Received: 19 October, 2011

Trend of standardized CPUE of oceanic whitetip shark (*Carcharhinus longimanus*) caught by Japanese longline fishery in the Indian Ocean

Yasuko Semba and Kotaro Yokawa
National Research Institute of Far Seas Fisheries

Abstract

Oceanic whitetip shark (*Carcharhinus longimanus*) has been caught as bycatch in Japanese longline fishery. Japan decided to include the oceanic whitetip shark in the logbook reporting system of longline fishery in 1997, while analysis of historical trend of CPUE of this species has not been conducted yet. This document reports the first result of standardized CPUE of this species caught in the Indian Ocean.

In this analysis, general linear model (GLM) with log-normal error structure was used for the standardization and GLM-tree model was applied for the area stratification. In the GLM, year, area, quarter, hooks per basket (as the proxy of set depth of gear) and interactions between year and another factor were set as explanatory variables. Unrealistic low estimate of CPUE were obtained in few years, which was supposed to be caused by the extremely low catch in these years. From 2003 and 2009, the standardized CPUE showed gradual decreasing trend.

Although some sets with unexpectedly high catchability might be contained in the data, the effect of such data was suggested to be relatively small. The estimated trend of standardized CPUE indicates the demand to collect catch and size data necessary for the stock assessment before the severe depletion of this population occurs.

Introduction

In the Indian Ocean, Japan has developed both tuna longline fishery (around after 1950's) and purse seine fishery (from late 1980s), but purse seine fishery gradually withdrew because of economic reason between 1994 and 2002 and only one experimental research vessel has operated (Okamoto et al. 1998, Ogura 2003). Therefore, catch of sharks by Japanese fishery operating in the Indian Ocean is available from the longline fishery. Since the beginning of operation, oceanic whitetip shark (*Carcharhinus longimanus*) has been caught as the bycatch and the catch number (or weight) of this species has been combined with other sharks and recorded as "sharks". Japan developed a new log-book reporting system in the longline fishery to record the catch of sharks in 6 categories, including oceanic whitetip shark. However, there was time-lag between the promulgation and the commencement of this reporting rule by all commercial vessels, which is mainly due to long trip (one-two years) away from Japan in these vessels. Therefore, probably it is after around 2000 that this new reporting style was actually implemented.

Oceanic whitetip shark is distributed in the tropical and warm-temperate waters in the world (Compagno 1984). As this species occurs both in the coastal and pelagic waters, the impact by fishery on its population has been concerned globally. In the Eastern Pacific Ocean, the decline of this species, especially emerging in the purse seine fishery data, has been concerned, which resulted in the prohibition of retaining this species on the vessel in the Antigua Convention in this July.

Standardized CPUE has been used to estimate the historical change of population abundance after removing the effect of factor other than year, such as season, area and gear. For wide-ranging species including pelagic sharks, the effect of area is considerable. Thus, the objective division of fishing area is important aspects in the standardization of CPUE. On this subject, we applied the GLMtree-model (Ichinokawa and Brodziak 2010) to obtain optimal area stratification used in CPUE standardization. This model estimates the position of area boundaries to produce the lowest values of AIC for the GLM model after the model structure was specified.

The objective of this document is to present the preliminary result of CPUE standardization for oceanic whitetip shark caught by the Japanese tuna longliners operating in the Indian Ocean with comments on its usefulness for the stock assessment.

Materials and methods

The spatial distribution of CPUE of oceanic whitetip from 2000 to 2009 was shown in Figure 1. The CPUE in the Arabian Sea and the western area is relatively higher than in the eastern area.

Data screening

Catch of sharks in Japanese logbook data contains varying degree of precision (Nakano and Honma 1996), mainly because sharks are often treated as bycatch because of lower commercial values than tunas and billfishes and the decision to land sharks (i.e. record of catch) is different depending on species and vessels. Matsunaga (2007) assumed the data of cruise with reporting rate (i.e. the number of operations with positive shark catch per total number of operations) higher than 80% contains information on catch of all commercially important sharks. To examine the applicability to oceanic whitetip, we calculated the reporting rate for each cruise and checked the yearly trend of nominal CPUE of this species (catch number of shark per 1000 hooks) by 10 % of reporting rate. The yearly trend of nominal CPUE was different between that calculated from data with lower reporting rate (< 40 %) and that with higher reporting rate (>= 40%). The former showed low stable trend and contains much “zero catch”, therefore, the data with reporting rate >= 40% was used for the analysis.

Finally, the data with apparent misidentification was removed by removing the data from area with latitude higher than 35°S considering the main geographical distribution of this species. The detail of data used in the analysis was shown in Table 1.

Area stratification

Using GLM-tree model, the area stratification with four sub-areas was adopted in this analysis (Figure 2). This is mainly because the data coverage tended to be low and data-missing occurred, when the area was divided in more sub-areas. The model structure adopted in this analysis was indicated below.

GLM analysis

CPUE standardization was conducted using general linear model (GLM). According to the application of GLM-tree model, the log-normal error was assumed for the error distribution of the model.

The main effects included in the model were:

- Year (10 years from 2000 to 2009)
- Quarter (4 categories; Q1: Jan.-Mar., Q2:Apr.-Jun., Q3: Jul.-Sep., Q4: Oct.-Dec.)
- Area (4 areas)
- Gear (3 categories based on hooks-per basket (hpb); G1: 5< hpb<15, G2: 15<= hpb<20, G3: hpb>=20)

These factors were set as categorical variables in the model. In addition to these main effects, the interaction term of each variable was included in the full model as follows;

Regarding year, the recorded catch number from 1997 to 1999 was very low, which can be regarded as the transitional stage from old format to new format. Additionally, data of 2010 is provisional (i.e. data in the fourth quarter is under compilation), which caused data-missing in the interaction term between year and quarter. As this term was significant in our analysis, the data of 2010 was removed and thus, the data from 2000 to 2009 was used in the analysis.

$$Log\ (CPUE+c) = Intercept + Y+Qr+A+G+Y*Qr+Y*A+Y*G+Qr*A+Qr*G+A*G+ \varepsilon\ , \quad \varepsilon \sim N(0, \sigma^2)$$

where *c* is constant, Y the year effect, Q the quarter effect, A the area effect, G the gear effect, while Y*Q, Y*A, and Y*G are the interaction term between year and quarter, area, and gear, respectively. ε denotes the error term. Constant (c) was added to nominal CPUE to overcome the problem of zero catch and the minimum value of nominal CPUE divided by 10 was substituted.

For this full model, the interaction terms with missing data or those which are not significant at 1 % were removed from the full model. The final model is;

Log (CPUE+c) = Intercept + Y+Qr+A+G+Y*Qr+Y*A+Y*G+ ε , $\varepsilon \sim N(0, \sigma^2)$

The result of ANOVA is shown in table 2.

The calculation of GLM analysis was performed through GLM procedure of SAS/STAT package (version 9.2).

Results and Discussion

Description of the catch and effort

Until 2007, the numbers of filtered sets and their total hook were relatively stable except for 2003 when the amount of filtered effort dropped suddenly, and it rapidly increased after 2007. According to this increase, the catch number of oceanic whitetip shark also increased (Table 1). The temporal change of the reporting rate is possible cause for this rapid increase. Around 2007, the domestic rule to encourage full utilization of sharks caught by longline was issued and fishermen followed this because the catch of tunas and billfish was apparently decreasing in recent years.

CPUE analysis for oceanic whitetip shark

Figure 3 shows the yearly trend of standardized CPUE and its 95% confidence intervals in the final model. The estimated lower values of CPUE in 2000 and 2001 should be affected by the small number of catch reported. The cause for this has been left to be clarified. After 2002, the standardized CPUE reached at its peak in 2003 and then showed gradually decreasing trend. Figure 4 shows the annual trend of standardized CPUE and nominal CPUE and both showed similar trend.

The distributional pattern of standardized residual in the final model was shown in Figure 5. In addition to the notable mode around the midpoint of standard residuals, one small mode was observed in the right side (two-mode). Although the remaining data of misidentification might be reflected in this small mode, it may suggest that there are some sets with unexpectedly high catchability for the oceanic whitetip shark and current GLM model did not fully adjust this effect. Further study is necessary to explore the way to standardize the effect of these sets.

The observation with high residual was widely distributed throughout year, area, quarter, and gear type used in this GLM analysis, however, the ratio of such observation in the total observation was low (3.85%). Therefore, the effect of such data is not suggested to be so largel and the annual trend of standardized CPUE estimated in this study would reflect the change of population status to some extent, especially after 2003.

The result of this study suggests the gradual decrease of oceanic whitetip shark in the Indian Ocean, and it is necessary to collect reliable catch and size data from all relevant countries to perform the stock assessment of this population before it becomes severely depleted.

Reference

Compagno LJV 1984. FAO species catalogue, Vol. 4: Sharks of the world; Part 2 Carcharhiniformes. Food and Agricultural Organization of the United Nations. Rome, Italy. 655p.

Ichinokawa M, and Brodziak J. 2010. Using adaptive area stratification to standardize catch rates with application to North Pacific swordfish (*Xiphias gladius*). Fish. Res. 106:249-260.

Matsunaga H. 2007. Standardized CPUE for blue sharks caught by the Japanese longline fishery in the Indian Ocean, 1971-2005. IOTC-2007-WPEB-17

Nakano H and Honma M. 1996. Historical CPUE of pelagic sharks caught by the Japanese longline fishery in the Atlantic Ocean. ICCAT CVSP 46 (4):393-398.

Ogura M. 2003. Japanese skipjack fishery and research activities in the Indian Ocean. IOTC Proceedings No.6:70-78.

Okamoto H, Tshuji S, and Miyabe N, 1998. Japanese tuna fisheries in the Indian Ocean. IOTC Proceedings No.1:47-55.

Table 1 The number of set, hook and sharks by year used in the analysis.

Year	No. of set	No. of hook	No. of shark
2000	2,904	8,495,202	86
2001	2,824	8,617,893	6
2002	2,848	8,880,403	152
2003	1,137	3,469,751	65
2004	2,190	6,695,472	190
2005	2,249	6,962,072	156
2006	2,258	7,182,416	186
2007	3,304	10,700,051	286
2008	9,980	32,509,395	765
2009	10,535	34,278,053	645

Table 2 ANOVA table of the final model of GLM.

Source	DF	Sum of Square	Mean Square	F-value	Pr > F
Model	89	627.74	7.05	22.41	<.0001
Error	40139	12631.49	0.31		
Corrected Total	40228	13259.23			

R-Square	CV	Root MSE	Mean of log CPUE
0.05	-15.49	0.56	-3.62

Factor	DF	Type III SS	Mean Square	F-value	Pr > F
yr	9	38.78	4.31	13.69	<.0001
qt	3	14.04	4.68	14.87	<.0001
area	3	15.28	5.09	16.18	<.0001
gear	2	47.67	23.83	75.73	<.0001
yr*qt	27	68.31	2.53	8.04	<.0001
yr*area	27	82.05	3.04	9.66	<.0001
yr*gear	18	118.30	6.57	20.88	<.0001

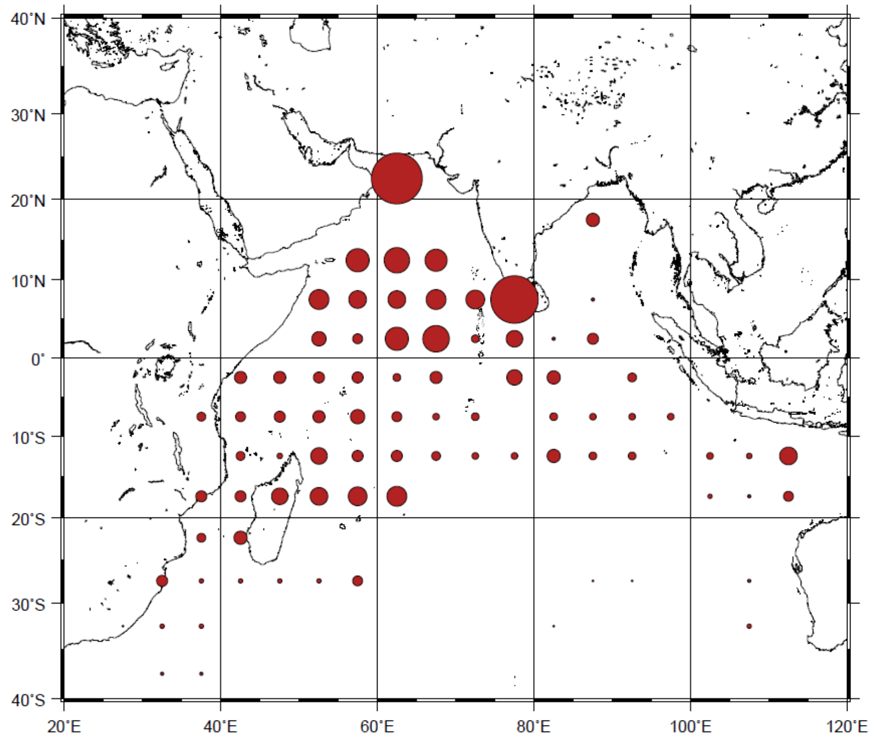

Figure 1 Spatial distribution of nominal CPUE of oceanic whitetip in the Indian Ocean from 2000 to 2009. The CPUE was depicted after square-root transformation.

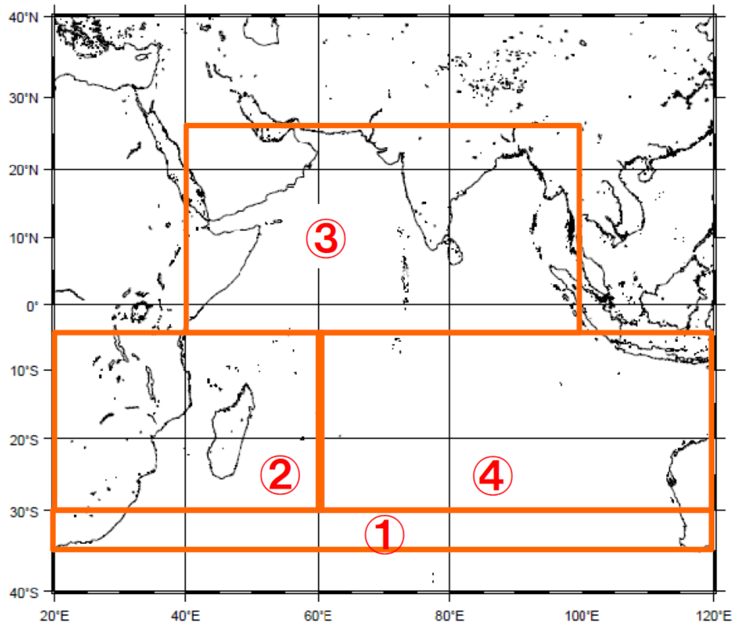

Figure 2 Area stratification used in the analysis.

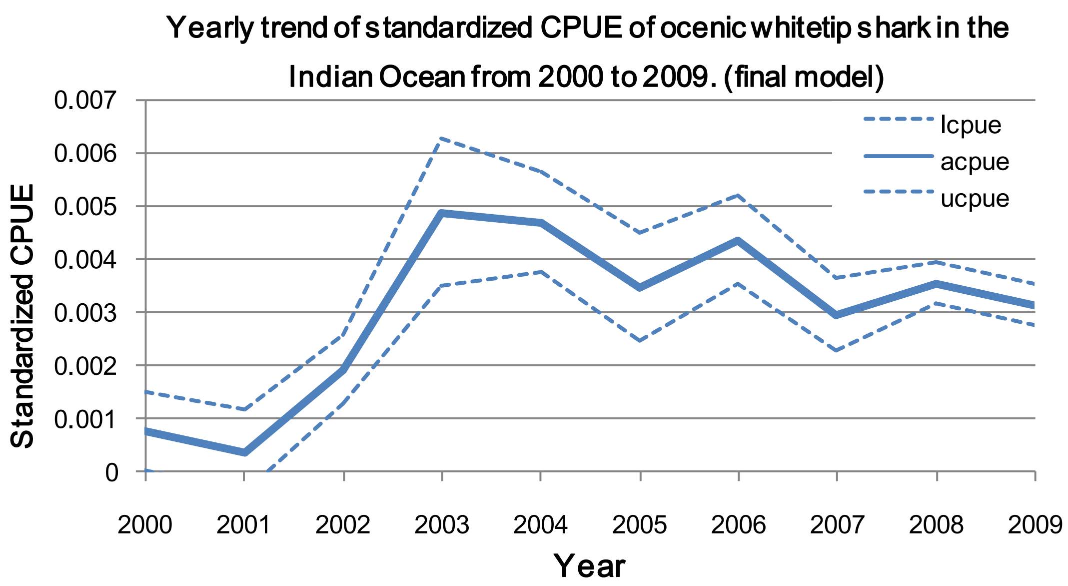

Figure 3 Trends of standardized CPUE of oceanic whitetip shark in the Indian Ocean with 95% confidence interval.

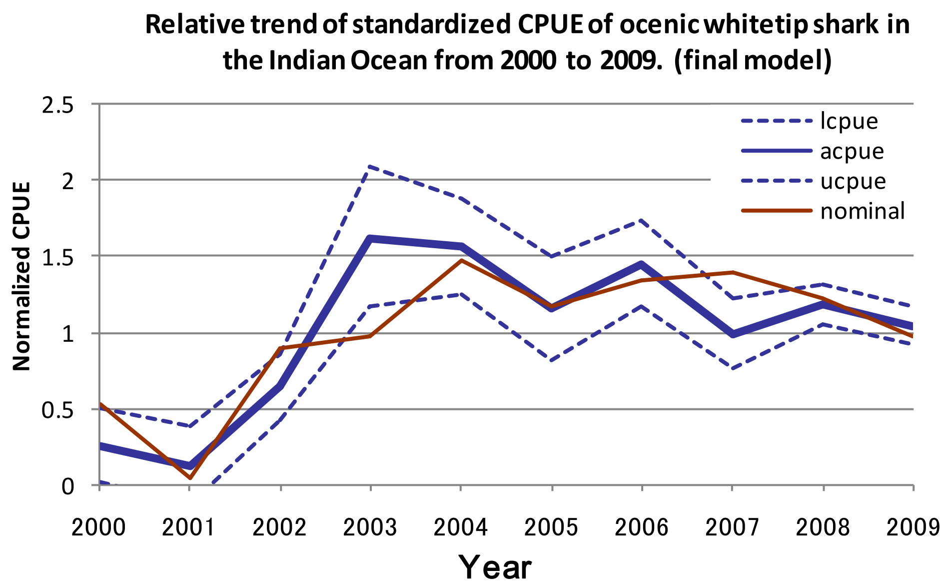

Figure 4 Relative annual trends of standardized CPUE and nominal CPUE for oceanic whitetip shark in the Indian Ocean (average value is set to be 1.0).

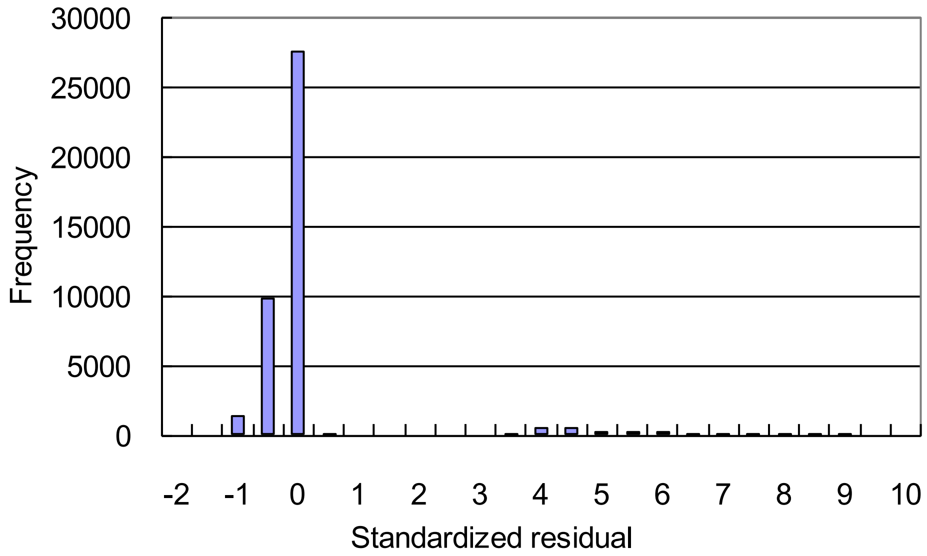

Figure 5 Distribution of standardized residual in the final model.