Preliminary standardized CPUE of blue shark in the Indonesian tuna longline fishery estimated from scientific observer data, for the period 2005 - 2014

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SUMMARY

The blue shark (Prionace glauca) is one of the dominant caught and most important bycatch shark species for Indonesian tuna longline fishery in the Indian Ocean. The number of Indonesian tuna longline fleets in Indian Ocean are 1,282 units. There are two types of tuna longline fleet in Indonesia, based on the product destinations, namely fresh and frozen tuna. This working document analyses the catch, effort, nominal and standardized CPUE trends for blue shark captured by this fishery, for the period between 2005-2014. Nominal annual CPUEs were calculated as number (N)/1000 hook. Standardized CPUEs were estimated with Generalized Linear Models (GLMs) using year, quarter, area, and operational characteristics of the gear. Model goodness-of-fit and model comparison was carried out with the Akaike Information Criteria (AIC) and the pseudo coefficient of determination (R2) and model validation with a residual analysis. The final estimated indexes of abundance were calculated by least square means (LSMeans). Preliminary results showed the factors that contributed most for the deviance were the area, followed by year, quarter, number of ooks between floats (NHBF), and then the other effects and the interactions. The trends of the standardized CPUEs were relatively similar to the nominal series, but with smoother peaks. In general there were no noticeable trends, with the series varying along the period.

KEYWORDS: Blue shark, standardized CPUE, Indonesian tuna longline, Indian Ocean

Introduction

Blue shark (*Prionace glauca*) is one of the dominant caught and most important bycatch shark species for Indonesian tuna longline fishery in the Indian Ocean. The number of registered fishing boats operating, as reported to IOTC as of 26 November 2014 in the Fisheries Management Areas (FMAs) 572, 573 and high seas Indian Ocean was 1,334 fishing vessels which consisted of 1,282 longliners, 40 purse seiners, 2 gillnetters and 10 carrier boats (Irianto et al., 2015). There are two types of tuna longline fleets in Indonesia, based on the product destinations, namely fresh and frozen tuna. The fresh tuna fleet typically operates in latitudes 10^0-15^0 S, with trip duration varying between 4-6 months each trip, while for frozen tuna operates in the high seas in latitudes southern than 15^0 S, with trip duration of above 1 year each trip.

The pelagic longline gear used by these fleets and in the region consists of a heavy monofilament mainline (20–75 km long), which is suspended at various depths below the surface and from which are suspended numerous lighter monofilament lines with a single large (size 7/0–11/0) hook at the end. Hooks are placed along the line at a ratio of 22-28 hooks/km. The average number of hooks used varies between 700–1.500 per longline set. The gear free-floats on the surface of the ocean, with the hook depths varying from 35 to 450 m. Some parts of the fleet used shark lines as additional gears for targeting shark and billfish.

Wudianto et al., (2003) stated that the fishing ground for tuna longliners are South central of Java island between 108^0 - 118^0 E and 8^0 - 22^0 S and fishing operation of tuna longliners (>70%) was mostly outside the EEZ of Indonesia, while Novianto et al., (2014) reported that the frozen tuna fleet catches more sharks than fresh tuna.

A trial scientific observer program for longline fishery at Benoa port commenced in July 2005, to address limitations of the data and information on catch rates (CPUE), funded by Australian Centre for International Agricultural Research (ACIAR) and Commonwealth Scientific and Industrial Research Organisation (CSIRO) until 2009 and its data widely covers high latitudinal areas in the south Indian Ocean, where blue shark is abundantly distributed. Unfortunately the number of trips and area distribution of observations in the Indian Ocean has decreased since 2010, due to limited funding and a decrease in the number of active observers, that have resigned for searched for different jobs.

Given the importance of the Indonesia longline fleet in shark catches of the Indian Ocean, the objective of the current study is to present a preliminary analysis of standardized blue shark CPUE indices for the Indonesian longline fleet estimated with observer data collected by the scientific observer program Research Institute for Tuna Fisheries (RITF), between 2005 – 2014.

Materials and methods

Data collection

Data collection was conducted by a scientific onboard observer program RITF from August 2005 to December 2014 in the tuna longline vessels mostly based in Benoa Harbour, Bali. Duration of fishing trips extent from three weeks to five months (**Table 1**). Data collections included the number of blue sharks caught, the total number of hooks used, the number of hooks between floats, length of float lines, length of branch lines, and the length between branch lines. Spatio-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 observer program. Operational data at the fishing set level was used, with the catch data referring to the total numbers (N) of blue shark captured per fishing set. For the CPUE standardization, the response variable was catch per unit of effort (CPUE), measured as numbers (N) of BSH per 1000 hooks deployed. The standardized CPUEs were estimated with Generalized Linear Models (GLMs).

There were a relatively large number of sets (69.1%) with zero BSH catches that results in a response variable of CPUE=0. As these zeros can cause mathematical problems for 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 2014;
- Quarter of the year: 4 categories: 1 = January to March, 2 = April to June, 3 = July to September, 4 = October to December;
- Area: defined by regression trees, according to the method developed by Ichinokawa and Brodziak (2010);
- 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 branchline, 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 by analyzing 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). 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, that for comparison purposes were scaled by the mean standardized CPUE in the time series.

Statistical analysis for this paper was carried out with the R Project for Statistical Computing version 3.2.0 (R Core Team, 2015) using several additional libraries (Venables and Ripley, 2002; Wickham, 2007, 2009; Fox and Weisberg, 2011; Gross and Ligges, 2012; Becker et al., 2013; Bivand and Lewin-Koh, 2013; Dunn, 2013; Stabler et al., 2013; Lenth, 2014).

Results

Spatial distribution of the data

The spatial distribution of the data analyzed comes from the Indonesia fishery, and is mostly from the eastern Indian Ocean area, in both tropical and more temperate waters (**Figure 1)**. Using the GLM tree method for area definitions (4 areas) resulted in a separation between the more tropical and the more temperate waters, and also a segregation between the more eastern and western locations (**Figure 2**). Those area definitions were used in the BSH CPUE standardization model as the spatial/area effects.

CPUE data characteristics

The nominal time series of the BSH CPUE is presented in **Figure 3**. In general the series was highly variable, with peaks in 2007 and 2012, and lower values in the remaining years. The percentage of fishing sets with zero catches of BSH in the fishery was high, specifically 69.5% of the fishing sets, varying annually between a minimum of 36.3% in 2007 and a maximum of 98.2% in 2011 (**Figure 4**). Overall, the nominal blue shark CPUE distribution was highly skewed to the right and become more normal shaped, but still skewed, in a log-transformed scale (**Figure 5**).

CPUE standardization

Several explanatory variables tested for the BSH CPUE standardization were significant and contributed significantly for explaining part of the deviance. Some interactions were also significant, and were therefore included in the final model. On the final model, the factors that contributed most for the deviance were the Area, followed by Year, Quarter, NHBF, and then the other effects and the interactions (**Table 2**). In terms of model validation, the residual analysis, including the residuals distribution along the fitted values, the QQ plots and the residuals histograms, showed that the model was adequate with no major outliers or trends in the residuals (**Figure 6**).

The final standardized BSH CPUE index (N/1000 hooks) for the Indonesian data in the Indian Ocean between 2005 and 2014 is shown in **Figure 7** and **Table 3**. The trends were relatively similar to the nominal series, but with smoother peaks. In general there were no noticeable trends, with the series varying along the period (**Figure 7**, **Table 3**).

Discussion

This preliminary analysis of standardized blue shark CPUE for Indonesia tuna longline showed that the majority of fishing sets were concentrated in the southeast Indian Ocean, southwest of Indonesia and northwest of Australia. Since 2010 (except 2012, with one trip in temperate waters) fishing sets took place more in tropical waters. Highly variable of BSH CPUE were observed according to the fishing areas. In 2007 and 2012, observers also covered the frozen tuna fleet that operates in more temperate areas of the south Indian Ocean. Blue shark is known to be abundant in higher latitudinal areas, likely more than in the tropical regions (FAO, 1984). For those reasons, the blue shark CPUE also showed higher values in 2007 and 2012, when compared to the remaining years. The high percentage of zero catches of BSH in the fishery indicates that in general, the fresh tuna longline fleet catches less blue sharks than the frozen tuna fleet. The results of the preliminary analysis of the standardized blue shark CPUE, showed that the factors that contributed most for the deviance were the area, followed by year, quarter, NHBF, and then the other effects, including some interactions. In general, there were no noticeable trends in the standardized series, with the series varying along the period and the standardized series relatively similar to the nominal series, but with smoother peaks. In the future, we will also attempt to add data from the log book and a national observer program, in order to provide a more comprehensive overview of the BSH catch rates and trends in Indonesia pelagic longline fishery.

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Figures

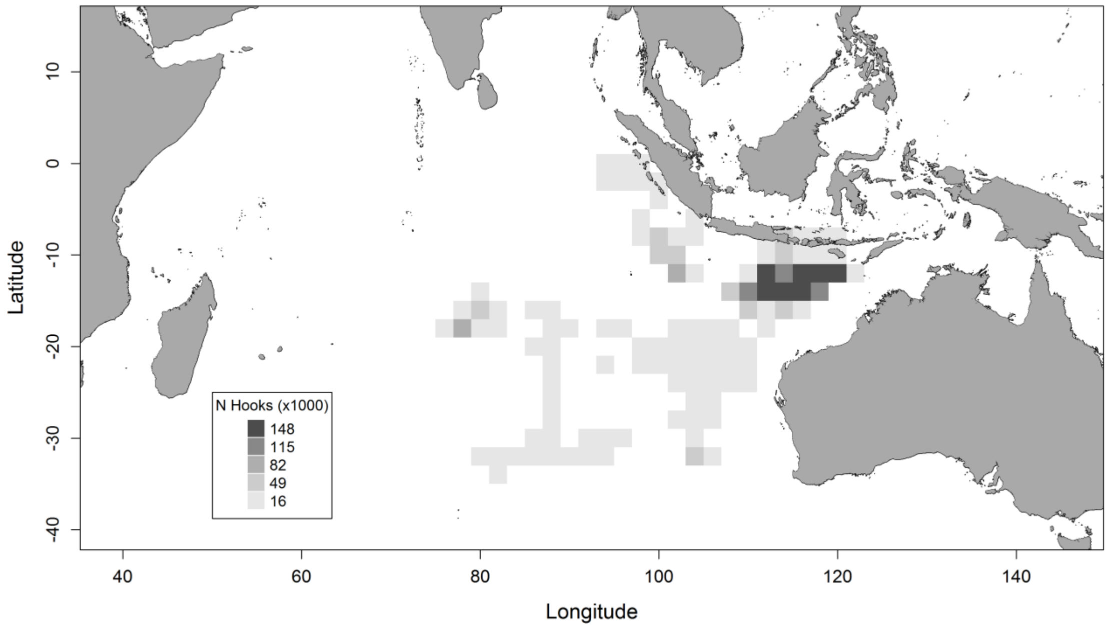

Figure 1. Distribution of the Indonesia observer data used in this BSH CPUE standardization. The effort is represented in 2*2 degree grids with darker and lighter colors representing respectively to areas with more and less effort in number of hooks.

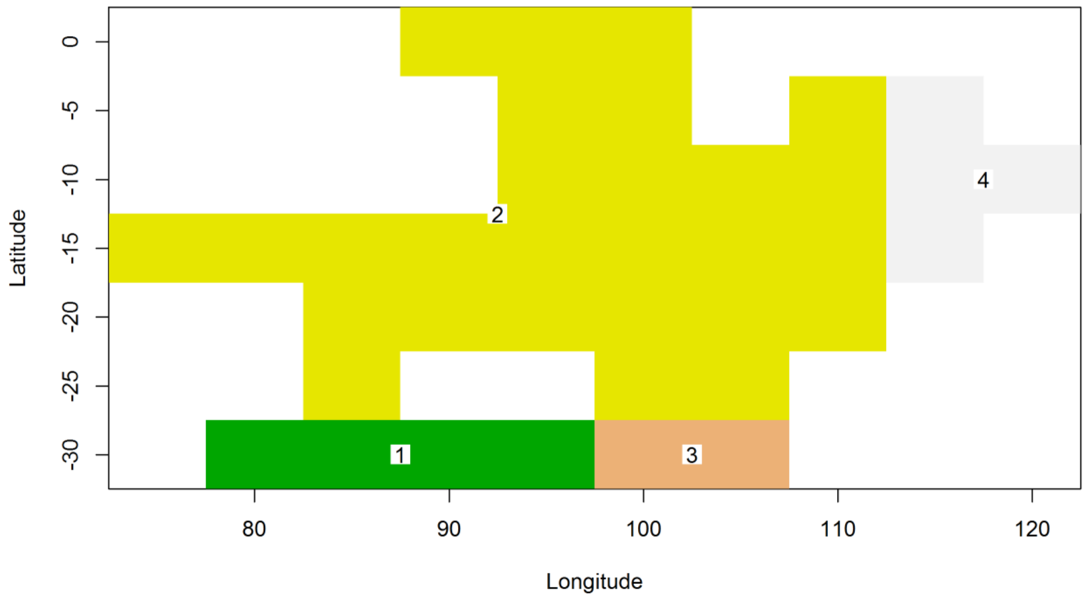

Figure 2. Results from the GLM tree method for area definitions (4 areas) using the Indonesia data for the BSH CPUE standardization.

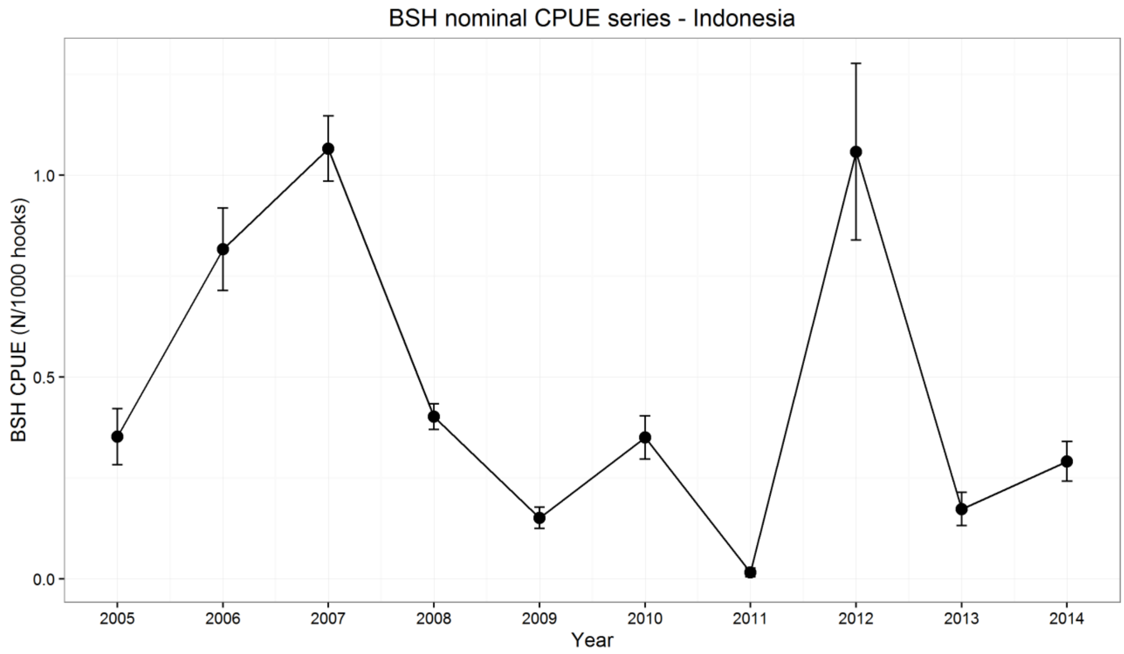

Figure 3. Nominal CPUE series (N/1000 hooks) for BSH in the Indonesia data, between 2005 and 2014. The error bars refer to the standard errors.

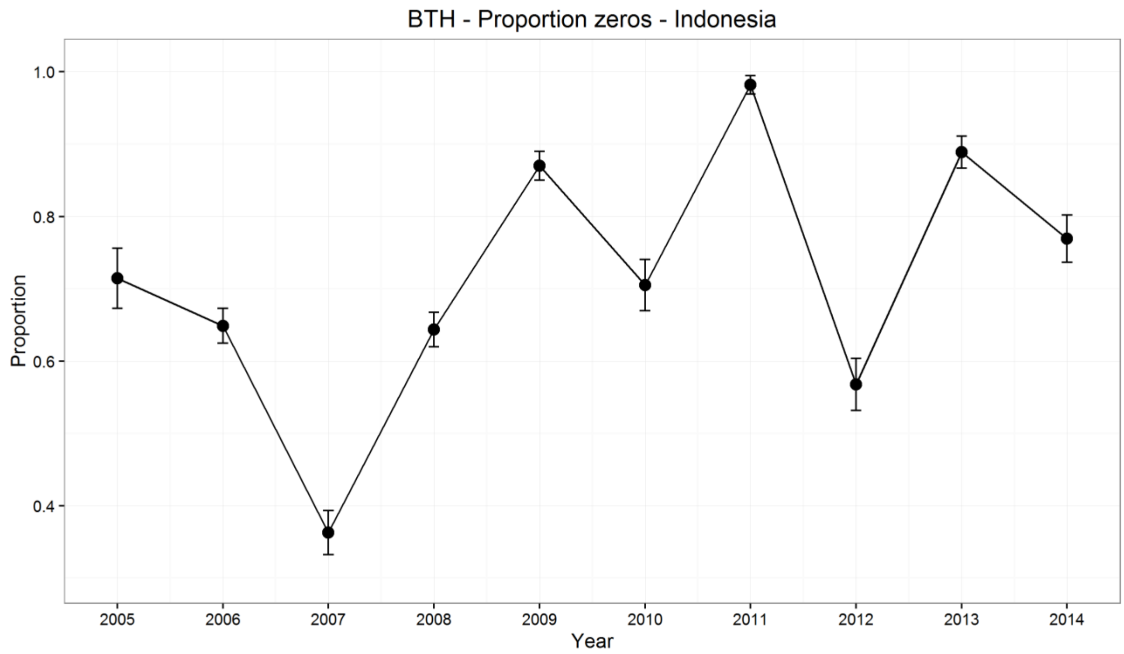

Figure 4. Proportion of zero BSH catches by set and per year, in the Indonesia data, between 2005 and 2014. The error bars refer to the standard errors.

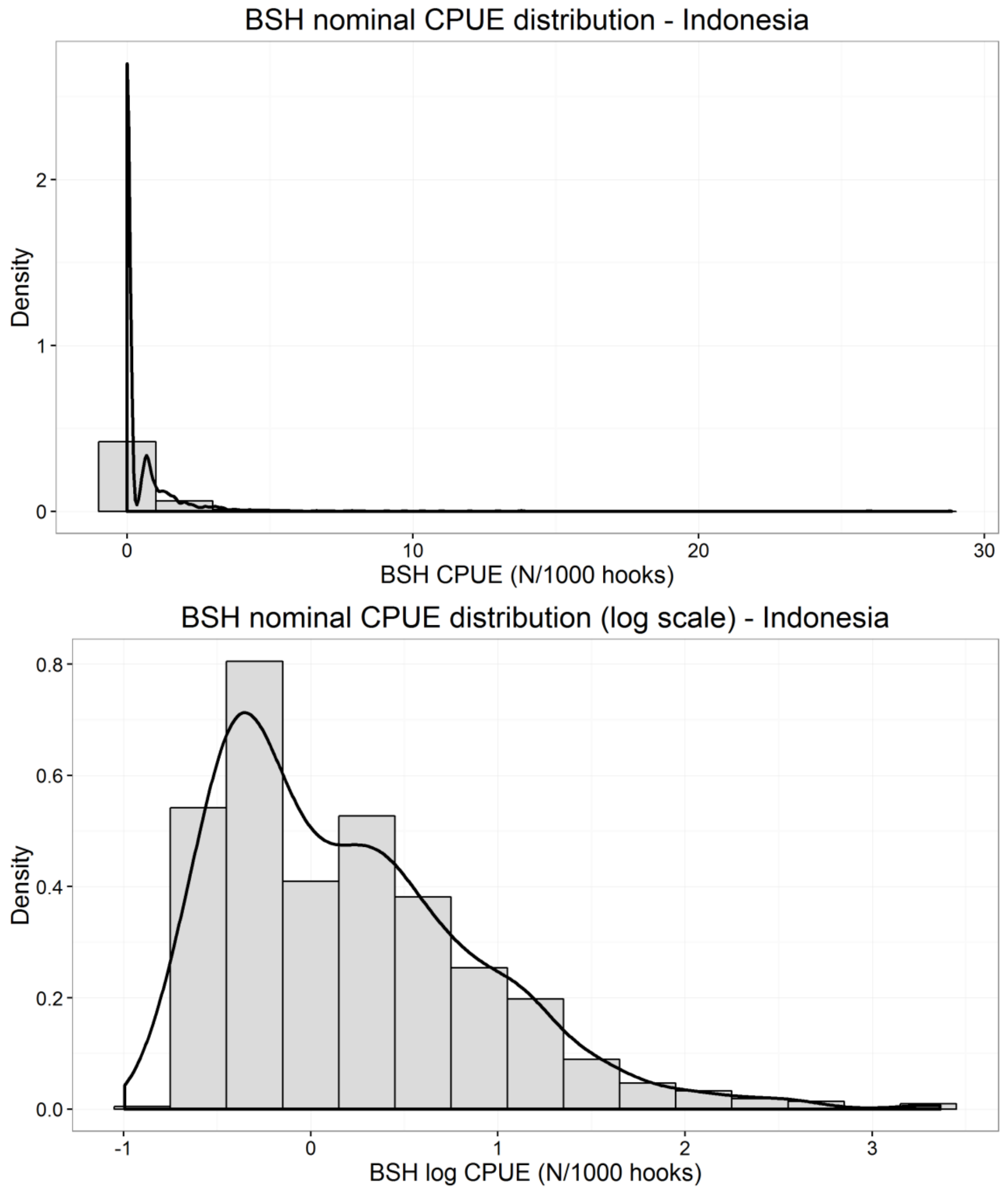

Figure 5: Distribution of the nominal BSH CPUE from the Indonesia data in non-transformed (top) and log-transformed (bottom) scales.

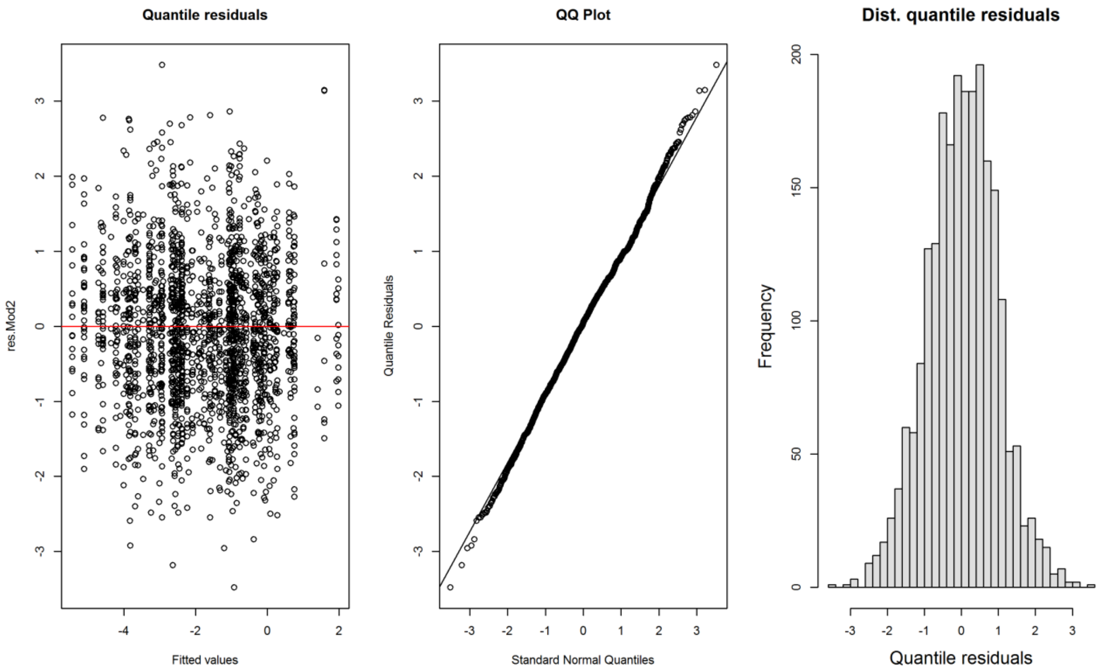

Figure 6. Residual analysis for the final BSH CPUE standardization model for the Indonesia data, between 2005 and 2014. In the plot it is presented the histogram of the distribution of the residuals (right), the QQPlot (middle) and the residuals along the fitted values on the log scale (left).

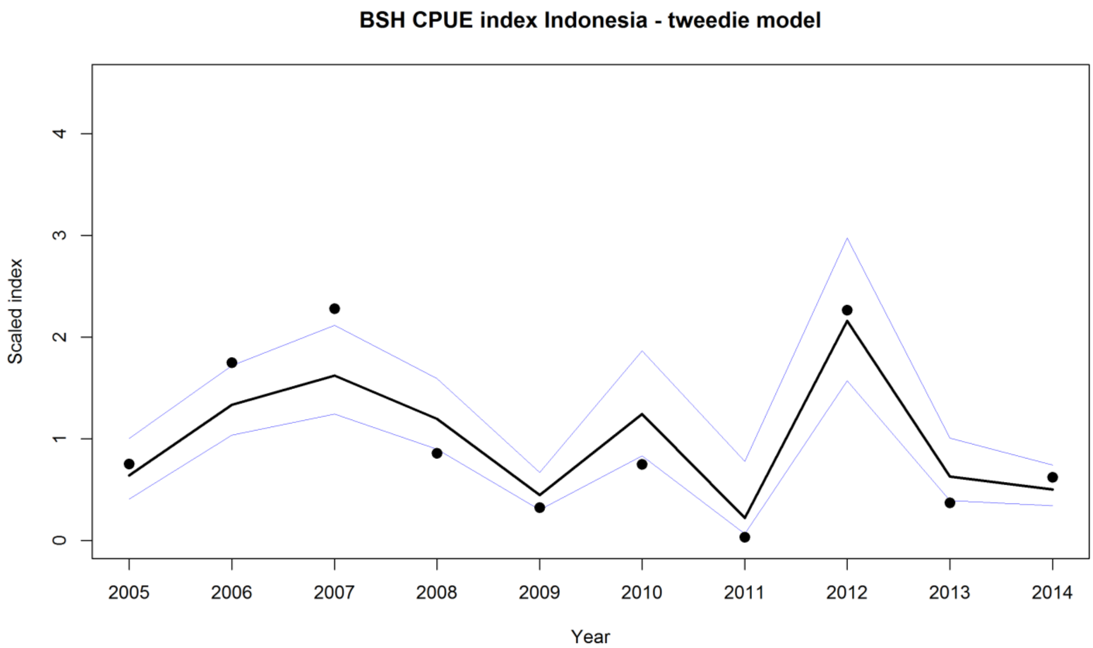

Figure 7. Standardized CPUE series for BSH from Indonesia data using a tweedie model, between 2005 and 2015. The solid lines refer to the standardized index with the 95% confidence intervals, and the dots represent the nominal CPUE series. Both series are scaled by their means.

Tables

Table 1. Activity Summary of scientific Observer in Eastern Indian Ocean during 2005 – 2014.

Year	Trip	Day at Sea	Latitude (South)	Longitude (East)
2005	9	117	12 – 16	107 – 116
2006	13	401	4 – 31	103 – 128
2007	13	258	9 -33	79 – 115
2008	16	404	9 – 18	76 - 119
2009	13	288	0 – 14	95 – 119
2010	5	152	9 – 15	110 – 120
2011	4	111	12 – 15	115 – 120
2012	8	192	1 – 32	85 – 117
2013	6	198	9 – 13	100 – 121
2014	6	265	6 - 13	100 - 120

Table 2. Deviance table of the parameters used for the BSH CPUE 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).

Parameter	Df	Dev	Resid. Df	Resid. Dev.	F-stat.	p-value
(Intersept only)		4509.3				
Year	9	694.5	2278	3814.8	42.07	< 0.001
Quarter	3	101.6	2275	3713.3	18.46	< 0.001
nhbf	1	79.2	2274	3634.1	43.17	< 0.001
length_between_branchline	1	60.5	2273	3573.6	32.98	< 0.001
Area	3	1004.1	2270	2569.5	182.48	< 0.001
Quarter:nhbf	3	32.4	2267	2537.1	5.88	< 0.001
Quarter:length_between_branchline	3	78.3	2264	2458.8	14.23	< 0.001
nhbf:length_between_branchline	1	31.5	2263	2427.3	17.16	< 0.001
nhbf:Area	3	19.6	2260	2407.8	3.56	0.014

Table 3. Nominal and standardized CPUEs (N/1000 hooks) for BSH using the Indonesia 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 (N/1000 Hooks)			
		Estimate	SD	Lower CI (95%)	Upper CI (95%)
2005	0.35	0.39	2.49	0.25	0.61
2006	0.82	0.82	2.56	0.63	1.05
2007	1.07	0.99	2.15	0.76	1.29
2008	0.40	0.73	2.96	0.55	0.97
2009	0.15	0.27	3.46	0.18	0.41
2010	0.35	0.76	2.66	0.51	1.14
2011	0.02	0.14	6.71	0.04	0.47
2012	1.06	1.32	2.25	0.96	1.82
2013	0.17	0.38	3.40	0.24	0.62
2014	0.29	0.31	2.58	0.21	0.45