NPFC-2022-TWG CMSA05-WP05

# North Pacific Ocean Chub mackerel Stock Assessment Report Based on BSSPM

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## 1. Introduction

As adopted by the TWG CMSA, five stock assessment model candidates (ASAP, SAM, VPA, BSSPM and KAFKA) will be used for Chub mackerel (*Scomber Japonicus*) in the NPFC. The paper provided the stock assessment results based on BSSPM (Bayesian State-Space Production Model). The input data and base case scenario were confirmed by the TWG CMSA04. However, due the model assumption of BSSPM, the different natural mortality, maturity and weight matrix could not be considered in the stock assessment. In this report, we summarized the estimates of key parameters and MSY-based biological reference points for the base cases.

## 2. Materials and methods

### 2.1. Input data

1) The catch data from 1970 to 2019 were included.
2) The Japanese fishery-independent egg survey for biomass estimates from 2005 to 2019 were included.
3) Japanese dip-net fishery CPUE (2003-2019), Chinese CPUE (2015-2019), and Russian CPUE (2016-2019) were considered.

### 2.2. Assessment methods

This assessment used catch data (1970-2019), Japanese CPUE (2003-2019), fishery-independent egg survey index (2005-2019), Chinese CPUE (2015-2019), and Russian CPUE (2016-2019) as input data (Figure 1). The assessment used a Bayesian state-space production model. The population dynamics were modeled by the following equations:

$$B_t = B_{t-1} + r \times B_{t-1}(1 - (\frac{B_{t-1}}{K})^s) - C_{t-1}$$

$$P_t = B_t/K$$

$$P_{t+1} = (P_t + r \times P_t \times (1 - P_t^s) - \frac{C_t}{K})exp(\mu_t)$$

$$\mu_t \sim N(0, \tau^2)$$

Where $B_t$ and $C_t$ denote biomass and catch, respectively, in year *t*. Parameters, *r*, *K*, *s* represent intrinsic population growth rate, carrying capacity, and production shape parameter respectively. $P_t$ and $\mu_t$ denote the ratio between biomass and carrying capacity and the process error, respectively, in year t. $\mu_t$ has a mean of zero and variance $\tau^2$.

The multiple indices were modeled by the following equations:

$$I_{i,t} = q_{i,t}KP_t exp(\varepsilon_{i,t})$$

$$\varepsilon_{i,t} \sim N(0, \sigma_i^2)$$

Where $I_{i,t}$ is the relative abundance of index *i* at year *t*. $q_{i,t}$ is the catchability coefficient for index *i* at year *t*. $\varepsilon_{i,t}$ is the observation error with a mean of zero and variance $\sigma_i^2$.

The base case scenarios were built based on TWG CMSA04 recommendation and used uniform prior distribution for catchability (*q*), carrying capacity (*K*), intrinsic population growth rate (*r*), initial biomass as a proportion of carrying capacity ($P_1$), and shape (*s*) (Table 1 and Figure 1). Inverse gamma prior distribution was used for the process ($\tau^2$) and observation ($\sigma^2$) error variance (Table 1).

The convergence of the posterior distributions of those parameters was examined with Gelman and Rubin's statistics (Gelman and Rubin 1992). MSY-based biological reference points were estimated from the models. Mean error between predicted and observed indices was calculated to determine the model goodness of fit.

## 3. Assessment results

The posterior densities of model parameters from all case scenarios showed that the densities were relatively smooth (Figures 2 and 3). All parameters from the base case showed well convergence of posterior distributions with Gelman and Rubin's statistic for all parameters were close to 1. The long-term abundance indices from Japan were fitted relative well, and dominant the assessment results (Figure 3).

The estimated mean, median, and 80% confidence interval CI of posterior estimates of parameters and MSY-based reference points were summarized in tables (Table 2). The median estimates for $r$ and $K$ were 1.53 and $8.41\times10^6$ ton, respectively. The MSY was estimated to be $1.41\times10^6$ ton, which is much higher than the total catch in 2019 ($4.6\times10^6$ ton). The biomass and fishing rate at the MSY level were estimated to be $3.76\times10^6$ ton and 0.42, respectively. The $B_{2019}/B_{MSY}$ and $F_{2019}/F_{MSY}$ were 1.53 and 0.22, indicating the health stock status of Chub mackerel in 2019.

The time series of biomass and fishing rate (catch/biomass), $B/B_{MSY}$, and $F/F_{MSY}$ were summarized (Figures 4-6). The median biomass of Chub mackerel fluctuated at the high level before 1991, then declined to the extremely low value at 2004~2005, and recovered to the maximum value in 2018. Generally, the median fishing rate kept at high value before 1980, but was still lower than the Fmsy (median 0.42), while only the extremely high values in 2004 and 2005 (0.55~0.56) were higher than Fmsy. The Kobe plots showed that the $B/B_{MSY}$, and $F/F_{MSY}$ in 2019 from base case scenario were in green quadrant with 77% probability and in the yellow quadrant with 20% probability (Figure 6).

**4. Conclusion**

This working paper presents the model structure and preliminary results of stock assessment for the North Pacific Ocean Chub mackerel stock using the BSSPM. The model structure and settings were constructed based on the BSSPM, which were adopted and used by NPFC for

Pacific saury benchmark stock assessment since 2017. The model parameters were estimated based on Bayesian framework with a MCMC method. The assessment results were diagnosed with the Gelman and Rubin's statistic, standardized residual plots, the shapes of posterior distributions for key parameters. The main assessment results were concluded as follows:

The estimated median $B_{2019}$ from the base case scenario was 562 (80%CI 121-1,081) $\times 10^4$ metric tons. The median $B_{2019}/B_{MSY}$ and $F_{2019}/F_{MSY}$ were 1.53 (80%CI 0.51-2.08) and 0.22 (80%CI 0.07-0.37), respectively. During the most recent years, the biomass of Chub mackerel kept at high value, with relative low fishing mortality. The probability of the population being in the green Kobe quadrant in 2019 was estimated to be greater than 77%.

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**Table 1. Prior assumptions of parameters used in BSSPM for Chub mackerel.**

| | | |
|---|---|---|
| ***q*_CPUE** | U(0,1) | |
| ***K*** | U(143,4290) | U(Cmax,30*Cmax). |
| ***r*** | U(0,3) | |
| $\boldsymbol{P_1}$ | U(0,1) | |
| ***s*** | U(0,3) | |
| $\boldsymbol{\sigma^2}$ | $1/\sigma^2$~Gamma(0.001, 0.001) | |
| $\boldsymbol{\tau^2}$ | $1/\tau^2$~Gamma(0.001, 0.001) | |

**Table 2. Estimates of parameters and reference points for base case scenario.**

| | Mean | Median | Lower 10th | Upper 10th |
|---|---|---|---|---|
| $C_{2019}$ | 46 | 46 | 46 | 46 |
| *r* | 1.48 | 1.53 | 0.12 | 2.32 |
| *K* | 1271 | 841 | 152 | 2342 |
| qJPN | 0.0029 | 0.0026 | 0.0008 | 0.0045 |
| qJPN_EggSurvey | 0.0053 | 0.0047 | 0.0013 | 0.0076 |
| qCHN | 0.0028 | 0.0017 | 0.0002 | 0.0048 |
| qRUS | 0.0029 | 0.0016 | 0.0002 | 0.0048 |
| Shape | 0.84 | 0.76 | 0.03 | 1.40 |
| sigma | 0.45 | 0.36 | 0.21 | 0.73 |
| tau | 0.44 | 0.48 | 0.03 | 0.67 |
| MSY | 171 | 141 | 61 | 250 |
| $B_{2019}$ | 705 | 562 | 121 | 1081 |
| $B_{MSY}$ | 579 | 376 | 80 | 1036 |
| $B_{2019}/B_{MSY}$ | 1.53 | 1.53 | 0.51 | 2.08 |
| $F_{2019}$ | 0.12 | 0.08 | 0.02 | 0.22 |
| $F_{MSY}$ | 0.56 | 0.42 | 0.02 | 1.06 |
| $F_{2019}/F_{MSY}$ | 0.33 | 0.22 | 0.07 | 0.37 |

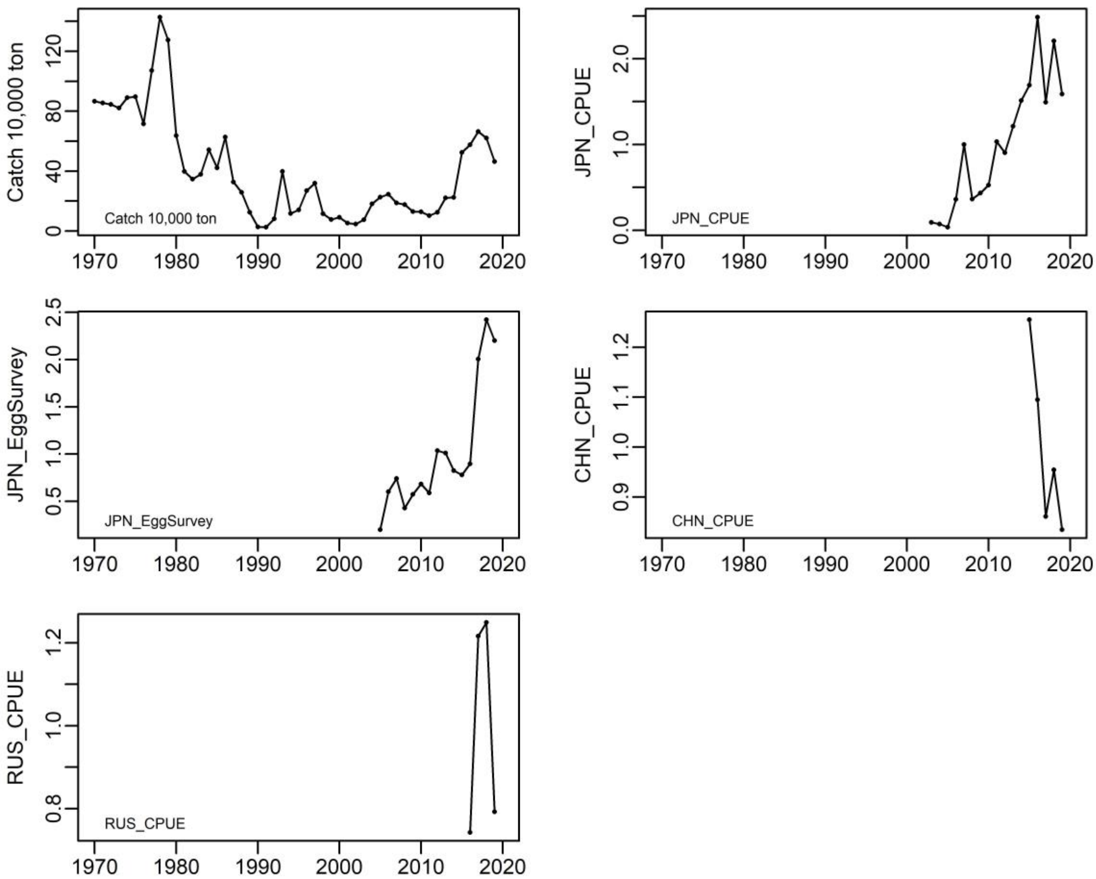


**Figure 1. Input data for Chub mackerel stock assessment BSSPM.**

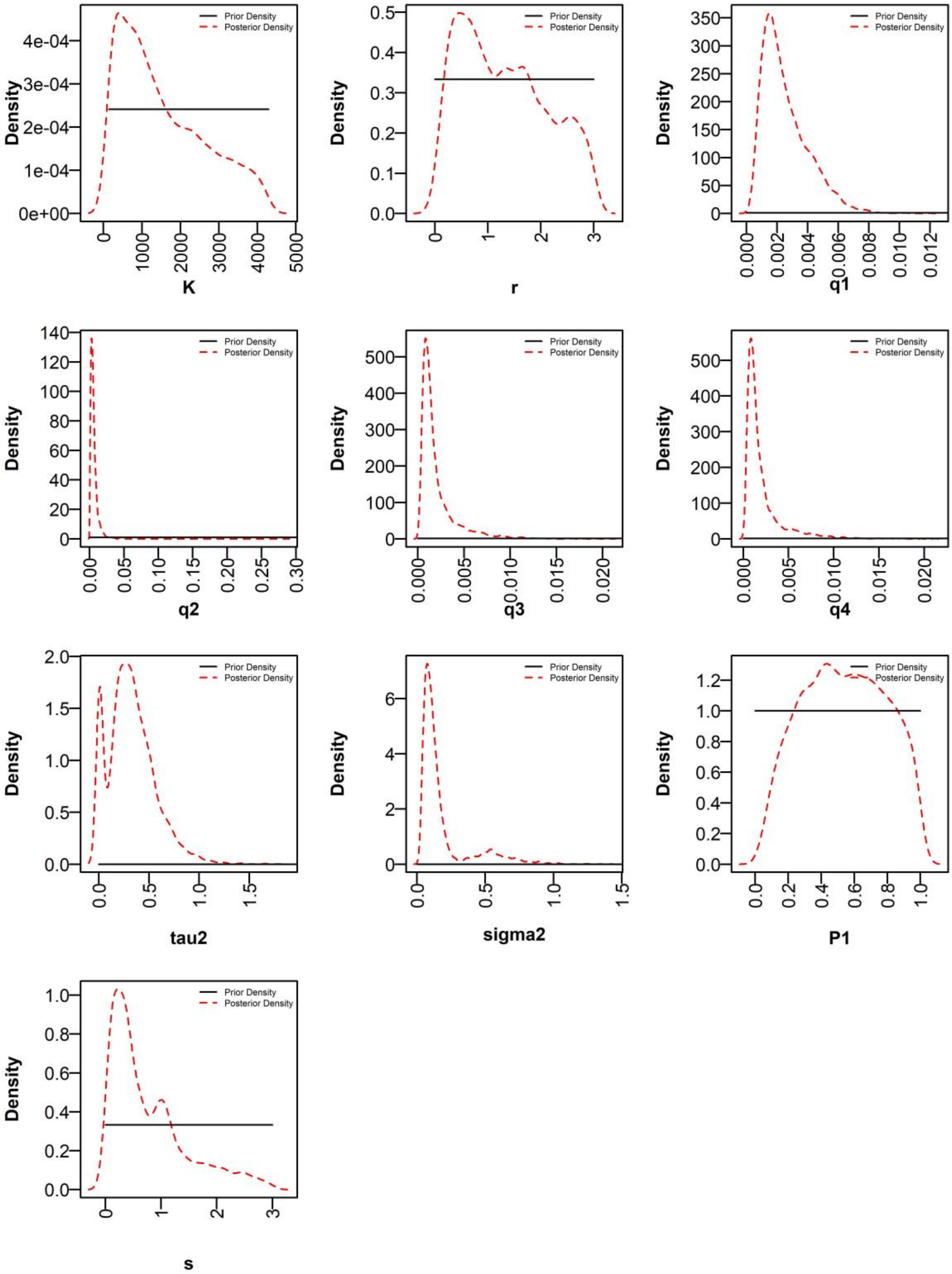


**Figure 2. Prior and posterior distributions of parameters from base case.**

q1 to q4 represent catchability of Japanese CPUE, Japanese egg survey, Chinese CPUE, and Russian CPUE, respectively. tau2 represents process error variance, sigma2 represents observation variance of CPUE. P1 represents B1/K and *s* represents shape.

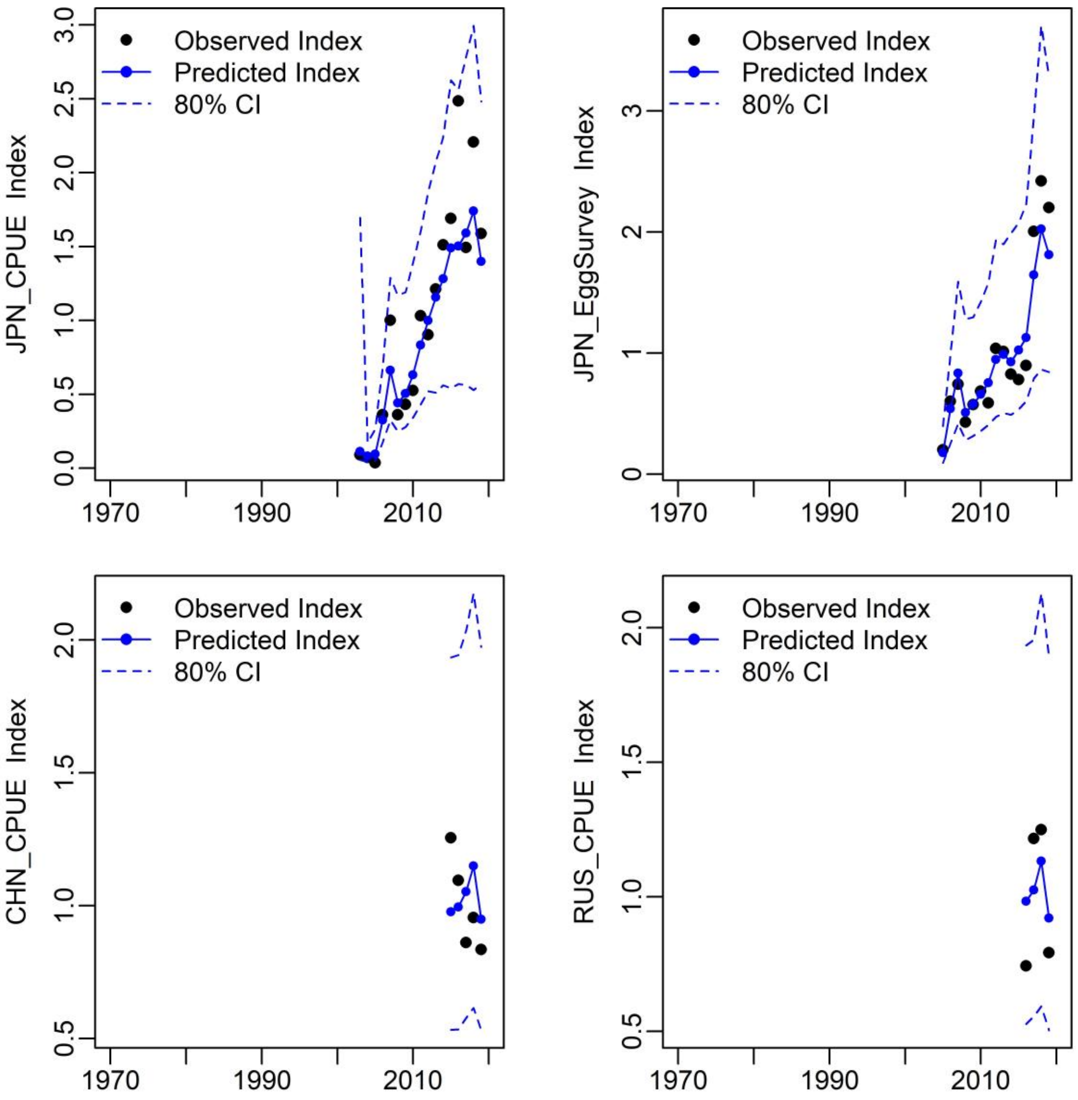


**Figure 3. Model fitting between predicted and observed indices from base case.**

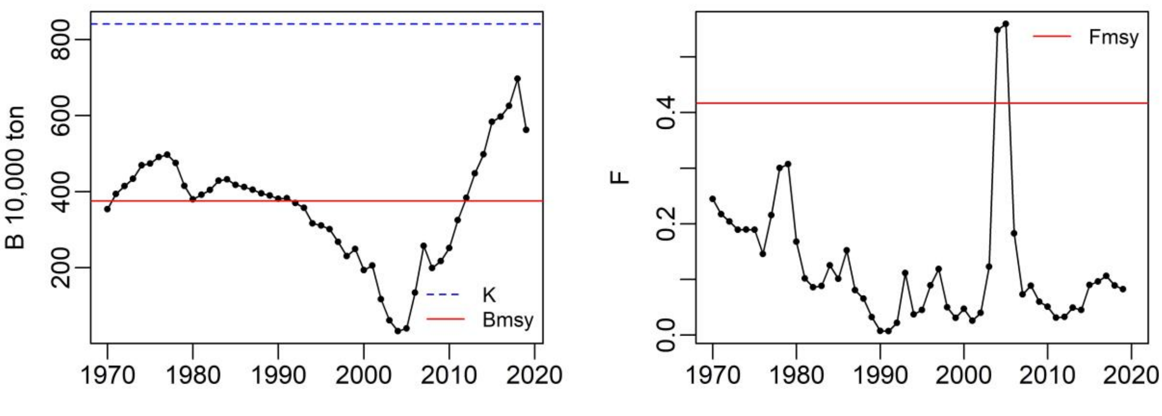


**Figure 4. Median biomass and Fishing rate for base case.**

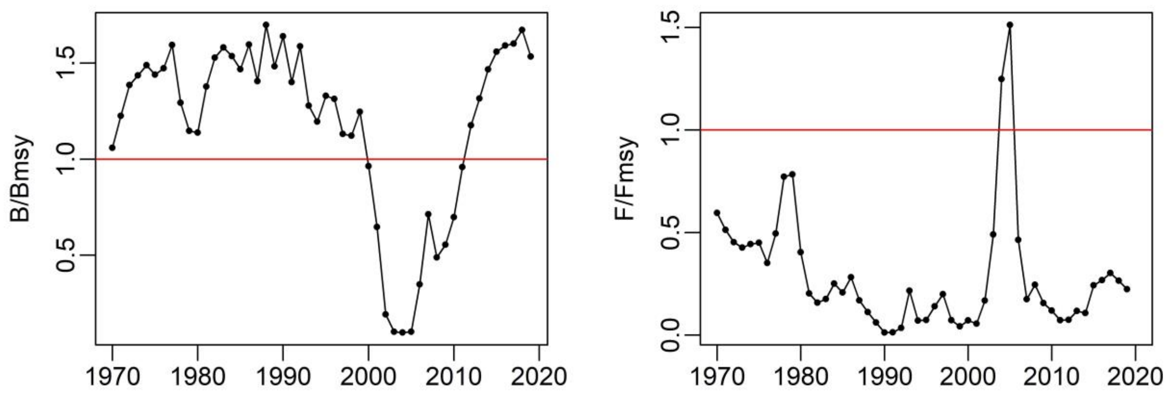


**Figure 5. Median B/Bmsy and F/Fmsy for base case.**

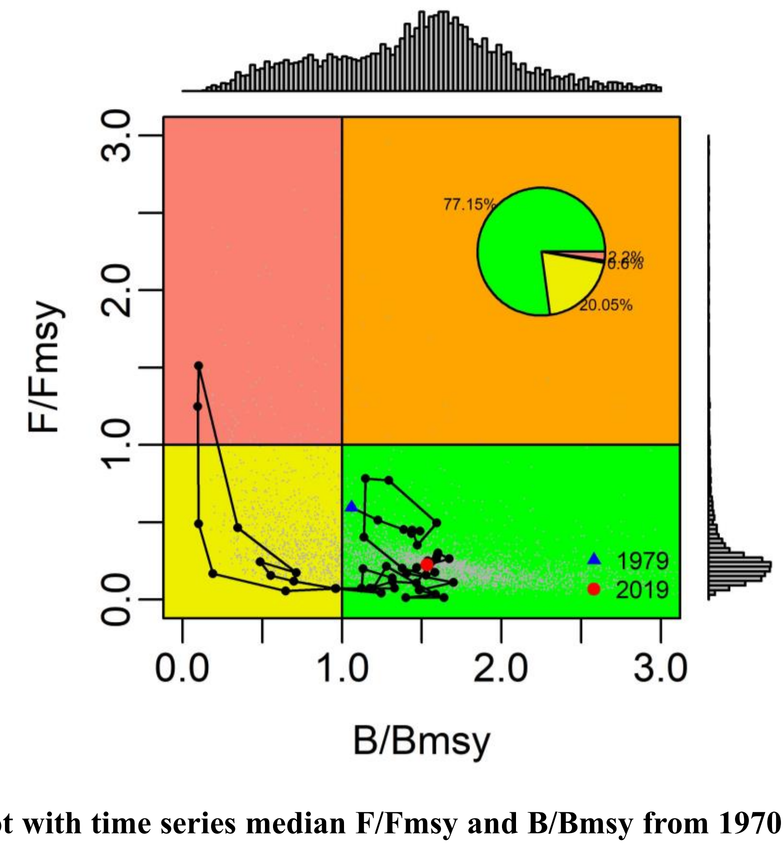


**Figure 6. Kobe plot with time series median F/Fmsy and B/Bmsy from 1970 to 2019 for base case.**