SCRS/2017/071 Collect. Vol. Sci. Pap. ICCAT, 74(4): 1710-1729 (2017)

STANDARDIZED CATCH RATES OF THE SHORTFIN MAKO (*ISURUS OXYRINCHUS*) CAUGHT BY THE TAIWANESE LONGLINE FISHERY IN THE ATLANTIC OCEAN

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SUMMARY

In this document, the shortfin mako shark catch and effort data from observers' records of Taiwanese large longline fishing vessels operating in the Atlantic Ocean from 2007-2015 were analyzed. Based on the shark by-catch rate, four areas, namely, I (north of 20ºN), II (5ºN-20ºN), III (5ºN-15ºS), and IV (south of 15ºS), were categorized. To cope with the large percentage of zero shark catch, the catch per unit effort (CPUE) of shortfin mako shark, as the number of fish caught per 1,000 hooks, was standardized using a two-step delta-lognormal approach that treats the proportion of positive sets and the CPUE of positive catches separately. Standardized indices with 95% bootstrapping confidence intervals are reported. The standardized CPUE of shortfin mako sharks in the South Atlantic was relatively stable from 2007-2014 but decreased in 2015. It peaked in 2009, decreased in 2010 and fluctuated thereafter for the North Atlantic shortfin mako sharks. The shortfin mako shark by-catch in weight of the Taiwanese large-scale longline fishery ranged from 2 tons (1989) to 89 tons (2009) in the North Atlantic Ocean and ranged from 29 tons (1989) to 280 tons (2011) in the South Atlantic Ocean.

RÉSUMÉ

Ce document analyse les données de prise et d'effort du requin-taupe bleu provenant des registres des observateurs déployés à bord des grands palangriers du Taipei chinois réalisant des opérations de pêche dans l'océan Atlantique entre 2007 et 2015. D'après le taux de prise accessoire de requins, quatre zones ont été délimitées, à savoir la zone I (Nord de 20ºN), II (5ºN-20ºN), III (5ºN-15ºS) et IV (Sud de 15ºS). Pour s'adapter au pourcentage élevé de captures zéros de requins, la capture par unité d'effort (CPUE) du requin-taupe bleu (nombre de spécimens capturés par 1.000 hameçons) a été standardisée au moyen d'une approche delta-lognormale en deux étapes qui traite séparément la proportion d'opérations positives et la CPUE de captures positives. Des indices standardisés avec des intervalles de confiance de 95 % par bootstrap sont déclarés. La CPUE standardisée du requin-taupe bleu dans l'Atlantique Sud était relativement stable entre 2007 et 2014, mais a diminué en 2015. Dans le cas du requin-taupe bleu de l'Atlantique Nord, elle a atteint un sommet en 2009 avant de diminuer en 2010 et de fluctuer par la suite. La prise accessoire du requin-taupe bleu en poids de la pêcherie palangrière à grande échelle du Taipei chinois a oscillé entre deux tonnes (1989) et 89 tonnes (2009) dans l'océan Atlantique Nord et a oscillé entre 29 tonnes (1989) et 280 tonnes (2011) dans l'océan Atlantique Sud.

RESUMEN

En este documento, se analizan los datos de captura y esfuerzo de marrajo dientuso procedentes de los registros de observadores embarcados en grandes palangreros de Taipei Chino que operaron en el Atlántico entre 2007 y 2015. Basándose en la tasa de captura fortuita de tiburones, se establecieron cuatro áreas, a saber, I (al norte de 20ºN), II (5ºN-20ºN), III (5ºN-15ºS) y IV (sur de 15ºS). Para tratar el gran porcentaje de captura cero de tiburones, la captura por unidad de esfuerzo (CPUE) del marrajo dientuso, así como el número de ejemplares capturados por 1000 anzuelos, fue estandarizada utilizando un enfoque delta-lognormal de dos etapas que trata por separado la proporción de lances positivos y la CPUE de las capturas positivas. Se comunican los índices estandarizados con intervalos de confianza de bootstrap del 95%. La CPUE estandarizada del marrajo dientuso en el Atlántico sur era relativamente estable

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entre 2007 y 2014, pero descendió en 2015. Alcanzó un pico en 2009, descendió en 2010 y fluctuó posteriormente para el marrajo dientuso del Atlántico norte. La captura fortuita de marrajo dientuso en peso de la pesquería de palangre a gran escala de Taipei Chino oscilaba entre 2 t (1989) y 89 t (2009) en el Atlántico norte y entre 29 t (1989) y 280 t (2011) en el Atlántico sur.

KEYWORDS

Shortfin mako sharks, Taiwanese longline fishery,
standardized CPUE, by-catch, observer programs, delta-lognormal approach

1. Introduction

The Taiwanese longline fishery has operated in the Atlantic Ocean since the late 1960s. However, the shark by-catch of Taiwanese tuna longline fleets was never reported until 1981 because of its low economic value compared with tunas. During the period from 1981 to 2002, only one category "sharks" was recorded in the logbook. The category "sharks" on the logbook has been further separated into four sub-categories namely the shortfin mako shark, *Prionace glauca*, mako shark, *Isurus spp*., silky shark, *Carcharihnus falciformis,* and others since 2003. As the Taiwanese longline fishery has widely covered the Atlantic Ocean especially the tropical waters and the South Atlantic, our fishery statistics must be one of the most valuable information that can be used to describe the population status of pelagic sharks.

Shortfin mako shark is the major shark by-catch species of Taiwanese large longline fishery. Since FAO and international environmental groups has concerned on the conservation of elasmobranchs in recent years, it is necessary to examine the recent trend of sharks by examining the logbook of tuna fisheries. However, standardization of Taiwanese catch rate on sharks is not straightforward because the logbook data have been confounded with many factors, such as under-reporting, no-recording of sharks and target-shifting effects. Therefore, the observer program for the large longline fishery was conducted to obtain detailed and reliable data for more comprehensive stock assessment and management studies. Relative abundance series for shortfin mako sharks from these sources were previously analyzed by Liu *et al*. (2004; 2008). Recently, the increase of coverage rate of observations enabled us to get a better estimation of shark by-catch. In present study, the CPUE series are therefore updated to examine recent trends in relative abundance of the shortfin mako sharks in the Atlantic Ocean.

A large proportion of zero values is commonly found in by-catch data obtained from fisheries studies involving counts of abundance or CPUE standardization. The delta-lognormal modeling, which can account for a large proportion of zero values, is an appropriate approach to model zero-heavy data (Lo *et al*., 1992). As sharks are common by-catch species in the tuna longline fishery, the delta lognormal model (DLN) should be conducted in CPUE standardization to address these excessive zero catch of sharks. However, our previous studies (Liu *et al*., 2004; 2008) did not consider this issue because the shortfin mako shark catch was estimated based on the ratio between shortfin makos and target species. In addition, CPUE standardization was solely based on general linear model (GLM). In this study, updated and revised CPUEs of shortfin mako sharks in the North and South Atlantic were standardized using delta-lognormal model based on observers' records data.

2. Material and methods

2.1. Source of data

The logbook data of Taiwanese large-scale longline fishery from 1981 to 2015, 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 species-specific catch data including tunas, billfishes, and sharks from observers' records in 2007-2015 were used to standardize CPUE of shortfin mako shark of Taiwanese longline fishery in the Atlantic Ocean. The summary of these data were shown in **Table 1**. In the Atlantic, Taiwanese tuna longline fishery targets different tuna species depending on the area; targeting albacore tuna (ALB) in the mid-high latitude of the North Atlantic, targeting tropical bigeye tuna (BET) in the low latitude of the North and South Atlantic, and targeting ALB in the mid-high latitude of the South Atlantic.

Shortfin mako sharks (SMA) caught by Taiwanese longline fishery in the Atlantic Ocean were mainly observed in the equatorial waters (**Figure 1**). Based on the shark by-catch rate, four areas, namely, I (north of 20ºN), II (5ºN-20ºN), III (5ºN-15ºS), and IV (south of 15ºS), were categorized. For standardization, CPUE was calculated by set of operations based on observers' records during the period of 2007-2015.

2.2. CPUE standardization

A large proportion of sets with zero catch of shortfin mako sharks (about 90% for both North and South Atlantic) was found in observers' records. Hence, to address these excessive zero catches, the delta-lognormal model (DLN) (Lo *et al*., 1992) was applied to the standardization of shortfin mako shark CPUE. The DLN is a mixture of two models, one model is used to estimate the proportion of positive catches and a separate model is to estimate the positive catch rate. The model was fit using glm function of statistical computing language R (R Development Core and Team, 2013) to eliminate some biases by change of targeting species, fishing ground and fishing seasons.

The standardized CPUE series for shortfin mako shark was constructed with interaction. The main variables chosen as input into the DLN analyses were year (Y), quarter (Q), area (A), group (targeting on albacore or bigeye tunas, GRP), SST (sea surface temperature) and interaction terms. The following additive model was applied to the data in this study:

For the DLN modeling, the catch rates of the positive catch events (sets with positive shortfin mako shark catch) were modeled assuming a lognormal error distribution:

Part 1: Lognormal model
$\ln(CPUE) = \mu + Y + Q+A+GRP+SST+Q*A+Q*GRP+A*GRP + \varepsilon_1$
where μ is the mean, Q*A, Q*GRP, and A*GRP are interaction terms, ε_1 is a normal random error term.

To estimate the proportion of positive shortfin mako shark catch (P), we used a model assuming a binomial error distribution (ε_2):

Part 2: Binomial model
$PA=\mu + Y + Q+A+GRP+SST+Q*A+Q*GRP+A*GRP+ \varepsilon_2$

The different group effect (GRP) is defined by targeting on ALB or BET, and quarter (Q) into the 4 classes of Jan-Mar (1st quarter), Apr-Jun (2nd quarter), Jul-Sep (3rd quarter) and Oct-Dec (4th quarter). The area strata used for the analysis were shown in **Figure 2**.

The best model for both Lognormal and Binominal models were selected using the stepwise AIC method (Venables and Ripley, 2002). For model diagnostics, the Cook's distance (Cook and Weisberg, 1982) was used to assess the influence of observations that exert on the model. The distribution of residuals was used to verify the assumption of the lognormal distribution of the positive catches. These diagnostic plots were used to evaluate the fitness of the models. In addition, deviance analysis tables for the proportion of positive observations and for the positive catch rates were also provided. The final estimate of relative annual abundance index was obtained by the product of the main annual effect of the Lognormal and Binomial components (Lo et al., 1992):

Standardized CPUE = CPUE*P

Empirical confidence interval of standardized CPUE was estimated by using a bootstrap resampling method (Efron and Tibshirani, 1993). The number of bootstrapped sub-samples was generated based on the sample size of CPUE in each year. The 95% confidence intervals were then constructed based on bias corrected percentile method with 10,000 replicates (Efron and Tibshirani, 1993).

2.3. Estimate of historical shortfin mako shark catch

Annual shortfin mako shark by-catch in number (C_y) from 2007 to 2015 was estimated by the following equations:

$$C_y = \sum_{i}^{4} \frac{\text{Nominal } CPUE_{i,y} \times Logbook\ effort_{i,y}}{Coverage\ rate_y}$$

where y is year, i = 1 is area A, i = 2 is area B, i = 3 is area C, and i = 4 is area D. Coverage rate is the total catch (bigeye tuna, albacore tuna, yellowfin tuna, and swordfish) in logbook to that in Task 1 (Nominal annual catch). Annual shortfin mako shark by-catch in number before 2007 was back-estimated using the same equation but area-specific nominal CPUE was replaced by the mean of area-specific nominal CPUE in the period of 2004-2015 because data limitations or no observers' records were available before 2007. As the weight records from observers were inconsistent (often recorded as processed weight instead of whole weight) and might be biased, the catch in weight of shortfin mako shark was estimated using the multiplication of mean weight (assumed to be constant) and estimated or back-estimated catch in number. The mean FL of shortfin mako sharks was calculated from observers' data and the mean weight was obtained by substituting the mean FL into the W-FL relationship as follows: $W = 5.2432\times10^{-6}\ FL^{3.1407}$ (Natanson et al, 2006).

3. Results and discussion

The mean fork length of shortfin mako sharks reported by observers was 167.15 cm FL (n = 3,349) and the estimated mean weight was 50.32 kg. The shortfin mako shark bycatch data are characterized by many zero values and a long right tail (**Figures 3 and 4**). Overall, there were 88.62% of sets in the North Atlantic and 90.25% in the South Atlantic had zero bycatch of shortfin makos (**Table 2**).

The best models for Lognormal and Binomial models chosen by AIC values in North Atlantic were " ln(CPUE) = μ + Q (AIC=208) " and " P = μ + Y + Q + A + GRP + Q*GRP + A*GRP (AIC=1254) ", respectively. And in South Atlantic were " ln(CPUE) = μ + Y + Q + A + GRP + SST + Q*A + Q*GRP (AIC= 1563) " and " P = μ + Y + Q + A + GRP + Q*A + Q*GRP + A*GRP (AIC= 9772) ". The best models for North and South Atlantic were then used in the later analyses.

The standardized CPUE series with 95% CI of the shortfin mako shark for North and South Atlantic using the DLN model were shown in **Figures 5 and 6**. The detail values for nominal and standardized CPUE were listed in Tables 3-4. The standardized CPUE trend contains the combined effects from two models, one that calculates the probability of a zero observation and the other one that estimates the count per year. The nominal CPUE of shortfin mako shark in both North and South Atlantic showed a strong inter-annual oscillation, particularly in year 2009 and 2008, respectively. The standardized CPUE of shortfin mako sharks in the South Atlantic was relatively stable in 2007-2014 but decreased in 2015. It peaked in 2009, decreased in 2010 and fluctuated thereafter for the North Atlantic shortfin mako sharks (**Figures 5 and 6**).

The estimated shortfin mako shark bycatch based on nominal CPUE were showed in **Table 5**. In this study, the historical shortfin mako shark by-catch obtained from area-specific nominal CPUE were chosen as the input values of stock assessment models. The results based on this method indicated that the estimated shortfin mako shark by-catch in number ranged from 47 in 1989 to 1,774 in 2009 in the North Atlantic. It ranged from 580 in 1989 to 5,573 in 2011 in the South Atlantic. The shortfin mako shark by-catch in weight of Taiwanese long-scale longline fishery ranged from 2 tons (1989) to 89 tons (2009) in the North Atlantic Ocean and ranged from 29 tons (1989) to 280 tons (2011) in the South Atlantic Ocean (**Table 5**).

In general, the diagnostic results from the DLN model do not indicate severe departure from model assumptions (**Figures 7-10**). However, the residual distributions skewed on the right-hand side because some predicted values obtained from the model corresponding to the high CPUE observations became positive. The ANOVA tables for each models are given in **Appendix 1**. However, only quarter factor was significant for lognormal model due to small sample size in the North Atlantic. On the other hand, most main effects and interaction terms tested were significant (mostly $P < 0.01$) in the South Atlantic case. However, many factors may affect the standardization of CPUE trend. 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 big-eye tuna in Indian Ocean (Okamoto *et al.*, 2001). In this report, environmental effects were included in the model for standardization of South Atlantic shortfin mako sharks. The results obtained in this study can be improved if longer time series of observers' data are available.

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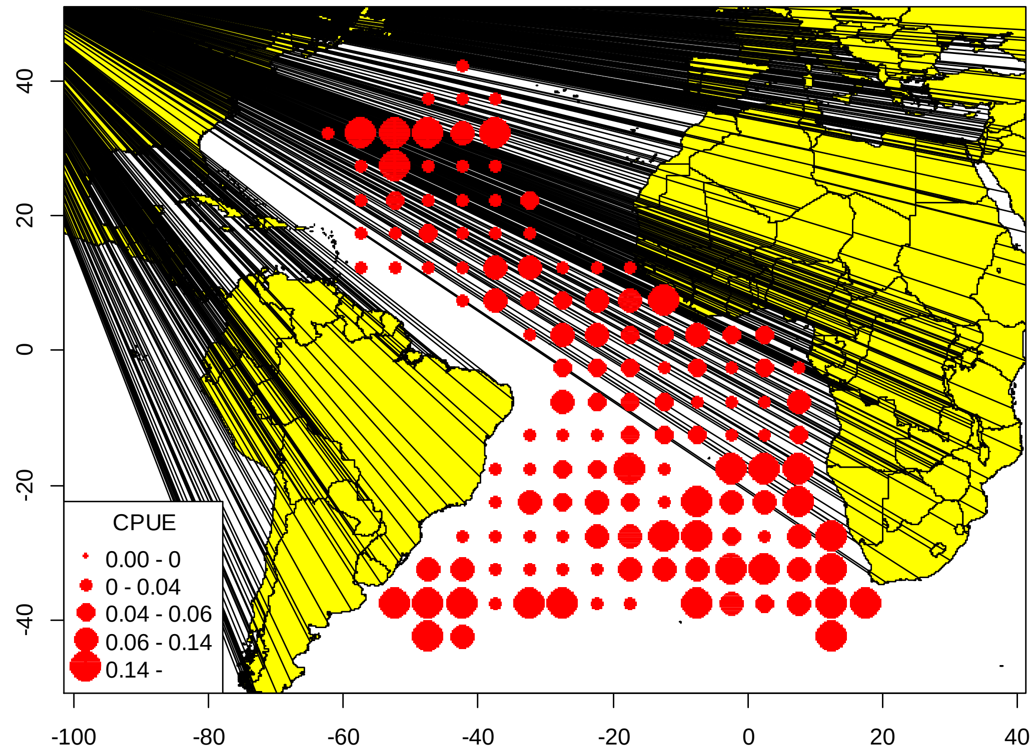

Figure 1. Observed distribution of shortfin mako sharks CPUE of Taiwanese tuna longline vessels in the Atlantic Ocean from 2007 to 2015.

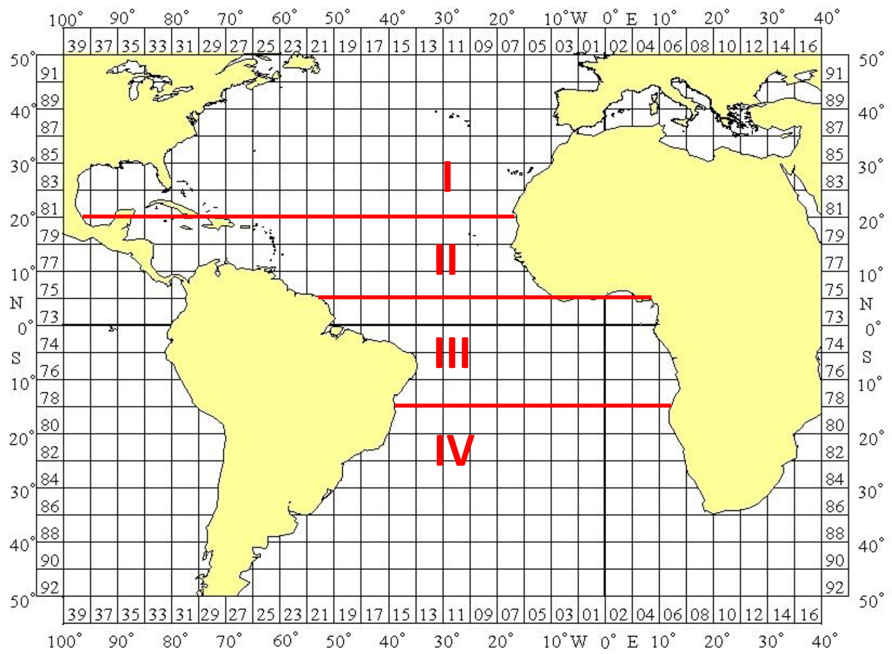

Figure 2. Area stratification in this study.

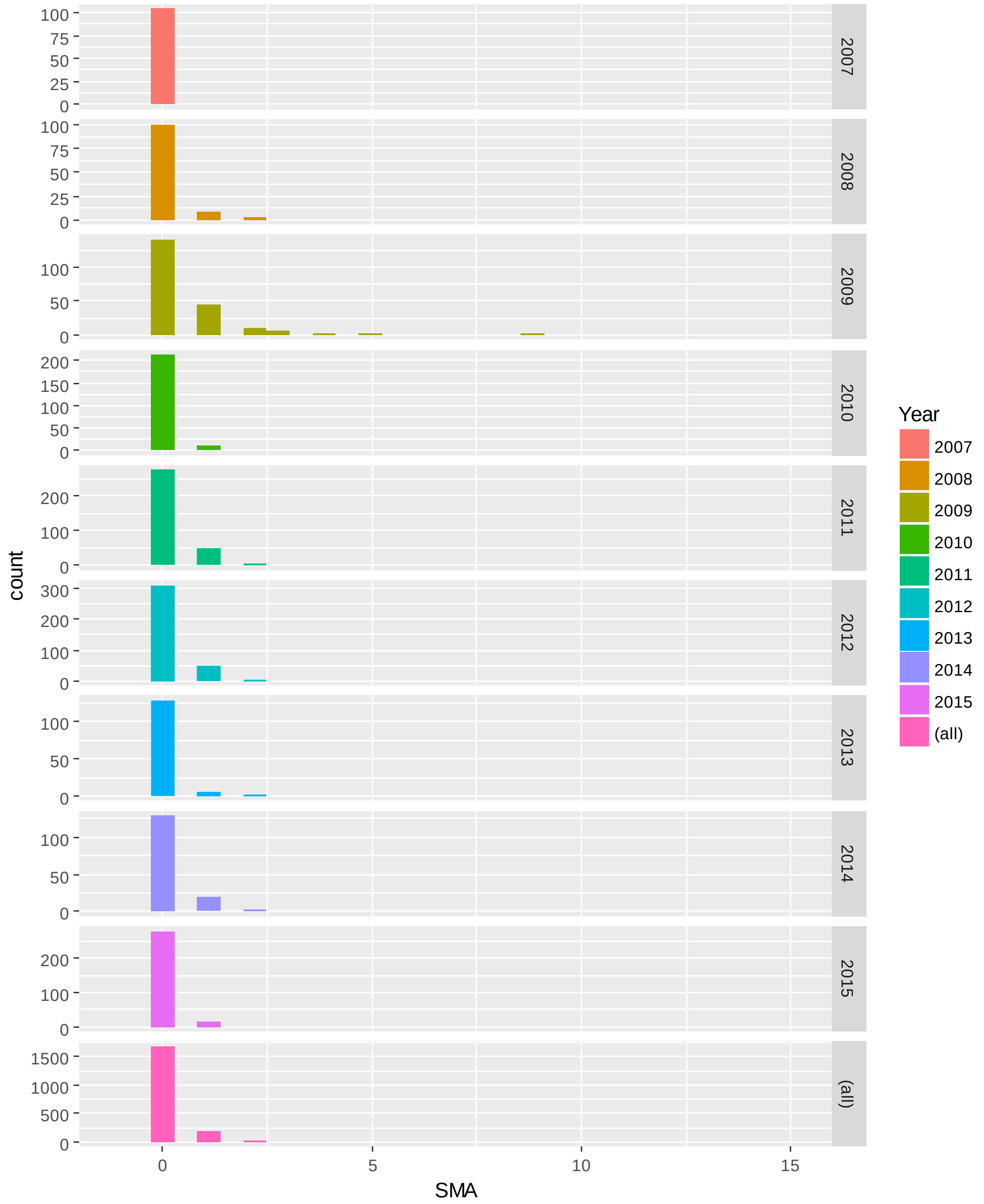

Figure 3. Annual frequency distribution of shortfin mako shark bycatch per set in the North Atlantic, 2007-2015.

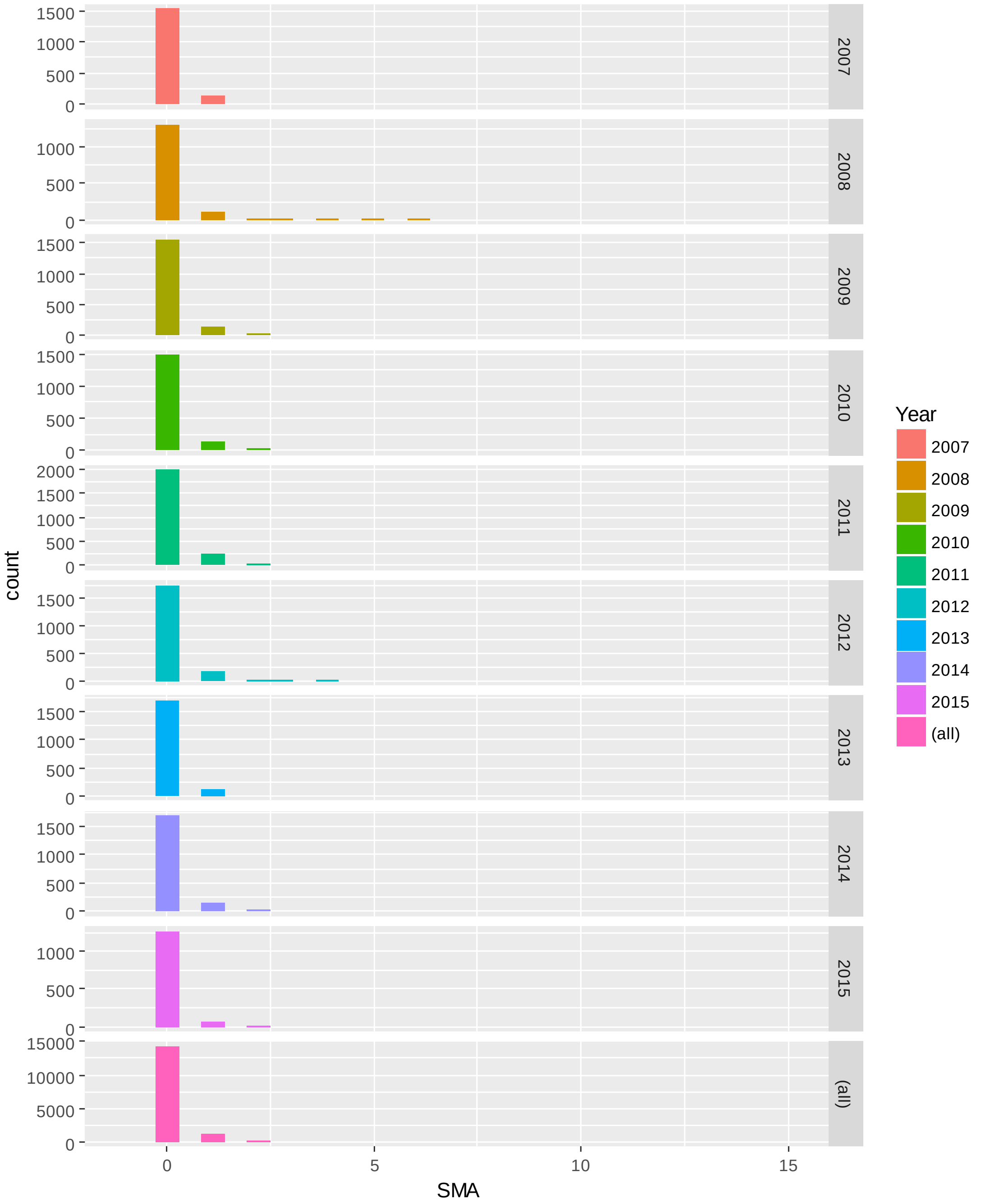

Figure 4. Annual frequency distribution of shortfin mako shark bycatch per set in the South Atlantic, 2007-2015.

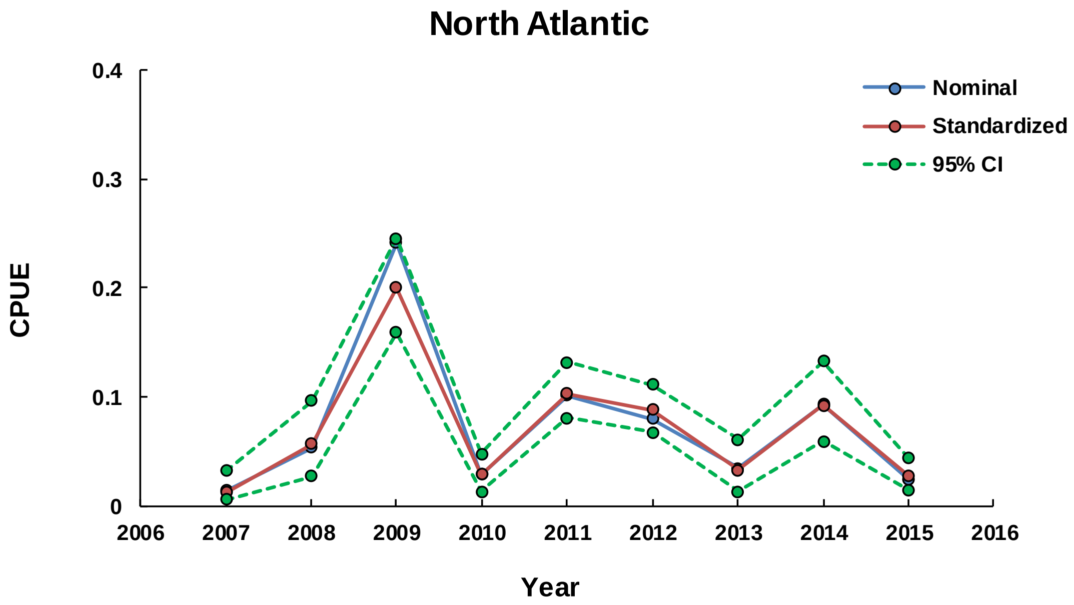

Figure 5. Observed nominal and standardized CPUE of shortfin mako shark by Taiwanese longline vessels in the North Atlantic from 2007 to 2015.

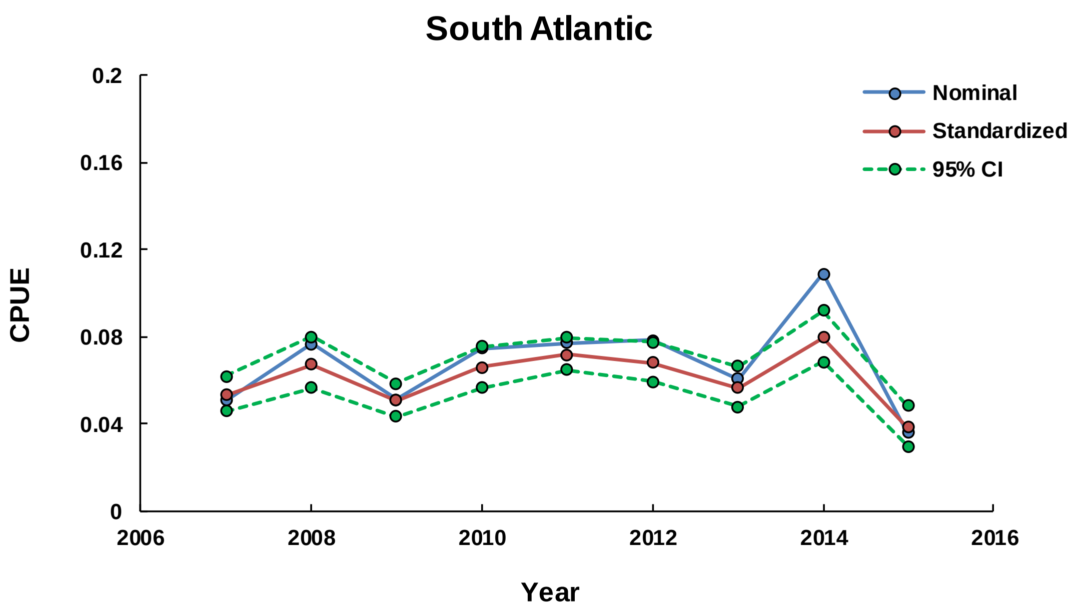

Figure 6. Observed nominal and standardized CPUE with 95% CI of shortfin mako shark by Taiwanese longline vessels in the South Atlantic from 2007 to 2015.

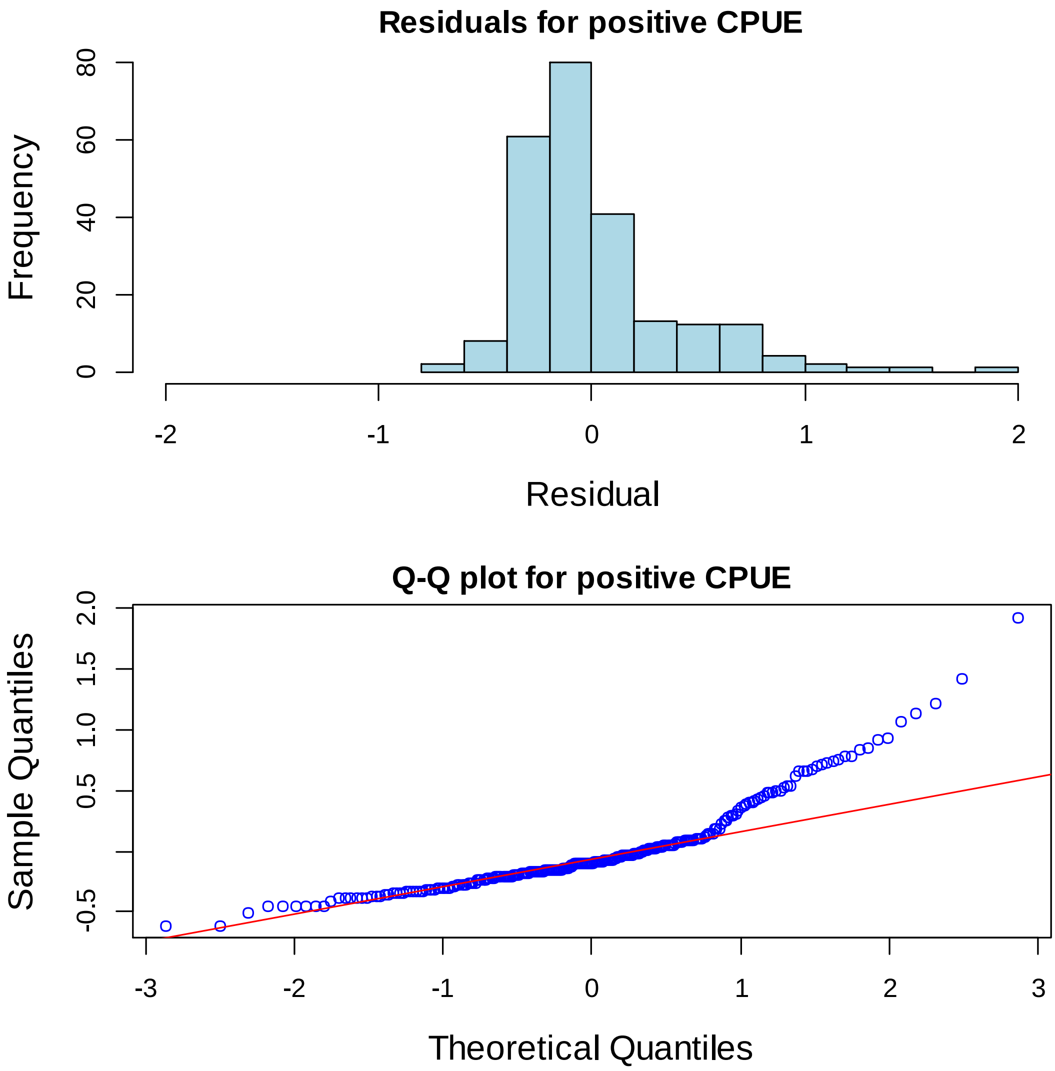

Figure 7. Diagnostic results from the GLM model fit to the North Atlantic longline shortfin mako shark bycatch data.

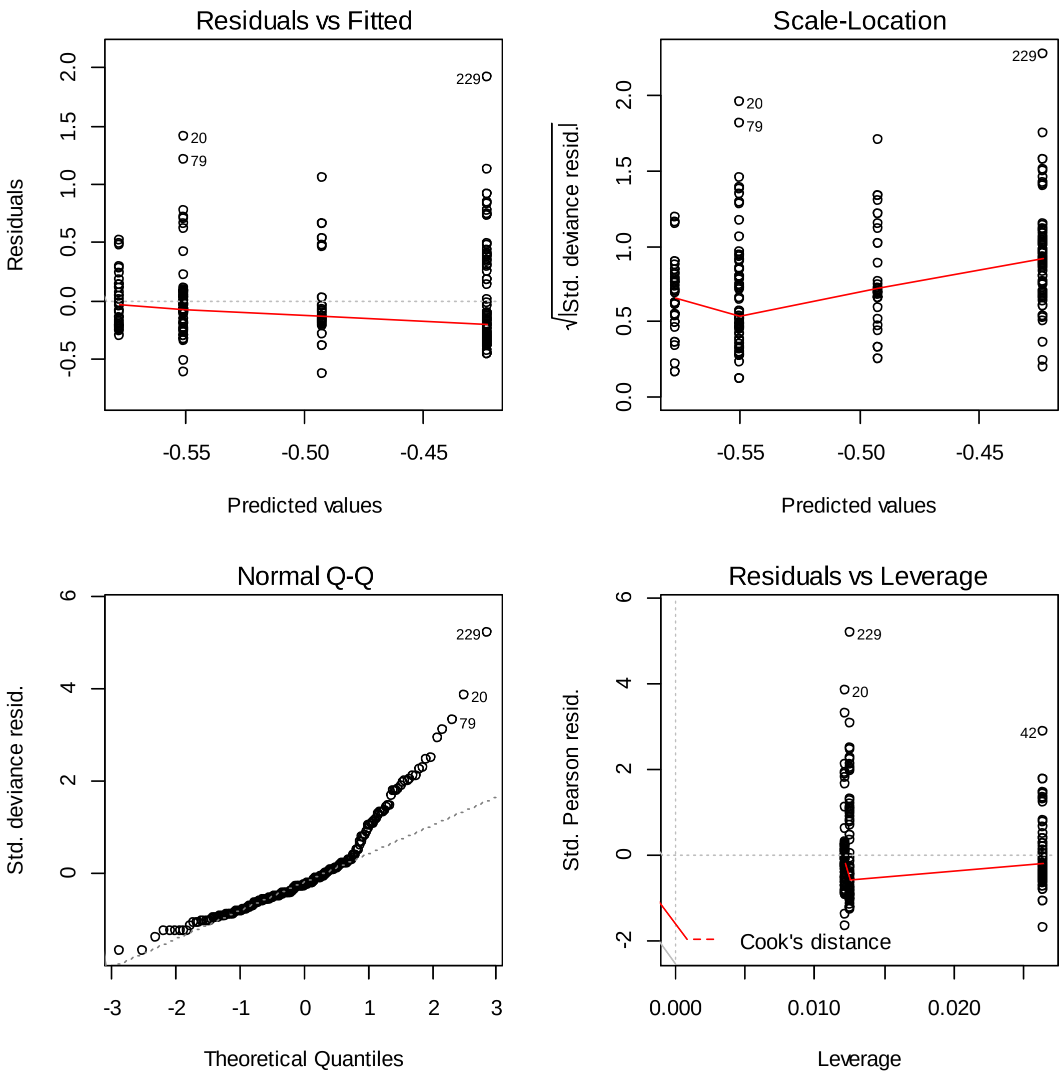

Figure 8. Residual plots for the GLM model fit to the North Atlantic longline shortfin mako shark bycatch data.

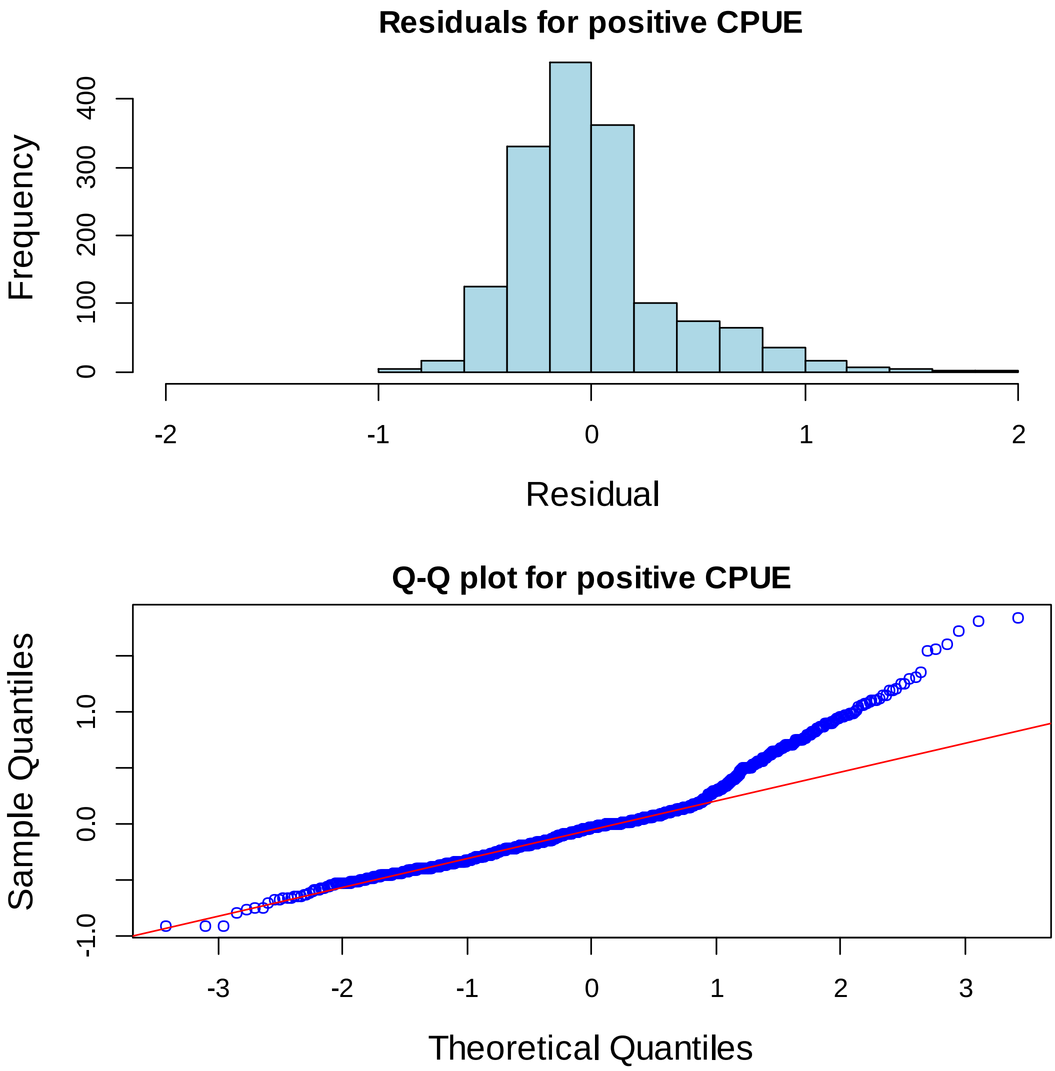

Figure 9. Diagnostic results from the GLM model fit to the South Atlantic longline shortfin mako shark bycatch data.

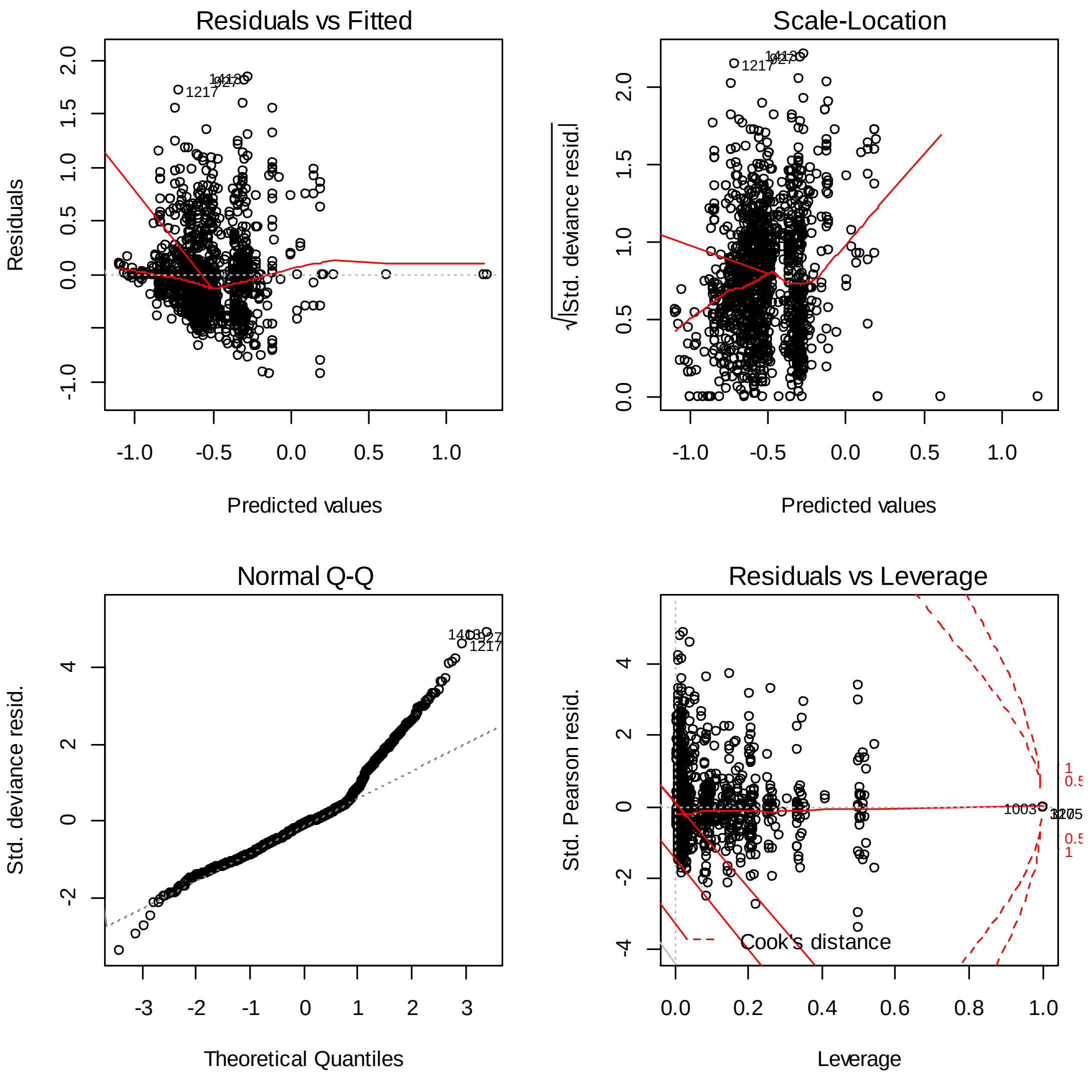

Figure 10. Residual plots for the GLM model fit to the South Atlantic longline shortfin mako shark bycatch data.

Table 1. Summary of information of the observers' data used in this study.

Year	North Atlantic		South Atlantic	
	No. of Hook	No. of Set	No. of Hook	No. of Set
2007	288,793	106	3,775,478	1,689
2008	226,049	111	3,172,312	1,462
2009	426,490	205	3,616,709	1,709
2010	419,197	224	3,561,132	1,684
2011	643,722	331	4,907,338	2,300
2012	763,769	364	4,056,603	1,976
2013	233,317	135	2,758,982	1,842
2014	247,759	150	2,930,770	1,888
2015	574,711	294	1,877,393	1,337
Average	431,364	275	3,598,298	2,189

Table 2. The observed percentage of zero-catch of shortfin mako shark for Taiwanese tuna longline vessels in the Atlantic Ocean from 2007 to 2015

Year	North Atlantic	South Atlantic
2007	98.11%	90.53%
2008	90.99%	90.15%
2009	68.78%	91.05%
2010	95.09%	88.60%
2011	83.08%	86.48%
2012	85.44%	88.41%
2013	94.81%	92.35%
2014	86.00%	89.35%
2015	95.24%	95.36%
Average	88.62%	90.25%

Table 3. Estimated nominal and standardized CPUE values for shortfin mako shark of the Taiwanese tuna longline fishery in the North Atlantic Ocean.

Year	Original values		Bias-corrected bootstrap confidence intervals				
	Nominal	Standardized	Lower CI	Upper CI	Mean	STD	CV
2007	0.0139	0.0122	0.0056	0.0315	0.0141	0.0079	0.5550
2008	0.0531	0.0563	0.0268	0.0959	0.0561	0.0173	0.3078
2009	0.2415	0.2000	0.1587	0.2457	0.1999	0.0221	0.1108
2010	0.0286	0.0285	0.0131	0.0472	0.0284	0.0084	0.2969
2011	0.1010	0.1032	0.0806	0.1319	0.1029	0.0129	0.1256
2012	0.0799	0.0877	0.0670	0.1111	0.0875	0.0112	0.1275
2013	0.0343	0.0327	0.0132	0.0609	0.0327	0.0122	0.3733
2014	0.0928	0.0925	0.0592	0.1322	0.0925	0.0185	0.1996
2015	0.0244	0.0278	0.0148	0.0444	0.0279	0.0075	0.2680

Table 4. Estimated nominal and standardized CPUE values for shortfin mako shark of the Taiwanese tuna longline fishery in the South Atlantic Ocean.

Year	Original values		Bias-corrected bootstrap confidence intervals				
	Nominal	Standardized	Lower CI	Upper CI	Mean	STD	CV
2007	0.0506	0.0529	0.0459	0.0618	0.0524	0.0040	0.0758
2008	0.0766	0.0671	0.0563	0.0797	0.0666	0.0059	0.0891
2009	0.0509	0.0507	0.0431	0.0586	0.0505	0.0040	0.0792
2010	0.0747	0.0657	0.0564	0.0754	0.0656	0.0049	0.0741
2011	0.0772	0.0719	0.0645	0.0797	0.0718	0.0040	0.0555
2012	0.0781	0.0680	0.0594	0.0774	0.0680	0.0046	0.0679
2013	0.0605	0.0565	0.0478	0.0664	0.0564	0.0048	0.0850
2014	0.1088	0.0795	0.0684	0.0921	0.0795	0.0060	0.0757
2015	0.0357	0.0383	0.0295	0.0482	0.0381	0.0048	0.1263

Table 5. Nominal CPUE values of each area used in shortfin mako shark historical catch correction.

Year	North Atlantic		South Atlantic	
	Area A	Area B	Area C	Area D
2007	0.00000	0.03923	0.04466	0.06440
2008	0.16373	0.00629	0.04204	0.15083
2009	0.39577	0.08502	0.03500	0.10531
2010	0.01419	0.03154	0.03610	0.21613
2011	0.02833	0.10098	0.05138	0.12707
2012	0.04247	0.09016	0.04739	0.13038
2013	0.00000	0.04070	0.05182	0.08297
2014	0.14194	0.02808	0.03474	0.25152
2015	0.00000	0.02657	0.03958	0.00477

Table 5. Estimated annual shortfin mako shark by-catch in number and weight (ton) of the Taiwanese tuna longline fishery in the North Pacific Ocean based on nominal and standardized CPUE.

Year	North Atlantic		South Atlantic	
	EstSMA (N)	EstSMA (ton)	EstSMA (N)	EstSMA (ton)
1981	643	32	2,162	108
1982	1,046	52	2,620	131
1983	1,186	59	1,186	59
1984	1,398	70	716	36
1985	1,417	71	1,816	91
1986	1,549	78	1,727	87
1987	443	22	1,308	66
1988	79	4	693	35
1989	47	2	580	29
1990	184	9	724	36
1991	784	39	1,604	80
1992	327	16	878	44
1993	173	9	625	31
1994	587	29	1,294	65
1995	629	32	1,729	87
1996	887	45	2,338	117
1997	841	42	2,777	139
1998	942	47	2,597	130
1999	1,489	75	3,949	198
2000	1,108	56	3,233	162
2001	930	47	2,395	120
2002	1,064	53	2,915	146
2003	738	37	1,664	83
2004	1,400	70	3,580	180
2005	1,360	68	4,495	226
2006	797	40	3,301	166
2007	126	6	2,932	147
2008	530	27	3,427	172
2009	1,774	89	2,818	141
2010	278	14	4,400	221
2011	1,083	54	5,573	280
2012	703	35	4,354	218
2013	263	13	2,570	129
2014	309	16	4,017	202
2015*	-	-	-	-

***** incomplete data

Appendix 1

Deviance tables for the Lognormal and Binomial models

North Atlantic:

```
Model: gaussian, link: identity

Response: log(DATA$CPUE)

Terms added sequentially (first to last)


     Df Deviance Resid. Df Resid. Dev      F  Pr(>F)
NULL                   237     32.926
Q     3  0.90921       234     32.016 2.2151 0.08708 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Model: binomial, link: logit

Response: DATA2$PA

Terms added sequentially (first to last)


      Df Deviance Resid. Df Resid. Dev       F    Pr(>F)
NULL                   1919     1439.0
yy     8  117.457      1911     1321.5 14.6821 < 2.2e-16 ***
Q      3    2.198      1908     1319.3  0.7328 0.5322566
A      1   16.855      1907     1302.5 16.8554 4.034e-05 ***
GRP    1   11.612      1906     1290.9 11.6118 0.0006553 ***
Q:GRP  3   67.584      1903     1223.3 22.5280 1.404e-14 ***
A:GRP  1    5.230      1902     1218.1  5.2302 0.0221978 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

South Atlantic:

```
Model: gaussian, link: identity

Response: log(DATA$CPUE)

Terms added sequentially (first to last)


       Df Deviance Resid. Df Resid. Dev       F    Pr(>F)
NULL                    1592     281.64
yy      8   30.140      1584     251.50 26.2164 < 2.2e-16 ***
Q       3    2.964      1581     248.54  6.8751 0.0001345 ***
A       1    0.278      1580     248.26  1.9343 0.1645051
GRP     1    0.660      1579     247.60  4.5893 0.0323385 *
SST   117   34.839      1462     212.76  2.0721 1.063e-09 ***
Q:A     3    1.461      1459     211.30  3.3900 0.0174280 *
Q:GRP   3    2.066      1456     209.24  4.7933 0.0025071 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Model: binomial, link: logit

Response: DATA2$PA

Terms added sequentially (first to last)


      Df Deviance Resid. Df Resid. Dev        F    Pr(>F)
NULL                  15886    10348.1
yy     8   105.73     15878    10242.3  13.2157 < 2.2e-16 ***
Q      3   112.31     15875    10130.0  37.4351 < 2.2e-16 ***
A      1   352.58     15874     9777.5 352.5772 < 2.2e-16 ***
GRP    1     0.20     15873     9777.3   0.2006 0.6542114
Q:A    3    31.02     15870     9746.2  10.3408 8.409e-07 ***
Q:GRP  3     3.00     15867     9743.2   1.0016 0.3909087
A:GRP  1    13.49     15866     9729.7  13.4896 0.0002399 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```