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Catch and standardized CPUE of the blue shark by Taiwanese large-scale longline fishery in the North Pacific Ocean[1]

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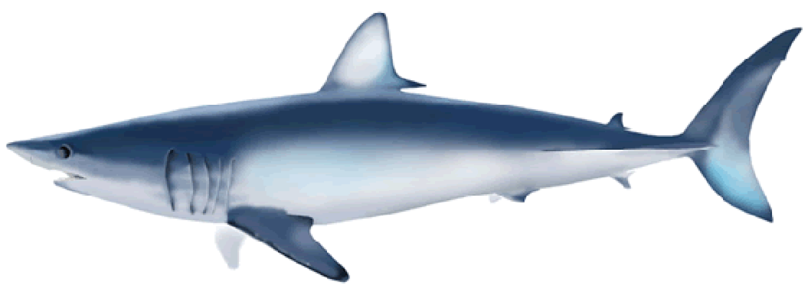

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ABSTRACT

In the present study, the blue shark catch and effort data from observers' records of Taiwanese large-scale longline fleets operating in the North Pacific Ocean from 2004-2010 were analyzed. Due to the large percentages of zero shark catch, the catch per unit effort (CPUE), the number of sharks caught per 1,000 hooks, was standardized by the zero inflated negative binomial model. The standardized CPUE showed a stable increasing trend for blue sharks during the time period. The results suggested that the blue shark stock in the North Pacific Ocean seems at the level of optimum utilization. The results in this study are preliminary and further investigation is needed.

Introduction

Blue shark is the major shark by-catch species of Taiwanese large-scale longline fisheries. Since FAO and international environmental groups has paid a lot of attention to the conservation of elasmobranchs in recent years, there is a necessity to examine the recent abundance trend of sharks by using logbook of tuna fisheries. However, standardization of Taiwanese catch rate on sharks is not straightforward because the data have been confounded with many factors, such as under-reporting and target-shifting effects. Fortunately, the observer program for the far seas fishery starting from 2002 provided an opportunity to collect detailed fisheries and biological information for more comprehensive stock assessment and management. Recently, the increasing observations enable us to get a better estimation of shark by-catch. Thus, the objective of this study is to estimate the CPUE and to back estimate historical catches of the blue shark in the North Pacific based on observers' records.

On the other hand, the problem of large proportion of zero values is common for by-catch data obtained from fisheries studies involving counts of abundance or CPUE standardization. The zero-inflated modeling, which allows the model to account for a large proportion of zero values, is an appropriate approach in modeling zero-heavy data (Lambert 1992; Hall 2000). As sharks are common by-catch species, in the present study, the zero inflated negative binomial (ZINB) model was applied to address these excessive zeros of shark catch for CPUE standardization.

Material and methods

The logbook data of the Taiwanese large-scale longline fishery from 1991 to 2010, provided by the Overseas Fisheries Development Council of the Republic of China, were used in this study. These logbook data contain basic information on fishing time, area, number of hooks and catches of 14 species including major tunas, billfishes and sharks. The observer program started in 2002. However, no observer was allocated in the North Pacific in 2002 and 2004. Therefore, the species-specific catch data including tunas, billfishes, and sharks from observers' records in 2004-2010 were used in estimation of standardized CPUE of blue shark of the Taiwanese longline fishery in the North Pacific Ocean. The standardized CPUE was used to back-estimatet the historical shark catch in number. The distributions of fishing effort from logbook and observers' records were shown in **Figure 1**.

Based on the suggestion of the ISC shark working group in 2012, the North Pacific Ocean was stratified into 2 areas namely A (north of 30ºN) and B (0ºN-30ºN). For standardization, CPUE was calculated on a set basis of operations based on observers' records during the period of 2004-2010. The area strata used for the analysis were shown in Figure 2.

There was a large proportion of sets with zero catches of blue shark (55%) from the observers' records. To address these excessive zeros, the Zero inflated Negative Binomial model was applied for CPUE standardization. The ZINB is a mixture of two distributions, one distribution is typically a Poisson or negative binomial distribution that can generate both zero and nonzero counts, and the second distribution is a constant distribution that generates only zero counts. The model was fit using NLMIXED procedure of SAS to eliminate the biases resulted by the switch of fishing ground and fishing seasons.

The standardized CPUE series for blue shark is constructed without interaction. The model is described as:

Catch = Year + Quarter + Area + ε

For the Zero Inflated Negative Binomial:

(Part 1: count models- Negative Binomial; Part 2: Binomial, link = logit)

The probability distribution of a zero-inflated negative binomial random variable Y is given by

$$\Pr(Y = y) = \begin{cases} \omega + (1-\omega)(1+k\lambda)^{1/k} & \text{for } y = 0 \\ (1-\omega)\frac{\Gamma(y+1/k)}{\Gamma(y+1)\Gamma(1/k)}\frac{(k\mu)^y}{(1+k\lambda)^{y+1/k}} & \text{for } y = 1, 2, \ldots \end{cases}$$

where *k* is the negative binomial dispersion parameter.

The blue shark catch in number before 2004 can be estimated by using the equation below:

$Catch_{e,t}$ = standardized CPUE × $(\text{logbook effort})_t$

where $catch_{e,t}$ is estimated catch in number in year t, $(\text{logbook effort})_t$ is fishing effort in year t, and the standardized CPUE is the mean of standardized CPUE of 2004-2010.

As the weight records were incomplete and might be biased, the annual catch in weight of blue shark was estimated by the multiplication of mean weight of blue shark and its corresponding catch in number. The mean weight of blue shark used in this study was 41.1 kg (Huang, 2006). Annual shark catch were then obtained by using the estimated shark catch in weight divided by coverage rate.

Results and discussion

The nominal CPUE of blue shark showed a strong inter-annual variation. This high variability was greatly reduced in the standardized CPUE . The standardized CPUE series for blue shark by the zero inflated negative binomial model was shown in **Figure 3**. Standardized CPUE series of the blue shark caught by Taiwanese large-scale longline fishery showed a stable increasing trend (**Figure 3**). This trend suggested that the blue shark stock in the North Pacific Ocean might be at the optimum utilization level.

Back-estimated blue shark by-catch in number ranged from 1994 of 151 to 2002 of 16,687 (**Table 1**). Blue shark by-catch in weight ranged from 6 tons (1994) to 686 tons (2002) in the North Pacific Ocean (**Table 2**).

The estimations of historical shark by-catch in this report were based on observers' records from 2004-2010. However, many factors may affect the standardization of CPUE. In addition to the temporal and spatial effects, environmental factors are important which may affect the representation of standardized CPUE of pelagic fish i.e., swordfish and blue shark in North Pacific (Bigelow *et al.,* 1999), and bigeye tuna in Indian Ocean (Okamoto *et al.,* 2001). In this report, environmental effects were not included in the model for standardization. Consequently, the results in this report are preliminary and further investigation is needed. The blue shark is the most important by-catch species for Taiwanese large-scale longline fishery. It is necessary to continue observer program to collect more biological, ecological information for stock assessment study in the future.

References

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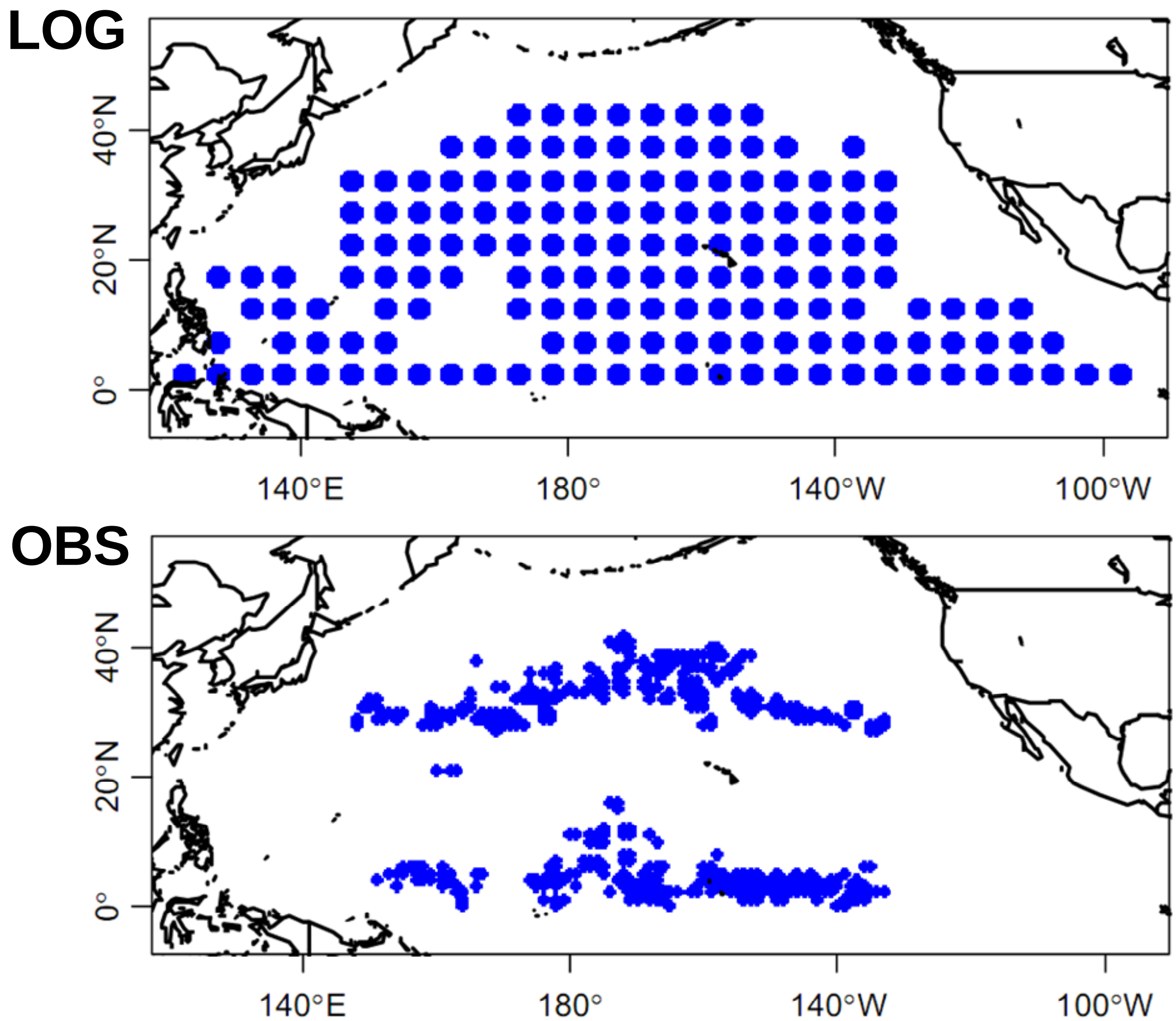

Figure 1. Distribution of fishing effort for Taiwanese large-scale longline fisheries from 2004-2010 (Logbook (Log) and Observed (Obs) vessels).

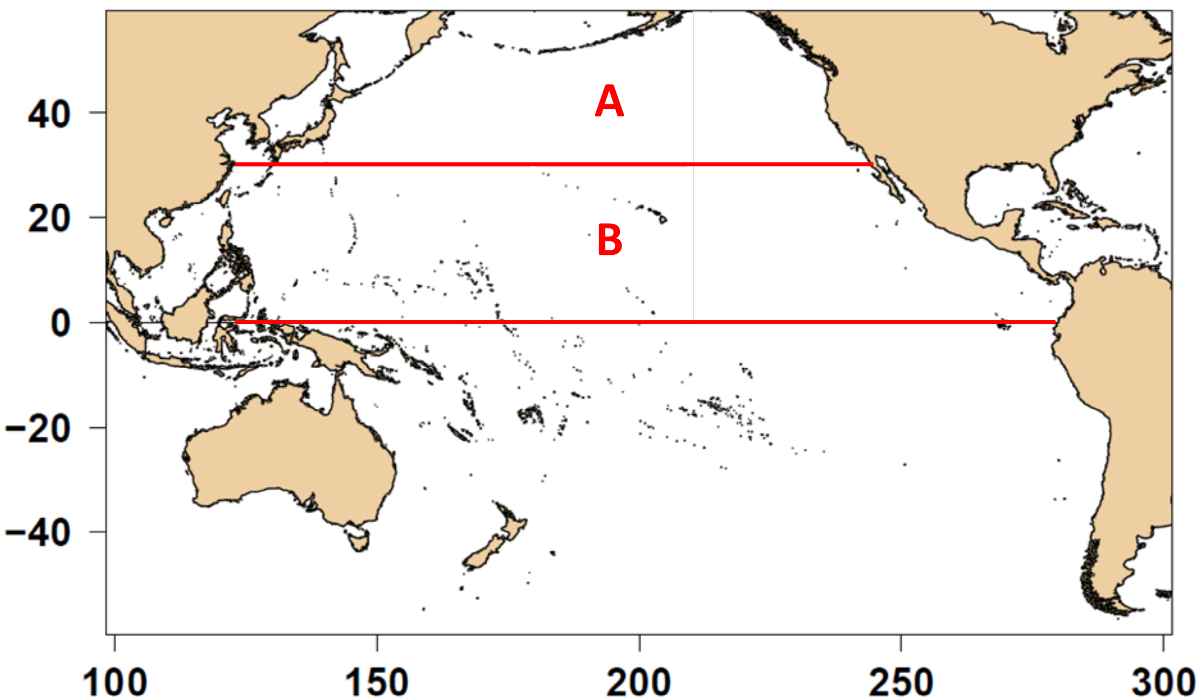

Figure 2. Area stratification used for the estimate of shark by-catch of the Taiwanese large-scale longline fishery in the North Pacific Ocean.

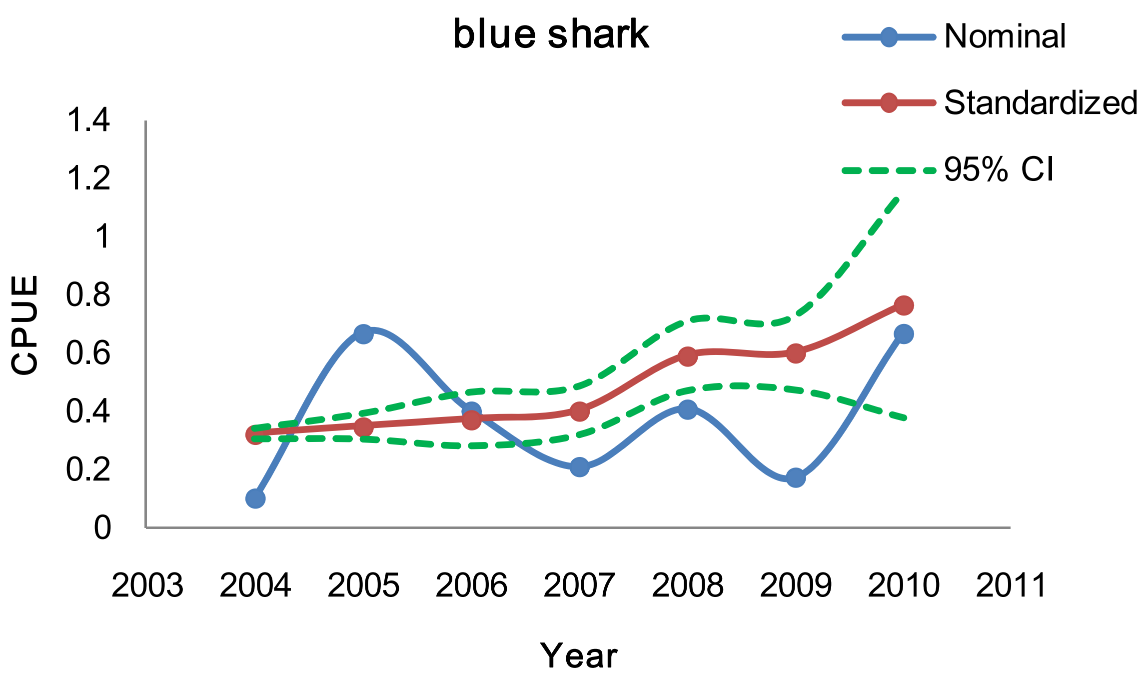

Figure 3. Nominal and standardized CPUE with 95% CI of blue shark by Taiwanese large-scale longline fisheries in the North Pacific from 2004 to 2010.

Table 1. Estimated annual blue shark catch in number of Taiwanese tuna longline fishery in the North Pacific Ocean.

Year	Blue shark
1991	2834
1992	926
1993	732
1994	151
1995	7850
1996	3380
1997	3941
1998	4139
1999	7664
2000	8407
2001	12097
2002	16687
2003	9553
2004	9704
2005	8054
2006	8331
2007	8327
2008	10153
2009	7273
2010	6778

Table 2. Estimated annual blue shark catch in weight (ton) of Taiwanese tuna longline fishery in the North Pacific Ocean.

Year	Blue shark
1991	116
1992	38
1993	30
1994	6
1995	323
1996	139
1997	162
1998	170
1999	315
2000	346
2001	497
2002	686
2003	393
2004	399
2005	331
2006	342
2007	342
2008	417
2009	299
2010	279