Impact of selection of abundance indices on estimates of biological reference points for Indian Ocean Albacore *(Thunnus alalunga)*

[1]Lulu Ma, [1]Jiangfeng Zhu, [1,2]Yuying Zhang

1. National Engineering Research Center for Oceanic Fisheries, Shanghai Ocean University, 999 Hucheng Huan Road, Shanghai 201306, China;

2. Department of Biological Sciences, Florida International University, North Miami, FL 33181, USA

Abstract: Stock assessment models using ASPIC platform were run to examine the impacts of alternative modeling components on parameter estimates and biological reference points (BRPs). The preliminary findings from this study were that the initial value of B1/K was less influential than the production models and model fitting criteria. However, considering the unrealistic BRP estimates derived from the models with Least Absolute Values (LAV) criteria, it needs to be cautious in using this method for ASPIC model for the albacore. It seems that using whole-area based Taiwanese CPUE index combining Fox production model with SSE criteria provides relatively reasonable parameters estimates and BRPs for Indian Ocean albacore. This study suggests that the production model shapes and model fitting criteria are also important and influential components when assessing Indian Ocean albacore stocks.

1 Introduction

The Indian Ocean albacore (*Thunnus alalunga*) resource was initially harvested by longlines since the 1950s and now is one of the main tuna recourses in the Indian Ocean. The stock assessments of albacore in the Indian Ocean using ASPIC (Prager, 2004; NOAA Fisheries Toolbox. 2011) were conducted at IOTC WPTmT meeting in 2012 and 2014. The ASPIC model, based on non-equilibrium surplus production model, ignores biological factors (e.g. the age and size structure, sexual ratio) when assessing stock status. The minimum data needed to estimate stock status with such models are time series of relative abundance index and catch. In tuna longline fishery, the standardized catch-per-unit-effort (CPUE; number of fish caught per 1000 hooks) is often used as the index of relative abundance.

Catch and effort data from major longline fleets (i.e., Japan, Korea, and Taiwan, China) are routinely used in developing abundance indices for Indian Ocean albacore. However, the CPUE trends from these fleets did not show consistency for at least some years of the fishing period, which potentially impacts the stock assessment results (e.g. estimates of model parameters and biological reference points or BRPs).

In the past WPTmT meetings, nominal CPUE data from the main longline fleets were separately standardized to develop indices of abundance. For the current WPTmT, longline operational data from main fleets were combined and four area-specific CPUE index series were developed for use in tuning stock assessment models.

The basic purpose of this study is to preliminarily investigate the impact of selecting CPUE indices on stock assessments of albacore using ASPIC model. The impact of using different model fitting criteria (e.g. objective function) and production model shapes are also examined.

2 Material and methods

2.1 Catch and CPUE indices

We used the nominal catch data (1980-2012) by fishery from the IOTC database (as of June, 2014). The fishery-specific catch was simply summed to derive the annual catch time series. Standardized CPUE series used are those developed based on Taiwanese longline (1980-2012) for WPTmT05 (Lee *et al*., 2014), and those developed based on combined operational data of Taiwanese, Japanese and Korea longline fisheries, considering the vessel identification factor for the WPTmT06 (i.e. the CPUE indices of 1979-2014; Hoyle *et al*. 2016; see Table 1).

2.2 Scenarios

For ASPIC, two types of surplus production models (i.e. Fox and Logistic model) can be integrated in the population dynamics modelling. Therefore, Fox model and Logistic model were considered in developing different scenarios.

In addition, for ASPIC, two model fitting criteria (i.e. represented by objective functions) can be used to estimate model parameters, i.e. the Minimum of Sum of Squared Errors (SSE) and Least Absolute Values (LAV) as shown below.

$$\mathrm{SSE} = (n-1)\left(S_y^2 - \frac{S_{xy}^2}{S_x^2}\right) \qquad (1)$$

$$\mathrm{LAV} = \sum_{i=1}^{n} |y_i - f(x_i)| \qquad (2)$$

And, the key initial guess (input) for the ASPIC model is B1/K (the ratio of the starting biomass over carrying capacity K). Therefore, we tried different levels of initial B1/K in alternative scenarios to look at their impacts on model results **(Table 2)**. After preliminary model runs, we found that the impact of initial B1/K on model results seems to be small (Scenarios1-18). So we did not consider this factor in other scenarios (**Table 2**). Thus, a total of 26 scenarios were considered, in terms of different starting values of B1/K, surplus production models, objective functions, and in particular the CPUE indices (**Table 2**).

The main outputs of the model include *K* (maximum biomass or carrying capacity), MSY (maximum sustainable yield), F_{MSY} (fishing mortality corresponding to MSY), *q* (catchability coefficient for CPUE series), B_{MSY} (biomass corresponding to MSY), and R^2 (coefficient of determination of model fit).

3 Results

3.1 Impact of starting biomass ratio (B1/K)

The starting biomass ratio (B1/K) does not impact on the model fitting and estimates of MSY and F_{MSY}, either in Scenarios 1-9 with Fox production model or Scenarios 10-18 with Logistic production model (**Table 2**). When using whole-area based Taiwanese longline CPUE indices and Fox production model, the MSY, B_{MSY}, and F_{MSY} was estimated to be 33,990 t, 134,500 t, and 0.2527, respectively (**Scenarios 1-9**; **Table 2**). However, the MSY, B_{MSY}, and F_{MSY} estimates differed greatly when Logistic production model was assumed (**Scenarios 10-18**; **Table 2**).

3.2 Impact of surplus production model and fitting criteria

Scenarios 19-22 in **Table 2** show the impact of different model fitting criteria and production models on modeling results, using two abundance indices (TWN-N and TWN-S, equally weighted). The estimates of MSY and B_{MSY} were unrealistically high in each of these scenarios, although the coefficient of determination of model fit (R^2) was close to those estimated in Scenarios 1-18. It seems that either the Logistic production model or Fox production model did not improve the model estimates of biological reference points for albacore. And, the results seem getting worse when LAV criteria was used (Scenarios 20 and 22). The CPUE index trends for those scenarios are shown in **Fig. 1,** and corresponding F/F_{MSY} and B/B_{MSY} trends shown in **Fig. 2**.

3.3 Impact of new CPUE indices

Since the shape of surplus production model did not improve the model results, and LAV criteria resulted in more unrealistic results, we only tried to use the Fox model and SSE criteria to model the population dynamics and estimate model parameters using the new area-specific CPUE indices for WTmT06 (**Scenarios 23-26**). The results showed that all of the four scenarios did not fit the model well in terms of R^2. The observed and estimated CPUE indices were shown in **Fig. 3**.

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Table 1 The CPUE indices used for ASPIC

Indices	Description	Source
TWN-ALL	Taiwanese longline, all areas combined, 1980-2012	WPTmT05
TWN-N	Taiwanese longline, 0-20S, 20-120E, 1980-2012	WPTmT05
TWN-S	Taiwanese longline, 25-40S, 20-50E, 1980-2012	WPTmT05
Area 1	Fleets combined, North-west Indian Ocean	WPTmT06
Area 2	Fleets combined, North-east Indian Ocean	WPTmT06
Area 3	Fleets combined, South-west Indian Ocean	WPTmT06
Area 4	Fleets combined, South-east Indian Ocean	WPTmT06

Table 2 CPUE indices, model configurations and partial results of different scenarios

Scenario	CPUE	Model	Func	B1/K	MSY	B_{MSY}	F_{MSY}	R^2
1	TWN-ALL	Fox	SSE	0.1	33990	134500	0.2527	0.7102
2	TWN-ALL	Fox	SSE	0.2	33990	134500	0.2527	0.7102
3	TWN-ALL	Fox	SSE	0.3	33990	134500	0.2527	0.7102
4	TWN-ALL	Fox	SSE	0.4	33990	134500	0.2527	0.7102
5	TWN-ALL	Fox	SSE	0.5	33990	134500	0.2527	0.7102
6	TWN-ALL	Fox	SSE	0.6	33990	134500	0.2527	0.7102
7	TWN-ALL	Fox	SSE	0.7	33990	134500	0.2527	0.7102
8	TWN-ALL	Fox	SSE	0.8	33990	134500	0.2527	0.7102
9	TWN-ALL	Fox	SSE	0.9	33990	134500	0.2527	0.7102
10	TWN-ALL	Logistic	SSE	0.1	29180	218900	0.1333	0.6929
11	TWN-ALL	Logistic	SSE	0.2	29180	218900	0.1333	0.6929
12	TWN-ALL	Logistic	SSE	0.3	29180	218900	0.1333	0.6930
13	TWN-ALL	Logistic	SSE	0.4	29180	218900	0.1333	0.6930
14	TWN-ALL	Logistic	SSE	0.5	29180	218900	0.1333	0.6929
15	TWN-ALL	Logistic	SSE	0.6	29180	218900	0.1333	0.6929
16	TWN-ALL	Logistic	SSE	0.7	29180	218900	0.1333	0.6930
17	TWN-ALL	Logistic	SSE	0.8	29180	218900	0.1333	0.6930
18	TWN-ALL	Logistic	SSE	0.9	29180	218900	0.1333	0.6930
19	TWN-N TWN-S	Logistic	SSE	0.5	70210	822500	0.0853	0.6573
20	TWN-N TWN-S	Logistic	LAV	0.5	121600	1787000	0.0680	0.7003
21	TWN-N TWN-S	Fox	SSE	0.5	90590	444600	0.2038	0.6731
22	TWN-N TWN-S	Fox	LAV	0.5	213100	1321000	0.0613	0.7078
23	Area 1	Fox	SSE	0.5	31500	348400	0.0904	0.2414
24	Area 2	Fox	SSE	0.5	40300	286600	1.4060	0.0384
25	Area 3	Fox	SSE	0.5	55070	326100	0.1689	0.3195
26	Area 4	Fox	SSE	0.5	71890	553200	0.1300	0.0763

Notes: Unit for catch and biomass: metric ton (mt). ‘Model’ indicates surplus production model. ‘R^2’ indicates the correlation coefficient of determination. ‘Func.’ indicates the objective function of fitting criterion.

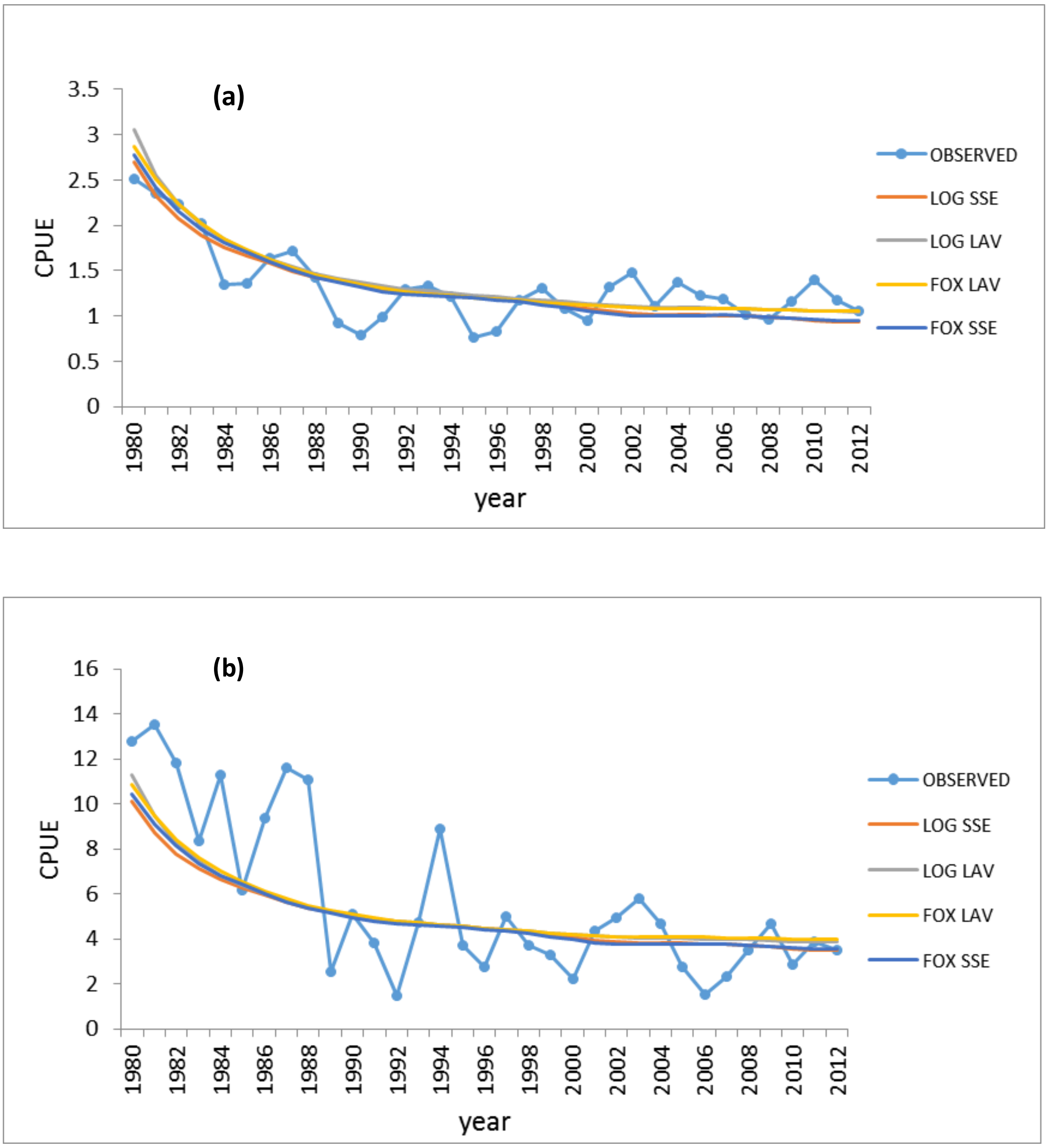

Fig. 1 The observed and estimated time series of CPUE indices of TWN-North (a) and TWN-South (b) derived from ASPIC with different surplus production models and fitting criteria.

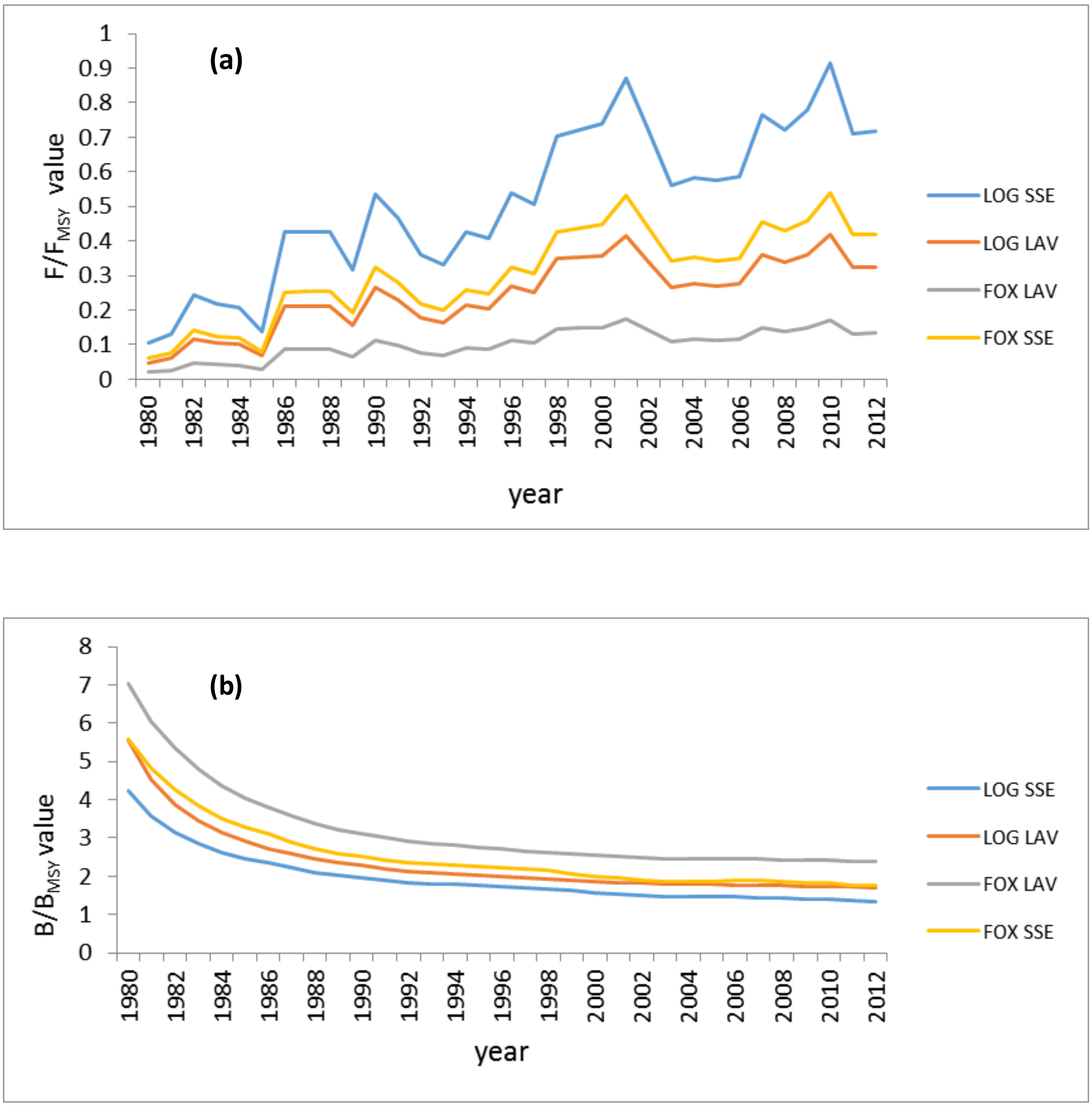

Fig. 2 The F/F_{MSY} (a) and B/B_{MSY} (b) estimated by ASPIC with different surplus production models and fitting criteria using equally weighted CPUE indices of TWN-North and TWN-South

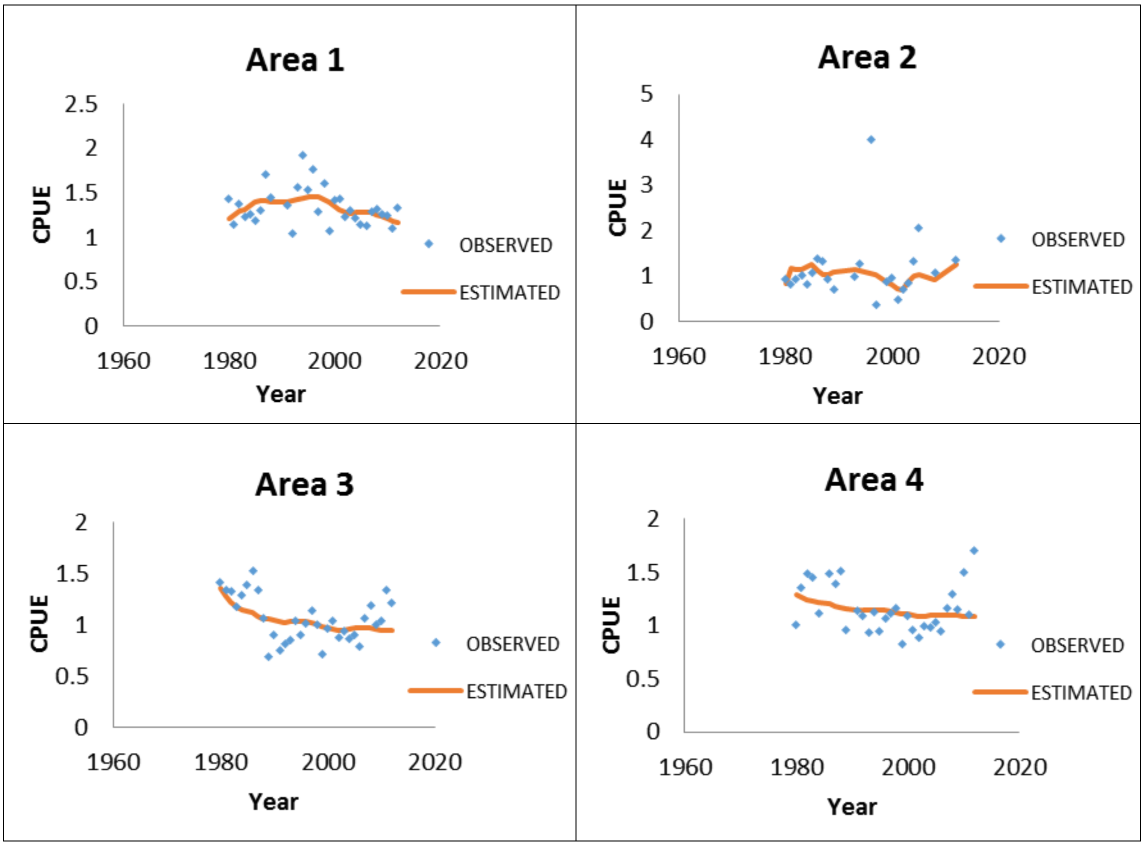

Fig.3 The area-specific CPUE index trends derived from ASPIC with Fox production model and SSE fitting criterion (Scenarios 23-26)