Standardized CPUE of Shortfin Mako Shark (*Isurus oxyrinchus*) from Indonesian tuna longline fleets in the northeastern Indian Ocean

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Abstract

The main objective of this study was to analyses the catch, effort, nominal and standardized CPUE trends for shortfin mako shark captured by the Indonesian tuna longline fishery for the period 2005-2021. The study aimed to address this region's information gaps associated with low coverage. A total of 3,296 observer data points were obtained from the Indonesian scientific observer program, covering the years 2005 to 2021. The nominal annual CPUE was calculated as the number (N)/1000 hooks. Standardized CPUE was estimated with Generalized Linear Models (GLM) using year, quarter, Lat/Lon, and gear operational characteristics. Model fit and model comparison were conducted with Akaike Information Criteria (AIC), apparent coefficient of determination (R^2), and model validation with residual analysis. The final estimate of the abundance index was calculated using the least square means method. The results showed that the factor contributing most to the deviation was Year, followed by Latitude, Quarter, Longitude, and other effects and interactions. The trend of standardized CPUE remained relatively stable (with very low abundance). These fluctuations were thought to be due to natural population variations and inter-annual environmental factors rather than operational changes.

Introduction

The shortfin mako shark (SMA), *Isurus oxyrinchus*, is a pelagic oceanic species with a widespread distribution in temperate and tropical waters of all the world's oceans (Compagno, 2001). The shortfin mako has been listed on the IUCN red list with different statuses based on regional waters. It was listed as an Endangered species globally (Rigby et al., 2019) and has been listed in CITES Appendix II since 2019.

The catch of SMA sharks in the Indian Ocean in 2022 was 666 tons, with stock status in the Indian Ocean is currently unknown (IOTC, 2023). In general, mako sharks are caught in both industrial and artisanal fisheries. They are caught as targets and bycatch from various fishing gear operating offshore and on open seas. Based on data from FMA 573 (Southern of Java Island waters), during 2016-2020, the catch of SMA from shark longlines constituted 3-54% of the annual total catch and From 2016-2019, the contributions of shark longlines ranged between 3-14% and in 2020, the contribution increased to 54% (Oktaviyani et al., 2022). They stated that During 2016-2020, the proportion of shortfin mako sharks caught by purse seine, beach seine, pole and line, and cast net ranged from 0-12% per year and from 2016 to 2020, SMA contributed at least 6% of shark's annual production in the Eastern Indian Ocean. The our objectives of this study are to standardized SMA CPUE indices for Indonesian longline fleet estimated using observer data collected by scientific observer program Research Institute for Tuna Fisheries (RITF) conducted 2005 – 2021. We believe the results are valuable as an important information to assess the status of SMA in the Indian Ocean.

Materials and Methods

Data Source

Data collection was conducted by a scientific observer program RITF, from August 2005 to December 2021 in the tuna longline vessels primarily located at Benoa Harbour in Bali. The observation program was initiated in 2005 through a collaborative effort between Australia and Indonesia (Project FIS/2002/074 of the Australian Centre for International Agricultural Research). From 2012 onwards, the Research Institute for Tuna Fisheries (RITF Indonesia) conducted the program. However, in 2022, the program was discontinued following the establishment of the National Research and Innovation Agency (BRIN).

Fishing trips typically range from three weeks to five months in duration. The dataset of 3.296 set-by-set records was obtained from Indonesia's scientific observer program. The dataset provides detailed information on a 1x1 degree latitude and longitude grid, covering the period from January 2005 to December 2021.

The fishing grounds explored in this study extend from the western to the Southern parts of Indonesian waters, spanning approximately from 75°E to 35°S (**Figure 1**). Data collections included the number of SMA caught, the total number of hooks used, the number of hooks between floats, the length of float lines, the length of branch lines, and the length between branch lines. Spatial-temporal information (date of operation, latitude and longitude) and the number of shark lines used were also collected and used for this analysis.

CPUE Standardization

The CPUE analysis was carried out using this official data from the RIFT scientific observer program. Operational data at the fishing set level was used, with the catch data referring to the total numbers (N) of SMA sharks captured per fishing set. For the CPUE standardization, the response variable was catch per unit of effort (CPUE), measured as numbers (N) of SMA per 1000 hooks deployed. The standardized CPUEs were estimated with Generalized Linear Models (GLMs).

There were a relatively large number of sets (83.51%) with zero SMA catches, resulting in a response variable of CPUE=0. As these zeros can cause mathematical problems in fitting the models, the approach chosen was a Tweedie model with link=log that can model both the continuous component of the response variable for the positive observations and the mass of zeros for the zero catches. For this model, the nominal CPUE was used directly in the response variable, given this specific characteristic of the distribution.

The covariates considered and tested in the models were:

- Year: analyzed between 2005 and 2021;

- Quarter of the year: 4 categories: 1 = January to March, 2 = April to June, 3 =July to September, 4 = October to December;
- Lat/Lon: Geographical information (latitude and longitude) in 5x5 degree blocks;
- Operational characteristics of the gear, which can be used as proxies for targeting effects: Number of hooks between floats (NHBF), Length of the float line; Length of the branch line, Length between branch line, and Number of shark lines used.

The significance of the explanatory variables in the CPUE standardization models was assessed with likelihood ratio tests comparing each univariate model to the null model and analysing the deviance explained by each covariate. Goodness-of-fit and model comparison was carried out with the Akaike Information Criteria (AIC) and the pseudo coefficient of determination (R^2) (Akaike, 1974). Interactions were considered and tested, and the significant interactions were used in the analysis.

Model validation was carried out with a residual analysis. The final estimated indexes of abundance were calculated by least square means (LSMeans) or Marginal Means, which, for comparison purposes, were scaled by the mean standardized CPUE in the time series.

Results

Fishing Information

The distribution of sets of Indonesian tuna longline commercial vessels mainly gathered in the area of the eastern Indian Ocean, with most of the positive catches occurring in the area south of Indonesian waters, between 0-20^0 S and 75-125^0 E (**Figure 1**). Observers recorded catch and operational data at sea following Indonesian tuna longline commercial vessels from 2005 to 2021. The final dataset contained 127 trips, 3309 sets, and almost 4.3 million hooks deployed, respectively (**Table 1**).

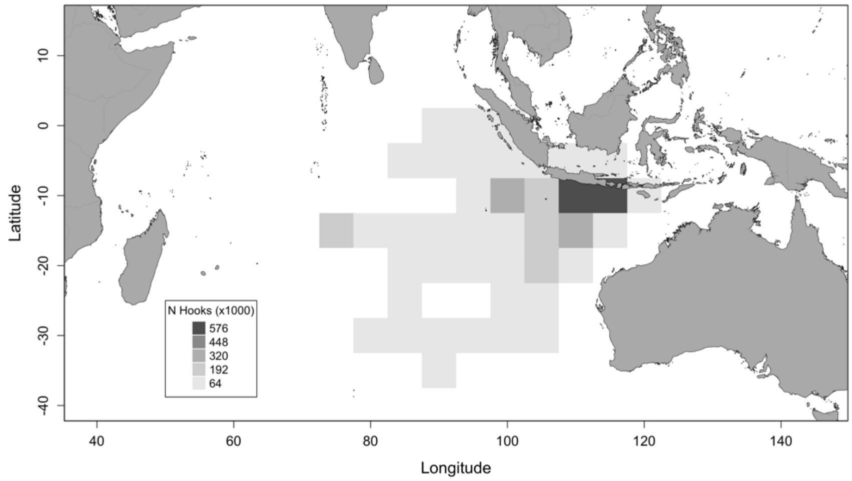

Figure 1. Distribution of the Indonesia observer reports from 2005 to 2021 data used in this SMA CPUE standardization. The effort is represented in 5*5 degree grids with darker and lighter colours representing respectively to areas with more and less effort in number of hooks.

Tabel 1. Summary of the Indonesia observer effort tuna longline commercial vessels from 2005-2021

Year	Trips	Sets	Total Hooks.	Mean Hooks	se
2005	9	116	170749	1464.87	14.54
2006	13	400	575989	1439.97	10.77
2007	13	262	403333	1539.44	19.96
2008	15	396	510702	1289.65	19.28
2009	13	288	328718	1141.38	13.82
2010	6	166	221274	1332.98	35.51
2011	3	105	110384	1051.28	16.97
2012	8	198	290265	1465.98	39.73
2013	7	210	231990	1104.71	14.11
2014	6	184	216705	1177.74	13.35
2015	5	150	174655	1164.37	11.81
2016	3	130	175868	1352.83	18.33
2017	4	139	192188	1382.65	33.82
2018	6	195	262856	1347.98	16.52
2019	9	164	216836	1322.17	15.14
2020	2	63	86845	1378.49	18.20
2021	5	130	197424	1518.65	27.32

CPUE Data Characteristics

In general, SMA catches have been relatively close to zero, with slight fluctuations over the last two decades and showing a decreasing trend in the last five years. In 2011, SMA was not recorded (zero catch), while the highest SMA CPUE was observed in 2017 (0.15 ± 0.44). On the other hand, the proportion of zero catch for SMA was very high, and showed a relatively stable trend. Similarly, for nominal CPUE, the trend varied annually, with a maximum of 100% in 2011 and a minimum of 84% in 2017 (Figure 2). There are 95.78 % of data zero SMA CPUEs with the average zero proportion was 83.52 % per year.

Figure 2. Nominal CPUE series (N/1000 hooks) (left panel) and Proportion of zero-catch-per-set (right panel) for SMA from 2006 to 2021. The error bars refer to the standard errors.

CPUE Standardization

Several explanatory variables tested for the SMA CPUE standardization were significant and contributed significantly to explaining part of the deviance. Some interactions were also significant and included in the final model. In the final model, the factors that contributed most to the deviance were the Year, followed by Lattitude, Quarter, and other effects and interactions (Table 2). The current SMA catch was more likely driven by temporal (Year and Quarter), specific spatial distribution (Latitude), and current operational aspect, i.e., Number hook between float (NHBF).

Table 2. Deviance table of the parameters used standardizations if the Indonesia data, using a Tweedie GLM with link=log. For each parameter, it is indicated the degrees of freedom (Df), the deviance (Dev), the residual degrees of freedom (Resid Df), the residual deviance (Resid. Dev), the F-test statistic and the significance (p-value).

	Df	Deviance	Resid. Df	Resid. Dev	F-stat.	p-value
NULL			3259	948.97		
Year	16	105.524	3243	843.45	4.7534	1.14e-09 ***
Quarter	3	19.041	3240	824.41	4.5746	0.003348 **
Lat	1	73.338	3239	751.07	52.8564	4.48e-13 ***
Lon	1	5.273	3238	745.80	3.8001	0.051337 .
NHBF	1	0.045	3237	745.75	0.0325	0.856967
LBBL	1	2.974	3236	742.78	2.1437	0.143258
Quarter : NHBF	3	16.891	3233	725.89	4.0579	0.006878 **
NHBF : LBBL	1	0.166	3232	725.72	0.1194	0.729742

*NHBF = Number hook between float; LBBL = length between branch line

In general, the trend of standardized CPUE has remained relatively stable (always caught but very few in number) over time with little noise across the series, except in 2007 and 2017, which showed very high spikes. However, the uncertainty remains mainly due to the limited coverage of scientific observer data.

The implementation of the National Observer Program by the Directorate General of Capture Fisheries, Ministry of Marine Affairs and Fisheries is expected to increase observer coverage on Indonesian commercial tuna longline vessels operating in the IOTC area in the coming years to address this issue.

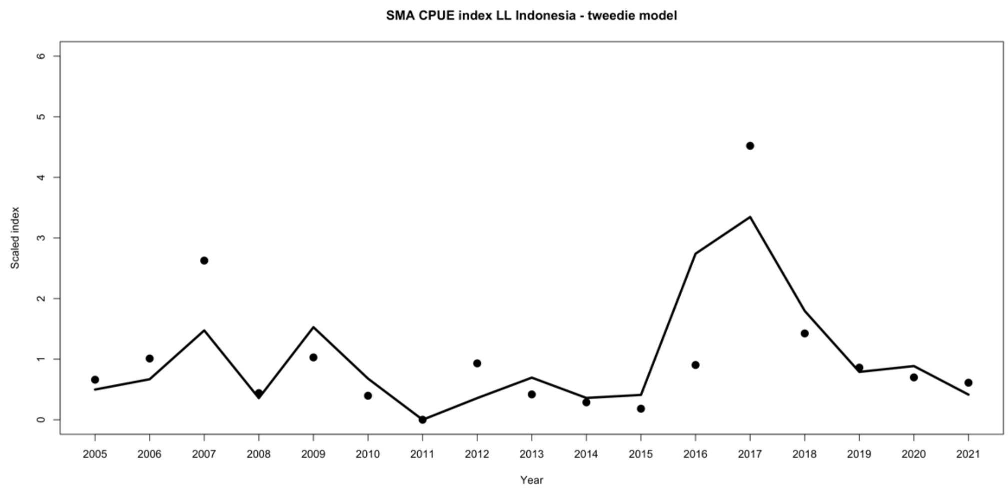

Figure 3. Standardized CPUE series for SMA from Indonesia data using a Tweedie model between 2005 and 2021. The solid lines refer to the standardized index and the dots represent the nominal CPUE series. Both series are scaled by their means.

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