small to large fish, and the prolonged operational period relative to the other fisheries (Kai, 2021). In addition, the Method "TA1.8" (Francis, 2011) was applied to do the down weighting of fleet-specific length composition data. The method is based on variability in the observed mean length by year, where the sample sizes are adjusted such that the fit of the expected mean length should fit within the uncertainty intervals at a rate that is consistent with variability expected based on the adjusted sample sizes (Method et al., 2020).

Bias adjustment parameters for stock-recruitment relationships (Method and Taylor, 2011) were adjusted using the estimated alternative inputs to SS3 control file. For the other remaining parameters, such as initial fishing mortality and catchability, the same estimation methods as those used in the previous assessment were applied.

Results

A list of items and comparisons of biological and spawner-recruit parameters between previous and current assessments are shown in **Table 1**. Some parameters of the growth curve, spawner-recruit steepness, and the time period of main recruitment deviation were slightly changed, but the same values were used for most of these parameters. The parameters of the sex-specific Richard growth curves (**Fig. 1**), derived from sex-specific von-Bertalanffy growth curves (Fujinami et al., 2019), were almost the same as those used in the previous assessment in 2017. The sex- and age-specific natural mortality rates (**Table 2**) were updated using the newly available growth curve parameters, resulting in natural mortality schedules almost the same as those in the previous assessment (**Fig. 2**). The maturity ogive of females (**Fig. 3**) and weight-at-length for males and females (**Fig. 4**) were not changed relative to the previous stock assessment. The Beverton-Holt (BH) steepness was updated using newly available biological parameters such as growth and natural mortality for females (**Fig. 5**). The sigma-R was fixed to 0.40 after tuning 6 times.

The sex-specific selectivity parameters for 13 fleets (F1: MEX, F3: CHINA, F4: JPN_KK_SH, F5: JPN_KK_DP, F7: JPN_ENY_DP, F8: JPN_LG_MESH_EARLY, F9: JPN_LG_MESH_LATE, F11: SM_MESH, F14: NON_ISC, F15: US_GILL, F17: US_HW_DP, F18: US_HW_SH, F19: TAIW_LG and F20: TAIW_SM) were estimated in the model. The selectivity patterns of other fleets were mirrored in consideration with the selectivity of each fleet (**Table 3**).

The calculated *CV*s and recommended variance adjustment is summarized in **Table 4**. Annual changes in the residuals between fitted and observed CPUEs and fitting of LOESS to observed CPUE were also shown in **Fig. 6**. The values of CV_{mean} for S1, S6, and S7 were larger than those of CV_{min}, so that the variance adjustment was fixed to 0. The other fleets were opposite results, so the variance adjustment was added up to 0.2 for each fleet.

Outcomes of the Method “TA1.8” are summarized in **Table 5**. Since all the suggested multiplier was larger than one except for F4, the second down-weigting was only applied to the size composition data for F4 after finishing the parameterization for all the selectivity curves.

Max bias adjustment in MPD was fixed to 0.50 based on the output of SS3 at the final stage of the conditioning.

Discussions

This working paper summarized a procedure of model configuration and parameterization for SS3 to select a base-case model candidate for the stock assessment of the North Pacific blue shark in 2022. The detailed changes in the control files of SS3 from the previous settings were described to clarify the difference of the parameters and model configurations.

The updated steepness was slightly smaller than that used in the previous stock assessment in 2017 due to the different maximum ages (16 vs. 24) in the estimation of steepness. Kai (2017) used the maximum age 16, which was an observed value for females from the growth study (Fujinami et al., 2019), and age 24 was a theoretical maximum age, estimated from the empirical equation (Taylor 1958), used in the SS3.

Unlike the previous stock assessment in 2017, the sigma-R was tuned using the function of r4ss. The tuned sigma-R seems reasonable because the value was lower than 0.6, which is commonly used for high productivity species such as tunas.

Though the low-fecundity stock-recruitment relationships (Taylor et al., 2013) is theoretically reasonable to apply to elasmobranchs such as blue sharks, it is necessary to use the conventional B-H stock recruitment relationship until an appropriate parametrization has been developed.

The criterion (i.e., 50) of data weighting was arbitrary in down weighting of length composition data. The Francis method (Francis, 2011) is commonly used to do down-weighting of length composition data. However, the estimated multipliers of length composition by fleet from Francis method “TA1.8” suggested that higher values are better for the adjustment of length composition data except for F4. These results mean that the application of all suggested multipliers is not suitable for the data weighting. We will need further study to improve the data weighting method.

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Table 1. Biological and spawner-recruitment parameters used in the previous and current stock assessment for North Pacific blue shark. Red denotes different values compared to those used in the previous assessment in 2017.

Parameter	Previous	Update	Source
Gender	2	2	ISC (2017)
Natural mortality	Age- and sex- specific (SeeTable 5)		Fujinami et al. (2021)
Reference age (a1)	1	1	
Maximum age (a2)	20	20	
Theoretical maximum age	24 for both sexes	24 for both sexes	Taylor (1958)
Female at first age	4	4	Fujinami et al. (2017)
Length at a1 (L1)	64.4 (Female)	64.3 (Female)	Fujinami et al. (2019)
	68.2 (Male)	68.2 (Male)	
Length at a2 (L2)	244.6 (Female)	245.2 (Female)	Fujinami et al. (2019)
	261.3 (Male)	261.5 (Male)	
Growth rate (K)	0.147 (Female)	0.146 (Female)	Fujinami et al. (2019)
	0.117 (Male)	0.117 (Male)	
CV of L1 (CV=f(LAA))	0.25 (Female)	0.25 (Female)	ISC (2017)
	0.25 (Male)	0.25 (Male)	
CV of L2	0.1 (Female)	0.1 (Female)	ISC (2017)
	0.1 (Male)	0.1 (Male)	
Weight-at-length	$W=5.388 \times 10^{-6}L^{3.102}$ (Female); $W=3.293 \times 10^{-6}L^{3.225}$ (male)	$W=5.388 \times 10^{-6}L^{3.102}$ (Female); $W=3.293 \times 10^{-6}L^{3.225}$ (male)	Nakano (1994)
Length-at-50% Maturity	156.6 (Female)	156.6 (Female)	Fujinami et al. (2017)
Slope of maturity ogive	- 0.16 (Female)	- 0.16 (Female)	
Fecundity (Litter size; (4)eggs=a+b*L)	Proportional to body length	Proportional to body length	Fujinami et al. (2017)
Slope of fecundity (b)	0.46	0.46	
Intercept of fecundity (a)	-45.54	-45.54	
Spawning season	1	1	ISC (2017)
Spawner-recruit steepness (*h*)	0.670 (shape: BH)	0.613 (shape: BH)	Fujinami et al. (2021)
Recruitment variability (σ_R)	0.3	0.3	ISC (2017)
Main recruitment deviations	1990-2013	1971-2020	

Table 2. Estimates of age- and sex- specific natural mortality used in the previous and current stock assessment for North Pacific blue shark. The schedules are based on the allocation method with life history parameters.

Age	Previous		Update	
	Female	Male	Female	Male
0	0.785	0.728	0.787	0.726
1	0.488	0.492	0.489	0.491
2	0.370	0.383	0.371	0.382
3	0.306	0.320	0.307	0.320
4	0.267	0.279	0.267	0.279
5	0.240	0.251	0.240	0.251
6	0.221	0.230	0.221	0.230
7	0.207	0.214	0.207	0.214
8	0.196	0.202	0.196	0.202
9	0.187	0.192	0.187	0.192
10	0.180	0.184	0.180	0.184
11	0.175	0.177	0.175	0.178
12	0.171	0.172	0.170	0.172
13	0.167	0.167	0.167	0.168
14	0.164	0.163	0.164	0.164
15	0.161	0.160	0.161	0.160
16	0.159	0.157	0.159	0.158
17	0.157	0.155	0.157	0.155
18	0.156	0.153	0.156	0.153
19	0.155	0.151	0.154	0.151
20	0.154	0.149	0.153	0.150
21	0.153	0.148	0.152	0.148
22	0.152	0.147	0.151	0.147
23	0.151	0.146	0.151	0.146
24	0.151	0.145	0.150	0.145

Table 3. Fleet-specific selectivity assumptions used in the stock assessment for North Pacific blue shark. The selectivity curves for fisheries lacking length composition data were assumed to be the same (i.e., mirror gear) as a related fishery operating in the manner or area.

Fishery number	Reference Code	Selectivity assumption	Time block or time varying selectivity	Mirror gear
F1	MEX	Double-normal-24		Estimate
F2	CAN	Double-normal-24		F1
F3	CHINA	Double-normal-24		Estimate
F4	JPN_KK_SH	Double-normal-24		Estimate
F5	JPN_KK_DP	Double-normal-24		Estimate
F6	JPN_ENY_SH	Double-normal-24		F4
F7	JPN_ENY_DP	Double-normal-24		Estimate
F8	JPN_LG_MESH_EARLY	Double-normal-24	1973-1981, 1982-1993	Estimate
F9	JPN_LG_MESH_LATE	Double-normal-24		Estimate
F10	JPN_CST_OTH	Double-normal-24		F9
F11	SM_MESH	Double-normal-24(Sex combined)		Estimate
F12	IATTC	Double-normal-24		F1
F13	KOREA	Double-normal-24		F3
F14	NON_ISC	Double-normal-24		Estimate
F15	US_GIILL	Double-normal-24		Estimate
F16	US_SPORT	Double-normal-24		F15
F17	US_HW_DP	Double-normal-24		Estimate
F18	US_HW_SH	Cubic spline in length-27		Estimate
F19	TAIW_LG	Double-normal-24	2004-2020	Estimate
F20	TAIW_SM	Double-normal-24		Estimate
S1	US_HW_DP	Double-normal-24		F17
S2	US_HW_SH	Double-normal-24		F18
S3	TAIW_LG	Double-normal-24		F19
S4	TAIW_SM	Double-normal-24		F20
S5	JPN_EARLY	Double-normal-24		F4
S6	JPN_LATE	Double-normal-24		F4
S7	JPN_RTV	Double-normal-24		F7
S8	SPC_OBS	Double-normal-24		F14
S9	SPC_OBS_TROPIC	Double-normal-24		F14
S10	MEX	Double-normal-24		F1

Table 4. Summary of *CV*s for each fleet and recommended variance adjustment. CV_{min} and CV_{mean} denotes a minimum average *CV* and a mean *CV* for each CPUE series respectively.

Fleet	CV_{min}	CV_{mean}	Varaiance adjustment
S1: HW_DP	0.132	0.398	0.000
S3: TAIW_LG	0.360	0.064	0.136
S5: JPN_EARLY	0.065	0.012	0.188
S6: JPN_LATE	0.100	0.129	0.000
S7: JPN_RTV	0.128	0.130	0.000
S9: SPC_OBS_TROPIC	0.201	0.144	0.056
S10: MEX	0.170	0.066	0.134

Table 5. Multiplier and its 95% confidence intervals for fleets suggested by Francis data weighting method of length composition data.

Fleet name	Suggested multiplier	Lower 95% interval	Upper 95% interval
F1_MEX	1.2	0.8	3.3
F3_CHINA	70.4	43.4	158.1
F4_JPN_KK_SH	0.3	0.2	1.1
F5_JPN_KK_DP	23.2	15.4	219.1
F7_JPN_ENY_DP	2.9	1.2	20.1
F8_JPN_LG_MESH_EARLY	4.5	2.3	681.7
F9_JPN_LG_MESH_LATE	10.4	6.0	32.2
F14_NON_ISC	77.2	53.6	193.0
F15_USA_GIILL	19.4	13.6	34.3
F17_USA_Lonline_DP	118.4	66.9	530.3
F18_USA_Lonline_SH	21.8	12.8	69.9
F19_TAIW_LG	4.5	2.7	11.5
F20_TAIW_SM	7.8	5.7	21.9

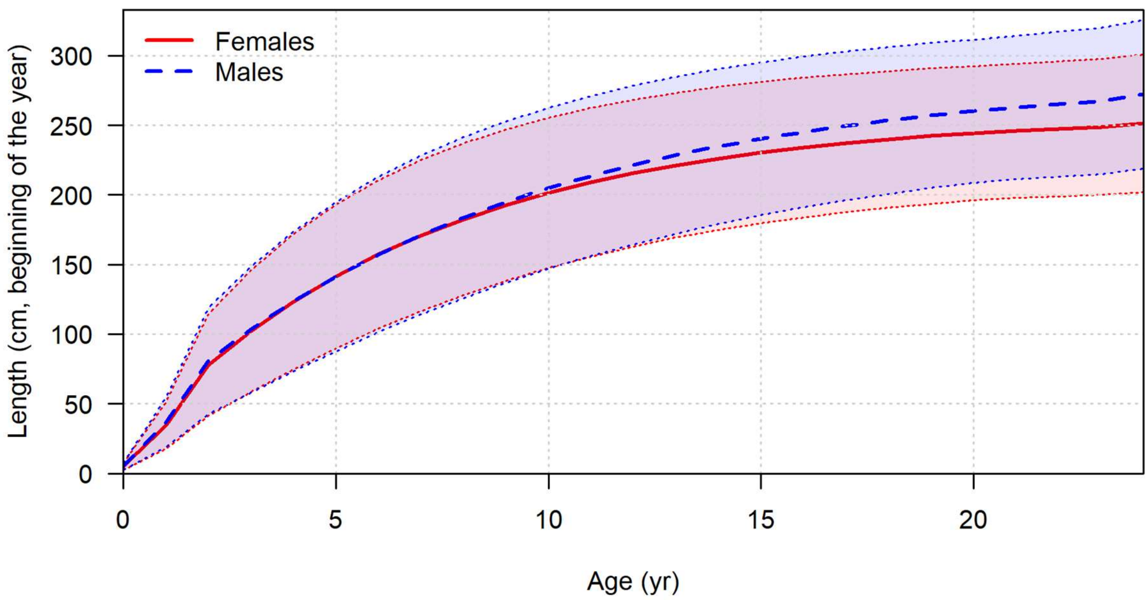

Figure 1. The sex-specific length-at-age for female and male blue shark used in the stock assessment.

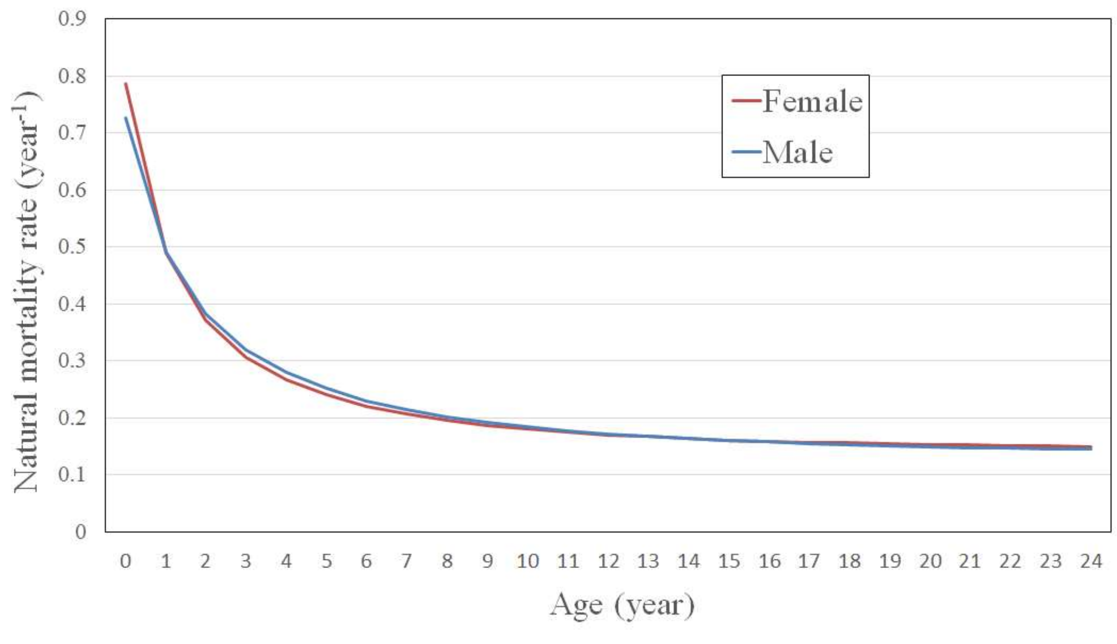

Figure 2. The sex-specific natural mortality schedule for blue shark used in the stock assessment.

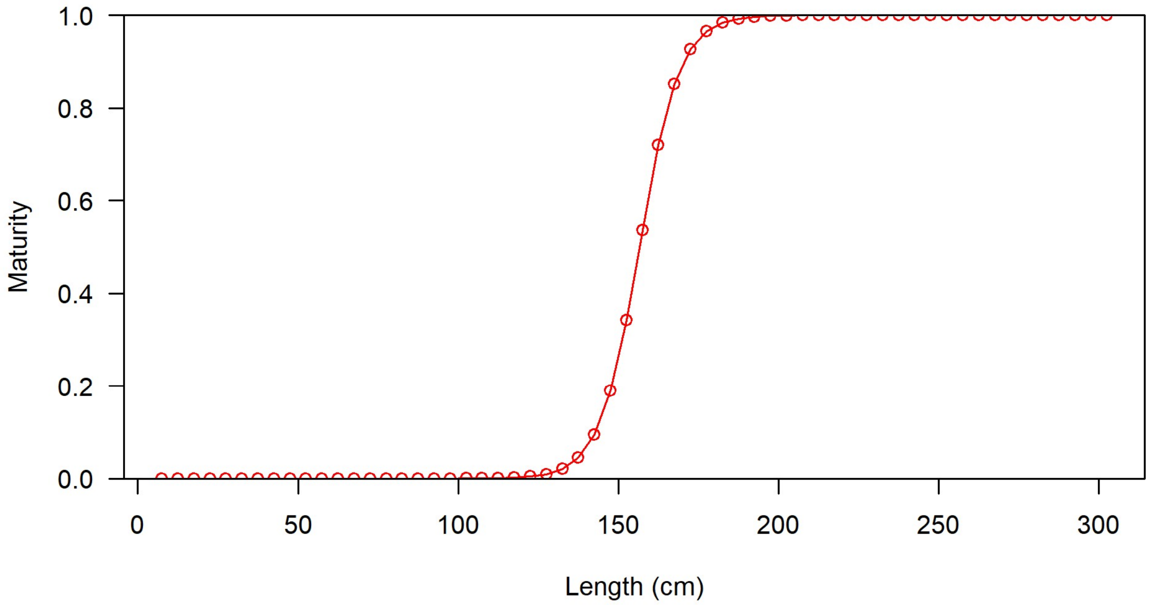

Figure 3. The maturity-at-length for female blue shark used in the stock assessment.

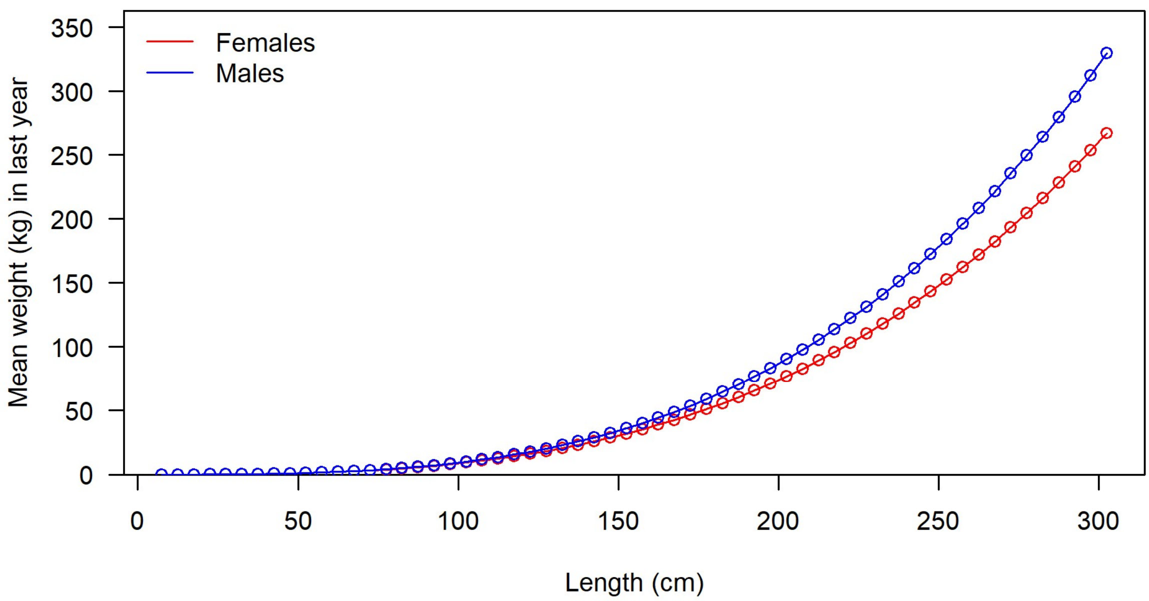

Figure 4. The sex-specific weight-at-length for female and male blue shark used in the stock assessment.

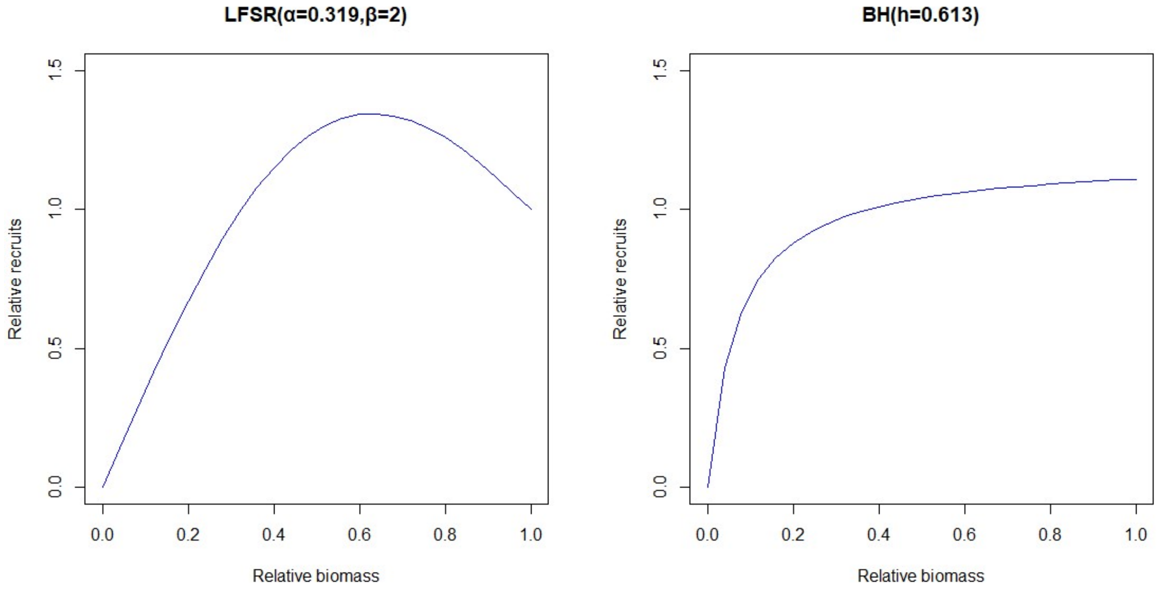

Figure 5. The low-fecundity stock-recruitment (SR) relationships used in the stock assessment in 2017 and the Beverton-Holt SR-relationships used in the base-case model of this assessment in 2022.

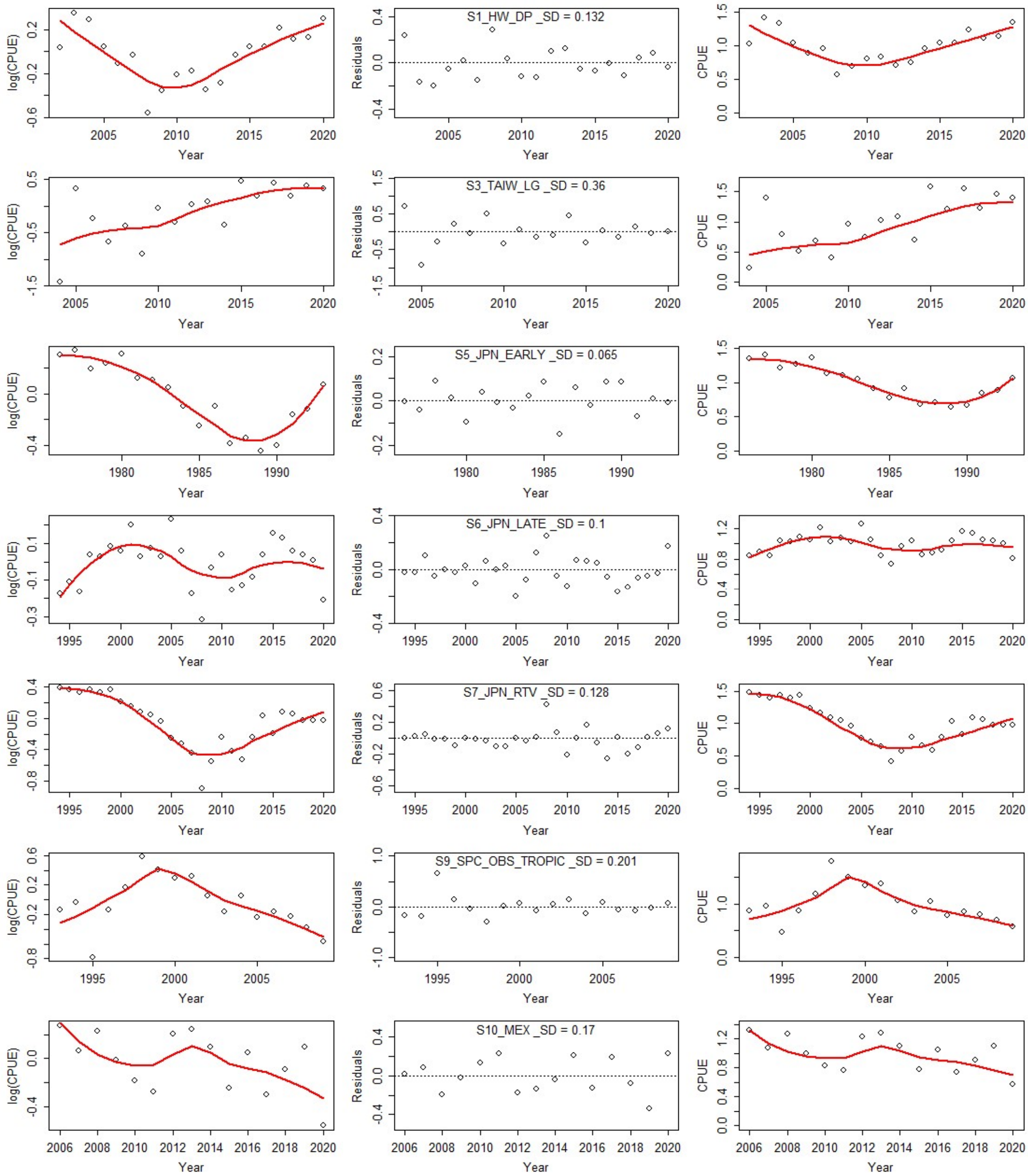

Figure 6. Annual changes in logarithmic CPUE, residuals between fitted and observed CPUE on the log-scale and observed CPUE for each fleet. The red curves denote the fit of CPUE using a LOESS smoother.