New data tests age-structured production model (ASPM) for Pacific bluefin tuna

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Summary

An age-structured production model (ASPM) is a recent revival of diagnostic in the stock assessment practice. The ASPM has been used to illustrate if a stock exhibits the production relationship to detect a fishing effect. The 2016 and 2018 stock assessment models for Pacific bluefin tuna were able to capture the signal of observed catches in adult indices. We used this established production relationship to quantify the degree of consistency between the different new data (newly available catch, discards, and longline and troll CPUE). We use internal model consistency criteria to provide an indirect validation of data based on the ability of the production relationship to predict the new data. The results may provide some insights into new data during the model development.

Introduction

The Pacific Bluefin tuna Working Group (PBFWG) of the International Scientific Committee for Tuna and Tuna-like species in the North Pacific Ocean (ISC) is tasked to conduct a benchmark stock assessment in March 2020. The PBFWG completed a benchmark stock assessment in 2016 (ISC 2016) and an update of the 2016 assessment in 2018 (ISC 2018).

In the past two assessments, dynamic models were able to capture the signal of observed catches in adult indices (based on the age-structured production diagnostics, ASPM). Additionally, the recruitment index used provided a reliable measure of age-0 abundance. In this well-defined system, all data used indicated a consistent population scale (based on the R0 profile analysis). With the newly available catch, discards, and longline and troll CPUE (age-0 abundance), the established production relationship in the ASPM developed from the 2018 stock assessment can be used to quantify the degree of consistency between the different data types. We use internal model consistency criteria to provide an indirect validation of data based on the ability of the production relationship to predict the new data.

Age-structured production model (ASPM)

We determined whether the PBF production relationship is present using a diagnostics tool, an age-structured production model (ASPM), proposed by Maunder and Piner (2015). An ASPM was developed by modifying the 2018 assessment model (ISC 2018). The modified assessment model estimates the full population dynamics with changes from the 2018 assessment model as follows: (1) assume the steepness of the Beverton-Holt spawner-recruit relationship to be 1.0, (2) assume the variability of the recruitment deviations to be 1.0 to be less constraining on the deviations, and (3) not fit to the age-0 CPUE index. An ASPM was created from this modified 2018 assessment model by (1) excluding all the size composition data, (4) fixing the selectivity parameters for each fleet at the maximum likelihood estimates from the modified 2018 assessment model, and (5) using deterministic mean recruitment. The ASPM only included catch by fleet and the Japan longline and Taiwan longline fisheries CPUE indices as contributing to the total likelihood function. The estimated parameters were lnR0 (unfished recruitment) and the parameters representing the initial conditions (recruitment offset for the first year of the model and two equilibrium fishing mortality, but no initial recruitment deviates). The diagnostic compared the results from ASPM to those from a modified assessment model estimating the full dynamics.

The adult CPUE indices of PBF exhibit both increasing and decreasing long-term trends along with shorter-term fluctuations. The long-term trends provide a good test for evidence of the production relationship. The ASPM model was able to replicate the increasing and decreasing patterns in the long-term trends (Fig. 1). The long-term trends support a connection between catch and adult trends via an elucidated production function.

Age-structured production model estimating recruitment variability (ASPM-R)

After determining the presence of the production relationship, we used improvements of the fits to the adult CPUE indices and scales within the ASPM to evaluate whether the addition of year-specific recruitment as indicated by the age-0 CPUE index is consistent with the existing production relationship. To derive the recruitment indicated by the age-0 CPUE index, we estimated recruitment and recruitment deviations in the ASPM (as described in the previous section) by forcing the model to match the age-0 CPUE index. We then re-ran the ASPM with the recruitment deviations fixed at these estimates without invoking the age-0 CPUE index (ASPM-R model).

The ASPM-R model estimated a similar magnitude of the global scale (unfished spawning biomass) to the ASPM model and improved fits to all adult CPUE indices relative to the ASPM (Fig. 1 and Table 1). The improvement of the fits of the adult CPUE indices suggests that the recruitment as indicated by the age-0 CPUE index was consistent with the catch, adult CPUE indices, and the production function.

New catch observations in the ASPM and ASPM-R models

To examine the effect of the new catch in the ASPM and ASPM-R models, catch observations up to 2018 fishing year were included in the likelihood estimation (the inclusion of the updated CPUE and discards will be examined in the following section). The new catch ASPM model estimated a similar global scale and had the same fits for all adult CPUE indices compared to the ASPM (Table 1). The new catch ASPM-R model also estimated a global scale close to the ASPM-R model. The CPUE fits were improved for the Japan longline CPUE (1993-2016) and Japan age-0 troll CPUE (1980-2016) but were degraded for the Taiwan longline CPUE (2000-2016). This implied that the recruitment as indicated by the age-0 troll CPUE is more consistent with new catch and Japan longline CPUE (1993-2016) compared to the ASPM-R (with old catch) model.

The new-catch-ASPM model indicated an upward trend of the adult biomass (age 6 and older) from 2017 to 2018, while the new-catch-ASPM-R model showed the steady adult biomass in 2017-2018 (Fig. 2). Both new-catch-ASPM and new-catch-ASPM-R models also estimated the expected fits for the new Japan longline CPUE (1993-2018) and new Taiwan longline CPUE (2002-2018) although both adult CPUE indices were not fit in the models (Fig. 3). The new-catch-ASPM model expected to capture the upward trend from 2017 to 2018 for the new Japan longline (1993-2018), whereas the new-catch-ASPM-R model does not. On the other hand, no trend from 2017 to 2018 was observed in the new Taiwan longline (2002-2018).

Is abundance high in 2018?

The observation in 2018 in the longline fisheries (catching age 4-8+ fish) was made with the recruits for 2010-2014. A new-catch ASPM-R model was re-run by arbitrarily adjusting the low recruitment observed in 2012 and 2014 to higher recruitment observed in 2011 and 2013, respectively (new-catch ASPM-R(2012&2014), Fig. 4). If the 2012 and 2014 recruitment were higher, the new-catch ASPM-R(2012&2014) model would expect to capture the upward trend from 2017 to 2018 for the new Japan longline (1993-2018) (Fig. 4).

New catch and CPUE indices observations

To examine the effect of the new catch and new CPUE in the ASPM and ASPM-R models, catch and longline and troll CPUE observations up to 2018 fishing year were included in the likelihood estimation. The new-catch&CPUE-ASPM and new-catch&CPUE-ASPM-R models estimated a similar global scale to the ASPM and ASPM-R models, respectively (Table 1). Both models had the same fit for the Japan longline CPUE (1974-1992) compared to the ASPM and ASPM-R models. The new-catch&CPUE-ASPM-R model fit the new Japan longline (1993-2018) and the new Taiwan longline (2002-2018) well (Table 1) with a flat trend from 2017 to 2018 (Fig. 5).

New catch and discards observations

To examine the effect of the new catch and discards in the ASPM model, catch and discards observations up to 2018 fishing year were included in the likelihood estimation. The new-catch&discards-ASPM model estimated a slightly larger global scale compare to the ASPM and new-catch-ASPM models (Table 2) with the greater improved fit for the Japan longline (1993-2016). The improvement supports a better connection between catch, discards, and adult trends via an elucidated production function.

Is the increase in CPUE real?

The new-catch-ASPM-R does not predict the increased CPUE in the 2018 index. This suggests that the increase in CPUE may not reflect an increase in abundance. There are a variety of hypotheses that might explain this including, but not limited to:

1) The recruitment index is too low for years 2012 and 2014 (or other recent years).
2) The catchability of the index increased in 2018.
3) The fishery targeted a different component of the stock.

There might be a piece of evidences that the Japan longline fleet targets strong cohorts. The length-frequency data for this fleet in 2017-2018 showed that smaller fish were caught (Fig. 6).

Further research needs to be conducted to determine which of these or other hypotheses explain the inability of the new-catch-ASPM-R model to predict the high 2018 CPUE.

References

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Table 1. The scale (unfished spawning biomass) and trend (root-mean-square error (RMSE) for three adult CPUE indices) of production function from the ASPM and ASPM-R models. The RMSE values in parentheses are the excepted fits to the index that is not used in the model.

	ASPM	ASPM-R	new-catch ASPM	new-catch ASPM-R	new-catch&CPUE ASPM	new-catch&CPUE ASPM-R
Scale						
Unfished spawning biomass (mt)	814,201	656,697	814,241	655,742	820,512	656,860
Trend						
Japan longline 1974-1992 (RMSE)	0.39	0.38	0.39	0.38	0.39	0.38
Japan longline 1993-2016 (RMSE)	0.43	0.29	0.43	0.26	(0.44)	(0.28)
Japan longline 1993-2018 (RMSE)	N.A.	N.A.	(0.43)	(0.31)	0.43	0.27
Taiwan longline 2000-2016 (RMSE)	0.32	0.29	0.32	0.31	(0.32)	(0.31)
Taiwan longline 2002-2018 (RMSE)	N.A.	N.A.	(0.30)	(0.28)	0.30	0.25
Process variability						
Japan troll 1980-2016 (RMSE)		0.15		0.14		(0.14)
Japan troll 1980-2018 (RMSE)		N.A.		(0.32)		0.14

Table 2. The scale (unfished spawning biomass) and trend (root-mean-square error (RMSE) for three adult CPUE indices) of production function from the ASPM models.

	ASPM	new-catch ASPM	new-catch&discards ASPM
Scale			
Unfished spawning biomass (mt)	814,201	814,241	889,281
Trend			
Japan longline 1974-1992 (RMSE)	0.39	0.39	0.39
Japan longline 1993-2016 (RMSE)	0.43	0.43	0.37
Taiwan longline 2000-2016 (RMSE)	0.32	0.32	0.31

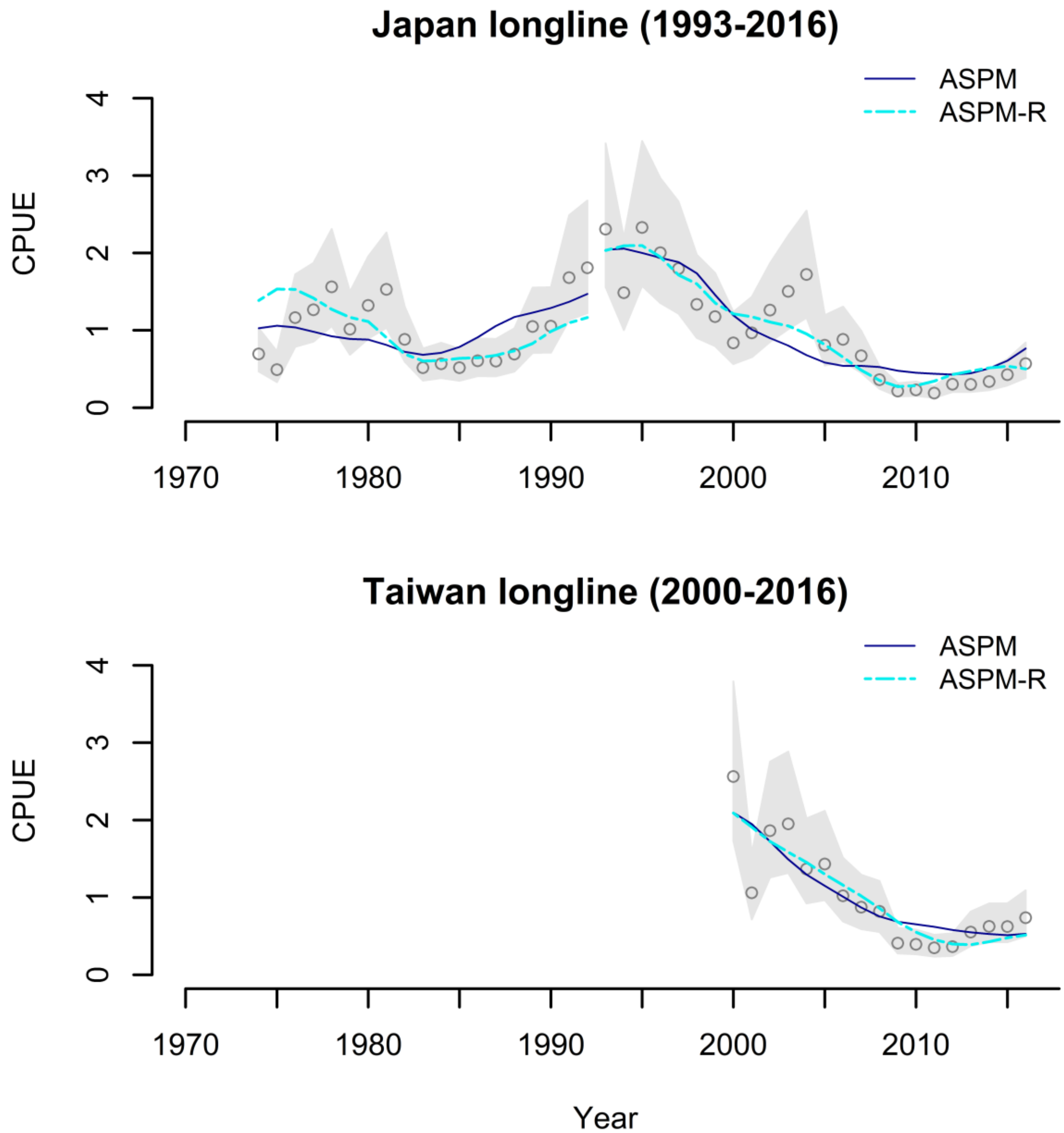


Fig. 1. Predicted adult longline CPUE indices (top panel: Japan longline CPUE; bottom panel: Taiwan longline CPUE) from the ASPM (darker blue lines) and ASPM-R (lighter blue lines). The open circles in represent the observed adult longline CPUE and gray area represent associated 95% confidence intervals.

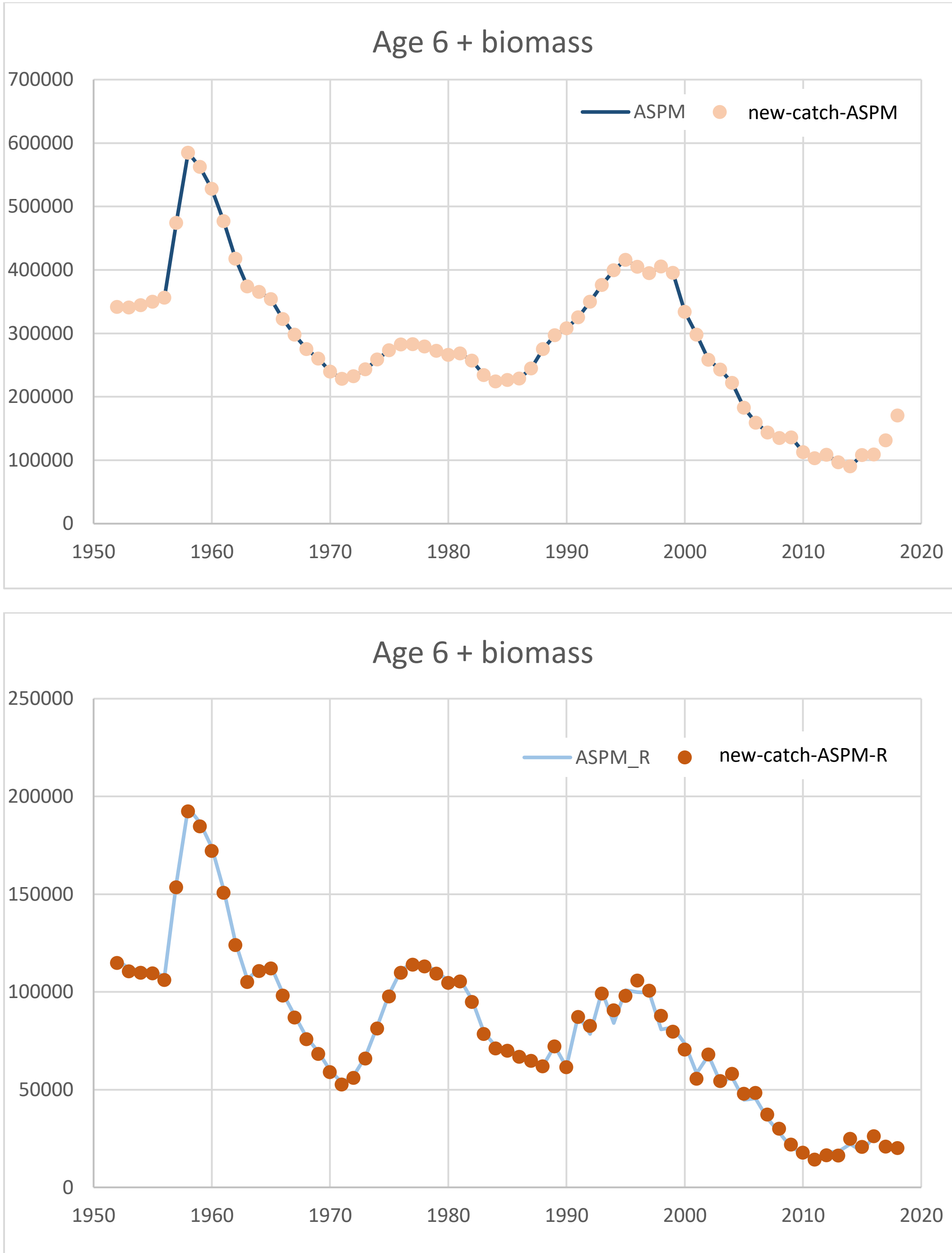


Fig. 2. Time series of age 6 and older stock biomass from the ASPM models (top panel) and ASPM-R models (bottom panel).

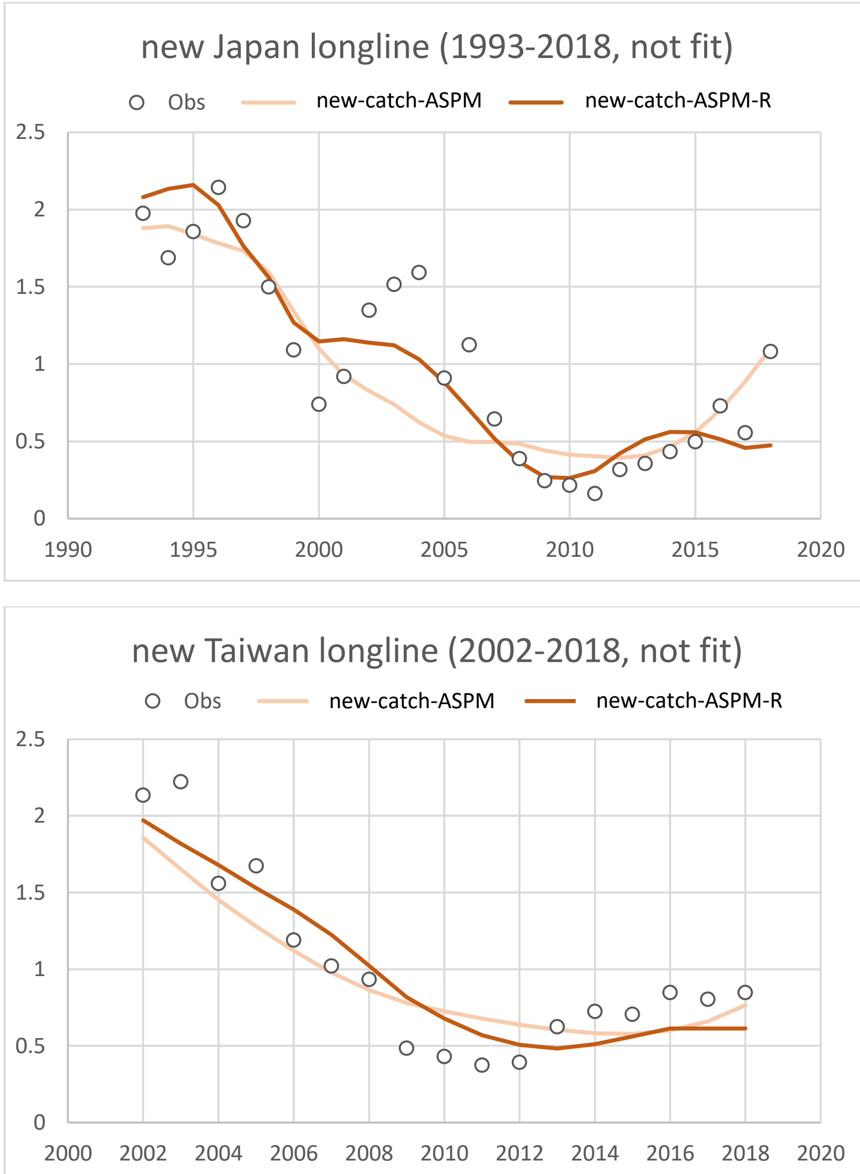
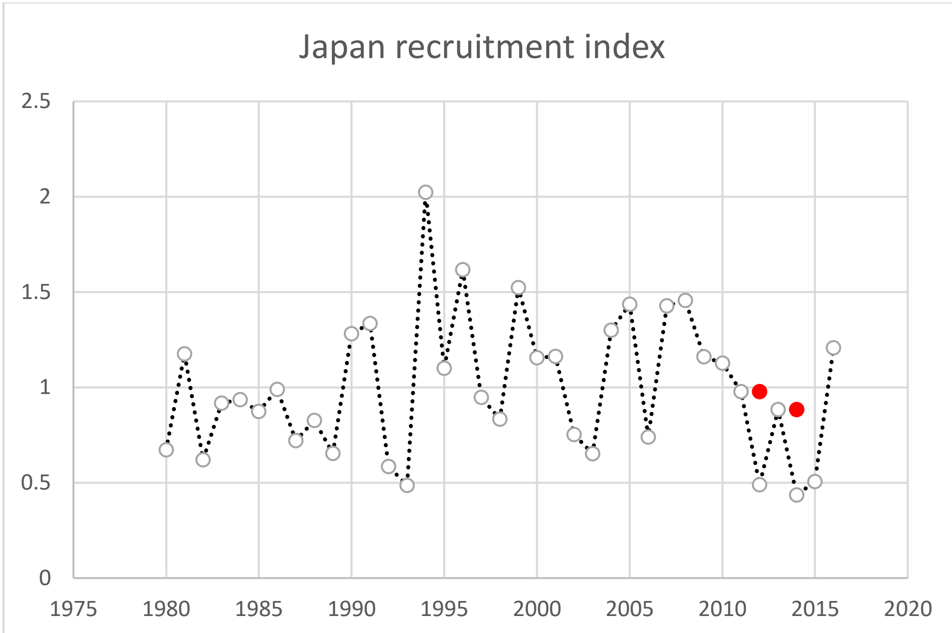


Fig. 3. Expected fits for the new Japan (top panel) and new Taiwan (bottom panel) longline CPUE indices from the new-catch-ASPM (lighter orange lines) and new-catch-ASPM-R (darker orange lines). The open circles in represent the observed adult longline CPUE.



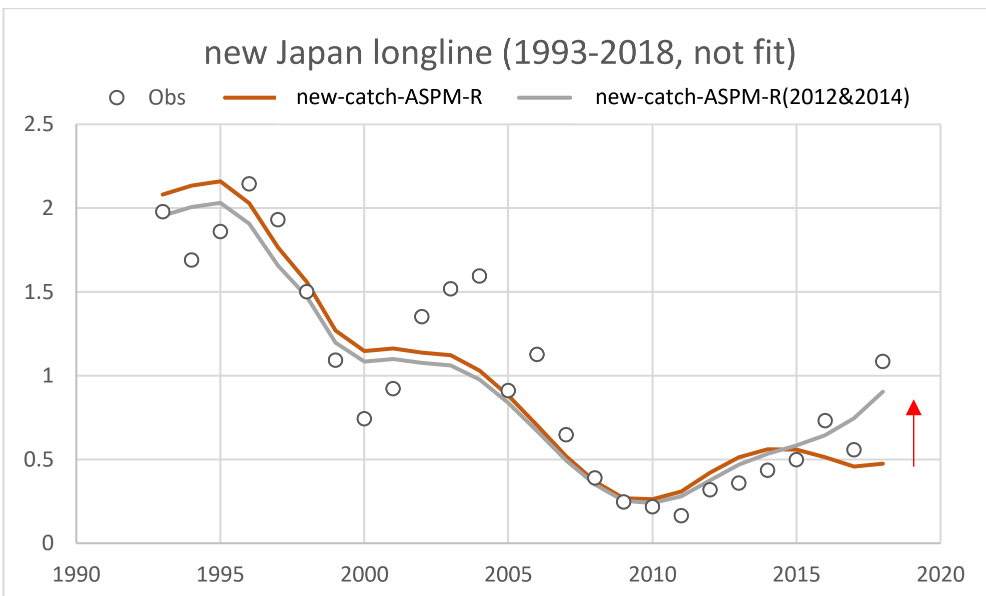


Fig. 4. Age-0 recruitment CPUE index from Japan troll fleets (top panel) and expected fits for the new Japan longline CPUE index from the new-catch-ASPM-R (orange line) and new-catch-ASPM-R(2012&2014) (gray line) models (bottom panel). The open circles in represent the observed CPUE.

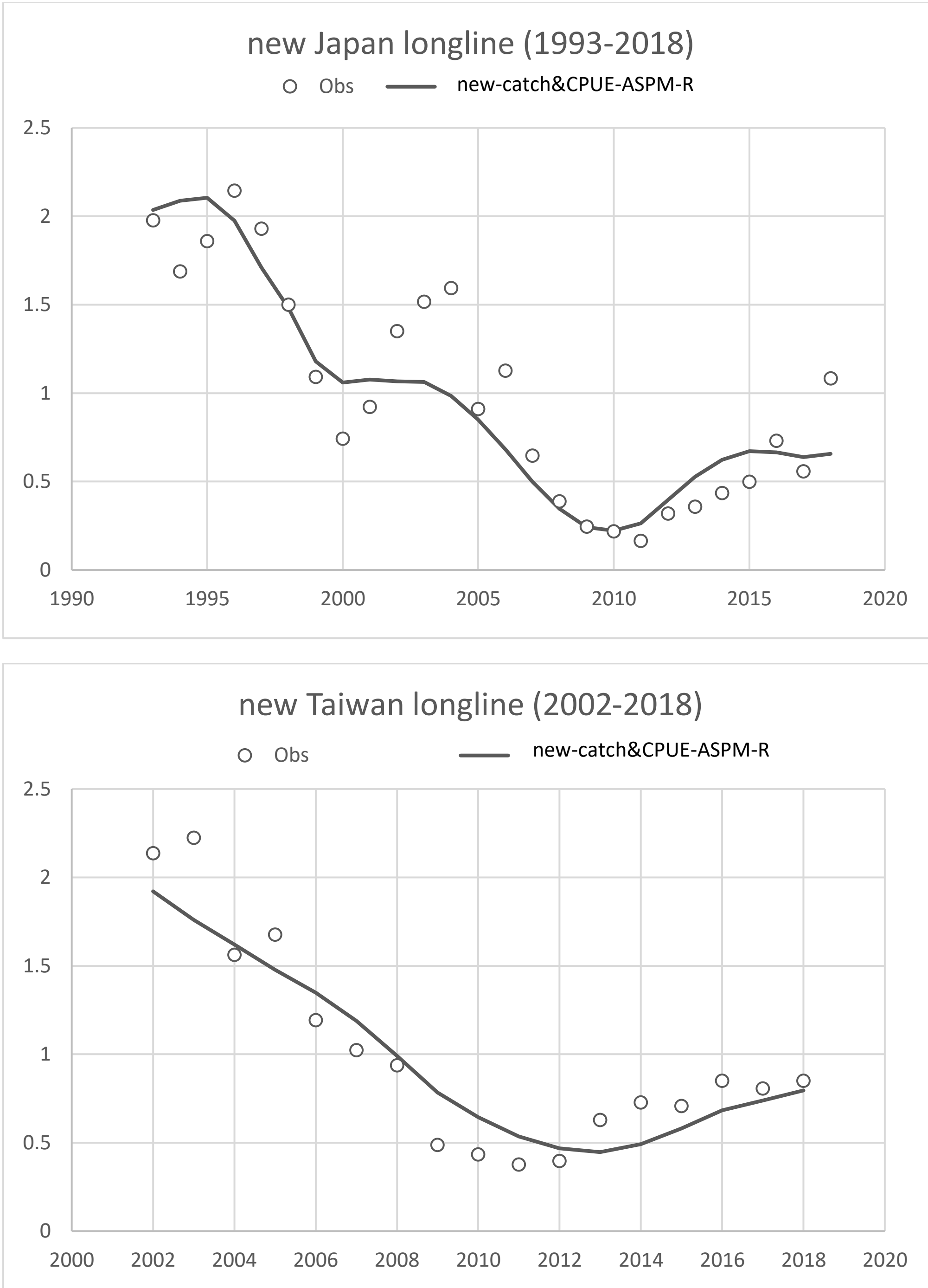


Fig. 5. Predicted adult longline CPUE indices (top panel: Japan longline CPUE; bottom panel: Taiwan longline CPUE) from the new-catch&CPUE-ASPM-R model (black lines). The open circles in represent the observed adult longline.

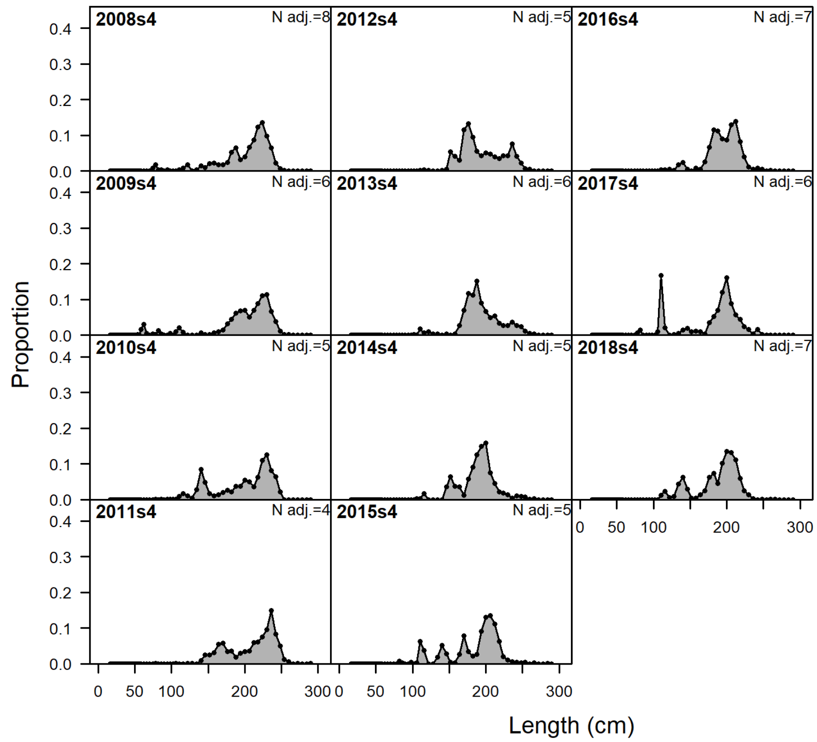


Fig. 6. Length-frequency data from the Japan longline fisheries for 2008-2018.