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Evaluation of changes in model settings focusing on the maturity schedule in the reference case model of the 2016 skipjack stock assessment

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Aoki, Y., Ohashi, S. and Kiyofuji, H.

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Aoki Y., Ohashi, S., Ijima H., and Kiyofuji H.

National Research Institute of Far Seas Fisheries,
Japan Fisheries Research and Education Agency
Shimizu-ku, Shizuoka-shi, Shizuoka 424-8633 Japan

Abstract

This document provides effects of change in a reproductive parameter of skipjack tuna on outputs (spawning stock biomass, depletion, reference points and etc.) as the stock status, because it is difficult to simultaneously look at the several effects of changes in the model settings due to the model complexity especially when new features are incorporated. Reference case data files used in the 2016 skipjack stock assessment and the same MFCL executable file of the 2016 assessment were used for comparison in this study. For the evaluations, other settings except for the reproductive parameter were fixed to examine the effect of the change in it alone. Model results were compared with the output of the reference case in the 2016 assessment.

Introduction

In an integrated stock assessment model, it is difficult to simultaneously look at the several effects of changes in the model settings due to the model complexity especially when new features are incorporated. Biological research underlays the biological assumptions in the model, which is often updated between stock assessments due to sample size increase and technical innovations in equipment as well as improvements of statistical methods. In the pre-assessment workshop for 2019 skipjack (*Katsuwonus pelamis*) stock assessment, maturity schedule was newly provided (Ohashi *et al.*, 2019). Passing the maturity schedule to the model as an input could affect the spawning stock biomass, hence yields and depletion. To quantify the effect of changes in the maturity schedule alone on the biomass related parameters, this document provides the potential effect of changes in maturity schedule focusing on the important variables for the stock assessment by using the reference case for the 2016 stock assessment.

Materials and Methods

Input and output files of the reference case of the 2016 skipjack stock assessment for multifan-CL (MFCL) was downloaded from SPC website (https://oceanfish.spc.int/en/ofpsection/sam/sam/213-skipjack-assessment-results#2016). Maturity schedule was referred to the recent study of histological analysis (Ohashi *et al.*, 2019), and the length at 50% maturity varies among tropical (50.1 cm), subtropical (53.7 cm), and temperate areas (55.9 cm). By converting the length to age using the same growth curve in the 2016 assessment, corresponding age class of 4.4, 4.8, and 5.1 was calculated as a half maturation age. To reflect this age class in the downloaded file of MFCL (skj.ini), beginning of maturity in the MFCL was changed from age class 3 as the 2016 reference case to age class 5 (Model1: MaturitySchedule1), and half maturation for age class 4 with 0.5 (Model2: MaturitySchedule2) (**Fig. 1** and **Table 1**). MFCL that are the same version (2.0.1.1) of the 2016 stock assessment was used to run the two models. Note that the settings other than the maturity schedule are the same as used in the reference case for the 2016 stock assessment (McKechnie *et al.*, 2016). MFCL output was extracted and plotted by using R packages of R4MFCL and FLR4MFCL available in github (https://github.com/PacificCommunity). The output of two models and reference case in 2016 skipjack stock assessment was compared focusing on the spawning stock biomass related variables, and detailed technical descriptions for these variables are given in Kleiber *et al*. (2019).

Result & Discussion

Comparison with reference case scenario of the 2016 skipjack assessment

Spawning potential biomass, depletion, and other biomass related variables were presented in **Figs. 2 & 3** and **Table 2**. The number of estimated spawning stock biomass for MaturitySchedule1 & 2 was lower than that in the 2016 reference case because of the schedules set older to get matured than that in 2016, and the decrease in the spawning biomass was more profound in "MaturitySchedule1" rather than "MaturitySchedule2" (**Fig. 2**). As well as the spawning biomass, unfished spawning biomass for two models was also lower than the reference case (**Fig. 3**). These results suggested that effect of the change in maturity schedule worked to reduce spawning biomass because of the definition of "spawning" used in the model. Further, the change of the spawning biomass and unfished biomass worked to decrease the depletion (**Fig. 3**). Interestingly, the slope of the depletion in MaturitySchedule1 became the steepest through the calculated years among three models. Although the reason for this is unclear due to the complexity of the model, the change in the slope can be confirmed by change in the depletion started from 1972 (**Fig. 4**). Turning attention from the spawning biomass to recruitment, it should be noted that the maturity schedule has little effect on the recruitment (**Fig. 6**). Although the impact on the recruitment was little, the parameters for stock recruitment relationship changed due to the decrease in spawning biomass (**Fig. 7**), hence leading to decrease in the MSY (Maximum Sustainable Yield) (**Table 2**).

Conclusion & recommendations for SC15

This document introduces potential impacts of maturity schedule on the spawning biomass and other related variables. The model version and settings used in the 2016 reference case is different from that of the 2019 skipjack stock assessment, still this sensitivity analysis would propose the potential impacts of changing maturity schedule independently.

Apparently, the late maturity schedule works to decrease the spawning biomass and at the same time, affect the stock-recruitment relationship and depletion of the skipjack tuna stock. This result is commonly found in other pelagic fish such as Pacific bluefin tuna (*Thunnus orientalis*) and pelagic sharks as maturity age has large impacts on the population growth (Yokoi *et al*., 2017; Ijima *et al*., 2019). On the other hand, the change in number of recruitment due to the late maturity schedule seems to be little even though the spawning biomass decreases, which could be underestimated. However, no biological or ecological evidences is available to evaluate whether this result is reasonable for the skipjack stock or not. Thus, further consideration is required to estimate the recruitment that should be driven by biological data such as estimation of batch fecundity, spawning season, and spawning interval. In addition, these incorporations into the MFCL can be one of the parts that improves the stock assessment as well as changes in the setting of spawning grounds (Kiyofuji *et al*., 2019). Based on the conclusions above, followings are recommended to consider at SC15 as future analyses for more precise stock assessment.

- It is recommended to note that the spawning biomass, depletion, and MSY decreases in the 2016 stock assessment reference model when setting late maturity schedule.
- It is recommended to investigate whether compensation for the decrease in spawning biomass occurs by adjusting other settings in the case of late maturity schedule, and if it occurs, identify which parameters would compensate the decrease.
- It is recommended to consider effects of the maturity schedule on recruitment by using batch fecundity, spawning season, and spawning interval driven by biological evidences in the future stock assessment.

Reference

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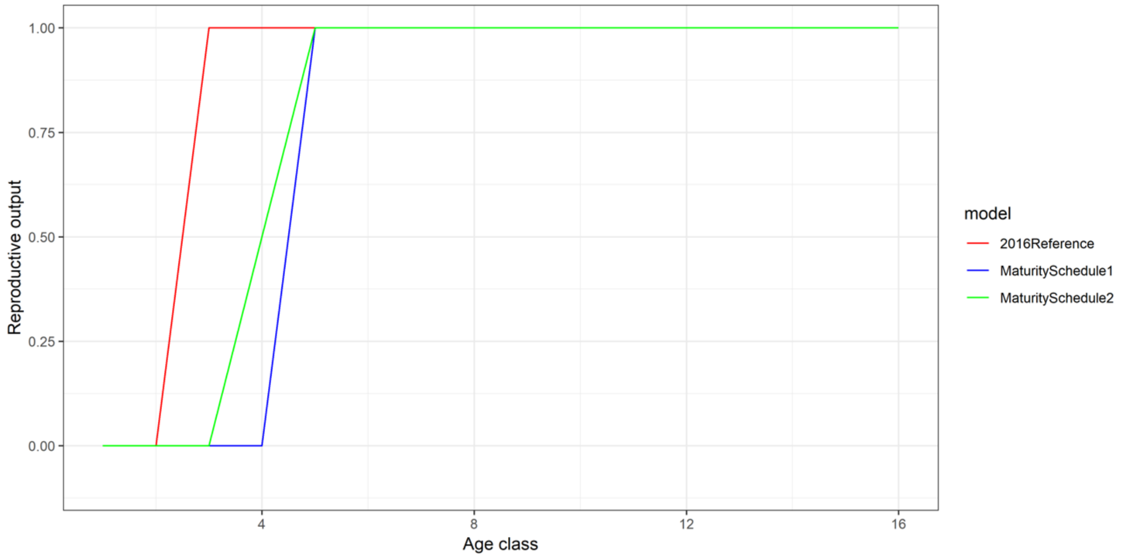

Figure 1. Maturity schedule for each model (red: reference case in the 2016 skipjack stock assessment (100% maturity at age class 3), blue: 100% maturity at age class 5, green: 50% and 100% maturity at age class 4 and 5).

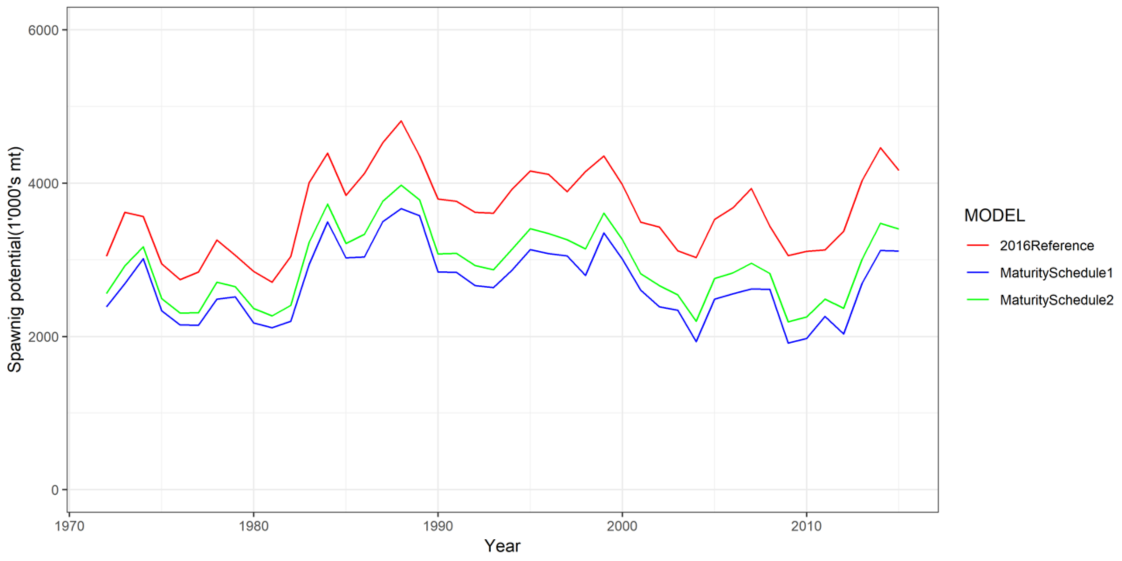

Figure 2. Overall spawning biomass through the calculated years.

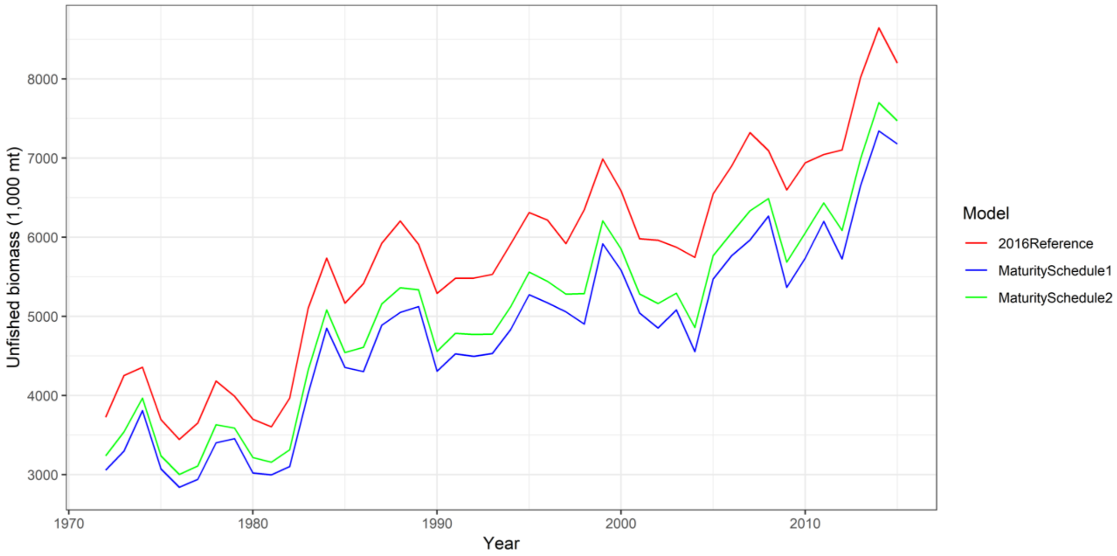

Figure 3. Unexploited spawning biomass obtained from the three models.

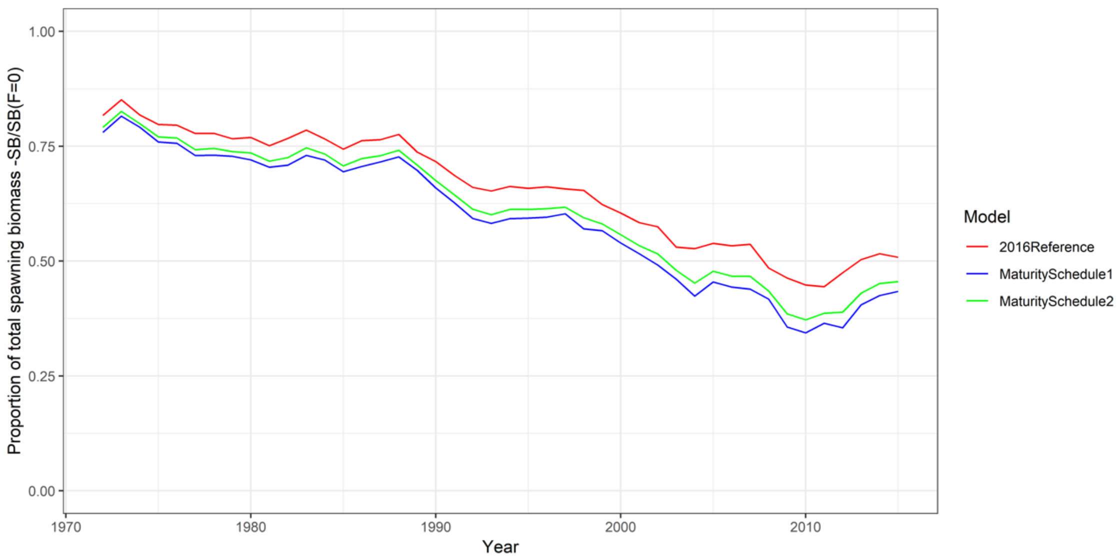

Figure 4. Fisheries depletion, ratio of exploited spawning biomass (SB) to unexploited spawning biomass ($SB_{F=0}$) of the three models.

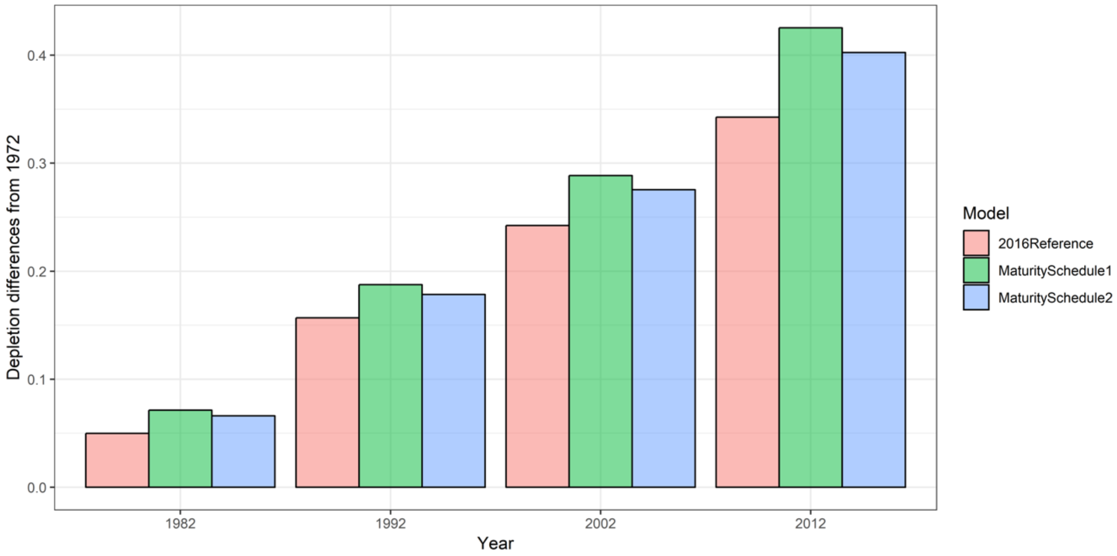

Figure 5. Decadal changes in depletion from 1972 of the three models.

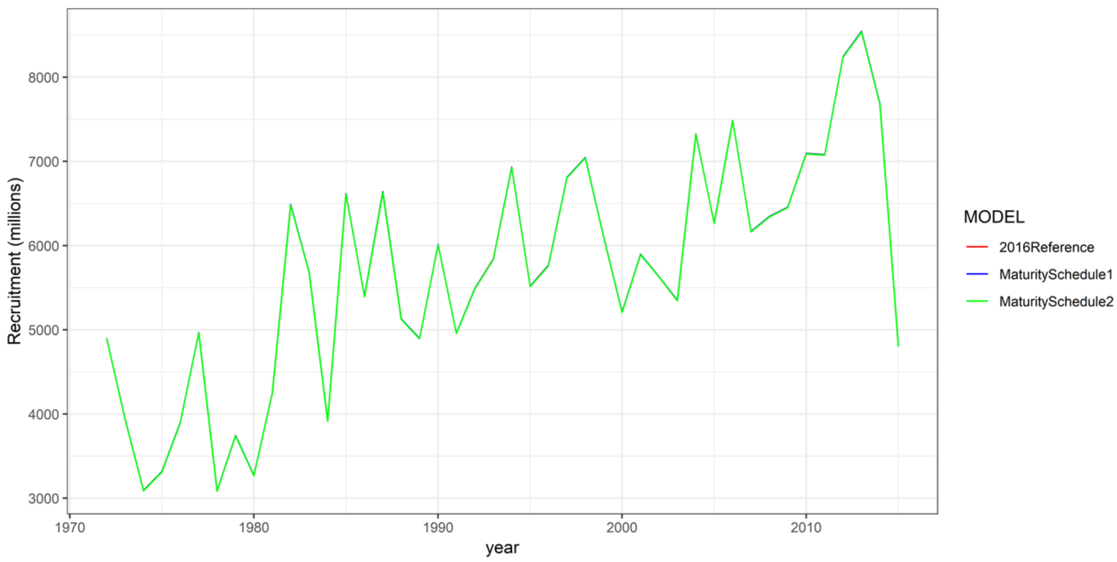

Figure 6. Changes in overall recruitment among models.

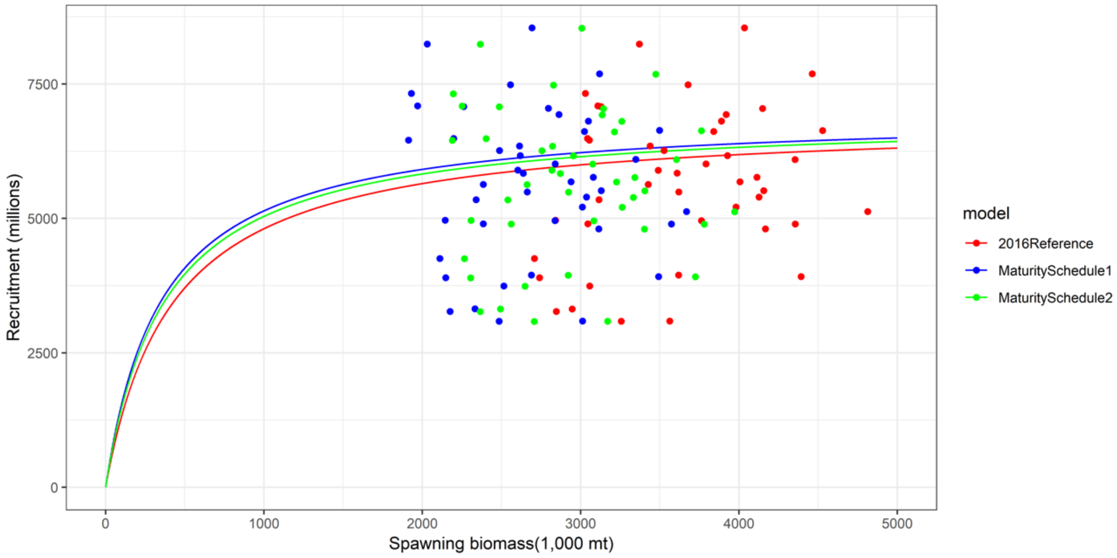

Figure 7. Stock recruitment relationship among models.

Table 1. Description of models used in this sensitivity analysis.

Label	Description
2016Reference	Jack Knife:100% maturity at age class 3 (around 37 cm)
MaturitySchedule1	Jack Knife:100% maturity at age class 5 (around 55 cm)
MaturitySchedule2	50% and 100% maturity at age class 4 and 5, respectively.

Table 2. Summarized important variables

Quantity	2016Reference	MaturitySchedule1	MaturitySchedule2
C_{latest}	1,679,528	1,679,529	1,679,523
MSY	1,891,600	1,841,200	1,855,200
$Y_{Frecent}$	1,594,800	1,609,200	1,602,800
f_{mult}	2.23	1.85	1.96
F_{MSY}	0.24	0.21	0.22
F_{recent}/F_{MSY}	0.45	0.54	0.51
SB_{MSY}	1,626,000	953,100	1,087,000
SB_0	6,764,000	5,651,000	5,941,000
SB_{recent}/SB_{MSY}	2.31	2.65	2.61