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Sensitivity of Estimated Spawning Biomass to Natural Mortality Assumptions in Pacific Bluefin Tuna Assessments

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Abstract

This study systematically evaluated the sensitivity of estimated Pacific bluefin tuna spawning biomass with respect to natural mortality assumptions. In the PBF base model (i.e., model used for status update in July 2010), natural mortality at age-0 (M_0), age-1 (M_1), and age-2+ (M_{2+}) were assumed to be 1.6, 0.386, and 0.25 respectively. In this study, we fixed M_0 at 1.6 but varied M_1 and M_{2+} systematically. For each run of the model, M_{2+} was changed from 0.05 to 0.45 in 0.01 steps, and M_1 was modified such that $(M_0\text{-}M_1)/(M_0\text{-}M_2)$ remained constant for all runs. Estimated spawning biomass increased relatively smoothly from M_{2+} = 0.15 to 0.25 but when M_{2+} was assumed to be >0.25, the rate of change of estimated spawning biomass increased substantially. This showed that sensitivity of spawning biomass increased substantially in the PBF base model, when M_{2+} is >0.25. In addition, spawning biomass ratio and other quantities also showed large increases in sensitivity when M_{2+} is >0.25. Therefore, it is suggested that adult natural mortality should not be in excess of 0.25, unless there is biological data that suggests otherwise. This study suggests that the PBFWG should be cautious in assuming high levels of natural mortality

Introduction

The stock status of Pacific bluefin tuna (PBF) was recently updated by the Pacific bluefin tuna working group (PBFWG) of the International Scientific Committee for Tuna and Tuna-like species (ISC), during a meeting at Nanaimo, Canada in July 2010 (Anonymous, 2010). During that and other recent meetings of the PBFWG, there was much discussion of the effects of natural mortality assumptions on estimated quantities like spawning biomass (e.g., Aires-da-Silva, et al., 2009). Despite these past efforts, questions remain on the sensitivity of estimated spawning biomass to natural mortality assumptions. For example, does estimated spawning biomass change smoothly with respect to mortality assumptions? Or are there 'breakpoints' that result in greatly increased sensitivity?

The objective of this study is to systematically evaluate the sensitivity of estimated spawning biomass with respect to mortality assumptions and determine if spawning biomass changes consistently with respect to mortality. In general, a higher assumed natural mortality is akin to assuming higher productivity for the stock, which will tend to increase the estimated spawning biomass time series. We should thus expect some degree of sensitivity of estimated spawning biomass to mortality assumptions. Consequently, the main question of interest in this study is not whether spawning biomass is sensitive to natural mortality but the degree of sensitivity and whether it changes consistently with mortality assumptions.

Materials and Methods

The data and model for this study was derived from the PBF base model used in the PBFWG update of PBF status in July 2010 (Ichinokawa, et al., 2010). The data and base control files for this study were identical to the files used for the PBF base model in July 2010 (Data08_20100611ver7.SS and Control08.SS, respectively). As in the PBF base model, Stock Synthesis 3 was used as the modeling framework (v3.10b). In the PBF base model, natural mortality at age-0 (M_0), age-1 (M_1), and age-2+ (M_{2+}) were assumed to be 1.6, 0.386, and 0.25 respectively. In this study, we fixed M_0 at 1.6 but varied M_1 and M_{2+} systematically. For each run of the model, M_{2+} was changed from 0.05 to 0.45 in 0.01 steps, and M_1 was modified such that $(M_0-M_1)/(M_0-M_2)$ remained constant for all runs. All other parameters remained the same as the base model in Ichinokawa et al. (2010). After all 41 runs were completed, the models were checked for convergence and derived quantities, like spawning biomass, were extracted from their respective report files. Models with M_{2+} below 0.15 did not converge adequately (Maximum gradient > 0.1) and were eliminated from further analysis.

Results

Estimated spawning biomass was sensitive to changing M_{2+} and the sensitivity of estimated spawning biomass increased substantially when M_{2+} was assumed to be >0.25 As expected, the estimated spawning biomass time series increased with increasing M_{2+} but the estimated spawning biomass (1952-2006) did not change consistently (Fig. 1 & 2). Estimated spawning biomass increased relatively smoothly from M_{2+} = 0.15 to 0.25 but when M_{2+} was >0.25, the rate of change of estimated spawning biomass increased substantially (Fig. 2), demonstrating a large increase in the sensitivity. This was in part due to the changes in expected recruitment of the stock, as seen in Figure 3. In addition, model likelihoods improved with increasing M_{2+}, suggesting that model fits improved with increasing M_{2+}. Interestingly, there did not appear to be abrupt changes to the likelihoods at around M_{2+} = 0.25 (Fig. 4).

The spawning biomass ratio (SBR) is the ratio of current spawning biomass to unfished spawning biomass and is used by some regional fishery management organizations (including the IATTC, SPC, and PMFC) as reference quantities to characterize stock status. It is therefore important to understand how the PBF model responds to changing M_{2+}, in terms of these quantities. Figure 5 shows how estimated mean spawning biomass and unfished spawning biomass changes with respect to M_{2+}. Similar to the abovementioned results, mean spawning biomass ratio increases substantially when M_{2+} >0.25. When M_{2+} >0.25, estimated spawning biomass increases rapidly with relatively little change in estimated unfished spawning biomass. On the other hand, unfished spawning biomass changes rapidly with relatively little change in estimated spawning biomass when $M_{2+} <0.25$. Changes in M_{2+} did not substantially change the pattern of the estimated fishing mortality (Fig. 6). However, the scale of the estimated fishing mortality changed substantially with changes in M_{2+}. Estimated fishing mortality was relatively high and changed rapidly when M_{2+} was relatively low, and vice versa.

Discussion

One of the concerns of the PBFWG, with regard to the PBF assessment model is the sensitivity of estimated quantities to natural mortality assumptions. It is expected that estimated spawning biomass increases with increases in natural mortality. However, this study showed that sensitivity of spawning biomass increases substantially if M_{2+} is higher than 0.25, given the current PBF base model structure. In terms of biology, it is also unlikely that an adult bluefin tuna would have a natural mortality in excess of 0.25. Therefore, it is suggested that adult natural mortality should not be in excess of 0.25, unless there is biological data that suggests otherwise. If the model structure of the assessment is changed to reflect new information and data, the results from this study would likely be modified. However, the general trends revealed by this study would likely remain valid. If sensitivity to natural mortality assumptions remain a concern in future assessments, the PBFWG should be cautious in assuming high levels of natural mortality.

References

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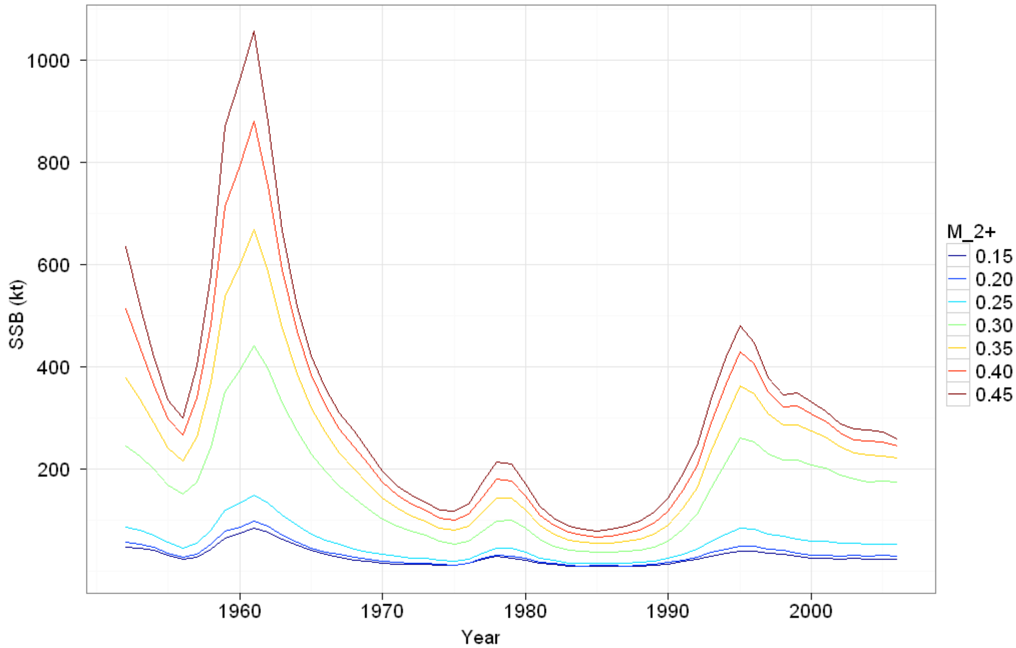

Figure 1. Estimated spawning biomass (SSB) time series (1952-2006), with M_{2+} ranging from 0.15 to 0.45.

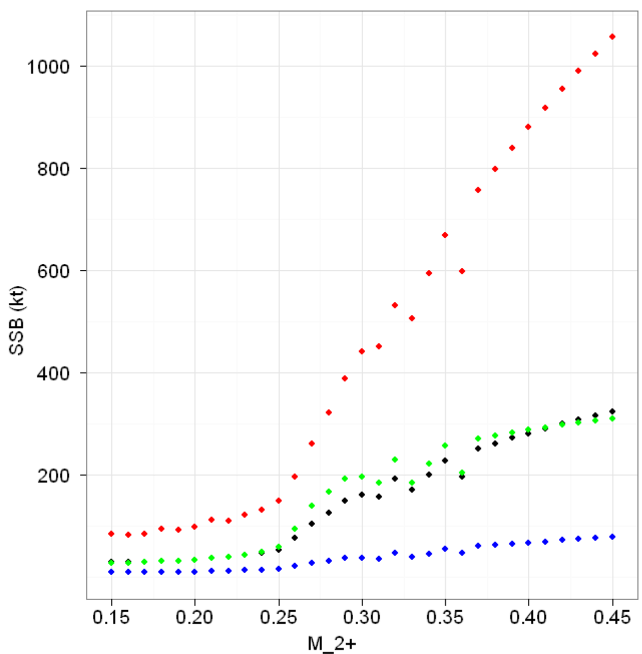

Figure 2. Mean (black), minimum (blue), maximum (red), and mean of last 10 years (green) of estimated spawning biomass (SSB) time series (1952-2006), with M_{2+} ranging from 0.15 to 0.45.

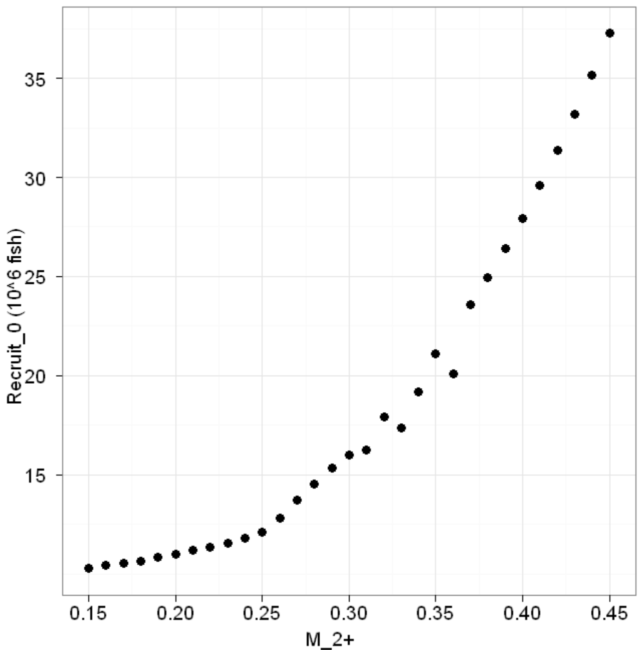

Figure 3. Estimated expected recruitment with M_{2+} ranging from 0.15 to 0.45.

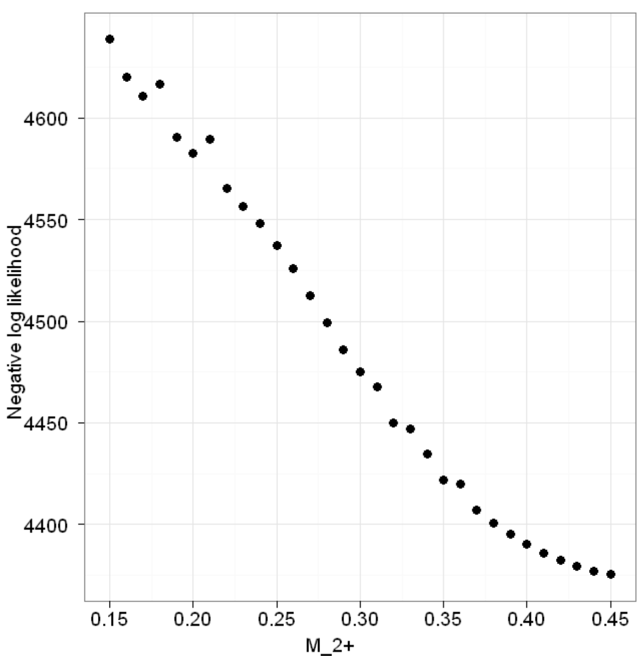

Figure 4. Negative log likelihoods of SS3 models, with M_{2+} ranging from 0.15 to 0.45.

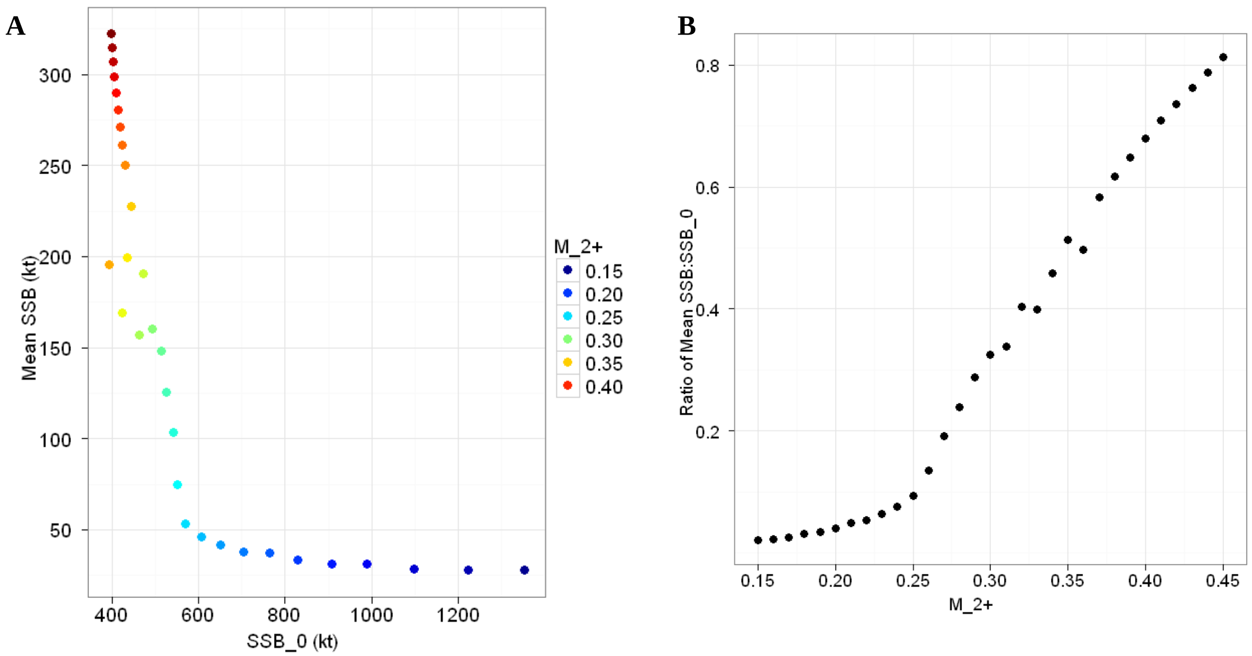

Figure 5. A) Estimated mean spawning biomass (1952-2006) and unfished spawning biomass (SSB_0), and B) estimated mean spawning biomass ratio, with M_{2+} ranging from 0.15 to 0.45.

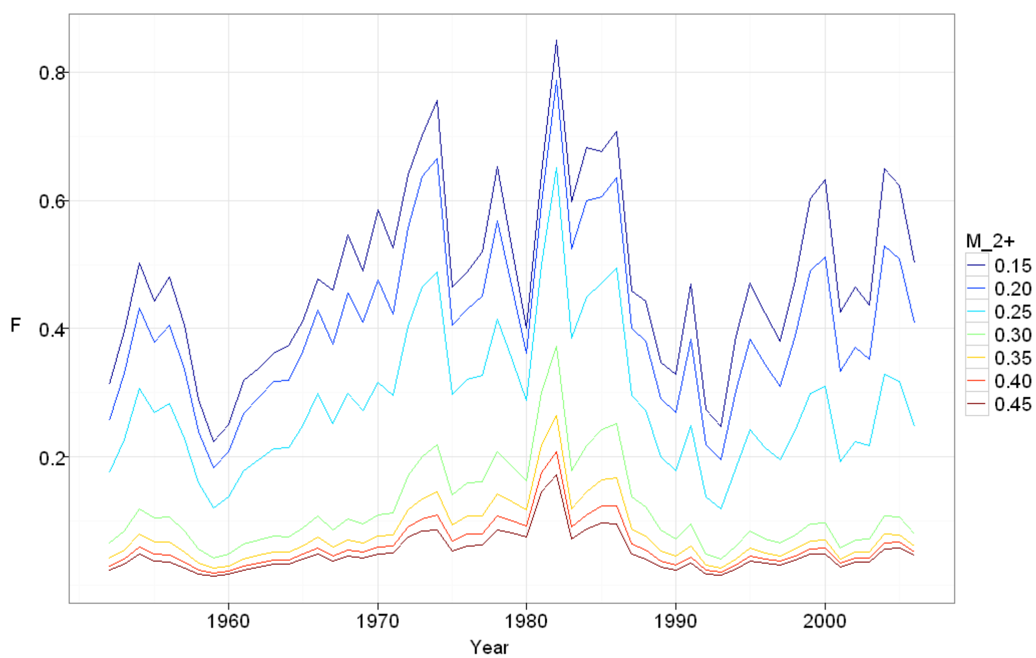

Figure 6. Estimated fishing mortality (F) from 1952 to 2006, at M_{2+} ranging from 0.15 to 0.45.