ESTIMATE OF LIVE RELEASE AND DEAD DISCARD OF THE SHORTFIN MAKO SHARK CAUGHT BY THE CHINESE TAIPEI LONGLINE FISHERY IN THE NORTH ATLANTIC OCEAN

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SUMMARY

*Chinese Taipei longline fisheries have ban retention of shortfin mako shark (*Isurus oxyrinchus*) in the North Atlantic Ocean since 2018. However, detailed information of the live release and dead discards of shortfin mako is still unknown. Although Chinese Taipei observer program started in 2004, the live release and dead discard without retention data were only available from 2017 to 2020. The nominal CPUE of shortfin mako obtained from observer's records from 2007 to 2020 were standardized using a Delta Lognormal model. The total shortfin mako shark catch in number of the Chinese Taipei longline fleets in the North Atlantic was estimated by a multiplication of standardized CPUE and total effort in the logbook of the Chinese Taipei longline fleets. The total live release and dead discard of shortfin mako caught by the Chinese Taipei longline fleets were estimated by the live release and dead discard ratio obtained from observer's records multiplying the estimated annual catch in number. These numbers multiplied by the mean weight in catch can obtain the total catch in weight of shortfin mako ranged from 6 to 32 tons including live release of 2-10 tons and dead discard of 4-22 tons for the Chinese Taipei fleets in the North Atlantic in 2018-2021.*

RÉSUMÉ

Les pêcheries palangrières du Taïpei chinois sont assujetties à une interdiction de rétention du requin-taupe bleu (Isurus oxyrinchus) de l'Atlantique Nord depuis 2018. Toutefois, les informations détaillées sur les rejets morts et les remises à l'eau de spécimens vivants restent inconnues. Bien que le programme d'observateurs du Taïpei chinois ait débuté en 2004, les rejets morts et les remises à l'eau de spécimens vivants sans données de rétention n'étaient disponibles que de 2017 à 2020. Les CPUE nominales du requin-taupe bleu obtenues d'après les registres des observateurs de 2007 à 2020 ont été standardisées en utilisant un modèle delta-lognormal. La capture totale de requin-taupe bleu en nombre des flottilles palangrières du Taïpei chinois dans l'Atlantique Nord a été estimée en multipliant les CPUE standardisées et l'effort total figurant dans les carnets de pêche des flottilles palangrières du Taïpei chinois. Le nombre total de rejets morts et de remises à l'eau de spécimens vivants de requin-taupe bleu capturé par les flottilles palangrières du Taïpei chinois a été estimé en multipliant le ratio de rejets morts et de remises à l'eau de spécimens vivants obtenu des registres des observateurs par la capture annuelle estimée en nombre. Ce nombre multiplié par le poids moyen de la capture permet d'obtenir la capture totale en poids du requin-taupe bleu allant de 6 à 32 tonnes, y compris des remises à l'eau de spécimens vivants de 2-10 tonnes et de rejets morts de 4-22 tonnes pour les flottilles palangrières du Taïpei chinois dans l'Atlantique Nord en 2018-2021.

RESUMEN

En las pesquerías de palangre de Taipei Chino está prohibida la retención del marrajo dientuso (Isurus oxyrinchus) *en el océano Atlántico norte desde 2018. Sin embargo, aún se desconoce la información detallada de los descartes de ejemplares vivos y muertos de marrajo dientuso. Aunque el programa de observadores de Taipei Chino comenzó en 2004, los datos de liberación*

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de ejemplares vivos y de descartes de ejemplares muertos sin retención solo estaban disponibles de 2017 a 2020. La CPUE nominal del marrajo dientuso obtenida a partir de los registros de los observadores de 2007 a 2020 se estandarizó utilizando un modelo delta lognormal. La captura total de marrajo dientuso en número de las flotas palangreras de Taipei Chino en el Atlántico norte se estimó multiplicando la CPUE estandarizada y el esfuerzo total de los cuadernos de pesca de las flotas palangreras de Taipei Chino. El total de liberaciones de ejemplares vivos y de descartes de ejemplares muertos de marrajo dientuso capturado por las flotas de palangre de Taipei Chino se estimó multiplicando la ratio de las liberaciones de ejemplares vivos y de los descartes de ejemplares muertos obtenida de los registros de los observadores por la captura anual estimada en número. Si se multiplican estas cifras por el peso medio en las capturas se puede obtener la captura total en peso del marrajo dientuso que osciló entre 6 y 32 t, lo que incluye 2 a 10 t de liberaciones de ejemplares vivos y de 4 a 22 t de descartes de ejemplares muertos para las flotas de Taipei Chino en el Atlántico norte en 2018-2021.

KEYWORDS

Observer, CPUE standardization, Delta lognormal model, bootstrap resampling

1. Introduction

The Chinese Taipei longline fishery has operated in the Atlantic Ocean since the late 1960s. However, the shark by-catch of Chinese Taipei 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 blue shark, *Prionace glauca*, mako shark, *Isurus spp*., silky shark, *Carcharihnus falciformis*, and others since 2003.

Shortfin mako shark (SMA) is the major shark by-catch species of Chinese Taipei large-scale 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. This species has been listed on CITES Appendix II in 2019. As under-reporting and no-recording of sharks were found in the logbook, 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). Tsai and Liu (2017) described the CPUE standardization of shortfin mako using GLM model and back-estimated the historical catch of the Chinese Taipei longline fishery in the Atlantic Ocean. The Fisheries Agency, Taiwan announced the ban retention of shortfin mako shark for the longline fishing fleets in the North Atlantic in 2018. As all shortfin mako shark catches were returned to the sea, the information of live release and dead discard become important as it is useful for estimating the total removal or post-capture mortality that is important input parameters for stock assessment. However, this information is still unknown. Thus, the objectives of this study were to estimate the total catch in weight, live release and dead discard of shortfin mako shark by the Chinese Taipei longline fishing fleets in the North Atlantic Ocean.

2. Materials and methods

2.1 Fishery data

2.1.1 Source of data

The logbook data of Chinese Taipei large-scale longline fishery from 1981 to 2020, provided by the Overseas Fisheries Development Council of Taiwan, 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 2007-2020 were used to standardize CPUE (catch in number per 1000 hooks) of shortfin mako shark of Chinese Taipei longline fishery in the North Atlantic Ocean. In the North Atlantic, Chinese Taipei tuna longline fishery targets different tuna species depending on the area; targeting albacore tuna in the mid-high latitude, targeting bigeye tuna in the low latitude. Shortfin mako sharks caught by Chinese Taipei longline fishery in the Atlantic Ocean were mainly

observed in the equatorial waters (Tsai and Liu, 2017).

2.2 Statistical model of CPUE standardization

The observer data from 2007 to 2020 were used in the standardization of SMA CPUE. A large proportion of sets with zero catch of shortfin mako shark (~89%, Tsai and Liu (2017)) were found in observers' records. Hence, to address these excessive zeros, 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, 2018) 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,), latitude (LAT), longitude (LON) and HPB (number of hooks per basket, HPB), and interaction terms. 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

$$\ln(\text{CPUE}) = \mu + Y + Q + A + HPB + LON + LAT + \text{interactions} + \varepsilon_1 \quad (1)$$

where μ is the mean, andε_1 is a normal random error term. The effect of gear configuration, HPB, was categorized into two classes: shallow set (HPB $\leqq$ 15), and deep set (HPB > 15), and quarter was categorized into 4 classes: the 1st quarter (Jan-Mar), the 2nd quarter (Apr-Jun), the 3rd quarter (Jul-Sep), and the 4th quarter (Oct-Dec). Two area strata (north of 20°N and 5-20°N) were used for the analysis. To estimate the proportion of positive shortfin mako shark catch(PA), we used a model assuming a binomial error distribution (ε_2):
Part 2: Binomial model

$$PA = \mu + Y + Q + A + HPB + LON + LAT + \text{interactions} + \varepsilon_2 \quad (2)$$

The best model for both Lognormal and Binominal models were selected using the backward STEPWISE-AIC-BEST method (Venables and Ripley, 2002). 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):

$$\text{Standardized CPUE} = \text{CPUE} * \text{PA} \quad (3)$$

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 bootstrap resampling 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_i) from 2007 to 2020 was estimated by a multiplication of standardized CPUE of year *i* and logbook fishing effort of year *i* as followings:

$$C_i = \text{standardized CPUE}_i \times \text{logbook effort}_i \quad (4)$$

Because the observer data of 2021 were incomplete, SMA catch of 2021 was estimated by a multiplication of standardized CPUE of 2020 and logbook effort of 2021.

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 166.8 cm calculated from observers' data of 2007-2017 and the mean weight was obtained by substituting the mean FL into the W-FL relationship as follows: $W = 5.2432 \times 10^{-6}\ FL^{3.1407}$ (Natanson *et al*, 2006). The mean catch in weight of SMA was 50.01 kg in 2007-2017 (Tsai and Liu, 2017).

2.4 Estimates of live release and dead discard

The live release and dead discard ratio of shortfin mako obtained from observer's records from 2017 to 2020 were used to estimate the total live release and dead discards of shortfin mako by the Chinese Taipei longline fleets.

$$LR_i = C_i \times \text{OBS Live Release percentage } SMA_{2017\text{-}2020} \quad (5)$$

$DD_i = C_i - LR_i$ ..... (6)
where LR_i: number of live released SMA of year *i* of the Chinese Taipei longline fleets in the North Atlantic, DD_i: number of dead discarded SMA of year *i* of the Chinese Taipei longline fleets in the North Atlantic, OBS Live Release percentage $SMA_{2017\text{-}2020}$: mean percentage of live release of observer records of 2017-2020.

3. Results and discussion

The best DLN models selected based on the stepwise AIC are as follows:

Lognormal model：

$$\ln(CPUE) = \mu + Y + Q + A + HPB + LON + LAT + Q*A + Q*HPB + \varepsilon_1$$

Binomial model：

$$PA = \mu + Y + Q + A + HPB + LON + LAT + Q*A + Q*HPB + \varepsilon_2$$

Standardized CPUE = CPUE*PA

The fishing effort of the Chinese Taipei longline fleets in the North Atlantic were 12.81, 11.15, 13.95 and 4.44 million hooks in 2018-2021 (**Table 1**). The standardized CPUE of SMA showed an increasing trend from 2007 to 2009, decreased in 2010 and stayed stable in 2011-2015, reached the second peak in 2016, and decreased again since 2018 when ban retention started (**Figure 1**). Standardized CPUE of SMA were 0.0500, 0.0133, and 0.0256 for 2018-2020. The decrease of standardized CPUE after 2018 may be related to the ban retention policy, but the actual reason cannot be clarified until longer time series data were collected. SMA catch in number with 95% confidence interval of the Chinese Taipei longline fleets in the North Atlantic were estimated as 640 (470-879), 148 (75-274), 357 (218-561) and 114 (69-179) individuals in 2018-2021 (**Table 2**). The observers recorded 11 live releases and 25 dead discards in 2017-2020, and the live release percentage was 0.3056 (**Table 3**). The live release in number with 95% confidence interval of the Chinese Taipei longline fleets in the North Atlantic was estimated as 195 (144-269) in 2018, 45 (23-84) in 2019, 109 (66-171) in 2020 and 35 (21-55) in 2021, respectively. The dead discard in number with 95% confidence interval was estimated as 445 (326-610) in 2018, 103 (52-190) in 2019, 248 (152-390) in 2020 and 79 (48-124) in 2021, respectively (**Table 4**). The live release in weight with 95% confidence interval of the Chinese Taipei longline fleets in the North Atlantic was estimated as 10 tons (8-13 tons) in 2018, 2 tons (1-4 tons) in 2019, 6 tons (3-9 tons) in 2020 and 2 tons (1-3 tons) in 2021, respectively. The dead discard in weight with 95% confidence interval was estimated as 22 tons (16-31 tons) in 2018, 5 tons (3-10 tons) in 2019, 12 tons (8-19 tons) in 2020 and 4 tons (2-6 tons) in 2021, respectively (**Table 5**). The lowest live release and dead discard of SMA in 2021 were due to a remark decrease of fishing effort in 2021 (**Table 1**) particularly the bigeye tuna fleet in tropical waters.

This study provided the first information of live release and dead discard of SMA by the Chinese Taipei longline fleets in the North Atlantic based on observer records. The estimated SMA catch in number was 114-640 individuals corresponding to 6-32 tons (50 kg per individual based on Tsai and Liu (2017)) in 2018-2021 which was very minor of the total catch of 3,115 tons in the North Atlantic in 2017 (Anon., 2019). However, as observer's records did not cover the entire fishing area of the Chinese Taipei longline fishing fleets and the sampling size and time series were very limited, continuity in collecting live release and dead discard information is needed for improving the estimation.

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Table 1. Fishing effort (number of hooks) of the Chinese Taipei longline fishery by fleet in the North Atlantic from 2018-2021.

Year	BET group	ALB group	Total
2018	6,949,105	5,863,592	12,812,697
2019	5,781,265	5,377,481	11,158,746
2020	9,626,175	4,328,456	13,954,631
2021	2,284,770	2,156,295	4,441,065

Table 2. Estimated SMA catch in number and weight of the Chinese Taipei longline fishing vessels in the North Atlantic Ocean from 2018-2021.

Year	number	Lower95	Upper95	Weight (tons)	Lower95	Upper95
2018	640	470	879	32	24	44
2019	148	75	274	7	4	14
2020	357	218	561	18	11	28
2021	114	69	179	6	3	9

Table 3. Live release and dead discard of SMA recorded by observers on board the Chinese Taipei longline fishing vessels in the North Atlantic Ocean from 2017-2020.

Year	Live release	Dead discard	Live release percentage
2017	2	11	0.1538
2018	3	7	0.3000
2019		3	0.0000
2020	6	4	0.6000
Total	11	25	0.3056

Table 4. Estimated live release and dead discard in number of SMA by the Chinese Taipei longline fishing vessels in the North Atlantic Ocean from 2018-2021.

Year	Live release	Lower95	Upper95	Dead discard	Lower95	Upper95
2018	195	144	269	445	326	610
2019	45	23	84	103	52	190
2020	109	66	171	248	152	390
2021	35	21	55	79	48	124

Table 5. Estimated live release and dead discard in weight (ton) of SMA by the Chinese Taipei longline fishing vessels in the North Atlantic Ocean from 2018-2021.

Year	Live release	Lower95	Upper95	Dead discard	Lower95	Upper95
2018	10	8	13	22	16	31
2019	2	1	4	5	3	10
2020	6	3	9	12	8	19
2021	2	1	3	4	2	6

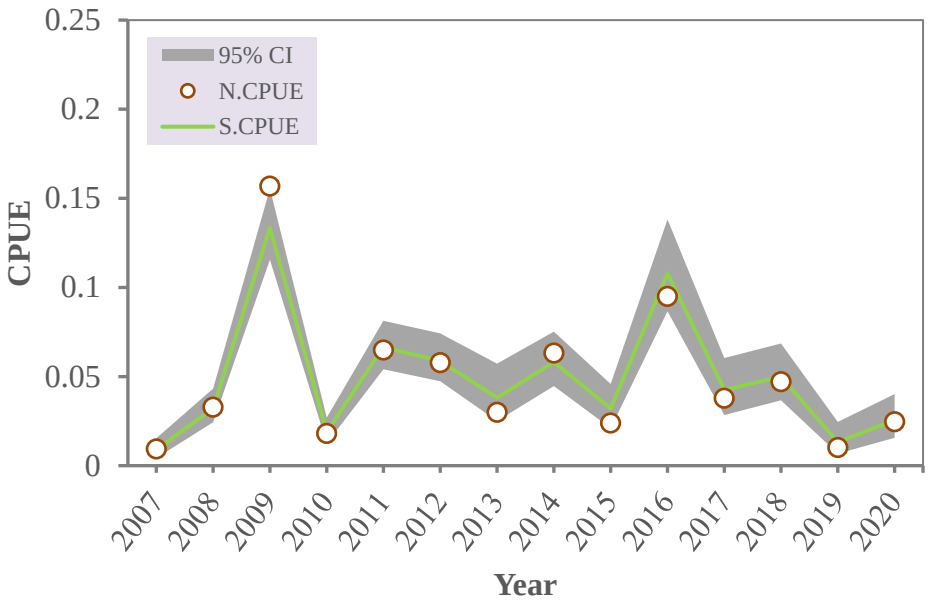

Figure 1. Nominal and standardized CPUE of SMA caught by the Chinese Taipei longline fisheries in the North Atlantic Ocean based on observer's data.