Developing an Abundance Index of Blue Shark From a Handline Fishery in Southern Java Waters Part of Eastern Indian Ocean

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Abstract
The Handline tuna fishing operations based in the Ocean Fishing Port location in Cilacap, Central Java, have expanded significantly. Several species of pelagic sharks, including the Blue shark, were reportedly captured and landed through handline operations. This working document provides information on an abundance index for blue sharks captured by handline tuna fishery from 2019 to 2022 based on fishery-dependent data. Generalized linear models (GLMs) were utilized to standardize the catch-per-unit-of-effort (CPUE) with year, quarter, number of the crew, and capacity (gross tonnage) serving as the prediction variables. Model selection and model goodness-of-fit were determined using the Akaike Information Criterion (AIC), the pseudo coefficient of determination (R^2), and model diagnostics with residual analysis. The final estimation of the abundance index was determined using least square means or marginal means. The results showed that the index was heavily influenced by the year and followed by quarter, but it did not relate to the vessel's capacity and number of crew. The trends of the standardized CPUEs were relatively similar to the nominal series, in general there were downward noticeable trends, even with high fishing effort, there is a clear decreased trend, with the maximum index value occurring in the second year of observation and continuing to down until it is lower than it was at the beginning of the year observation.

KEYWORDS: *Blue shark, abundance index, handline, Indian ocean*

1. Introduction

The Indonesian handline tuna fishery has been evolving for a long Time and was not published until the 1990s [1]. In Indonesia, handline fisheries are considered small-scale with vessel capacities < 10 GT [2]. In recent years, fishing fleet based in the Ocean Fishing Port (OFP) Cilacap, registered with the fisheries authority has shifted gears from drift gill net that targets tuna and like species to hand line (HL) that is more adaptable to capture tuna as the primary target and as well as economically species such as squid (Sthenoteuthis), hairtail (Trichiurus sp.), and some small pelagic species. Between 2018 and 2022, recorded a 143.12% average increase in HL fleets with an average size of 21 to 30 GT [3]. With its adaptive fishing methods, HL cannot avoid capture by other pelagic sharks, such as the blue shark. Even though this proportion is rarely captured, the production of sharks from HL significantly increases the value of this fishery.

In the recent stock assessment on blue shark, the stock status suggested the stock is currently not overfished nor subject to overfishing but showing consistent trends towards overfishing and subject to overfishing [4]. This study presents new information on an abundance index derived from fishery-dependent data, particularly from HL fisheries. In terms of filling a research void and contributing supplementary data for assessing the status of the blue shark in the Indian Ocean, we believe the results are valuable.

2. Materials and Methods

2.1 Data collection

A total of 2667 trip data from 392 unique vessel names were collected and extracted from a form of seaworthy (SL3), a tabulation of reported catch and effort from the fishers (fish tickets) from January 2019 to December 2022. The form was submitted to the Cilacap Ocean Fishing Port (OFP) authority right after the catch was sorted, weighted, and transported. SL3 data includes information on fishing operations (ship name, type of fishing gear, date of departure and arrival, gross tonnage, number of crew, fishing location, number of species, and weight), fish auction results, and the logistics required for a single trip.

2.2 CPUE standardization

The CPUE analysis was conducted using this SL3 official data from the Cilacap OFP. Operational data at the fleet landed reports were used, with the catch data referring to the total numbers (N) of blue shark captured per trip. For the CPUE standardization, the response variable was catch per unit of effort (CPUE), quantified as numbers (N) of BSH per day at sea. The standardized CPUEs were estimated with Generalized Linear Models (GLMs).

Catch-per-unit-of-effort was described as the total biomass of the BSH (kg) caught on a trip basis per vessel. Since the effective fishing days were unavailable in the dataset, total days at sea were used instead. In this study, a relatively large proportion of zero BSH catches (82.86%) resulted 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 following variables from each record were considered in the model:

- Catch : The total biomass of the skipjack caught per trip is stated in kilograms. This was treated as a response variable;
- Effort : The Time interval between the vessels' departure and arrival ranges from 10 to 60 days. This was treated as a response variable;
- Vessel ID : Categorical variable, unique identifier of each vessel;
- Year : Categorical variable range from 2019 to 2022;
- Quarter : Categorical variable, represented by 1 to 4 (Quarter 1 = January–March, Quarter 2 = April–June, Quarter 3 = July–September, and Quarter 4 = October–December);
- Capacity : Continuous variable, represented by gross tonnage (GT);
- Crew : Continuously variable, ranging between 5 and 15 individuals;
- Area : Defined as a unique value representing ¼ degree blocks.

Simple models were fitted with one variable at a time to determine which explanatory variables should be included in the comprehensive model. First, the variable that provided the model with the lowest residual deviance was chosen. In the second stage, the model containing the selected variable received additional variables individually, and the model with the lowest residual deviance was again chosen. As new variables were added to the previously selected model, this process was repeated until the deviation did not decrease.

The significance of the explanatory variables in the CPUE standardization models was assessed by likelihood ratio tests comparing each univariate model to the null model and by analyzing the deviance explained by each covariate. Goodness-of-fit and model comparison was carried out with the Akaike information criterion (AIC) [5] and the pseudo-coefficient of determination (R^2). Interactions were excluded to avoid overfitting, and significant interactions were used in the analysis. Model diagnostics were carried out with a residual analysis. The final estimated abundance index was calculated by least square means (emmeans package) [6]. For comparison purposes, these were scaled by their mean. Statistical analysis was undertaken with R Project for Statistical Computing version 4.2.3 [7], using several additional libraries, that is grid [7], ggplot2 [8], doBy [9], Tweedie [10], statmod [11], car [12], nortest [13]. The map was produced using QGIS version 3.8 [14].

RESULTS

2.1 Spatial distribution of the data

The spatial distribution of the effort was represented by ¼ degree blocks with darker and lighter colors representing, respectively, areas with more and less effort in days-at-sea. Higher efforts were concentrated around 60-80 nm from the port, while the fishing area spanned from 105–110° E. Most trips were conducted inside the Indonesian Exclusive Economic Zone (EEZ) (Figure 1). Total efforts were between 1.684 and 49.603 days or 51 and 1277 trips, averaging 21404.64 ± 34.41 days/year. The lowest effort recorded was in 2019, and the highest was in 2022 (Table 1).

2.2 Fleet Characteristics

Handline gear can be found along the Southern part of Indonesia. However, the largest port-based handline targeting tuna and like species is in the Ocean Fishing Port (OFP) Cilacap, Central Java. It had a gross tonnage between 18 and 30 GT, and the overall length (LOA) ranged from 14 to 19 meters, which is considerably larger than the handline fleet in several regions in Indonesia with less than 10 GT. This is because this vessel was originally constructed for gillnet operations, whereas vessels under 10 GT are particularly designed for the efficiency of capturing tuna in FADs. In contrast to the original handline fleet, which utilized bulk ice to preserve their catches, the OFP handline fleet has been equipped with freezers to enable extended fishing operations. The handline fleet in OFP has a crew of 8 to 12, unlike the original handline fleet of 3 to 5. Variables such as trip duration, fleet capacity, number of crew, as well as the year and quarter of capture are believed to have a substantial effect on the CPUE of this fishery.

2.3 CPUE data characteristics

The nominal Time series of CPUE BSH is presented in Figure 2. In general, the series has a peak in 2020 and lower values in the remaining years. The percentage of fishing trips with zero catches of BSH in the fishery was high. Specifically, 82.68% of total fishing trips vary annually between a minimum of 79.72% in 2020 and a maximum of 87.12% in 2021 (Figure 3). Overall, the nominal blue shark CPUE distribution was highly skewed to the right and became more normally shaped but still skewed in a log-transformed scale (Figure 4).

2.4 CPUE standardizations

Several explanatory variables tested for the BSH 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 year, followed by quarter, and then the other effects and the interactions (Table 2). Regarding model diagnostics, the residual analysis, including the residuals distribution along the fitted values, the QQ plots, and the residuals histograms, was possible to detect the presence of some outliers. Residual analysis showed that the model fit the data quite well, with no major outliers or trends over the four years of observation (Figure 5).

The final standardized BSH CPUE index (N/Days) for the HL data in the Indian Ocean between 2019 and 2022 is shown in Figure 6 and Table 3. The trends were relatively similar to the nominal series but with smoother peaks. In general, there were downward noticeable trends, even with high fishing effort, there is a clear decreased trend, with the maximum index value occurring in the second year of observation and continuing to down until it is lower than at the beginning of the year observation. (Figure 6, Table 3).

DISCUSSION

Fishery-dependent data has been widely used to model catch rates, such as in Palabuhanratu, West Java [15], Prigi, East Java [16], and Cilacap Central Java [17]. However, care must be taken when processing the data, and frequent interactions are needed with statistical staff members who record SL3 data to validate the data and consult regarding deviations and discrepancies. It is commonly associated with abnormal capture in a single year (very high or low), low effort (< 5 days) but a high catch rate, and incorrect geographical information. Before conducting any further analysis, it is necessary to conduct a thorough data inspection; failure to do so will result in mistaken assumptions or wrong conclusions.

Accidental shark capture in handline fisheries has been reported in previous research studies in the Indonesian region [18-20]. Based on the results of interviews with the skipper of the handline fleet based at OFP Cilacap, obtained information that sharks are rarely caught around Fish Aggregating Device (FAD), but that sharks are caught more frequently if the ship is used as a drifting FADs during the East monsoon from July to September. Although not significant in the capture of sharks, shark catches are still considered important to increase income for fishers so that handline fleets can still catch sharks in large numbers.

Changing fishing targets and gears is also a frequent practice in these fisheries. They carry multiple fishing gears, which makes it simpler for them to adapt to the species of fishing targets. Typically, fishers use handline fishing gears with live bait (squid, flying fish) to capture large tuna. However, occasionally sharks will consume this bait as well. From Fishery-dependent Data, the final model of the blue shark CPUE index from handline fisheries showed the condition of the catch rate trend is declining. For the final model, year had the most influential effect on the model followed Quarter, on the other hand, gross tonnage (GT) and number of crew was insignificant. At the same Time, the area was dropped from the model because it provoked multicollinearity. Although the results presented should be considered preliminary, this study provides insights into the relationship between catch rates of BSH and related handline fishing patterns. In future work, using fishing logbook data and SL3 data of fishing ports in the Indian Ocean region, we will analyze the aggregate data of the handline fleet operating in the Indian Ocean.

Acknowledgment
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Figures

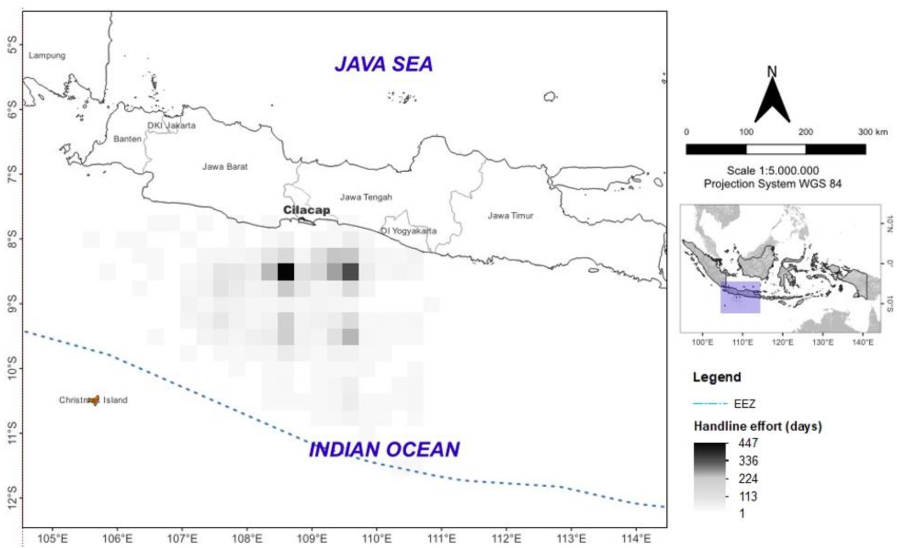

Figure 1. Distribution of handline data used in this BSH CPUE standardization. The effort is represented in ¼ degree blocks with darker and lighter colors representing respectively to areas with more and less effort in number days at sea.

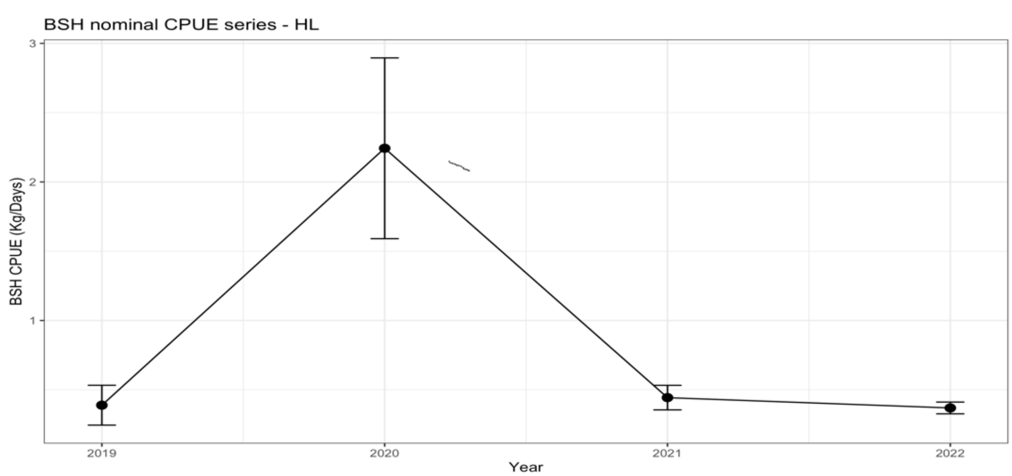

Figure 2. Nominal CPUE series (Kg/Days) for BSH in handline fishery, between 2019 and 2022. The error bars refer to the standard errors.

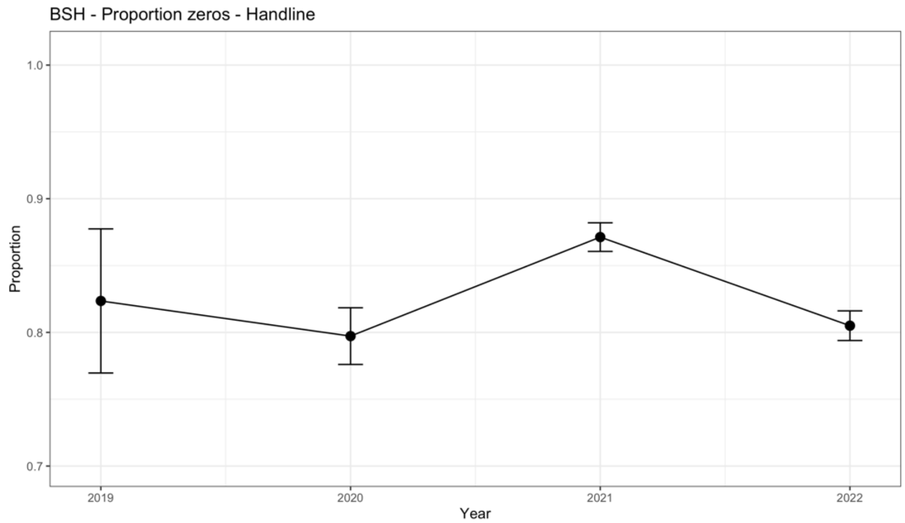

Figure 3. Proportion of zero BSH catches by handline and per year, between 2019 and 2022. The error bars refer to the standard errors.

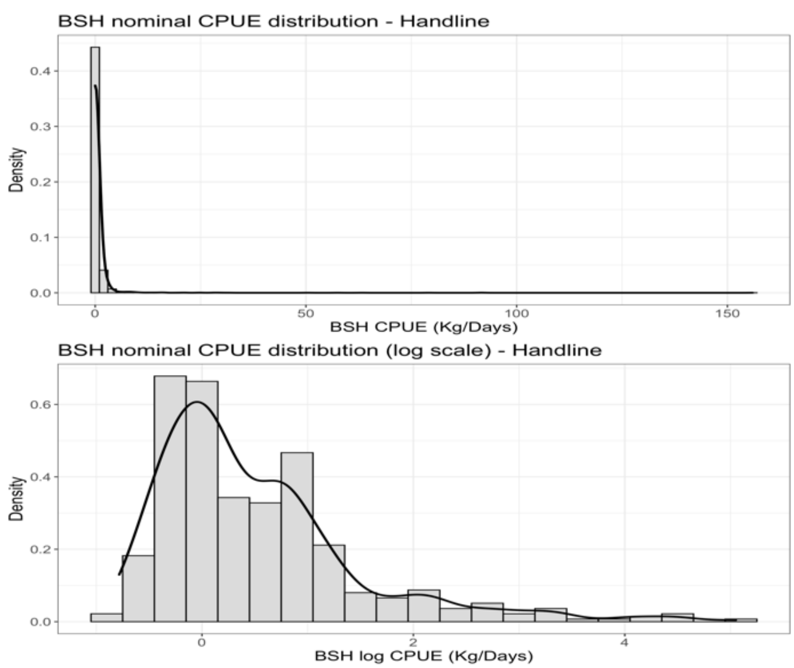

Figure 4: Distribution of the nominal BSH CPUE from the handline fishery data in non-transformed (top) and log-transformed (bottom) scales.

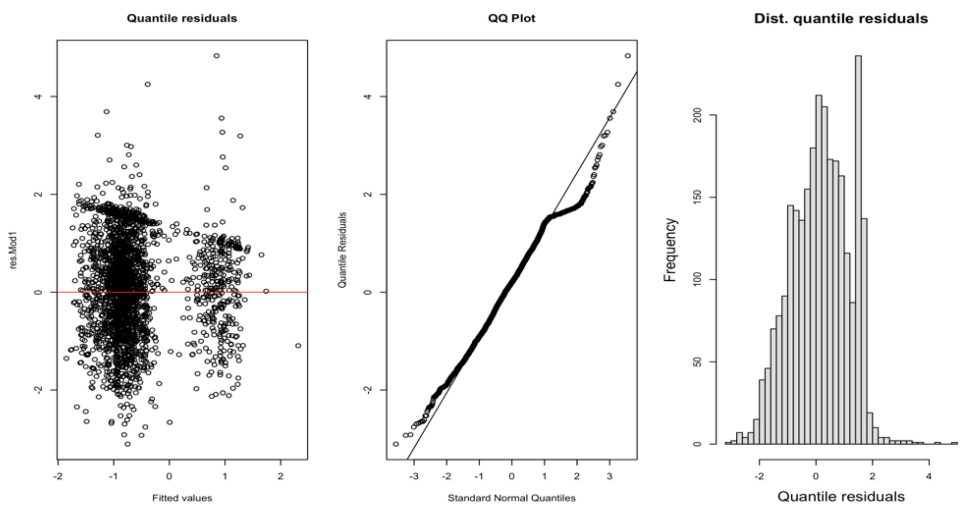

Figure 5. Residual analysis for the final BSH CPUE standardization model for handline fishery data, between 2019 and 2022. In the plot it is presented the histogram of the distribution of the residuals (right), the QQPlot (middle) and the residuals along the fitted values on the log scale (left).

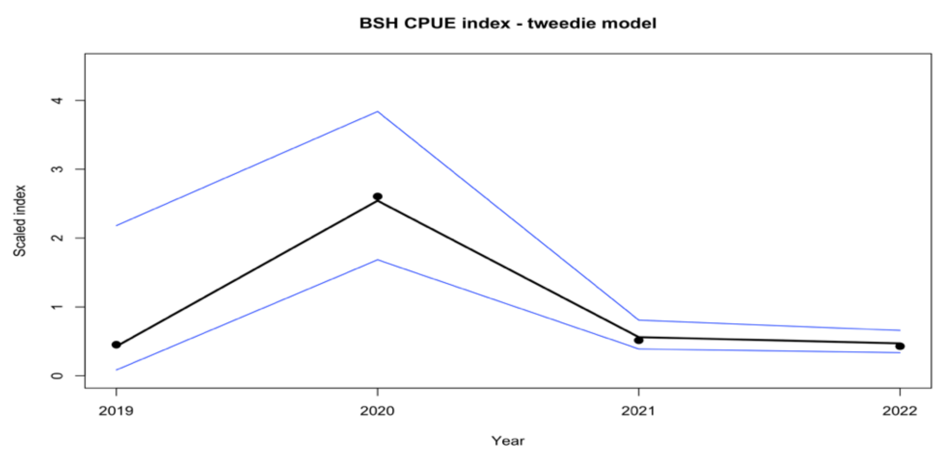

Figure 6. Standardized CPUE series for BSH by HL using a Tweedie model, between 2019 and 2022. The solid lines refer to the standardized index with the 95% confidence intervals, and the dots represent the nominal CPUE series. Both series are scaled by their means.

Tables

Table 1. Trip summary of handline fishery during 2019–2022. Results are pooled and also presented by year of observation. Operational parameters are means and standard deviations (inside parentheses). GT: gross tonnage.

Year	Trips	Total Days at-Sea	Mean GT		Mean Latitude (°S)		Mean Longitude (°E)	
2019	51	1684	28.78	(2.5)	8.96	(0.9)	108.90	(0.8)
2020	360	10313	26.95	(4.6)	8.75	(0.8)	108.89	(0.7)
2021	979	30172	27.19	(6.3)	9.00	(0.8)	108.53	(1.2)
2022	1277	49603	28.07	(5.4)	9.01	(0.7)	107.92	(0.9)

Table 2. Deviance table of the parameters used for the BSH CPUE standardizations in the handline fishery 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).

Parameter	Df	Dev	Resid. Df	Resid. Dev.	F-stat.	p-value
(Intersept only)			2665	11017.9		
Year	3	1196.06	2662	9821.8	19.7489	< 0.001 ***
Quarter	3	66.35	2659	9755.4	1.0956	0.3497
GT	1	4.01	2658	9751.4	0.1986	0.6559
Crew	1	37.00	2657	9714.4	1.8329	0.1759
Quarter:GT	3	4.91	2654	9709.5	0.0837	0.9689
Quarter:Crew	3	61.33	2651	9648.2	1.0449	0.3715

Table 3. Nominal and standardized CPUEs (Kg/Days) for BSH using the handline Fishery-dependent data in the Indian Ocean. The point estimates, 95% confidence intervals and the standard deviation (SD) of the standardized index are presented, as well as the nominal CPUE values.

Year	Nominal CPUE	Standardized CPUE index (KG/Days)			
		Estimate	SD	Lower CI (95%)	Upper CI (95%)
2019	0.389	0.312	5.84	0.061	1.600
2020	2.243	1.865	3.94	1.235	2.816
2021	0.443	0.411	5.78	0.285	0.592
2022	0.369	0.344	6.11	0.245	0.483