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Update stock assessment based on ASAP (age-structured assessment program) for Chub mackerel in the North Pacific Ocean

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Introduction

To support the development of operating model for Chub mackerel *Scomber Japonicus*, this research established an Age-Structured Assessment Program (ASAP), which is the one of four stock assessment model candidates (ASAP, SAM, VPA, and KAFKA) for Chub mackerel in the NPFC. This document provided the progress of ASAP for Chub mackerel, updating based on the preliminary exploration in NPFC-2020-TWG CMSA03-WP09. The updated ASAP, considered all scenarios, which were adopted in the last meeting of the technical working group for Chub mackerel stock assessment (TWG CMSA03). Additionally, the new natural mortality estimates were also applied in this research.

Materials and methods

The dataset used in this study, was still the data that China, Japan and Russia submitted in September, 2020, and complied by Dr. Shota Nishijima. This dataset includes catch-at-age, maturity-at-age, weight-at-age and abundance index. To be consistent with Japanese indices and to simplify the stock assessment model fitting process, the indices from China and Russia were all scaled by their mean values (Figure 1). The natural mortality *M* were derived from NPFC-2019-TWG CMSA02-WP01 (Rev.2), which were the median estimate 0.41 and age-specified *M* from Gislason 1 method.

Based on the above dataset, 6 scenarios were set for operating model, considering the different *M* estimates, different trend of maturity and weight at age among three members (Table 1). There were two base case models and four reference cases as sensitivity analysis. In the SWG OM01 intersessional meeting on 26 April 2021, Japanese scientists update the estimates for natural mortality, which are much higher than the estimates from NPFC-2019-TWG CMSA02-WP01 (Rev.2). Even there are some unsolved model fitting issues for von Bertalanffy parameters, the updated *M* parameters were also considered.

ASAP is a fisheries toolbox model developed by NOAA, which has been used as an assessment tool for many fisheries, such as Pacific sardine and Pacific mackerel by SWFSC, Greenland halibut by ICES, etc. ASAP is an age-structured model that uses forward computations assuming separability of fishing mortality into year and age components to estimate population sizes given observed catches, catch-at-age, and indices of abundance.

Results and discussions

Estimated catch were fitted well through all 12 scenarios, while the abundance indices fittings were various among different indices (Figure 2). The indices from Japanese and Chinese fisheries fitter reasonably well, while the CPUE derived from Russia fishery fitted not well. The indices derived from fishery-independent survey only fitted well in the previous years. Results of objective function indicated that the constant *M* among ages could improve the model fitting (Table 2). The reference cases with lowest weight and maturity performed similar with base cases, while the S3 and S4 with highest weight and maturity fitter much worse. The scenario with updated higher *M* estimates, performed worse than others. The base case 1, with constant M=0.41 and average data among three members, performed best among these 12 scenarios, with no obvious retrospective pattern (Figure 12).

The overall trends of total stock number, spawning stock biomass (SSB), and fishing mortality (*F*) were much similar among these 12 scenarios. The biomass of Chub mackerel has kept at high level before 1980, then declined to low value, recovered since 2010, with a similar trend of abundance and spawning stock biomass (Figures 3-5). During 1985~2005, the fishing mortality for Chub mackerel was high, and stock abundance was much low (Figures 6-8).

There are no significant difference of abundance and fishing mortality estimates among all scenarios. The reference cases with highest maturity and weight matrix (S3 and S4), would provide much higher estimate for SSB, while SSB estimates from reference cases with lowest maturity and weight matrix (S5 and S6), were much lower (Figures 3-8). The scenarios with higher *M* estimated higher abundance and SSB with lower *F*, compared with other scenarios.

The maximum sustainable yield (MSY) for Chub mackerel was estimated to be 1.75×10^5 and 1.65×10^5 metric tons from S1_41 and S2_age, respectively (Table 1). The fishing mortality and SSB in the MSY level were about 1.32 and $0.62\sim0.63\times10^5$ metric tons, respectively. The Kobe plots revealed that the stock of Chub mackerel was almost in the green zone, indicating this stock has not been overfished or subject to overfishing in the last 50 years (Figures 9-11). However, the estimates of SSB/SSB_{MSY} were extremely high, with too lower estimates of SSB_{MSY}.

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Tables

Table 1 Operating model setting for Chub mackerel in the North Pacific Ocean

	Scenarios	**M**	**Weight-at-age**	**Maturity-at-age**	**Catch-at-age**	**Abundance Index**	**Fleet**
Base cases	S1_41_average	0.41	Average	Average	Average	All six	Single
	S2_age_average	Gislason at age	Average	Average	Average	All six	Single
Reference cases	S3_41_high	0.41	Highest	Highest	Average	All six	Single
	S4_age_high	Gislason at age	Highest	Highest	Average	All six	Single
	S5_41_low	0.41	Lowest	Lowest	Average	All six	Single
	S6_age_low	Gislason at age	Lowest	Lowest	Average	All six	Single

Table 2 Model fitting and estimations for Chub mackerel by all ASAP scenarios

Scenarios	**Objective function**	$F_{0.1}$	F_{max}	$F_{30\%SPR}$	$F_{40\%FPR}$	F_{MSY}	F_{2019}	**SSB_{MSY} (t)**	**MSY (t)**
M 2019									
S1_41_average	2310	0.47	1.68	0.45	0.31	1.32	0.18	62030	175333
S2_age_average	2323	0.32	7.88	0.32	0.21	1.32	0.21	63276	165655
S3_41_high	2314	0.42	0.80	0.62	0.44	0.78	0.14	312256	235106
S4_age_high	2328	0.34	0.74	0.51	0.34	0.71	0.16	340732	229258
S5_41_low	2311	0.42	1.34	0.31	0.22	0.89	0.20	34735	145901
S6_age_low	2323	0.28	7.88	0.24	0.17	0.77	0.24	50299	138553
M updated									
S1_53_average	2348	0.69	7.83	0.60	0.41	2.23	0.16	35430	209399
S2_age_average	2365	0.61	7.79	0.51	0.35	2.34	0.18	34447	204362
S3_53_high	2349	0.54	1.29	0.78	0.55	1.19	0.12	219503	256650
S4_age_high	2367	0.50	7.79	0.74	0.51	1.32	0.14	191668	246143
S5_53_low	2350	0.61	7.83	0.37	0.27	1.23	0.18	17733	165077
S6_age_low	2366	0.53	7.78	0.33	0.23	1.23	0.20	17848	156148

Figures

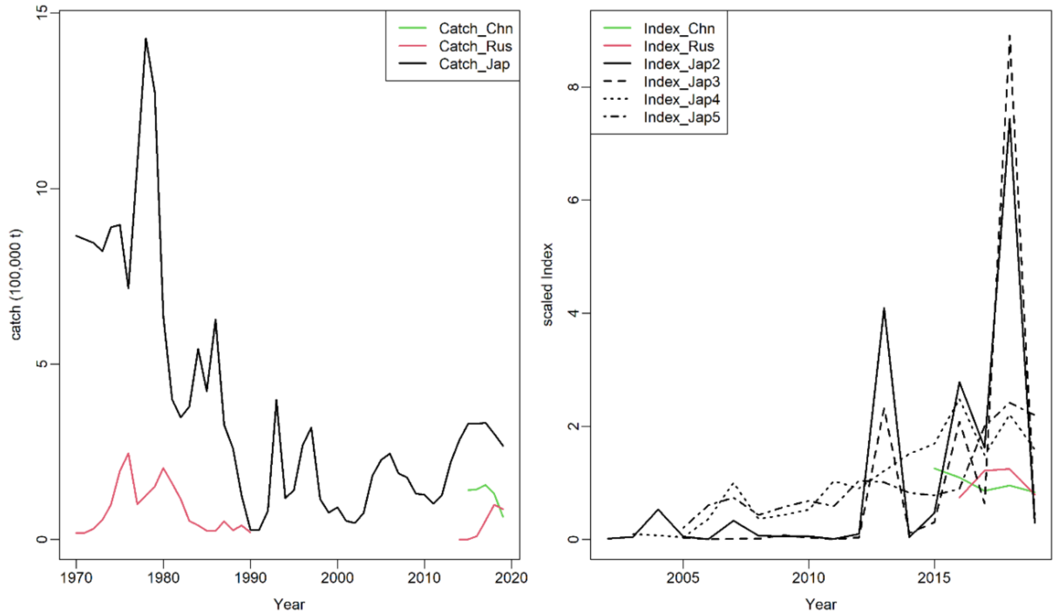


Figure 1. Catch and abundance index of Chub mackerel fisheries of China, Japan and Russia in the north Pacific Ocean from 1970 to 2019

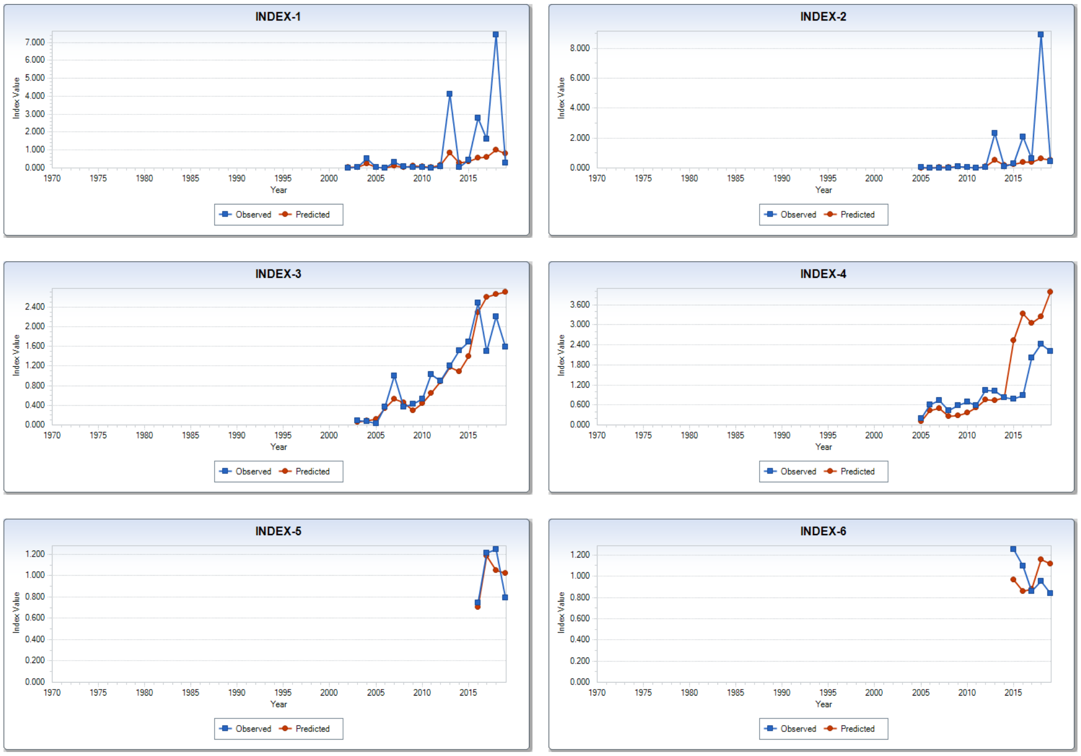


Figure 2. Index fitting in the ASAP Base Case 1 for Chub mackerel.

INDEX-1 represents the Index_Jap2, form the Japanese Recruitment survey in summer.
INDEX-2 represents the Index_Jap3, form the Japanese Recruitment survey in autumn.
INDEX-3 represents the Index_Jap4, form the Japanese die-net fishery.
INDEX-4 represents the Index_Jap5, form the Japanese egg survey.
INDEX-5 represents the CPUE from Chinese fishery.
INDEX-6 represents the CPUE from Russian fishery.

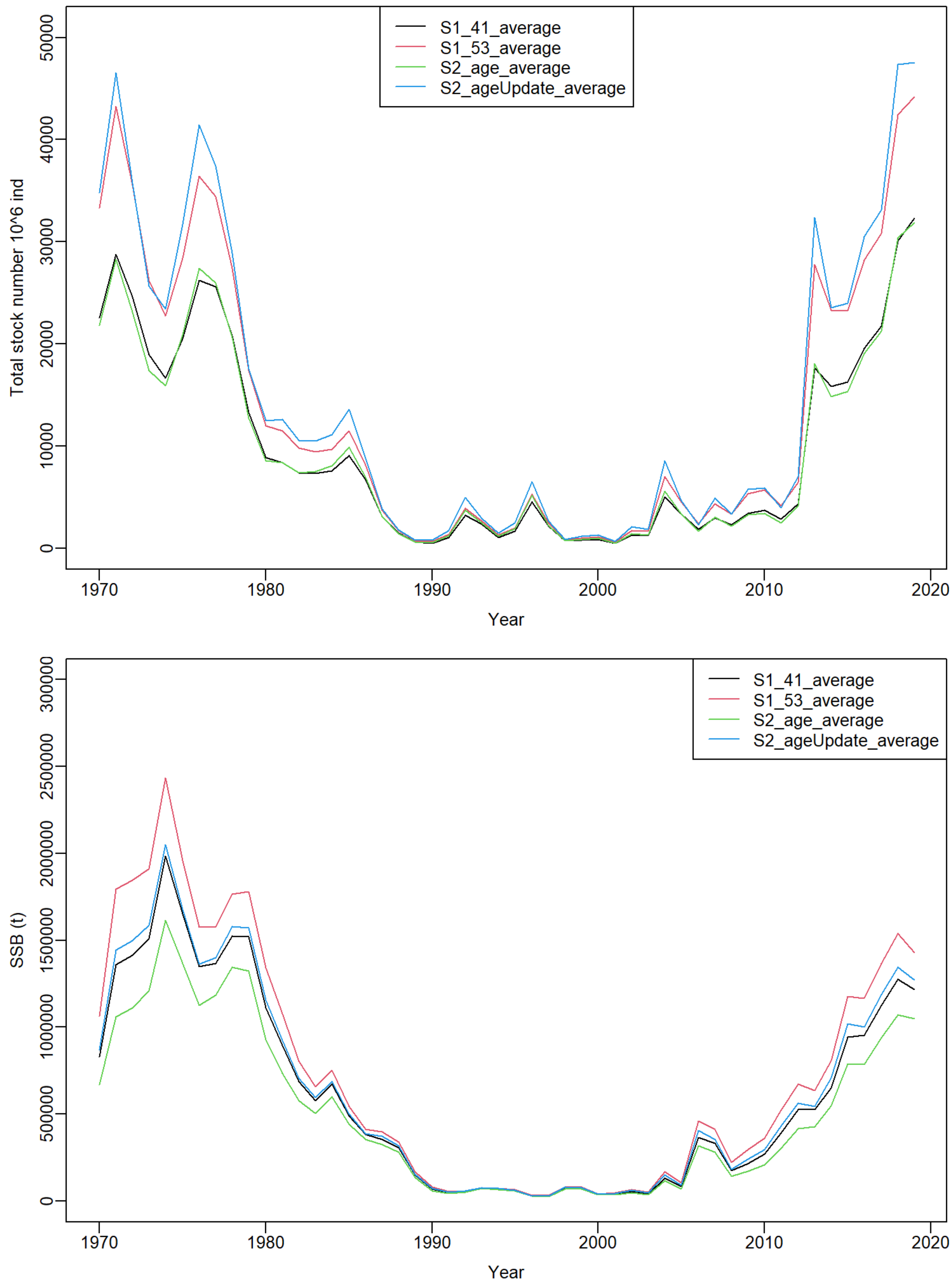


Figure 3. The abundance and SSB estimates from ASAP Base cases 1&2 for Chub mackerel

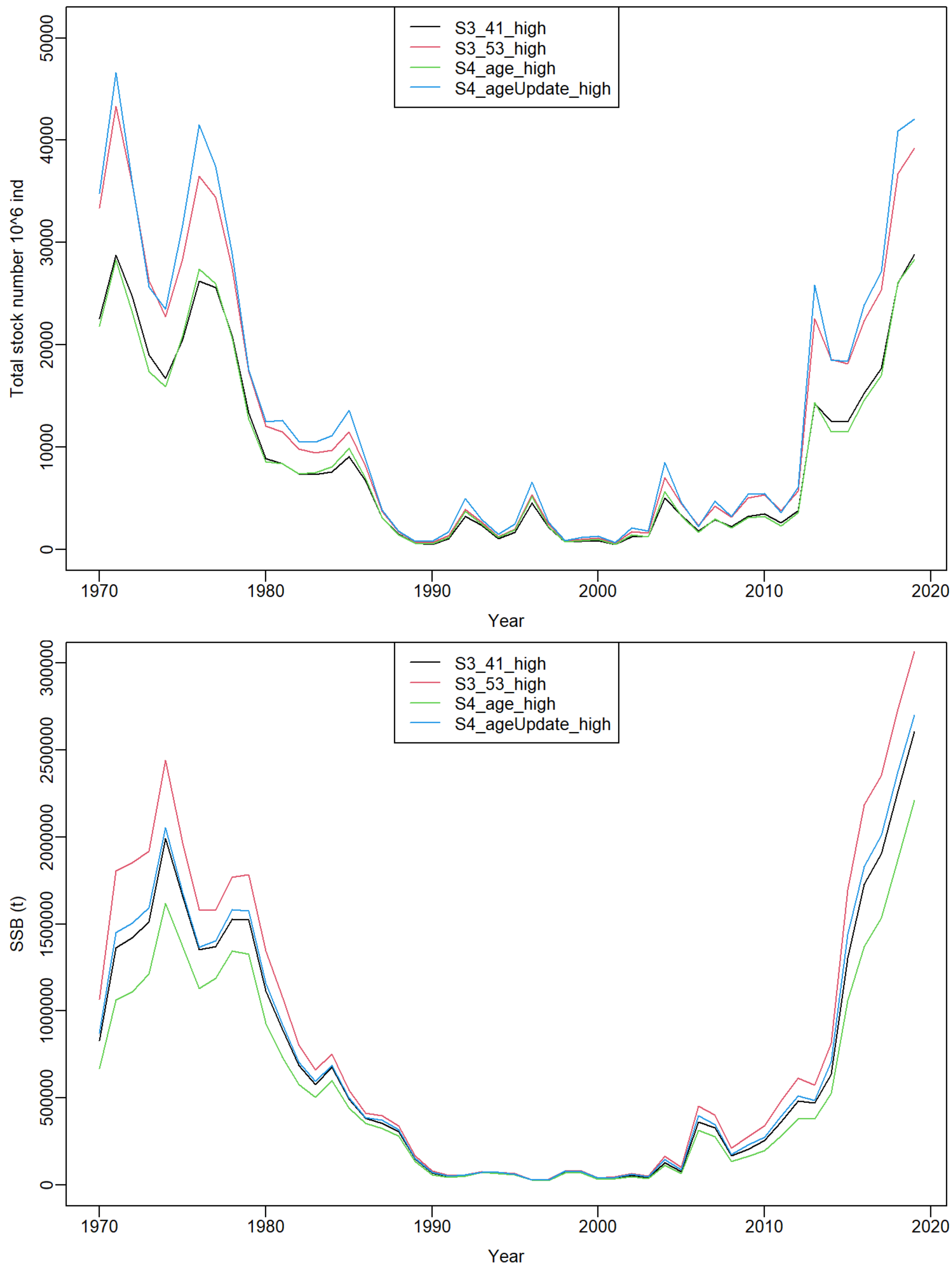
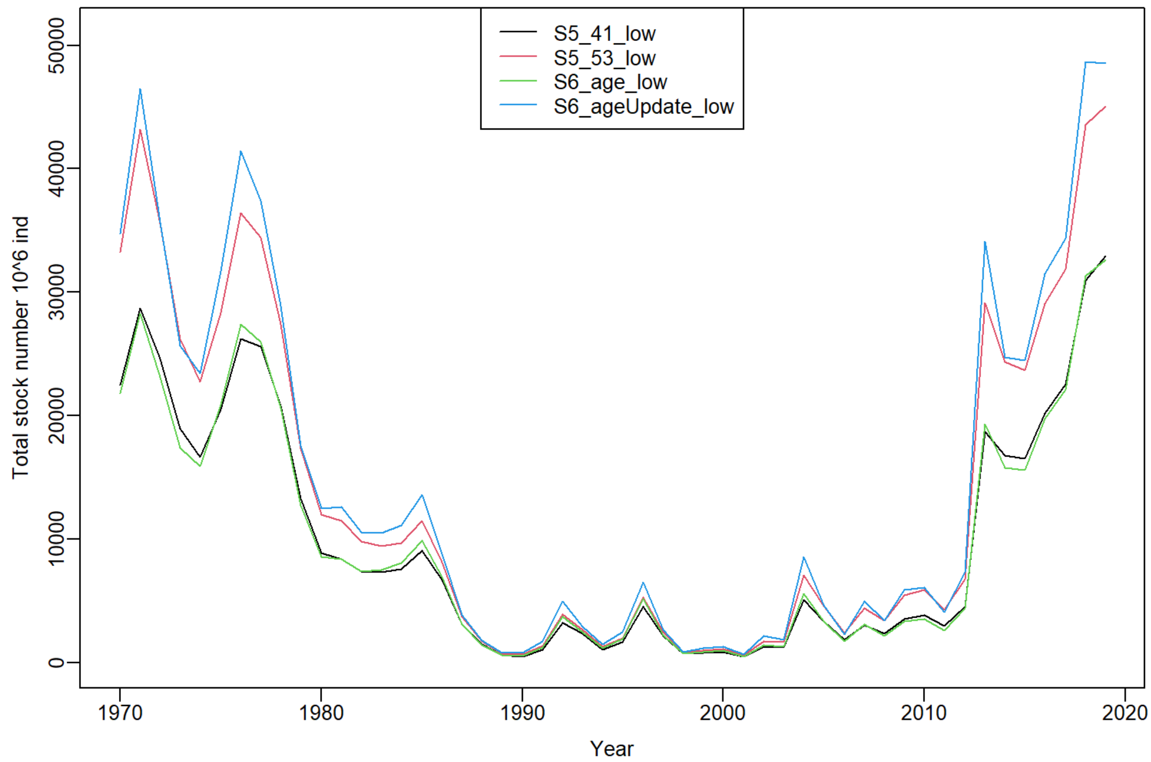


Figure 4. The abundance and SSB estimates from ASAP Reference cases 3&4 for Chub mackerel



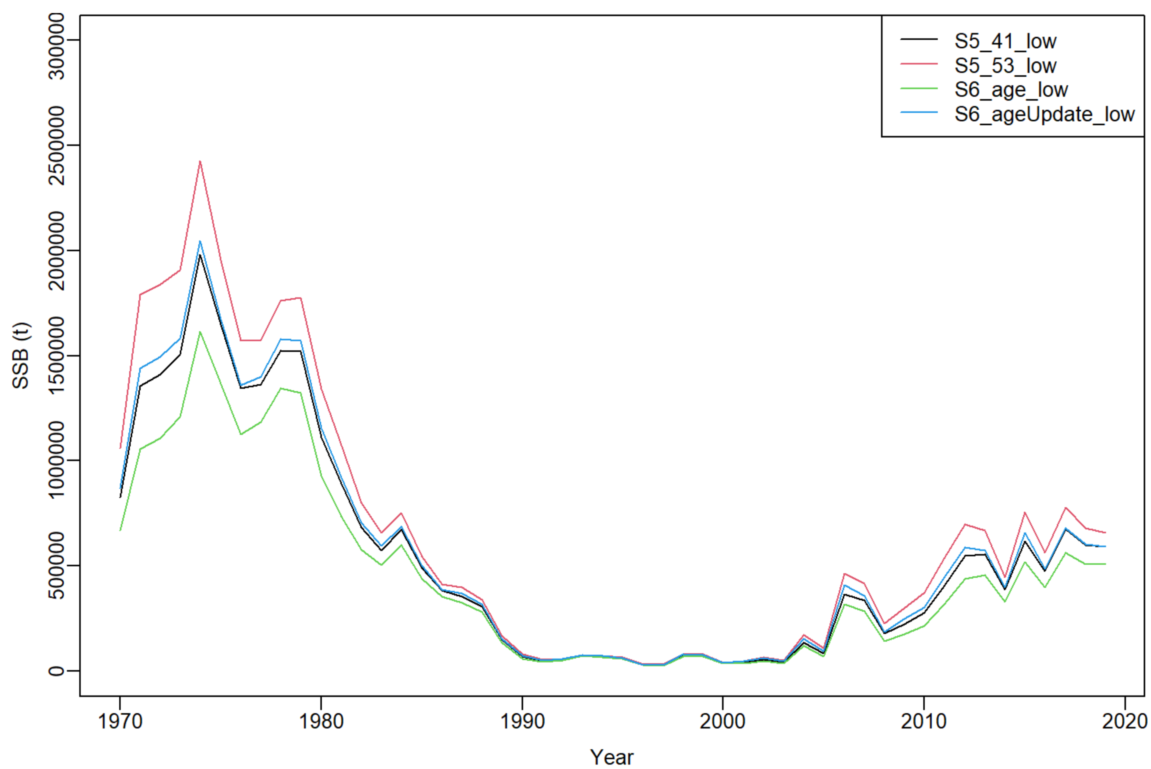


Figure 5. The abundance and SSB estimates from ASAP Reference cases 5&6 for Chub mackerel

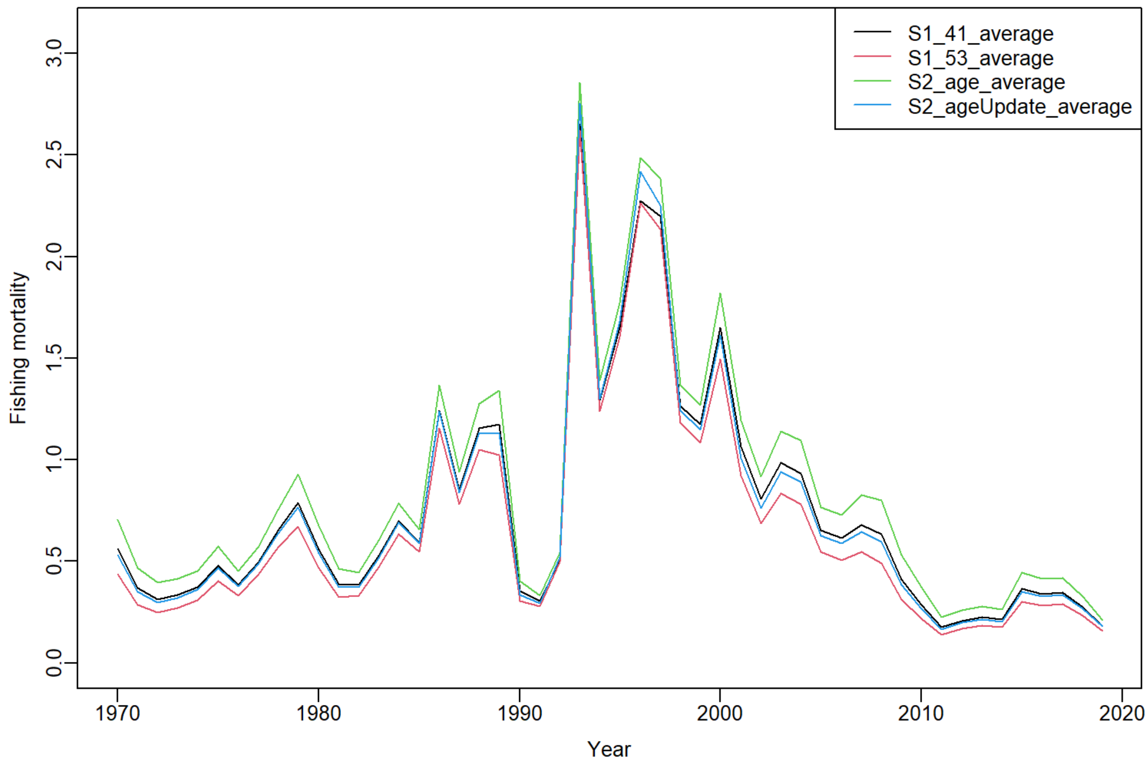


Figure 6. The fishing mortality estimates from ASAP Base Cases 1&2 for Chub mackerel

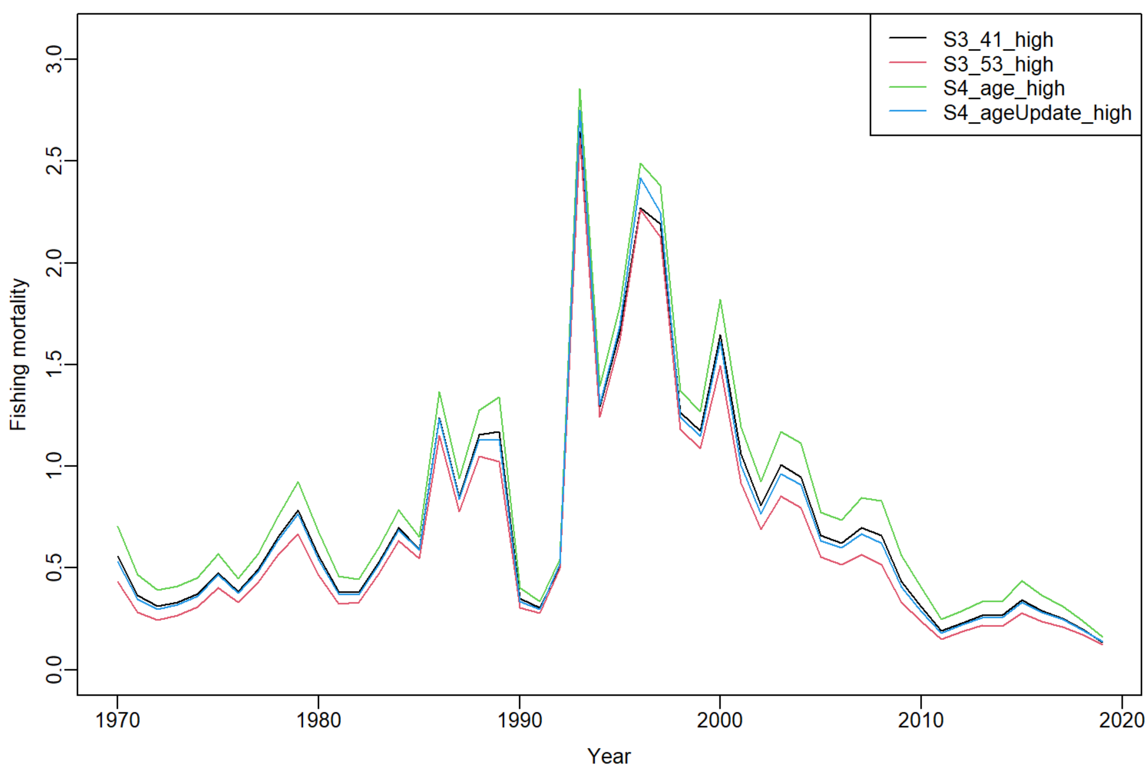


Figure 7. The fishing mortality estimates from ASAP Reference Cases 3&4 for Chub mackerel

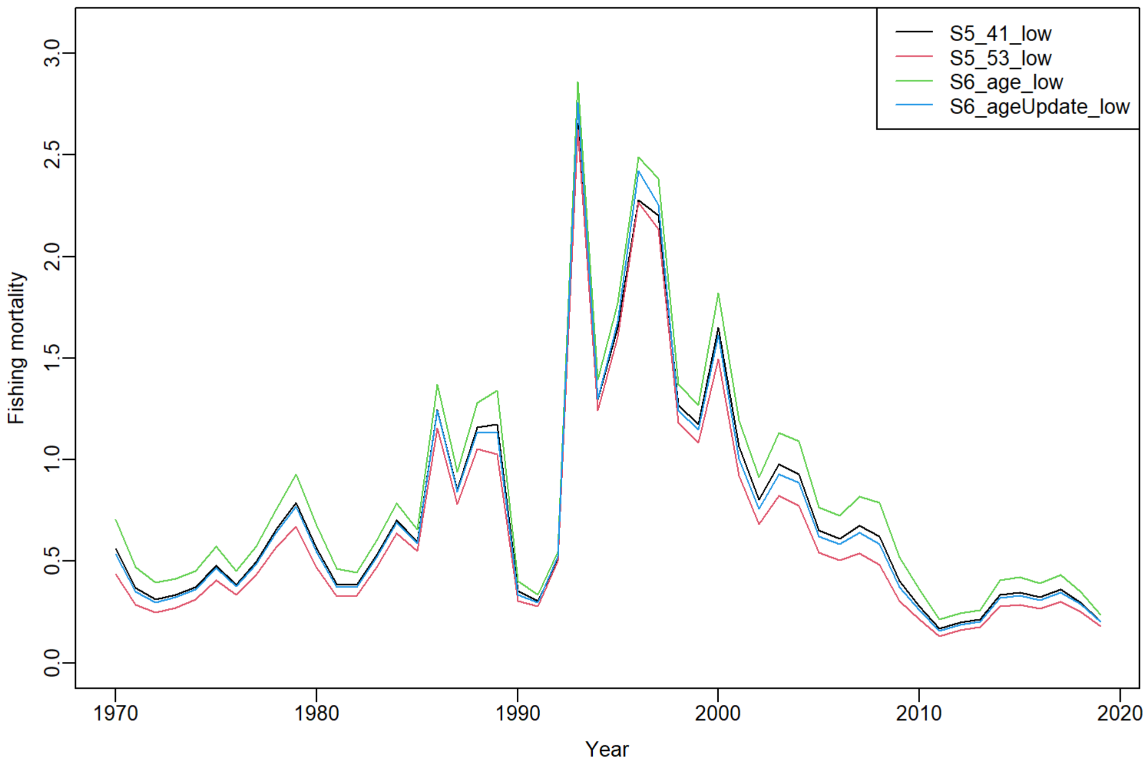


Figure 8. The fishing mortality estimates from ASAP Reference Cases 5&6 for Chub mackerel

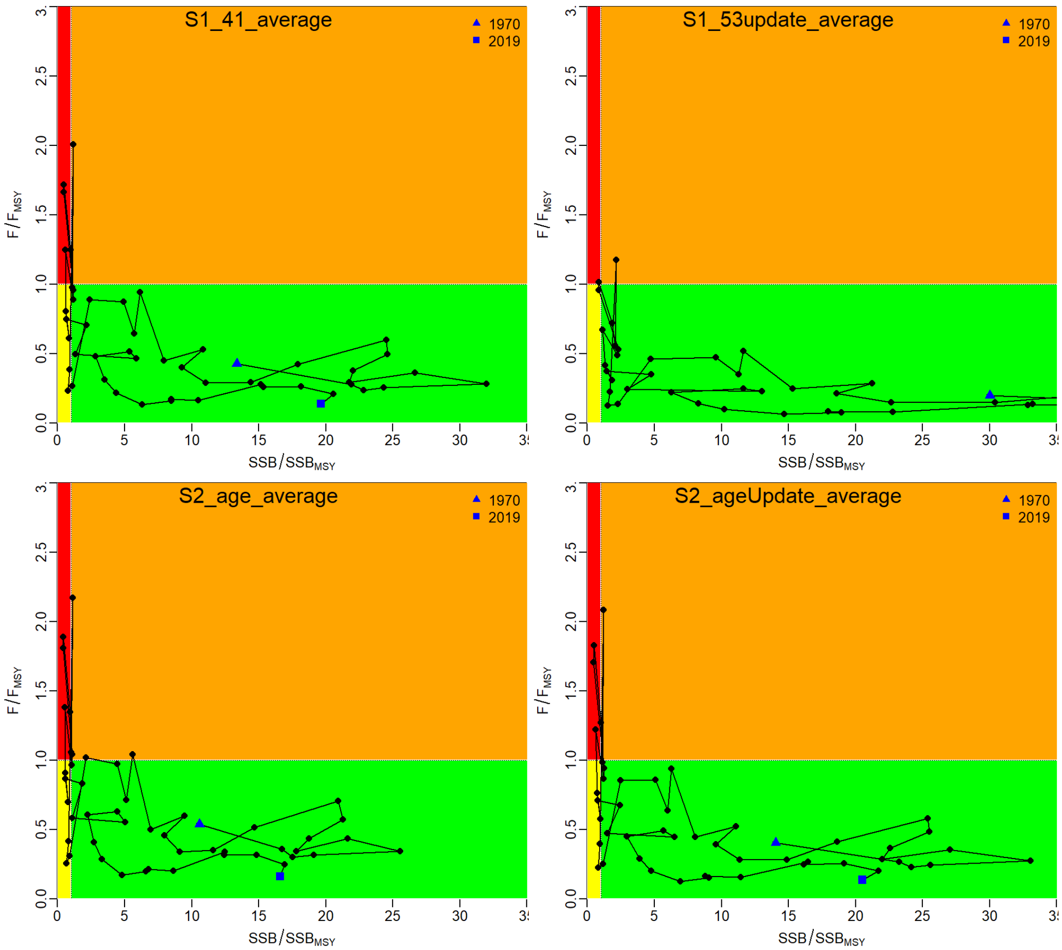


Figure 9. The Kobe plot among 1970-2019 from ASAP Base Case 1&2 for Chub mackerel.

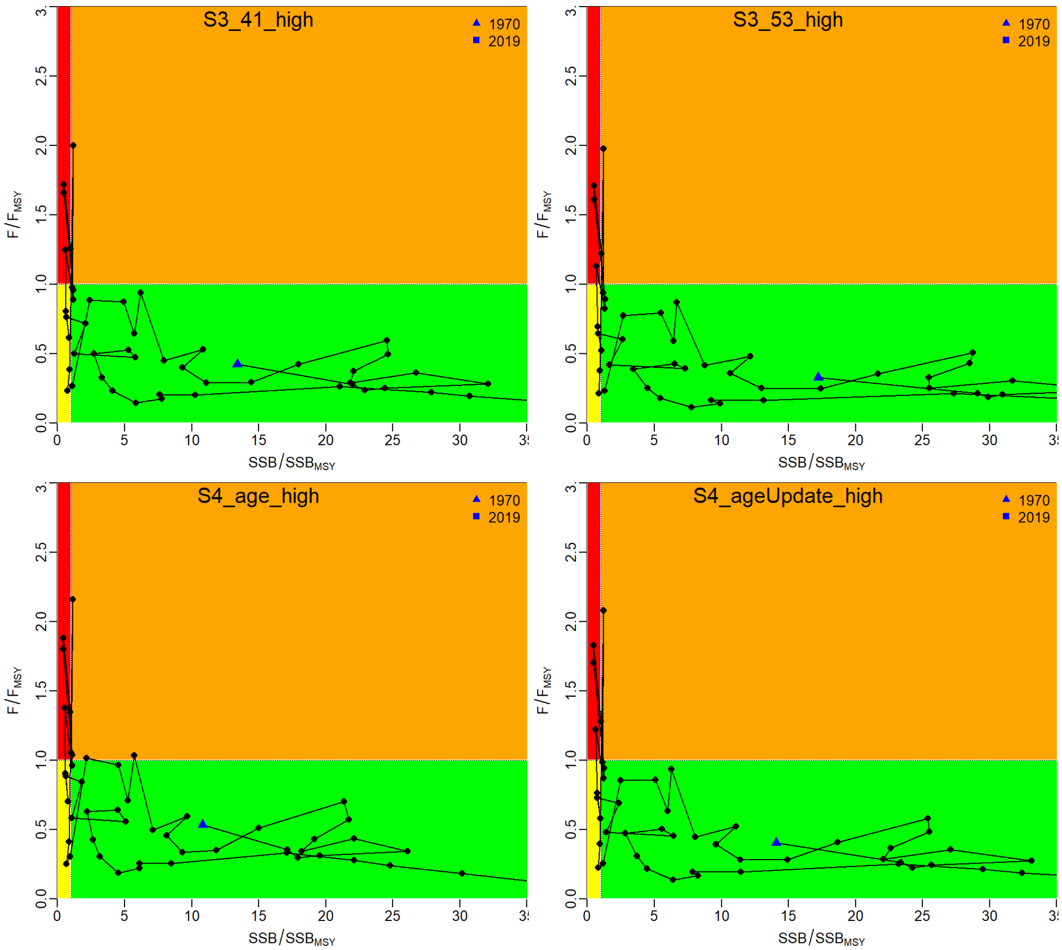


Figure 10. The Kobe plot among 1970-2019 from ASAP Reference Case 3&4 for Chub mackerel.

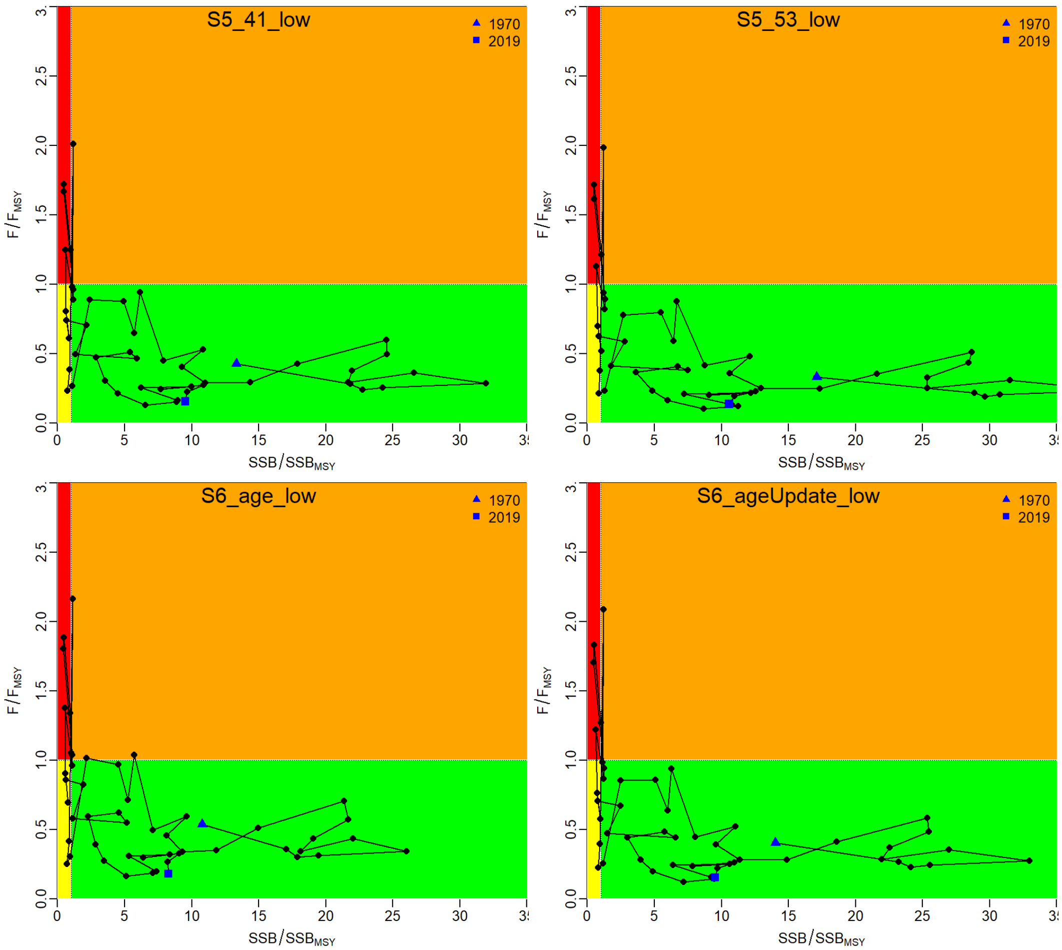
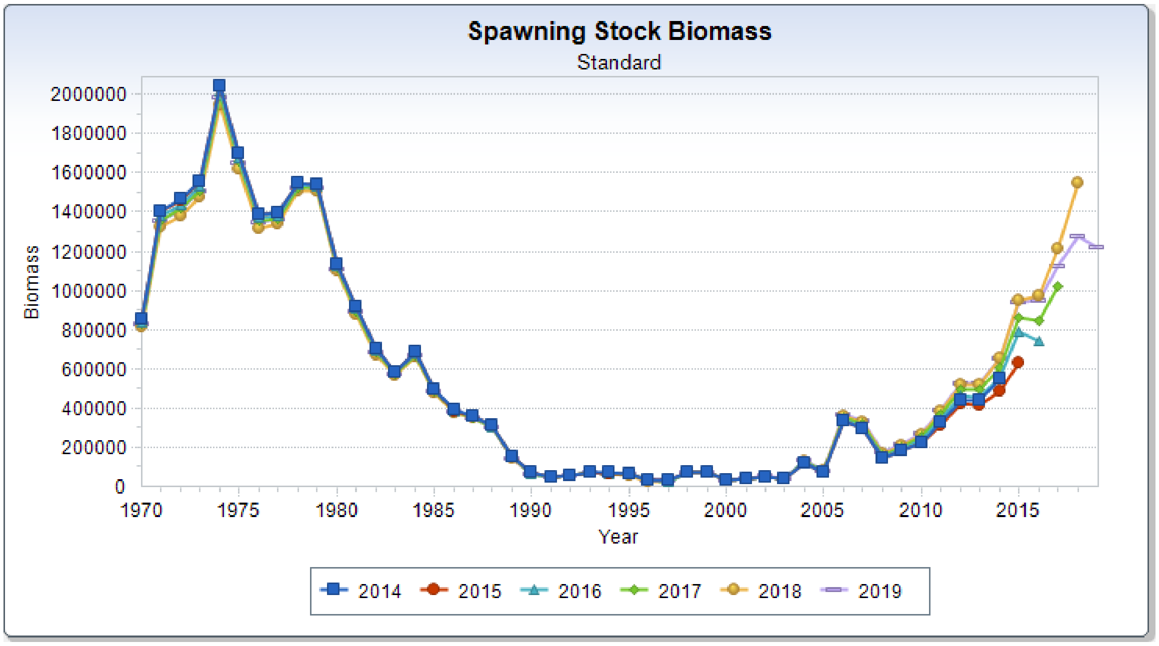


Figure 11. The Kobe plot among 1970-2019 from ASAP Reference Case 5&6 for Chub mackerel.



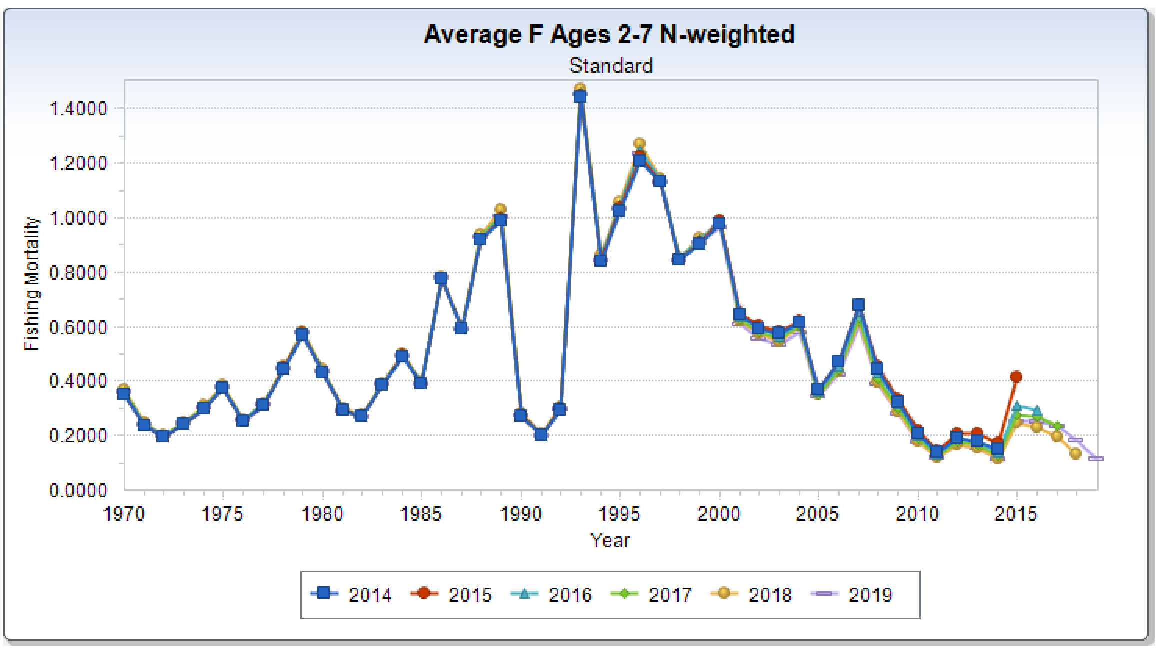


Figure 12. The retrospective pattern of spawning stock biomass and fishing mortality from ASAP S1_41_average for Chub mackerel. (Mohn's Rho= -0.11692 and 0.16115, for SSB and *F*, respectively)

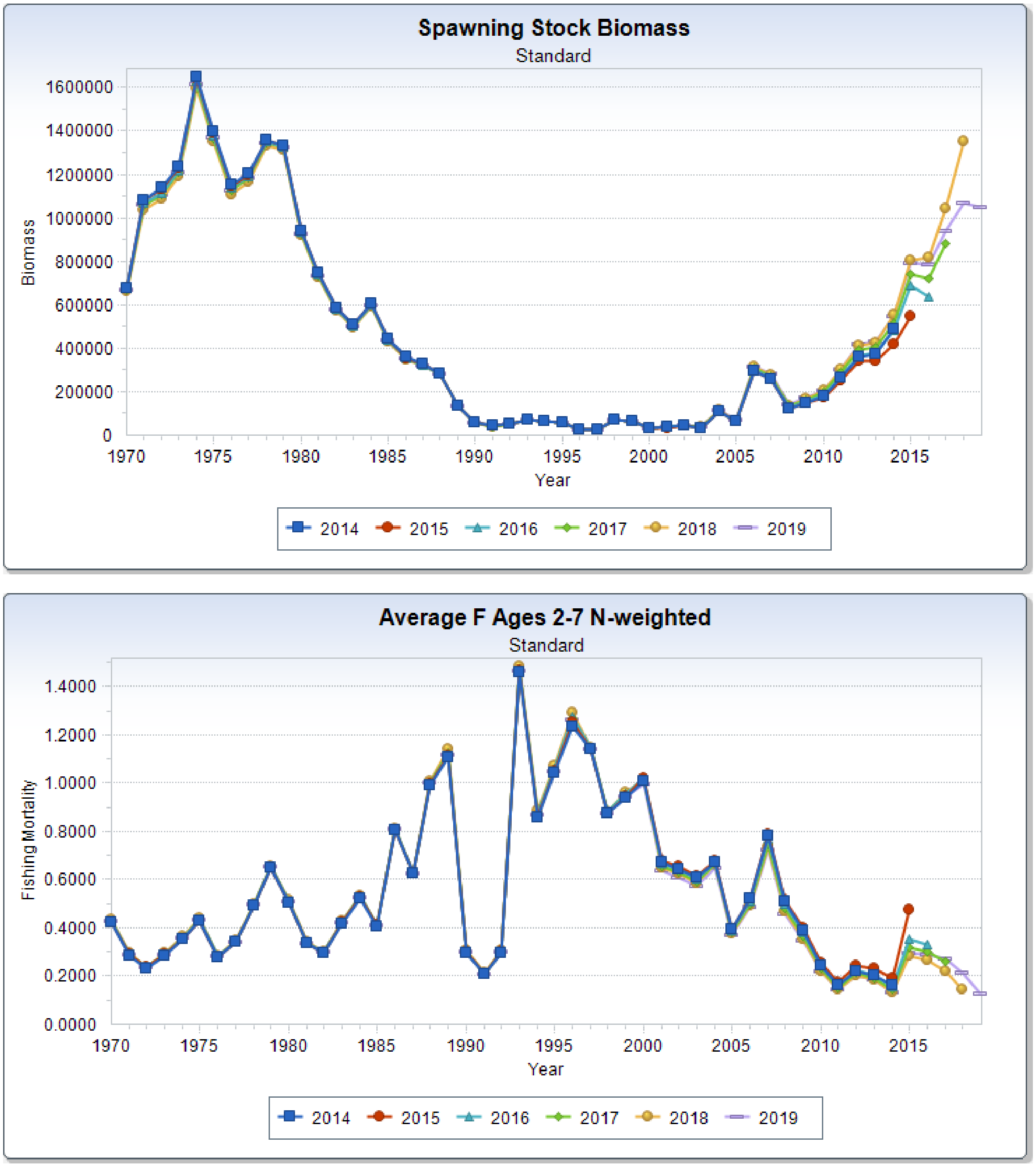


Figure 13. The retrospective pattern of spawning stock biomass and fishing mortality from ASAP S2_age_average for Chub mackerel. (Mohn's Rho= -0.08040 and 0.11379, for SSB and *F*, respectively)