Impact of parameter uncertainty on striped marlin stock assessment in the Western Central North Pacific Ocean

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Abstract. Striped marlin is a species subject to commercial and recreational fishing in the western-central North Pacific Ocean. However, assessing the stock state accurately has proven difficult. Here, we analysed the differences in the von Bertalanffy growth curves and model settings between two stock assessments conducted in 2022 and 2023, to identify sources of uncertainty in the model predictions and their potential impact on stock assessment results. Our analysis showed that the combination of initial mortality multiplier parameter (f) and equilibrium recruitment (R_0) significantly affected the assessment results. The estimated values of these parameters for the 2022 assessment led to a larger spawning stock biomass and lower fishing mortality than the values estimated for the 2023 assessment, with the stock being severely overfished only in the latter case. However, the estimate of f had significant uncertainty, highlighting weak informativeness of available data with respect to this important parameter. Our findings emphasise the need for continued improvement of the striped-marlin stock assessment, and particularly for addressing the sources of error and bias in the data used for model parameter estimation.

Introduction. In 2019, a benchmark stock assessment was conducted on striped marlin in the western-central north Pacific Ocean (ISC 2019). The results of this assessment indicated that the stock was in a poor state relative to the reference limits. In 2020, the Western and Central Pacific Fisheries Commission (WCPFC 2021) accepted the results of the assessment, but also requested the billfish working group to develop a roadmap to address a set of technical issues identified in relation to the 2019 stock assessment (WCPFC 2021). In response, it was decided to perform another stock assessment in 2022, which introduced several improvements to the previous assessment (ISC 2022). However, it was later discovered that changing the von Bertalanffy growth curve from the 2019 assessment had been scientifically unwarranted.

In light of this, the WCPFC requested a redo of the 2022 assessment while addressing the remaining issues. The latest assessment was performed in 2023, and the billfish working group updated the von Bertalanffy growth curve while making minimal changes to the model settings. The results of the 2023 assessment were strikingly different from those of the 2022 assessment. While the 2022 assessment had indicated that the stock was close to the reference limits, the 2023 assessment revealed that the stock was severely overfished. The reasons behind this significant change in results are investigated in this paper, because understanding these reasons is crucial in deciding whether a rebuilding plan is necessary or not. Such a decision requires a solid justification due to the substantial effort that goes into formulating a rebuilding plan and the effects that the plan may have on the livelihood of fishers.

Methods. We obtained the necessary data from the report files produced by Stock Synthesis 3, utilising the settings from both the 2022 and 2023 striped-marlin stock assessments. Our focus was on the differences in the von Bertalanffy growth curves and the implications of the updated growth curve for the stock assessment results. We also examined other changes made to the model settings to accommodate the updated growth curve.

In our analysis, we paid particular attention to the sources of uncertainty in the model predictions and their potential impact on the stock-assessment results. We evaluated whether the results of the stock assessment fully reflect the effects of these sources of uncertainty.

Results. Our analysis reveals several key results, as shown in Figure 1. First, we compared the von Bertalanffy growth curves between the 2022 and 2023 stock assessments. The curves were similar up to age 5, but started to diverge somewhat from ages 6 and onwards (Figure 1a). These differences in the growth curves were reflected in the corresponding parameters: size at age 0.5 (L_1), size at age 15 (L_2), and the von Bertalanffy growth rate (k). To accommodate the updated growth curve, several additional model settings were changed for the 2023 stock assessment relative to the 2022 stock assessment (Figure 1b). These changes included increasing the coefficient of variation for the growth curve, treating recruitment deviations as individual parameters, removing weights from the likelihood function, and deciding which datasets are used for model fitting.

Interestingly, the estimated catch-at-age numbers for 2020 were similar between the two stock assessments (Figure 1c). This is because most of the caught fish are younger than age 6, and the growth curves noticeably diverge only from age 6 onwards.

Another key finding concerns the initial mortality multiplier (f) and equilibrium recruitment (R_0), two important parameters in Stock Synthesis. While the latter can be estimated with much confidence, the estimate of the former based on the used data is accompanied with wide confidence intervals (Figure 1d). The used data provide a poor foundation for estimating this parameter.

The difference in point estimates of the parameters f and R_0, combined with nearly the same catch-at-age numbers, results in a substantial difference in the spawning stock biomass between the two stock assessments (Figure 1e). Specifically, the same catch numbers are obtained from a larger spawning stock when f is smaller and R_0 larger (2022 stock assessment) relative to when f is larger and R_0 smaller (2023 stock assessment). This causes the fishing mortality throughout the whole run period from 1977 to 2020 to stay lower in the 2022 stock assessment than in the 2023 stock assessment (Figure 1f).

Discussion. Our findings implicate the different point estimates of parameters f and R_0 in causing the 2022 and 2023 stock-assessment results to differ. A larger f and a smaller R_0 typically lead to a smaller initial spawning stock biomass. Here, however, this initial difference persists rather stably through time for two reasons. The above-mentioned similarity in catch-at-age numbers requires the mortality of the smaller stock to be persistently higher, and a large value of the steepness parameter for striped marlin (h=0.87) produces the same number of recruits almost irrespective of spawning stock biomass.

One of the key parameters, f, is estimated with substantial uncertainty, making it impossible to determine which value is more appropriate. Given such large uncertainty, it is essential to identify and address sources of error and bias in the data. For example, we plan to re-evaluate datasets with questionable reliability, such as the Japanese driftnet data prior to 1994, and assess whether this resolves the conflict between datasets in such a way as to reduce the uncertainty in parameter estimates, particularly the large uncertainty in the estimated value of f.

A change in the growth curve used in the stock assessment model could potentially have a large impact on the age-structured composition of the spawning stock, and ultimately the stock's evaluation. We tested if this was the case and found mostly similar composition for the period from 1975 to 2020. One notable difference between the two stock-assessment models is that the 2023 model somewhat overrepresents early adults and underrepresents later adults. This is consistent with a larger mortality in the 2023 model.

In conclusion, our study emphasises the importance of addressing uncertainty in the striped marlin stock assessment. Future efforts should focus on improving the quality and reliability of data, resolving conflicts between datasets, and refining the methods used to estimate model parameters. By doing so, we can ensure that management decisions are based on the most accurate and reliable information available, and promote the long-term sustainability of the striped marlin fishery.

The ISC billfish working group may consider the following options:

- Conducting a broader examination of consistency between datasets; for example, look at the negative log-likelihood difference profile for parameters other than R_0, especially if a parameter is estimated with large uncertainty and the stock-assessment model is highly sensitive to the parameter's value.

- Investigating the causes of inconsistency between informative datasets and, if possible, correcting for those causes; for example, use statistical or machine learning methods to improve misspecified or incomplete records.
- Improving the parameter estimation process by naturally allowing more informative and mutually consistent datasets to determine parameter values; for example, treat likelihood weightings as parameters whose sum is constrained to a fixed value.

References

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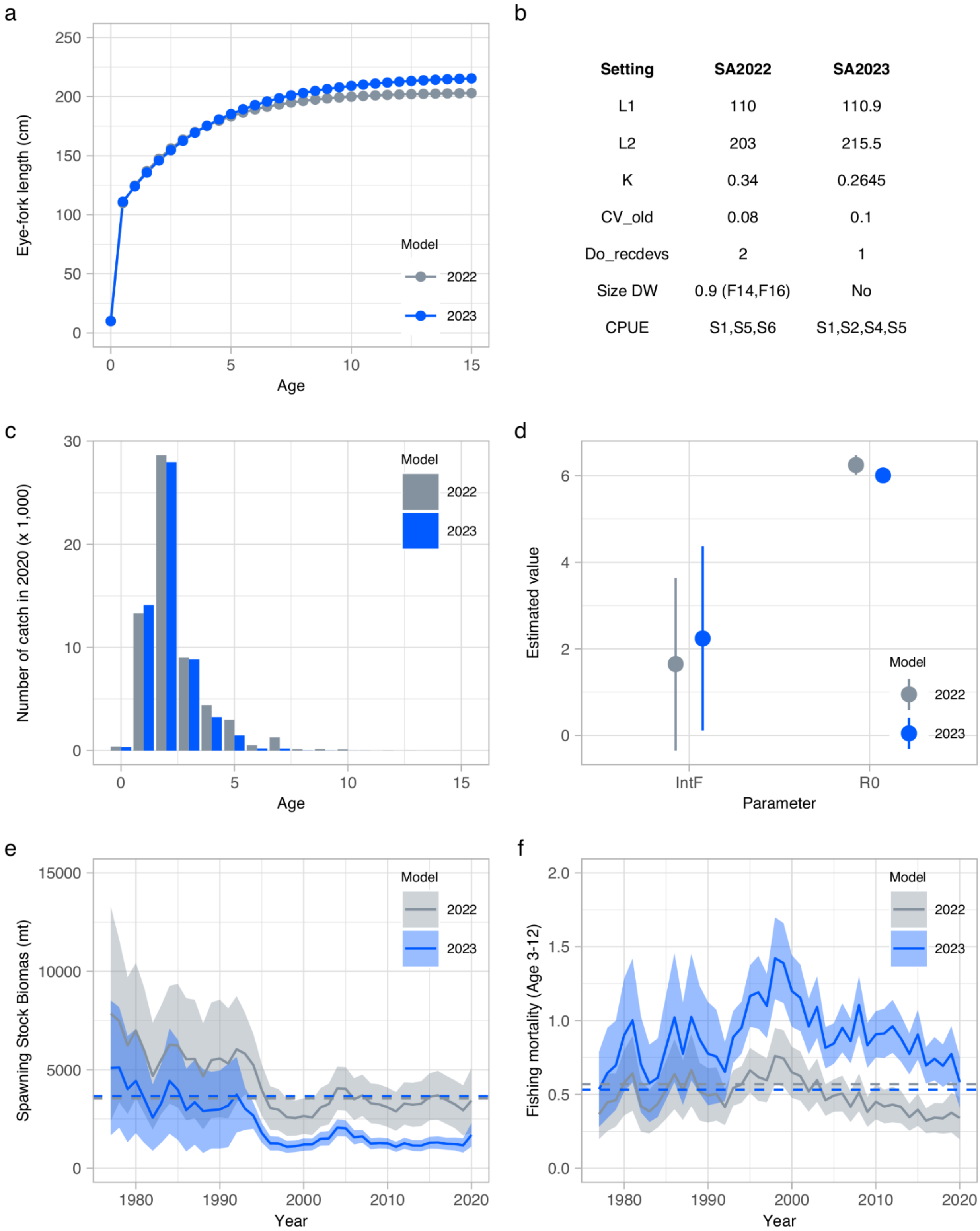

Setting	SA2022	SA2023
L1	110	110.9
L2	203	215.5
K	0.34	0.2645
CV_old	0.08	0.1
Do_recdevs	2	1
Size DW	0.9 (F14,F16)	No
CPUE	S1,S5,S6	S1,S2,S4,S5

Figure 1. Comparison of Stock Synthesis 3 results based on settings for 2022 and 2023 assessments. **a**, von Bertalanffy growth curves used in the two stock assessments. **b**, The differences in stock-assessment model settings. **c**, Model-estimated catch-at-age numbers for 2020. **d**, Point estimates and the corresponding 95% confidence intervals for initial mortality multiplier (*f*) and equilibrium recruitment (R_0). **e**, Model-estimated spawning stock biomass (SSB) from 1977 to 2020. Dashed horizontal lines indicate the management objective in the form of 20%$SSB_{F=0}$ for the period from 2001 to 2020. **f**, Model-estimated fishing mortality averaged over age groups 3 to 12. Dashed horizontal lines indicate the management objective in the form of F_{MSY}.

Figure 2. The age-structured composition of spawning stock biomass in the 2022 (grey) and 2023 (blue) stock assessments from 1975 to 2020.