Updated on CPUE standardization of black marlin (*Istiompax indica*) from Indonesian tuna longline fleets 2006-2023

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Abstract

The black marlin (*Istiompax indica*) is a valuable by-catch in tuna longline fisheries, but its status is uncertain due to recent catch increases and conflicting data, particularly in the abundance index. Therefore, this study was intended to analyse the catch-per-unit-of-effort (CPUE) of black marlin, particularly in the north-eastern Indian Ocean, by utilising scientific observers data. The analysis hopefully can address the existing information gap associated with low coverage in this region. Catch and effort data from more than 3,000 sets were obtained from the Indonesian scientific observer program, spanning the years 2006 to 2023. These data were spatially disaggregated into one-degree blocks and were collected alongside commercial longline fleets. To analyse the dataset, Poisson and negative binomial models were considered, with number of fish as the response variable and total hooks as an offset. Six covariates were included in the models, i.e., $year$, $quarter$, cat_hbf, $moon$, lat, lon. The results showed that, despite inter-annual fluctuations, the trend in black marlin CPUE remained relatively stable over time but exhibited a decline in the past four years. The need for improved and continued monitoring is imminent to enhance our understanding and management of this important by-catch species.

Introduction

Black marlin (*Istiompax indica*) is a highly migratory apex predator, and is considered to be a non-target species from Indonesian industrial and small-scale tuna fisheries (Nugraha and Setyadji, 2013; Sulistyaningsih et al., 2011; Widodo et al., 2016). It is the second most landed billfish species after swordfish (Setyadji and Nugraha, 2012), and has high commercial value, both in the tropical and subtropical Indian and Pacific Ocean (Nakamura, 1985). It is mostly caught between 20°N and 45°S, but more often off the western coast of India and the Mozambique Channel (IOTC-WPB20, 2022).

In the Indian Ocean, black marlin is largely caught by gillnets (~59%), followed by longlines (~19%), with remaining catches recorded under troll and hand lines (IOTC-WPB20, 2022). The Indonesian fleet caught around 10% (under 2000 tons) of the total catch of black marlin in the Indian Ocean between 2018-2023, ranked fourth after Iran, India, and Sri Lanka (IOTC-WPB20, 2022). The latest stock assessment using JABBA (Parker, 2021) suggested that the stock is not overfished or subject to overfishing, but there is high uncertainty in this assessment due to recent catch increases and conflicting data. The next stock assessment is anticipated in 2024, which may provide further clarity on the stock's status.

Estimates of relative abundance indices can support the use of more detailed models (Maunder and Punt, 2004), which can provide important information concerning the status of the black marlin stock. Statistical models such as Generalized Linear Models (GLM) can be used to “standardize” commercial catch per unit effort (CPUE) in order to calculate relative abundance indices, which are the input data for several stock assessment models (Maunder et al., 2020). Estimates of standardized CPUE for Indian Ocean black marlin are constrained by several data limitations (Parker, 2021). Detailed data are scarce, with time trends only available from 1979 onward. Additionally, there are discrepancies in CPUE estimates between Japanese and Taiwanese sources prior to 2005, and the Taiwanese data is restricted to the northern part of the Indian Ocean.

In response to data scarcity, Indonesia proposed a scientific observer program which started in mid-2005, and has been providing information on black marlin caught by longline boats operating in the north-eastern Indian Ocean (Setyadji and Andrade, 2016). In this paper we used a GLM to calculate standardized CPUE of black marlin caught by Indonesian longline fleet in the Eastern Indian Ocean. Results can be used to assess the status of the black marlin stock, which is an important fishery resource in the Indian Ocean.

Materials and Methods

Data Collection

This research analyses data collected by Indonesian scientific observers on commercial tuna longline vessels, primarily located at Benoa Fishing Port in Bali. Vessel selection was voluntary and dependent on availability as determined by the fishing company. 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) conducted the program. However, in 2022, the program was discontinued following the establishment of the National Research and Innovation Agency (BRIN) (Burhani et al., 2023). Consequently, the data utilized in this study were obtained from the Directorate General of Capture Fisheries under the Ministry of Marine Affairs and Fisheries. However, the coverage was lower than the IOTC requirement, which is 5%.

A total of 3,756 set-by-set data from 2006 to 2023 were obtained from scientific observers. Fishing trips usually last from three weeks to three months. The main fishing grounds cover the western and southern parts of Indonesian waters, stretching from 75° – 130ºE and 0º – 35°S (Figure 1). The dataset includes information such as the species-specific catch quantities, total number of hooks, number of hooks between floats (HBF), start time of the set, start time of haul, soak time, and geographic positions where the longline sets were deployed.

CPUE Standardisation

Two GLMs were considered in this study, with. nominal catch (number of fish) as the response variable, either a Poisson or a negative binomial response distribution, and a log link function. Each set has a fixed number of hooks, and at most one fish can be caught per hook. Effort (total hooks) was therefore included as an offset. If hooks are assumed independent, the multinomial is the natural starting point for models of counts of fish of multiple species caught per set. However, where the number of hooks per set is large and the species of interest have low probabilities of being caught on each hook, the joint distribution of counts per set for these species can be approximated by independent Poisson distributions (Johnson et al., 1997; p. 124). We therefore consider Poisson regression for counts of black marlin per set. The negative binomial is widely used to model overdispersion in count data, so we also consider negative binomial regression.

The following explanatory variables were included:

a. $year$: observation year (2006-2023), treated as a categorical variable;
b. $quarter$: quarters within the year (i.e., Q1 = January-March, Q2 = April-June, Q3 = July-September, Q4 = October-December), treated as a categorical variable;
c. cat_hbf: Number of hooks between floats was included as a categorical variable, with categories. 1 if HBF <10 hooks (surface longline), and 2 if HBF ≥10 hooks (deep longline) following (Sadiyah et al., 2012);
d. $moon$: Moon phase information refers to the eight shapes of the directly sunlit portion of the moon that we can see from Earth. The moon phase was calculated using lunar package (Lazaridis, 2014), treated as a categorical variable;
e. lat/lon: Geographical information (latitude and longitude) in 5x5 degree blocks and incorporated as a continuous variable.

We conducted Anova Type II analysis from the car package (Fox and Weisberg, 2018; p. 322) to select the best model. This method performs likelihood ratio tests by comparing a model without each term against the full model. It allowed us to assess the significance of predictors.

Results

Fishing dynamics

The final dataset contained 147 trips, 3718 sets, and more than 5 million hooks (Table 1). Sets were mostly concentrated in the eastern Indian Ocean, with most of the positive catches in the area south of Indonesian waters, between 0-20ºS and 75-125ºE (Figure 1).

Table 1. Summary of observed effort from Indonesian tuna longline fishery during 2006–2023.

Year	Trips	Sets	Total hooks	Mean hooks	se	Mean HBF	se
2006	13	400	575,989	1,440	10.8	11.2	0.20
2007	13	262	403,333	1,539	20.0	14.0	0.27
2008	15	396	510,702	1,290	19.3	12.7	0.22
2009	13	288	328,718	1,141	13.8	12.2	0.29
2010	6	166	221,274	1,333	35.5	13.6	0.40
2011	3	105	110,384	1,051	17.0	12.0	0.00
2012	8	198	290,265	1,466	39.7	14.1	0.16
2013	7	210	231,990	1,105	14.1	12.4	0.15
2014	6	184	216,705	1,178	13.4	15.0	0.14
2015	5	150	174,655	1,164	11.8	14.1	0.26
2016	8	210	279,868	1,333	11.5	12.7	0.30
2017	14	236	297,780	1,262	26.0	16.7	0.29
2018	6	195	262,856	1,348	16.5	14.8	0.18
2019	9	164	216,836	1,322	15.1	10.8	0.35
2020	2	63	86,845	1,378	18.2	13.5	0.11
2021	5	130	197,424	1,519	27.3	11.3	0.29
2022	6	122	221,196	1,813	33.6	12.7	0.37
2023	8	239	531,479	2,224	50.9	6.72	0.13

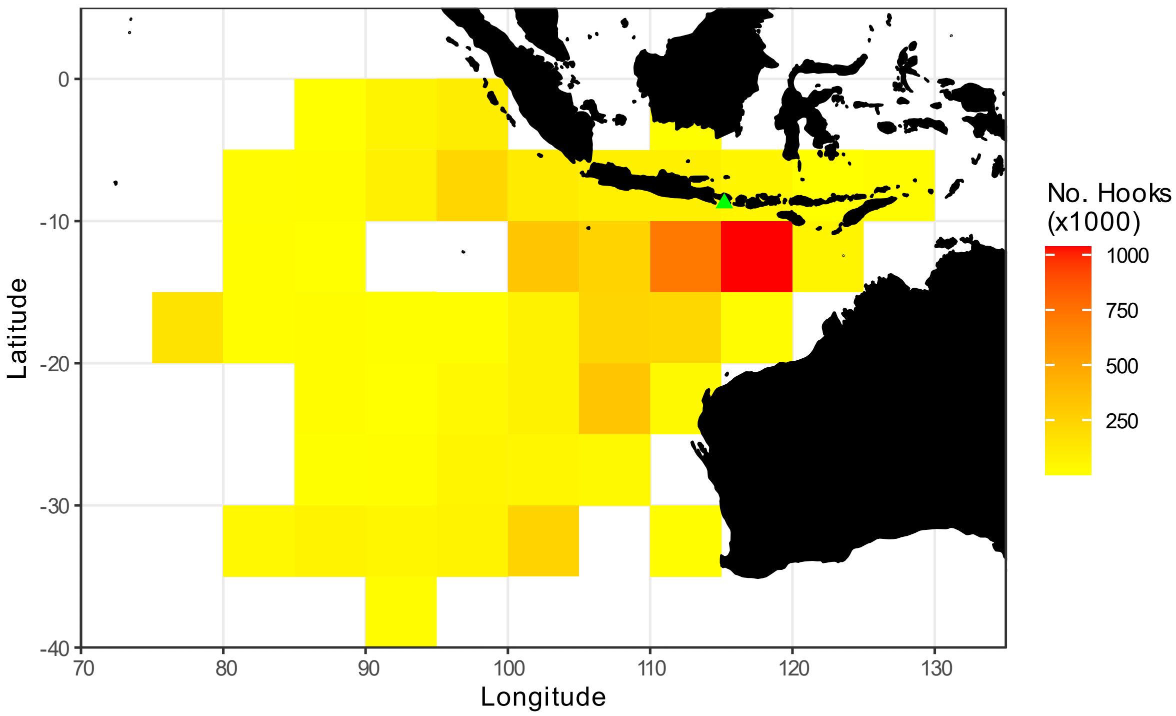

Figure 1. Indonesian tuna longline fishing efforts distribution based on scientific observer reports from 2006 to 2023. Note: Green triangle is Port of Benoa, Bali.

CPUE characteristics

In general, the catches of black marlin varied substantially over the years. The lowest CPUE was recorded in 2013 (0.018 ± 0.01), while the highest was observed in 2020 (0.224 ± 0.01). The proportion of zero catch per set was high, with a maximum of 96% in 2023 and a minimum of 77% in 2016 (Figure 2). The average proportion of zero-catch-per-set was 88% per year.

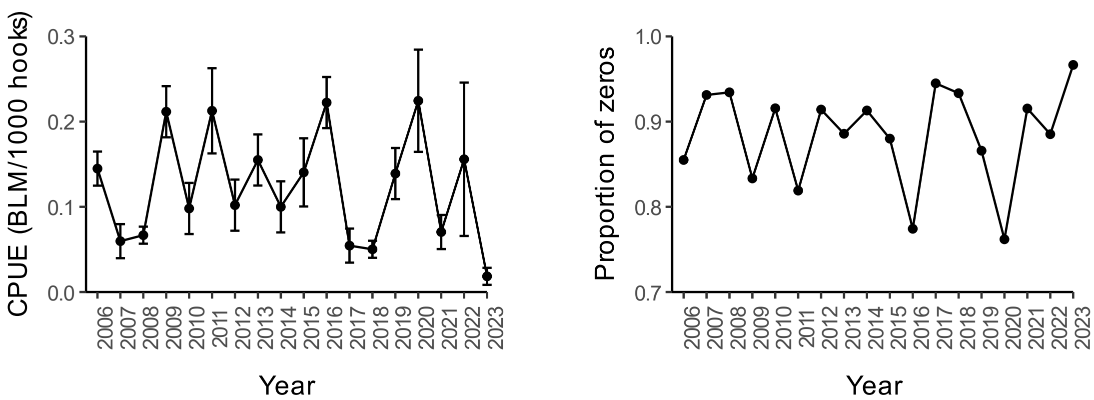

Figure 2. Nominal CPUE series (N/1000 hooks) (left panel) and proportion of zero-catch-per-set (right panel) for black marlin from 2006 to 2023. The error bars on the left panel refer to the standard errors.

CPUE standardisation

For each response distribution, the full model was compared to models in which each explanatory variable was removed in turn, using likelihood ratio tests. This was done using the Anova() function in the car package (Fox and Weisberg, 2018; p. 322), with the option type = II for Poisson model and dropterm() for Negative Binomial model. The results, summarizing the individual effects of model terms on our response variable, are presented in Table 2 and Table 3. After applying the AIC model selection criteria for Poisson and Negative Binomial models, $moon$ effect was omitted. The current catch was likely to be sporadic and driven by temporal ($year$ and $quarter$), spatial distribution ($latitude$ and $longitude$), environmental ($moon$) and current operational aspect, i.e., number of hooks between floats (cat_hbf).

Table 2. The deviance table for the Poisson model. Remarks: LR Chisq = Likelihood Ratio Chi-Square, Df = Degrees of freedom, and P-value = p-value associated with a chi-square test statistic.

Parameter	LR Chisq	Df	P-value
$year$	132.4	17	1e-6
$quarter$	29.4	3	1e-6
lat	18.7	1	1e-6
lon	109.9	1	1e-6
cat_hbf	11.7	1	1e-6

Table 3. The deviance table for the negative binomial model. Remarks: LRT = Likelihood Ratio, AIC = Akaike information criterion, Df = Degree of freedom, and P-value = p-value associated with a chi-square test statistic.

Parameter	AIC	LRT	Df	P-value
	2978.7			
$year$	3025.3	80.6	17	1e-6
$quarter$	2989.8	17.0	3	1e-6
lat	2994.3	17.6	1	1e-6
lon	3050.4	73.7	1	1e-6
cat_hbf	2983.3	6.5	1	0.01

In general, the standardised CPUE did not show any consistent trend over time, although there was substantial year-to-year fluctuations, especially in the last few years. However, limited coverage of scientific observer data still become a major issue. The implementation of the National Observer Program by the Directorate General of Capture Fisheries, Ministry of Marine Affairs and Fisheries is anticipated to improve observer coverage in the coming years, addressing this concern.

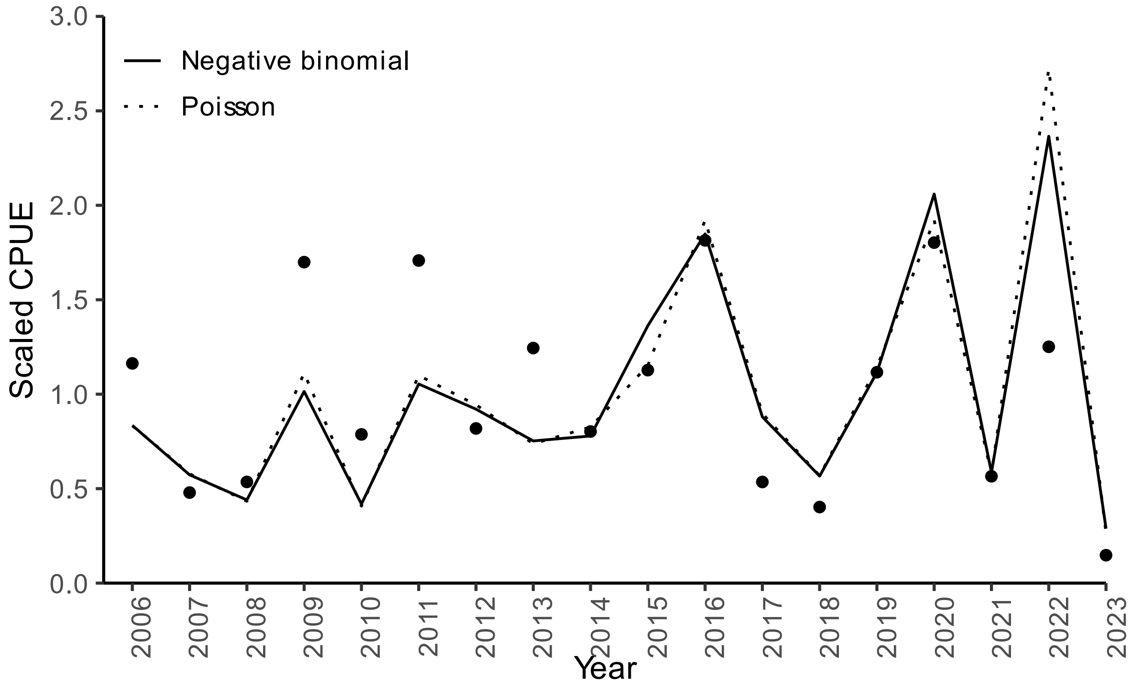

Figure 3. Standardized catch-per-unit-effort (CPUE) calculated using Poisson (green) and Negative Binomial (red) models. Values were scaled by dividing them by their means. Black dots are nominal CPUE.

Acknowledgement

The authors express their sincere gratitude to the scientific observers from the Research Institute for Tuna Fisheries (RITF) of the Ministry of Marine Affairs and Fisheries for their valuable contributions to data collection throughout the years. Additionally, we would like to extend our appreciation to various organizations, including the Commonwealth Scientific and Industrial Research Organization (CSIRO), the Australian Center for International Agricultural Research (ACIAR), and the Research Institute for Capture Fisheries (RCCF), for their collaboration in the FIS/2002/074 project on Capacity Development to Monitor, Analyze, and Report on Indonesian Tuna Fisheries. We also acknowledge the support from the Fisheries Improvement Project (FIP) for their funding assistance during the challenging period of the Covid-19 pandemic. Lastly, our gratitude goes to the national observer from the Directorate General of Capture Fisheries.

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