Update of standardized CPUE of blue shark (Prionace glauca) in the Indian Ocean estimated from Japanese observer data between 1992 and 2015.

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1. Introduction

We updated the standardized CPUE of blue shark based on the Japanese observer data collected in the Indian Ocean between 1992 and 2015. The model structure and procedure of the analysis are basically same with Kanaiwa et al. (2014) and Semba et al. (2015). We modified the following points:

1) We added the observer data which was collected outside the traditional CCSBT observer program which was collected in the Indian Ocean

2) We added observer data with deep set and set operated in the tropical area.

3) We used observed total hook number instead of deployed total hook number as the effort.

2. Materials and methods

In this update, we added the data collected by Indonesian observer on board Japanese longline vessel operated in the Indian Ocean between 2013 and 2015. This data consists of CCSBT observer data, IOTC observer data and ICCAT observer data from which set deployed in the Indian Ocean was extracted. In addition, observer data with deep set (number of hooks per basket: HPB ≥14) and set operated in the area northern than 25˚S was included (Fig. 1). Consequently, we could include the data of 2013, which was removed in the past analysis due to small sample size. Regarding the filtering for erroneous data, we removed sets without latitude or longitude or hooks or HPB, as with Semba et al. (2015). The general information on the number of set, catch number, observed hook and nominal CPUE per year after data filtering is shown in Table 1. We applied three GLM (Poisson model, zero-inflated Poisson model, and zero-inflated negative binomial model) which were applied in Semba et al. (2015), with same covariates. As a result of model selection by AIC (Table2), zero-inflated Negative binomial GLM with the following covariates was selected;

$$Count\ process's\ catch = \beta_1 \cdot year + \beta_2 \cdot area + \beta_3 \cdot season + \beta_4 \cdot year : area + \beta_5 \cdot area : season + intercept + \varepsilon_1$$
$$False\ zero\ prob = \beta_6 \cdot year + \beta_7 \cdot area + intercept + \varepsilon_2$$

Here, $\beta_1 \sim \beta_7$ are coefficients for each factors. ε_1 denotes error terms followed by negative binomial distribution and ε_2 denotes error terms followed by binomial distribution. Former model's link function is log and later models link function is logit. Log(number of hooks) was used as offset term. The definition of season, area, and gear is same with that in Semba et al. (2015).

For the selected model, the 95% confidence interval for the annual CPUE was estimated by bootstrap with one thousand replicates. C.V. for estimates of annual CPUE was calculated by dividing the standard deviation of the estimates by median of the estimate for each year.

Results and Discussion

In this analysis, the longline data not only targeting for southern bluefin tuna (*Thunnus maccoyii*) but also tropical tuna such as bigeye tuna (*Thunnus obesus*) was included. Along with the addition of Indonesian observer data, the GLM analysis converged after including data of 2013 unlike past analysis. Inclusion of set in the tropical area may cause the increase of zero catch data, it is suggested that we could address this issue by the zero-inflated negative binomial model selected in this analysis to some extent. Although the zero catch ratio is not particularly high (fluctuating between 0 and 0.3; Fig. 2), Kanaiwa et al. (2014) suggests that treatment of zero catch produce better results in case of lower zero catch ratio, when the ratio fluctuates.

The standardized CPUE based on zero-inflated negative binomial GLM indicates large spike in the 1999 and 2006 as in the past analysis, but there is no continuous increasing or decreasing trend throughout the period (Fig. 3). The modifications added in the current analysis did not cause a large change in the trend of abundance compared to estimates in the past analysis (Appendix Fig.1), except for slight change in the absolute values of standardized CPUE. The reason for the small difference between the past and current analysis is suggested to be because the data newly added in the current analysis mainly consists of set from tropical area where the abundance of this species is relatively small, as described above. Estimated abundance index and its CV is shown in Table 3. For model validations, Pearson residuals for year, area and season were shown in Appendix Figures 2-4.

References

Kanaiwa, M., Y. Semba. and K. Yokawa. 2014. Standardized CPUE of blue shark in the Indian Ocean estimated from observer data in the period between 1992 and 2012. IOTC–2014–WPEB010-26.

Semba, Y., M. Kanaiwa, and K. Yokawa. 2015. Update of standardized CPUE of blue shark (*Prionace glauca*) in the Indian Ocean estimated from Japanese observer data in the period between 1992 and 2014. IOTC-2015-WPEB11-30 Rev_1.

Table 1. Summary of data used in the analysis.

year	catch number	observed hook	nominal CPUE
1992	2549	1,310,404	1.945
1993	1323	656,373	2.016
1994	1981	986,045	2.009
1995	2892	1,252,228	2.309
1996	4222	1,007,713	4.190
1997	2552	1,289,690	1.979
1998	2724	731,948	3.722
1999	3682	533,777	6.898
2000	1655	395,313	4.187
2001	3777	1,090,940	3.462
2002	2043	623,211	3.278
2003	3423	794,412	4.309
2004	2922	1,221,501	2.392
2005	4845	1,724,604	2.809
2006	4797	2,004,561	2.393
2007	2898	1,122,223	2.582
2008	958	295,009	3.247
2009	1916	433,950	4.415
2010	743	589,901	1.260
2011	1363	513,921	2.652
2012	1738	537,239	3.235
2013	1010	875,151	1.154
2014	3174	1,707,821	1.859
2015	3915	1,075,236	3.641

Table 2. AIC values for three GLM analysis for standardization of CPUE of blue shark.

Poisson GLM	zero-inflated Poisson GLM	zero-inflated negative binomial GLM
108822.3	96912.84	53733.45

Table 3. Estimated abundance index and its CV for blue shark calculated based on observer data for Japanese tuna longline fishery operated in the Indian Ocean.

	Median of standardized CPUE	C. V.
1992	1.746	0.068
1993	2.351	0.099
1994	2.954	0.108
1995	2.645	0.066
1996	4.452	0.055
1997	2.050	0.075
1998	4.237	0.078
1999	7.070	0.095
2000	3.481	0.150
2001	3.997	0.117
2002	3.866	0.081
2003	4.553	0.052
2004	2.017	0.064
2005	3.048	0.073
2006	2.565	0.053
2007	2.612	0.071
2008	2.791	0.054
2009	6.046	0.076
2010	1.169	0.083
2011	2.812	0.092
2012	3.442	0.079
2013	1.235	0.086
2014	1.868	0.059
2015	3.571	0.068

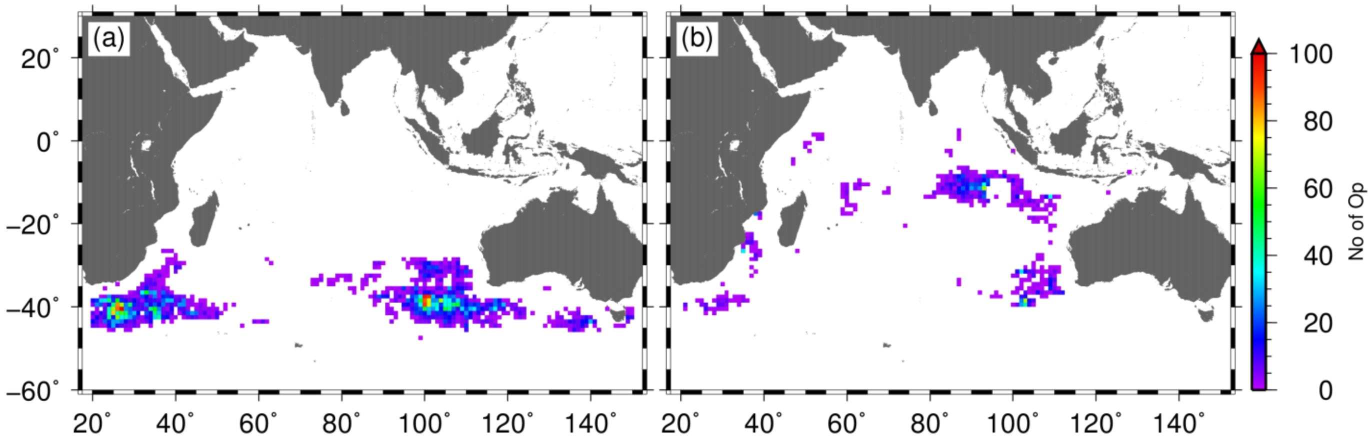


Fig.1 The location of set used in the analysis in the past analysis (a) and that newly added in the current analysis (b).

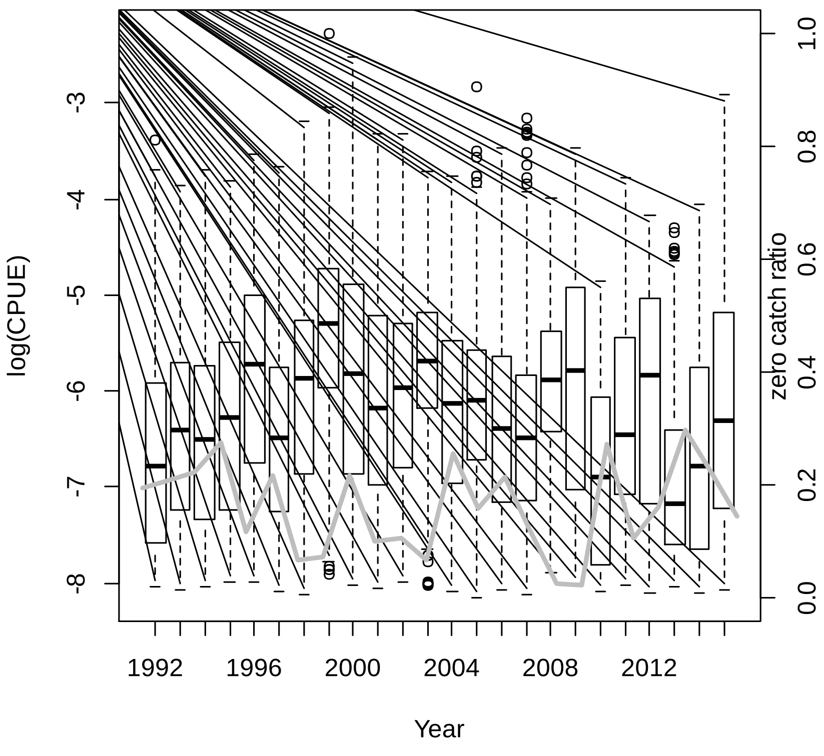


Fig 2. Annual trend of zero catch ratio (grey line and right y-axis) and positive CPUE (box plot: log scale, n / hooks; left y-axis) of blue shark calculated based on observer data for Japanese tuna longline fishery operated in the Indian Ocean between 1992 and 2015.

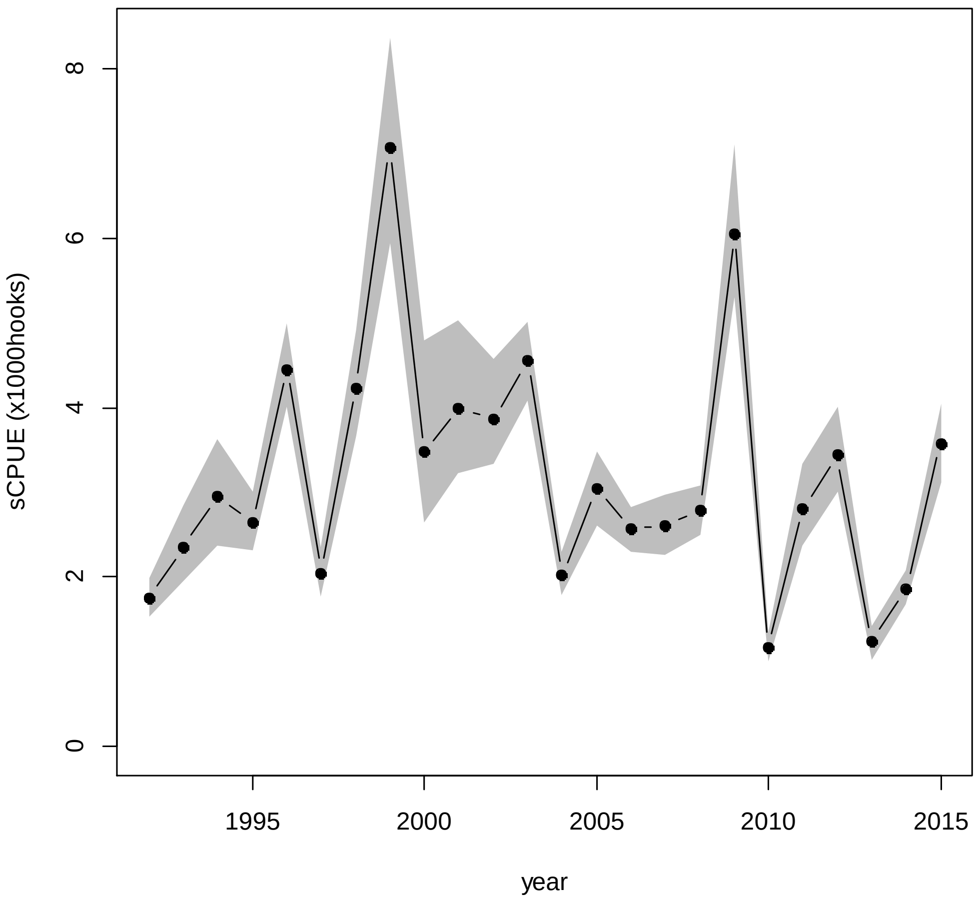
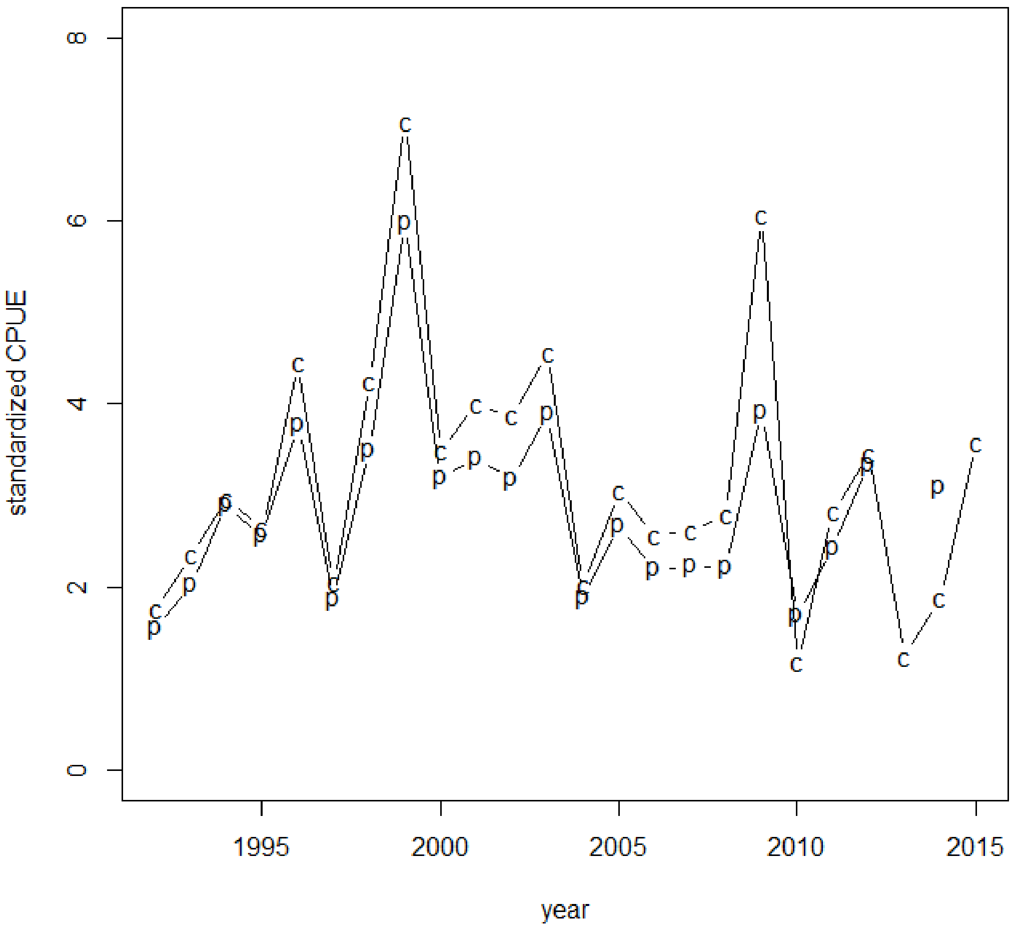
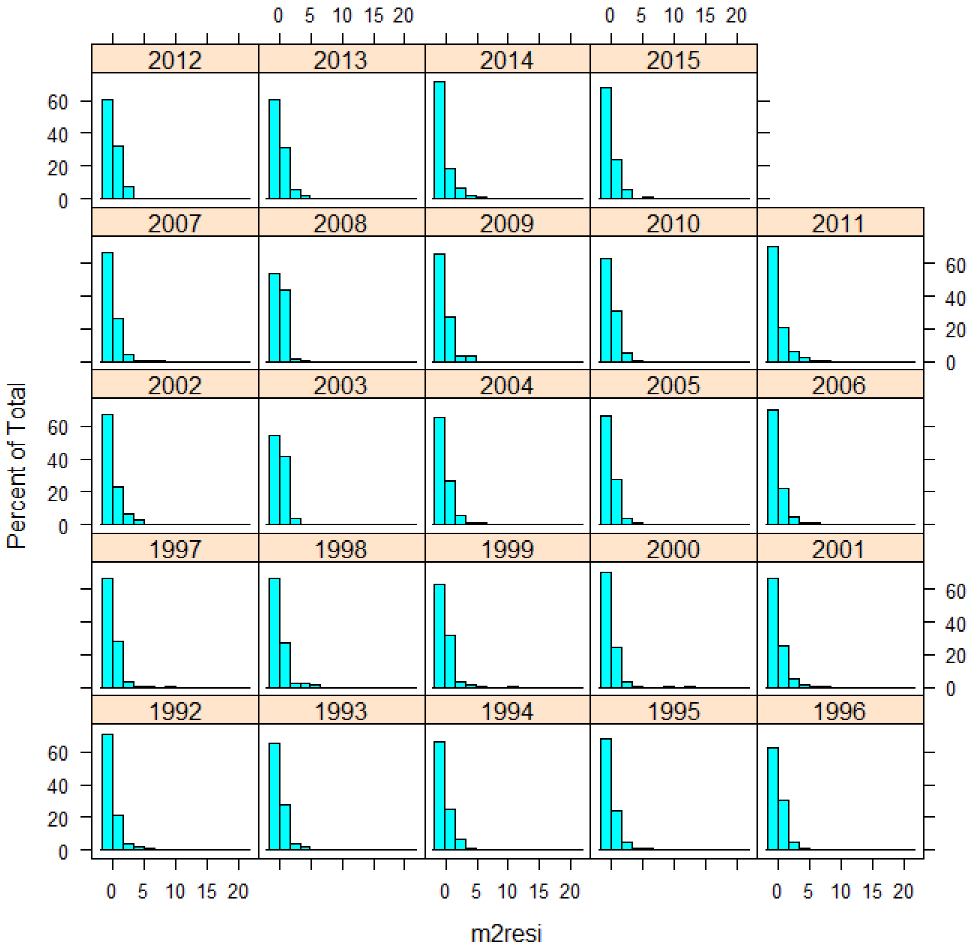


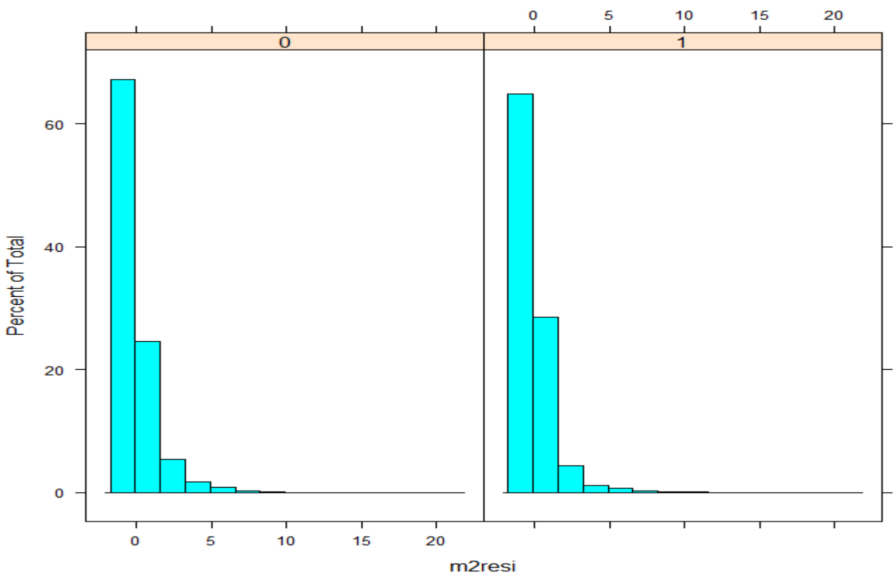
Fig. 3 Estimated abundance index of blue shark based on observer data for Japanese tuna longline fishery operated in the Indian Ocean from 1992 and 2015. Zero-Inflated negative binominal model was applied for the standardization and 95% confidence interval was estimated by bootstrap with one thousand replicates.



Appendix Fig.1 Compasiron of estimates of standardized CPUE of blue shark based on observer data between past ("p" from Semba et al. (2015)) and current ("c") analysis.

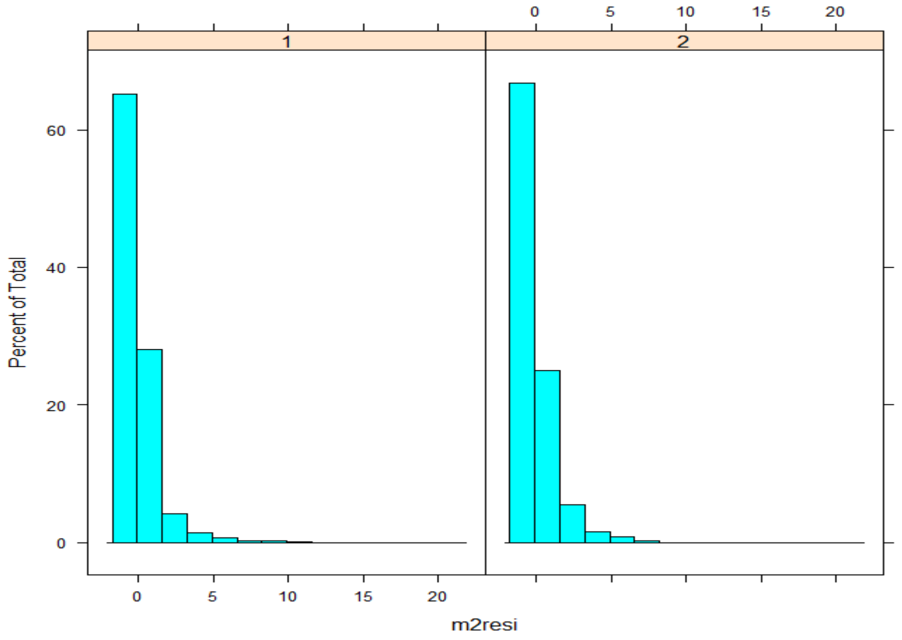


Appendix Fig.2 Annual residuals pattern for standardized CPUE of blue shark based on the observer data for Japanese tuna longline fishery operated in the Indian Ocean.



Appendix Fig.3 Area specific residuals pattern of analysis of CPUE of blue shark based on the observer data for

Japanese tuna longline fishery operated in the Indian Ocean. In this panel, left graph shows pattern of area 1 and right is area 2.



Appendix Fig.4. Season specific residuals pattern of analysis of CPUE of blue shark based on the observer data for Japanese tuna longline fishery operated in the Indian Ocean. In this panel, left graph shows pattern of season 1 and right is season 2.