North Pacific Fisheries Commission

NPFC-2020-TWG CMSA03-WP09 (Rev. 1)

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

Member: **China**

Introduction

Chub mackerel *Scomber Japonicus* is one of the most important fishery species in the North Pacific Ocean, as a priority species managed by the North Pacific Fisheries Commission (NPFC). Three members (China, Japan and Russia) have considerable fisheries targeting Chub Mackerel in their national waters and/or the conventional area, while Japan has conducted a regular stock assessment for Chub mackerel in recent years with rich available data. The technical working group for Chub mackerel stock assessment (TWG CMSA) in NPFC has started the studies for this important species, and is now focusing on the development of an operating model to evaluate the candidate stock assessment models for Chub mackerel. In this study, Age-Structured Assessment Program (ASAP), one candidate model, was explored preliminarily based on data from China, Japan and Russia.

Materials and methods

Data

According to the meeting report of TWG CMSA02, members agreed to submit their available data to be used in the development of the operating model for Chub mackerel. China, Japan and Russia all shared fishery-dependent and fishery-independent data by September, 2020, with much intersessional discussion and update before TWG CMSA03.

Several different gears were used in the fisheries for Chub mackerel, i.e. purse seine and pelagic trawl for China, purse seine, mid-water trawl and stick-held dip net for Russia, purse seine and bottom trawl for Japan. Therefore, with different gears and fishing area and effort, catch of three members show different trends (Figure 1). Since the start year of the operating model is 1970, whether to include the catch of Russia during 1970~1990 or not is a major concern. The catch of Russia (derived from NPFC-2019-TWG CMSA02-WP05) is about a quarter of the total Chub mackerel fishery during 1970~1990, which should not be ignored. In the two models of this study, these data were excluded.

The approaches for calculating the abundance index also varies among different fleets, and the CPUE indices were not standardized. The inconsistency of data treatment among fleets leads to many difficulties during the stock assessment, which requires much discussion and improvement during the TWG CMSA03. There are four abundance indices from Japan, while only one index from China and one index from Russia (Figure 1). 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 means. The selectivity of the recruitment and egg indices was hard to assume and estimate, which could lead to a model convergence problem. Therefore, these indices were not used in the stock assessment model, while the egg index was considered in the separate model 1.

In this study, two models were constructed based on ASAP for Chub mackerel. In Model 1, data from three members were included separately, while Model 2 used merged data. However, due to the model diagnostic problem, not all the data were input to the ASAP. For example, the weight matrix and catch-at-age data are only from Japan. The natural mortality data were derived from NPFC-2019-TWG CMSA02-WP01 (Rev.2), which was estimated by Gislason 1 method to be age-specified.

Age-Structured Assessment Program

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. ASAP allows fleet-specific computations, with time-varying catchability and selectivity associated with each abundance index. In the ASAP, input data should be available for most years, but missing years are allowed.

The expected recruitment R was estimated from spawning stock biomass (SSB) based on the Beverton and Holt stock recruitment relationship in ASAP. The SSB is calculated based on the population abundance at age (N_a), the fecundity (φ), and the proportion of the total mortality (Z) during the year prior to spawning (p_{SSB}) as

$$SSB_t = \sum_a N_{t,a}\phi_{t,a}e^{-p_{SSB}Z_{t,a}}$$

The total mortality is calculated based on the natural mortality *M*, selectivity *Sel* and fishing mortality *F* over all fleets, when there is no discard,

$$Z_{t,a} = M_{t,a} + \sum_{ifleet} F_{ifleet,t,a} = M_{t,a} + \sum_{ifleet} Fmult_{ifleet,t,a}Sel_{ifleet,t,a}$$

Other details of ASAP calculation process could be found in the technique manual. In this study, the stock assessment was constructed based on the ASAP version 3.0.17 (Legault and Restrepo, 1998). Monte Carlo Markov Chain (MCMC) is used to estimate uncertainty and confidence intervals, with a thinning rate of 100 and total of 2000 iterations saved. The retrospective analysis was conducted with 5 years of data successive removed (2015~2019).

Results and discussions

Based on the two ASAP models, the catch and several indices were fitted well, except the index_Jap5 in Model 1 during 2013~2019, which is the absolute numbers of eggs for tuning spawning stock biomass (Figures 2 and 7). However, due to the much-limited time coverage of the indices from China and Russia, there is a substantial retrospective pattern for fishing mortality and spawning stock biomass (Figures 3 and 8).

The biomass of Chub mackerel kept at high level before 1980, then declined to low value, recovered since 2005, but declined again in recent years, with a similar trend of abundance and spawning stock biomass (Figures 4 and 9). The fishing mortality during

1985~2005 was high for Chub mackerel, with much low stock abundance in this period (Figures 5 and 10).

The maximum sustainable yield (MSY) for Chub mackerel was estimated to be 2.16×10^5 and 3.04×10^5 metric tons from Model 1 and Model 2, respectively, while the total catch in 2019 is 4.18×10^5 metric tons (Table 1). The fishing mortality and SSB in the MSY level were about 0.15 and $9.17\sim13.0\times10^5$ metric tons, respectively. The Kobe plots revealed that the stock of Chub mackerel was almost in the red zone, indicating this stock has been overfished and subject to overfishing in the last 50 years (Figures 6 and 11).

The model diagnostic suggested the current ASAP model did not perform well, with strong retrospective bias. The 50-year worse stock status without stock depletion but recovery, is also an unreasonable situation. Besides the model configuration and assumptions, the availability and quality of data for Chub mackerel have a large influence on the stock assessment results and model performance as well. For example, the inclusion of catch data of Russia from 1970~1988, the treatment of unstandardized CPUE data from three members, and the merge approach of data from different fleets require much more discussions during the TWG CMSA meeting.

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Tables

Table 1 Estimations of parameters and reference points from Model 1 and Model 2

	Model 1 (separate)	**Model 2 (merged data)**
$F_{0.1}$	0.28	0.28
F_{max}	7.06	7.13
$F_{30\%SPR}$	0.267	0.274
$F_{40\%FPR}$	0.182	0.186
F_{MSY}	0.150	0.151
F_{2019}	0.38	0.66
SSB_{MSY} (t)	9.17×10^{5}	13.0×10^{5}
MSY (t)	2.16×10^{5}	3.04×10^{5}
q_{Jap4}	3.38×10^{-6}	4.28×10^{-6}
q_{Jap5}	2.41×10^{-3}	
q_{Rus}	1.63×10^{-6}	2.25×10^{-6}
q_{Chn}	0.68×10^{-6}	0.69×10^{-6}

Figures

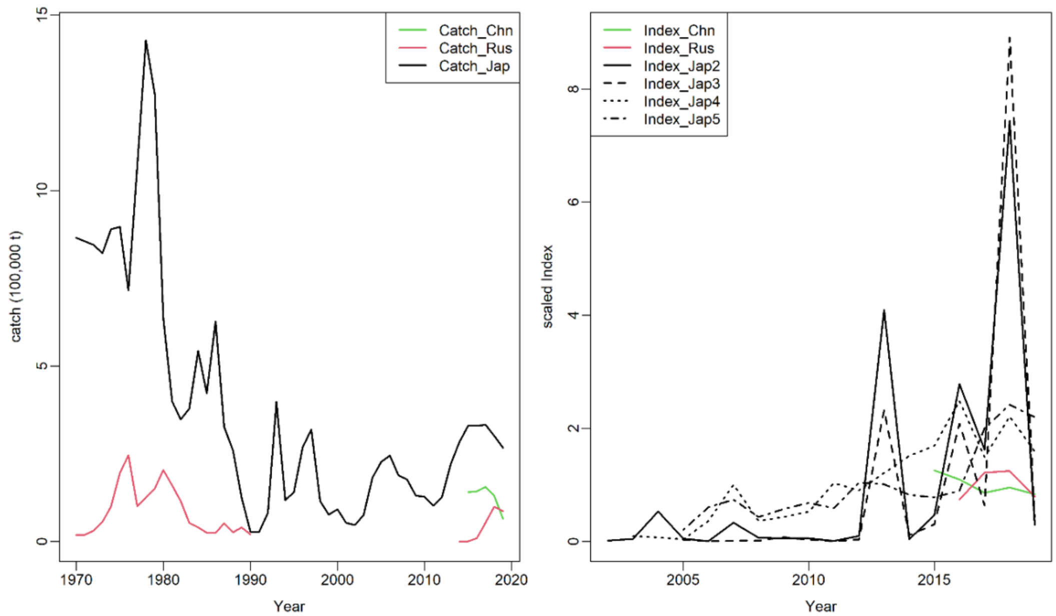
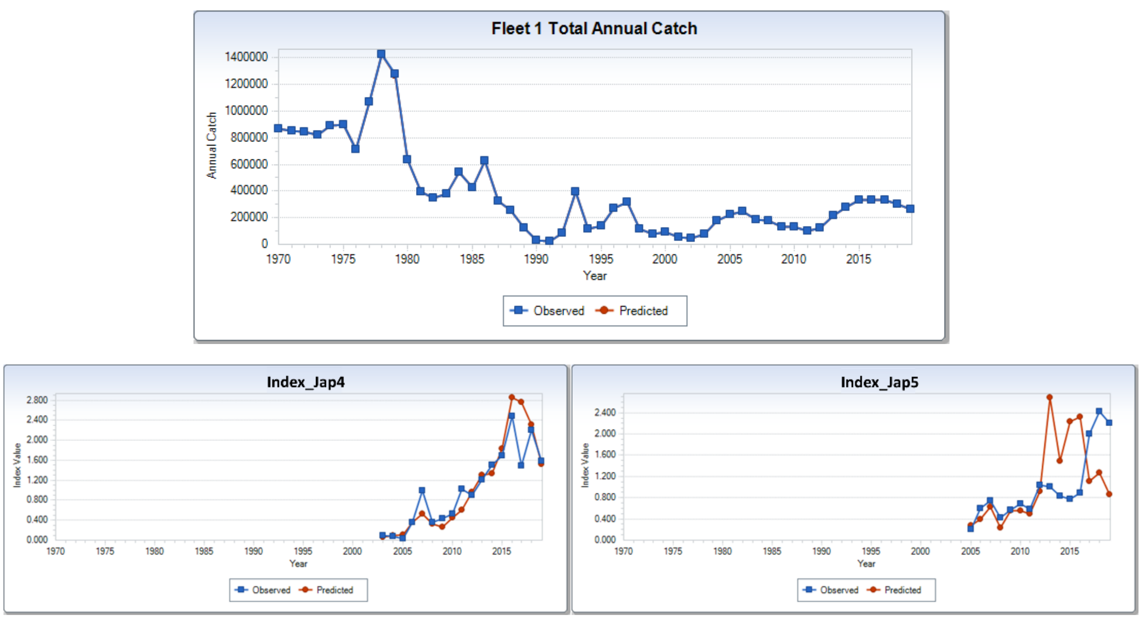


Figure 1. Catch and abundance index of Chub mackerel fisheries of China, Japan and Russia in the north Pacific Ocean from 1970 to 2019



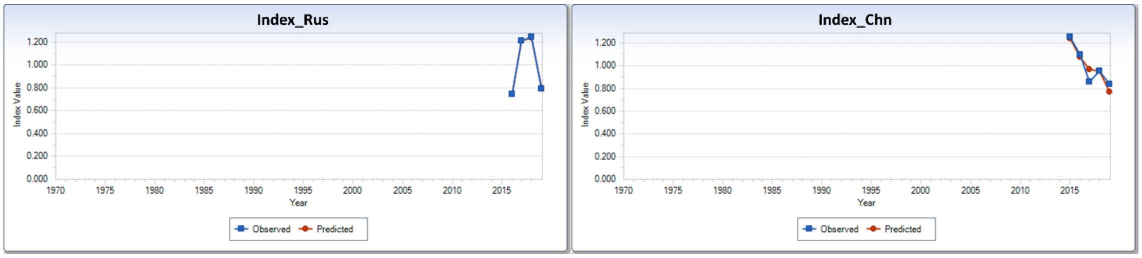


Figure 2 Catch and index fitting in the ASAP Model 1 for Chub mackerel

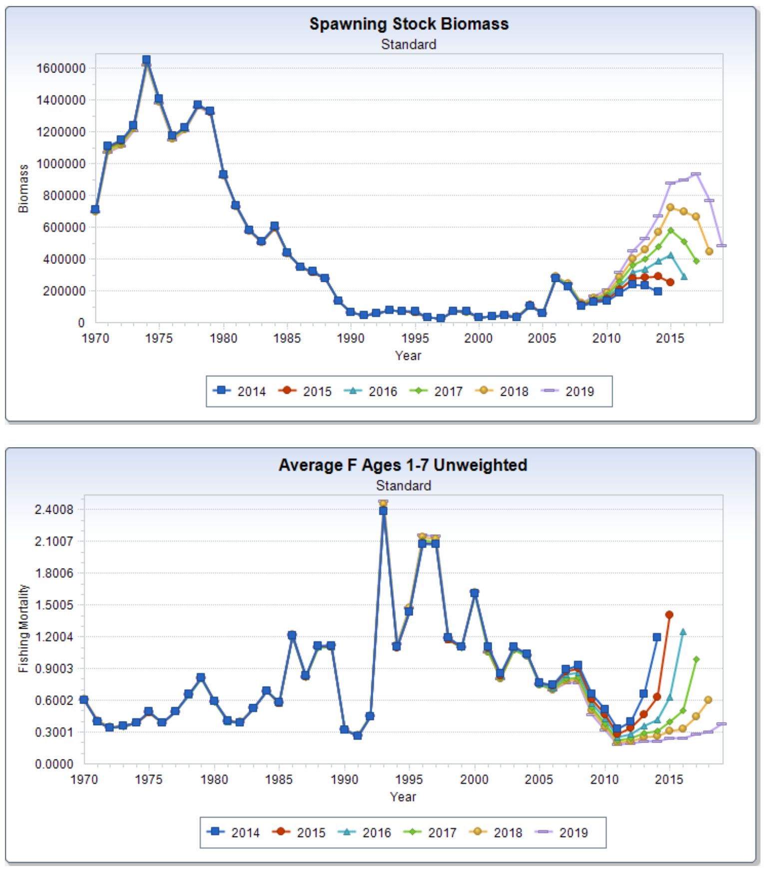


Figure 3. The retrospective pattern of spawning stock biomass and fishing mortality from ASAP Model 1 for Chub mackerel

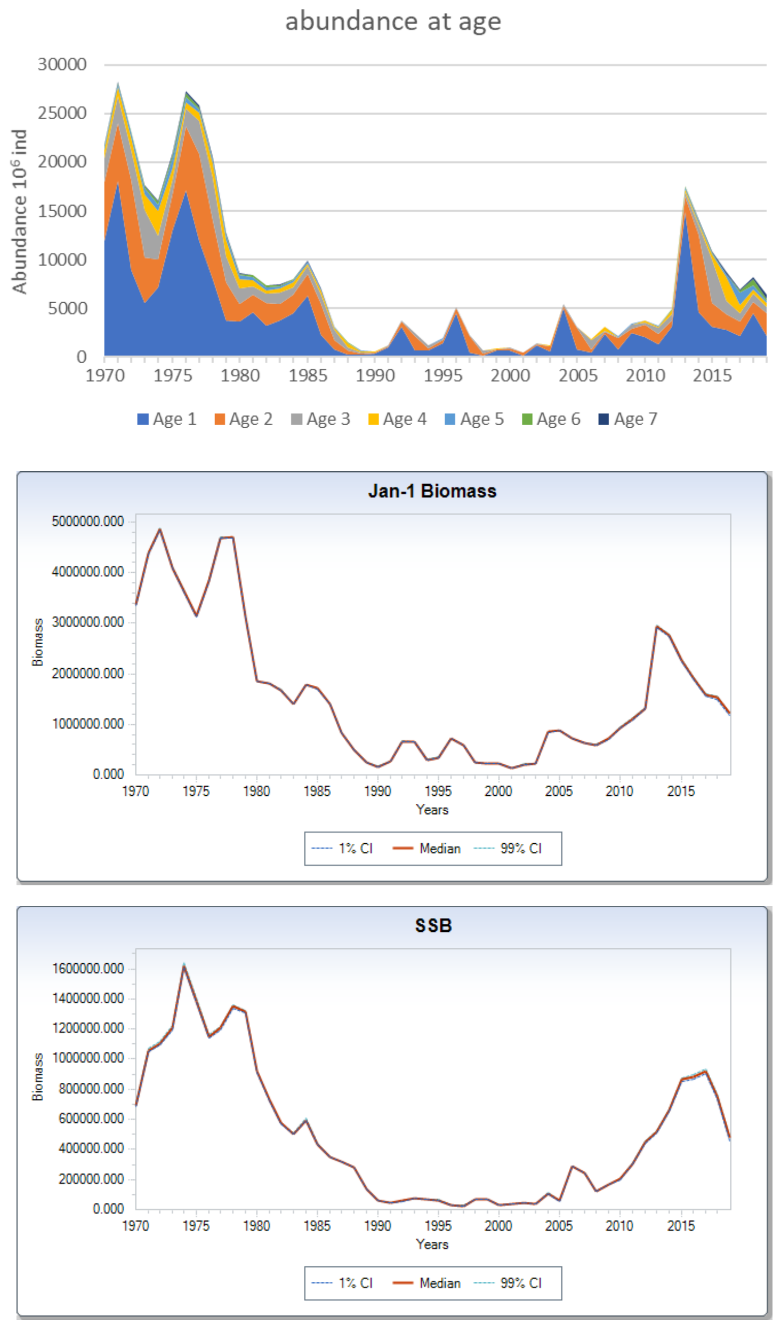


Figure 4. The abundance, biomass and SSB estimates from ASAP Model 1 for Chub mackerel

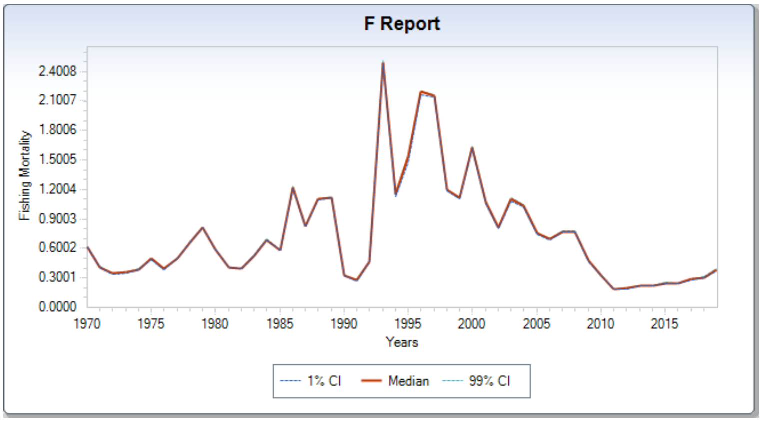


Figure 5. The fishing mortality estimates from ASAP Model 1 for Chub mackerel

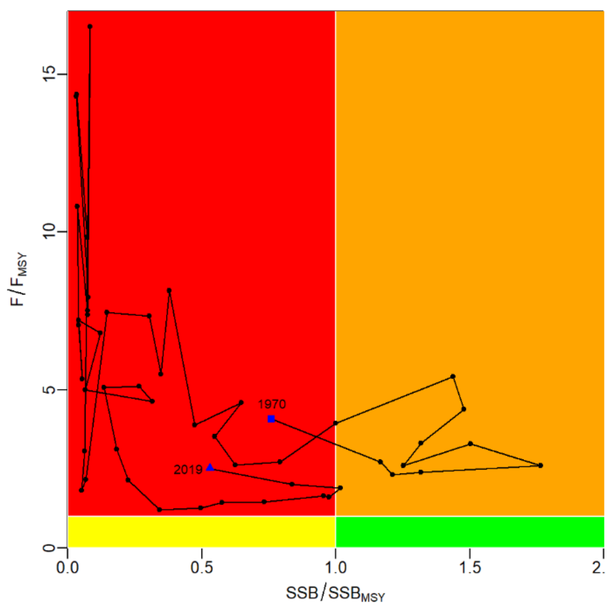


Figure 6. The Kobe plot among 1970-2019 from ASAP Model 1 for Chub mackerel.

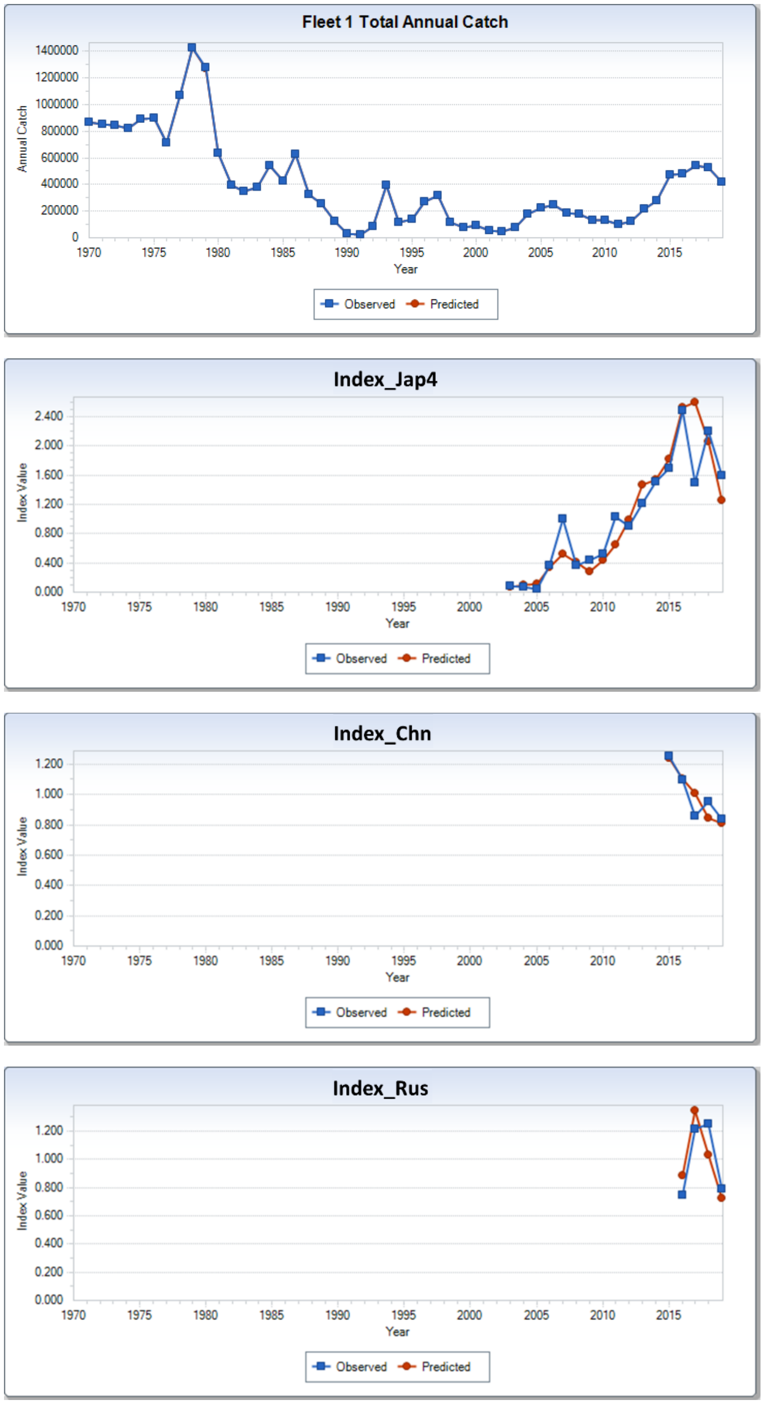


Figure 7 Catch and index fitting in the ASAP Model 2 for Chub mackerel

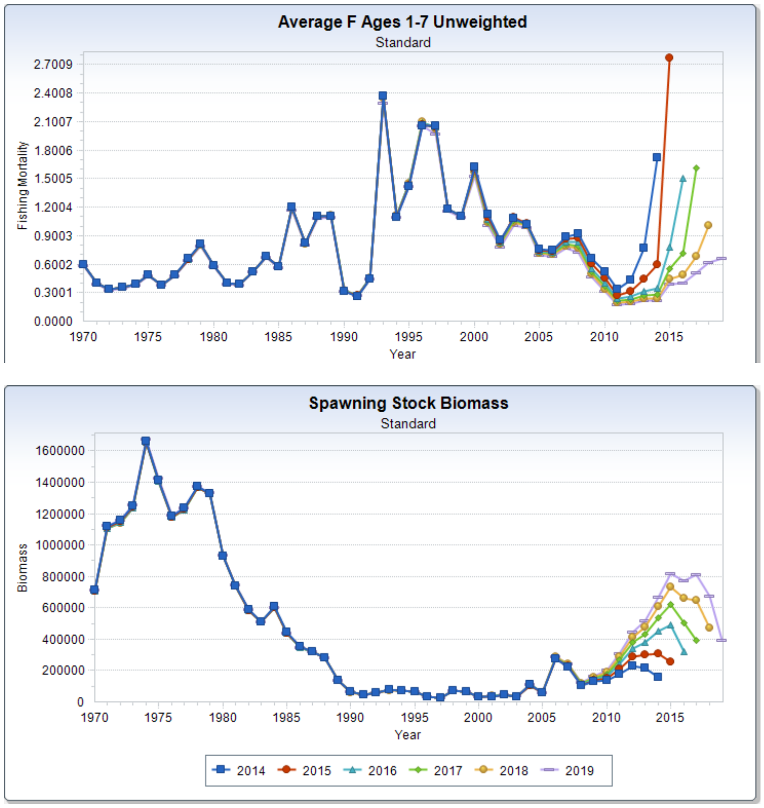
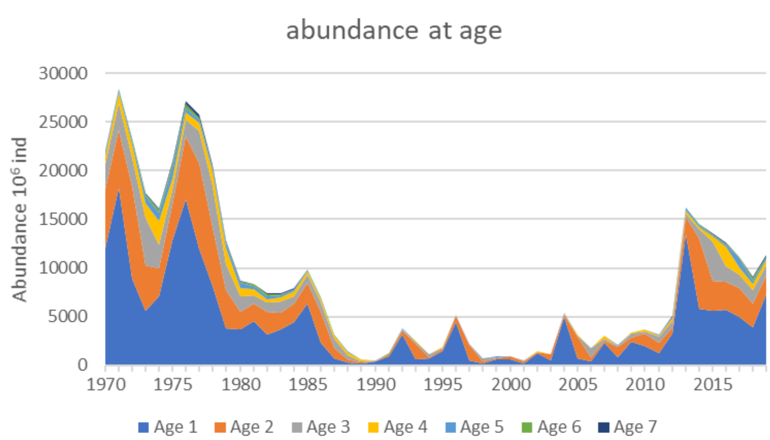
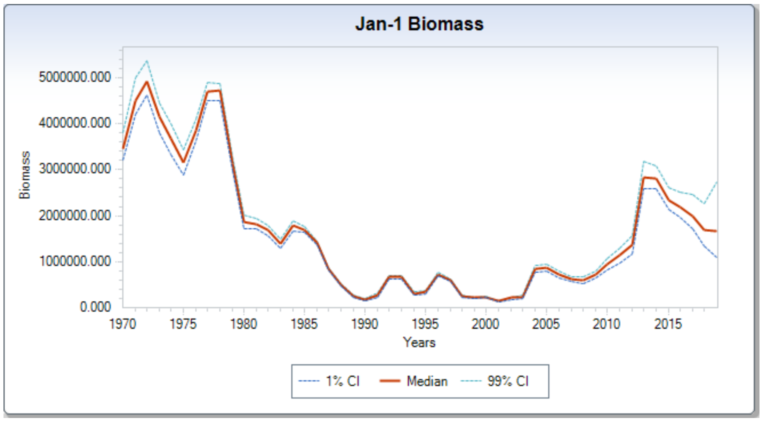


Figure 8. The retrospective pattern of spawning stock biomass and fishing mortality from ASAP Model 2 for Chub mackerel





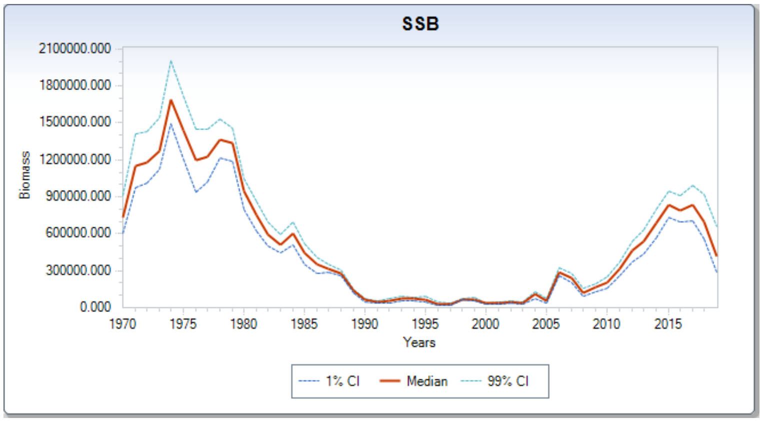


Figure 9. The abundance, biomass and SSB estimates from ASAP Model 2 for Chub mackerel

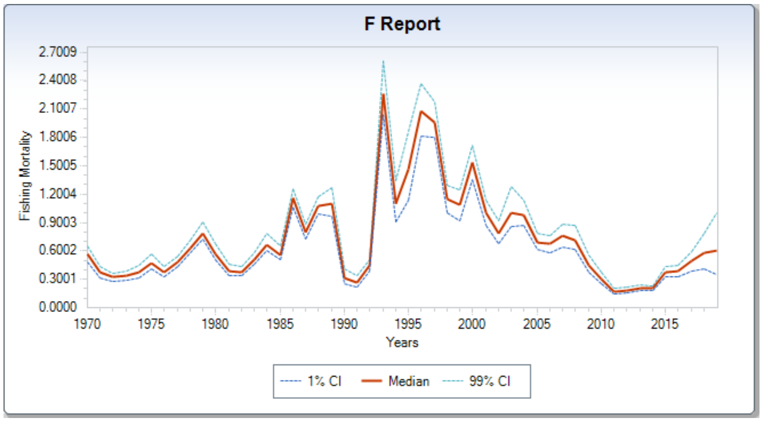


Figure 10. The fishing mortality estimates from ASAP Model 2 for Chub mackerel

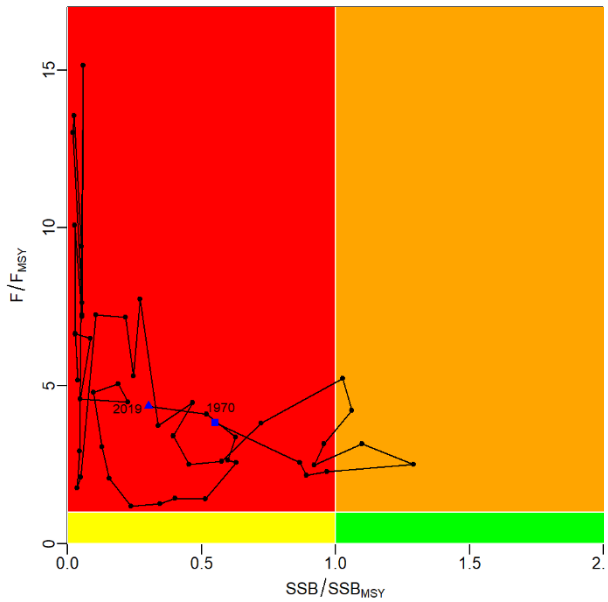


Figure 11. The Kobe plot among 1970-2019 from ASAP Model 2 for Chub mackerel.